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Erosion Control in Otjomuise, Namibia

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Abstract

The settlements in Windhoek, Namibia are plagued by erosion problems resulting from severe rainstorms and inefficient use of rainwater. This project focused on the community of Otjomuise, and how various erosion control measures can be implemented to reverse the effects of erosion and utilize rainwater for productive purposes. Working with community members we constructed several structures that served as replicable demonstrations for residents of Otjomuise and surrounding settlements. By working alongside the community we helped mobilize an effort toward erosion control and prevention and effectively improved the sustainability of future projects.

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Executive Summary

Despite the fact that the average annual rainfall in Namibia is only 300 millimeters, erosion is a significant problem. In the formal and informal settlements located just outside the capital city of Windhoek, where homes are built on poor soil and steep hillsides, erosion is an especially dangerous problem during the rainy season from December until late March. Flooding of homes is a common occurrence, and large, hazardous channels are often carved out of the surface soil due to fast moving runoff water.

The Namibia Housing Action Group (NHAG) and the Department of Land Management of the Polytechnic of Namibia are two organizations that have attempted to solve problems within the settlements, such as this erosion problem, through the use of sustainable development projects. Our project group, four students from Worcester Polytechnic Institute, has been asked by these two sponsor organizations to develop solutions to erosion and rainwater problems in the settlements, specifically in the recently formalized settlement of Otjomuise.

The Namibia Housing Action Group and its partner organization, the Shack Dweller's Federation of Namibia (SDFN) have organized the shack settlements into savings groups, which collect money from each household for the purchase of land, water, electricity, and other amenities that would be beneficial to the community. Our project group was assigned to work with four savings groups within the settlement of Otjomuise. The work of these sponsoring organizations led us to use a community development strategy called Participatory Action Research to help us solve erosion problems. Participatory Action Research allows members of the savings groups to work alongside the project team members in order to generate, design, and implement solutions to the erosion problems.

Design and Implementation

First, a committee of community members interested in the project was formed to help the project team collect data within the community. This committee asked community members to point out areas of high erosion and rainwater damage, to describe what types of damage may occur, and brainstorm possible solutions to these problems. We also conducted several informal walkthroughs within the community in order to establish trusting relationships with community members and to observe the erosion problems firsthand. By taking into consideration the views of community members and the observations made by project team members, we chose an area of focus to implement erosion control solutions.

The second step of the project was to generate and choose the designs of erosion control structures and systems to be built in the focus area. After consulting a variety of experts, including those in the professions of agriculture, architecture, civil engineering, and sustainable development research, as well as community members, we organized a packet of the various erosion control methods that could be implemented in Otjomuise. Solutions such as gabions (rock walls) and tire walls were suggested because they are simple to construct and can be used to redirect and slow runoff water while encouraging absorption into the ground. Vegetation was suggested because it can be used to reduce the effects of erosion and slow runoff water as the roots of plants help anchor the soil and use the water for nourishment. This packet was circulated throughout the community to allow community members to choose which methods to use and where to construct them.

Once methods for the area were selected and design of the focus area was finalized, implementation of the erosion control systems began. In our area of focus the community and team members constructed two tire walls, two half tire walkways, two mulch pits, and various other tire structures used to redirect runoff water. We were also able to place excess rock, retrieved from the digging processes, beneath rooftops as a mode of minimizing the energy of impact, and thus velocity of flowing water. We used these systems because they were simple to build, time efficient, and could be constructed with free or very inexpensive materials.

Challenges

One of the major challenges we dealt with throughout this project was rallying enough community support to complete the project. During our initial visits to Otjomuise, many community members felt intimidated by the project team due to potential formality. However, after several informal walkthroughs and community meetings we were able to establish positive relationships with many community members. During the early construction stages participation in the building process was somewhat minimal. Once clear systems began to emerge, several community members became involved in the process. One of the more difficult tasks we faced was finding a time where community members were available to help construct systems. Although most community members were home after work, they often had housework and errands to complete. As a solution to this problem, we selected and built projects that could be completed within an hour's time.

The final and most significant challenge we faced was the language barrier throughout the community. Although many community members speak English as a second language, the primary languages spoken in Otjomuise are Otjiherero, Oshiwambo, Afrikaans, and Damara. To help combat this issue our two Oshiwambo speaking teammates from the Polytechnic of Namibia often helped us by translating conversations. This translation process was a crucial aspect of the project.

Although we dealt with significant challenges throughout this project, our team was able to find solutions that enabled project success.

Sustainability

The project team took several steps to ensure the continuation of the project. First, we created several packets and pamphlets that illustrated methods which can be used to control erosion and flooding as well as how to construct these methods. These packets and pamphlets contained large pictures and were produced in both English and Afrikaans. We gave several presentations to the community as a form of conveying the status of the project and informing community members of what they can do to help. These presentations were given in both English and Oshiwambo.

To obtain materials for the fabrication of erosion control structures, we first asked for tire donations from several local tire suppliers. Because of the high expense to dispose of tires at a city landfill these tire suppliers were more than willing to donate their used tires for the project. The Habitat Research and Development Centre (HRDC), which teaches the people of the settlements how to complete sustainable development projects, was a major materials contributor, donating soil and cutting the tires in half for our half tire walkways. At the completion of our project, the community was left the means to contact the HRDC and various tire suppliers so that they would still be able to receive the materials needed to build additional structures.

Many people in the community expressed interest in making gardens and planting various forms of vegetation for erosion control purposes. We traveled to the National Directorate of Forestry in Okahandja to buy trees for a modest price. After we bought the trees, we organized a system in the community for obtaining and planting the trees. All of the trees were stored at our community leader's home. She was also provided with a sign up list of all the types of trees and the amount of each type available to enable community members to easily sign up for and pay for the trees. This system intended to set up a tree purchasing cycle by using the money earned from selling the trees in the community to buy trees and other types of helpful vegetation for the community in other seasons.

Recommendations

After successfully completing this project we made a list of recommendations for our sponsors, the people of Otjomuise, and future project teams. These recommendations include the following suggestions:

- To the Namibia Housing Action Group; we recommend that a smaller area, such as one or two savings groups, be designated for sustainable development projects within the settlements of Windhoek. In addition to this we recommend organized knowledge exchanges between savings groups throughout the Windhoek settlements as well as the distribution of the educational materials created by our team on erosion control structure completion.
- To the Shack Dweller's Federation of Namibia; we recommend more participation in projects sponsored by the Namibia Housing Action Group. We encourage the use of the SDFN Center in Hakahana as a mode of conveying information to other savings groups and communities. We also recommend that that the educational materials created by our group be distributed to people living in other savings groups and settlement areas by the SDFN.
- To future project teams; we recommend a thorough reading of the appendices in this project, frequent visits to the community with which you work, more dependence upon ideas generated by members of the community, and placing an emphasis on the importance of the residents' ability to obtain their own materials.

1 Introduction

Rainfall in some southern African regions often occurs in erratic patterns throughout a brief rainy season. During the rainy season, significant to very limited amounts of rainfall occurs, depending on the year. One of the major issues communities located within these arid and semi-arid regions face is a lack of technology and resources to adequately control the amount of stormwater they collect and utilize depending on their needs and interests.

The informal and formal settlements of the capital city of Windhoek, Namibia, are greatly affected by the lack of efficient means to control and collect rainwater. Otjomuise is a formal settlement outside of Windhoek that can experience both water scarcity and flooding each year. Although Windhoek receives an average annual rainfall of less than three hundred-fifty millimeters, this rain falls only in certain months of the year and can come in intense downpours. As the soil in arid and semi-arid regions is not conducive to absorbing large amounts of water, excess runoff water may erode surface soil and cause flooding, especially in sloped areas. In such areas, water could be redirected or slowed using erosion control or rainwater harvesting systems so that the community could benefit from this excess supply rather than be damaged by it. Due to the fact that most people living in Otjomuise have little money and time to spare to build erosion control systems, these systems must be easy to build, inexpensive, and easy to maintain.

In the past, WPI students have completed several projects in Windhoek's settlements addressing water management issues. One project in particular developed a system of arranging old, discarded tires to help control erosion on hillsides during the rainy season in Otjomuise. The rainwater which came into contact with the tires was expelled away from the houses and directed downhill, but there is great potential for utilizing, not just diverting this rainwater. It has also been found that, although the tires aided in redirecting water, they often created new erosion channels through the residents' plots, which caused additional problems. The Namibia Housing Action Group and the Habitat Research and Development Centre are two organizations that have worked with the formal and informal settlements of Windhoek to initiate erosion control projects. These two groups have provided members in some communities with the tools and necessary skills to design and build their own erosion control systems.

Although an erosion control project had been previously completed in Otjomuise, in the spring of 2008 there was still no system in place that utilized the redirected water. There are a variety of civil engineering solutions and methods that can be explored for use in Otjomuise. Such methods could be designed and implemented with the community's help, to alleviate erosion problems and provide the community with a way to use stormwater for beneficial purposes. Such a system has not yet been designed or implemented in Otjomuise.

This project enabled our team to work alongside community members to design an erosion control system that utilized a variety of different methods. Using Participatory Action Research, we determined the needs of the community and gathered their ideas for controlling erosion. By combining the ideas of community members with methods obtained from experts in the field, we designed a prototype erosion control system that was implemented in a neighborhood that affects a large number of households. In an attempt to make this project sustainable, we educated the community members on how to design and construct such systems and also left them with the means to obtain the resources necessary to complete them. It is our hope that these ideas will spread not only to other parts of Otjomuise, but also to the other settlements in Windhoek.

2 Background

In order to understand the challenges of how to introduce sustainable erosion control and rainwater harvesting techniques in poor communities, such as those in Windhoek, Namibia, we will discuss informal and formal settlements, sustainable development projects, community approach methods, soil erosion control, and gardening in this chapter. Understanding informal and formal settlements and their reaction to past projects helps establish the community aspects of the project while rainwater harvesting, erosion control, and gardening provide the basis for the technical portion of the project.

2.1 Informal and Formal Settlements

Informal settlements are typically low-income housing areas erected under conditions of informal or traditional land tenure (U.N. Habitat 2008). These settlements, also known as squatter settlements or shantytowns, commonly emerge throughout the world in urban development areas as a result of rapid urbanization and economic struggle (Skuse & Cousins, 2007). In many cases, significant changes within governments, such as the abolishment of apartheid regimes, result in the gradual formalization of settlements.

2.1.1 Settlement Formation

Informal settlement formation occurs when the current land administration and planning fails to address the needs of the population as a whole (Skuse & Cousins, 2007). An area which exemplifies settlement emergence as a result of rapid urbanization and economic struggle is Nkanini in Cape Town, South Africa. In this area, a housing crisis resulting from the abolishment of apartheid in 1990 created a need for housing which the government of South Africa could not immediately provide. Communities in which the native Africans live do not have adequate access to necessary goods and services, are under little or no local and national governance, and lack easy access to locations with formal employment opportunities. In places such as Gauteng, South Africa, laws passed setting limitations on allotted living space for native Africans in the city have resulted in the formation of tightly packed and inadequately structured settlements (Stephens & Rule, 1999). This failure of the government to accept the inevitability of urbanization and meet demands for housing is familiar in other areas of the world. Several areas, such as Cairo, Egypt, Abidjan, Cote D'Ivoire, and Nairobi, Kenya, are currently facing similar issues (El-Batran & Arendel, 2007; Yapi-Diahou, 1995; Alger, 1995).

2.1.2 Life within the Settlements

Figure 1: The Hakahana Settlement in Windhoek, Namibia

Informal settlement areas are known for having an absence of infrastructure and services (Yapi-Diahou, 1995). As shown above in Figure 1, they are generally characterized by a multitude of small, makeshift shelters built from locally available and minimally expensive materials and by considerable social problems. Families living in such settlements are often overwhelmed by bleak economic conditions, usually due to the lack of availability of regular employment, especially jobs requiring skills. In places such as Abidjan, Cote D'Ivoire, although there are some jobs available which require prior training and education, the majority of settlement residents hold monotonous jobs based off of unskilled labor. In such situations, the wage earned by these employees is not sufficient to meet the needs of the family as a whole.

Settlements are also known for an almost constant internal migration of people from rural areas (Skuse& Cousins, 2007). Despite the alleged equality which currently exists in South Africa, native Africans from the Nkanini settlement have been poorly incorporated, if at all, into society. While this inequality is apparent to those inhabiting settlements like this, those who come to the city in search of work are unaware of the situation they will be presented with. This continuous expansion, common worldwide, is the cause of the often-chaotic state of settlements.

