FEASIBILITY STUDY: INCREASING WATER STORAGE WITH LOW-COST URBAN AGRICULTURE

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The Philippines, Cebu City, December 23th 2014

PREFACE

After four months of working in the Philippines, this what lies before you, is the result of a feasibility study about increasing the water storage in Cebu City with low-cost urban agriculture. A pre-study is done in the first month at the company Cyber in the Netherlands. The research is made out of field studies, literature studies, interviews, discussing's and building/testing a pilot. The research is done by 2, 3rd year water managements students and is meant for the Presidential Commission for the Urban Poor and the urban poor in Cebu City.

Instead of building floating houses in the Maldives for example, we are more interested in creating low-cost urban agriculture in a country where it can be useful and meaningful like in the Philippines. We are interested in getting the maximum out of the available technology. Creating something useful with the least possible materials is what we strive for. With all the common problems in the Philippines what is further discussed in the problem analysis, the Philippines is a city what could really use this research.

Our thanks goes to Mrs Osano and her staff working at the Presidential Commission for the Urban Poor, they provided us of workspace and guided us through the investigation. Other thanks goes to our lectures Mr Heikoop and Mrs Loois for their valuable advice and insight into this research. We also would like to thank the Alaska Mambaling school for implementing our pilot. Without all these people this research would not be able to be completed in this form.

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Cebu City, 23th December 2014

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SUMMARY

Cebu city is the second biggest city of the Philippines and is quickly expanding in population with a growth rate of 1.88% per year. Cebu City experiences multiple problems which are mostly affecting the lower class. Because of the quickly expending population there is a shortage in space in Cebu City. Cebu gets often flooded because of heavy rainfall during the monsoon season. Global warming intensifies the monsoon seasons in the future which will result in even bigger floods appearing more often. The poor are mostly affected by these floods because they live on the lower grounds in homes which are not floods resistant. The lower class does also experience food shortage, especially during floods.

The goal of this research is to reduce food scarcity, increase the water storage, decrease the stormwater runoff and find a solution for spatial problems in Cebu City. This is done by building low-cost urban agriculture since this project focusses on the lower-income households.

The main question of the feasibility study is “How can low cost urban agriculture contribute to increasing the water storage and reduce food scarcity during floods in Cebu City?”. This question is divided in multiple sub-questions which are answered in this study. Methods used to answer these questions are literature study, SWOT, field study, MCDA, interviews and an interest vs influence grid. After answering these questions two designs of urban agriculture which reduce food scarcity and reduce the effects of heavy rainfall have been made. These designs both catch rainwater from roofs and slowly drain this water over a large amount of time to the vegetation which slows down the rainwater runoff. The effects of the designs have been calculated and the most successful reduces watering days with 156 days a year, which spares 1400L water.

This design has been made as a pilot and it worked in reality. However the effect was less because of a mistake that was made with the water flow. This can be easily prevented by making a small adjustment in the design.

To answer the main question, this design has the ability to reduce food scarcity, reduce the effects of heavy rainfall and it can be used by the urban poor because of its small area usage and its cheap/local materials.

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INTRODUCTION

1.1. MOTIVATION

Cebu City is a large city within the Philippines that is often affected by floods. Cebu City is within the Visayas as displayed in figure 1.
The current growth rate is 1.88% a year (Philippine Statistics Autority , 2013). With the rapid increase in population, urbanization and industrialization, the quality of water is being influenced negatively and the city is running out of space (WEPA, 2003). The Philippines are affected annually by hurricanes and monsoons which brings heavy rainfall to the area (Manjaro, 2012). Due to global warming, the water levels are rising as well. These factors contribute to the many floods in Cebu City since the sewerage system is not able to handle the high amount of water. These floods cause a lot of damage, resulting in high economic costs. Floods often cause food and potable water scarcity (AFP, 2013). All these problems are undesirable for a city such as Cebu City with an overall population of 870.000 (World Population review, 2014).

Figure 1 Location Cebu City

The poor people always suffer the most during floods. They live in the highly populated low-lying areas which are especially vulnerable. By applying low-cost urban agriculture the poor can do something their selves to reduce the consequences of heavy rainfall. This was a lead to investigate the possibilities of increasing the water storage an reducing food scarcity by use of urban agriculture. Urban agriculture can reduce the chance of floods and therefore improve the living conditions of the urban poor. Below are shown examples of urban agriculture.

Figure 2 Example urban agriculture 1

Figure 3 Example urban agriculture 2

1.2. OBJECTIVE

The goal of this research is to reduce food scarcity, increase the water storage, decrease the stormwater runoff and find a solution for spatial problems in Cebu City. This is done by building low-cost urban agriculture since this project focusses on the low-income households. By increasing the water storage capacity and decreasing the stormwater runoff the consequences of heavy rainfall will be reduced. Urban agriculture can also be used as an alternate food source during floods. A pilot will be made and tested in Cebu City. It is the intention that the inhabitants will be able to copy this pilot themselves.

1.3. RESEARCH QUESTIONS

In order to find out how urban agriculture can contribute to solve these problems multiple research questions have to be made. The main-question that will be answered by this project is "*How can low cost urban agriculture contribute to increasing the water storage and reduce food scarcity during floods in Cebu City?*". This research question can be divided in multiple sub-questions.

1. **What are the advantages and disadvantages of urban agriculture?**
   This question determines what the advantages and disadvantages of urban agriculture are and also whether the advantages outweigh the disadvantages.

2. **What type of urban agriculture is suitable for Cebu City?**
   There are different types of urban agriculture. To know what type of urban agriculture qualifies the most for Cebu City a MCDA (Multiple Criteria Decision Analysis) is made. The MCDA will grade each type on multiple criteria. The one with the highest score will be chosen for further research and eventually a design will be made.

3. **What kind of vegetation qualifies the most for urban agriculture?**
   There are different types of vegetation that can be used for urban agriculture. The vegetation has some specific demands. It needs to be resistant to Cebu's climate, the amount of water it can hold, the cost etc. These criteria will be put in a MCDA as well.

4. **Which stakeholders are involved?**
   It is important to know which stakeholders are involved when building urban agriculture. Stakeholders will be identified and researched for their willingness to contribute to this project and their advice.

5. **Which locations in Cebu City qualify the most for urban agriculture?**
   With this question the best place to introduce urban agriculture in Cebu City is determined. This location depends on aspects such as spatial quality, but also the need for urban agriculture and its water storage capacity.

1.4. STRUCTURE

At first, the methodology of this research is discussed. The methodology will describe which methods are used to complete the research. Afterwards, the research question advantages and disadvantages is answered in chapter 3. Chapter 4 is called “types of urban agriculture”, this chapter will answer sub-question 2. The next chapter is called “vegetation”, this chapter will answer sub-question 3. After this, sub-question 4 is answered in chapter 6 “Stakeholders analysis” and describe which stakeholders are involved and what their interests and influences are. The last sub-question is answered in chapter 7 Location. Chapter 8 contains the designs and their aspects. In chapter 9 “Pilot”, the results of the pilot are discussed. Chapter 10 will give an conclusion followed by an recommendation and discussion of the research.

2. METHODOLOGY

This chapter describes the methods used to find answers to the sub-questions. These methods are literature studies, interviews, MCDA's, field studies etc.

2.1. SUB-QUESTION 1: ADVANTAGES & DISADVANTAGES URBAN AGRICULTURE

The first sub-question is: "What are the advantages and disadvantages of urban agriculture?". The answer for this question will help to determine whether the advantages outweigh the disadvantages.

2.1.1. LITERATURE STUDY

Several advantages and disadvantages need to be analysed in this project. These will be found and analysed with the help of a search plan and a literature study. The search plan (table 1) will be the foundation for the literature study and will be a guide for finding information.

Table 1 Search plan advantages and disadvantages

Question	Which information? Data or knowledge	Where is the information?	How do you get the information?	What to do with the information?
What are advantages of urban agriculture?	Data/knowledge	Internet/library	Literature study	Process into a report
What are disadvantages of urban agriculture?	Data/knowledge	Internet/library	Literature study	Process into a report

To be able to find correct information about these subjects, a list of synonyms and other helpful search words is made in table 2 on the next page.

Table 2 Synonym list advantages and disadvantages

Language	Urban agriculture	Advantages	Disadvantages	Cebu City
Synonym (English)	• Farming • Tillage • Tilth • Urban • City • Intown	• Good points • Benefits • Positive points • Profit • Pros	• Bad points • Cons	• Philippines • World city • Cebu City
Synonym (Dutch)	• Landbouw • Akkerbouw • Agricultuur • Stedelijk	• Voordelen • Positive punten • Baten	• Nadelen • Slechte punten	• Cebu City • Wereldstad • Filipijnen

2.2. SUB-QUESTION 2: TYPES OF URBAN AGRICULTURE

To know what type of urban agriculture qualifies the most, a literature study about existing different types and self-designed types will be done. Multiple types are put in a multiple-criteria decision analysis (MCDA). Examples of these types are green roofs, vertical gardening etc. These types will be rated by multiple criteria.

2.2.1. LITERATURE STUDY

A literature study is needed to find information about different existing types of urban agriculture. To find enough information, the question is divided into three subjects:

- Types of urban agriculture
- Local materials for urban agriculture
- Existing urban agriculture in the Philippines

With 'urban agriculture in the Philippines' can be investigated if there is already urban agriculture in the Philippines. The information about these existing designs could be used for this project since they should bear the same climate, have the same technique and financial aspects. If this is not the case, this subject is inapplicable.

These three subjects are put into a search plan table (3) shown on the next page. This table shows how we are planning to find the information we need.

Table 3 Search plan types of urban agriculture

Subjects	Which information? Knowledge or data?	Where is the information?	How do you get the information?	What to do with the information?
Types of urban agriculture	Data	Internet	Literature study	Determine if it belongs in the MCDA
Local materials for urban agriculture	Data	Internet/client/environment	Literature study/interview/field study	Decide what types of urban agriculture can be built in the Philippines
Existing urban agriculture in the Philippines	Data	Internet/client and inhabitants/in the field	Literature study/interview/field study	Determine if it belongs in the MCDA

For the literature study a synonym table (4) has been made and placed below. This table is filled with synonyms that can be used to find the information that is needed. This will speed up the information searching process.

Table 4 Search synonyms types of urban agriculture

Language	Types of urban agriculture	Local materials for urban agriculture	Existing urban agriculture in the Philippines
Synonyms (English)	• Types • Urban • Agriculture • structures • Farming • Tilling • Water • Water adaptive • Water storage	• Materials • Cebu • Local • Urban • Structures • Concrete • Bamboo • Wood • Frame • Bottles	• Urban • Agriculture • Cebu City • Philippines • Existing • Current • Built
Synonyms (Dutch)	• Type • Stedelijk • Drijvend • Landbouw • Platformen • Beploegen • Water adaptief • Water berging	• Materiaal • Cebu • Lokaal • Stedelijk • Structuur • Bamboo • Frame • Flessen	• Stedelijke • agricultuur • Cebu City • Filipijnen • Bestaand • Huidig • Gebouwd • Stadslandbouw

2.2.2. MCDA

The Multiple-Criteria Decision Analyses (MCDA) is used for structuring, solving decisions and planning problems involving multiple criteria. The MCDA will help deciding what type of urban agriculture would be implemented most effectively in Cebu City. The types of urban agriculture will be rated by the following criteria placed in table 5.

The method of making an MCDA is explained in appendix 6 (Method MCDA). For this MCDA is chosen to use the +/- unit consistently instead of specific units that fit each criteria separately, because of a lack of specific information.

Table 5 MCDA types urban agriculture

Criteria	Option 1	Option 2	Option 3	Option 4
Expense				
Lifetime				
Materials				
Water storage capacity/ decrease water runoff				
Food quality				
Area usage				
Accessibility				
Construction period				
Visual quality				

Every criteria will have its own weight (1-10). This weight is determined by the importance of the criterion as shown in table 6. The next step is to multiply **Score * Weight**. The result is a score which will determine what type of urban agriculture construction qualifies the most for Cebu City.

Table 6 Weigh scale types urban agriculture

Criteria	Weight (scale 1-10)
Expense	9
Lifetime	8
Materials	8
Water storage capacity/ decrease water runoff	7
Food quality	6
Area usage	6
Accessibility	5
Construction period	3
Visual quality	2

2.3. SUB-QUESTION 3: VEGETATION

It is very important to grow the right vegetables in order to have the most profit. In this sub-question is researched which types of vegetation should be used in the pilot projects.

2.3.1. LITERATURE STUDY

A literature study is needed to find information about different types of vegetation that qualify the most for Cebu City. To find this information, the question is divided into four subjects:

- Types of urban agriculture vegetation
- Vegetation suitable for Cebu´s climate
- Vegetation’s water storage capacity
- Vegetation maintenance/costs

These four subjects are put into a search plan table (7) shown below.

Table 7 Search plan vegetation

Subjects	Which information? Knowledge or data?	Where is the information?	How do you get the information?	What to do with the information?
Types of urban agriculture vegetation	Data	Internet	Literature study	Determine if it belongs in the MCDA
Vegetation suitable for Cebu´s climate	Data/knowledge	Internet/client/ environment	Literature study /interview/field study	Determine if it belongs in the MCDA
Vegetation’s water storage capacity	Data	Internet/client	Literature study /interview/testing	Determine if it belongs in the MCDA
Vegetation maintenance/costs	Data	Internet/ environment	Literature study/field study	Determine if it is affordable for the people in Cebu and if it belongs in the MCDA

2.3.2. INTERVIEW

There are multiple stakeholders who are already implementing certain forms of urban agriculture. These stakeholders will be interviewed in order to gain as much information such as the plants they use and which technics they use to grow them. The method of interviewing stakeholders is explained in paragraph 2.2.1.

2.3.3. MCDA

To find out what kind of vegetation qualifies the most a MCDA will be made. These analyses will show the good and the bad qualities of the proposed vegetation. The proposed vegetation is climate proof and is found in the literature study. There are multiple aspects that have to be taken into account when choosing a type of vegetation. The aspects that are taken into account are listed below under “Criteria” (table 8).

Table 8 Vegetation criteria method

Criteria	Object 1	Object 2	Object 3
Climate resistance			
Cost			
Water consumption			
Value vegetables			
Yield kg/hectare			
Weight of the vegetable			

Table 9 Vegetation weight method

Criteria	Unit	Weight (1/10)
Climate resistance	+/-	9
Cost	Php/100 seeds	8
Water consumption	(l/dag)	7
Value vegetables	(Php/kg)	6
Yield kg/hectare	kg/hectare	4
Weight of the vegetable	(kg)	2

Every criteria will have its own weight (1-10). This weight is determined by the importance of the criterion as shown in table 9. The next step is to multiply score by weight (**Score * Weight)**. The result is a score which will determine what type of urban agriculture construction qualifies the most for Cebu City.

2.4. SUB-QUESTION 4: STAKEHOLDER ANALYSIS

It is important to know which stakeholders are involved when building urban agriculture. In this sub-question stakeholders will be interviewed and asked if they are willing to contribute to this project, if they will allow urban agriculture in Cebu City and if they have advice for the development of the project.

2.4.1. INTERVIEW

Stakeholders will be interviewed if this is possible. Every stakeholder will get a set of individual questions based on the template shown down below. These questions are prepared before the interviews and are listed in appendix 4. The questions will then be answered by the stakeholder and reported with the use of a tablet or a notebook.

Background information
At first we ask the stakeholder questions about what there functions is in the company and what they do. Other background information is also asked like what kind of projects does the company who they work with or more specific questions.

Explanation
After we have asked about the stakeholders background we explain what we are doing and who we are doing it for. We tell them about our project, our ideas and our methods and write down their remarks if there are any.

Related projects
Now we have made clear what our project is about we ask the stakeholder if he has any experience with similar projects they have executed. We ask info about these projects if there are any. This will be info like what kind of methods they used or what kind of materials they used.

Tips
At last we ask if they have any tips or options we should consider. We also ask about certain types of data or photos which can be used for the project.

The stakeholders that are planned to be interviewed are listed below (other stakeholders can be interviewed if they have extra value for the project).

- Presidential Commission for the Urban Poor
- City Agriculture Department
- Department of Agriculture
- Councillor Engr. Nestor D. Archival
- Alaska Mambaling school

2.4.2. INFLUENCE VS INTEREST GRID

To be able to compare the interests and influence of different stakeholders a grid is used. An example of such a grid is shown below in illustration 4. This grid makes it possible to estimate the value of certain stakeholders to this project.

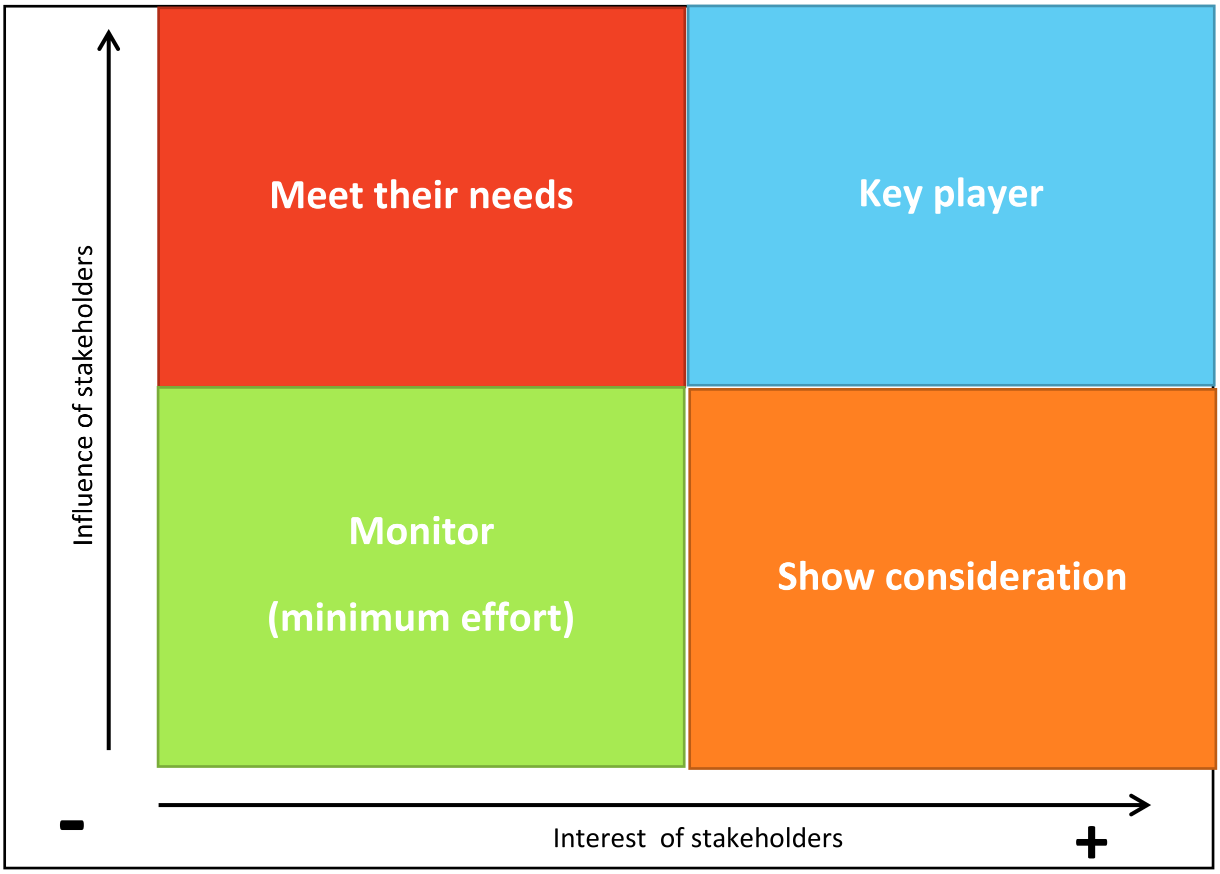

Figure 4 Inflence vs intressed grit example

2.5. SUB-QUESTION 5 LOCATION

It is very important to find the right location for urban agriculture, as the location has a big effect on the success of the pilot. The design depends partly on the location. At first a literature study is done to find possible locations for urban agriculture. A field study is done in Cebu City and the locations are analysed. The chosen location will be rated by a SWOT analysis to know the weaknesses, strengths, opportunities and threats.

2.5.1. LITERATURE STUDY

To find available locations for urban agriculture multiple aspects are taken into account.

- Flood area
- Need for vegetables
- Accessibility
- Shadow
- Need for water storage
- Space for urban agriculture (roofs, walls, gardens)

It is important that the location is inside a flood area. The people there need the benefits of urban agriculture the most. The location needs to be accessible for maintenance and harvesting.
The urban agriculture cannot be placed inside the shadow of a building for example. The plants need the sunlight to grow. There does also need to be space for urban agriculture like roofs, walls or gardens.

Search plan

To find out which locations can be used for the project, analyses of multiple locations will be made and discussed. With these analyses the possible locations will be determined.
To make sure that the correct information is found, a search plan has been made as shown in table 10. This search plan shows where specific data can be found and how it should be handled.

Table 10 Search plan location

Question	Which information? Data or knowledge	Where is the information?	How do you get the information?	What to do with the information?
Where in Cebu City is enough space?	Data	Internet and on location	Literature study/observation	An analyses will be made
What are the flood zones in Cebu City?	Data	Internet and on location	Literature study/observation	An analyses will be made
Where in Cebu City is a shortage of vegetables?	Data	Internet and on location	Literature study/observation	An analyses will be made

A list of synonyms is made to facilitate the information finding process as shown in table 11.

Table 11 Synonym list

Language	Location	Flood zone	Cebu City	Vegetables shortage
Synonym (English)	• Place • Space • Point in • Area	• Floods • Area • Wave • Tide • Overflow • Downpour • Sector • Region	• Philippines • World city • Cebu City	• Shortage • Not enough • Needed • Herbs • Edible plants • Fruit • food
Synonym (Dutch)	• Locatie • Gebied • Plangebied • Plek • Ruimte	• Overstroming • Gebied • Golven • Getijde • Overstroming • Stortbui • Sector • Regio	• Cebu City • Wereldstad • Filipijnen	• Te kort aan • Niet genoeg • Gebrek • Groenten • Fruit • Voedsel

2.5.2. FIELD STUDY

The possible locations found in de literature study will be analyzed in Cebu City by visiting the locations and taking multiple photos from different angles.
To be able to calculate the number of sun hours certain data needs to be obtained. To calculate the number of sun hours the situation of every location is needed and it is important to know where north is. It is also important to choose a wall within the location which could be used for the agriculture. The front of the wall could not be facing to the north because this means that almost no sun will shine on the wall. To the south is the perfect situation because this means that the sun will be able to shine long on the wall. East and West can also be used, but the wall will get less sun. Possible buildings around the chosen wall can have a big influence on the number of sun hours. To calculate the amount of sun hours, data about the height, the distance of the building and the direction of the building from the wall needs to be obtained. With this data the angle from the agriculture to the top of the building (when the sun gets past the building) can be calculated. This is done by using the following formula: "tan^{-1}(opposite side/abutting side)". These angles can be used to find out when the sun shines on the agriculture as shown in figure 5. For this the Cebu city sun hour service of timeanddate.com is used (Time and Date, 2014).

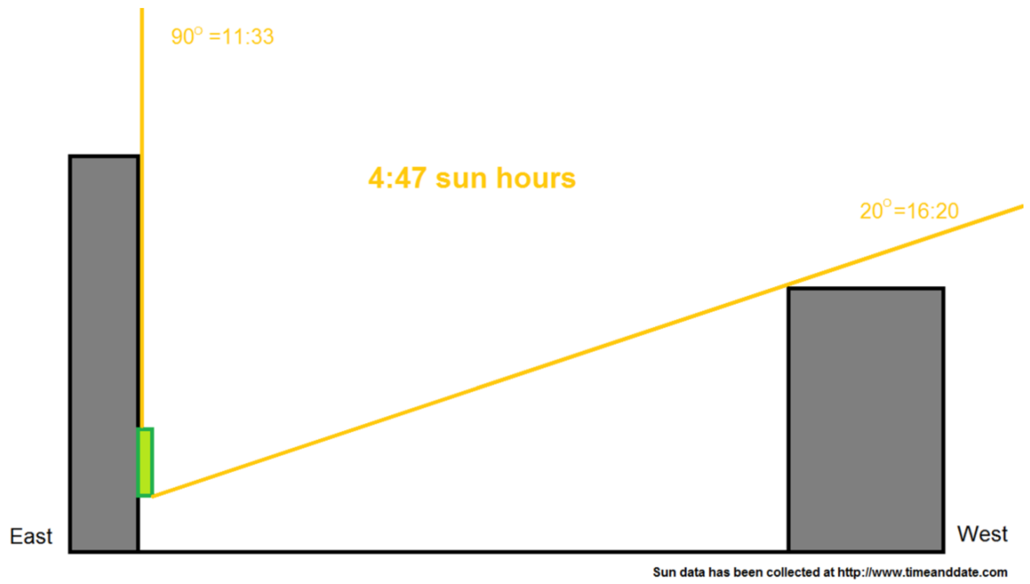

Figure 5 Sun hours calculation example

The walls and roofs will be measured as well since the design needs to be adjusted to its environment. Items that will be brought to the field study:

- Notebook
- Pencil
- Measurement tools
- Photo camera

2.6. PILOT

When the analysis are finished a pilot will be made. The pilot designs need to meet several requirements and needs. This chapter will describe the materials and methods that are needed for several measurements and for making a successful pilot.

2.6.1. PROGRAM OF REQUIREMENTS & DESIGN FUNCTIONS

To ensure the quality of the pilot and make sure it does what it is made for a program of requirements is made. The pilot need to meet these requirements in order to be successful, the program of requirements forms the fundament of a design (ToornendPartners, 2014).
The design functions are divided into hard- and soft design functions. Hard design functions are functions that must put into the design in order to meet the requirements. Soft design functions are optional for the design.

2.6.2. DESIGN

To ensure that the pilot is high quality, multiple designs will be made. Each of these designs will be highly discussed whether it is an option or not.
The following materials and programs are used for making these designs.

- MS Paint (Sketching)
- SketchUp (Design, Impression images)
- Adobe Illustrator (Designs)
- Adobe Photoshop
- Pencil
- Ruler
- Eraser

2.6.3. MINDMAP

To organize all the possibilities within the brainstorming process a mindmap is made. A mindmap is a tool used to find as many possibilities and ideas within the designing process of an object. These are the steps taken to make a mindmap.

Step 1. Setting the goal
At first it important to set a clear goal for the mindmap. What is it that needs brainstorming? This can be used to help designing, but also to summarize a book or organize a vacation.

Step 2. Generate a topic
The goal that needs to be accomplished needs to have a main topic. The topic for a mindmap is placed in the middle of the canvas such as in figure 6. The topic for a mindmap is for a design typically the design itself. For example, when you are designing a new chair for elderly then your topic would be “Chair for elderly design”. When you are not designing an object, but brainstorming about another topic such as a vacation the topic could be “Vacation 2014”.

Step 3. Main points
Main points are things that are part of the topic or things that are needed/desired from the topic. These main points are placed around the topic and connected to the topic with lines such as shown in figure 7. When designing a chair a main point could be “chair legs” or “comfortable” (because these things are part of the chair or are needed/desired from the chair). Main points that influence each other can be connected with other lines (the red lines in figure 6).

Step 4. Sub points
Sub points are written down around the main points (see figure 6). Sub points give extra information about the connected main point. A sub point can be an example of a main point, but also a part. When designing a chair a main point can be “color”. A sub point that fits with the main point “color” can be “green” or “light colors”.

Step 5. Discuss
After making the mindmap it is very important to discuss the options and ideas for the analyzed object. This is often done while creating the mindmap. It is important to discuss all the possibilities that come to mind.

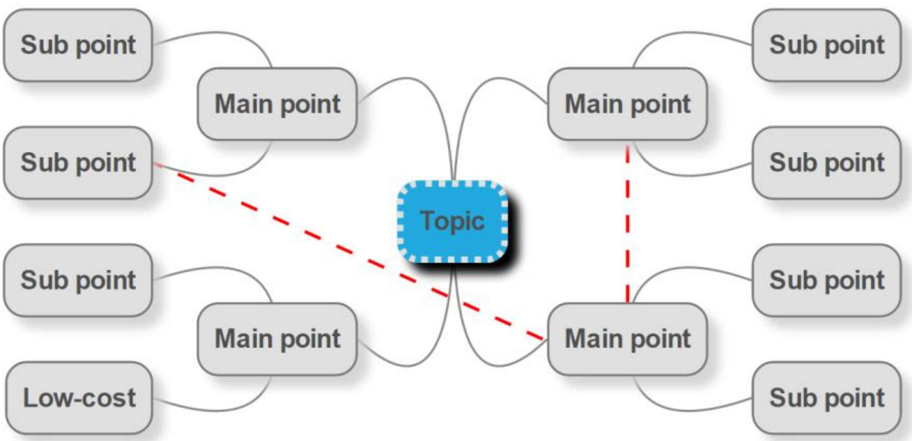

Figure 6 Mindmap method

2.6.4. SWOT

As explained in paragraph 2.5.3. a SWOT analysis is an useful technique for understanding the **S**trengths, **W**eaknesses, **O**pportunities and **T**hreats of a design in this case. It can help uncover opportunities that can be exploited (Mind Tools essential skills for an excellent carreer, 2014). And by understanding the weaknesses of a design, it is possible to eliminate threats that would otherwise come by surprise (Mind Tools essential skills for an excellent carreer, 2014). This method will lower the chance of making mistakes in the pilot. Figure 6 shows the SWOT table, this table will be filled for each location to give a clear overview of its strengths, weaknesses etc.

Figure 6 SWOT table (Sharen, 2012)

confrontation matrix

After the SWOT has been made, the points can be put into a confrontation matrix.
The confrontation matrix will look at the 'match & mismatch' between the strengths/weaknesses and the opportunities/threats from the SWOT analysis (Marlou Landers, 2013). The confrontation matrix should give clarity to these 4 questions (Marlou Landers, 2013).

- How can strong points respond to opportunities?
- How can strong points be enabled to repel threats?
- How can weak points be strengthened to respond to opportunities?
- How can weak points be strengthened to provide resistance to threats?

Each confrontation will be rated with 0/-/--/+/++. When comparing the points the positive can compensate the negative or the other way around, based on this result it can score + or -.
When counting all the scores the confrontation matrix will show which points are the best opportunities, strength, weaknesses and which one is the highest threat.

3. ADVANTAGES & DISADVANTAGES

3.1. ADVANTAGES

Urban agriculture uses resources in cities that would otherwise go to waste (Sprouts in the side way, 2009). Gardens can be built in empty lots, on steep slopes, at river banks and on roofs (Sprouts in the side way, 2009). These are all examples of space that would otherwise be unproductive. These gardens can use rain water to water their crops (Sprouts in the side way, 2009). The crops will slow down the water what will reduce the pressure on the sewerage system (Sprouts in the side way, 2009). They produce food, jobs and a several quantifiable benefits which are listed below.

Socially (Sprouts in the side way, 2009)

- Help bring families and communities together by working toward a common goal that will benefit for all
- Creates a better living environment by adding more green to the city and making it more productive
- Teaches people life skills such as how to be more self sufficient
- Helps reducing food scarcity
- Creates potential jobs, income and food

Environmentally (Sprouts in the side way, 2009)

- Greens up the city
- Increase the amount of food grown and bought locally
- Slows down the water, this will leave the soil less saturated
- Can help to clean rain water and air

Economically (Sprouts in the side way, 2009)

- Can create jobs and income from otherwise unproductive space
- The people rather not rely on food from far away
- Can be beneficial to people of any income
- It can make use of valuable resources such as compost, that would otherwise go to waste in a city

3.2. DISADVANTAGES

Urban agriculture has many advantages, but nothing is perfect. There are also some disadvantages with urban agriculture. Urban agriculture can be very vulnerable which is a big disadvantage. Potential vulnerabilities and other disadvantages are listed below (Sprouts in the side way, 2009).

- **Polluted or contaminated soils**
  The soil can be polluted or contaminated. This will affect the plants negatively.
- **Toxic chemicals (car pollution for example)**
  Urban agriculture is placed within cities. Big cities have often a lot of traffic, the exhaust gasses of cars can pollute the plants.
- **Use of water**
  Water scarcity is a common problem in Cebu. The plants will need water in order to grow, it is possible that the urban poor rather use the water themselves than give it to the plants.
- **Theft of the produced vegetables**
  There is always a risk of theft. The urban poor will not be able to benefit from the vegetables when its stolen.

3.3. CONCLUSION

There can be concluded that the advantages of urban agriculture outweigh the disadvantages. The disadvantages can be avoided by taking a few measurements.
The measurements are:

- **Polluted or contaminated soils**
  This can be avoided by making sure the soil is maintained by an active community.
- **Toxic chemicals (car pollution for example)**
  This can be avoided by placing the urban agriculture not near busy roads. This will minimize the pollution from cars and other factors.
- **Use of water**
  This can be avoided by storing rainwater. The water can feed the plants overtime so that a minimum amount of water is wasted.
- **Theft of the produced vegetables**
  This can be avoided by having an active community working on the urban agriculture. The community can look after the agriculture so that nothing happens to it.

4. TYPES OF URBAN AGRICULTURE

This chapter will determine which type of urban agriculture qualifies the most for Cebu City based on a MCDA.

4.1 MCDA

Four types of urban agriculture have been chosen to be put into the MCDA. These 4 types are community gardens, container gardens, vertical gardens and green roofs. These 4 types are rated per criteria shown in table 12 Below. These ratings are based on literature research placed in appendix 1. The criteria in table 12 is chosen for particular reasons. These reasons are explained in appendix 1 as well.