Several governments have taken the initiative to analyze the status of their country's informal settlements and have begun to address problems within them through settlement formalization and emphasis on sustainable development (Müller, 2006). This formalization process is usually comprised of, allowing individual land ownership, followed by government installation of basic amenities such as toilets, taps, electricity, and streetlights. Part of this process can be seen below in Figure 2. The formation of educational, health, and other social services within reasonable proximity to the settlements is usually the last step of formalization. The formalization of settlements is integral to the stabilization of countries worldwide which have suffered from similar economic and social struggle.

Figure 2: A home in Hakahana undergoing the formalization process

2.1.3 Namibian Settlement Formation

The settlements within the city of Windhoek, Namibia, were created during the apartheid system, which dominated the southwest African region for over forty years in the 20th century. Soon after Namibia's independence in 1990, the once informal settlements became designated as formal settlements in order to encourage the advancement of the quality of life within these communities. This somewhat recent abolition of apartheid has resulted in a dramatic increase in settlement population and has left many residents in unfavorable economic situations. Currently, these settlements are characterized by high levels of unemployment, low literacy and education levels, and an ever-growing population of children.

The incorporation of Greenfield sites into the Windhoek settlement areas was a proposed solution to alleviate the crises of overpopulation and poverty that Windhoek's settlements face (City of Windhoek, 2008). A Greenfield site is a piece of undeveloped urban land designated by local authorities to accommodate a growing population. In 1991, the Windhoek City Council began a mission to accommodate as many migrants as possible by designating Greenfield sites for self-constructed housing. Before residents move into these sites, known as formal settlements, necessary amenities such as water taps, sewer lines, and in rare cases electricity, are put in place. More than 4,399 Greenfield sites have been developed for residents of Windhoek since 2000.

2.1.4 Life within the Settlements of Namibia

Studies estimated that as of 2001 at least 26% of Windhoek's urban population—a total of 60,000 people—were living in informal and recently formalized settlement areas (City of Windhoek, 2008). Due to internal migration trends, this percentage is expected to increase by 14% by the year 2016. The largest group of informal settlements in Windhoek is located in a township created during the apartheid regime called Katutura. Katutura, which was named by its people, means "a place where we do not stay". Access within these settlements to utilities like portable water and sewerage are generally very limited.

Despite these adverse conditions, settlement residents have formed amiable relationships among themselves and often work vigorously for the betterment of the whole community (Labbe, McBride, & Ray, 2006). The ongoing process of upgrading the settlement areas has resulted in the formation of many self-help and savings groups. These groups, associated with the Shack Dweller's Federation of Namibia (SDFN) and Namibia Housing Action Group (NHAG), reside in low-income communal areas. The groups save collectively to purchase land in a large block as well as obtain certain amenities such as electricity.

2.1.4.1 Otjomuise

Otjomuise, shown below in Figure 3, is a formal settlement that resulted from the constant expansion of locations such as Katutura and Khomasdal in Windhoek (Pendleton, 1993). Both NHAG and the SDFN are groups dedicated to the positive advancement of these communities. The land in Otjomuise was bought by the SDFN and NHAG from the municipality of Windhoek in 2004 as an area for urban development. Several permanent homes have been built which all have a kitchen, one bathroom, one bedroom, and space on their plot for home expansion. Those that live on the land are members of savings groups, which, in addition to working for the benefit of the community, encourage a continuous learning environment in which the people can help themselves without assistance from outside organizations. These savings groups are a key aspect to the sustainability of all development that occurs within Otjomuise and all formal settlements in Namibia.

Figure 3: Sunset over Dimbokro Street and Kitchner Street, Otjomuise, Namibia

2.2 Sustainable Development Projects

Sustainable projects focus on achieving environmental preservation, economic prosperity, and social equality (USDA Forest Service, 2008). They do so by developing practical solutions to problem solving throughout the world. For countries like Namibia the creation of sustainable advancement methods is integral to the success of both short and long term community development. Projects that work to benefit the community must be completed with as little outside aid as possible to be successful as well as replicable in other communities. If sustainable development projects are encouraged throughout the country, the stability of Namibia may dramatically increase.

2.2.1 Making Projects Sustainable

The settlements in Namibia are located within semi-arid and arid regions, and as a result suffer the consequences of less fertile soil, sporadic rainfall patterns, and soil instability (Kottek et al., 2006; FAO, 1989). These three characteristics lead to an erosion-prone topography. By using practical solutions to problems that make use of readily available resources, sustainability is an achievable goal (USDA Forest Service, 2008). Available resources include those found in nature, those that are in excessive supply, and those that can be obtained at as little cost as possible. In order for projects to be successfully sustainable, they must also be based on topics that the people benefitting from the project can understand and gain ownership of (Müller, 2000). It is important to encourage the people to come up with their own solutions to problems so they feel as though they have had a significant effect on what has been done and have the desire to spread their knowledge.

2.2.2 Settlement Response to Previously Completed Projects

Despite the negative impressions created by the government's inability to manage them, many settlement areas have been able to form a strong sense of community and have the desire to better their environment (Human Settlement Development, 2003). In communities such as Nkanini in Cape Town, South Africa, groups work together in hopes that their efforts will create a more organized infrastructure and, after doing so, will draw the attention of local and national governments in order to receive increased aid (Skuse & Cousins, 2007). In many cases, settlers actively resist the city's attempt at aiding the settlements formation because they see it as counterproductive to the promotion of communication within the newly formed communities. In such cases, communities have held meetings to establish themselves as groups that are more formal and have even called for monetary contributions to their cause from all members of the community.

Several governments have begun to address problems within their settlements through sustainable development projects. These projects focus on strengthening the infrastructure within communities by creating groups of people who work for the benefit of the community as a whole. One example of this is in Cairo, Egypt (Yapi-Diahou, 1995). Projects have been implemented in Cairo's informal communities with the purpose of upgrading the settlements since as early as the 1970s. These projects have attained various levels of success. In cases where the government has encouraged participation by the local population, community members have typically been extremely enthusiastic, engaged, and glad to contribute. However, there are often cases in which the government implements these projects in areas that present potential gain in either economic or political pursuits as a result of media attention. It is cases such as these that discourage settlers from participating in projects geared toward their aid, and, perhaps on a larger scale, hinder their ability to trust outsiders.

In Namibia, several of Windhoek's formal settlement areas, including Otjomuise, have worked on projects in the past that dealt problems such as the control of erosion (Labbe, McBride, & Nicholas, 2006). In addition to these projects, both NHAG and SDFN are groups dedicated to the positive advancement of these communities. Through the encouragement of effective communication with the residents of Otjomuise, sustainable development projects can be fostered to improve the living conditions and livelihoods of those who live in the settlements of Windhoek.

2.3 Community Approach Methods

In order to help communities in developing nations gain a better quality of life, researchers and scientists have used a variety of development strategies to aid these communities in achieving their goals. Common strategies used in sustainable development projects in third world countries include Community Development, Integrated Rural Development, Rapid Rural Appraisal, Participatory Rural Appraisal, Participatory Action Research and Policy Analysis for Participatory Poverty Alleviation. These approaches have all been created in an attempt to discover the most successful research approach to sustainable development projects.

2.3.1 Community Development

Community Development (CD) is a broad strategy that promotes participation from community members with the purpose of bettering the community (Sneets, 2007). Promoters engage community members in learning community issues, understanding social, environmental, and economic impacts, as well as how to propose and carry through solutions to community problems. Advocates must incorporate the many interests and opinions of the diverse population in their community so that the majority of community members will be happy with the decisions that are made. These promoters must also encourage members of the community to become actively involved so that there is an increase of community leadership.

Community Development focuses specifically on social relationships within the community and manipulates power balances between various sub-groups of the community to complete tasks and solve problems (Rafiq, 2008). Community Development would be an effective strategy to use to ensure that group members are cooperative and practicing good communication before another method is used to solve a specific problem. Community Development brings a community together to solve general problems, but for our project, we needed a method that focused on specific problems.

2.3.2 Integrated Rural Development

Another community development method that has often been used in developing nations is Integrated Rural Development (IRD). IRD is an approach in which governmental departments attempt to work together to devise a plan which addresses a specific community problem and then directs the community through this plan of action (Cohen, 1987). Community members have little influence on what the solution to the problem is and they are under the direction of the expert organization. A well known example of IRD is the Ethiopian Case, which was in the 1970's and early 1980's. In Ethiopia, researchers attempted to improve agriculture by implementing an intensive plan that included fixed prices for farm equipment, rural public works, marketing facilities, adequate farm credit and stronger village management systems. The execution of this plan created much debate in Ethiopia as some aspects of the project had negative effects on Ethiopian citizens. Such negative effects included land tenure issues and changes in local government patterns.

The community in which erosion control systems would be implemented would likely be more content with a system they helped create, rather than a system that is forced upon them. Therefore, an approach in which the community makes most of the major decisions concerning the problem at hand was best for our project.

2.3.3 Rapid Rural Appraisal

Another community development strategy is Rapid Rural Appraisal (RRA). RRA is a way to obtain new information and to diagnose problems occurring in rural communities. In the case of RRA, research is carried out by interdisciplinary teams who use techniques such as individual interviews, sampling methods, group interviews, and direct observation (Kachondham, 1992). These teams are composed of experts and the researchers make most of the decisions surrounding the type of data they are collecting. In RRA, field visits are usually short and the purpose of the research is to diagnose problems and evaluate existing problems. These researchers do not focus on proposing solutions or work with the community to produce solutions. For example, a group of researchers in Papua New Guinea was investigating malnutrition with emphasis on health and agriculture. The main problems they found were problems of seasonality, intra-family food sufficiency, women's roles, and the importance of "minor crops."

Although features of RRA are appropriate for this erosion control project, RRA was not a sufficient method to practice for the erosion control project in Windhoek. The goal of our project is to implement a solution for the community's water management problems and not to diagnose a problem as RRA is designed to do. We must participate with the people in order to choose and implement a possible solution.

2.3.4 Participatory Rural Appraisal

Participatory Rural Appraisal (PRA) focuses specifically on rural development and permits rural communities to form Village Resource Management Plans to attain their goals (Ford, 1989). Development of rural communities can preserve natural resources and increase rural food production that will specifically support Africa's large rural populations. Through this method, rural communities solve their sustainable development problems by first creating and maintaining local leadership, rural based organizations, and government organizations. PRA also gives villages the opportunity to plan and implement solutions to their problems by utilizing technologies that the villagers can manage and maintain themselves.

PRA concentrates on uniting the community to develop an action plan toward a specific goal and encourages interactive problem analysis to produce solutions. PRA utilizes mostly visual materials and educational methods to display data as this is the most effective way to solicit participation from community members. This development method seeks to create or increase the influence of Non-Governmental Organizations (NGOs), government agencies, and district or regional committees that may help the rural community. Lastly, PRA is fast and inexpensive with an average research period of nine days. As PRA usually takes place in rural settings, it was not used in this project.

2.3.5 Participatory Action Research

Participatory Action Research (PAR) is a type of research in which researchers work with the community to identify problems, choose solutions, implement those solutions, and devise action plans in order to assure that the solutions are sustainable after the researchers leave (Nieuwenhuys, 1997). PAR promotes independent thinking, uniting the community to actively solve its problem, and utilizing management based action research. An example of a PAR study was an attempt to help homeless children on the streets of Bombay find homes and ways to increase their income. Using PAR, researchers discovered the children's needs, balanced participation with mediation, and helped form a children's agency. Researchers worked with children to provide them with the skills they needed to transform their environment by using their own abilities.

The study of children in Bombay referenced another study in Rwanda in which children collectively concluded that their most sought after resource was clothing (Nieuwenhuys, 1997). Through the help of a facilitator, the children decided to sell charcoal at a market in order to generate income that would be used to purchase clothing. Also in Bombay, researchers utilized counseling methods with children to teach them how to assist their peers and plan ways for the children to interact with agencies and educators. The research team helped to increase the children's self-esteem by talking to them about human rights and strengthening their ability to help themselves. Researchers also encouraged children to establish an organization that furthers their rights. Not all interactions between children and researchers went as well as those discussed above. However, at the end of the study children began to leave their demeaning jobs to start their own businesses.