Table 12 Types criteria score +/-

Criteria	Community gardens	Container gardens	Vertical gardens	Green roofs
Expense	++	+	+	--
Lifetime	--	+	+	++
Materials	+	++	++	--
Water storage capacity/ decrease water runoff	+	-	+	++
Food quality	-	+	++	++
Area usage	--	+/-	++	++
Accessibility	+	+	++	-
Construction period	-	++	+	--
Visual quality	++	+/-	+	-

The score varies between --, -, +/-, +, ++. The highest score is ++ and -- is the lowest. Every score is given a number in table 13. The lowest score will get 0 and the highest score will get 1.

Criteria	Community gardens	Container gardens	Vertical gardens	Green roofs
Expense	1	0.75	0.75	0
Lifetime	0	0.75	0.75	1
Materials	0.75	1	1	0
Water storage capacity/ decrease water runoff	0.75	0.25	0.75	1
Food quality	0.25	0.75	1	1
Area usage	0	0.50	1	1
Accessibility	0.75	0.75	1	0.25
Construction period	0.25	1	0.75	0
Visual quality	1	0.50	0.75	0.25

Table 13 Types criteria score

Table 14 shows the weight per criteria on a scale 1-10. Why each criteria has this specific weight is explained in Appendix x.

Table 14 Types criteria weight

Criteria	Weight (scale 1-10)
Expense	9
Lifetime	8
Materials	8
Water storage capacity/ decrease water runoff	7
Food quality	6
Area usage	6
Accessibility	5
Construction period	3
Visual quality	2

Table 15 shows the end results of the MCDA. These are calculated by multiplying the weight by the score.

Table 15 Results MCDA types

Criteria	Community gardens	Container gardening	Vertical gardening	Green roofs
Expense	9	6.75	6.75	0
Lifetime	0	6	6	8
Materials	6	7	8	0
Water storage capacity/decrease water runoff	6	8	5.25	7
Food quality	1.5	4.5	6	6
Area usage	0	3	6	6
Accessibility	3.75	3.75	5	1.25
Construction period	0.75	3	2.25	0
Visual quality	2	0.5	1.50	0.50
Total	29	42.5	46.75	28.75

4.2 CONCLUSION

The sub-question is "What type of urban agriculture is suitable for Cebu City?".
The results of the MCDA shows that vertical agriculture has the highest score. Container gardening has the second highest score, community gardening is third highest score and green roofing has the lowest score.
Green roofs are simply too expensive and too complicated to build. This project focusses on the lower-class households, so green roofs are not a viable option.
The most decisive factor to not choose community gardening was the lifetime. The lifetime is a criteria that scores high since it is important for the PCUP. Community gardens score very low on this criteria and therefore it has not the highest score.
Container gardening is the only type of urban agriculture that came really close to the score of vertical gardening. However, water storage and decrease of the water runoff is an important criteria because the main goal of the project is to reduce water related problems. Container gardening scores not high enough on this criteria which was the decisive factor which made us not choose this type of urban agriculture.
Vertical gardening scores high on all criteria. It can be made very cheap and has the potential to store and slow down a large amount of water.
There are multiple ways to apply vertical agriculture, we choose for the vertical container gardens. Green walls are simply too expensive for a low-cost project. There are still many ways to design the vertical container gardens and various materials can be used.

5. VEGETATION

This chapter will compare multiple types of vegetation with the help of a MCDA. The result of the MCDA will determine which kind of vegetation will be used for the pilot.

5.1. MCDA

Before making this MCDA a literature study has been executed to find multiple types of vegetation that are able to grow well in the tropical climate of Cebu City. This study found 8 different types of vegetation that were able to grow well in the Philippines. These possible types of vegetation are tropical tomatoes, tomatillo tropical beans, tropical lettuce substitutes, Asian broccolis, Asian, cucumber, Courgettes substitute, eggplants. These types of vegetation are further discussed in appendix 2. The vegetation are rated on different criteria which are also further discussed in appendix 2. In table 16 is the first version of the MCDA with the data visible.

Table 16 Vegetation criteria

Criteria	Tropical tomatoes	Tomatillo	Tropical beans	tropical lettuce substitutes	Asian Broccolis	Asian cucumber	Courgettes substitute	Eggplants
Climate resistance	++	++	++	++	++	++	++	++
Cost (Php/100 seeds)	450	360	108	200	40	800	670	550
Water consumption (l/dag)	0.3	0.43	0.5	0.4	0.4	0.54	0.92	1.8
Value (Php/kg)	70	60	30	80	175	14	120	45
Yield kg/hectare	9400	15000	6600	11000	5380	8300	11000	3000
Weight (kg)	0.12	0.10	0.18	0.50	0.75	0.37	0.40	0.25

The data from table 16 is discussed in appendix 2. The data has to be converted to scores in order to compare them what is done in table 17. The highest possible score is converted into a 1 and the lowest into a 0. All the data between the maximums and minimums are converted between 0 and 1. The used scale is visible in table 18.

Table 1712 Vegetation scores

Criteria	Tropical tomatoes	Tomatillo	Tropical beans	tropical lettuce substitutes	Asian Broccolis	Asian cucumber	Courgettes substitute	Eggplants
Climate resistance	1	1	1	1	1	1	1	1
Cost (Php/100 seeds)	0.55	0.64	0.892	0.8	0.96	0.2	0.33	0.45
Water consumption	0.3	0.43	0.5	0.4	0.4	0.54	0.92	1
Value (Php/kg)	0.35	0.3	0.15	0.4	0.88	0.07	0.6	0.225
Yield kg/hectare	0.47	0.75	0.33	0.55	0.27	0.42	0.55	0.15
Weight (kg)	0.88	0.90	0.82	0.50	0.25	0.63	0.60	0.75

The criteria is difference in importance and therefor they have different weights. The weights of each criteria is visible in table 18 and is further explained in appendix 2.

Table 13 Vegetation weight/scale

Criteria	Scale (0/1)	Weight (1/10)
Climate resistance	--/++	9
Cost (Php/100 seeds)	1000/0	8
Water consumption	0/1	7
Value vegetables (Php/kg)	0/200	6
Yield kg/hectare	0/20000	4
Weight of the vegetable	1/0	2

Table 149 MCDA vegetation results

Criteria	Tropical tomatoes	Tomatillo	Tropical beans	tropical lettuce substitutes	Asian Broccolis	Asian cucumber	Courgettes substitute	Eggplants
Climate resistance	9	9	9	9	9	9	9	9
Cost (Php/100 seeds)	4.40	5.12	7.14	6.40	7.68	1.60	2.64	3.60
Water consumption	2.10	3.01	3.50	2.80	2.80	3.78	6.44	7
Value (Php/kg)	2.1	1.8	0.9	2.4	5.25	0.42	3.60	1.35
Yield kg/hectare	1.88	3.00	1.32	2.20	1.08	1.68	2.2	0.60
Weight (kg)	1.76	1.80	1.64	1.00	0.50	1.26	1.20	1.50
Total	**21.24**	**23.73**	**23.5**	**23.8**	**26.31**	**17.74**	**25.08**	**23.05**

After implementing the scale and the weight into the MCDA table the final score is visible (table 19).

5.2. CONCULSION

The sub-question is which kind of vegetation qualifies the most for urban agriculture in Cebu City. The final table of the MCDA (table 19) has shown that the Asian broccoli has the highest score of all the vegetables. Asian broccoli scored high on climate, cost and value, these criteria weighed heavily in this project. Because of the high score, it is most likely that Asian broccoli will be planted for urban agriculture.

Courgettes has the second highest score of all. It scored noticeable high on the criteria water consumption. Since this project focusses on increasing the water storage capacity of Cebu City, it is wise to choose courgettes for the urban agriculture as well.

Tropical lettuces scored third highest of all plants. Lettuces scored high on cost and yield. It is possible to produce many on a small area. For this reason we decided to add lettuces as final plant to the urban agriculture as well.

These types of vegetation will be used as urban agriculture in this project. The other vegetables are still optional and can be chosen in the course of the project.

6. STAKEHOLDER ANALYSIS

6.1 STAKEHOLDER INFORMATION

Table 20 below gives an overview of the stakeholders with general information that have influence or/and interests in this project. These are investigated and interviewed.

Table 20 Stakeholder overview

Municipal government	Abbreviation	Representative	Location
Presidential Commission for the Urban Poor	PCUP	Chloe Manlosa-Osano	Cebu City
City Agriculture Department	CAD	Joelito L. Baclayon	Cebu City
Department of Agriculture	DA	Angel C. Enriquez	Mandaue City
NGO´s (non-governmental)	**Abbreviation**	**Representative**	**Location**
Councillor Engr. Nestor D. Archival	NDA	Nestor D. Archival	Cebu City
Alaska Mambaling school	AMS	Principal Mrs. Teresa Alviado	Cebu City

6.2 STAKEHOLDER SELECTION

Table 21 placed below gives a description about the stakeholder and the reason why it is selected for this project.

Table 21 Stakeholder selection

Stakeholder	Description	Reason of selection
PCUP	The *Presidential Commission of the Urban Poor or PCUP* is a direct link between the poor and the government in the cities of the Philippines. PCUP is a governmental organisation and has multiple functions. They start programs to help the urban poor. They make communication between the urban poor and the government of the Philippines possible and they support other non-governmental organisations who are also trying to help the urban poor. The vision of PCUP is creating a society in which the urban poor are strong and confidant, give an economic contribution, work with the government to fight poverty and work at the development of agriculture around the city.	The PCUP is the organization we work for. The PCUP has a lot of connections and can arrange meetings with other important stakeholders. The PCUP focusses on the urban poor as well as this project so they have big interests. They also know the urban poor locations in Cebu City. The PCUP held competitions to make the lower class citizens grow and learn urban agriculture. Our designs will help them educate

	PCUP is trying to reach this vision by quickly creating programs to help the urban poor where needed and by finding more organisations who are trying to accomplish the same goals.	inhabitants to create more water storage by growing food.
CAD	*"The City Agriculture Department is an institution which excels in dynamic food production and ecological growth through efficient and effective agricultural extension services and community-based development and management in Cebu City* (Cebucity the most livable city for all, 2011). The CAD (City Agriculture Department) is responsible for maximizing the output of food products, development and conservation of forest and agriculture resources, and increasing family income through agricultural production and home industries (Cebucity the most livable city for all, 2011; Cebucity the most livable city for all, 2011). The department maintains contact with the heads of National, Provincial, Regional and Local Government units, and Civic Clubs in Cebu City for greater services and efficiency in the production of livestock, crops, poultry and in the conservation of agricultural resources (Cebucity the most livable city for all, 2011).	The CAD works in the urban agriculture sector and thus have a lot of experience. They teach the inhabitants to plant their own plants in urbanized areas. This means CAD can give advice about the designs, plants and maintenance. They can implement our designs and provide materials for this project.
DA	The Department of Agriculture is the principal agency of the Philippines government responsible for the promotion of agriculture and fisheries development and growth (Department of Agriculture Regional Field Office No. 7, 2014). It directs investments and, in partnership with the local government units, provides support where necessary to make agriculture and fisheries profitable. Also to help spread the benefits of development to the poor, particularly those in rural areas (Department of Agriculture Regional Field Office No. 7, 2014). Their vision is a modernized smallholder agriculture and fisheries; a diversified rural economy that is dynamic, technologically advanced and internationally competitive (Department of Agriculture Regional Field Office No. 7, 2014).	The Department of agriculture has much information about vegetables that are able to grow well in the climate of Cebu. The DA has much experience with learning citizens to grow vegetables in a urban situation.
NDA	Councillor Nestor D. Archival is a professional Engineer and he designed the Eco-house. It is placed in Cebu City and the only of its kind in the	Nestor Archival is a very experienced engineer who has a passion for living

	Philippines. The Archival Eco house has embodied a household-based sustainable environment living. The Eco House is integrated with sustainable features that enhance the environment, making it sufficient to operate on its own.	durable. He has built a house which is surrounded by different types of urban agriculture designs and sustainable features. He is able to give us information about growing urban agriculture and about growing agriculture durable. This could help creating designs.
Alaska Mambaling school	The Alaska Mambaling school is a stakeholder that was added later on in the research. After interviewing them and after a field research the school was the chosen location for the pilot. The school is located in a flood area and thus experiences many floods. Also, the water bill is very high which they want to reduce.	The Alaska Mambaling school is a very important stakeholder. It owns the location where the pilot will be implemented. Further reasons of selection are described in the location analysis in chapter 7.

6.3 INTEREST AND INFLUENCE

This paragraph will describe the interests and influence per stakeholder. Every stakeholder is rated on its influence and interest and processed into an influence versus interest grid.

Table 152 Stakeholder interest/influence

Stakeholder	Interests	Influence
Presidential Commission for the Urban Poor (PCUP)	Helping the urban poor	Arrange meetings with other stakeholders and showing us possible locations for urban agriculture. The PCUP needs to understand the design so that they can teach the citizens to implement the agriculture themselves.
City Agriculture Department (CAD)	Creating extra food resources in urban areas. Children need to eat more vegetables.	The CAD is willing to provide seeds and soil for urban agriculture projects.
Department of Agriculture (DA)	Affordable food production	Providing information about planting urban agriculture.
Councillor Engr. Nestor D. Archival (NDA)	Sustainable urban agriculture	Providing information about design possibilities. Investing in future sustainable projects.

Alaska Mambaling school	Reducing use of water and teach students more about urban agriculture.	Providing the location, materials and maintenance.

Table 16 Stakeholder interest/influence degree

Presidential Commission for the Urban Poor (PCUP)	Degree of Interests (1-5)	Degree of Influence (1-5)
City Agriculture Department (CAD)	4	3
Department of Agriculture (DA)	2	1
Councilor Engr. Nestor D. Archival (NDA)	3	2
Presidential Commission for the Urban Poor (PCUP)	4	5
Alaska Mambaling school (AMS)	5	5

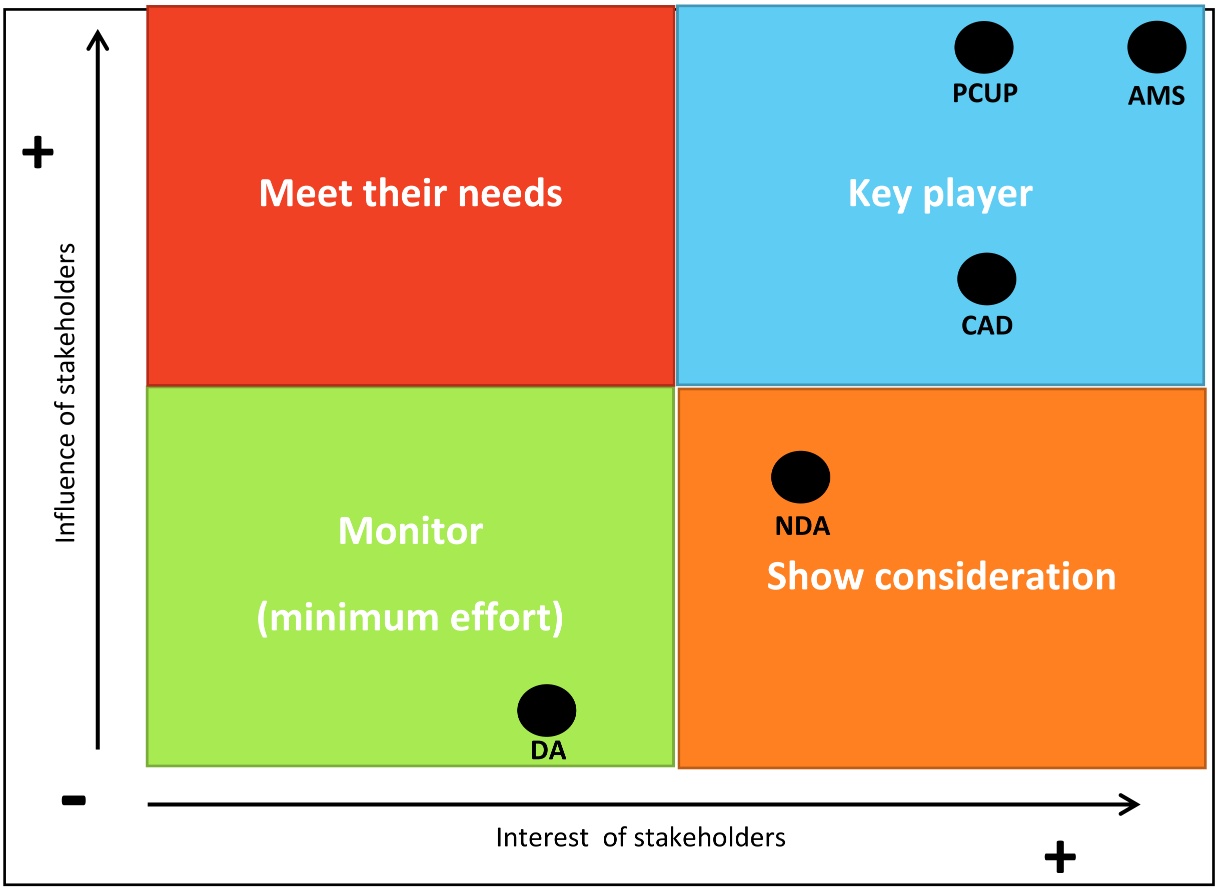

Figure 8 Interest vs influence grid

As shown in figure 8 the PCUP, City Agriculture Department and the Alaska Mambaling school are the most important stakeholders. Councilor Engr. Nestor D. Archival is also an important stakeholder but has not much influence on the project. Therefore, Councilor Engr. Nestor D. is Archival is not a key player but we have to show consideration. The Department of Agriculture has not much influence or interests and is therefore less important for this project.

7. LOCATION

It is important for this project that a location in Cebu City is found that is suitable for urban agriculture. The location has a lot of influence on the success of the pilot. Therefore, multiple locations are rated on criteria which are important for this project and put into a MCDA. In appendix 3 is placed the full analysis. The appendix will show the steps taken in the whole research.

7.1 SELECTED LOCATIONS

In order to find out which location qualifies the best for urban agriculture multiple locations were visited. After interviewing City of Agriculture they suggested to place our pilot at a school. Schools often have problems with floods. The students also could learn from the pilot and maintain the plants. The PCUP helped selecting the locations. They know which areas are occupied by the urban poor. After visiting multiple locations four were chosen (table 24) to break down in a MCDA. Below are shown pictures of the possible locations.

Table 24 Selected locations

Nr.	Street	Location coordinates
1	Alaska Mambaling integrated school	10.288097, 123.881908
2	Mambaling elementary school	10.290799, 123.875149
3	Pundok sa Katawhan Sitio Lower Lumar – Brgy. T. Padilla	10.304375, 123.905269
4	Lnai Hoa	10.294019, 123.885273

Alaska Mambaling school

Figure 9 Alaska Mambaling school

Mambaling elementary school

Figure 10 Mambaling elementary school

Pundok sa Katawhan Sitio Lower Lumar

Figure 11 Pundok sa Katawhan Sitio Lower Lumar

Lnai Hoa

Figure 12 Lnai Hoa

7.2 MCDA

Below is placed the results of the location analysis. The whole location analysis is placed appendix 3.

Table 175 Location criteria

Criteria	Alaska Mambaling integrated school	Mambaling elementary school	Pundok sa Katawhan Sitio	Lnai Hoa
Construction stability	++	+	+/-	-
Flood zone	+	+/-	+	+
Sun hours (hours)	7.92	5.17	3	2.67
Maintenance options	+	+	+/-	+/-
Accessibility	+	+	+/-	+

Table 26 Loation criteria scores

Criteria	Alaska Mambaling integrated school	Mambaling elementary school	Pundok sa Katawhan Sitio	Lnai Hoa
Construction stability	1	0.75	0.50	0.25
Flood zone	0.75	0.50	0.75	0.75
Sun hours (7.92=1 & 0=0)	1	0.65	0.38	0.34
Maintenance options	0.75	0.75	0.50	0.50
Accessibility	0.75	0.75	0.50	0.75

Table 187 Location criteria weight

Criteria	Weight
Construction stability	8
Flood zone	7
Sun hours	5
Maintenance options	4
Accessibility	3

Table 198 Location MCDA results

Criteria	Alaska Mambaling integrated school	Mambaling elementary school	Pundok sa Katawhan Sitio	Lnai Hoa
Construction stability	8	6	4	2
Flood zone	5.25	3.50	5.25	5.25
Sun hours	5	3.25	1.90	1.70
Maintenance options	3	3	2	2
Accessibility	2.25	2.25	1.50	2.25
Total	**23.50**	**18.00**	**14.65**	**13.20**

7.3 CONCLUSION

The sub-questions is which location in Cebu City qualifies the most for urban agriculture.
The MCDA results that the Alaska Mambaling school has the highest score. This school is located in a poor area which is needed since this project is for the urban poor. This location does also have many sun hours per day. The school has firm buildings that can easily support the weight of the agriculture. However, there are also multiple floors in some buildings. To gain easy access to the urban agriculture the building chosen to use for urban agriculture is selected in figure 13.
Another benefit of the school is that the students and teachers could maintain the pilot and they could also use it for research purposes. In the end, the goal of this project is too learn people how to storage water with urban agriculture and use the water as efficient as possible. Implementing this into a school would therefore be a wise choice. The other locations did not have all those benefits and therefore scored lower in the MCDA. After talking to the principal of the school about implementing the pilot an other place within the school terrain got assigned to us. This was because this was closer to the allready excisting garden and therefor better for education purposes.

Figure 13 Building marked red

8. DESIGNS

8.1. DESIGN 1

8.1.1. DESIGN DESCRIPTION

A sketch of the first design is shown in figure 14. A bigger illustration is placed in appendix ??. This design catches water from the roof and re-directs it into a tank by making use of a gutter. The tank is connected to a tube or hose. The tube is closed at the end, this means the tube will also be filled with water. However, the tube has tiny holes so that the water will flow very slowly out of the tube into the vegetation hung beneath the tank. The vegetation is placed in bottles placed horizontally. Multiple rows of bottles are placed beneath each other. The bottles are placed oblique so that water can flow down towards the ground in case of too much water.
This design will store rainwater during rainfall. Since the water can only flow out very slowly, it will water the plants over a large amount of time.
The design can be attached to a ceiling by making use of ropes or it can be nailed to a wall. This depends on the location. Figure 15 shows an intersection from 2 different angles. With the chosen location the design will have an height of around 2.3 meters.

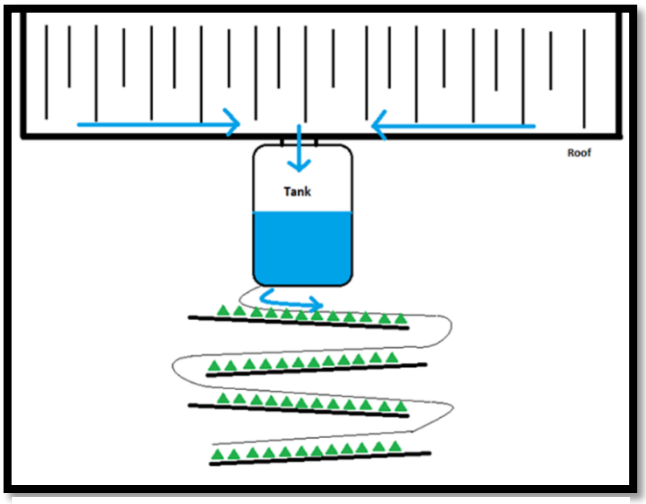

Figure 14 Design 1 sketch

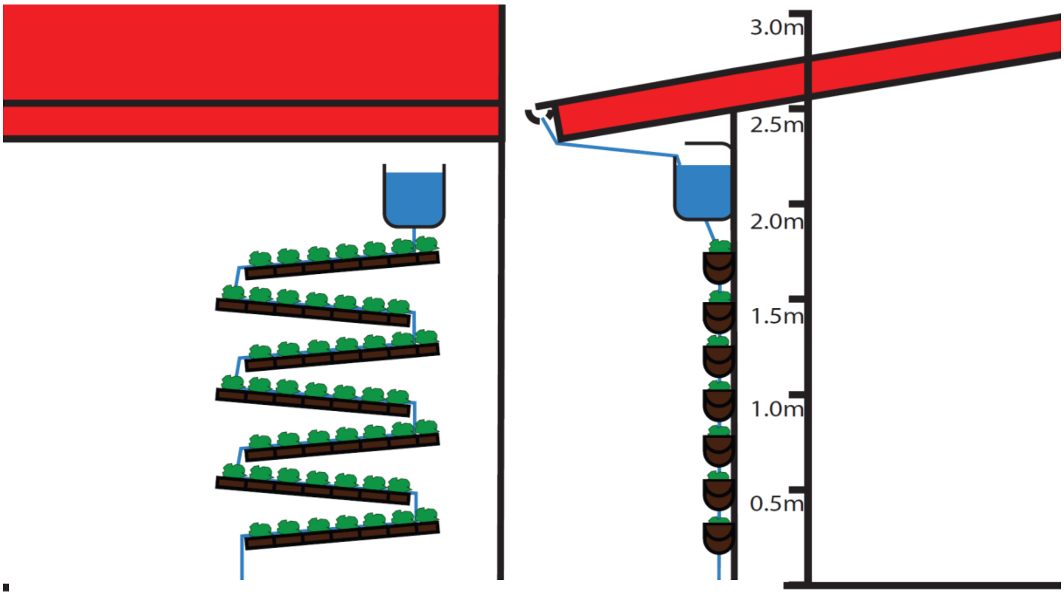

Figure 15 Intersection two different angles design 1

Figure 16 shows a more factual view of the design. All these figures are also placed in the appendix on larger scale. In appendix 5 is placed a full analysis of the design.

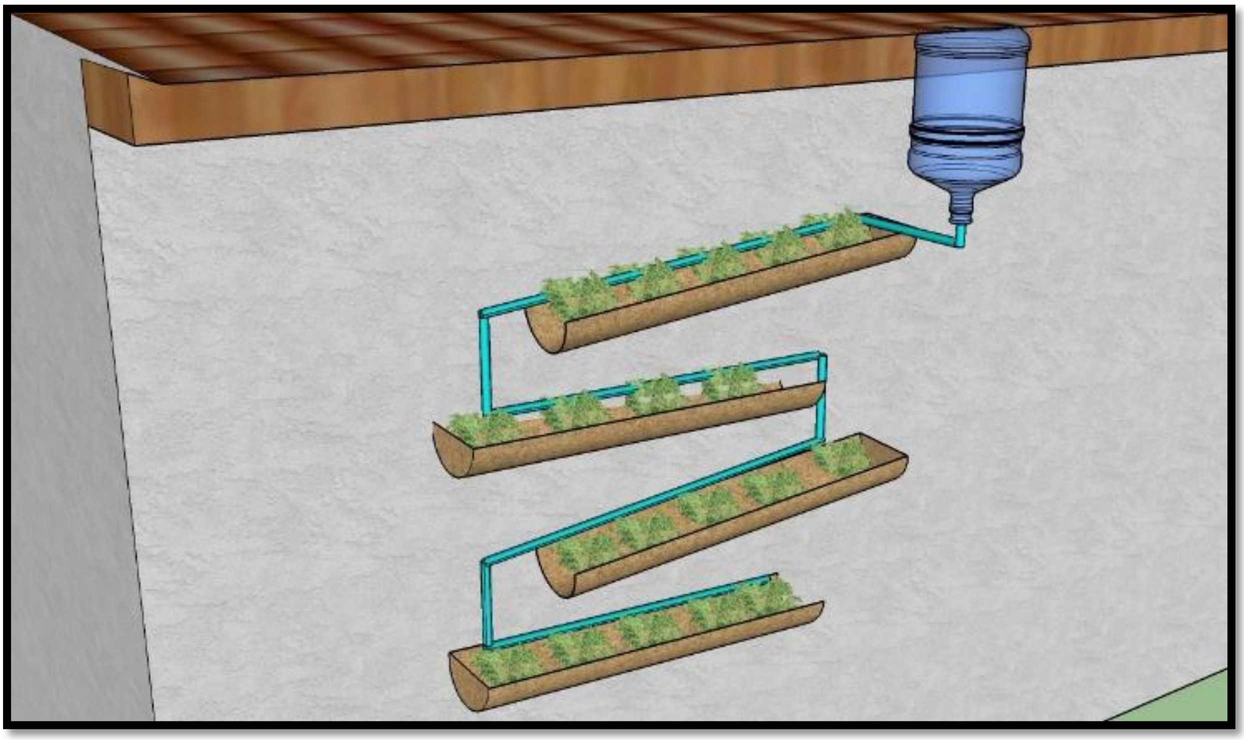

Figure 16 3d design 1

Multiple materials are needed to make this design. The materials needed for design 1 are listed in table 29 with their costs. Materials that are recycled or provided are considered $0 in costs.

Table 29 Materials design 1

Materials	Description	Unit	Cost ($)
Tank (19L)	The tank is used to store water	1	$0.45
Bamboo (2m)	Bamboo will be cut in half and used as gutter on the roof. The gutter will lead the rainwater into the tank.	1	Recycled $0
Tube or hose (4m)	The tube can be a garden hose for example. Tiny holes will be made in the hose so that water slowly drips on the vegetation.	1	$4
Bottles (1.5-2L)	Around 15 empty bottles are needed as a container for the plants, the best size will be around 1.5L-2L. Bamboo can also function as a container for the plants but is more expensive.	49	Recycled $0
Nails or rope	Nails are needed to attach the structure to adjacent buildings. Rope can also be used but is more difficult and probably less stable.	± 10	$0.90
Cork or tape	A cork or tape can be used to attach the tube to the tank. However, tape is probably not as firm as tape.	1	$0.30
Soil	The soil is provided by the City Agriculture Department.	± 20 kg	Provided $0
Seeds	The seeds are provided by the City Agriculture Department.	± 50	Provided $0
Total costs			$5.65 (=±300 Php)

8.1.2. SWOT

Table 30 SWOT 1

Strengths	Weaknesses
-Increase water storage -Watering plants over time -People spare water -Room for a lot of vegetation -Cheap -Simple technology -Use of local materials -No obstruction for roads or ways	-Requires more materials (than other design) -Durability -Quite wide
Opportunities	**Threats**
-Locals could learn from design -People will eat more vegetables -Make environment greener -Can be implemented on large scale -Reduce consequences of heavy rainfall	-Could be difficult to attach -Drowning the plants -People will not maintain the pilot -Design failures -Tank can flood with too much rain -Insect pests

Overview of the most important topics

Increase water storage

The main purpose of this design is to storage water. It is an adaptive solution since the water is used for vegetation. The tank on top of the design allows it to storage an amount of rainwater.

Watering plants over time

The plants are watered over time. This is important because main problems in the past with urban agriculture was that the people would not maintain the plants enough. By watering the plants over time this problems is reduced. Also the plants will slow down the water so that the ground is less likely to be saturated.

Quite Wide

This design is quiet wide which is a disadvantage. This means it is not possible to place many next to each other to catch more rainwater.

Could be difficult to attach

A big threat is that it could be difficult to attach the design to adjacent buildings or walls. This design has many loose parts, each of these parts need to be attached separately.

People will eat more vegetables

After interviewing the City of Agriculture they mentioned that people and especially the children do not eat enough vegetables. This design produces a vast amount of vegetables and could encourage the people to eat more healthy.

Confrontation matrix

The confrontation matrix will look at the 'match & mismatch' between the strengths/weaknesses and the opportunities/threats from the SWOT analysis (Marlou Landers, 2013). The confrontation matrix should give clarity to these 4 questions (Marlou Landers, 2013).

- How can strong points respond to opportunities?
- How can strong points be enabled to repel threats?
- How can weak points be strengthened to respond to opportunities?
- How can weak points be strengthened to provide resistance to threats?

Each confrontation will be rated with 0/-/--/+/++. When comparing the points the positive can compensate the negative or the other way around, based on this result it can score + or -. When counting all the scores the confrontation matrix will show which points are the best opportunities, strength, weaknesses and which one is the highest threat. Table 29 shows the confrontation matrix of the first design.

Table 31 Confrontation matrix 1

		Opportunities					Threats						
		Locals could learn from design	People will eat more vegetables	Make environment greener	Can be implemented on large scale	Reduce consequences of heavy rainfall	Could be difficult to attach	Drowning the plants	People will not maintain the pilot	Design failures	Tank can flood with too much rain	Insect pests	
Strength	Increase water storage	++	0	++	+	++	-	-	--	--	-	-	-1
	Watering plants over time	++	+	+	++	++	-	0	+	--	-	-	4
	People spare water	+	0	+	+	0	-	0	+	-	-	0	1
	Room for a lot of vegetation	0	++	++	+	++	-	--	0	-	-	-	1
	Cheap	+	+	0	++	0	+	-	0	-	-	0	3
	Simple technology	+	0	0	++	0	+	0	+	+	0	0	4
	Use of local materials	+	0	0	++	0	0	0	+	-	-	-	1
	No obstruction for roads or ways	0	0	0	++	0	0	0	0	0	-	0	1
Weaknesses	Requires more materials	+	-	-	-	0	-	0	-	-	0	0	-5
	Durability	-	-	-	-	-	-	0	--	-	-	-	-11
	Quite wide	0	0	+	-	0	-	0	0	-	0	0	-2
		8	2	5	10	5	-5	-3	-1	-12	-8	-5	

Important results of the confrontation matrix

- When implementing this design the water storage will increase. This means that the consequences of heavy rainfall will reduce in the future.
- The design is made out of many loose parts and thus difficult to attach. This could mean that it is more likely design failures can occur and forms a threat for this project.
- When people see that this design will store water and give plants water over time, they could be more interested in learning how it works so that they can implement it themselves.
- The design is made so it will water the plants automatically. Therefore, the people do not have to maintain in that often so the strength can be used to repel a threat.
- When something is built very complicated using advanced technology, the chance of design failures is higher. Since the design is made using simple technology, this is not the case. It will reduce the chance of design failures.
- Durability is the biggest weakness of the design.
- Design failures is the highest threat of the design.
- When people see that this design stores water and is made by local materials and simple technology they could be more interested in maintaining the pilot.

8.1.3. WATER SYSTEM ANALYSIS DESIGN 1

To water the 49 plants of design 1 you would need a water flow of around 1.0L/h (0.5L/day/plant). After testing and measuring the pilot project we found out that this could be achieved by making 5 holes in the hoze/tube.
By implementng the first design 2.7m³ of rainwater is stored and slowly drained per year. The amount of days that the pilot is watering the vegetation is 102 days per year on average (figure 17). In these 102 days you do not have to water the plants yourself so you save around 2500L water per year. The steps that are taken to calculate these numbers are explained in appendix 5 Design report.

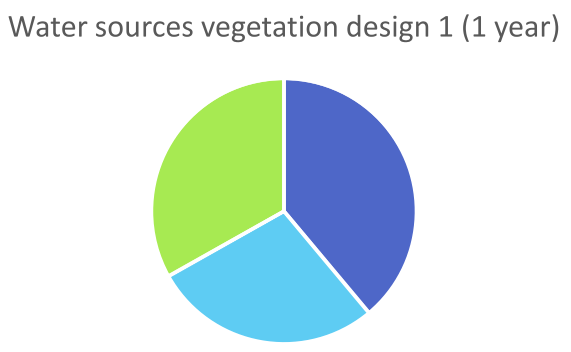

Figure 17 Water sources design 1

8.2. DESIGN 2

8.2.1. DESIGN DESCRIPTION

The second design is shown in figure 18 below, a bigger illustration is placed in appendix 4. This tank can also be placed beneath a roof to store rainwater. In this design the plants are placed beneath each other. They are connected with each other by use of bottles. A tube is connected with the tank and placed through the soil vertically. The tube also has tiny holes so that it will water the vegetation over a large amount of time. Holes are made in the bottles so that the vegetation can grow towards the sun. The design can be attached with rope to the roof or by nails against the wall, depending on the location. This design is very small which opens up the opportunity to place multiple next to each other. Figure 19 shows an intersection from two different angles. With the chosen location the design will have an height of around 2.3 meters.

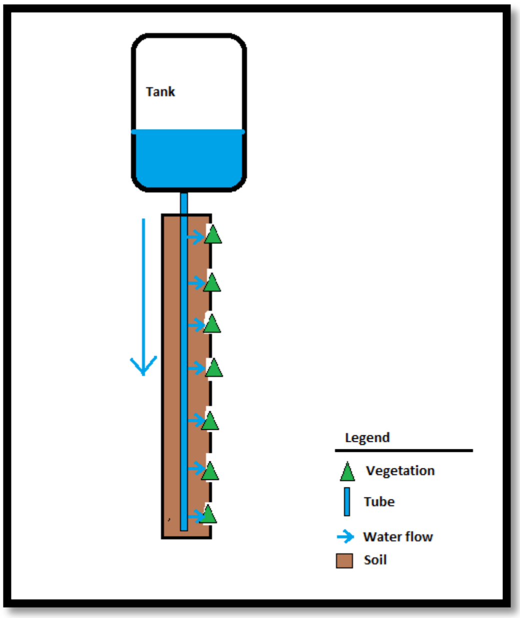

Figure 18 Design 2 sketch

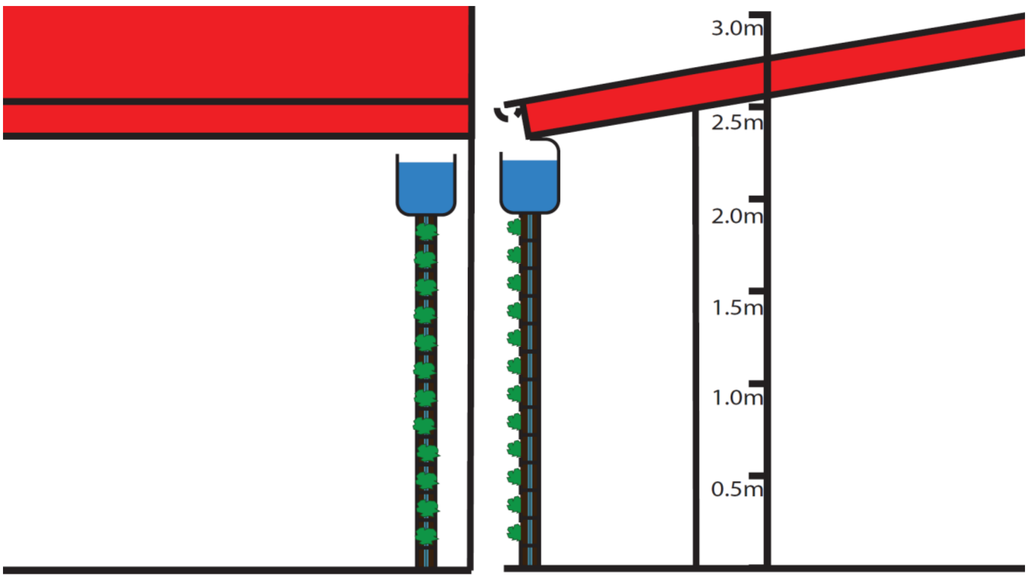

Figure 19 Intersection from 2 angles design 2

Figure 20 shows a more factual view of the design. In appendix 5 is placed a more detailed analysis of the design.

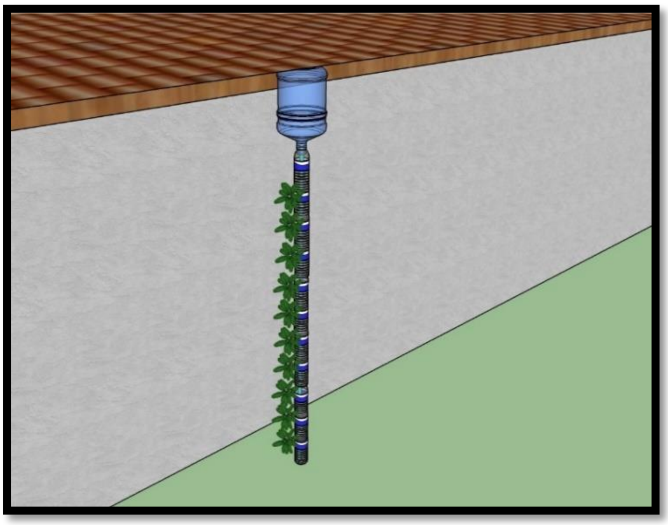

Figure 20 3d design 2

Multiple materials are needed to make this design. The materials needed for design 2 are listed below in table 32 with their costs. Materials that are recycled or provided are considered $0 in costs.

Table 32 Materials design 2

Materials	Description	Unit	Cost ($)
Tank (19L)	The tank is used to store water	1	$0.45
Bamboo (2m)	Bamboo will be cut in half and used as gutter on the roof. The gutter will lead the rainwater into the tank.	1	Recycled $0
Tube or hose (2m)	The tube can be a garden hose for example. Tiny holes will be made in the hose so that water slowly drips on the vegetation.	1	$2
Bottles (1.5-2L)	Around 15 empty bottles are needed as a container for the plants, the best size will be around 1.5L-2L.	12	Recycled $0
Nails or rope	Nails are needed to attach the structure to adjacent buildings. Rope can also be used but is more difficult and probably less stable.	± 5	$0.45
Cork or tape	A cork or tape can be used to attach the tube to the tank. However, tape is probably not as firm as tape.	1	$0.30
Soil	The soil is provided by the City Agriculture Department.	± 10 kg	Provided $0
Seeds	The seeds are provided by the City Agriculture Department.		Provided $0
Total costs			$3.20 (±150 Php)

8.2.2. SWOT

Table 33 SWOT 2

Strengths	**Weaknesses**
-Increase water storage -Watering plants over time -People spare water -Room for vegetation -Cheap -Simple technology -Use of local materials -No obstruction for roads or ways	-Has not that many plants (compared to other design) -Durability
Opportunities	**Threats**
-Locals could learn from design -People will eat more vegetables -Make environment greener -Can be implemented on large scale -Reduce consequences of heavy rainfall	-Drowning the plants -People will not maintain the agriculture -Could be instable -Design failures -Tank can flood with too much rain -Insect pests

Overview of the most important topics

Increase water storage

The main purpose of this design is to storage water. It is an adaptive solution since the water is used for vegetation.

Watering plants over time

The plants are watered over time. This is important because main problems in the past with urban agriculture was that the people would not maintain the plants enough. By watering the plants over time this problems is reduced.

Has not many plants

An disadvantage of this design is that it has not that much room for plants compared to the other design. This could reduce the amount of water it can hold and the amount of vegetation it will produce.

Scalability

A big opportunity of this design is the scalability. The form of this design makes it possible to place multiple of these designs next to each other. Since it is able to do this multiple can be placed under the same roof what will increase the water storage significanct

Stability

A big threat could be the stability of the design. Every bottle needs to be connected firm enough to each other or it might collapse.

Table 34 Confrontation matrix 2

		Opportunities					Threats						
		Locals could learn from design	People will eat more vegetables	Make environment greener	Can be implemented on large scale	Reduce consequences of heavy rainfall	Could be instable	Drowning the plants	People will not maintain the pilot	Design failures	Tank can flood with too much rain	Insect pests	
Strength	Increase water storage	++	0	++	+	++	-	-	--	--	-	-	-1
	Watering plants over time	++	+	+	++	++	-	0	+	--	-	-	4
	People spare water	+	0	+	+	0	-	0	+	-	-	0	1
	Room for vegetation	0	++	++	+	++	0	--	0	-	0	-	3
	Cheap	+	+	0	++	0	+	-	0	-	0	0	2
	Simple technology	+	0	0	++	0	+	0	+	+	0	0	6
	Use of local materials	+	0	0	++	0	+	0	+	-	0	-	3
	No obstruction for roads or ways	0	0	0	++	0	-	0	0	0	0	0	1
	Does not need much space	+	0	+	++	0	+	0	0	0	0	0	5
Weaknesses	Has not that many plants	0	--	--	0	-	+	+	+	0	-	+	-2
	Durability	-	-	-	-	-	--	0	--	-	-	-	-12
		8	1	4	13	4	-2	-3	-1	-8	-5	-4	

Important results of the confrontation matrix

- When implementing this design the water storage will increase. This means that the consequences of heavy rainfall will reduce in the future.
- When people see that this design will store water and give plants water over time, they could be more interested in learning how it works so that they can implement it themselves.
- The design is made so it will water the plants automatically. Therefore, the people do not have to maintain in that often so this strength can be used to repel a threat.
- When something is built very complicated using advanced technology, the chance of design failures is higher. Since the design is made using simple technology, this is not the case. It will reduce the chance of design failures.
- A big opportunity is that this design can easily be implemented on large scale. This is due the fact that this design does not need much space, materials and is low-cost.
- Durability is the biggest weakness of the design.
- Design failures is the highest threat of the design.
- When people see that this design stores water and is made by local materials and simple technology they could be more interested in maintaining the pilot.
- A weakness is that this design does not have room for that many plants. A threat is that this design could be unstable and could fall out of balance. The fact that there are not many plants reduces the weight and chance that it will fall out of balance. For this reason, a weakness reduces the chance a threat will occur.
- When there are less plants, the people have to maintain less.
- The water storage capacity is reduced since this design has not many plants.
- Insects are lured by flowing water and the plants. This design has less room for plants and the vegetation is better hidden in the bottles. This reduces the chance of insect pests.

8.2.3. WATER SYSTEM ANALYSIS DESIGN 2

Design 2 has only 18 plants which means that a lower water flow can be used in the pilot. The water flow that is needed for this design is 0.38L/h. This can be achieved by making two holes. However it is better to use 3 holes so the water is more equally devided.

By implementing the second design 2.5m³ of rainwater is stored and slowly drained per year. The amount of days that the pilot is watering the vegetation is 156 days per year on average (figure 21). This means that in those 156 days around 1400L water is spared in 1 year on average. The steps that are taken to calculate this are placed in appendix 5 Design report.

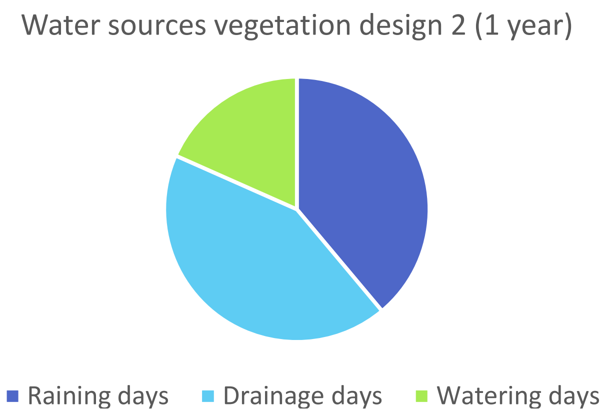

Figure 21 Water sources design 2

9. PILOT

This chapter will show the end result of the pilot, what materials are used and the results of testing the pilot.

9.1 CREATING PHASE

On December 12, 2014 design 2 has been made and placed at the Alaska Mambaling school. Figure 22 shows the end result of the pilot. There are 2 designs that could be implemented and tested. Due to lag of time we chose to only make 1 design. Design 2 was eventually chosen for the following reasons.

- Design 1 is more complicated to build
- Design 1 is more expensive to make
- Design 2 qualified better in the chosen location Alaska Mambaling school since the pilot is difficult to attach to a wall.
- Design 2 has more strong points that respond to opportunities
- Design 2 has more strong points that enable to repel threats.

Figure 22 Pilot Photo

After all the materials were gathered it only took 4 hours to build the pilot. On the next page a table is shown with the materials that were used to make this pilot.

Table 35 Materials pilot

Materials	Description	Unit	Cost ($)
Tank (19L)	The tank is used to store water	1	$0.45
Bamboo (2m)	Bamboo will be cut in half and used as gutter on the roof. The gutter will lead the rainwater into the tank. Another bamboo pole is used to attach the bottles to it to make it more stable.	2	Recycled $0
Tube or hose (2m)	A garden hose is used as hose. Tiny holes are made in the hose so that water slowly drips on the vegetation.	1	$2
Pen	A pen is used to plug the end of the tube so it will stop the water. The pen is wrapped in plastic to make it waterproof.	1	Recycled $0
Wooden planks (±30cm)	Wooden planks were used to attach the gutter to the roof	4	Recycled $0
Bottles (5L)	10 empty bottles are used as container for the plants. These 5L bottles are used because they were available at the school.	10	Recycled $0
Nails	Nails are used to attach the structure to the adjacent building.	± 5	$0.45
tape	Tape is used to attach the tube to the tank.	1	$0.30
Copper wire (1m)	Copper wire is used to attach the bottles to the bamboo pole	10	$0.45
Soil	The soil is provided by Alaska Mambaling school	± 10 kg	Provided $0
Alugbati plants	Plants are provided by the Alaska Mambaling school	18	Provided $0
Total costs			$3.65 (=±160 Pesos)

During the creating phase multiple problems occurred. The first problem that occurred was that the whole structure collapsed because there was too much pressure on the lowest bottles. After it was rebuild a bamboo pole was attached (figure 23) to the roof and to every bottle with copper wire. Thanks to this solution the pilot is more stable and will not collapse.
The lowest bottle is closed and empty. The reason for this is that a requirement was that the pilot should be 20 cm above the ground to protect vegetation. Now the lowest bottle is empty so there is no vegetation that can be damaged by pests or floods.
Tiny cuts are made in the lowest bottle so that water that has been go through the whole system will leave the pilot and go into the ground.
A small hole is made at the back on top of the tank so that water will flow out of the tank in case it rains to heavily. The water will not stream into the opening of the bottles into the plants but instead, it will go towards the ground.
This pilot has room for more than 20+ Alugbati plants. This is more than we expected because of the 5L bottles that are used.
Tiny cuts inside every bottle cap are made so that only the tube can go through and the soil remains inside the bottles.

Figure 23 Pilot bamboo pole

9.2 TESTING PHASE

After testing, this pilot can hold 1L of water for a duration of 30 min before it is completely distributed throughout the system. This results in a water flow of 2L/h. This is very high compared to the designs we made beforehand. This is because we made 9 holes in the tube which is too many. Figure 24 shows that with 9 holes there are 165 days per year the people need to water the plants themselves. There is an average of 142 raining days in the Philippines which will then water the plants. And there are 58 days per year that the drainage system provides water for the vegetation. So these 58 days the people will not have to water the plants which they would have without this design. In these 58 days is a total amount of 500 L/year water spared.
So it is advised to make 3 holes in the hose instead of 9 holes. When making 3 holes the graph should look more like the small circle in figure 24. You can see that in the small circle the drainage day are a lot more and the watering days is significant less.
The steps that are taken to calculate these numbers are explained in appendix 5 Design report.

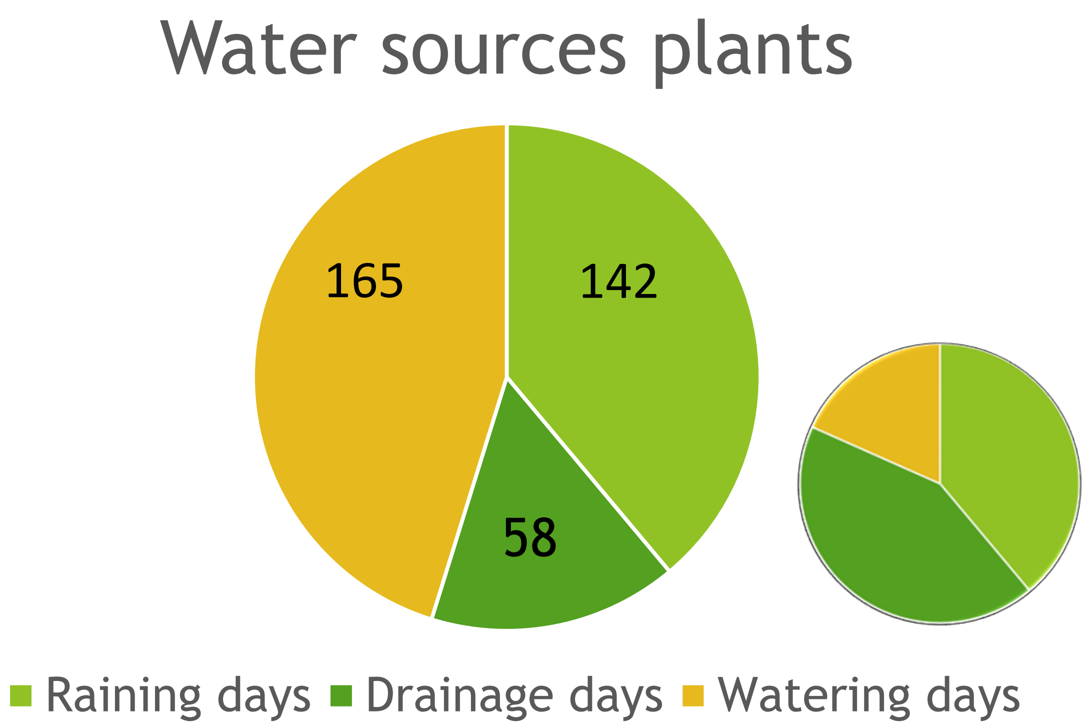

Figure 24 Pilot water sources graph

The water falls onto the roof and flows into the bamboo gutter. The gutter will lead the water into the tank (18.9L). The tank is attached to a hose which is plugged at the end so it will stop the water. The tube will be filled with water and will be divided onto the vegetation through tiny holes. The water will flow down through the soil and vegetation and will end up after a long period of time in the ground.

10. CONCLUSION

The poor people often suffer the most during floods. They live in the highly populated low-lying areas which are especially vulnerable. By applying low-cost urban agriculture the poor can do something their selves to reduce the consequences of heavy rainfall. This was the reason to investigate the possibilities of increasing the water storage an reducing food scarcity by use of urban agriculture. Urban agriculture can reduce the chance of floods and therefore improve the living conditions of the urban poor.

For this reason, the main question is ”*How can low-cost urban agriculture contribute to increasing the water storage and reduce food scarcity during floods in Cebu City?*”.
To answer this question multiple sub-questions are answered first. Regarding the conclusions of the sub-questions multiple things can be concluded.
There is concluded that the advantages of urban agriculture outweigh the disadvantages. The disadvantages can easily be avoided by taking certain measurements. This means that implementing urban agriculture in Cebu City will most likely have a positive influence on the city as a whole.
The type of urban agriculture that qualifies the most for Cebu is vertical gardening. This is concluded from the MCDA in chapter 4. Vertical gardening scores high on all criteria. It can be made very cheap and has the potential to store and slow down a large amount of water.
There are multiple ways to apply vertical agriculture, we choose for the vertical container gardens. Green walls are simply too expensive for a low-cost project.
The vegetation that qualifies the most for Cebu City is Asian broccoli regarding the MCDA in the vegetation analysis. Broccoli can hold a large amount of water, the seeds are cheap and it is resistant to the climate of the Philippines.
The location chosen for this project is the Alaska Mambaling school. This school is located in a poor area, which is needed since this project is for the urban poor. The school has firm buildings that can easily support the weight and has many sun hours per day.
Another benefit of the school is that the students and teachers could maintain the pilot and they could also use it for education purposes. In the end, the goal of this project is too teach people how to store water with urban agriculture and use the water as efficient as possible. Implementing this into a school would therefore be a wise choice.
The stakeholder analysis shows that the City Agriculture Department is willing to provide seeds and soil for the urban poor when implementing the pilot. The PCUP can help the urban poor by suggesting this design during their urban agriculture projects.

There are 2 designs that could be implemented and tested. Due to lack of time we chose to only make 1 design. Design 2 was eventually chosen for the following reasons.

- Design 1 is more complicated to build
- Design 1 is more expensive to make
- Design 2 qualified better in the chosen location "Alaska Mambaling School" since the pilot is very difficult to attach against the wall
- Design 2 has more strong points that respond to opportunities
- Design 2 has more strong points that repel threats

To answer the main question, this design could be used to contribute to increasing the water storage and reduce food scarcity during floods in Cebu City for the urban poor.
Design 2 does not use that much space so multiple pilots can be placed next to each other in order to catch a whole roof (figure 25). It only uses materials that are available locally and is made used simple technology. The whole pilot cost around 160 Pesos ($3.65) and can be made in only 4 hours. It does not need as much maintenance as in the traditional situation. This is because the plants are watered over time by stored rainwater.
This pilot has room for more than 20 Alugbati plants, so it produces quiet amount of food. This design slows down and holds the water so that the ground is less likely to be saturated. This pilot can catch 3-4m^2 of roof. If it is significant less than this, the plants could dry out because they are not getting enough water and the full water storage capacity of the pilot is not exploited. If it is too much, the chance that the tank will just overflow onto the ground is higher.
With the created pilot the plants need to be watered 165 days per year. The drainage system provides 58 days per year water for the plants. So in these 58 days you save 500 L/year, this is with 9 holes inside the hose. The amount of water you save can be increased by almost 3 times (1400 L/year) by making 3 holes instead of 9 inside the hose.

This pilot is an example for the urban poor. They could implement the exact design but it is always possible to adjust it. For example, if you want to increase the area of water catchment you simply use a tank with a bigger volume. It is also possible to increase the length of the design by adding more bottles so that more plants can be added. However, when doing this it is important that the structure stays stable by attaching it to a bamboo pole for example.

Figure 25 Photo pilot complete

11. RECOMMENDATION

It is recommended to the urban poor to use this design. The PCUP could help suggesting this design to the urban poor during their urban agriculture competitions. To maximize the effects of the design it is the best to use it on large scale. So multiple designs beneath a roof is recommended.

It is recommended to add the following features.

- Do not make much more than 3 holes inside the tube.
- Divide the holes equally over the length of the tube.
- Add a bamboo pole and attach every bottle to it.
- Place the vegetation at least 20 cm above the ground.
- Make tiny cuts on the bottom side of the lowest bottle.
- Make a small hole at the back on top of the tank.
- Make tiny cuts inside every bottle cap so that only the tube/hose goes through.

It is also recommended to use seeds and soil provided by the City Agriculture Department. They are more than happy to provide these.
When implementing the design it is recommended to use the Asian broccoli as vegetation. Regarding the vegetation analysis Asian broccoli is the best alternative. However, Asian broccoli is not perfect for every situation. This means when other on the MCDA high scoring vegetation is available, it would also be a valid option.

12. DISCUSSION

An organization called East-West Seed provides seeds that grow faster than normal seeds. In areas that are struck often by monsoons and hurricanes this could be very useful. They could provide seeds for the urban agriculture in Cebu City. In order to get East-West Seeds in collaboration with the PCUP contact has been made by mail for several weeks. Unfortunately, since it is not certain on what scale our design will be implemented in the future we cannot tell what extent of commitment is expected of the East-West Seed organization. For this reason, it is hard for East-West Seed to make any agreements. Providing fast growing seeds for the urban could be very valuable. Therefore, further research about collaboration options between East-West Seed and the PCUP is advised.

The water system analysis is partly based on “averages”. An example is that the water consumption of a plant is averaged on 0.5L/day. In reality this varies per plants so it is possible that with certain plants the actual result could change for a small proportion.
Another example is the average rainfall per day. We were not able to find the information therefore we estimated the average rain duration per day on 30 min with help of personal experiences. The rainfall durations in the Philippines are very short but intense.

The Dutch organization Deltasync was interested to know if this form of urban agriculture would be applicable for floating houses in Manila. The vertical agriculture could probably be attached to the walls of the floating house since it does not take in that much space. However, the whole design can weigh around 30 kilograms. This can have negative influence on the stability of a floating buildings, but this depends on the structure of the building.

While building the pilot a mistake was made. Too many holes were cut in the tube. This increased the water flow. In total 9 holes were cut, this should be around 3 holes. When making 3 holes in the tube the amount of draining days will increase and the amount of water that is spared will also increase.

Unfortunately, there was not enough time to build both the designs. In order to know exactly which design is better both should be made, tested and compared with each other. So further research is advised in order to determine this exactly.

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ILLUSTRATION				
Nr	**Description**	**Source**	**Date of publication**	**Author**
1	Location Cebu City	http://www.globalsecurity.org/military/world/philippines/maps.htm	Global serurity	No date
2	Example urban agriculture 1	Photo made: Timo Hoekstra	Timo Hoekstra	23-10-2014
3	Example urban agriculture 2	http://www.milkwood.net/2011/10/15/vertical-garden-meets-aquaponics/	Kirsten	14-10-2011
4	Interest vs influence grid example	Paint/Word	Ian Mullens	3-11-2014
5	Sun hours calculation example	Paint	Ian Mullens	29-10-2014
6	Mindmap	Bubbl.us	Ian Mullens & Timo Hoekstra	17-11-2014
7	SWOT table	http://pp-eye.blogspot.com/2011_12_28_archive.html	PP-eye	4-1-2012
8	Interest vs influence grid	Paint/word	Timo Hoekstra & Ian Mullens	10-12-2014
9	Alaska Mambaling school	Photo taken	Timo Hoekstra	30-10-2014
10	Mambaling elementary school	Photo taken	Timo Hoeksta	30-10-2014
11	Pundok sa Katawhan Sitio Lower Lumar	Photo	30-10-2014	Timo Hoekstra
12	Lnai Hoa	Photo	30-10-2014	Timo Hoekstra
13	Building marked red	Photo	10-12-14	Timo Hoekstra
14	Sketch design	Made with MS Paint	14-11-14	Timo Hoekstra
15	Intersection two different angles design 1	Made with Adobe Illustrator	10-12-14	Ian Mullens
16	3d design 1	Made with SketchUp	14-11-14	Ian Mullens

17	Water sources design 2	Water system analyses	15-12-14	Ian Mullens
18	Design 2 sketch	Made with MS Paint	13-11-14	Timo Hoekstra
19	Intersection from 2 angles design 2	Made with Adobe Illustrator	9-12-14	Ian Mullens
20	3d design 2	Made with SketchUp	14-11-14	Ian Mullens
21	Water sources design 2	Water system analyses	15-12-14	Ian Mullens
22	Pilot Photo	Photo	12-12-14	Timo Hoekstra
23	Pilot bamboo pole	Photo	12-12-14	Timo Hoekstra
24	Pilot water sources graph	Water system analyses	15-12-14	Ian Mullens
25	Photo pilot complete	Photo	12-12-14	Timo Hoekstra

APPENDIX 1. TYPES OF AGRICULTURE ANALYSIS

What type of urban agriculture is suitable for Cebu City?

Inhoud

1. Criteria

This chapter will explain why we chose for these criteria and describe them. Every criteria is given a weight. This will be explained as well and is placed in a table.

Expense (purchase costs + maintenance)

Since the project is held for the Presidential Commission of the Urban Poor, the costs of the urban agriculture need to be as low as possible. It is meant for the lower-income households. That is why the criteria expense is given a 9 on the weight scale 1-10. Expense is both purchase costs and maintenance. Every type of urban agriculture has different purchase costs and needs different maintenance.

Every type of urban agriculture will grow food and vegetables. The people can sell this food and make profit. The amount of profit will be compared with the costs in a cost-benefit analysis for every type of agriculture.

Lifetime

The lifetime of the types of urban agriculture is also something that will have a high score on the weight scale. The agriculture need to last as long as possible. It is not profitable when it breaks within few weeks. This criteria is also something what earlier projects about urban agriculture in Cebu City struggled with.

For this reason, lifetime will get a score of 8 on the weight scale 1-10.

Materials

It is important that the inhabitants can repair the gardens themselves. They can only do this when the materials are locally available. If this is not the case, the people will need to get the materials from other countries. This will cost extra money and time what is not desired. And not everyone has access to foreign countries. For this reason, materials scores an 8 on the weight scale 1-10. If it is not made by local materials then this project is unrealistic.

Water storage capacity/decrease water runoff

There are several water related problems in Cebu City. One of them is heavy rainfall in combination with a weak sewerage system. By using urban agriculture the water storage capacity can be increased. The plants will also decrease the runoff of the rainwater so that it takes more time for the water to go into the sewers. This will reduce pressure on the sewerage system of Cebu.

Therefore, every type of urban agriculture will be rated on its water storage capacity and water runoff decreasement.

This criteria will get a score of 7 on the weight scale 1-10.

Food quality

Every type of agriculture will be rated on its production. Some ways of urban agriculture will produce better quality food than one another. Urban agriculture needs to produce food for the inhabitants of Cebu City. The people will have an alternative food source during floods for example. This criteria scores a 6 on the weight scale 1-10. Other criteria score higher than this one because they are more reliable for the project to succeed and have genuine results. If it does not meet these requirements, then the project will be useless.

Area usage

Every type of urban agriculture uses space in a different way. In Cebu City is not that much space so smart usage of the area is needed. This criteria scores a 6 on the weight scale 1-10. This score might change in the course of the project. Area usage depends on how much space is available in Cebu for urban agriculture. For example, when there are is not much space this criteria's weight will increase and vice versa.

Accessibility

Accessibility is one of the less essential criteria but does still have an effect on the outcome of the project. People are less attracted to the agriculture when it is hard to reach. The criteria scores a 5 on a scale 1-10. This might change during the project because citizens of Cebu can have another attitude then we expected.

Construction period

The construction period is important when the construction creates problems with other functions in the city. The construction of a green roof or a community garden can cut off a road which causes problems. This will probably not be a problem and therefore the construction period has a low score of 3 on a scale 1-10.

Visual quality

The visual quality is less important. It is more important that the structure functions well and is affordable. This project focusses more on lower class people, therefore it does not needed to look neat. This is why it scores a 2 on the scale weight 1-10.

Table 1 shows all the criteria weight in one table.

Table 1 Criteria weight

Expense (Maintenance)	9
Lifetime	8
Materials	8
Water storage capacity/ decrease water runoff	7
Production	6
Area usage	6
Accessibility	5
Construction period	3
Visual quality	2

2. Community gardens

This chapter will describe community gardens. It will describe the advantages and disadvantages based on the criteria. The score given to each criteria in the MCDA is based on each description.

2.1 General information

Community gardens can be placed on publicly-owned land or land trust (Five Borough Farm, seeding the future of urban agriculture in NYC, 2014). These gardens are managed by local residents and volunteers. These kind of gardens can be used to grow fruit or vegetables. The gardens can grow vegetables and flowers, as well as providing and gathering space for socializing (Five Borough Farm, seeding the future of urban agriculture in NYC, 2014).

Figure 1 example community gardens

Community gardens also provide greater access to fresh and nutritious vegetables (Five Borough Farm, seeding the future of urban agriculture in NYC, 2014)Therefore, community gardens can play a role in increasing public health and liveability in Cebu City as well. An example of a community garden is shown in figure 1.

2.2 Lifetime

The average community garden in New York has a lifespan from 15 to 20 years (University at Albany SUNY, 2000). In Cebu City is a tropical climate which makes it that the ground is exhausted sooner. This reduces the lifespan of the community gardens. There is also a flood problem in Cebu City which can destroy entire community gardens at once. This makes it that the estimated lifespan of a community garden in Cebu City is around 3 years. The lifespan of the community gardens can expand when measures against the floods are taken. A measure can be elevating the ground, but this would be too expensive for a garden meant for the poor. Because of this the community gardens score low on the lifetime.

2.3 Materials

The materials used to make community gardens are listed below (Douglas County Health department, 2010).

- **Seeds**
  The seeds that will be used will be determined by the vegetation research.
- **Soil**
  Soil is needed for the plants.
- **Path**
  These paths will be placed between the plots. They can be from sand/gravel/dirt.
- **Notice board**
  A notice board can be made of wood for example. This sign will contain the garden's name, sponsors, phone number for help etc.
- **Multiple plots**
  These plots can be simply made from local wood or stone.
- **Fences**
  Fences can be made from almost every material. They serve as much to mark possession of a property as to prevent entry. A short fence that will keep out dogs for example is enough.
- **Wheelbarrows**
  Wheelbarrows are used for transporting the soil and plants.