PAR was used in this project to collect information on current erosion control and rainwater harvesting methods, gather people's opinions on erosion control and rainwater harvesting, propose solutions, and create a group of community members who are devoted to the project. One main difference between PRA and PAR is that PRA is usually conducted in a rural setting whereas PAR does not have to be applied rurally. In PAR and during the erosion control project in the city of Windhoek, Namibia, municipal policies and laws that are different from those in rural areas must be considered. Also, instead of dictating how to solve problems, PAR enables the community to become involved in the decision making process. The people must be content with the system to be implemented in order to be willing to invest in it. Without their support, a successful and sustainable system would not be possible.

2.3.6 Policy Analysis for Participatory Poverty Alleviation

Policy Analysis for Participatory Poverty Alleviation (PAPPA) is a newly developed approach to poverty alleviation that helps local groups influence national policy. PAPPA uses quantitative data from the community to inform and shape national policy on issues such as taxes, incentives, subsidies, and land management (Clark University and GOVA, n.d.). PAPPA combines the qualitative information attained by PRA with scientific data collected from the community. This technique assists local community action groups in forming partnerships with regional and national groups of the national government. To meet the needs of the poor, community groups and national associations use quantitative data such as maps and charts to propose solutions, settle community conflicts, and suggest plans. These data would be available to district planners who can seek out development partners and create integrated databases to store the data.

PAPPA was not appropriate for this erosion control and rainwater harvesting project because the community of interest, Otjomuise, already had the support of the SDFN and NHAG to promote community policies and work with the municipality towards their efforts. Some aspects of PAPPA however, such as obtaining qualitative and quantitative data, were useful.

2.4 Soil Erosion Control

One major problem faced by many places in the world today is soil erosion and the impact it has on our environment (Lang, 2006). According to ecology Professor David Pimentel of Cornell University, other than population growth, soil erosion is the most crucial environmental issue we must consider today (People's Daily Online, 2002). In 2002, at the 12th International Soil Conservation Organization (ISCO) Conference held in Beijing, representatives claimed that salinization, desertification, and erosion have led to damage on more than 65% of the earth's surface soil. Since then, this percentage has continued to increase. This is significant because erosion is the result of water or wind redistributing particles of earth. In areas where erosion is an apparent problem due to water, it is likely that there is a large amount of excess runoff water and no place for it to go. This means that runoff water flowing across surface soil will eventually cause soil erosion. The resulting eroded land then creates surface soil unfit for growing crops, which poses a huge threat when 99.7% of food consumed by humans comes from crops, either directly or indirectly.

There are many methods to help control erosion; some of which include reforestation, hydroseeding, and contour plowing. Although these methods, as well as many others, are perfectly functional alternatives, many of them are not feasible due to cost, availability and the nature of the surrounding environment. The following section discusses a few other cost-effective methods that help control erosion in almost any environment or situations; they include rainwater harvesting, gabions, tire structures, and vegetation.

2.4.1 Rooftop Rainwater Harvesting

When designing domestic rainwater harvesting catchment systems there are four main components that must be considered which include rooftops, gutters, down pipes, and storage units (Global Development Research Center, 2008). When rain falls onto rooftops, the water is channeled down into gutters attached to the bottom of the roof and then flows into a downpipe. An example of this system can be seen below in Figure 4. In some rainwater harvesting systems the initial rainwater flows through the down pipe and is discarded from the system to reduce the chances of collecting dirty, contaminated water. After the initial rainfall, a valve in the down pipe is turned so that the rainwater is channeled into the storage tank. At the opening of the storage tank, small mesh netting is placed over the top to separate out large chunks of debris and eliminate mosquitoes. If the water gathered from this system is to be used for doing laundry, flushing toilets or irrigation, no chemical treatment is required. However, if the rainwater is used for drinking, careful treatment to remove contaminants and pathogens must occur.

Figure 4: Rooftop rainwater harvesting illustration

In locations such as Texas, rooftops are typically made of corrugated iron or aluminum (Krishna, 2005). An ideal rooftop material is Galvalume, which is a metal consisting of 55% aluminum and 45% zinc alloy sheet metal. Where materials are limited, tile, concrete, asphalt, or slate can be used. The Global Development Research

Center emphasizes the importance of selecting a rooftop that does not have lead content in the roofing material, since it can be very harmful to human health. Avoiding such contaminants is crucial and ensures that the rainwater remains clean and safe. Similarly, when selecting gutters and down pipes, the material should be durable and lead free (Krishna, 2005). The most successful systems use aluminum gutters and down pipes, which work effectively because aluminum does not rust. Many other materials are equally functional and cheaper, but do not last as long as aluminum and require more frequent cleaning.

The most expensive part of implementing a rainwater system is the cost of the storage unit (Krishna, 2005). Selecting a unit that will hold large volumes of water, in the event of a major rainstorm, can be difficult if materials are limited. In Thailand, large jars made of concrete are used as storage units for rainwater. In more developed countries, however, ferrocement or polyethylene tanks are used (Global Development Research Center, 2008). Although these tanks may be better quality, they are also more expensive. In places where such materials cannot be found or funding is not available, almost any large, closed container is sufficient. The size of the tank depends on the rainfall patterns and the rooftop surface area.

2.4.2 Runoff Rainwater Harvesting

Another type of rainwater harvesting is based on the collection of water that flows across the ground (Global Development Research Center, 2008). In places where the terrain is not flat, runoff water that flows over surface soil may be collected and utilized for productive purposes. It is important to take the slope of the ground into consideration while selecting a region to collect the water. As the slope of the ground increases, the amount of water infiltrating the soil decreases. Therefore, selecting a region with a steeper slope will increase the amount of water collected. Shrubberies, trees, and other vegetation are factors which should be taken into account when designing a surface rainwater collection system. As the amount of vegetation increases, runoff volume decreases because the vegetation absorbs water and then releases it through a process called evapotranspiration. Runoff water that flows downhill may be captured in a valley or a low point in the region which acts as a retention pond. The water may then be pumped out of the storage pond and used for its intended purpose. In addition, when using a system like this, it is crucial to remember that many contaminants come in contact with water that lies on the surface of the ground. If the water is being used for drinking, then it must be filtered and then undergo rigorous chemical treatments. An analysis of runoff flow for purposes of rainwater harvesting is shown below in Figure 5.

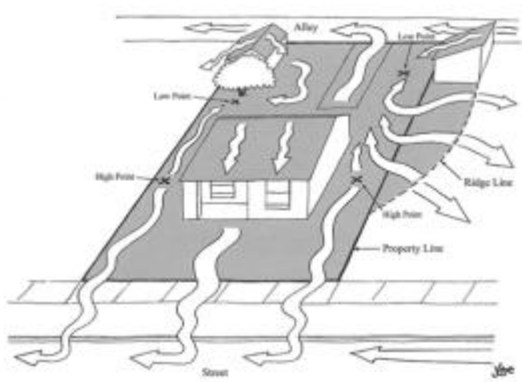

Figure 5: Runoff rainwater harvesting flow analysis

2.4.3 Gabions

Dr. Andreas Wienecke (personal communication, March 12, 2008) the head researcher at the Habitat Research and Development Centre (HRDC), proposed to the project team that an effective means to control erosion and slow large volumes of flowing water is to use gabions. Gabions are constructed by filling a wire frame with rocks, construction material, and debris (Coastal Engineering Research Center, 2007). In a typical system, the wire frame is coated with PVC or galvanized for durability. Ideally, the filler material should be smooth on the surface and have a high specific gravity. This helps in eliminating deterioration of the wire frame. When assembling a gabion, the wire mesh should first be put into place. The rocks or filler material should then be added. The material should be packed so that there are a small number of voids which will elongate the life span of the system. This will also aid in slowing the flow rate of the water and secure the stability of the gabions. In areas where large volumes of water flow rapidly, several tiers of gabions are more appropriate. As the water flows through each tier, the flow rate will gradually decrease. The resulting exit flow will be a slower, more controlled stream, which can safely move into a desired area. A gabion from the HRDC is shown below in Figure 6.

Figure 6: Gabion constructed at the HRDC in Katutura, Windhoek, Namibia

Historically, gabions have been used for many years as a way to manage erosion (Maccaferri, 2007). More than seven thousand years ago, gabions made of woven reeds were used along the Nile River to help with erosion issues. Today they are still a common tool for controlling erosion. Gabions have been used extensively throughout Europe this past century to stabilize soil. Another recently completed erosion control project in South Africa, located along the coastline, also had success by using gabions to help eliminate further deterioration of the eroded coastline.

2.4.4 Tires

Another possible method for erosion control is to use tires to help divert water and control the flow rate of runoff water (A. Wienecke, personal communication, March 12, 2008). Tires can be used individually to help control runoff in specific areas or they can also be layered on top of each other, forming a tire wall. Individual tires can be placed anywhere to help divert runoff water. The tire walls, however, work best in regions where there is a significant drop in elevation. Building a tire wall can help slow the flow rate of runoff as it flows down through the tires and help distribute runoff water evenly across the soil. Over time, various grasses and other vegetation grow in the tire walls, which also help to absorb runoff stormwater. Additionally, planting vegetation in the individual tires helps absorb the runoff water while stabilizing the surrounding soil. An example of such a system can be seen below in Figure 7.

Figure 7: Tire wall used at the HRDC in Katutura, Windhoek, Namibia

Another benefit when using tires for erosion control is the cost and availability of tires. Used tires are readily available in almost all parts of the world since appropriate disposal is difficult and often incurs a cost. For example in the United States, placing tires in a landfill is not only a fire hazard, but it also provides a habitat for mosquitoes to breed (NC Office of Waste Reduction and Division of Solid Waste Management, 1995). Tires also take many years to break down and decompose. For these reasons, many landfills have banned tires due to their unsafe environmental impact. In some countries such as the United States and England, these regulations must be followed. In other places in the world, however, such as Africa, large, open landfills are located on the outskirts of major cities (United Nations Environment Programme, 2008). The regulations may be strict but are rarely enforced. Utilizing used tires from these landfills and dumpsites for erosion control is a useful way to recycle a material that would otherwise be negatively impacting the environment.

Using tire walls for erosion control has proven to be an effective method of controlling erosion. Professor Hoenig from the University of Arizona discussed the success of implementing a tire wall and states that it has helped to prevent sand from running into the road, as well as created a region for vegetation and other plant life to survive further down the road (University of Arizona, 1999). Another larger scale tire project was completed throughout central and southwest regions of Oklahoma a few years ago (Nairn, 2004). Along the banks of seven different rivers, tire walls were built to help with erosion control. Despite the fact that there were a few minor failures in the systems, the tire walls proved to be an effective way to control erosion. The Habitat Research and Development Centre located in Windhoek, Namibia also promotes the use of tire walls which stabilize the soil and prevent erosion.

2.4.5 Vegetation

Vegetation helps to control erosion on two fronts. As stated in the *Alabama Handbook for Erosion Control, Sediment Control, and Stormwater Management on Construction Sites and Urban Areas*, "a dense, vigorous growing vegetative cover protects the soil surface from raindrop impact, a major force in causing erosion and sedimentation" (USDA, 2003). Vegetation provides coverage for top soil, effectively absorbing most of the energy produced by the falling rainwater. The *Alabama Handbook* also states that, “vegetation will shield the soil surface from the scouring effect of overland flow and decreases the erosive capacity of the flowing water by reducing its velocity” (USDA, 2003, p. 17). Once an area of vegetation has formed, the rate of runoff water coming from the tops of hills is slowed when it passes through the plants. This, in turn, improves the situation for the area below the vegetation and can be easily managed.

Introducing vegetation into an area with little plant life helps to stabilize the soil due to the plants' roots (USDA2003). Having the topsoil anchored by the roots of plants, lessens the impact of surface runoff water. A permaculture expert at the Polytechnic of Namibia, Ibo Zimmerman (personal communication, March 27, 2008), suggests that when mulch pits and trenches are used in a stormwater management system, vegetation can be grown alongside these trenches. In order to replenish organic matter in the soil, vegetation, preferably rapid, self-seeding plants, such as elephant grass, can be used to line the bottom of the trenches. Along with the benefits of using vegetation for erosion control, plants can be grown and consumed as a food source.