- **A simple irrigation system**
  An example of a simple irrigation system is a hose bib or a faucet.
- **Garden tools**
  Garden tools will be needed by the inhabitants to harvest and nurture the plants.

These materials are all available in the Philippines. There is no advanced technology needed as well. For this reason, community gardens will score high on this criteria.

2.4 Water storage/runoff

The water storage of the gardens depend on the volume of the soil layer and the plant species. Community gardens are built on the ground, this means that there is a possibility to create a thick soil layer which can hold a lot of water. Because a community garden is built on the ground there is a possibility for bigger vegetation such as trees. Bigger vegetation needs more water and will therefore be able to hold more water. The runoff will be slowed down a little because the ground will have a high friction level, but this will have no great influence. Because of the big water storage of the soil the community gardens score relatively high.

2.5 Food quality

Community gardens provide greater access to fresh and nutritious vegetables since the garden could be next door (Department of urban and regional planning, 2004). Therefore, community gardens can play a role in increasing public health and liveability in Cebu City.
Although, community gardens are placed on the ground what increases the chance the plants will get infected by diseases.
Since it is placed on the ground the gardens have a higher risk of being eaten/infected by insects or dogs. For this reason, community gardens will not score high on food quality.

2.6 Area usage

There are more than 490 community gardens in New York City, covering just under 40 hectare total area (Department of urban and regional planning, 2004). This is around 816 m^2 per garden which could be around 28m by 28m.
Although, the area usage of community gardens can vary in many sizes. Since we focus on a low cost garden the size will be kept to a minimum.
In comparison with the other types of urban agriculture, community gardens still take up the most space.

2.7 Accessibility

The accessibility of community gardens is very good compared with the other types, but this does also have a higher influence on the community gardens compared with other gardens. Community gardens need to be good accessible because otherwise citizens will not come to the gardens. The community gardens score relatively high on accessibility compared to the other forms of urban agriculture.

2.8 Construction period

The construction period of community gardens are relatively long in comparison with the other types of urban agriculture. At first, an empty spot need to be found, this spot need to be cleaned first. After this, the paths and the multiple plots can be made. When all this is done, soil can be added and a fence can be placed. This all could take a few weeks including the supply of materials.

2.9 Visual quality

The visual quality of a community garden is very high because citizens will plant different kinds of vegetation and maybe even flowers. This will enhance the visual quality in the poor parts of Cebu rapidly because the visual quality is relatively bad at the moment.

2.10 Cost-benefit analysis

Community gardens are often made by the municipality. The inhabitants can rent these plots and use the gardens to grow their own fruit/vegetables. Maintenance is the responsibility of the renters/volunteers, so they will pay their own maintenance costs.
Development cost is based on what size the community garden will be built. It will also depend on what materials are used.
Maintenance cost is based on what plants and how many plants are used, number of plots and paths.
An overview of the costs and incomes is shown in table 2.

Table 2 Cost table community gardens

Financials	Value
Development costs ($/m²)	**$8-$12/m²**
Maintenance costs ($/year) • Water use • Electricity use • Soil conditioners • Infrastructure maintenance (paths, fences, plots) • Financial administration	**To be determined**
Income rent, municipality ($/plot/year)	**$20-$30 per plot/year**
Income food, renters ($/year)	**$100-$300/plot/year**

3. Container gardening

This chapter will describe container gardening. It will describe the advantages and disadvantages based on the criteria. The score given to each criteria in the MCDA is based on each description.

3.1 General information

Container gardening is planting plants in a container instead of planting them in the ground. It will allow citizens to grow food practically anywhere with much greater control and flexibility (Man, 2014). Container gardening also allows you to bring nature into your house, garden or office (Fuller, 2009). Essentially, some dirt, something to contain it in, some seeds, sunlight and water is only necessary (Man, 2014). This is a very cheap way to grow food since it is not required to use expensive pots or containers, tools and equipment (Man, 2014). Empty cola bottles or old pots and pans are enough (Man, 2014).

Figure 2 example container gardening

3.2 Lifetime

The lifetime of vegetation grown in a container is on average longer than the traditional way of growing vegetation. This is because the vegetation does not come in direct contact with the ground, which reduces the chance of the vegetation getting infected by insects or viruses. Pest control is also easier than with the traditional way of gardening (Vick & Poe, 2011). Because of this the container garden scores high on lifetime.

3.3 Materials

The materials used to make a container gardens are listed below.

- Container (bottle, plastic, pot, wood, etc.)
- Seeds
- Soil
- Wheelbarrows

As shown above, container gardening does not need many materials. All of the above are available in the Philippines as well.
It is also possible to raise beds. when the beds are elevated they provide easier access for elderly or disabled gardeners. If this is the case, more dirt is needed to elevate the beds (Vick & Poe, 2011).
Container gardens will score high on this criteria.

3.4 Water storage/runoff

With container gardening the volume of the container is a decisive aspect of the size of the water storage. The volume of the containers and the density of the ground determine the size of the water storage. The runoff of rainwater will be slowed down because of the infiltration speed of the ground, but even more water can be slowed down by connecting rooftops to the containers. There are possibilities with this subject, but containers cannot hold as much water as the traditional way of growing vegetation on the ground can. But, in big cities there are shortages of unpaved ground which makes containers a great alternative.

3.5 Food quality

Container gardens can produce higher crop yields, have easier pest control and less soil erosion (Vick & Poe, 2011). This is due the protection of the container. Container gardens will therefore score high on food quality.

3.6 Area usage

Container gardens are often constructed in urban areas because they have the ability to maximize space and allow gardening on "difficult" sites (Vick & Poe, 2011). Traditional methods are more difficult on these sites such as on hard surfaces, hillsides, rooftops and sites that are contaminated or unsafe.
For this reason, container gardens will score average on area usage.

3.7 Accessibility

The accessibility of container gardens is very good compared to the traditional way of gardening. Because of the containers the vegetation is transportable which means that the owner can replace them when the surrounding changes. The containers can also be raised, this makes it possible for elderly and disabled people to garden (Vick & Poe, 2011). because of these points the container gardens score high on the accessibility.

3.8 Construction period

The construction period is very low for container gardening. All the materials are available in the Philippines what will spare time. It is also very easy to build. There is not much needed to build it, a few containers should be able to be made within a day. Therefore, container gardens score high on this criteria.

3.9 Visual quality

The visual quality of container plants is about the same level as the traditional way of growing vegetation. Compared to the surrounding of the vegetation they will look nicer and have a positive effect on the visual quality, but the container gardens will not score exceptionally high.

3.10 Cost-benefit analysis

The total maintenance cost and development costs are determined by the number, size of the container and type of plant. Therefore, we cannot determine the total costs yet.

Table 3 Cost table container gardens

Financials	Value
Development costs ($/container)	**$2-$8/container**
Maintenance costs ($/year) • Water use • Soil conditioners	**To be determined**
Income food ($/year/container)	**$30/year/container**

4. Vertical gardening

This chapter will describe vertical gardens. It will describe the advantages and disadvantages based on the criteria. The score given to each criteria in the MCDA is based on each description.

4.1 General information

There are multiple forms of vertical gardening, some of which are very creative. People often confuse vertical gardens with green walls, but green walls are just a form of vertical gardening. Vertical gardens have a lot of benefits. They reduce the urban heat island effect (Daniels & Caggiano, 2014). Vertical gardens also improve air quality by reducing smog and producing oxygen. When vertical gardens are built against buildings it insulates and cools the building as well as protecting it from the elements (Daniels & Caggiano, 2014). On average people are happier living in a surrounding with vegetation than without (Jonathan Kaplan, 2009). It is proven that happy people are less likely to get sick (Carnegie Mellon University, 2006), therefore vegetation has an indirect positive effect on the human health.

Vertical container gardens

Vertical container gardens make use of different kinds of containers in which vegetation can grow from. The container can be a bucket or a flowerpot but also a rain pipe or a bag. Vertical container gardens have many of the advantages as the normal container gardens have. Because of the container viruses and insects are less likely to spread. The gardens is portable which makes it adaptable to the changes of the surrounding.

Figure 3 example vertical container gardens

Walls made of organic material (green walls)

Green walls generally use vines that may grow from ground soil or from containers and each location will have different irrigation and nutrient requirements (Green Roofs, 2008). These plants grow out of the wall and get their nutrients partly from the wall.

Figure 4 example green walls

4.2 Lifetime

The lifetime depends the chosen type of vertical agriculture. If the plants hang on the wall they are more vulnerable for strong winds then when placed on the ground. But the plants can avoid risks from the ground like floods, animals, children, etc. For these reasons, vertical gardening scores high on lifetime.

4.3 Materials

Materials for vertical gardening depends on what type of vertical gardening is used. The materials used to make vertical gardens are listed below.

Vertical container gardens

- Container (pot, sack, back, bottle)
- Soil
- Seeds
- Hang material (rope, nails)

Green walls

- Stacking materials (concrete, plastic)
- Plants
- seeds
- Soil
- Container

As shown above, vertical gardening does not need many materials. All of the above are available in the Philippines as well. Although, green walls are more difficult to make than vertical container gardens. If something breaks, the inhabitants will probably not be able to repair it themselves. Regarding to this criteria, vertical container gardens is a more viable option than green walls.

4.4 Water storage/runoff

The runoff of the rain is slowed down by the vertical gardens, but in the traditional way of vertical gardening there is little water storage. However there are options to create water storage. Water can be stored in basins and can be re-used to water the vegetation.

4.5 Food quality

Plants that are above the ground are healthier and improves the air circulation (Gibson, 2012). Healthier plants have less problems with pest and diseases (Gibson, 2012). It also minimizes damage due to pets or wild animals digging up garden ground for example (Gibson, 2012).
Vertical gardens will score high on this criteria.

4.6 Area usage

Vertical gardens make very smart usage of the available space and therefore it can be used in urban areas with limited space.
Vertical gardens will score very high on this criteria.

4.7 Accessibility

The accessibility of vertical gardens is high (Gibson, 2012). Plants are easier to reach since they are built on eye level. This makes fertilizing, watering, pruning and harvesting the plants easier. This reduces pressure on your back compared to the usual way of gardening (Gibson, 2012).

4.8 Construction period

The construction period of vertical container gardening is very short. All the materials are available locally. Green walls are more complex to build and thus will cost more time. They also need more materials than vertical container gardening.

4.9 Visual quality

Vertical gardens are stunning, and plants create wonderful visually appealing walls which can turn drab concrete into something spectacular.
When you live or work in a densely populated area, access to green spaces can help to reduce stress. Many social scientists believe that vertical gardening can reduce anxiety and anger in individuals, families and teams (LiveWall, 2008).

4.10 Cost-benefit analysis

The development costs are determined by the amount of time put into the construction and the material costs. The total maintenance cost is determined by how often the plants need to be watered, how often the structure needs to be repaired and by the cost of the seeds. The data of the table below is estimated and can only be determined with vital data such as the type of vegetation.

Table 4 Coste table vertical gardening

Financials	Value
Development costs ($/container)	**$5-10/plant**
Maintenance costs ($/year) ● Water use ● Soil conditioners	**To be determined**
Income food ($/year/plant)	**$30/year/plant**

5. Green roofs

This chapter will describe green roofs. It will describe the advantages and disadvantages based on the criteria. The score given to each criteria in the MCDA is based on each description.

5.1 General information

A green roof is an extension of an existing roof which involves a high quality waterproofing repellent system, a drainage system, filter cloth and plants.
Green roofs reduces energy costs with natural isolation, create peaceful retreats for people and animals, and absorb storm water (Dowdey, 2012). Green roofs also help reduce the Urban Heat Island Effect (Dowdey, 2012). This is an condition in which a city and suburban development absorb and trap heat (Dowdey, 2012). Figure 5 shows an example of a green roof.

Figure 5 example green roofs

5.2 Lifetime

The lifetime of a green roof can be over 50 years in the right conditions (Conservation Technology, Inc), because of this green roofs score very high on lifetime (although a cheap version could not last that long).

5.3 Materials

There are many choices on the market and many ways to great these systems. This is just an example and for giving a good impression from what it could be made of.
The materials used to make green roofs are listed below.

- A strong root barrier (Songer, 2011)
- Existing roof
- Lightweight framing
- Brickwork and blockwork
- Drainage Soil Mixture
- Drainage system
- Seeds (Songer, 2011)

As shown above, there are some materials needed to make a green roof. These materials are not all available locally. Making a green roof is also quite complex. The inhabitants will probably not be able to repair it themselves when damaged.
Green roofs are weigh around 7-23 kg per m^2. This means roof should be firm enough to hold this amount of weight.
For these reasons, green roofs will score low on the criteria materials.

5.4 Water storage/runoff

The size of the water storage of a green roof depends on the thickness of the soil layer. The water storage of a green roof varies between 11.9l/m^2 and 40.2l/m^2 (Conservation Technology, Inc). The runoff will also be slowed down because of these roofs. Because of the relatively big water storage and the slower runoff the green roofs will score high on this criteria.

5.5 Food quality

The food is healthier since it is above ground level. Insects and diseases will have a harder time to reach the plants. Dogs and other animals who could damage the crops cannot reach it as well.

5.6 Area usage

The area that is used for green roofs is traditionally wasted because it is only used as a roof. By creating green roofs another function has been added to this roof which uses this traditionally wasted area. This is more expensive than planting vegetation on ground, but in cities there is an area shortage what means that this way of reusing roofs is profitable.

5.7 Accessibility

The accessibility is not high. Every time the plants need to be watered or harvest, someone will need to get on the roof. Because of this elderly or disabled people are not able to get to the vegetation for harvesting or watering .

5.8 Construction period

The construction time is relatively long compared with the other types of urban agriculture. Not all materials are locally available, these materials need to be ordered from foreign countries. It also takes a long time to install it on a roof.

5.9 Visual quality

The visual quality of green roofs is lower than other forms of urban agriculture. This is because the citizens are not able to see big parts of the vegetation, because the vegetation grows in the roofs.

5.10 Cost-benefit analysis

The development cost can vary between \$10-\$100/m² because there are many types of green roofs. The cost will depend on the available roofs in Cebu City. When there are strong roofs it will cost less than when the roof is weak.
The total maintenance cost depends on the size of the roof. Therefore, it is not yet possible to estimate the maintenance cost.

Table 5 cost table green roofs

Financials	Value
Development costs (\$/m²)	**\$10-100/m²**
Maintenance costs (\$/year) ● Water use ● Soil conditioners	**To be determined**
Income food (\$/year/plant)	**\$50/m²**

6. MCDA

Table 6 MCDA score +/-

Criteria	Community gardens	Container gardens	Vertical gardens	Green roofs
Expense	++	+	+	--
Lifetime	--	+	+	++
Materials	+	++	++	--
Water storage capacity/ decrease water runoff	+	-	+	++
Food quality	-	+	++	++
Area usage	--	+/-	++	++
Accessibility	+	+	++	-
Construction period	-	++	+	--
Visual quality	++	+/-	+	-

In table 6 every criteria is given a score per type of urban agriculture. The score vary between --. -. +/- , +, ++. The highest score is ++ and -- is the lowest. Every score is given a number in table 7 on the next page. The lowest score will get 0 and the highest score will get 1.

Table 7 MCDA score number

Criteria	Community gardens	Container gardens	Vertical gardens	Green roofs
Expense	1	0.75	0.75	0
Lifetime	0	0.75	0.75	1
Materials	0.75	1	1	0
Water storage capacity/ decrease water runoff	0.75	0.25	0.75	1
Food quality	0.25	0.75	1	1
Area usage	0	0.50	1	1
Accessibility	0.75	0.75	1	0.25
Construction period	0.25	1	0.75	0
Visual quality	1	0.50	0.75	0.25

Table 8 Criteria weight

Criteria	Weight (scale 1-10)
Expense	9
Lifetime	8
Materials	8
Water storage capacity/ decrease water runoff	7
Food quality	6
Area usage	6
Accessibility	5
Construction period	3
Visual quality	2

In table 9, the numbers in table 7 are multiplied with the weight scale in table 8.

Table 9 MCDA results

Criteria	Community gardens	Container gardening	Vertical gardening	Green roofs
Expense	9	6.75	6.75	0
Lifetime	0	6	6	8
Materials	6	7	8	0
Water storage capacity/decrease water runoff	6	8	5.25	7
Food quality	1.5	4.5	6	6
Area usage	0	3	6	6
Accessibility	3.75	3.75	5	1.25
Construction period	0.75	3	2.25	0
Visual quality	2	0.5	1.50	0.50
Total	29	42.5	46.75	28.75

7. Conclusion

The results of the MCDA shows that vertical agriculture has the highest score. Container gardening is second, community gardening is third and last is green roofing.
Green roofs are simply too expensive and too complicated to build. This project focusses on the lower-class households, so green roofs are not a viable option.
The most decisive factor to not choose community gardening was the lifetime. The lifetime is a criteria that scores high since it is important for the PCUP. Community gardens score very low on this criteria and therefore not the highest score.
Container gardening is the only type of urban agriculture that came really close to the score of vertical gardening. However, water storage and decreasing of the water runoff is a criteria that is important if we want to reduce water related problems. Container gardening scores not high enough on this criteria which was the decisive factor to not choose this type of urban agriculture.
Vertical gardening scores high on all criteria. It can be made very cheap and has the potential to store and slow down a large amount of water.
There are multiple types of vertical agriculture, we choose for the vertical container gardens. Green walls are simply too expensive for a low-cost project. There are still many ways to design the vertical container gardens, various materials can be used as well. It is not yet clear what materials or what design we will use. Further research in the Philippines is needed to retrieve more knowledge about this subject. After this, a design will be made with programs like Sketchup and Adobe Illustrator.

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Illustrations

Figure	Description	Author	Link
Figure 1	example community gardens	Kevin Matteson	https://farm3.staticflickr.com/2055/2195340974_3bbe4eaa84_o_d.jpg
Figure 2	example container gardening	Anna-Maria	http://gallery.forum-grad.ru/files/6/2/5/0/8/small-balcony-ideas-03.jpg
Figure 3	example vertical container gardens	Tara West	http://socialmoms.wpengine.netdna-cdn.com/wp-content/uploads/2012/06/Vertical-Garden.jpg
Figure 4	example green walls	Patrick Blanc	http://www.theurbn.com/wp-content/uploads/2011/12/tacoma_goodwill_1-641x400.jpg
Figure 5	example green roofs	Miodrag	http://uredjenjestanova.rs/wp-content/uploads/2013/06/zeleni-krovovi14.jpg

Pre-research Vegetation

oktober 1

2014

Urban agriculture in Cebu City, Philippines

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Urban agriculture Cebu City

Pre-research vegetation

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Study:	Water management
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Module:	Stage (internship)
Modulecode:	WAMSTG30
Version:	1.0
Date:	1-10-14

Inhoud

1. Motivation

There are loads of different kinds of vegetation that can be used for urban agriculture, this makes is very difficult to choose the right one. Every kind of vegetation has aspect that can be positive or negative related to the situation. In this pre-research the question “What kind of vegetation qualifies the most for Cebu City?” is treated. After this pre-research there will be multiple candidates that can be chosen for the pilots. The type of vegetation that will be used for the pilots will be chosen after the research in the Philippines.

2. Criteria

There are multiple Influences on the types of vegetation that will be chosen. In this chapter these Influences will be explained.

Climate

The climate of the Philippines has very big influences on the type of vegetation. There are multiple types of urban agriculture that are not able to grow well in the tropical climate of the Philippines. But some types of vegetation grow very good in a tropical climate. When the vegetation is not able to grow it will have no use, therefor climate is a very important aspect.

Costs

The cost of the vegetation is also very important. The project is meant for the poor and must therefore remain cheap. This means that the seeds need to be affordable.

Value

With value, the total value of a grown fruit or vegetable is determined. This will indicate how much the food is worth expressed in Php/kg. The people can choose to sell the food or to eat it.

Yield per hectare

Vegetation has differences in yield per hectare. It is important that there is enough fruit and vegetables produced while spending as little as possible space.

Water consumption

The water consumption is important as well since this project is also trying to increase the water storage capacity of Cebu city. Plants that can consume a lot of water during heavy rainfall, this can be useful for this project.

Weight of the vegetable

For some designs it is important that the vegetation is not too big or too heavy. This can make the construction unstable. The volume is important because when the vegetation is to big there can simply be a shortage in available space. For these reasons, the weight of the vegetable when full grown is determined.

Table 1 Weight table

Criteria	Weight (scale 1-10)
Climate resistance	9
Cost/ Maintenance	8
Water storage capacity	7
Value	6
Yield per hectare	4
Weight/volume	2

Every criteria has been given a number between 1 to 10 based on its importance for this project. These numbers are shown in the table above.

3. Tropical tomatoes

There are multiple types of vegetation that are able to withstand the tropical climate of the Philippines and grow fruit or vegetables. An example of these types of vegetation is introduced in this chapter.

Figure 1 Tropical tomatoes

3.1 Climate

Normal tomatoes are often unable to grow well in a tropical climate, but there are multiple tomatoes that grow very well in the tropical climate (Bradtke, 2012). Examples of these tomatoes are the Atkinson tomato and the homestead 24 tomato (Lacey, 2007).

3.2 Costs

The price of 1 kg tomatoes in Cebu is around P70 (Expatistan, 2014). The seeds of a tomato cost around P450 per 100 seeds (Seedman, 2014).

3.3 Yield per hectare

Tomatoes have an average yield of 14400kg per hectare (Ronald C. Smith, 2010).

3.4 Water consumption

A young tomato consumes 300 ml/day in a normal situation and 1 L/day on a hot and windy day (Chapter 13 Water consumption, 2006).
Fully matured tomato plant consumes 1.2 L/day in a normal situation and 2.5 L/day on a hot and windy (Chapter 13 Water consumption, 2006).

3.5 Weight/volume

Tomatoes need to grow vertical because the fruit will rot when it touches the ground for too long (Kris, 2010). The roots of the plant are normally in the upper 20cm of the soil. One plant needs about 125 gram fertilizer.
An average tomato weighs around 115 grams. This means that the container does not have to hold that much weight (Karen Demboski, 2001).
Dwarf tomatoes need around 1-2 gallons soil volume per plant. Full sized tomato plants need a soil volume of 4-5 gallons per plant (Karen Demboski, 2001).

4. Tomatillo

The tomatillo shares multiple aspects with the tomato. The tomatillo is from the same family and has low calories and is very healthy just as the tomato (Blessing, 2011). However the tomato has more vitamins and is healthier than the tomatillo (Blessing, 2011). The tomatillo and the tomato are both used as vegetables while strictly speaking it are fruits. Tomatillos are able to grow in the wet and warm climate of Cebu city (Hutchinson, 2010).

Figure 2 Tomatillos

4.1 Climate

Tomatillos are a tropical plants sort which requires a warm climate such as the climate of Cebu (Growing Interactive, 2014). Because of this Tomatillos are supposed to grow well in Cebu city.

4.2 Costs

The cost of tomatillos is a little cheaper than normal tomatoes and about P60 for a kilogram tomatillos (USDA, 2014). Seed are very cheap around the P180 for 50 seeds.

4.3 Yield per hectare

Tomatillos have an average yield of 15000kg per hectare (University of Kentucky, 2012).

4.4 Water consumption

Tomatillos consume around the 3 litres of water a week (Culinary Cory, 2011). This is less than the tomato because tomatillos don't need much water, but they don't grow well when dry.

4.5 Weight/volume

Tomatillos grow in plants which are very much like tomato plants. They need a container with a volume of at least 19 litre (Grow This, 2013). And have an average weight around the 15 kilogram (Gardenweb, 2010). The average height of a full grown tomatillo plant is around the 1 metre (Organicgardening, 2014). The average weight of one tomatillo is around the 0.1 kilogram (SkipThePie, 2012)

5. Tropical beans

5.1 Climate

Normal beans like French beans don't grow very well in climate of Cebu, but there are multiple tropical beans who grow very well (Bradtke, 2012). Winged beans or snake beans grow very well in a tropical climate (Bradtke, 2012). Mung beans, soy beans and cow peas are also supposed to grow well in this climate (Bradtke, 2012).

Figure 3 Winged beans

5.2 Costs

The price of winged beans is P70 per 100 grams of seeds and P30 per kilo beans (Magkonopo , 2014). The weight of an average winged bean seed is 0.65 gram (Green Harvest Organic Gardening Supplies, 2014).

5.3 Yield per hectare

Beans have an average yield of 2600 kg per hectare.

5.4 Water consumption

The velvet bean (another tropical bean) is used to estimate the average water consumption of tropical beans. The velvet bean is estimated to consume around the 0.5 liter water a day (Taylor, 2012).

5.5 Weight/volume

The service seize of winged beans is around 180 grams (Self nutrition data, 2014).

6. Tropical lettuce substitutes

Normal kinds of lettuce are not able to grow in a hot tropical climate, but there are various lettuce substitutes. Salad mallow and Ceylon spinach are a lot like normal lettuce and are able to grow in the warm climate. The difference in taste is that the substitutes are more lettuces.

Figure 4 Ceylon spinach

6.1 Climate

Normal lettuce is unable to grow in the tropical climate of Cebu but there are some lettuce substitutes that are able to grow there very well. They are fast growing and are able to withstand high numbers of rainfall (WorldCrops, 2004).

6.2 Costs

The seeds of tropical lettuce substitutes are cheap, around the P100 for 50 seeds (Thompson & Morgan, 2014). The price of a tropical lettuce substitute is estimated around the P80 per kilogram (OLX, 2014).

6.3 Yield per hectare

The average yield per acre of a Lettuce substitute is around the 11000 kilogram (Ronald C. Smith, 2010).

6.4 Water consumption

The water consumption of a fully matured tropical lettuce substitute is estimated around the 0.4 litre per day (McDermott, 2009).

6.5 Weight/volume

The height and the width of the tropical lettuce plant is estimated around the 23cm (Veggieharvest, 2008). The roots of a tropical lettuce substitute are estimated to reach 2 feet into the ground (Martin, Slack, & Pegelow, 2009). The average weight of a lettuce head is 0.5 kilogram (Whole food Market, 2014).

7. Asian broccolis

Figure 5 Asian broccolis

7.1 Climate

There are a lot of Asian broccoli species that are able to withstand the tropical climate of the Philippines. Examples of Asian broccolis that withstand a tropical climate are Mizuna, Mibuna and arugula. These vegetables are very low ground and therefore perfect as vertical gardening vegetation.

7.2 Costs

The price of broccolis in Cebu is around P150-200 per kilo (Fresh Plaza, 2014). The seeds will cost around P40 per 100 seeds.

7.3 Yield per hectare

The yield of broccoli is 5 ton per hectare (Agriculture and rural development, 2012).

7.4 Water consumption

A broccoli crop is estimated to need about 0.4L water a day on average in its lifetime (Alex Parker, 2014).

7.5 Weight/volume

Broccoli heads can weigh between 100 and 800 grams (Zvalo, 2007). The heads are from 5 to 25 cm in diameter (Zvalo, 2007). The stem is around 15 cm when fully grown (Zvalo, 2007). Side shoots are from 5 to 10 cm in diameter and can weigh from 100 to 500 g each (Zvalo, 2007).
The roots may extend between 30 and 45 cm (Beal, 2012). This gives an average total weight of 0.75 kilogram.

8. Asian cucumber

Figure 6 Suyo long

8.1 Climate

Asian cucumbers grow better than normal cucumbers in a tropical climate, especially the suyo long cucumber (Bradtke, 2012). This cucumber tastes almost the same as a continental cucumber accept from his hairs on the skin (Bradtke, 2012).

8.2 Costs

The cost of the seeds of an Asian cucumber are estimated on an average of P200 for 25 seeds (Amazon, 2013). The price of an Asian cucumber is around the 5 pesos each (Hogeschool Utrecht, sd). The average weight of a tropical cucumber is estimated on 0.37kg apiece (Ask, 2014). This gives an average price of P13.5 per kilogram.

8.3 Yield per hectare

The suyo long cucumber needs about 61 days till it is fully grown (Johnny's selected seeds, 2014). The average yield of a cucumber is around the 8300 kilogram per acre (Ronald C. Smith, 2010).

8.4 Water consumption

The average water consumption of a cucumber plant is 0.54 litre per day (Thomas, 2014).

8.5 Weight/volume

The average weight of a tropical cucumber is estimated on 0.37kg apiece (Ask, 2014). The average length of Suyo Long cucumber is 0.35 metre and the average diameter is about 4 centimetre (Bbbseed, 2013).

9. Courgettes substitute

9.1 Climate

Courgettes are not able to grow well in the Philippines because they have to many problems with bugs and mildew (Bradtke, 2012). The angled luffa is a great substitute for couchettes because it has no problems with the bugs or the mildew. The angled luffa is also great for vertical agriculture because it climbs (Lau, 2012).

Figure 7 Angled luffa

9.2 Costs

The Angled luffa cost around P15-25 apiece (Marketman, 2005). The weight of a courgette is around the 0.17kg apiece, this give a price of P120 per kilogram. The seeds of a courgette cost around the 670 per 100 pieces.

9.3 Yield per hectare

Angled Luffa produce around 10-15 ton/ha (Soladoye, 2014). 2-3 kilo of seeds are needed per ha (Soladoye, 2014).

9.4 Water consumption

Courgettes consume an average of 0.92 L/day (Koken voor morgen, 2014).

9.5 Weight/volume

A full grown Angled luffa weighs 0.40 kg and is around 50 cm long (Glovegarden, 2014).

10. Eggplants (Aubergine)

10.1 Climate

Figure 8 Eggplant

The eggplant is a plant that grows best in very sunny and well-drained locations (Tropical Permaculture, 2014). This plant likes the heat and will not be troubled by bugs just because it gets hot (Tropical Permaculture, 2014). Any fertile soil with a pH from 6.3 to 6.8 will satisfy the plant.

10.2 Costs

Eggplants seeds estimate costs is around P5 (OLX, 2014). Full grown eggplants can be sold for approximately P40-50 per kg (Desiderio, 2013).

10.3 Yield per hectare

The first harvest begins 65 to 90 days from transplanting (Jett, 2005). Eggplants can yield 7500-10500 kg per acre (Jett, 2005).

10.4 Water consumption

The water consumption of eggplants is estimated on 1.8l/dag (Goyal, 2005) (Rose, 2014). This is an exceptionally high water consumption and therefor it may be wrong, but no other data was avaidable.

10.5 Weight/volume

An eggplant grows 40 to 150 cm (16 to 57 in) tall, with leaves that are 10 to 20cm (4-8 in) long and 50 to 10 cm (2-4 in) wide. The average weight of an eggplant is around 250 grams (Cookipedia, 2012).

11. MCDA

11.1 Rating

Table 2 Rating table

Criteria	Tropical tomatoes	Tomatillo	Tropical beans	tropical lettuce substitutes	Asian Broccolis	Asian cucumber	Courgettes substitute	Eggplants
Climate resistance	++	++	++	++	++	++	++	++
Cost (Php/100 seeds)	450	360	108	200	40	800	670	550
Water consumption (l/dag)	0.3	0.43	0.5	0.4	0.4	0.54	0.92	1.8
Value (Php/kg)	70	60	30	80	175	14	120	45
Yield kg/hectare	9400	15000	6600	11000	5380	8300	11000	3000
Weight (kg)	0.12	0.10	0.18	0.50	0.75	0.37	0.40	0.25

This table is a tool that is used to compare different types of vegetation. Based on this table a multi criteria decision analyses is made which helps to determine what kind of vegetation fits Cebu city the most. Each vegetable is compared to each other on multiple criteria. This table is based on information that has been found on the internet. The sources of this data can be found in the text of the particular vegetation.

11.2 Scale & Weight

Table 3 Scale & weight table

Criteria	Scale (0/1)	Weight (1/10)
Climate resistance	--/++	9
Cost (Php/100 seeds)	1000/0	8
Water consumption	0/1	7
Value vegetables (Php/kg)	0/200	6
Yield kg/hectare	0/20000	4
Weight of the vegetable	1/0	2

The scale and weight (visible in table 3) are very important in order to get the right score. The scale important because each criteria has a different maximum score and lowest score. The number 500 is very small for the criteria yield, but it is extremely big for the criteria “weight of the vegetable”. To compare the different criteria the maximum and minimum of each criteria has been converted to a number between 0 and 1.

The weight of each criteria is also important because the one criteria has more importance to the success of this project than the other. To add this weight methodology, the ratings are multiplied by their weight.

11.3 Rating with scale

Table 4 Rating with scale

Criteria	Tropical tomatoes	Tomatillo	Tropical beans	tropical lettuce substitutes	Asian Broccolis	Asian cucumber	Courgettes substitute	Eggplants
Climate resistance	1	1	1	1	1	1	1	1
Cost (Php/100 seeds)	0.55	0.64	0.892	0.8	0.96	0.2	0.33	0.45
Water consumption	0.3	0.43	0.5	0.4	0.4	0.54	0.92	1
Value (Php/kg)	0.35	0.3	0.15	0.4	0.88	0.07	0.6	0.225
Yield kg/hectare	0.47	0.75	0.33	0.55	0.27	0.42	0.55	0.15
Weight (kg)	0.88	0.90	0.82	0.50	0.25	0.63	0.60	0.75

The score of every criteria is scaled in table 4 so it is possible to multiply and count them.

11.4 Final rating ((rating & scale) x weight)

Table 5 Final rating table

Criteria	Tropical tomatoes	Tomatillo	Tropical beans	tropical lettuce substitutes	Asian Broccolis	Asian cucumber	Courgettes substitute	Eggplants
Climate resistance	9	9	9	9	9	9	9	9
Cost (Php/100 seeds)	4.40	5.12	7.14	6.40	7.68	1.60	2.64	3.60
Water consumption	2.10	3.01	3.50	2.80	2.80	3.78	6.44	7
Value (Php/kg)	2.1	1.8	0.9	2.4	5.25	0.42	3.60	1.35
Yield kg/hectare	1.88	3.00	1.32	2.20	1.08	1.68	2.2	0.60
Weight (kg)	1.76	1.80	1.64	1.00	0.50	1.26	1.20	1.50
Total	**21.24**	**23.73**	**23.5**	**23.8**	**26.31**	**17.74**	**25.08**	**23.05**

Regarding the table shown above, Asian broccoli has the highest score of all the vegetables. Asian cucumber has the lowest score.

11.5 Conclusion

The MCDA has shown that Asian broccoli has the highest score of all the vegetables. Asian broccoli scored high on climate, cost and value, these criteria weighed heavily in this project. Because of the high score, it is most likely that Asian broccoli will be planted for urban agriculture.
Courgettes has the second highest score of all. It scored noticeable high on the criteria water consumption. Since this project focusses on increasing the water storage capacity of Cebu City, it is wise to choose courgettes for the urban agriculture as well.
Tropical lettuces scored third highest of all plants. Lettuces scored high on cost and yield. These plants are eaten by many people and it is possible to produce many on a small area. For this reason we decided to add lettuces as final plant to the urban agriculture.
For now, this project will continue with these three types of vegetables for urban agriculture. the other vegetables are still optional and can be chosen in the course of the project.

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Figure 1: Tropical tomatoes	http://www.fruitsinfo.com/images/tomatoes.jpg
Figure 2: Tomatillos	http://cdn.blogs.sheknows.com/vegan.sheknows.com/2011/05/tomatillos1-300x232.jpg
Figure 3: Winged beans	http://us.123rf.com/450wm/sommai/sommai1208/sommai120800031/14731743-green-winged-beans-vegetable-isolated-on-white-background.jpg
Figure 4: Ceylon spinach	http://www.specialtyproduce.com/produce/ProdPics/8956.jpg
Figure 5: Mizuna	http://www.health.com/health/gallery/0,,20487719_3,00.html
Figure 6: Suyo long	http://img.docstoccdn.com/thumb/orig/78995665.png
Figure 7: Eggplant	http://articles.latimes.com/2012/dec/18/news/la-lh-how-to-grow-eggplant-as-a-perennial-20121217
Figure 8: Asian cucumber	https://o.btcdn.co/193/large/156610-broccoli.jpg?1409775656

Location analysis

December 1

2014

Urban agriculture in Cebu City, Philippines

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Table of content

1. Introduction

It is important that the right locations for the pilot projects are chosen. The location has a great influence on the result of the project and therefor the location has to be chosen carefully. The possible locations are chosen based on a few aspects. The possible locations will then be analysed in a MCDA to determine which location qualifies the best for urban agriculture. The criteria used to rate the locations are sun hours, flood zones, maintenance options, construction stability and accessibility. The last chapter will give a conclusion about why a certain location is chosen and which options are available.

2. Location selection

This chapter will describe which factors were decisive choosing the multiple locations for urban agriculture.

In order to find out which location qualifies the best for urban agriculture multiple locations were visited. After interviewing City Agriculture Cebu they suggested to place the pilot at a school. Schools often have problems with floods. The students could also learn from the pilot and maintain the plants. The PCUP helped selecting these locations and schools. They know which areas are occupied by the urban poor and which are owned by the government. After visiting multiple locations four were chosen to break down in a MCDA (table 1).

Table 1 Location selection

Nr.	Street	Location coordinates
1	Alaska Mambaling integrated school	10.288097, 123.881908
2	Mambaling elementary school	10.290799, 123.875149
3	Pundok sa Katawhan Sitio Lower Lumar – Brgy. T. Padilla	10.304375, 123.905269
4	Lnai Hoa	10.294019, 123.885273

These four locations were also chosen since they are located within a flood area.
These locations are placed as black dots in figure 1 below. The red, orange and yellow marks indicate the flood areas in Cebu City. Yellow means 0.1-0.5m once a 100 years. Orange means 0.5-1.5m once a 100 year. Red means >1.5m once a 100 years.

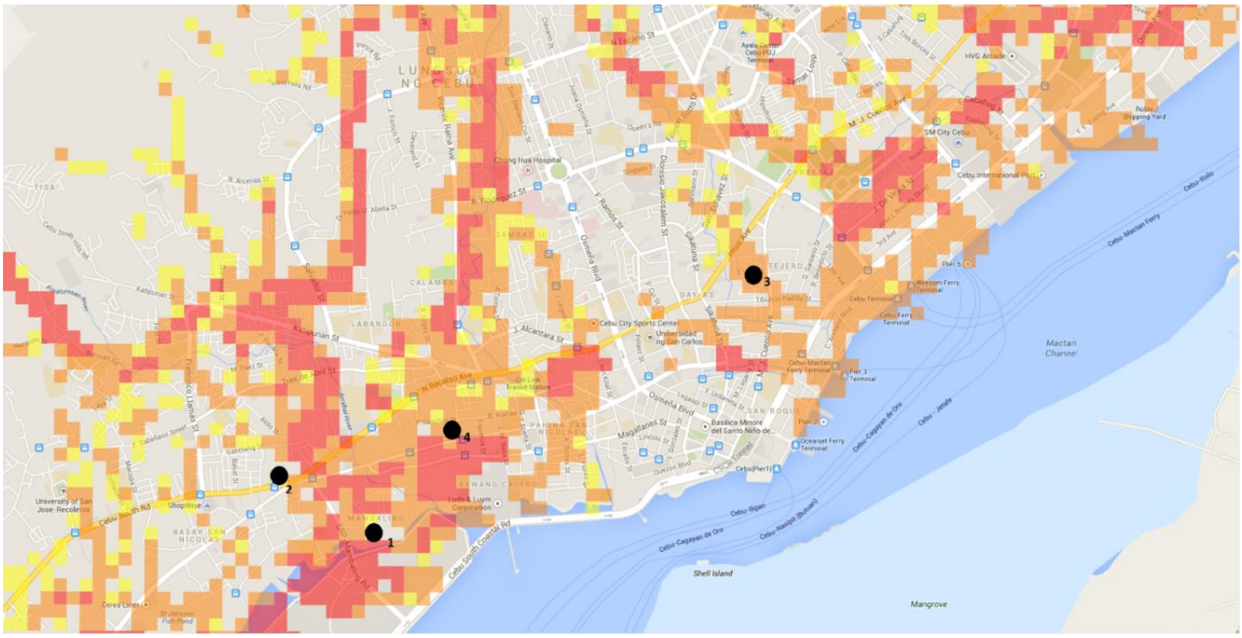


Figure 1 Flood map Cebu

3. Criteria

There are various criteria that need to be taken into account when analysing the locations. These criteria all effect the results of the pilot and have different values and importance. Below a table with the criteria, their value and weight is shown.

Table 2 MCDA weight and value

Criteria	Value	Weight
Construction stability	++/+/+-/-/--	8
Flood zone	++/+/+-/-/--	7
Sun hours	hours	5
Maintenance options	++/+/+-/-/--	4
Accessibility	++/+/+-/-/--	3

3.1 Construction stability

It is important that the walls and buildings in the location are strong in enough to carry the weight of the pilot. The pilot will hold a certain amount of water and soil which can weigh a few kilograms. If the structure is not able to support the weight, the pilot can collapse which means that the design failed. For this reason, construction stability is the most important criteria. It is given the weight 8 and rated +/-.

3.2 Flood zone

This project is meant to help the urban poor. The people in flood areas have the most problems with floods. So the locations in flood zones have the priority over locations that are not located in flood zones. For this reason, “flood zone” is an important criteria with a weight of 7. The value of the criteria quantified in +/-.

3.3 Sun hours

The vegetation need sunlight in order to grow. Therefore, it is important that the locations are not located entirely in the shadow. The amount of sun hours is calculated for each locations. For this project it is not that important if a location has less hours of sunlight than another location, but it is still relevant. Therefore, this criteria has a weight of 5 and is rated in sun hours.

To be able to calculate the number of sun hours certain data needs to be obtained. To calculate the number of sun hours the situation of every location was needed and it was important to know where north was. It was also important to choose a wall within the location which could be used for the agriculture. The front of the wall could not be facing to the south because this means that almost no sun will shine on the wall. To the north is the perfect situation because this means that the sun will be able to shine long on the wall. East and West can also be used, but the wall will get less sun.

Possible buildings around the chosen wall can also have a big influence on the number of sun hours of the vegetation. To calculate the amount of sun hours, data about the height, the distance of the building and the direction of the building from the wall needs to be obtained. With this data the angle from the agriculture to the top of the building (when the sun gets past the building) can be calculated. This is done by using the following formula: “tan^{-1}(opposite side/abutting side)”. These angles can be used to find out when the sun shines on the agriculture. For this the Cebu city sun hour service of timeanddate.com is used (Time and Date, 2014).

3.4 Maintenance options

The criteria "maintenance options" rates the location on the chance that people are willing to do maintenance on the vertical agriculture. There are two possible groups in these criteria. When implementing the vertical agriculture in a poor neighbourhood the inhabitant could do the maintenance if they are willing to. When implementing the vertical agriculture at a school the students or teachers could do the maintenance.

3.5 Accessibility

Accessibility is the least important criteria. People need to be able to maintain and harvest the vegetation, therefor it needs to be reachable. Accessibility is also less important because has no direct effect on the outcome of the pilot.

4. Location analysis

4.1 Alaska Mambaling integrated school

Construction stability

This location is a school. As shown on figure 2 the buildings look very stable and firm. These buildings are primarily made of concrete and would be capable of carrying the weight of urban agriculture. For this reason, this location scores a '++' for construction stability.

Figure 2 Alaska Mambaling school

Flood zone

The Alaska Mambaling school is located in number 3 within the orange are in figure 3. This means the location has a chance to flood 0.5-1.5m once a 100 year. Because it is within a flood zone we can assume that it will also be likely to flood during monthly heavy rainfall, but it would be less than 0.5-1.5 meters. The goal of implementing urban agriculture is to reduce the consequences of heavy rainfall. Therefore, this location could need the positive influence of urban agriculture. The location scores a '+' on flood zone.

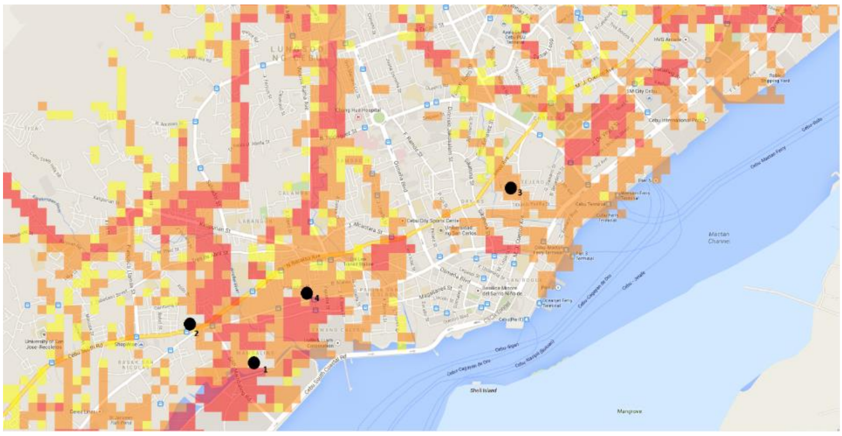


Figure 3 Flood zone map Cebu

Sun hours

The building in de red square could be used to place the agriculture, this is faced to the south (figure 4). The sun goes from East to South to West and therefore has many sun hours. The total sun hours is 7:55 per day as shown in figure 5.

Figure 4 Alaska Mambaling school sun hour

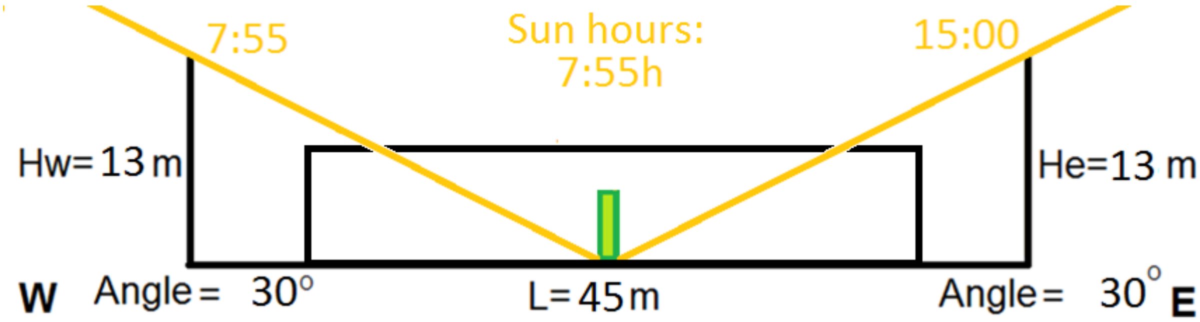


Figure 5 Alaska sun hour sketch

Maintenance options

Since this location is a school there are a lot of maintenance options. The students and teachers could maintain the urban agriculture and for research purposes as well as for the vegetation. This will reduce the chance that the urban agriculture will become neglected. For this reason, the school scores a '+' on maintenance options.

Accessibility

As shown on figure 6 the school has multiple roads to access the school. Within the school area is everything also very reachable, there is a lot of space as shown on figure 2. It is recommended to build the agriculture on ground level since it is easier and safer to reach. This criteria scores a '+'.

Figure 6 Streets Alaska Mambaling school

4.2 Mambaling elementary school

Construction stability

As shown in figure 7 the school is mostly build of wood and looks more than firm and stable enough to support the weight of vertical agriculture. Therefore, the school scores a '+' on this criteria.

Figure 7 mambaling elementary school

Flood zone

The Mambaling elementary school is located in number 2 on figure 8, partly within the orange are and partly within the grey area. This means that some areas in the location has a chance to flood 0.5-1.5m once a 100 year. Because it is within a flood zone we can assume that it will also be likely to flood during monthly heavy rainfall, but it would be less than 0.5-1.5 meters. The goal of implementing urban agriculture is to reduce the consequences of heavy rainfall. Therefore, this location could need the positive influence of urban agriculture. The location scores a '+/-' on flood zone.

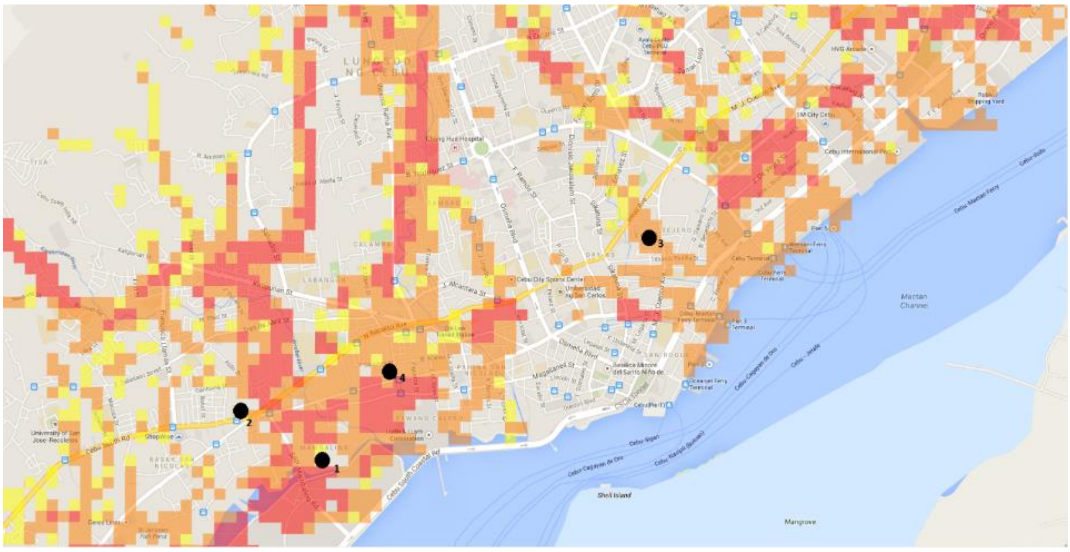


Figure 8 Flood zone map Cebu

Sun hours

The building is facing east. The sun comes up in the east and sets in the west. The building is not facing any other building close so an angle of 10 degrees is chosen since the building is in a city. The sun hours are calculated with help of timeanddate.com. The total sun hours is 5:10 per day.

Figure 9 Mambaling elementary school sun hours

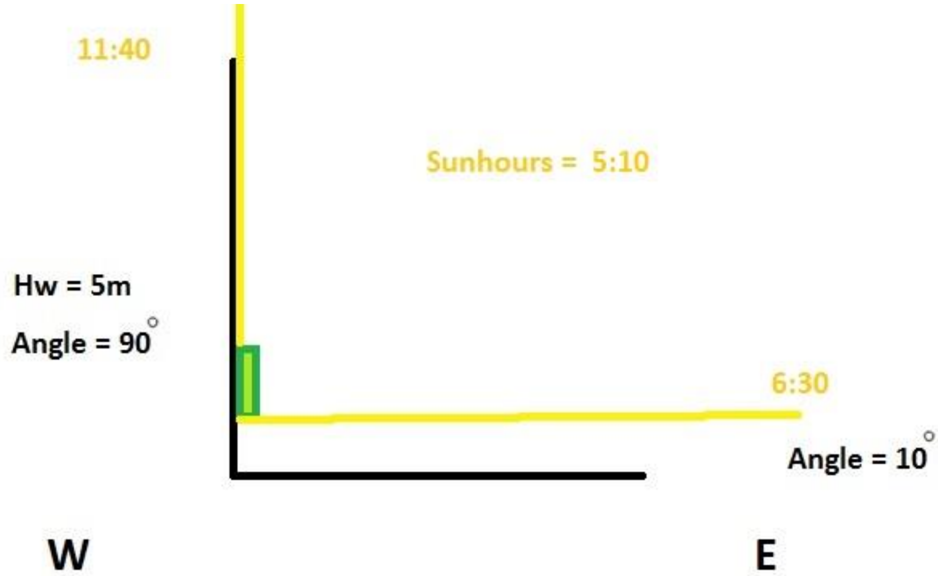


Figure 10 Mambaling sun hour sketch

Maintenance options

Since this location is a school there are a lot of maintenance options. The students and teachers could maintain the urban agriculture and for research purposes as well as for the vegetation. This will reduce the chance that the urban agriculture will become neglected. For this reason, the school scores a '+' on maintenance options.

Accessibility

As shown on figure 9 the school is placed next to a main street. The school buildings are not higher than 1 level (figure 7) which makes it easy to implement vertical agriculture. Therefore, this location scores a '+' on accessibility.

Figure 9 Street map Mambaling school

4.3 Pundok sa Katawhan Sitio Lower Lumar – Brgy. T. Padilla

Construction stability

The houses as shown on picture 10 are pretty firm and stable. Most houses are built of stone or concrete. These houses would be strong enough to carry the weight of vertical gardening. For this reason, this location scores a '+/-' on construction stability.

Figure 10 Pundok sa Katawhan Sitio

Flood zone

This location is number 4 on figure 11 and is located within the orange area. This means the location has a chance to flood 0.5-1.5m once a 100 year. Because it is within a flood zone we can assume that it will also be likely to flood during monthly heavy rainfall, but it would be less than 0.5-1.5 meters. One of the goals of implementing urban agriculture is to reduce the consequences of heavy rainfall. Therefore, this location could need the positive influence of urban agriculture. The location scores a '+' on flood zone.

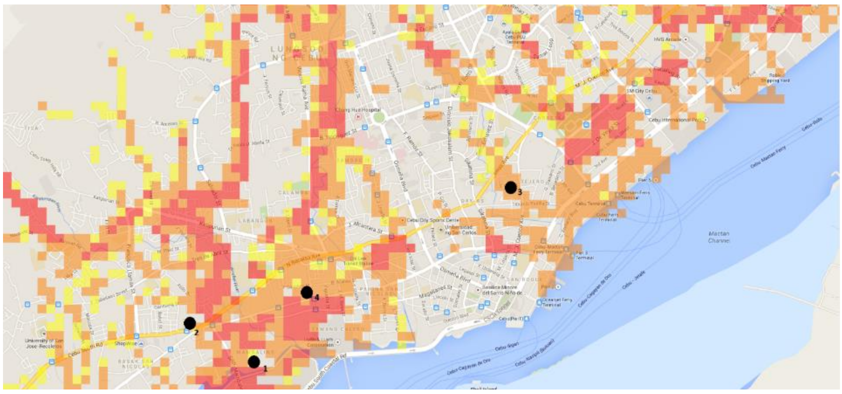


Figure 11 Flood zone map Cebu

Sun hours

On this location the pilot could be placed on the right side of figure 12 against the building. The building on the east side has an average height of 4 meters. The house on the west side with the plants has an average height of 2.5 meters. This results in 3 hours of total sunlight per day.

Figure 12 Pundok sa Katawhan sun hours

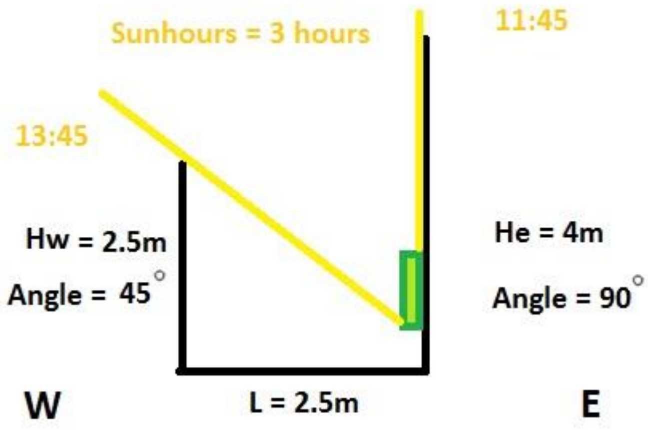


Figure 13 Pundok sun hours sketch

Maintenance options

The inhabitants in this area could maintain the urban agriculture. However, it is not certain if they will contribute maintenance since they will not get paid for it. For this reason, this location scores a '+/-' on maintenance options.

Accessibility

The location is good accessible through the T. Villa street and the M. J. Cuenco Ave (figure 14). Although there are already many plants in the area as shown on figure 8, there is still some room for urban agriculture. The buildings are not too high so that the people can reach it. Therefore, this criteria scores a '+/-'.

Figure 14 Street map Pundok sa Katawhan Sitio

4.4 Lnai Hoa

Construction stability

Lnai Hoa is a location where the urban poor live. As shown on picture 15, the houses are not stable enough for placing much urban agriculture. Therefore, it scores a – on construction stability.

Figure 15 Lnai Hoa

Flood zone

Lnai Hoa is number 4 and located within the orange area. This means the location has a chance to flood 0.5-1.5m once a 100 year. Because it is within a flood zone we can assume that it will also be likely to flood during monthly heavy rainfall, but it would be less than 0.5-1.5 meters. The goal of implementing urban agriculture is to reduce the consequences of heavy rainfall. Therefore, this location could need the positive influence of urban agriculture. The location scores a '+' on flood zone.

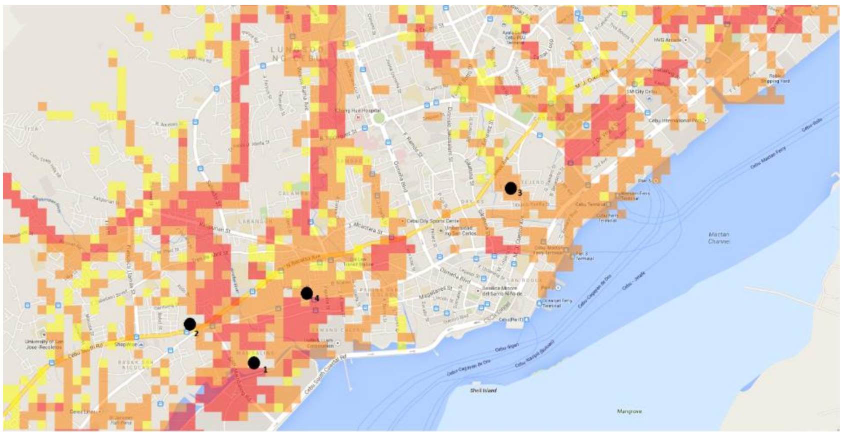


Figure 16 Flood zone map Cebu

Sun hours

On this location the pilot could be placed on the left side of figure 17. With an average height of 5 meters on the west side and on the east side an average height of 7 meters, it has a total amount of 2:40 sun hours per day.

Figure 17 Lnai Hoa sun hours

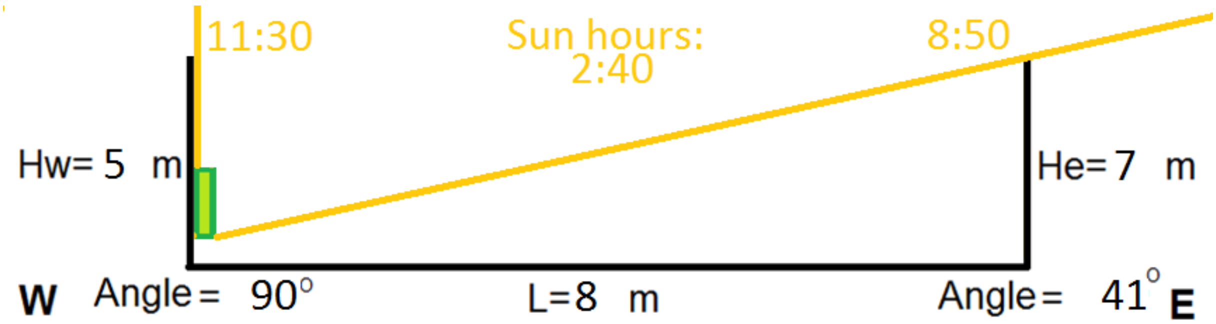


Figure 18 Lnai Hoa sun hour sketch

Maintenance options

The inhabitants in this area could maintain the urban agriculture. However, it is not certain if they will contribute maintenance since they will not get paid for it. For this reason, this location scores a '+/-' on maintenance options.

Accessibility

Lnai Hoa is easiliy accessible by the main road P. Sanchez Street. It is also shown on the picture in figure 13. The buildings are also not very high and easy to reach. For this reason, the location scores a '+' on accessibility.

Figure 19 Streets Lnai Hoa

5. MCDA

Criteria	Alaska Mambaling integrated school	Mambaling elementary school	Pundok sa Katawhan Sitio	Lnai Hoa
Construction stability	++	+	+/-	-
Flood zone	+	+/-	+	+
Sun hours (hours)	7.92	5.17	3	2.67
Maintenance options	+	+	+/-	+/-
Accessibility	+	+	+/-	+

Criteria	Alaska Mambaling integrated school	Mambaling elementary school	Pundok sa Katawhan Sitio	Lnai Hoa
Construction stability	1	0.75	0.50	0.25
Flood zone	0.75	0.50	0.75	0.75
Sun hours (7.92=1 & 0=0)	1	0.65	0.38	0.34
Maintenance options	0.75	0.75	0.50	0.50
Accessibility	0.75	0.75	0.50	0.75

Criteria	**Weight**
Construction stability	8
Flood zone	7
Sun hours	5
Maintenance options	4
Accessibility	3

Criteria	Alaska Mambaling integrated school	Mambaling elementary school	Pundok sa Katawhan Sitio	Lnai Hoa
Construction stability	8	6	4	2
Flood zone	5.25	3.50	5.25	5.25
Sun hours	5	3.25	1.90	1.70
Maintenance options	3	3	2	2
Accessibility	2.25	2.25	1.50	2.25
Total	**23.50**	**18.00**	**14.65**	**13.20**

6. Conclusion

The MCDA results that the Alaska Mambaling school has the highest score. This school is located in a poor area which is needed since this project is for the urban poor. This location does also have many sun hours per day. The school has firm buildings that can easily support the weight of the agriculture. However, there are also multiple floors in some buildings. To gain easy access to the urban agriculture the building chosen to use for urban agriculture is selected in figure 20.
Another benefit of the school is that the students and teachers could maintain the pilot and they could also use it for research purposes. In the end, the goal of this project is too learn people how to storage water with urban agriculture and use the water as efficient as possible. Implementing this into a school would therefore be a wise choice. The other locations did not have all those benefits and therefore scored lower in the MCDA. After talking to the principal of the school about implementing the pilot an other place within the school terrain got assigned to us. This was because this was closer to the allready excisting garden and therefor better for education purposes.

Figure 20 Building marked red

APPENDIX 4. INTERVIEWS

DEPARTMENT OF AGRICULTURE

When we went to The Department of Agriculture Mr. Enriquez had forgotten our appointment. Because of this we were not able to ask allot of questions. Since he had little time he was only able to talk about what their department did and that they did not have allot of experience with urban agriculture, just with agriculture in general.

Have you got any experience with vertical agriculture?

They do the Maundaue Agriculture service. Every year there is a training and a contest. Both vertical and horizontal agriculture.

Have you ever done any projects about the possibility of increasing water storage with urban agriculture? What kind of plants have you used? Who maintained these plants?

Have you ever done any projects about the possibility of reducing the rainwater runoff?

Have you ever done any related projects similar to our project?

What kind of plants would you use, and why?

a. ***Which plants don't need allot of attention?***
b. ***Which plants are fairly cheap?***
c. ***Which plants can grow well in slim containers?***

How would you manage the maintenance?

Have you got any data we could use?

a. ***Water consumption***
b. ***Prices***
c. ***Attention***

Interview documentation

After visiting the DA they did not had that much information for us about urban agriculture because they have more experience with farming than with urban agriculture. However, they could give us information about vegetables and fruits. We got a list of vegetables that are able to grow in the Philippines, this is listed below.

- Leafy vegetables: Lettuce, Kangkong, Cabbage, Pechay, Mustard, Sweet Potato and Alugbati.
- Root or bulb crops: Onions, Carrots, Radish, Garlic, Sweet Potato
- Beans: Munggo, String beans, Snow peas
- Fruit vegetables: Eggplant, Okra, Tomato, Sweet Pepper
- Flower vegetables: Cauliflower, Broccoli
- Vine Fruits Vegetables: Squash, Cucumber, Ampalaya, Sayote, Upo, Patola
- Tree fruits vegetables: Malunggay, Camansi

Two folders were given to us that also described how to plant these type of vegetables. All these types of vegetation is able to grow in containers.
Examples of recycled containers are:

- Native basket wares and wooden containers
- Used household wares
- Transform mineral water bottles into decorative pots.
- Tin cans
- Plastic gallon containers
- Recycled old tires
- Bamboo vines to grow vine vegetables
- Recycling gutters
- Glass and ceramic wares

The folder contains more information about the following subjects:

- Methods of sowing vegetable seeds
- Watering
- Pest and Diseases
- Harvesting
- Fertilization

CITY AGRICULTURE DEPARTMENT

Below are the questions that were prepared before the actual interview with its answers. Not all question were asked for reasons as shortage of time or the interviewed person wanted to talk about other subjects.

Have you got any experience with vertical agriculture?

Urban agriculture program (clients schools high schools military and poor programs) faith food always in the home project at schools. They teach them so they can us the knowledge at home. Lack of space. They give space, knowledge, seeds and soil. Day care centre. They use waste of Sam Miguel as fertilizer.

Have you ever done any projects about the possibility of increasing water storage with urban agriculture? What kind of plants have you used? Who maintained these plants?

They have used special ways of watering so bugs are less attracted.

Have you ever done any projects about the possibility of reducing the rainwater runoff?

No, they the main reason for urban agriculture was to grow vegetables with smart usage of space. Another problem was that the children not like to eat the vegetables.

Have you ever done any related projects?

Bottle towers, normally problems with distributing water to plants. Beatifying is also important.

What kind of plants would you use, and why?

1. ***Which plants don't need allot of attention?***
2. ***Which plants are fairly cheap?***
3. ***Which plants can grow well in slim containers?***
4. ***How would you manage the maintenance?***

Mostly reorganisation. They make contact and help people when they are in need. different groups and ages and these groups also often have leaders who understand everything better for group questions.

How do you find space for your projects? Only governmental ground or also private property like a fence. Do you often have problems with finding space?

Only governmental space and give it to them temporarily. Then they look at the results and make a decision.

Interview documentation

On 20 October 2014 we went to the City Agriculture Department of Cebu City for an interview with Mr. Joelito L. Baclayon.

We were able to talk to Mr. Joelito L. Baclayon and we had enough time to ask all our questions. He told us that the City Agriculture Department had multiple programs. They have military projects, school projects, high school projects and projects for the urban poor. They teach the younger children about the importance of food and vegetables, using the FAITH method. FAITH stands for Food Always In The Home.

After we asked him if he had any experience with increasing the rainwater runoff he told us they did not though they had special methods to reduce bugs who wanted to go to the water. They mostly did this by using lemongrass which is repellent to certain kinds of insects.

The City Agriculture organisation is mostly trying to educate people about the importance of vegetables and about what they can do to grow them their self. Joelito Baclayon said that the urban poor have three main problems with growing vegetables. A lack of knowledge, a lack of space to grow vegetables and a lack of containers and seeds. To solve these problems the City Agriculture department give trainings, lend space and give people seeds for growing. They also teach people how to recycle garbage as containers such as old tires or old shoes.

When we told Mr. Baclayon about our project and our plans he told us that this would solve one of their problems and therefor they were very interested. He told us that watering plants was often a problem because water is often hard to get cheap in certain areas. Because of this he was very interested in our projects and he is an important stakeholder.

We asked Baclayon if he had any experience with special ways of watering plants. He told us that they had a design called a “bottle tower”. This kind of design recycles old plastic bottles and uses them as a container. The plants can be watered from the top and the water flows to the different plants because of gravity (illustration 1).