Soil erosion is a serious consideration in the construction industry. The Iowa Department of Natural Resources has published the *Iowa Construction Site Erosion Control Manual* (2006). This document outlines various types of erosion, factors which contribute to erosion, and various methods on how to control erosion. The vegetative methods outlined in the manual include grass channels, mulching, seeding and fertilizing, sodding, and vegetative filter strips. These methods encompass the benefits of using vegetation as an erosion control measure, including soil anchoring by roots, topsoil coverage from falling rainwater, and runoff rainwater prevention. In order for these methods to be utilized in semi-arid or arid conditions, vegetation would have to be grown at appropriate times during the year to maximize the chances of growth and sustainability.

2.5 Gardening

Gardening in arid and semi-arid regions in the world has been well documented, especially in Africa (Batchelor, Lovell and Semple, 1994). Factors such as climate, soil conditions, erosion and gardening knowledge within the community play a role in the success of gardening in these regions. Methods for identifying arid and semi-arid regions and characterizing weather patterns have been developed to provide a better understanding for worldwide climate differences. Arid and semi-arid climates influence soil conditions and the ability of soil to produce vegetation (FAO, 1989). The level of organic matter, texture, structure and topsoil depth are less than ideal in arid regions. This makes it difficult to start and sustain gardening.

2.5.1 Climate and Weather

One of the most important factors in determining the success of a gardening environment is the climate in which the gardening takes place. The densely packed vegetation of the world's rainforests provides ideal conditions for plants. Warm temperatures, rain and humidity help sustain plant life and vegetation growth all year long. However, these conditions only exist on six percent of the Earth's surface (Crass, 2003). The rest of the planet must deal with varying weather conditions, periods of drought and excessive heat or cold. Variation in climate has been researched for many years in order to classify what areas in the world experience different weather patterns.

The Köppen-Geiger Climate Classification, developed by Wladimir Köppen and Rudolf Geiger, is an important tool in determining climate conditions in every section of the globe (Kottek et al., 2006). Each color on the map in Figure 8 represents a particular climate. From these classifications, certain characteristics regarding rainfall patterns and temperature can be determined (see Appendix B for an explanation of the Köppen-Geiger Climate Classification colors).

For the purposes of this project, most of the research regarding climate focused on arid and semi-arid climates. Areas with the arid classification receive between 100 and 300 mm of rain per year, while semi-arid areas receive between 300 and 500 mm annually (Sweet and Burke 2002).

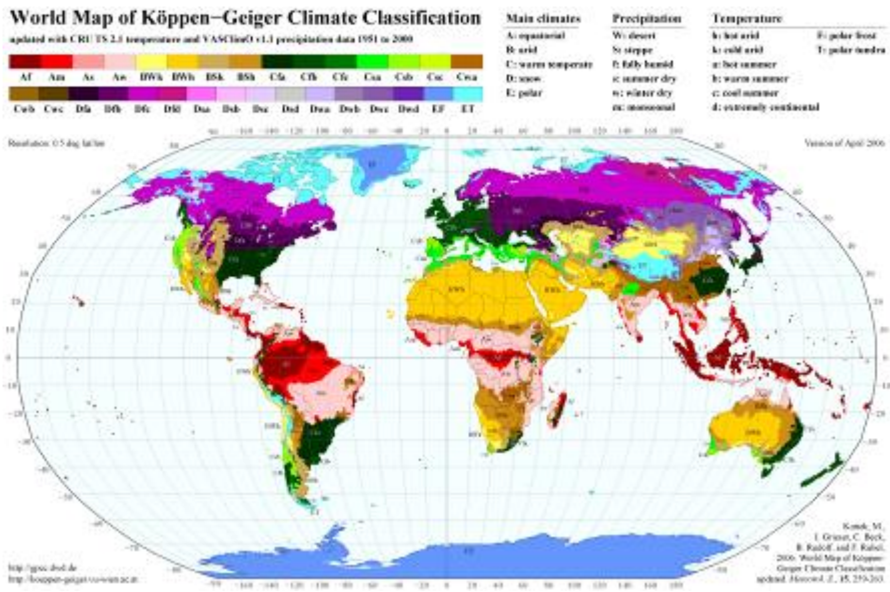

Figure 8: Köppen-Geiger Climate Classification (Kottek et al., 2006)

2.5.2 Soil

Soil is a key factor in the success of gardening in any area of the globe (FAO, 1989). In arid and semi-arid regions, the amount of arable soil is limited. One of the factors contributing to the lack of quality soil is the water retention of the soil in arid regions. Water-holding capacity is dependent upon soil texture, structure, and depth. A fine textured soil generally has a greater water-holding capacity. Although sand has a fine texture, its structure makes it difficult to support vegetation growth. Soil structure is defined as the internal arrangement of soil particles (FAO, 1989). In general, the structure of soil is influenced by the amount of organic matter contained within the soil.

Arid regions normally have little vegetation and no overhead canopy, therefore the accumulation of organic material is negligible.

The most important factors in determining soil's ability to support plant life are all related to water (FAO, 1989). In order for plants to grow, there must be an adequate water table that is attainable by the roots. A water table is the upper limit of the portion of the ground wholly saturated with water. Without a sufficient supply of water to the roots, there is no chance for plants to have a constant nutrient source. It is also important to have an adequate soil thickness to allow for a water reserve. A deeper topsoil thickness permits more water to be stored. Thin topsoil decreases the water-holding capacity and can be greatly affected by wind and water erosion. The third key factor that contributes to soil's arability is its texture and structure. Regardless of the depth of topsoil, the structure of the soil determines how much water a plant's roots can absorb.

2.5.3 Subsistence Farming and Ways to Improve Soil Quality

For farmers and gardeners in arid and semi-arid climates, it may not be possible to carry out an agricultural operation on a large scale. For reasons related to climate, soil quality and financial burden, farmers may lack the necessities for large-scale farming. When farmers lack the necessary resources to carry out a large scale farming operation, subsistence farming may be suitable. Subsistence farming is a method of farming in which a family grows only enough food to provide for the family or to sell as a means of additional income (Waters, 2007). Our project focused on the possibility of implementing gardening as a supplemental food or income source, but not on the same level as subsistence farming. Where the subsistence farmer's primary source of food is grown during the year, gardening provides a secondary source of food.

As with any form of gardening or farming, it is important to replenish nutrients in the soil where crops are grown. Gardeners in areas with poor soil quality must be especially conscious of what nutrients are contained in the soil. In subsistence farming crop rotation, manure, and compost are vital to soil restoration, as opposed to chemical fertilizers utilized by large-scale farming. Crop rotation is a planned growing cycle of certain plants in order to improve or maintain the soil for sustainable gardening (Peel, 1998). Peel writes that the main benefits of crop rotation is improved soil fertility, tilth and aggregate stability, soil water management, and reduced soil erosion.

Another means of improving the soil on which small-scale farming is done is the use of natural fertilizers such as manure or compost (NEPAD, 2006). Manure is readily available and it can be easily collected and spread as fertilizer. Compost is another source of fertilization for plants that is easy to produce and relatively cost free (Recyclenow, 2008). Using plant materials, manure, fruit and vegetable trimmings, cardboard, and many other materials that would normally be thrown away, compost piles can be formed and used for gardening. Compost piles need some moisture in order to sustain the bacteria necessary for composting, but this can be assisted using mulch pits and other rainwater harvesting techniques.

Through extensive research, various water management systems and ways of implementing the systems in a community have been looked at. Rainwater harvesting systems and factors which affect the growth of vegetation indicate there are a variety of solutions that can be applied in arid regions. Community development can be accomplished by using participatory research methods, which have shown to be successful in communicating with and mobilizing communities. In the next chapter, we describe how we achieved our goal of identifying a viable rainwater harvesting and erosion control systems in Otjomuise and the settlements in Windhoek, Namibia.

3 Methodology

Due to the combination of poor topsoil, arid climate, and erratic, heavy patterns of rainfall, the settlements outside of Windhoek, Namibia face severe rainfall damage and erosion that causes the flooding of houses and streets while also creating an unsafe environment. Many residents of these communities have identified possible solutions to these problems, but they do not have the material or financial resources necessary to implement them. This lack of technical knowledge and resources led to the formation and completion of this erosion control and rainwater harvesting project. To carry out this project we formed a committee of community members dedicated to the project in order to create rainwater harvesting and erosion control systems which slow and divert rainwater away from houses and roads. These systems also maximize the use of rainwater for gardening.

To achieve our goals we worked alongside the community throughout the design and implementation of these systems. The team educated the community in problem solving tactics and measures to ensure project sustainability after our departure. The methods outlined in this section were used to assess and improve upon community involvement in the project, as well as to design and implement various rainwater harvesting and erosion control techniques.

3.1 Effective Community Mobilizing Methods

Community involvement was crucial to the success of designing and implementing sustainable erosion control and rainwater harvesting systems in underdeveloped areas such as Otjomuise. If community members are to rely on a system, the majority of ideas and opinions involved in the system's creation must be their own. To pave the way for such an environment, the project team used a community development technique called Participatory Action Research that allows team members to work alongside community members as peers in the project development process. Through the use of informal interviews, observations, and visual expression methods we were able to obtain the residents' preferences concerning system locations and specific types of systems to be constructed.

After installing the systems chosen with the community's help, we were able to educate them on how to maintain system sustainability as well as design and create similar projects in other locations in the settlement. The various informal education methods used to complete the education portion of this project are detailed in section 3.6.

3.1.1 Establishing Trust within the Community

The project team worked with the residents of four savings groups located in Otjomuise between Dimbokro Street and Kitchner Street to complete erosion control and rainwater harvesting systems. The savings groups involved were the Longa Shoye, Omusati, Datango, and Ehiroruyanoi groups. In order to ensure success in the implementation and sustainability of the project we placed an emphasis on establishing good relationships with the members of these groups.

Participatory Action Research techniques were initiated by completing several informal community walk-throughs which served to encourage friendly communication between the project team members and the residents of the community. We overcame the community language barrier with the help of two Oshiwambo speaking students from the Polytechnic of Namibia. Laudika Kandjiga and Andreas Shigwedha were assigned to the project by Jane Gold of the Department of Land Management at the Polytechnic of Namibia and, in addition to playing a major role in the design and implementation processes of the project, they also served as our translators during our time in Namibia, as shown in Figure 9. Other successful communication methods we used were describing situations as simplistically as possible and using visual aids, such as pointing towards objects or drawing on the ground. With these alternative forms of communication, we found that despite the language barrier, communication was certainly possible.

Figure 9: Residents of Dimbokro Street interacting with the project team

3.1.2 Formation of a Dedicated Committee for Community Mobilization

To ensure sustainability, we formed a volunteer committee of community members in order to promote expansion of the project. This committee had the responsibility of collecting data from the community to help design and implement successful erosion control and rainwater harvesting systems. This method, called the Community Land Information Program (CLIP) by the SDFN, allowed us to form trusting relationships with the residents of our street as well as ensure a faster approach to problem solving.

Figure 10: Residents of Dimbokro Street attending a community meeting

Following the initial observational period dedicated to establishing trust within the community, we completed a series of informal discussions with the community members, as shown in Figure 10, in order to gauge interest in the project as well as generate design possibilities. These discussions were used to discover the residents' ideas as how to harvest rainwater and what they prefer the water be used for. Clear leaders emerged almost immediately from these discussions. Edlagh Ujava, the owner of erf (house) 2846A, had an extremely positive outlook on these types of projects, appeared to communicate well with other members of the community, and immediately suggested several possible solutions to erosion problems and systems for rainwater harvesting. After only our first meeting with the group, we were able to designate Edlagh as our community leader. Several other community members suggested similar solutions to these problems such as the growth of vegetation to slow down the flow of water, and the implementation of a rooftop catchment system to put more water to use. Through many exercises like these, the community became mobilized and residents were willing to contribute to the project.

3.2 Acquiring Professional Consultation on Technical Problems

As this project required the design and implementation of technical systems, we decided that it would be helpful to contact experts in related fields to generate design ideas, obtain materials, and generally support the progress of the project. Such experts included founders of the Shack Dweller's Federation of Namibia, employees at the Namibian Housing Action Group, employees at the Habitat Research and Development Centre, faculty at the Polytechnic of Namibia, and other outside contacts. The first two organizations provided information concerning community development while the remaining organizations presented information regarding design generation and materials collection. Other contacts included various specialists in the engineering, agriculture, and architecture fields to provide expertise in the technical aspects of the project.