We asked Mr. Baclayon how maintenance was organised. He told us that usually they use different groups of people and teach them how to grow vegetables as they should. After this they often choose somebody who understands it better than the rest and turn him into a person who is able to answer questions to the rest of the group. Only if he does not know the answer people from the City agriculture department need to be involved.

Our last question was how the organisation was able to find ground for the projects. He told us that they only use governmental ground. He also told us that it is possible to use a school for our pilot projects. Schools often have water related problems and the students could maintain the plants if possible. This location is something we took in consideration.

ARCHIVAL'S ECO-HOUSE

Before we had this interview we got a tour around the house and his terrain. We were able to see what kind of methods he used for growing plants and storing rainwater. Based on this tour we realized that it would be more appropriate to ask about his methods and designs and its technical aspects. This means that not all the questions listed below came to mind.

What is your experience with vertical agriculture?

He had a lot of experience with vertical agriculture. He had many different self-designed forms of urban agriculture around his house. He grew vegetables on his roofs and on the walls.

Have you ever done any projects about the possibility of increasing water storage with urban agriculture?

He made a barrel with gravel and plants. The barrel was attached with an hose and a pump to a fish tank. The pump, pumped the water out of the fish tank into the gravel. The fish tank provides nutrients which is needed for the plants. Rainwater falls into the barrel, when the barrel is full the water will go to the fish tank.

What kind of plants have you used?

He used all different of kind of plants. He was also still experimenting with types of plants.

Who maintained these plants?

His community.

Have you ever done any projects about the possibility of reducing the rainwater runoff?

Have you ever done any related projects to our project?

What kind of plants would you use, and why?

How would you manage the maintenance?

Interview documentation

Counsellor Archival has given us a lot of valuable information about vertical agriculture. He had many examples and experiments going on his land. As shown on the pictures in paragraph 3.4 he had already a lot of experience with urban agriculture and vertical gardening in general.
He had 200 households in the community that made use of his sustainable features.

After watching our designs we had in mind for vertical gardening, he noticed that the plants and its roots will probably drown in the water. After this, he had shown some of his experiments that were similar to our design. One of his designs made use of fish tanks as shown on figure X. The fish waste will add nutrients to the water what is needed for the plants. The water for the plants is by use of a pump discharged into the container with the plants. The water will eventually flow back to the container with fish and so it is an ongoing cycle. This idea was unfortunately not viable for our project since a pump is too expensive and we focus on the urban poor. The water storage was also not efficient enough for our means.
Mr. Archival did not know what plants are better for what purpose, he was still experimenting.
Even though his designs were not perfect for this project, they still had some important features we could use in our design and he gave is valuable advice.

INTERVIEW PRINCIPAL MRS. TERESA ALVIADO, ALASKA MAMBALING SCHOOL

This interview was held at Alaska Mambaling school in Cebu City. The person who was interviewed was the principal of the school.

Are you prepared to let us implement our design into your school?

Yes, we are very interested in these new adaptive solutions. We also have very high bills for water, this design could help reduce that. The school is also located in a flood area which results in occasional floods. We have a garden in our school terrain which can be used for your pilot designs.

Can you help us get materials for the pilot?

Yes, we will help with anything you need. The children can help collect 2/1.5 L bottles for example.

Are you willing to maintain the pilot?

Yes, we will let the students maintain it just like it is done right now in our garden.

Are you willing to duplicate more of these designs yourself in the future?

If the pilot you are setting up right now works, then yes we are very interested in duplicating the design ourselves in the future. This will make it easy since the pilot is not difficult to make.

Are you willing to assist us implementing the design?

We will assist you in any way we can. However, we can only help on workdays.

Interview documentation

On 10-12-2014 we went to the Alaska Mambaling school to talk with the principal. We asked if we were allowed to use this location for our pilot since it has many benefits for it. The principal was already very excited about our idea and thus after explaining our design she agreed. She told us that the school garden would be an appropriate location for our design. We agreed and went to their school garden and determined which place would fit our pilot the most. We noticed that not the whole roof was made out of strong wood because it started rotting or it was cracked. There still was a good spot we choose with a stronger foundation that we could use. We then told them we still needed around 8, 5L-2L-1.5L bottles which they could arrange for us.

Design report: Increasing water storage with low-cost urban agriculture

2 designs made for implementing a pilot in Cebu City

Design report: Increasing water storage with low-cost urban agriculture

2 designs made for implementing a pilot in Cebu City

Ian Mullens
Timo Hoekstra

Presidential Commission for the Urban
Rotterdam University of Applied Science
Supervisors: Mr. R. Heikoop (lecturer), Mrs. A. Loois (Lecturer) and C. Osano (Regional director)
The Philippines, Cebu City, December 23th 2014

Table of content

1. Introduction

For this research 2 designs are made and 1 of those is tested. These designs are given certain demands and requirements which they need in order to success. The demands and requirements are placed in chapter 2-3. The designs are made with Sketchup, MS Paint and Adobe Illustrator. For each design is determined what its weaknesses and strengths are with a SWOT analysis.
After the designs are finished and determined whether they qualify for the pilot, one of them will be built and tested. The tests will find place on the chosen location in the location analysis (Alaska elementary school). These tests are done to calculate the water flow of the pilot. This data is placed in chapter 8, the water system analysis.
At first the plan was to make a pilot for both the designs. Unfortunately, due a lag of time we were not able to build 2 pilots. Therefore, there was chosen to build only the design that qualified the most.

2. Program of requirements

There are multiple requirements the pilots must cope with. The designs must meet these requirements in order to be successful.

- **Costs**
  The costs of a pilot cannot be higher than Php300. This project focusses on low-cost urban agriculture so it cannot be too expensive.
- **Water storage capacity**:
  The pilots need to store at least 15L in order to be able to water the plants over a longer period of time.
- **Design lifetime**
  The pilot needs to last at least for 2 years with maintenance. In order to be profitable this is considered to be long enough of a lifetime.
- **Food production**
  The pilot needs to have at least 15 plants to make enough fruit and vegetables to have any effect.
- **Height**
  The plants need to be placed at least 20cm above the ground. Since there is chosen for vertical agriculture it is important that the pilots are designed to be placed at least 20cm above the ground. This to prevent damage from animals, floods, pests, etc.

3. Design functions

The design functions are divided into hard design functions and soft design functions. Hard design functions are functions that the pilot must have in order to function well and be successful. Soft design functions are functions that are optional and not needed.

3.1 Hard design functions

- Design has to storage rainwater
- Design has to make good use of the available space
- Design has space to grow vegetables and fruits
- Construction needs to be firm (flood resistant)
- Design has to slow down the rainwater runoff
- Design cannot hinder people and traffic
- No advanced technology can be used, local people should be able to repair it themselves
- Materials should be available locally
- The design needs to be safe (no sharp edges, no collapse danger)
- It should not weaken adjacent structures

3.2 Soft design functions

- The design connects with the surrounding environment and atmosphere
- The design has to have a positive influence on the environment
- Stored rainwater needs to water the plants continuously over a long period of time
- The design needs to make optimal use of the sunlight
- Add a sign that explains what the design does and how it works, this will educate people

3.3 Solutions

Design has to storage rain water

To storage and catch rainwater a possible solution is to add a barrel. The barrel could store the water and slowly distribute it to the plants. Rainwater on rooftops could also be collected and led to the containers by using pipes for example. This will increase the water storage capacity.

Design has to make good use of the available space

The design will most likely be a form of vertical agriculture. This form of urban agriculture is not very space consuming because it uses space that was unused in the past.

Design has space to grow vegetables and fruits

The design could be made out of bottles connected with each other for example. Vegetables and fruits could be planted inside these bottles. Another solution is to make use of wooden planks or plastic bins.

Construction needs to be firm

The construction need to be firm so it can resist heavy rainfall and other forces of nature. To do this the construction could be attached with nails or other forms of stable construction methods. The materials of the construction will not break down fast and are water resistant.

Design has to slow down the rainwater runoff

Rainwater will be slowed down by the design by catching it on the roofs and slowly watering the plants. After this water is partly consumed by the plants and partly distributed to the sewer system. The soil in the containers will also slow down the water.
Water that falls directly on the vertical agriculture will also be slowed down by the soil and the plants.

Design cannot hinder people and traffic

To avoid this, the design will be placed on locations where it cannot hinder people or traffic. For example on roofs or walls. It will also be taken into account during the designing process so that the structure will not become too wide for example.

No advanced technology can be used; local people should be able to repair it themselves

The design papers need to be as clear as possible so the local people can understand it. Also, the structure will be made using only simple technology. This is also needed to make it low-cost and the people would be able to repair it themselves when broken.

Materials should be available locally

To ensure the structure is only made from local materials, we will build it ourselves. When building it, materials will be collected from local stores, the PCUP and other organizations.

The design needs to be safe (no sharp edges, no collapse danger)

Using sharp edges will be avoided as much as possible, and when sharp edges are inevitable they need to be shielded.

It should not weaken adjacent structures

To avoid this, a few measurements are taken. The structure will not be built against weak buildings or walls. The structure must not weigh too much to prevent structures from collapsing. Caution is permitted while building the structure.

4. Design process

A few steps are taken during the design process. The first step is finding reference images. These are placed below in figure 1, 2 and 3.

Figure 3 Vertical agriculture 1

Figure 2 Vertical agriculture 2

Figure 1 Vertical agriciulture 3

The second step is making a mind map. The mind map is placed below in figure 4. To organize all the possibilities within the brainstorming process a mind map is made. A mind map is a tool used to find as many possibilities and ideas within the designing process of an object or idea. The mind map is also shown in a bigger format in appendix 8.

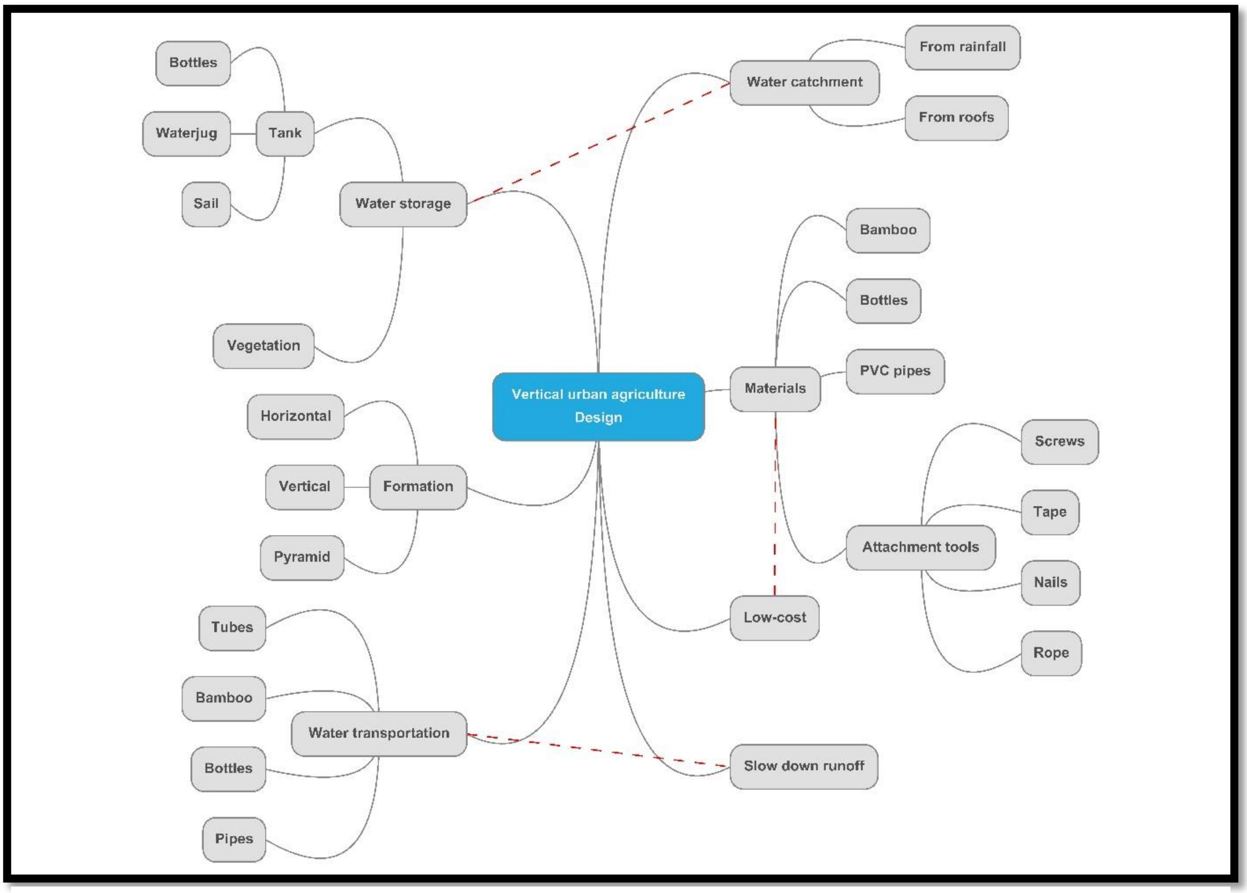


Figure 4 Mindmap

5. Design 1

5.1 Design description

A sketch of the first design is shown in figure 5. A bigger illustration is placed in appendix 1. This design catches water from the roof and re-directs it into a tank by making use of a gutter. The tank is connected to a tube or hose. The tube is closed at the end. This means the tube will also be filled with water. However, the tube has tiny holes so that the water will flow very slowly out of the tube into the vegetation hung beneath the tank. The vegetation is placed in bottles placed horizontally. Multiple rows of bottles are placed beneath each other. The bottles are placed oblique so that water can flow down towards the ground in case of too much water.
This design will store rainwater during rainfall. Since the water can only flow out very slowly, it will water the plants over a large amount of time.
The design can be attached to a selling by making use of ropes or it can be nailed to a wall. This depends on the location. Figure 6 shows an intersection from 2 different angles. With the chosen location the design will have a height of around 2.3 meters.

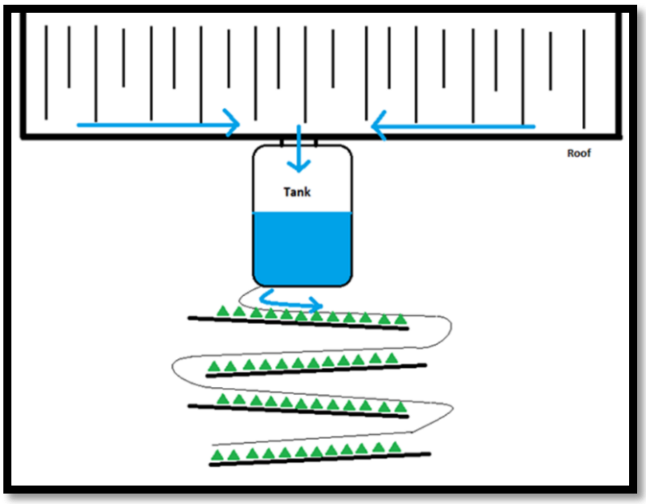


Figure 5 Sketch design 1

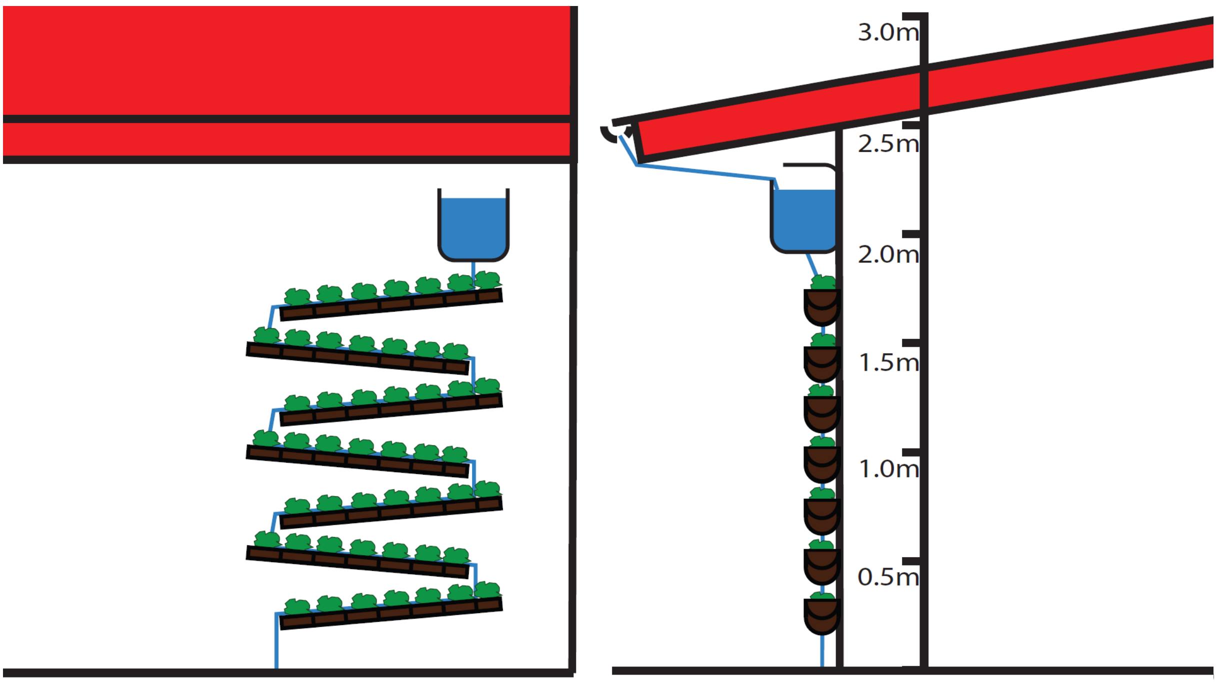


Figure 6 Intersection two different angles design 1

Figure 7 shows a more realistic view of the design to give a good idea what it will look like in reality. All these figures are also placed in the appendix on larger scale.

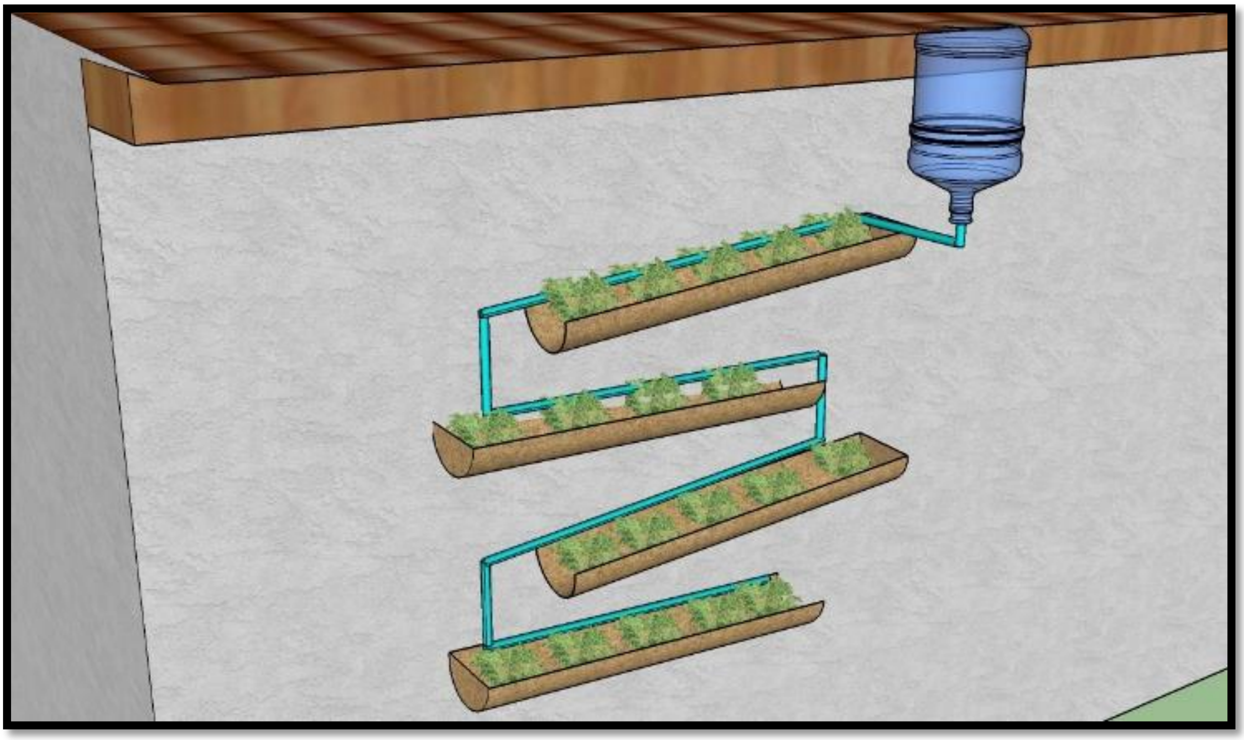


Figure 7 3d design 1

Multiple materials are needed to make this design. The materials needed for design 1 are listed below in table 1 with their costs. Materials that are recycled or provided are considered $0 in costs.

Table 1 Materials design 1

Materials	Description	Unit	Cost ($)
Tank (19L)	The tank is used to store water	1	$0.45
Bamboo (2m)	Bamboo will be cut in half and used as gutter on the roof. The gutter will lead the rainwater into the tank.	1	Recycled $0
Tube or hose (4-5m)	The tube can be a garden hose for example. Tiny holes will be made in the hose so that water slowly drips on the vegetation.	1	$4
Bottles (1.5-2L)	Around 15 empty bottles are needed as a container for the plants. The best size will be around 1.5L-2L. Bamboo can also function as a container for the plants but is more expensive.	49	Recycled $0
Nails or rope	Nails are needed to attach the structure to adjacent buildings. Rope can also be used but is more difficult and probably less stable.	± 10	$0.90
Cork or tape	A cork or tape can be used to attach the tube to the tank. However, tape is probably not as firm as tape.	1	$0.30
Soil	The soil is provided by the City Agriculture Department.	± 20 kg	Provided $0
Seeds	The seeds are provided by the City Agriculture Department.	±50	Provided $0
Total costs			$5.65 (=±300 Pesos)

5.2 SWOT

Table 2 SWOT 1

Strengths	Weaknesses
-Increase water storage -Watering plants over time -People spare water -Room for a lot of vegetation -Cheap -Simple technology -Use of local materials -No obstruction for roads or ways	-Requires more materials (than other design) -Durability -Quite wide
Opportunities	**Threats**
-Locals could learn from design -People will eat more vegetables -Make environment greener -Can be implemented on large scale -Reduce consequences of heavy rainfall	-Could be difficult to attach -Drowning the plants -People will not maintain the pilot -Design failures -Tank can flood with too much rain -Insect pests

Overview of the most important topics

Increase water storage

The main purpose of this design is to storage water. It is an adaptive solution since the water is used for vegetation. The tank on top of the design allows it to storage an amount of rainwater.

Watering plants over time

The plants are watered over time. This is important because main problems in the past with urban agriculture was people not maintaining the plants enough. By watering the plants over time this problem is reduced. Also the plants will slow down the water so that the ground is less likely to be saturated.

Quite Wide

A disadvantage of this design it is quiet wide. This means it is not possible to place many next to each other to catch more rainwater.

Could be difficult to attach

A big threat is that it could be difficult to attach the design to adjacent buildings or walls. This design has many loose parts, each of these parts need to be attached separately.

People will eat more vegetables

After interviewing the City of Agriculture they mentioned that people and especially the children do not eat enough vegetables. This design produces a vast amount of vegetables and could encourage the people to eat healthier.

Confrontation matrix

The confrontation matrix will look at the 'match & mismatch' between the strengths/weaknesses and the opportunities/threats from the SWOT analysis (Marlou Landers, 2013). The confrontation matrix should give clarity to these 4 questions (Marlou Landers, 2013).

- How can strong points respond to opportunities?
- How can strong points be enabled to repel threats?
- How can weak points be strengthened to respond to opportunities?
- How can weak points be strengthened to provide resistance to threats?

Each confrontation will be rated with 0/-/--/+/++. When comparing the points the positive can compensate the negative or the other way around, based on this result it can score + or -.
When counting all the scores the confrontation matrix will show which points are the best opportunities, strength, weaknesses and which one is the highest threat.

Table 3 Confrontation matrix design 1

		Opportunities					Threats						
		Locals could learn from design	People will eat more vegetables	Make environment greener	Can be implemented on large scale	Reduce consequences of heavy rainfall	Could be difficult to attach	Drowning the plants	People will not maintain the pilot	Design failures	Tank can flood with too much rain	Insect pests	
Strength	Increase water storage	++	0	++	+	++	-	-	--	--	-	-	-1
	Watering plants over time	++	+	+	++	++	-	0	+	--	-	-	4
	People spare water	+	0	+	+	0	-	0	+	-	-	0	1
	Room for a lot of vegetation	0	++	++	+	++	-	--	0	-	-	-	1
	Cheap	+	+	0	++	0	+	-	0	-	-	0	3
	Simple technology	+	0	0	++	0	+	0	+	+	0	0	4
	Use of local materials	+	0	0	++	0	0	0	+	-	-	-	1
	No obstruction for roads or ways	0	0	0	++	0	0	0	0	0	-	0	1
Weaknesses	Requires more materials	+	-	-	-	0	-	0	-	-	0	0	-5
	Durability	-	-	-	-	-	-	0	--	-	-	-	-11
	Quite wide	0	0	+	-	0	-	0	0	-	0	0	-2
		8	2	5	10	5	-5	-3	-1	-12	-8	-5	

Important results of the confrontation matrix

- When implementing this design the water storage will increase. This means that the consequences of heavy rainfall will reduce in the future.
- The design is made using simple technology, this could mean that it is more likely design failures can occur and forms a threat for this project.
- When people see that this design will store water and give plants water over time, they could be more interested in learning how it works so that they can implement it themselves.
- The design is made so it will water the plants automatically. Therefore, the people do not have to maintain in that often so the strength can be used to repel a threat.
- When something is built very complicated using advanced technology, the chance of design failures is higher. Since the design is made using simple technology, this is not the case. It will reduce the chance of design failures.
- Durability is the biggest weakness of the design.
- "Design failures" is the highest threat of the design.
- When people see that this design stores water and is made by local materials and simple technology they could be more interested in maintaining the pilot.

6. Design 2

6.1 Design description

The second design is shown in figure 8 below. A bigger illustration is placed in appendix 4. This tank can also be placed beneath a roof to store rainwater. In this design the plants are placed beneath each other. They are connected with each other by use of bottles. A tube is connected with the tank and placed through the soil vertically. The tube also has tiny holes so that it will water the vegetation over a large amount of time. Holes are made in the bottles so that the vegetation can grow towards the sun. The design can be attached with rope to the roof or by nails against the wall, depending on the location. This design is very small which opens up the opportunity to place multiple next to each other. Figure 9 shows an intersection from two different angles. With the chosen location the design will have a height of around 2.3 meters.

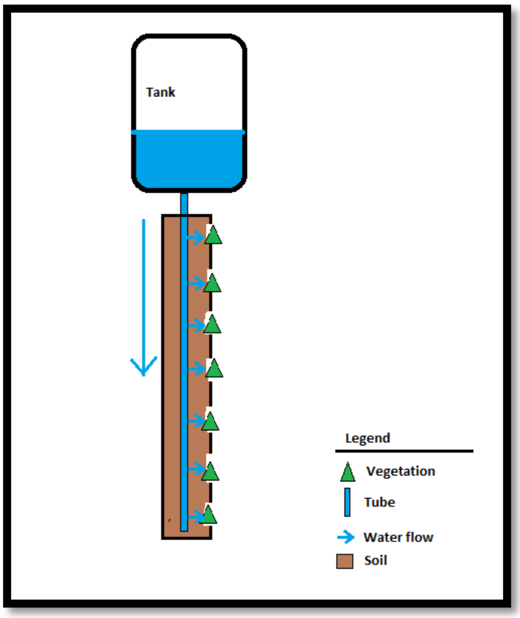


Figure 8 Design 2 sketch

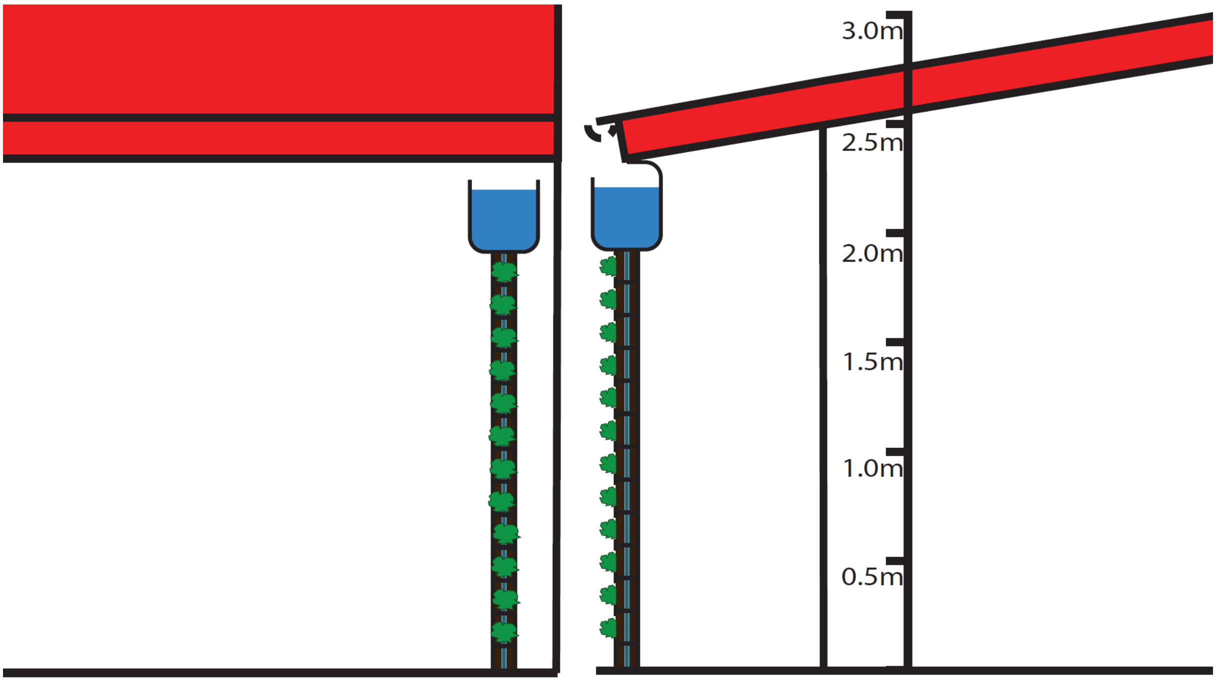


Figure 9 Intersection from 2 angles design 2

Figure 10 shows a more factual view of the design. This design figure is also placed in appendix 5 in a bigger format.

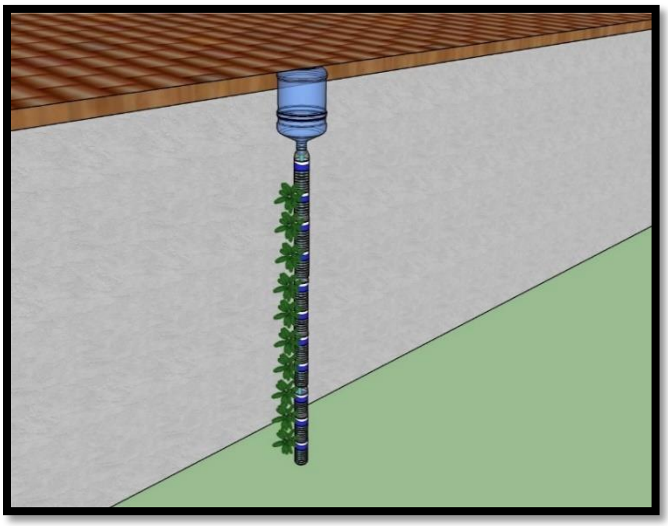


Figure 10 3d design 2

Multiple materials are needed to make this design. The materials needed for design 2 are listed below in table 4 with their costs. Materials that are recycled or provided are considered $0 in costs.

Tablet 4 Materialen design 2

Materials	Description	Unit	Cost ($)
Tank (19L)	The tank is used to store water	1	$0.45
Bamboo (2m)	Bamboo will be cut in half and used as gutter on the roof. The gutter will lead the rainwater into the tank.	1	Recycled $0
Tube or hose (2m)	The tube can be a garden hose for example. Tiny holes will be made in the hose so that water slowly drips on the vegetation.	1	$2
Bottles (1.5-2L)	Around 15 empty bottles are needed as a container for the plants. The best size will be around 1.5L-2L.	12	Recycled $0
Nails or rope	Nails are needed to attach the structure to adjacent buildings. Rope can also be used but is more difficult and probably less stable.	± 5	$0.45
Cork or tape	A cork or tape can be used to attach the tube to the tank. However, tape is probably not as firm as tape.	1	$0.30
Soil	The soil is provided by the City Agriculture Department.	**± 5** kg	Provided $0
Seeds	The seeds are provided by the City Agriculture Department.		Provided $0
Total costs			$3.20 (=±150 Pesos)

6.2 SWOT

Table 5 SWOT 2

Strengths	**Weaknesses**
-Increase water storage -Watering plants over time -People spare water -Room for vegetation -Cheap -Simple technology -Use of local materials -No obstruction for roads or ways	-Has not that many plants (compared to other design) -Durability
Opportunities	**Threats**
-Locals could learn from design -People will eat more vegetables -Make environment greener -Can be implemented on large scale -Reduce consequences of heavy rainfall	-Drowning the plants -People will not maintain the agriculture -Could be instable -Design failures -Tank can flood with too much rain -Insect pests

Overview of the most important topics

Increase water storage

The main purpose of this design is to storage water. It is an adaptive solution since the water is used for vegetation.

Watering plants over time

The plants are watered over time. This is important because main problem in the past with urban agriculture was that the people would not maintain the plants enough. By watering the plants over time this problem is reduced.

Has not many plants

A disadvantage of this design is that it has not that much room for plants compared to the other design. This could reduce the amount of water it can hold and the amount of vegetation it will produce.

Scalability

A big opportunity of this design is the scalability. The form of this design makes it possible to place multiple of these designs next to each other. Since it is able to do this multiple can be placed under the same roof what will increase the water storage significance.

Stability

A big threat could be the stability of the design. Every bottle needs to be connected firm enough to each other or it might collapse.

Confrontation matrix design 2

Table 6 Confrontation matrix 2

		Opportunities					Threats						
		Locals could learn from design	People will eat more vegetables	Make environment greener	Can be implemented on large scale	Reduce consequences of heavy rainfall	Could be instable	Drowning the plants	People will not maintain the pilot	Design failures	Tank can flood with too much rain	Insect pests	
Strength	Increase water storage	++	0	++	+	++	-	-	--	--	-	-	-1
	Watering plants over time	++	+	+	++	++	-	0	+	--	-	-	4
	People spare water	+	0	+	+	0	-	0	+	-	-	0	1
	Room for vegetation	0	++	++	+	++	0	--	0	-	0	-	3
	Cheap	+	+	0	++	0	+	-	0	-	0	0	2
	Simple technology	+	0	0	++	0	+	0	+	+	0	0	6
	Use of local materials	+	0	0	++	0	+	0	+	-	0	-	3
	No obstruction for roads or ways	0	0	0	++	0	-	0	0	0	0	0	1
	Does not need much space	+	0	+	++	0	+	0	0	0	0	0	5
Weaknesses	Has not that many plants	0	--	--	0	-	+	+	+	0	-	+	-2
	Durability	-	-	-	-	-	--	0	--	-	-	-	-12
		8	1	4	13	4	-2	-3	-1	-8	-5	-4	

Important results of the confrontation matrix

- When implementing this design the water storage will increase. This means that the consequences of heavy rainfall will reduce in the future.
- The design is made using simple technology, this could mean that it is more likely design failures can occur and forms a threat for this project.
- When people see that this design will store water and give plants water over time, they could be more interested in learning how it works so that they can implement it themselves.
- The design is made so it will water the plants automatically. Therefore, the people do not have to maintain in that often so the strength can be used to repel a threat.
- When something is built very complicated using advanced technology, the chance of design failures is higher. Since the design is made using simple technology, this is not the case. It will reduce the chance of design failures.
- A big opportunity is that this design can easily be implemented on large scale. This is due the fact that this design does not need much space, materials and is low-cost.
- Durability is the biggest weakness of the design.
- "Design failures" is the highest threat of the design.
- When people see that this design stores water and is made by local materials and simple technology they could be more interested in maintaining the pilot.
- A weakness is that this design does not have room for that many plants. A threat is that this design could be unstable and could fall out of balance. The fact that there are not many plants reduces the weight and chance that it will fall out of balance. For this reason, a weakness reduces the chance a threat will occur.
- When there are fewer plants, the people have to maintain less.
- The water storage capacity is reduced since this design has not many plants.
- Insects are lured by flowing water and the plants. This design has less room for plants and the vegetation is better hidden in the bottles. This reduces the chance of insect pests.

7. Pilot

This chapter will show the end result of the pilot, what materials are used and the results of testing the pilot.

7.1 creating phase

On December 12, 2014 design 2 has been made and placed at the Alaska Mambaling School. Figure 11 shows the end result of the pilot. There are 2 designs that could be implemented and tested. Due to lag of time we chose to only make 1 design. Design 2 was eventually chosen for the following reasons.

- Design 1 is more complicated to build
- Design 1 is more expensive to make
- Design 2 qualified better in the chosen location Alaska Mambaling school since the pilot could not be made against the wall
- Design 2 has more strong points that respond to opportunities
- Design 2 has more strong points that enable to repel threats.

Figure 11 Pilot

After all the materials were gathered it only took 4 hours to build the pilot. On the next page a table (7) is shown with the materials that were used to make this pilot.

Table 7 Materials Pilot

Materials	Description	Unit	Cost ($)
Tank (19L)	The tank is used to store water	1	$0.45
Bamboo (2m)	Bamboo will be cut in half and used as gutter on the roof. The gutter will lead the rainwater into the tank. Another bamboo pole is used to attach the bottles to it to make it more stable.	2	Recycled $0
Tube or hose (2m)	A garden hose is used as hose. Tiny holes are made in the hose so that water slowly drips on the vegetation.	1	$2
Pen	A pen is used to plug the end of the tube so it will stop the water. The pen is wrapped in plastic to make it waterproof.	1	Recycled $0
Wooden planks (±30cm)	Wooden planks were used to attach the gutter to the roof	4	Recycled $0
Bottles (5L)	10 empty bottles are used as container for the plants. These 5L bottles are used because they were available at the school.	10	Recycled $0
Nails	Nails are used to attach the structure to the adjacent building.	± 5	$0.45
tape	Tape is used to attach the tube to the tank.	1	$0.30
Copper wire (1m)	Copper wire is used to attach the bottles to the bamboo pole	10	$0.45
Soil	The soil is provided by Alaska Mambaling school	± 10 kg	Provided $0
Alugbati plants	Plants are provided by the Alaska Mambaling school	18	Provided $0
Total costs			$3.65 (=±160 Pesos)

During the creating phase multiple problems occurred. The first problem that occurred was that the whole structure collapsed because there was too much pressure on the lowest bottles. After it was rebuild a bamboo pole was attached (figure 12) to the roof and to every bottle with copper wire. Thanks to this solution the pilot is more stable and will not collapse.

The lowest bottle is closed and empty. The reason for this is that a requirement was that the pilot should be 20 cm above the ground to protect vegetation. Now the lowest bottle is empty so there is no vegetation that can be damaged by pests or floods.

Tiny cuts are made in the lowest bottle so that water that has been gone through the whole system will leave the pilot and go into the ground.

A small hole is made at the back on top of the tank so that water will flow out of the tank in case it rains too heavily. The water will not stream into the opening of the bottles into the plants but instead, it will go towards the ground.

This pilot has room for more than 20+ Alugbati plants. This is more than we expected because of the 5L bottles that are used.

Figure 12 Pilot bottle close-up

7.2 Testing phase

After testing, this pilot can hold 1L of water for a duration of 30 min before it is completely distributed throughout the system. This results in a water flow of 2L/h. This is very high compared to the designs we made beforehand. This is because we made 9 holes in the tube which is too many. From we were able to calculate the water flow of one hole, this is 0.22L/h. Figure 13 shows that with 9 holes there are 165 days per year the people need to water the plants themselves. There is an average of 142 raining days in the Philippines which will then water the plants. And there are 58 days per year that the drainage system provides water for the vegetation. So these 58 days the people will not have to water the plants which they would have without this design. In these 58 days is a total amount of 500 L/year water is spared.
So it is advised to make 3 holes in the hose instead of 9 holes. When making 3 holes the graph should look more like the small circle in figure 13. You can see that in the small circle the drainage day are a lot more and the watering days is significant less.

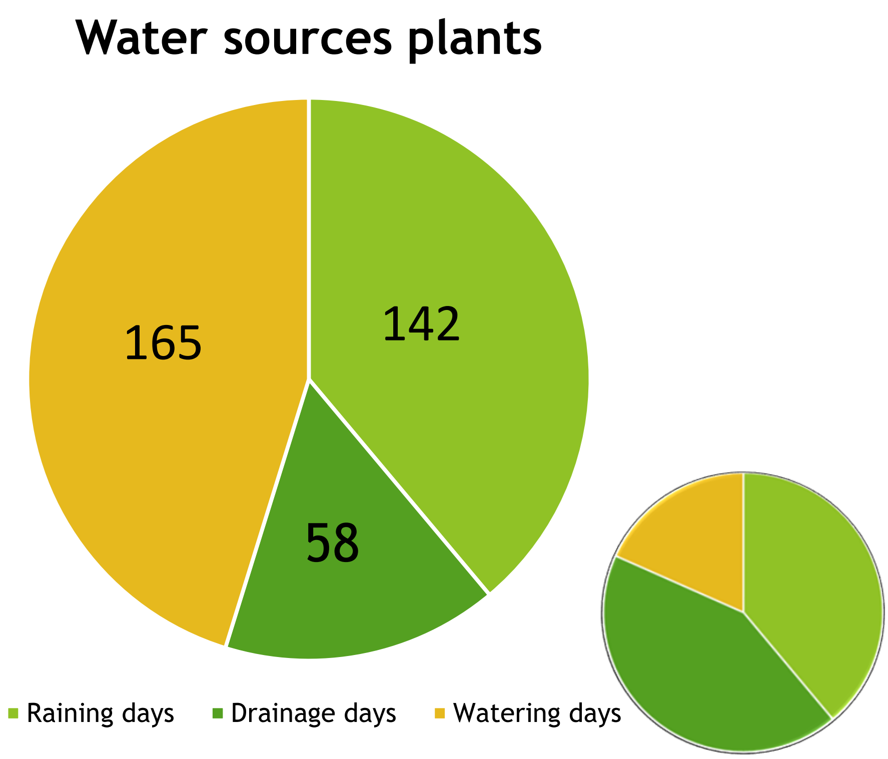


Figure 13 Water sources Pilot

Water flow
The water falls onto the roof and flows into the bamboo gutter. The gutter will lead the water into the tank (18.9L). The tank is attached to a hose which is plugged at the end so it will stop the water. The tube will be filled with water and will be divided onto the vegetation through tiny holes. The water will flow down through the soil and vegetation and will end up after a long period of time in the ground.

8. Water system analysis

To show the water flows in the water system of garden area (appendix 9 shows a top view) a bucket model has been made as you can see in figure 14. Within the chosen school area, the precipitation falls on three different types of surfaces. The water that falls on the paved surface will partly evaporate back into the air, but the biggest part of it will flow to the garden. This water together with the water that fall directly on the garden and a part of the water from the roof will flow to the ground water. A small percentage of the roof is caught by the pilot. This water is drain over a longer amount and this water is partly absorbed by vegetation. The remaining water from the pilot drains slowly to the paved surface. After this the water flows into the groundwater through the garden.

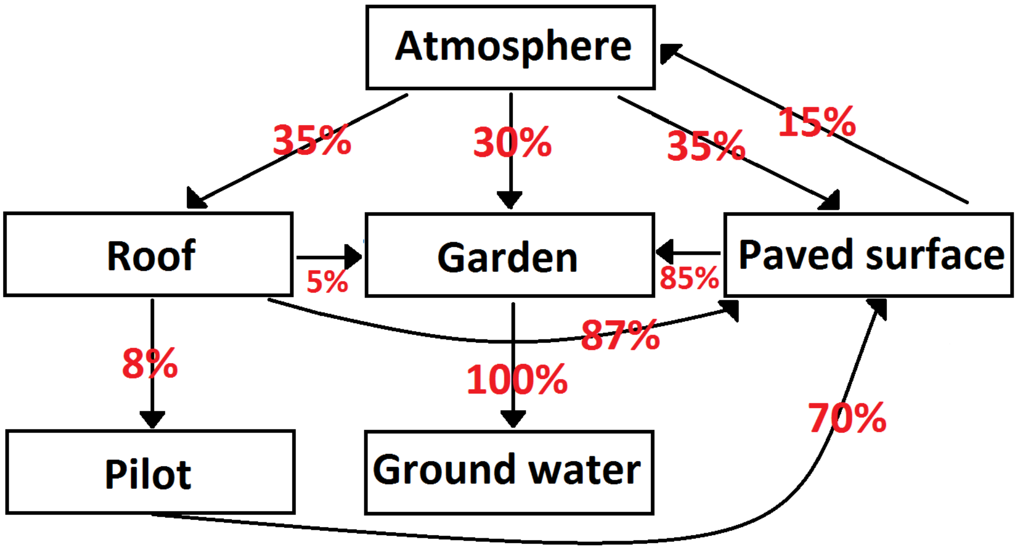


Figure 14 Bucket model

The calculations made in the water system analyses can be split into 3 paragraphs. The first paragraph is “Input”. In the paragraph “Input” is the rain flowing to the tank calculated. The second paragraph is “Storage”. In this paragraph is calculated how much water will be saved by the tank. The third paragraph is called “Output”. In this chapter is the water flow to the agriculture calculated. The last paragraph will show the results of the calculations.

Each of these paragraphs is divided into 3 parts, “Known data”, “Calculated data” and “Formula explanation”. The known data is data that has to be obtained before calculating. Some of this data can be obtained with the help of the internet, but other data are specific for the design situation and need to be obtained by measuring the designs.

Some data can only be calculated with the help of other data. Because of this, data needs to be calculated in a specific order. The order in which data can be calculated is shown by the “stage” of the data. Known data is always stage one because this data is obtained beforehand and not calculated. The calculations can also be found in the chronological order in the example in appendix 7.

8.1 Input

Known data

Table 8 Known input data

Data	Abbreviation	Unit	Source	stage
Number of months	t_y	Months	Common sense	1
Days per month	t_m	Days	Common sense	1
Days with precipitation per month	t_p	Days	(Weatherbase, 2014)	1
Average precipitation per month	P_a	mm	(Weatherbase, 2014)	1
Length of the roof	L_r	m	Measured with steps	1
Width of the roof	W_r	m	Measured with steps	1
Length of the catching area	L_c	m	Measured with tapeline	1
Width of the catching area	W_c	m	Measured with tapeline	1
Average shower length	t_s	min	Estimated based on experience	1

Calculated data

Table 9 Calculated input data

Data	Abbreviation	Unit	Stage
Area of the roof	A_r	m^2	2
Rain catching area	A_c	m^2	2
Average days between showers per month	t_b	Days	2
Precipitation on roof	P_r	m^3	3
Precipitation on catching area	P_c	m^3	3
Precipitation on catching area (average shower)	P_s	L	4
Overlapping day 1	t_{o1}	Days	7
Overlapping day 2	t_{o2}	Days	8
Overlapping day 3	t_{o3}	Days	9
Total overlapping	t_{oTotal}	Days	10

Table 10 input formulas

Abbreviation	Formula
A_r	L_r*W_r
A_c	L_c*W_c
t_b	t_m/t_p
P_r	$(P_a/1000)*A_r$
P_c	$(P_a/1000)*A_c$
P_s	$(P_c/100)/(t_p*100)$
t_{o1}	$t_m*(t_p/t_m)^2*(\text{if } t_d>1 \text{ then } t_d-1 \text{ else } 0)$ Days of month * Chance * Wasted days in scenario
t_{o2}	$t_m*((t_p/t_m)^3+((t_p/t_m)^2*(1-(t_p/t_m))))*(\text{if } t_d>2 \text{ then } t_d-2 \text{ else } 0)$ Days of month * Chance * Wasted days in scenario
t_{o3}	$t_m*((t_p/t_m)^4+((t_p/t_m)^3*(1-(t_p/t_m)))+((t_p/t_m)^3*(1-(t_p/t_m)))+((t_p/t_m)^2*(1-(t_p/t_m))^2))*(\text{if } t_d>3 \text{ then } t_d-3 \text{ else } 0)$ Days of month * Chance * Wasted days in scenario
t_{oTotal}	$t_{01}+t_{02}+t_{01}$

Formula explanation

Most of the formulas stated above are quite simple. Although, the overlapping days need extra clarification. If the raining starts at day one, the tank will also be filled. From the tank water is drained to the vegetation over time. This process can take multiple days in which there is also a chance of rain. If the rain starts for the second time while the water from the tank was still draining, less water can be distributed compared to when the second shower starts after the tank is done with draining. These days that water what should normally be stored in the tank when it is empty, cannot be stored since the tank is still partly full and thus is wasted (figure 15). These days are called overlapping days. To calculate the number of days that have this problem, chance calculation methods have been used.

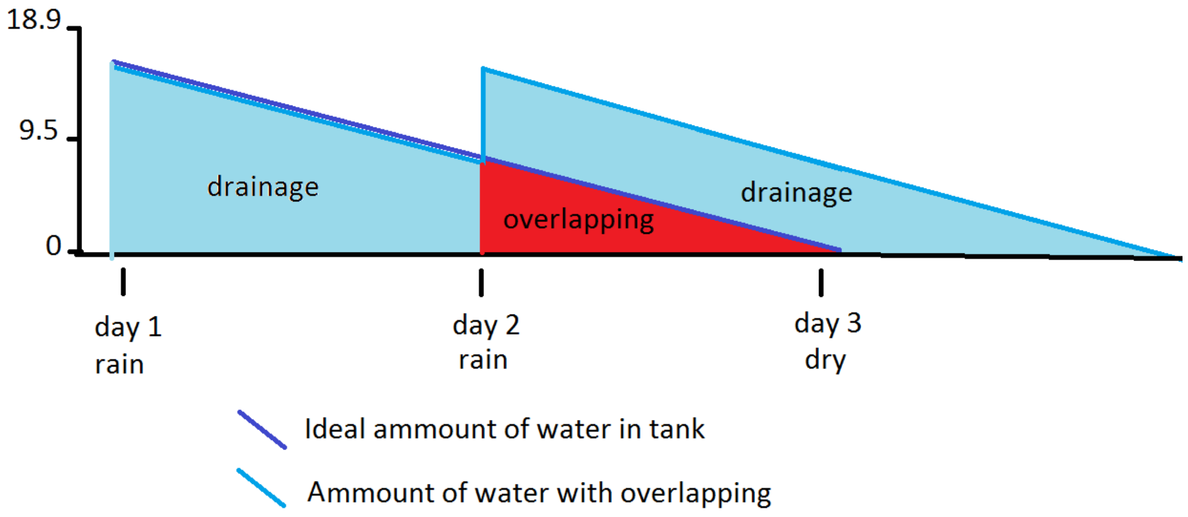


Figure 15 Example, overlapping

To calculate the overlapping of the second day we calculated the chance that it would rain 2 times after each other. At first we need to be able to calculate the chance of raining once a day. This can be calculated by dividing the number of rainy days in the month by the number of days in that month which means t_p/t_m. The chance of this happening two times after each other can be calculated by multiplying this chance with itself which means $(t_p/t_m)^2$. This is the chance that it will rain two times after each other. To calculate how many days in a month this will happen we multiplied the chance by the number of days in the month which means $T_m*(t_p/t_m)^2$. But the drainage can be longer or shorter than one day which means that multiple or no days are wasted. This can also be put in the formula with "if, then, else". *If* the drainage takes longer than one and a half day to empty the tank *then* the one and a half day are subtracted from the drainage days to get the remaining days *else* 0 which means if t_d>1 then t_d-1 else 0. The 0 needs to be there because when the drainage time is less than 1 the overlapping days will not affect volume of the drained water. The formula is multiplied by the outcome of this part which means $T_m*(t_p/t_m)^2*$(if t_d>1 then t_d-1 else 0).

8.2 Storage

Known data

Table 11 Known storage data

Data	Abbreviation	Unit	Source	stage
Tank volume	V_{tmax}	L	Tank label	1

Calculated data

Table 12 Calculated storage data

Data	Abbreviation	Unit	Stage
Water in tank (average shower)	V_t	L	5
Drain time (average shower)	t_d	Days	6
Amount of drained water after 24h	V_{24}	L	6

Table 13 Storage formulas

Abbreviation	Formula
V_t	If P_s>V_{tmax} then V_{tmax} else P_s
t_d	$V_t/(Q*24)$
V_{t24}	If $24*Q<V_t$ then $24*Q$ else V_t

Formula explanation

V_t is the amount of water that is stored in the tank after the average shower of the particular month. This is the same as P_s (amount of water fallen on the catching area per shower) except when the amount of water is more than can be stored in the tank. If that is the situation then the total volume of the tank will be V_t which means If P_s>V_{tmax} then V_{tmax} else P_s.

V_{t24} is the amount of water that flows from the tank to the agriculture in one day. This can be calculated by multiplying the water flow by the time of a day (24h). But the amount of water cannot be more than the amount of water that is stored in the tank after a shower. Because of this the "if, then, else" method is used, which results in If $24*Q<P_t$ then $24*Q$ else V_t .

8.3 Output

Known data

Table 14 Known output data

Data	Abbreviation	Unit	Source	stage
Water flow (<0.2L/h)	Q	L/h	Measured per hole with stopwatch at the pilot	1

Calculated data

Table 15 Calculated output data

Data	Abbreviation	Unit	Stage
Watering days (old)	t_{wo}	Days	2
Not watering days (new with overlapping)	t_{nno}	Days	7
Not watering days (new without overlapping)	t_{nn}	Days	11
Watering days (new)	t_{wn}	Days	12
Saved water	V_s	M^3	12

Table 16 Output formulas

Abbreviation	Formula
t_{wo}	t_m-t_p
t_{nno}	t_p+t_p*t_d+(t_p*t_r/60/24)
t_{nn}	If t_{nno}-t_{oTotal}>t_m then t_m else t_{nno}-t_{oTotal}
t_{wn}	t_m-t_{nn}
V_s	((t_p*t_d-t_{oTotal})*v_{24})/1000

Formula explanation

The number of not watering days in the old scenario is the same as the number of rainy days. This is because vegetation in the climate of Cebu needs to be watered every day except on a rainy day. The number of watering days of the old scenario is calculated by subtracting the not watering days from the amount of days in the month.

The number of not watering days (new with overlapping) are calculated by looking at the old not watering days. In the new scenario there is no need to water the plants on a rainy day just as in the old scenario, but now instead of the usual 1 day of not watering, the drainage time is added every shower which means t_p+t_p*t_d. But the shower itself also takes a little bit of time, therefore the duration of the shower is added every time a shower occurs which means t_p+t_p*t_d+(t_p*t_r/60/24).

The number of not watering days (new without overlapping) are calculated by subtracting the number of the total overlapping days of the number of not watering days (new with overlapping). Overlapping occurs when the water tank is filled up before it has drained empty. When this occurs less water can be stored in total which means the drainage will take less time (because there is less water) in total. This number can be higher than the number of days in the month. This means that there is a big chance that the tank will drain every day of the month. But because a month is limited to a number of days the number of drainage days is also not able to be more. This is limited with the "if, then, else" method which means if t_{nno}-t_{oTotal}>t_m then t_m else t_{nno}-t_{oTotal}.

The amount of save/distributed water can also be calculated. To calculate this, the number of draining days per month need to be calculated. This can be done by multiplying the number of rainy days per month with the drainage time or t_p*t_d. After this number of overlapping days need to be subtracted which means t_p*t_d-t_{oTotal}. These are the number of draining days per month. This number needs to be multiplied by the draining time (t_p*t_d-t_{oTotal})*v_{24}. This answer is the amount of water saved by the tank per month in litres. This number is divided by 1000 to get the amount of saved water in cubic metres.

8.4 Results

With the help of the explained formulas it was possible to calculate the different effects that the designs would have on the water system. The two Designs have different effects on the water system because they have a different amount of plants. This means that the designs need to have a different water flow.

To water the 49 plants of design 1 you would need a water flow of about 1.0L/h (0.5L/day/plant). After testing and measuring the pilot project we found out that this could be achieved by making 5 holes in the hoze/tube.
Design 2 has only 18 plants which means that a lower water flow can be used in the pilot. The water flow that is needed for this design is 0.38L/h. This can be achieved by making two holes. However it is better to use 3 holes so the water is more equally devided.

By implementng the first design 2.7m³ of rainwater is stored and slowly drained per year. The ammount of days that the pilot is watering the vegetation is 102 days per year on average (figure 16). This means that about 2500L water is spared in 1 year on average.

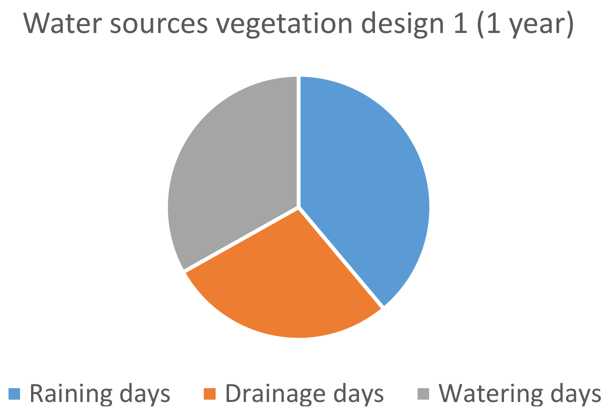


Figure 16 Water sources design 1

By implementing the second design 2.5m³ of rainwater us stored and slowly drained per year. The amount of days that the pilot is watering the vegetation is 156 days per year on average (figure 17). This means that about 1400L water is spared in 1 year on average.

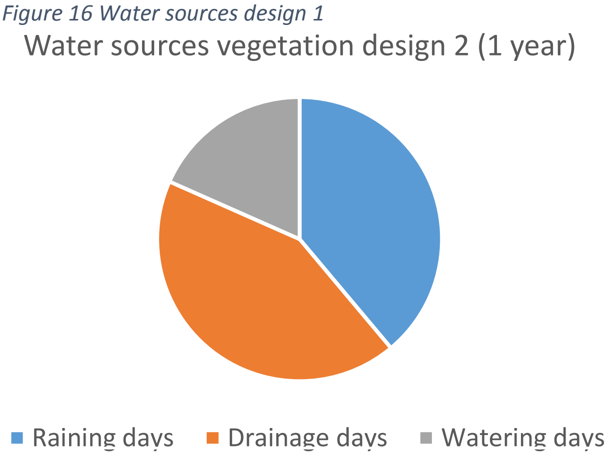


Figure 17 Water sources design 2

The pilot has different results than the design because too many (9) holes where made into the hose which caused a very high water flow of 2L/h. When the water flow is too high the tank is empty faster and there are less watering days. The pilot stores 2.7m³ of rain water a year. The amount of days that this pilot is watering the vegetation is 58 days per year on average (figure 18). This means that about 500L water is spared in 1 year on average. This could be as much as in design 2, but too many holes were made into the tube.

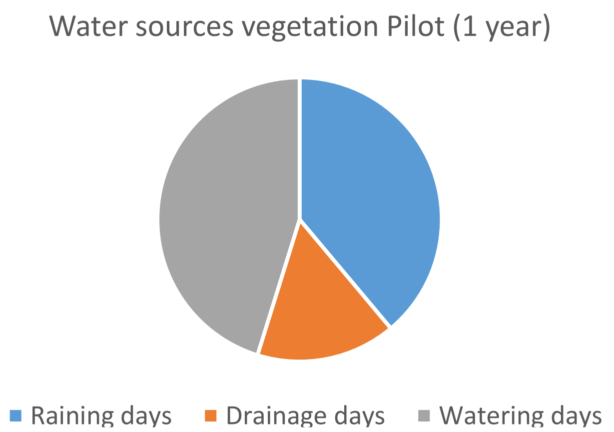


Figure 18 Water sources Pilot

9. Conclusion

There can be concluded that design 2 is a better option than design 1 for Cebu City. Design 2 only costs 150 Pesos, it is made of locally available materials, the design does not use much space, it slows down the rainwater, it produces food and it stores rainwater.
Design 1 is also pretty complicated to build and is more expensive compared to design 2. Design 2 also has more strong points that respond to opportunities and repel threats regarding the confrontation matrix. The amount of days that this pilot is watering the vegetation is 156 days per year on average. This means that about 1400L water is spared in 1 year on average.

After testing, this pilot can hold 1L of water for a duration of 30 min before it is completely distributed throughout the system. This results in a water flow of 2L/h. In total the amount of water that is spared is 500 L/year. The 500L water would in a normal situation be given to the plants.
This can be increased by reducing the amounts of holes made inside the tube.

The following details are important to make when implementing this pilot (figure 19).

- Do not make much more than 3 holes inside the tube.
- Divide the holes equally over the length of the tube.
- Add a bamboo pole and attach every bottle to it.
- Place the vegetation at least 20 cm above the ground.
- Make tiny cuts on the bottom side of the lowest bottle.
- Make a small hole at the back on top of the tank.
- Make tiny cuts inside every bottle cap so that only the tube can go through.

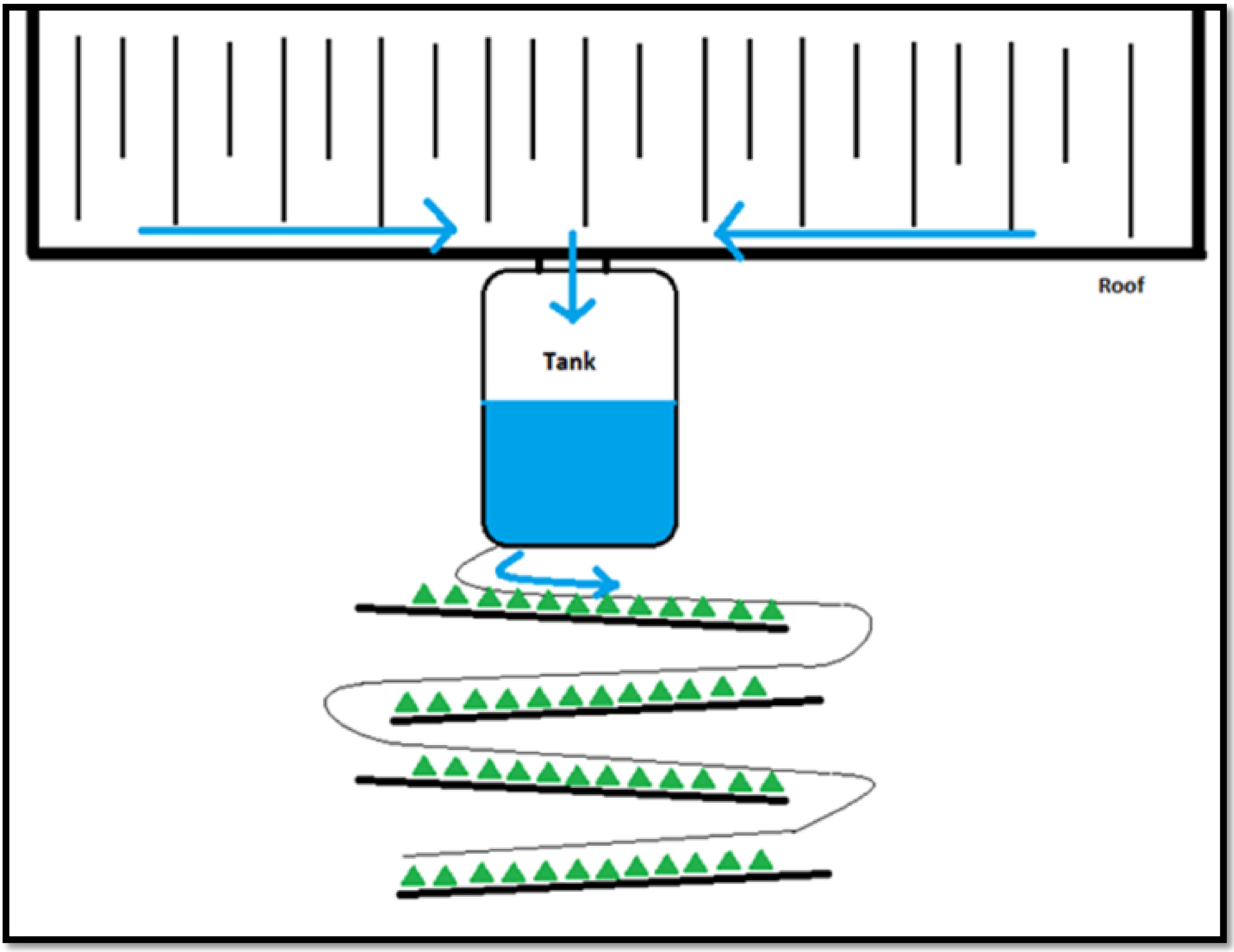
Figure 19 Pilot project finnished

10. Illustrations

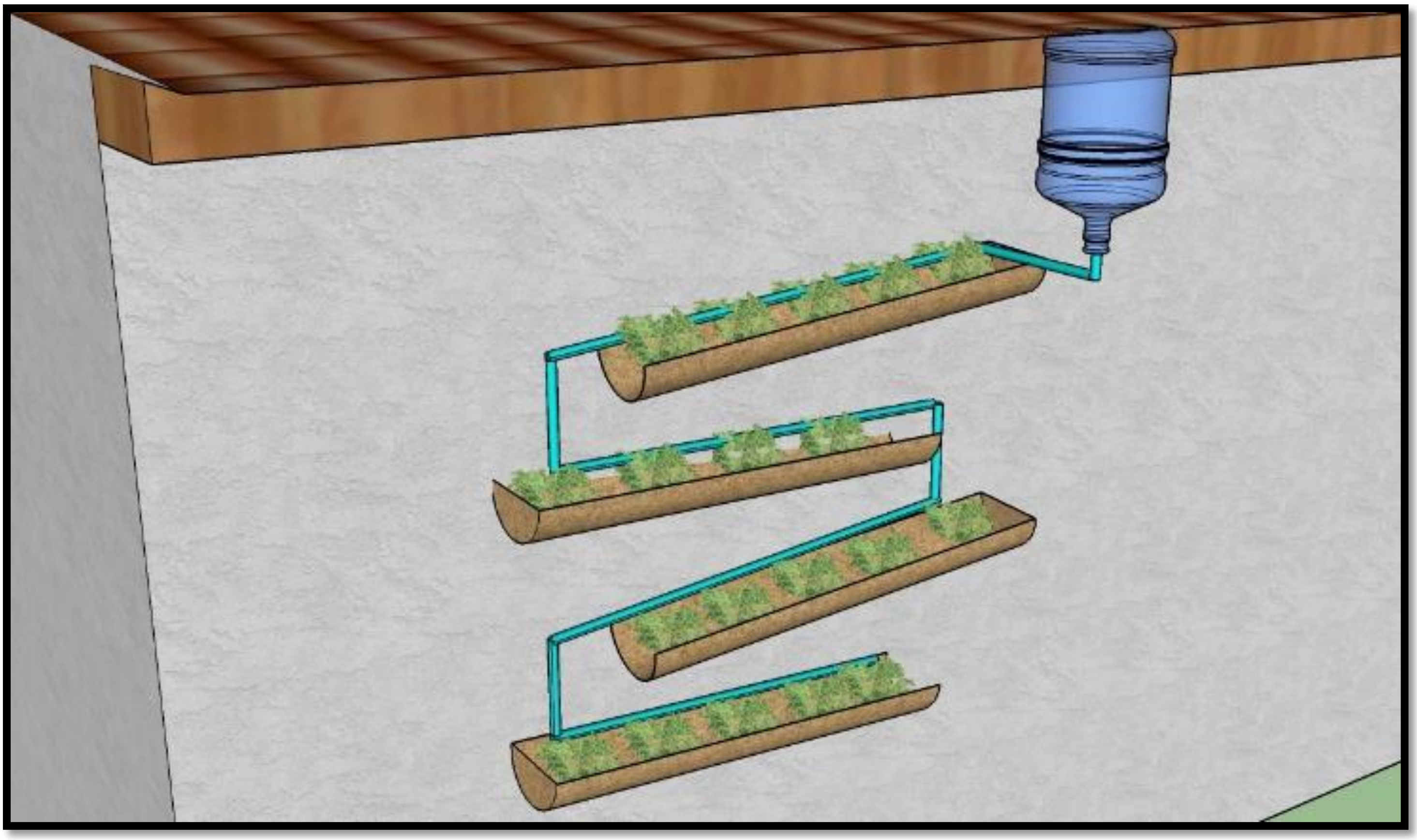
Nr	Name	Source	Date of publication	Author
1	Vertical agriculture 1	http://www.inmagz.com/wallbank/1688-vertical-gardening-ideas-with-wire-fence.jpg	24-8-2013	Interior Magazine
2	Vertical agriculture 2	http://meergroenzelfdoen.nl/wp-content/uploads/2013/01/Verticaal-tuinieren-sla-in-dakgoten.png	1-4-2013	Rob van Eeden
3	Vertical agriculture 3	http://www.handmadekultur.de/up/2012/07/window1-600x760.jpg	13-7-2012	Britta Riley
4	Mindmap	Bubbl.us	14-11-14	Ian Mullens & Timo Hoekstra
5	Sketch design	Made with MS Paint	14-11-14	Timo Hoekstra
6	Intersection two different angles design 1	Made with Adobe Illustrator	10-12-14	Ian Mullens
7	3d design 1	Made with SketchUp	14-11-14	Ian Mullens
8	Design 2 sketch	Made with MS Paint	13-11-14	Timo Hoekstra
9	Intersection from 2 angles design 2	Made with Adobe Illustrator	9-12-14	Ian Mullens
10	3d design 2	Made with SketchUp	14-11-14	Ian Mullens
11	Pilot	Photo	12-12-14	Timo Hoekstra
12	Pilot bottle close-up	Photo	12-12-14	Timo Hoekstra
13	Water sources pilot	Water system analyses	15-12-14	Ian Mullens & Timo Hoekstra
14	Bucket model	Water system analyses	11-12-14	Ian Mullens