3.2.1 Obtaining Information Regarding Existing Community Development Strategies

The first organization the team contacted was the Shack Dweller's Federation of Namibia. The SDFN can be considered experts in the area of social work as well as land project implementation. Communities developed through the SDFN are responsible for their own advancement. The residents of these communities unite to identify community problems and create plans for solving these problems. Systems organized by the SDFN encourage savings groups to visit other areas where projects have been completed. The project team put an important emphasis on this method in the concluding weeks of our time spent in the community. Detailed data pertaining to the savings groups within Otjomuise that were affected by this project were given to the group by the SDFN. The insight that the SDFN was able to provide concerning the formation of settlements, the emergence of leadership within communities, and the methods that work best with the cultural backgrounds of the people living in these settlements were an essential source of knowledge for the project team.

3.2.2 Establish Contacts at the HRDC

During our first site visit to Otjomuise, the group was scheduled to meet with the research manager at the Habitat Research and Development Centre in Windhoek, Dr. Andreas Wienecke. The HRDC was created to research alternative energy and renewable resources to help improve the quality of life in the communities on the outskirts of Windhoek. Dr. Wienecke is an expert in designing and implementing erosion control and rainwater harvesting systems using limited resources. Our group was given the opportunity to tour the HRDC to observe technologies being worked on in the centre and to get a brief description and commentary on these systems by Dr. Wienecke. This tour helped to establish many of the erosion control ideas presented to the community of Otjomuise. Also, Dr. Wienecke gave us the contact information for his assistant, Mawisa, who helped us when he was unavailable. Our contacts at the HRDC helped us launch numerous erosion control systems in Otjomuise and provided many of the materials used in the systems.

3.2.3 Establish Professional Contacts for Technical Expertise

Along with the various organizations supporting our efforts in Otjomuise, our sponsors encouraged the help of outside contacts to provide constructive comments and professional opinions on our designs and the project as a whole. The director of NHAG, Anna Müller, suggested the help of Canadian architect Andrea Saldanha who is involved with the Namibia Nature Foundation. Andrea attended a site visit during the design stage of the project and gave helpful suggestions on brainstorming techniques during the design process of our erosion control systems for the area we were concentrating on. She also gave constructive criticism during our designs, which helped us to address issues we had overlooked.

As with NHAG, our sponsor in the Department of Land Management at the Polytechnic of Namibia, Professor Jane Gold, was able to set up a meeting with Professor Collert Moyo, a civil engineer at the Polytechnic of Namibia. During our meeting, we discussed the project and potential designs for the erosion control systems. Professor Moyo was also involved in the design review process. With the help of outside contacts, such as Professor Moyo, our group was able to get alternate opinions on our project which helped us to recognize latent problems with our designs and offered ways to improve our designs to reach the best possible solution.

Professor Ibo Zimmerman is a permaculture expert at the Polytechnic of Namibia, who was referred to us by Jane Gold. He was able to provide information regarding vegetation, and how it can be integrated with various rainwater harvesting methods to control erosion. Professor Zimmerman introduced us to the idea of mulch pits. He explained the purpose of the mulch pits and how they are constructed. The introduction of mulch pits and his critique on our previous designs helped validate the effectiveness of our project.

3.3 Assessing Primary Needs within the Community

Before designing and implementing rainwater harvesting and erosion control systems, we first had to assess the existing damage to the land caused by rainfall and other potentially problematic areas. In order to complete this task, we observed the layout of the community—existing erosion control systems and vegetation—and then utilized maps to document evidence of erosion patterns caused by rain while talking with community members to obtain additional input. The community members were familiar with the topography and were knowledgeable about existing problem areas, therefore their ideas were essential to the success of the project. Lastly, a large area was selected as a prototype area to complete several different types of rainwater harvesting and erosion control measures based on its ability to impact the community.

3.3.1 Surveying the Effects of Local Rainfall to Determine a Focus Area

Figure 11: Dimbokro Street, Otjomuise, Windhoek, Namibia

We spent the first week in Otjomuise making observations about the existing rainwater damage. The street of focus in Otjomuise lies between two hills, as can be seen in Figure 11. The hills that surround the street cause powerful and dangerous runoff currents to form when it rains. After only fifteen minutes, the soil becomes saturated and streams of water begin to form causing deep channels in the ground as shown in Figure 12. By way of such channels, water flows into the street, floods houses, and poses a safety hazard—especially for children. We also spoke with residents of the community to pinpoint major problems and to obtain more information about the rainwater damage. This interaction with the residents helped to introduce the project team to the community

Figure 12: Example of stormwater damage in Otjomuise

and to inform them of the project goals and objectives.

During one of the first visits to Otjomuise, the project team experienced rainwater damage first hand by observing erosion and flooding during a rainstorm. The team documented existing rainwater control methods including ditches, vegetation, stones and the use of tires. By observing the damage directly, we were able to clearly understand the magnitude of the problem.

3.3.2 Mapping Activity

After conducting initial walkthroughs, we began to assess the layout of Otjomuise. Prior to visiting the community, we obtained maps of Otjomuise from the Namibia Housing Action Group that showed all of the houses, savings groups, altitude and contour lines of the region. We made copies of smaller maps, which displayed the entire community. We also made copies of larger, more detailed maps, which were broken down into the four savings groups of our specific area of Otjomuise.

When we arrived on site, we split up into three teams to plot the runoff flow patterns and existing vegetation in the settlement. Each team was assigned a portion of the community to assess and highlight channels, areas of particularly bad erosion, and vegetation. While we plotted our own observations, we asked community members for their input as well. They showed us areas where flooding occurred most frequently and described the runoff flow patterns. Using the information they provided us, we highlighted additional problem areas on our maps where necessary.

After each team had assessed its sections, we compiled all of our maps. We then transferred our observations onto the larger, more detailed maps for comparison and discussion. Each team presented its findings to the rest of the group, pointing out particularly important areas of interest. This step helped us determine our main area of focus discussed later in this section.

3.4 Determining the Availability of Suitable Construction Materials

After we completed our assessment of Otjomuise, we proceeded to determine the materials needed for our project—based on the systems at the HRDC—and their availability in and around Windhoek. Before acquiring materials from other sources and finding transportation for these materials, we identified available materials within the settlement with the help of community members. Next, we visited the Eros dumping site to look for free scrap material and contacted the Shack Dwellers Federation of Namibia to discuss the availability of tools for construction. We then proceeded to visit several tire suppliers to see if they would be able to provide free tires to be used in the construction of erosion control structures. We purchased tools at a hardware store in Windhoek initially to start the project. Later, we were able to locate available tools in the community.

3.5 Implementation

After we obtained our materials, we began implementing our erosion control systems. The first step was to select the location where these systems would be constructed. Next was to create a design plan for the region of interest and present the plan to the community and our sponsors. We then discussed possible revisions to our design plan and revised it accordingly. After our sponsors and the community approved our design plan, we began to build several different types of erosion control methods.

3.5.1 Selection of Example Implementation Area

After reviewing and discussing the erosion pattern maps, we determined one main area of interest to apply our erosion control methods and rainwater harvesting systems. We found many areas that require attention in Otjomuise, but due to time constraints, we selected one initial region to focus on with the hope that the community members themselves could expand on our project to other parts of the community. We wanted to thoroughly complete one system to serve as an example for the community and to demonstrate several different possible methods for erosion and runoff control. Based on initial observations that were made and the number of houses impacted by this runoff, we selected a smaller area of the community to focus on. A total of ten homes experienced flooding and erosion problems due to the runoff in this particular area. The following map displays the selected area of interest for implementing our structures.

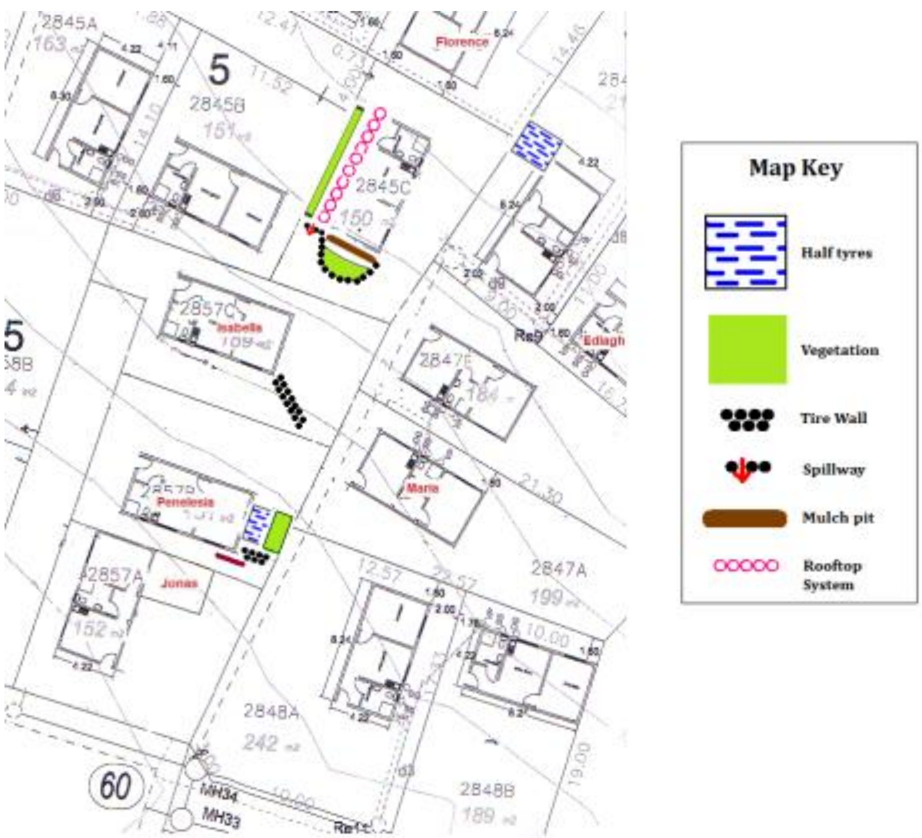

Figure 13: Implementation Map

3.6 Visual Aids for Sustainability

The language barrier that existed between the project team and community members meant that non-formal education methods were utilized extensively in order to effectively communicate with community members. Such methods included the aforementioned mapping exercises, posters, pamphlets, demonstrations, presentations, and models. Visuals such as these were necessary because they offered an effective way of communicating without needing spoken language. All visual aids used for this project can be found in the appendices of this report.

This chapter discussed the individual steps we took in order to ensure the success of our erosion and runoff control system. The first part in completing our project was to establish a solid relationship with the community and create a group of community members to participate in implementing the erosion control measures. After we accomplished this, we worked with both the community and with several experts to help plan and develop appropriate designs for Otjomuise based on the needs of the people and specific situations. We then located available materials and tools in the Windhoek area to be used in constructing systems. The following chapter will discuss the specific designs that were chosen, how they were built, the materials and tools we used, and all observations of our system.

4 Results and Analysis

The purpose of our project was to have community members work alongside the project team in order to design and build structures and systems that prevent erosion and flooding and, where applicable, use the rainwater to support gardens. In order to do this, the team first created an information packet complete with pictures and descriptions of various methods that could be used to help with these problems. Next, the community selected the methods to be used in the area of focus in the community and decided where to place them. This area would be used as a demonstration for the rest of the community. After obtaining the necessary materials for these projects, community members and project team members worked with one another to build the structures. Throughout the construction, we involved community members during the design and implementation process and informed them of what they could do to help.

4.1 Identifying Erosion Control Methods with the Community

The following section describes the results of the erosion control methods developed by the community and the project team. In order to communicate our ideas for erosion control, we provided our community leader with a laminated information packet, demonstrating the various types of systems we thought would be appropriate to implement. The packet included colored photographs of a single layer tire diversion system, a tire wall, a gabion, and a rooftop rainwater harvesting system. Each method was presented with a brief explanation of how the system works. We brought this packet to Edlagh, the community leader, to present to the community. We also proposed that the community use vegetation as a method for controlling erosion. After presenting these ideas, we discussed the concepts with the community to get their feedback. We then altered our methods based on the input of the community and created our design plan accordingly. The presented methods and the role of the community in developing these methods are discussed below.

4.1.1 Using Vegetation for Erosion Control

Vegetation was one suggested method presented to the community to help absorb and slow rainwater runoff. For our project in Otjomuise, we proposed that the community plant vegetation to stabilize the soil and decrease the amount of erosion in the area. When we made this suggestion, community members approved the idea. In fact, many community members expressed great interest in planting vegetation that produces food and in growing gardens. A list of community members interested in participating in growing trees can be found in Table 1. The house number, or erf number, for each of the community members can also be found in the table below. The trees that they requested include orange, fig, grape, banana, lemon, apple, guava, mango and palm trees. Other members were interested in growing onions, watermelon, rice, tomatoes, sugar cane, and flowers. Their only concern with growing these trees and gardens was the cost to purchase all of the plants. Considering this, we agreed to help them find vegetation at an affordable price. This step was crucial for both the completion of our project in Otjomuise and the success of future projects in other communities.

Table 1: Community Members Interested in Trees

Name	Erf No.
Sem	2851B
Uutako	2850B
Vilho	2855B
Lena	2850A
Bertha	2851A
Simon	2852
Loine	2853B

Name	Erf. No.
Edlagh	2846A
Monica	2844B
Florence	2844C
Clinstofin	2846B
Penelesia	2847B
Isabella	2857C
Neftaline	2844A

4.1.2 Incorporating Tire Walls and Walkways

Another proposed method for diverting, slowing, and dispersing runoff water to prevent erosion was to create structures using tires. After sharing our proposed tire wall and walkway designs, which can be seen in Figures 14 and 15, with the community using the information packet we created, we were able to speak with individual community members who lived in areas we thought would benefit most from the implementation of these structures. After we clarified that our project is not the same erosion control project completed in 2006, the community expressed interest in our ideas and agreed that our proposed tire methods would be beneficial to controlling erosion in Otjomuise.

Figure 14: Proposed tire wall design

Figure 15: Proposed tire walkway design

Individuals in the community had no objections to our design plan and encouraged implementation of the appropriate erosion control methods where we were suggesting them to be used. At the top of hill, where our system began, the homeowner of erf 2846B reviewed our methods packet and suggested we implement a tire walkway through part of her yard to help slow runoff where the problem started. The residents of erf 2845C also expressed interest in implementing a tire wall and an individual tire diversion system running through their plot of land. Both homeowners agreed to contribute and help construct the structures when we began installing them. The participation of the community members in the design, decision-making, and implementation processes was essential to the progression of the project.

4.1.3 Use of Gabions

Our final proposed method for controlling erosion was the use of gabions to slow large volumes of water moving rapidly across the surface soil. In general, the community responded well to the concept of this method, however, when we discussed the necessity of wire for construction, we found that purchasing this material is expensive. Creating a system that required material that the community members could not afford would not be reasonable, as it would not lead to sustainable projects. Our project emphasized the importance of replicability in other communities, thus making cost a primary criterion. Considering cost, gabions were determined to be an inappropriate solution for this community and similar communities in the Windhoek area.

4.2 Availability of Materials

After we completed our assessment of Otjomuise, we proceeded to determine available materials for our project. We used several methods to obtain these materials, which included discussions with organizations and the community, and various material site visits. In Otjomuise, we held discussions with the community involving the availability of materials within the area that could be used for erosion control and rainwater harvesting measures. In addition to this, we visited the Eros landfill site with Dr. Andreas Wienecke from the HRDC to look for free scrap material, and we contacted the SDFN to discuss the availability of vegetation, specifically trees, for erosion control.

4.2.1 Locally Available Building Materials

After speaking with members of the community and surveying the area, we were able to identify readily available materials. The most prevalent material observed in all areas of the community was rocks. The land on which Otjomuise was built is covered on the soil surface and subsurface with rocks of all sizes. The obvious impact rocks have on erosion control can be seen immediately, since they are currently used as a method to decrease the velocity of runoff water as it flows down the hillside. Each of the methods we proposed for our project involves rocks in either the construction of the structure or as a means of erosion control. Rocks by themselves are cost-free and available everywhere, making them an ideal material for our project.

Another important material that is readily available is the vegetation found on the hillside that surrounds the end of Dimbokro Street. It was suggested by Ibo Zimmerman of the Polytechnic of Namibia that we remove some of the unwanted vegetation with a sickle or scythe. He noted that it was important not to simply pull the roots out of the soil, as this would cause the soil to become unstable. After removing the vegetation, it could then be used as organic matter in mulch trenches and pits. It is important for organic material to be added to the trenches to improve the quality of the soil and encourage the growth of vegetation surrounding the entrenched area.

Some materials we observed in the community, such as wire, were used as building materials for houses and other applications. The use of such materials for erosion control structures became a concern when we learned their prices and availability. We found several community members who used wire for building fences, but the wire obtained for fences is expensive and therefore unavailable for our purposes. Sheets of corrugated iron are normally used for rooftops within Otjomuise and other settlements, and our group wanted to use this as a possible material for gutters in a rooftop rainwater harvesting system. During a site visit, Professor Ibo Zimmerman suggested a different method for controlling rooftop rainwater due to the cost of the roofing material and the availability and effectiveness of readily available materials such as rocks. Professor Zimmerman suggested placing large rocks, approximately fifteen centimeters in diameter, under the rooftops of the houses so that they would absorb the energy of the falling rooftop water. This would also slow the flow of rooftop water once it reached the ground.

4.2.2 Visit to Eros Landfill Site

Our main contact at the HRDC, Dr. Andreas Wienecke, informed our group that the Eros landfill site in Windhoek was a possible source for low-cost material. Andreas and his associate Mawisa took our group to Eros to see what materials would be available. It was apparent that bricks and other construction debris were prevalent in the dumping site. Employees of the dumping site offered cleaned brick for sale for fifty Namibian cents and forty cents for slightly lower quality bricks. Dr. Wienecke explained that the low-priced bricks would be the best financial decision. The time commitment involved in making bricks (three to four weeks to allow the material to set properly) does not outweigh the immediate availability of pre-made bricks. Our current methods do not involve the use of bricks, but they provide the community with another material to use in applying future systems—gabions, walls, and energy absorbing material for rooftop rainwater.

The material we were most interested in, and the main purpose for our visit to Eros, was pipes of various sizes and lengths. We took a few measurements and found a selection of thirteen centimeter and eighteen centimeter outside diameter concrete pipes. The pipes were of various lengths, but the vast majority measured slightly more than one meter and could be cut to size using an angle grinder. The pipes could be taken from the dumping site free of cost and delivered to the desired location in Otjomuise. Our contacts at the HRDC assured us that there would be no problems in obtaining the pipes and transporting them out to Otjomuise. After assessing the possibility of using pipes to control erosion in Otjomuise, it was decided that focusing water into small areas, such as pipe diameters, would create problems due to the large volumes of water that would be produced. We have learned in our project that large volumes of water, moving at high velocity can cause major damage. In order to avoid this, we decided against using pipes to control erosion.

4.2.3 Trees and Plants

Throughout informal discussions held with the residents of Dimbokro Street, it became clear that trees were of great interest to the majority of the people. In addition to providing a form of erosion control, trees may be able to bear fruit, thus supplying the community with a supplemental food source. In addition, the trees could provide shade during the hot, sunny days. Community members explained that the SDFN had attempted to encourage the incorporation of trees into the settlements by making a number of trees available for purchase, but that this system was thought to be too expensive by the residents. After clarification from one of our team's sponsors, Professor Jane Gold of the Polytechnic of Namibia, we discovered that this was not the case, and that trees and plants may be acquired at a relatively low cost from the National Directorate of Forestry in Okahandja.

Professor Gold took two members of our team on a trip to the Directorate of Forestry to obtain saplings and seedlings for the community. The intention of this trip was to acquire as many plants and trees as possible for the community of Otjomuise for the purposes of gardening and erosion control. Upon arrival, we were given a tour of the available plants. After familiarizing ourselves with the plants, we chose plants that would be useful to the community. These plants included four fruit tree species and five indigenous trees. We obtained between five and ten trees of each kind for a cost of five Namibian dollars for the fruit trees and eight dollars for the indigenous trees. A total of three hundred and fifty dollars was spent on fifty-five trees.

After making our purchase, we created a system for the community members to order their trees through their community leader. All of the plants were given to Edlagh to sell to the other members of the community. In order to simplify the situation, the plants were sold for ten Namibian dollars apiece. Once Edlagh had received three hundred and fifty dollars from the sale of the trees, the money was returned to Professor Gold in order to ensure the sustainability of the program. Anything sold after the initial goal of three hundred and fifty dollars was kept by Edlagh as an incentive for selling the trees. This tree program provided a simple, inexpensive way for the community to obtain trees that could be used in conjunction with the implemented erosion control systems.

The only challenge presented by this system is that it is important to sell the trees community-wide, and not just in one specific area. In order to be sure of this, the erf numbers of those who bought plants were collected, and the community leader was encouraged to go to households that have not yet purchased anything to try to sell additional trees.

4.2.4 Other Sources of Materials

In addition to visiting local landfills and organizations that have previously completed similar projects, the team also contacted businesses for free or inexpensive materials. By using a local phone book, we compiled a list of possible companies from which we could obtain building materials such as tires, wire, and pipes. The HRDC also gave us various contacts for wire and tire providers within the municipality.

Our group made a trip to visit tire retailers to determine their willingness to donate old, discarded tires that would otherwise be sent to a dumping site. It was apparent from the first visit that tires would not be difficult to obtain. Due to the costs associated with dumping tires, the companies we visited were more than willing to hand over their old tires for our project. We visited three companies and arranged to pick the tires up in a truck. The Namibian Housing Action Group provided the truck and driver. We collected thirty-eight tires from Continental and thirty-five tires from Tiger Tyre & Wheel. The truck's bed was filled to capacity after stopping at the first two companies and we decided to deliver the seventy-three tires we had to Otjomuise.

4.2.5 Materials Storage Areas

Just as important as obtaining cost-free and inexpensive materials is the need to store the materials in the community until they are needed. While speaking with members of the community, we discussed the issue of storing materials that were to be dropped off by various contributors. The community informed us that soil and other materials that would be used immediately for a building project could be stored at the top of Dimbokro Street next to the toilets to allow for closer and easier access to houses. For excess or large materials, there was an area set aside for storage next to erf 2846A, accessible via Kitchener Street. This location is ideal because it is easily accessible for trucks and it keeps cumbersome materials off the street that could otherwise present a hazard to children.

One of the most important goals for our project was to keep the price of materials as low as possible to make it easier for the community to obtain them for future implementation and sustainability. Choosing locally available materials, such as rocks and vegetation, and receiving donated materials such as tires and soil, gave the project a better chance of succeeding in the future and spreading to other communities. In the next section, we will begin to discuss how these materials are used to construct the erosion control systems used in Otjomuise.

4.3 Prototype Erosion Control Structures

After we obtained all materials needed to complete the erosion control structures, it was time to organize the community and begin building. The four types of erosion control methods deployed as examples in a section of Otjomuise were the mulch pit, the tire wall and spillway system, and the half tire walkway. These systems were built on a hillside area that was prone to extensive erosion damage and flooding.

4.3.1 Mulch Pit

We decided to build the mulch pit and accompanying tire wall first, as we had adequate tools and materials for this task. Mulch pits are made to enrich the soil and make it suitable for plant growth, and thus encourage the incorporation of vegetation into the erosion prone areas in the community. Originally, our system tried to collect all of the runoff storm water and direct it into one large channel. We realized, however, that collecting large amounts of water and channeling it into one area would cause large, flowing volumes of water, which would inevitably cause damage to the area where we channeled the water. Using multiple mulch pits down a hillside allows for some of the water to be absorbed into the soil, which lessens the impact of the water at the bottom of the hill.

To build the mulch pit, we, along with members from the community, began digging a large trench. After completing the initial trench, we explained how to fill a mulch pit with appropriate materials. This explanation was intended to make the system more replicable for the community members. The trench was then filled two-thirds full with hard vegetation and sticks such as tree trimmings obtained from the end of

Dimbokro Street. Next, the trench was topped with manure and soil from Gammams Water Care Works to provide nutrients for the soil. Seeds and plants can be sown in this top layer. Figure 16 shows the multiple layers of the mulch pit.

Figure 16: Layers of the mulch pit

As this was our first system, community involvement was initially very limited. After seeing the work we were doing people became more enthusiastic and eventually came to help us throughout the rest of the building process. The first completed mulch pit can be seen in Figure 17.

Figure 17: Completed mulch pit

The mulch pit was made in conjunction with a tire wall and spillway system to maximize both erosion control and plant growth. This tire wall and spillway are discussed in the next section.

4.3.2 Tire Wall with Spillway

As there was a sudden change in elevation where we built the mulch pit, we decided that a tire wall and spillway surrounding the mulch pit would be an efficient system that could both slow water down and support the development of arable soil for planting. A spillway is used to divert water into the mulch pit and then allows excess water an outlet to flow down the hill into other systems. Spillways can be used as an alternative to a rooftop collection system because the materials involved in creating a rooftop system are expensive and difficult to acquire.