15	Example overlapping	Water system analyses	4-12-14	Ian Mullens
16	Water sources design 1	Water system analyses	15-12-14	Ian Mullens & Timo Hoekstra
17	Water sources design 2	Water system analyses	15-12-14	Ian Mullens & Timo Hoekstra
18	Water sources pilot	Water system analyses	15-12-14	Ian Mullens & Timo Hoekstra
19	Pilot project finished	Photo	12-12-14	Timo Hoekstra

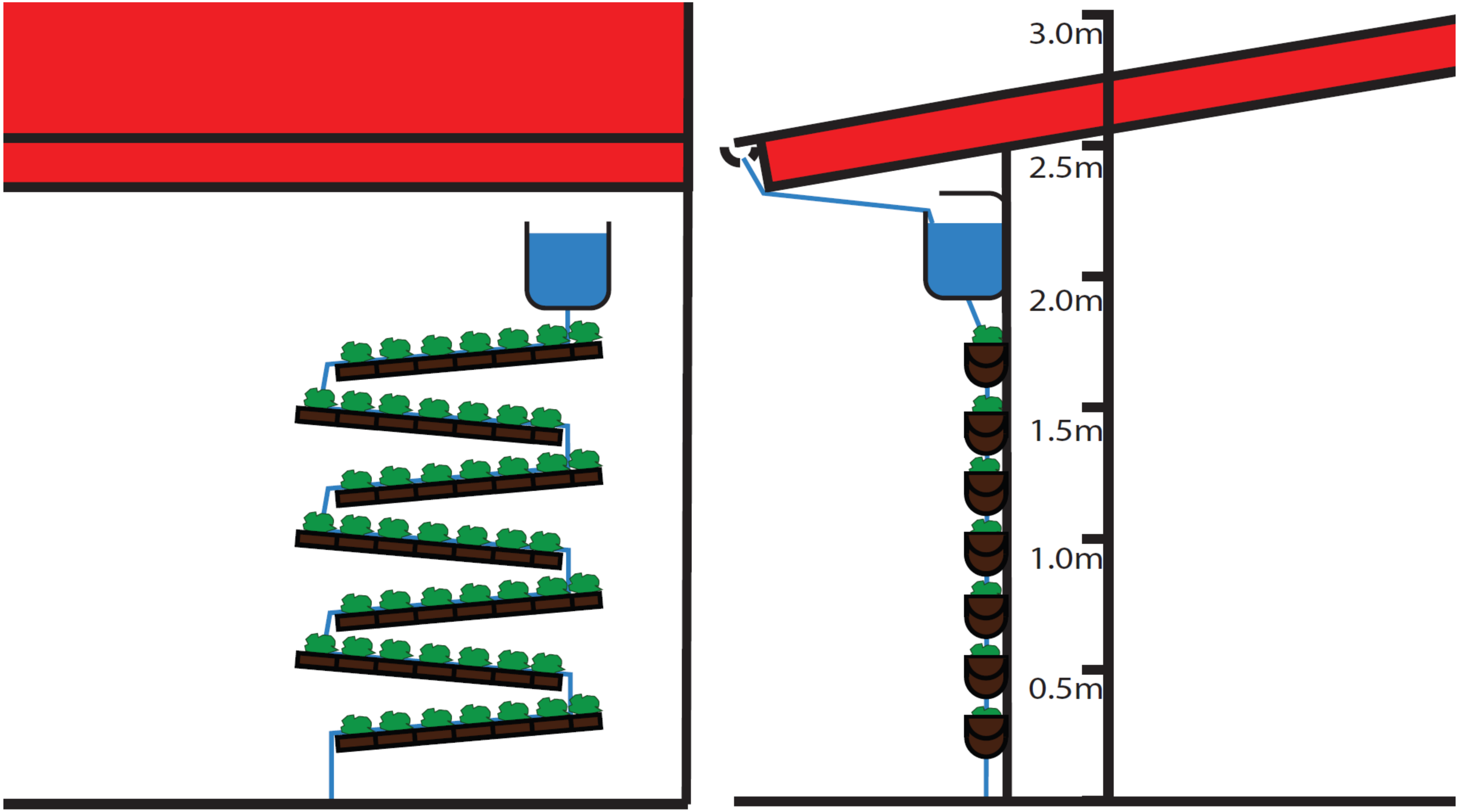
Appendix 1 Sketch design 1



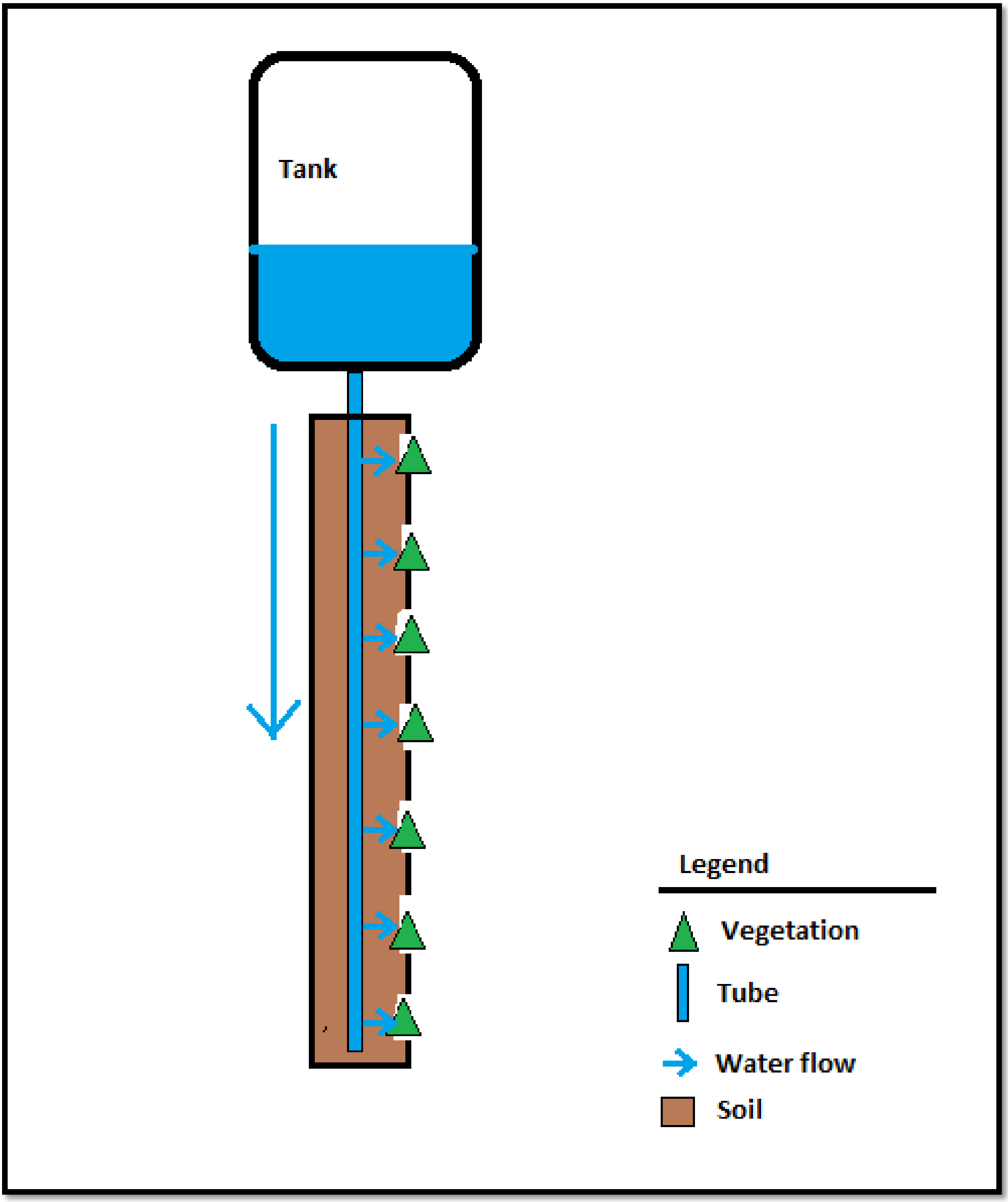
Appendix 2 3d Design 1



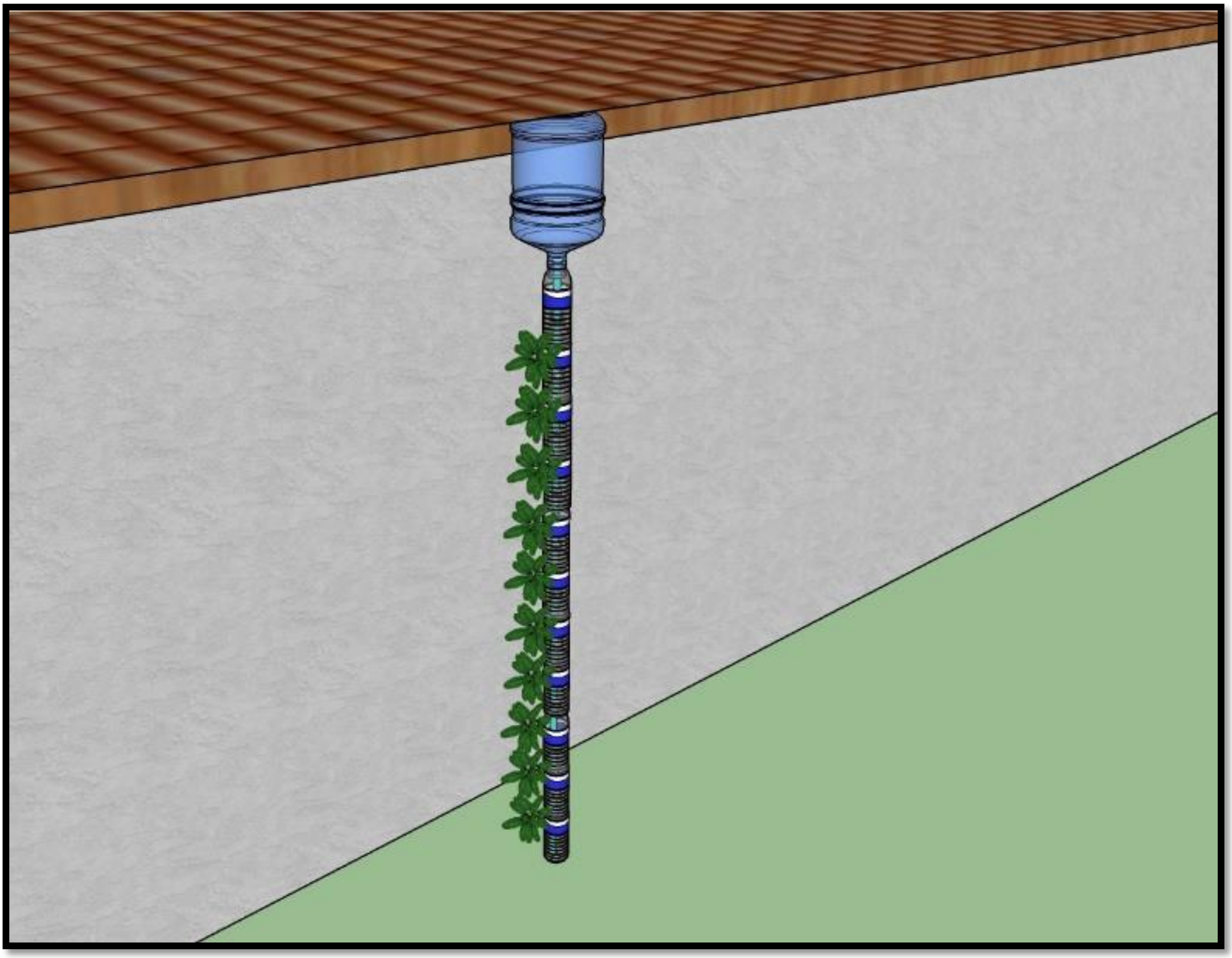
Appendix 3 Intersection design 1



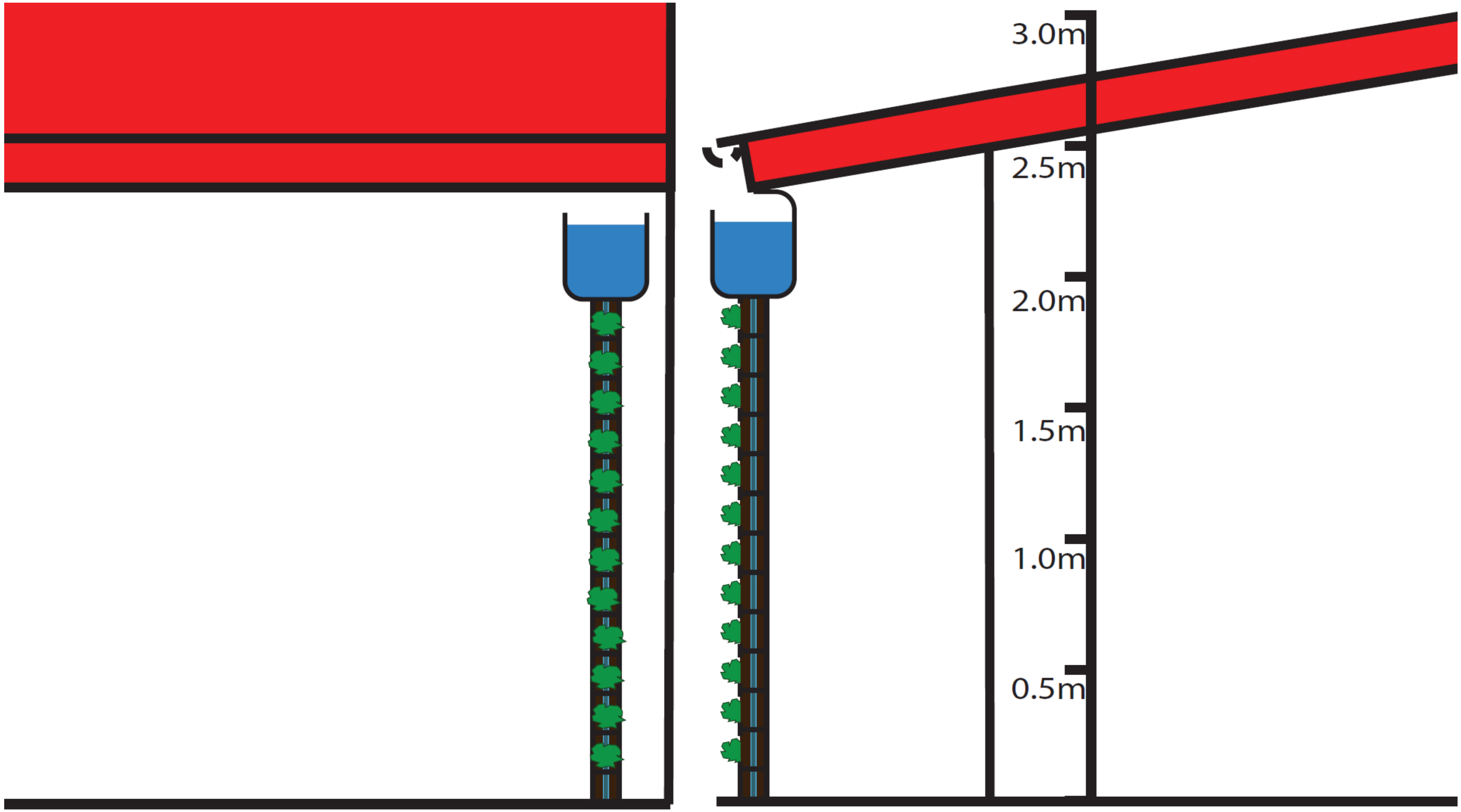
Appendix 4 Sketch design 2



Appendix 5 3d Design 2



Appendix 6 Intersection design 2



Appendix 7 Calculations

Area of the roof (stage 2):

$A_r=L_r*W_r$
$A=35*6=210m^2$

Rain catching area (stage 2):

$A_c=L_c*W_c$
$A=2*3=6m^2$

Average days between showers per month (stage 2):

$t_b=t_m/t_p$
$t_b=31/14=2.21days$

Watering days (old) (stage 2):

$t_{wo}=t_m-t_p$
$t_{wo}=31-14=17days$

Precipitation on roof (stage 3):

$P_r=(P_a/1000)*A_r$
$P_r=(110/1000)*210=23.1m^3$

Precipitation on catching area (stage 3):

$P_c=(P_a/1000)*A_c$
$P_c=(6/1000)*210=0.66m^3$

Precipitation on catching area shower (stage 4):

$P_s=(P_c/100)/(t_p*100)$
$P_s=(0.66/100)/(14*100)=47.1L$

Water in tank (average shower) (stage 5):

V_t=if $P_s>V_{tmax}$ then V_{tmax} else P_s
V_t=if 47.1>18.9 then 18.9 else 47.1=18.9L

Drain time (average shower) (stage 6):

$T_d=V_t/(Q*24)$
$T_d=18.9/(0.25*24)=3.15days$

Amount of drained water after 24h (stage 6):

V_{t24}=If 24*Q<V_t then 24*Q else V_t
V_{t24}=If 24*0.25<18.9 then 24*0.25 else 18.9=24*0.25=6L

Not watering days (new with overlapping) (stage 7):

$t_{nno}=t_p+t_p*t_d+(t_p*t_r/60/24)$
t_{nno}=14+14*3.15+(14*30/60/24)=59.1days

Overlapping day 1 (stage 7):

$t_{o1}=t_m*(t_p/t_m)^2*$(if t_d>1 then t_d-1 else 0)
(Days of month)*(Chance)*(Wasted days in scenario)
$t_{o1}=31*(14/31)^2*$(if 3.15>1) then 3.15-1 else 0
$t_{o1}=31*(14/31)^2*(3.15-1)$=13.6days

Overlapping day 2 (stage 8):

$t_{o2}=t_m*((t_p/t_m)^3+((t_p/t_m)^2*(1-(t_p/t_m))))*$(if t_d>2 then t_d-2 else 0)
(Days of month)*(Chance)*(Wasted days in scenario)
$t_{o2}=31*((14/31)^3+((14/31)^2*(1-(14/31))))*$(if 3.15>2 then 3.15-2 else 0)
$t_{o2}=31*((14/31)^3+((14/31)^2*(1-(14/31))))*(3.15-2)$=7.3days

Overlapping day 3 (stage 9):

$t_{o3}=t_m*((t_p/t_m)^4+((t_p/t_m)^3*(1-(t_p/t_m)))+((t_p/t_m)^3*(1-(t_p/t_m)))+((t_p/t_m)^2*(1-(t_p/t_m))^2))*$(if t_d>3 then t_d-3 else 0)
(Days of month)*(Chance)*(Wasted days in scenario)
$t_{o3}=31*((14/31)^4+((14/31)^3*(1-(14/31)))+((14/31)^3*(1-(14/31)))+((14/31)^2*(1-(14/31))^2))*$(if 3.15>3 then 3.15-3 else 0)
$t_{o3}=31*((14/31)^4+((14/31)^3*(1-(14/31)))+((14/31)^3*(1-(14/31)))+((14/31)^2*(1-(14/31))^2))*(3.15-3)$ =0.9days

Total overlapping (stage 10)

$t_{oTotal}=t_{01}+t_{02}+t_{01}$
t_{oTotal}=13.6+7.3+0.9=21.8days

Not watering days (new without overlapping) (stage 11):

t_{nn}=if $t_{nno}-t_{oTotal}>t_m$ then t_m else $t_{nno}-t_{oTotal}$
t_{nn}=if 59.1-21.8>31 then 31 else 59.1-21.8=31days

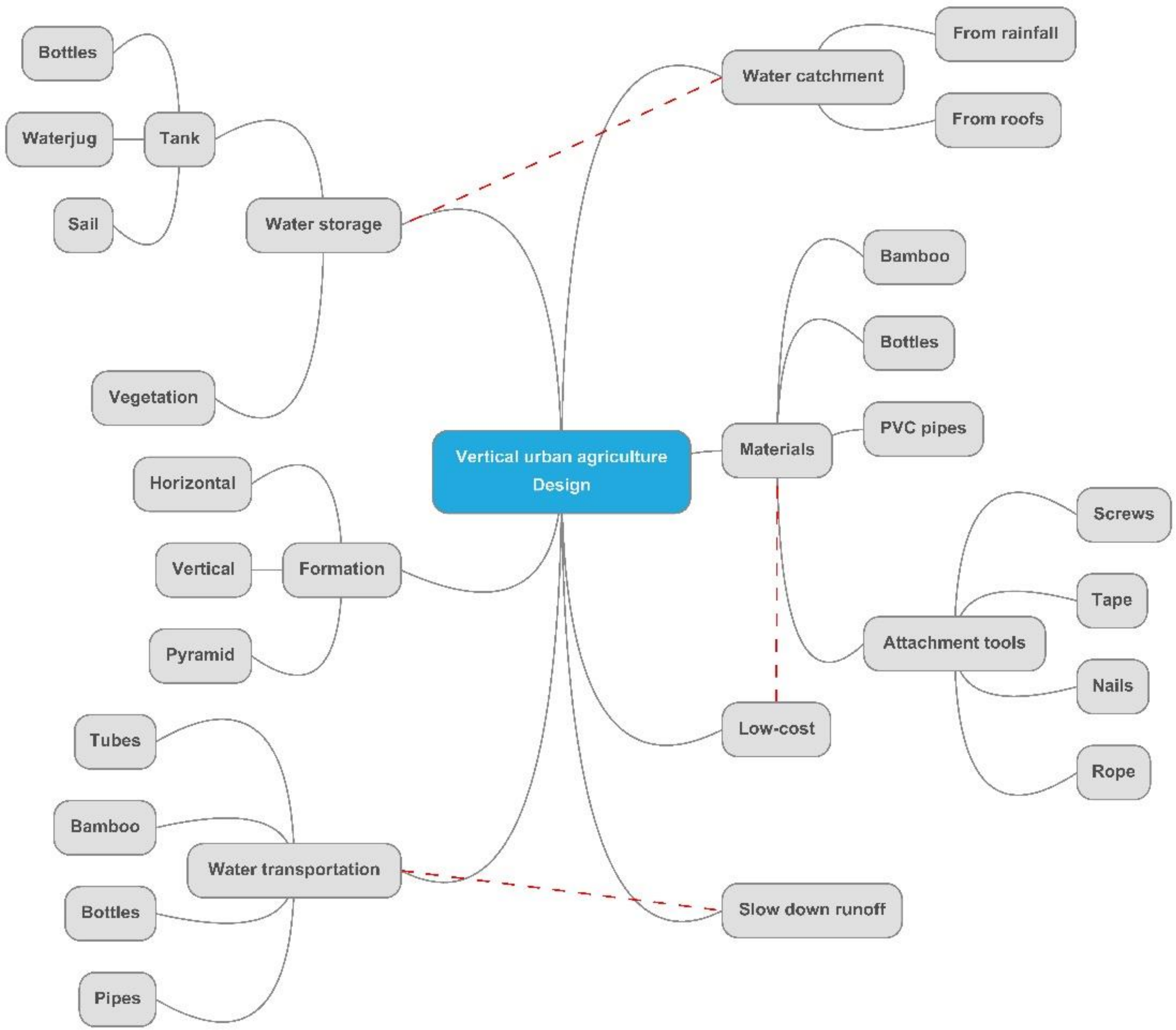
Watering days (new) (stage 12):

$t_{wn}=t_m-t_{nn}$
$t_{wn}=31-31=0$days

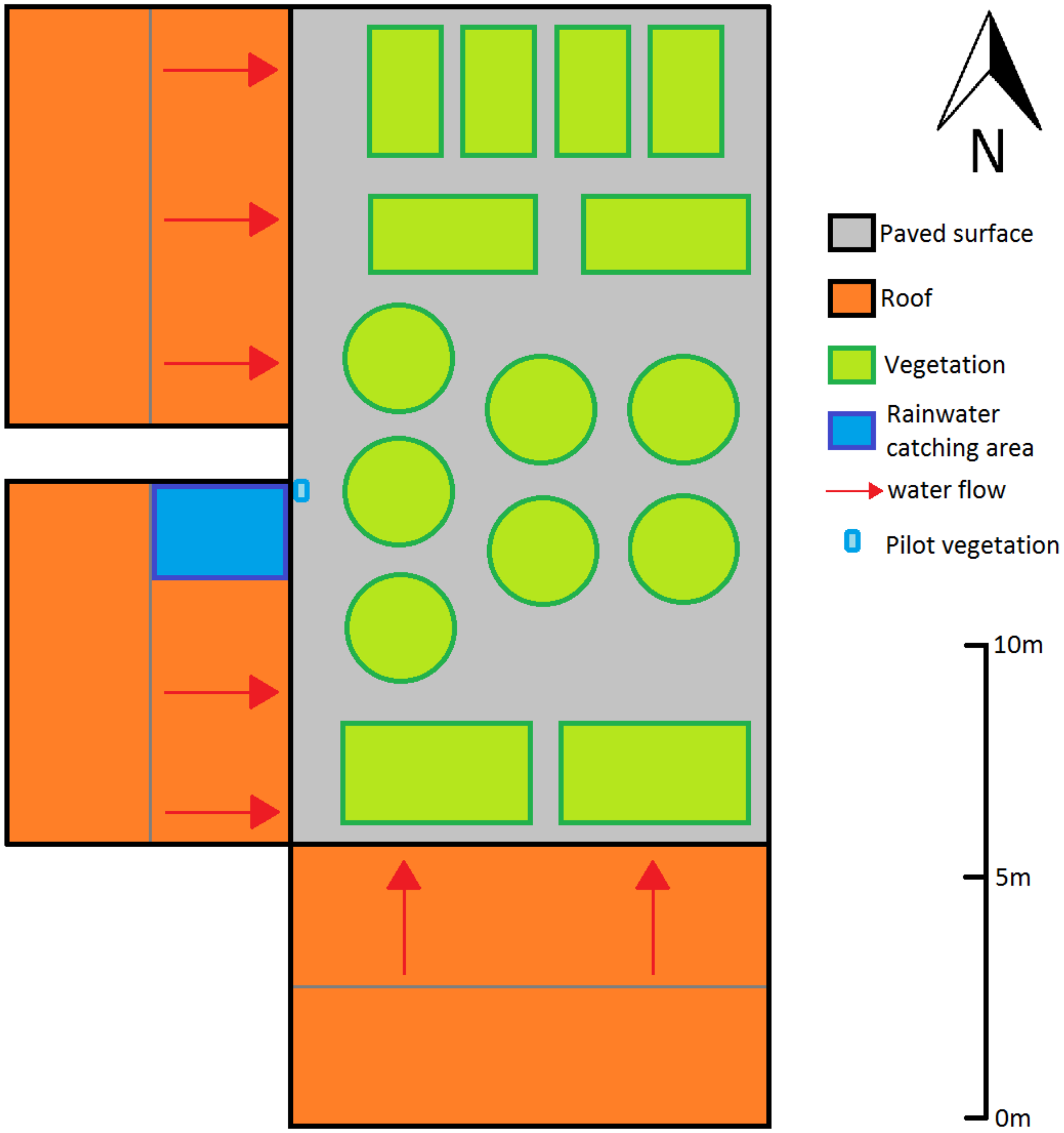
Saved water(stage 12):

$V_s=((t_p*t_d-t_{oTotal})*v_{24})/1000$
$V_s=((14*3.15-21.8)*6)/1000=0.13m^3$

Appendix 8 Mind map



Appendix 9 Area usage school garden



APPENDIX 6. MCDA METHOD

A multi criteria decision analyses is a tool which can be used to compare multiple aspects (criteria) of designs or options. In order to use the MCDA method multiple steps need to be taken.

Step 1 Goal

At first is it important to ask the question that needs to be answered by the MCDA. The goal of a MCDA is to answer this question by comparing the different options. An example question is "What type of urban agriculture qualifies the most for Cebu City?".

Step 2 Identification options

Identification of the options is important in order to compare them. Options can be found with the help of a literature study or in some cases the options are obvious, such as the number of designs that are made. The options that are identified will be compared with each other in the MCDA.

Step 3 Determine criteria

After the options have been identified the criteria that will be used to rate the options need to be determined. The criteria can be things like: expense, durability, area usage, construction period, visual quality etc. These criteria need to be put into a table with the options such as shown in the table below (???).

Table 1 Empty MCDA

Criteria	Option 1	Option 2	Option 3	Option 4
Criteria 1				
Criteria 2				
Criteria 3				
Criteria 4				

After the table has been made it can be filled in. Every option will get different scores for every criteria. Criteria often have their own units, such as Php (Currency used in the Philippines) for expense, but sometimes there is chosen to use the +/- unit because of a lack of information or there is no existing unit for the criteria. After filling in the table it looks like table ???.

Table 2 MCDA +/-

Criteria	Option 1	Option 2	Option 3	Option 4
Criteria 1	++	+	+	--
Criteria 2	--	+	+	++
Criteria 3	+	++	++	--
Criteria 4	+	-	+	++

Step 4 Scale criteria

Different criteria can have different units and therefore they can be difficult to compare, this is not a problem with the +/- unit but it is less accurate. The maximum score of the table will be changed to a 1 and the lowest to a 0. All the scores between these are also scaled between 0 to 1. After the scaling the table looks like table ???.

Table 3 MCDA with score

Criteria	Option 1	Option 2	Option 3	Option 4
Criteria 1	1	0.75	0.75	0
Criteria 2	0	0.75	0.75	1
Criteria 3	0.75	1	1	0
Criteria 4	0.75	0.25	0.75	1

Step 5 Weigh criteria

Some criteria are more important than others and because of these every criteria gets a weight. A weight is a score of importance with a scale from 1 to 10. These weights are put into a weight table, see table ???.

Table 4 Weight table

Criteria	Weight (scale 1-10)
Criteria 1	9
Criteria 2	8
Criteria 3	8
Criteria 4	7

Step 6 Score the options

After giving each criteria a scale it is possible to calculate the score of each option. To do this every score from the 0-1 table will be multiplied by their weight. After this, these scores need to be added up to one total score (see table ???).

Table 5 MCDA results

Criteria	Option 1	Option 2	Option 3	Option 4
Criteria 1	9	6.75	6.75	0
Criteria 2	0	6	6	8
Criteria 3	6	7	8	0
Criteria 4	6	8	5.25	7
Total	21	27.75	26	15

Step 7 Discuss result, Decide

After step 6 the total score has been calculated and the comparison has been completed. It is very important to look at the results and discuss why an option has a higher score than the other. Afterwards, it is important to decide which of the options will be used in the project. Usually this will be the one with the highest score, but sometimes another option should be used because of a reason which had no effect on the score. Other options with high scores should also be considered as a candidate in the discussion as well. The goal of the MCDA can also have a big influence on what option will be chosen.