First, we built the spillway, which consisted of two layers of tires with a gap in between the two tires in the top layer in order to allow water to pass through the gap during times of intense rainfall. In this system, the water would first flow into the mulch pit. When the mulch pit became saturated, the water would then flow through the spillway. We built additional erosion control systems down the hillside to slow the water that would pass through the spillway. An example of a spillway system can be seen in Figure 18 and the completed spillway is shown in Figure 19.

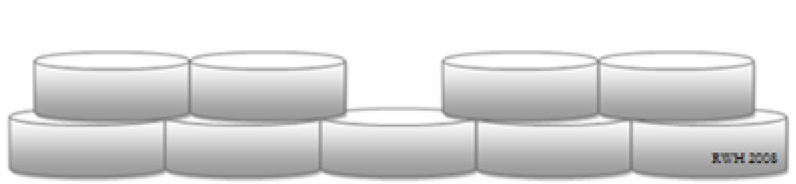

Figure 18: Example of a two-layer tire spillway

Figure 19: Completed spillway system

Extending sideways from the spillway was a two-layer tire wall. First, the community members dug into the side of the hill to form a flat space for the first layer of tires. Next, tires of the same size (205 mm) were placed flush to one another in a long row around the mulch pit. The tires were then filled with rocks to keep them in place. The children of the settlement collected large and small rocks alike. To do this they filled the insides of extra tires with rocks and smaller stones and rolled them up the hillside. After the first layer of tires was filled with stones and soil, community members filled in the back of the first tire layer to prepare for the second layer. The second layer of tires did not sit directly on the first layer of tires but was set farther back into the hill, creating a step like structure. This design enables vegetation to be planted inside the tires. The tires were also placed on top of each other off center so that water could seep through the cracks between the tires. The construction of the first tire wall that was completed can be seen in Figures 20-22 below.

Figure 20: Placing the first row of the tire wall

Figure 21: Filling the tires with stones

Figure 22: First completed tire wall

Lastly, soil brought to the community from the HRDC was used to fill in and around the tires. The soil was packed and stomped into the tires to stabilize them. Once we had our work underway, more community members came to help and seemed interested in the project. The next system to be built was the half tire walkway, which would be located at the very top of the hill.

4.3.3 Half Tire Walkway

After attending a community meeting to ask all community members for help, we received much more support for the half tire walkway system. Community members lent tools such as pick axes and shovels as well as manpower to help complete this task. This system was assembled at the top of the hill to encourage the implementation of systems that would slow the rainwater at its source, not just where the most eroded areas were.

First, a large hole was dug so that the tire would be buried up to the sidewall. The soil in this area ranged from a clay-like material to several feet of nearly solid rock, and it took a combined community effort to dig the hole and remove large rocks. This Process can be seen in Figure 23. As an added benefit, these large rocks were placed under the rooftops of several houses to aid in absorbing the energy of water falling from the roof. This is an inexpensive way to reduce the amount of erosion damage under the rooftops and slow the flow of the water down the hill.

Figure 23: Digging for the half tire walkway

Next, half tires were placed in alternating rows and held by community members and children to be set in place using soil as a filler material. This alternating row pattern, shown below in Figure 24, is believed to foster the most efficient erosion control system.

Soil was then filled in, around and underneath tires to hold them in place. The soil was also packed for extra stability. Lastly, small stones and pebbles were placed around the tires to slow the potential effects of water and further erosion. The completed half tire walkway at the top of the hill in Otjomuise can be seen in Figure 25. The overall purpose of the half tire walkway is to facilitate the movement of water in different directions and thus reduce the intensity of the flow of water.

Figure 24: Design Pattern of the half tire walkway

Figure 25: Completed half tire walkway

4.3.4 Identify Locations for Further Erosion Control Work

After all example structures had been put in place the project team volunteered to walk with residents of Dimbokro Street and suggest possible methods that could be implemented on their land. On the first day, five community members walked around with one of the team members to show problematic areas and the effects those areas had on their homes. Using the methods packet we produced, the community members were able to identify potential methods to put in place on their side of the street and on their own plots.

4.4 Effectiveness of Communication Strategies and Methods

Throughout the implementation of our project, we worked extensively with both verbal communication and visual aids in order to maximize community involvement and the understanding of our project. The effectiveness of these communication strategies can be measured both qualitatively and quantitatively by the level of community response. We gathered this information so that we could recommend which approaches should be used in years to come and which were not found to be useful.

4.4.1 Communicating the Purpose of the Project

It was important that the community members had a clear understanding of our purpose in Otjomuise within the initial two weeks of our visit to Namibia. Informal community discussions conducted by the team provided us with a much better understanding of the effects the rainy season has on the lives of the residents of Otjomuise, as well as what the people think should be done to solve these problems. After discussing flooding and erosion problems with several people, we were able to set up a formal community meeting for further discussion and brainstorming of solutions.

The formal community meeting, held on March 16, 2008 had an excellent turnout. At least fifteen people from varying ethnic backgrounds (Owambo, Herero, and Damara tribal groups) participated in the brainstorming process. The greatest concerns expressed were the large channels in the yards that were hazardous to children and house flooding because of both groundwater runoff and rooftop rain. People expressed interest in creating new erosion control systems as well as rooftop rainwater harvesting systems. We were able to obtain the "erf" (plot) numbers and names of several of the people interested in completing the project, as well as identify our community leader—Edlagh. A table of those initially interested in the project is displayed below.

Table 2: Contact Information for Community Members

Contact Information	
Name	**Erf No.**
Edlagh	2846A
Elise	2852A
Norway	2850A
Hiene	2858B
Ruusa	2858A
Bertha	2851A
Soini	2859
Jonas	2857A
Isabella	2857C
Maria	2847A

The greatest challenge we faced in these initial stages was that of the language barrier. Many people were afraid or unwilling to come to our meetings because they feared they did not speak English well enough to communicate with us. To help with this issue, our two teammates from the Polytechnic of Namibia, Laudika Kandjinga and Andreas Shigwedha, translated what we said into Oshiwambo, as well as what the people said into English. We were also able to conquer this obstacle by using visuals as simple as drawing in the dirt to express our ideas.

Another significant challenge encountered in the project communication process was that of the previous erosion control project from 2006. Many people expressed concerns with the use of tires, which are important to the completion of sustainable projects not only in Otjomuise, but also throughout the world. The main concern was that this project would be a repeat of the project already in place, which, in addition to being difficult to remove, had created new erosion pathways. From that point forward a strong emphasis was placed on the difference between the previously completed project and our own.

The final challenge identified by community members was the amount of anticipated project participation. First, the physical location of the plots of those who attended the meetings was the same neighborhood—all attendees were from the Ehiroruyanoi savings group. Second, concern was raised that not enough people would be involved in implementing systems in the problematic areas. A suggested solution to this was to create systems by the street, but this suggestion presented another problem. In order to work on common land, such as the street, permission from the municipality to do so must be obtained.

4.4.2 Encouraging Project Expansion

In the final stages of the implementation process, we created a PowerPoint presentation to spread the word throughout the four savings groups on Dimbokro Street. This presentation outlined the purpose for our being in Namibia, what the goals of our project were, what some useful erosion control methods were, and what systems had already been completed within the community. This presentation was shown in the bar on Dimbokro Street on April 12, 2008. Attendance at the presentation was much higher than expected and included approximately 25 residents from both sides of the street.

Laudika provided full translation in Oshiwambo for the community members who could not speak English.

The people were willing to ask questions and waited for our responses. They seemed enthusiastic about what had been and could be accomplished. We put an emphasis on the fact that our structures and methods are meant to serve as examples. In the last few weeks, we brainstormed possible solutions to erosion problems in other areas. This strategy was employed for several reasons. A PowerPoint presentation allowed for visuals, which had proved to be important in bridging the communication gap. The community had been responsive to the use of pictures throughout the process, which may have been the reason for the high attendance.

We gave another PowerPoint presentation at the SDFN's Hakahana Center on April 19, 2008 in order to portray the same information as the previous presentation to a different population. Many of the people that attended this presentation were from the settlement of Hakahana. We saw an almost immediate response to our project after this presentation. In less than one week a member of the SDFN who attended the meeting had both tires and soil delivered to his home in order to start this same project in his neighborhood. This was extremely good news for us as well as for NHAG and SDFN.

4.4.3 Communicating Problem Solving Techniques

Visual aids, such as packets with written explanations and pictures, as well as written correspondence between the team and the community leader, played an important role in the communication of project goals and methods. The methods packet proved to be very useful in communicating our ideas, sparking the interest of community members, and feeding community members' brainstorming sessions. The methods packet was given to two community members on opposite sides of the street, Elise and Edlagh. These women went from house to house with the methods and explained to the people how they worked. The fact that the packets visually represented our visions of tire usage made it much easier to convince community members that our project differed from the erosion control project completed in 2006. We were able to see more community enthusiasm after the packet was circulated and felt more confident in the community's ability to mobilize people to work on the project.

A limitation of this procedure was that we did not know how many people were actually reached by both Edlagh and Elise. We know that Edlagh visited at least nine homes, but there is no estimate for Elise's impact. Both packets had been left with the community to be shown to interested people. It is up to the community leader to ensure that word is spread to others about these possible techniques. Again, the language barrier could present a problem, so the information packet was translated into Afrikaans.

The vegetation packet was created to aid the community in visualizing the plants available for purchase. At first, the packet was printed in black and white and contained only pictures of the actual plants purchased. After discovering this was minimally helpful due to lack of color and presentation of mature plants, another packet was created. The second packet, in color, included information regarding how to grow each plant, the benefits the plants would provide, and photos of mature versions of the plants. The response of the community after receiving the second packet was much more positive than before. Below, Table 3 displays the sales of plants to community members before the color packet and sales after the color packet was distributed.

Table 3: Plant Purchase List

Plant Name	Quantity	Purchased Prior to Packet	Purchased Post-Packet
Mango	10	9	10
Cashew Nut	10	1	5
Lemon	6	5	6
Wild Olive	5	3	0
False Ebony	5	0	3
White Stinkwood	5	0	0
Rhus	5	0	2
Albezia	5	0	0
Grapes	5	0	2

This response suggests the idea that visual aid has a significant effect on the participation of community members.

4.5 Effectiveness of PAR Approach to Solving Community Problems

Participatory Action Research (PAR) was a very successful approach to take for this type of project. The community's initial response to our presence in Otjomuise was of excitement as well as a little concern. This concern dealt mostly with the fact that they were worried about formality within the meetings—more specifically if there were speeches being made to the people they would not be understandable due to the language barrier. This concern among the residents gave the project an initial slow start, but we remained persistent in our efforts to involve the community. After it was clear to the residents that our intent was not to lecture them but to involve them in the design and building process, things began to work more smoothly.

The informal, interactive approach employed throughout the project seemed to have strengthened the success of the project immensely. Community members thoroughly enjoyed giving personal tours of the area. They explained work they needed done in order to help prevent more erosion and flooding. Is also seemed they looked forward to the team's daily arrival in the settlement. By the final stages of system implementation, a significant number of people willingly came to help with each step along the way. The emphasis placed on informality seemed to be an extremely important element of this approach in areas such as Otjomuise. PAR may have worked so well in Otjomuise because this settlement was already familiar with working collectively in groups. The community may have been less receptive to this approach if they had not been used to forming savings groups and working together as a community to solve problems.

While achieving the goal of designing and building various erosion control and rainwater harvesting systems, the project team worked with the community, and a variety of other experts to create the best systems possible. Throughout this process we had many informal discussions and presentations on what the people of Otjomuise could do to help with the project. Recommendations to the community of Otjomuise and our sponsors, as well as the outcomes of our project are discussed in the next chapter.

5 Conclusions and Recommendations

The following chapter discusses the affordability of our erosion control methods, the expert opinions and advise we received through the course of our project, and the success we had using Participatory Action Research. We also present several recommendations for the community of Otjomuise, the Department of Land Management at the Polytechnic of Namibia, the Namibia Housing Action Group, the Shack Dweller's Federation of Namibia, and future project teams.

5.1 Economical Erosion Control Systems

- Designing and implementing erosion control systems that are inexpensive, reproducible, and effective allows other settlements similar to Otjomuise to incorporate sustainable systems into their communities with ease.

5.1.1 Utilizing Natural Resources

- Using natural resources is a useful way to control erosion because it is cost-effective and convenient.
- Invasive vegetation can be used for erosion control.

5.1.2 Using Free Materials

- Tires are critical for the success of our erosion control systems.
- Manure is helpful in assisting the growth of vegetation.

5.2 Necessity of Expert Opinion

- Expert opinion in the varying fields relating to sustainable development projects is integral to the success of the project.

5.2.1 Technical Aspects of the Project

- Tire can be used in a number of ways to help manage stormwater.
- Vegetation is a key aspect to erosion control.
- Spillways can be used as an alternative to rooftop rainwater catchment. .
- Erosion control must begin at the top of the hill.

5.2.2 Community Mobilization

- Mobilization and involvement of the community is the most important aspect of sustainable development projects.
- With the help of experts, we were able to develop design ideas and implementation strategies, validate our designs, gather information for project sustainability, and spread the message of our project to other communities in Windhoek.

5.3 Successful Participatory Action Research

- Participatory Action Research, when used in combination with the aforementioned steps, results in effective community mobilization.
- Project teams that take a purely facilitative role, not an authoritative role, encourage the creation of structures and systems which can be implemented by the community without outside support.

5.4 Recommendations

The following section discusses our recommendations after completing the project.

5.4.1 Recommendations for the Community of Otjomuise

We recommend that the entire community participate in projects like this. Stormwater has an effect on every household, be it small or large. Although those who live at the top of the hill do not experience as much water-related damage as those at the bottom, systems need to be constructed from the top of the hill, to the bottom, in order to benefit everyone. The plot of land belongs to the whole savings group and they should therefore be concerned with the well-being of everyone in the area.

We recommend that savings groups dedicate a certain portion of their savings to a gardening program. A system much as the one used for this project can be used if previously saved money is set aside for seeds and plants. The community leader would be responsible for purchasing seeds and plants with this money. He/she would then sell the plants back to community members. The money made from this process would go back into the savings group fund. This way there is a consistent supply of money set aside for gardening and erosion control purposes.

We recommend that the people of Otjomuise be in contact with the companies and people who have helped with material gathering throughout this project. The contact numbers for all tire companies who donated to the project as well as for the Habitat Research and Development Centre in Katutura are readily available for the people. Tire companies should be willing to drop tires off in Otjomuise for free, and the HRDC is often helpful in terms of cutting tires in half and also donating soil.

5.4.2 Recommendations for the Department of Land Management

We recommend that the Polytechnic continue erosion control projects and create opportunities for students to learn about erosion control. An important part of completing our project was to create a solution that could be repeated in places where there are similar erosion control problems and parameters. Continuing projects that emphasize the importance of erosion control in Namibia and educating communities about the possible solutions is critical. Creating opportunities at the Polytechnic of Namibia for students to participate in erosion control projects and classes could have a great impact on reducing the number of erosion issues. Allowing students to participate in similar, interactive projects will let them gain necessary fieldwork expertise while spreading knowledge to the general population.

We recommend using Participatory Action Research or similar methods for carrying out future projects sponsored by the Department of Land Management. Using Participatory Action Research allows students and communities to find solutions together. It encourages communities to participate in the project and allow them to have a sense of ownership of the project. For students, they are given the opportunity to interact with a community, learn from the community, and spread knowledge.

5.4.3 Recommendations for the Namibia Housing Action Group

We recommend that a smaller area, such as one or two savings groups, be designated for sustainable development project completion within the settlements of Windhoek. In the time we had available, we found that attempting to cover such a large area as the four savings groups of Dimbokro Street was difficult to handle and may have caused residents to feel as though their storm water issues were regarded as less important. It is more important to create well constructed systems in one area than a multitude of less structurally sound systems. After the completion of demonstration systems, projects should easily be able to be extended to other areas.

We recommend that the educational materials created by our group be distributed to people living in other savings groups and settlement areas by NHAG. The materials created for Otjomuise throughout the project can be put to good use in other communities as well. NHAG should feel free to make modifications to the packets we have created as needed to adjust to new situations.

We recommend organized knowledge exchanges between savings groups throughout the settlements of Namibia.

The most important part of this project is its replicability. The residents of Dimbokro Street in Otjomuise should be able to serve as educators and encourage the expansion of their project.

5.4.4 Recommendations for the Shack Dweller's Federation of Namibia

We recommend that the Shack Dweller's Federation of Namibia become more directly involved in projects sponsored by the Namibia Housing Action Group. Though the project team worked indirectly with the SDFN, we believe that they have a lot to add to these projects due to their experience with both sustainable development projects and the communities the projects are completed in.

We recommend that the SDFN Center in Hakahana be used as a center for conveying the message to other savings groups and communities. The center would have been an excellent place to present and spread word about this specific project throughout its duration, not only at the end. If informational sessions had been held earlier on, it might have been possible to have several savings groups work on their own projects simultaneously.

We recommend that the educational materials created by our group be distributed to people living in other savings group and settlement areas by the SDFN. The materials created for Otjomuise throughout the project can be put to good use in other communities as well. The SDFN may feel free to make modifications to the packets we have created as needed.

5.4.5 Recommendations for Future WPI Project Teams

We recommend a thorough reading of the appendices in this project. The appendices of this project include detailed notes regarding the team's initial interactions with the community, how the team went about making its professional contacts, and how the team acquired its materials for the project. They also include valuable information regarding plants that can grow in the area.

We recommend frequent visits to the community with which you work. It may be initially discouraging to see community members shy away because you are English speaking. The best way to alleviate this problem it to go to the community as frequently as you can. Language will be a barrier initially, but with enough persistence you will be able to form good relationships with many of the people in the community.

We recommend that future teams depend more upon ideas generated by members of the community. A sense of ownership of the project by the residents will be an extremely important factor in the sustainability of the project. It will also encourage the generation of new ideas regardless of the presence of the project team.

We recommend that future project teams place an emphasis on the importance of the residents' ability to obtain their own materials. Although all of the materials used for this project are readily available at no cost, transportation of these materials is necessary. By working with the SDFN residents should be able to acquire what they need.

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Glossary of Terms

Namibian to English

- ***Robot -*** traffic light
- ***Erf (pl.erven) -*** plot of land in Katutura which is owned by those living on it
- ***Savings Groups -*** groups that form within the settlements to pool their resources in support of community advancement. Savings groups are also used to show the Namibian government that the poor are capable of helping themselves and are not simply waiting for outside aid and donations. The suggested size of these groups is around 30-35 people.
- ***Spade -*** shovel
- ***Epanda -*** stake
- ***Muddle -*** confuse
- ***Nawa -*** (used in many of the tribal languages) good/a greeting
- ***Tyre -*** tire

English to Namibian

- ***Traffic Light -*** robot
- ***Plot of Land -*** erf (pl. erven); is owned by the people living on it
- ***Shovel -*** spade
- ***Stake -*** epanda
- ***Confuse -*** muddle
- ***Good -*** nawa
- ***Tire -*** tyre

Appendices

Appendix A: Namibia Housing Action Group and Polytechnic of Namibia Department of Land Management

Mission

The Namibia Housing Action Group (NHAG) supports the Shack Dwellers Federation of America (SDFN) by financing projects and maintaining regional information centers and technical support (Müller, 2000). SDFN aims to improve the lives of the urban poor through several major activities: savings schemes, information collection, knowledge exchanges for development, and affordable land, resources, and infrastructure for the poor (Müller, 2006). The Polytechnic of Namibia Department of Land Management aids NHAG by developing the concept of sustainable development toward the purpose of land management. To do this, the department fosters an environment of excellence and learning through technology, research, and service (Department of Land Management, 2006).

Savings schemes are a type of social organization whereas by the urban poor obtain financial strength from the resources of their own community. By organizing into savings schemes, the poor population may exchange information and spread awareness of certain issues among themselves and with other communities. By collecting information in the urban communities the SDFN has assembled statistics on median income, the difference between the income of men and women, and other information that may help pinpoint specific problems (Müller, 2000). Community members also share information about their economic and living conditions with other members. This information is used to negotiate resources needed for the development of the community (Müller, 2006).

NHAG finances informal settlement projects by utilizing the Twhangana loan fund that is available for house building, generation of income and other SDFN activities (Müller, 2000). NHAG plans and builds houses within the informal settlements by drawing and finalizing plans, assigning land plots, and by providing training to members.

History

Starting in 1987, Namibians living in informal settlements organized themselves into groups so that collectively they could obtain land and houses. As more and more groups were created, a voluntary organization named the Namibia Housing Action Group was created in 1992. NHAG managed separate groups that had their own projects and that concentrated on different types of project management. The association soon concentrated their focus on managing these individual groups according to formal procedures instead of directly improving lives. Leaders of these individual groups felt that their goal of improving lives could be met if they formed a people's organization. Therefore, in 1998, individual savings schemes organized themselves in to the Shack Dwellers Federation of Namibia that concentrates specifically on those activities that will improve lives of the shack dwellers. NHAG became an NGO of the SDFN and acted as a support service with its own management arrangement.

Problem Relevance

Both NHAG and the Department of Land Development of the Polytechnic of Namibia focus on projects that promote sustainable development in the informal settlements of Namibia. Sustainable development refers to the realization of the people's needs while preserving the environment (Environmental law 2008). The rainwater harvesting project's goal is to help the urban poor build and tend to gardens so that they may be able to grow their own food. NHAG will utilize the SDFN system of knowledge exchanges so that many different communities will learn how to construct the harvesting system and gardens. One of the main goals of NHAG and the SDFN is to provide the urban poor with inexpensive and affordable resources, such as water. An extremely inexpensive way to obtain water to use for gardening is to utilize rainwater or to re-use water.

Funding

NHAG is a volunteer association helping people who live in low-income housing (Kummer, 2004) and is supported by IBIS, Misereor (Germany), Oxfam Canada and Homeless International (UK), Intermon and FCEAR (Spanish Corporation, Spain) (Müller, 2006). The Twahangana Fund has been established through Deswos (Germany), the Royal Norwegian Consulate, and the Ministry of Regional Local Government and Housing. Loans needed for building houses are offered by the Decentralized Build Together Program of the Ministry Regional, Local Government, housing and Rural Development (Müller, 2006).

Organization Structure

NHAG currently has seven employees with offices in Windhoek and Oshakati. Our primary contact person, Anna Müller is director of NHAG. The other employees aid the SDFN by funding its various activities on the regional and national level. NHAG also upholds equality in the allocation of needed resources, facilitates knowledge exchanges, advises savings communities and helps promote SDFN legislation ideas (Müller, 2006).

The Polytechnic of Namibia Department of Land Management currently has 17 staff members, at least 3 of whom work in the area of sustainable development. Mr.Mwewa is a professor of sustainable waste management and physical urban expansion monitoring; Mrs. Jane Gold is a lecturer on urban informal settlements, and

Mr.Endjala is Town and Regional Planning/Property development and construction lecturer (The Department of Land Management, 2006)

Resources

The Polytechnic of Namibia will provide the knowledge of lecturers that have experience in projects of sustainable development. The professors will give ideas on how to make the Namibian soil suitable for sustaining plant growth as well as how to implement processes that transport water to the soil. In addition, the Polytechnic will provide project members with two students to serve as guides and translators in the informal settlements. NHAG can provide group members with the knowledge of the informal settlement community dynamics as well as how to persuade community members to accept and implement our project. They may also provide extensive information on how to use knowledge exchanges to our advantage so that the project is continued after we have left Namibia. Although they may not be able to give the community members a large budget in which we could carry out our project, NHAG may provide villagers with resources we could use for minimal cost (for example recycled or scrap material).

Other Organizations

NHAG is a member of Slum Dwellers International (SDI), which has grown into a network encompassing twenty-four countries on three continents. The mission of SDI is to obtain housing and resources for poor people of third world countries by appealing to formal institutions and by organizing knowledge exchanges among communities of shack dwellers. NHAG is a formal organization that oversees the actions of the people's association SDFN by providing funding and managing resources used by the SDFN (SDI, 2006).

The Desert Research Foundation of Namibia (DRFN) is a non-governmental organization that plan, research and implement projects that attempt to solve problems surrounding sustainable development (DRFN, 2008). While NHAG and SDI focus on savings schemes and knowledge exchanges to spread various ideas, the DRFN focuses on the technical aspects of the problem and through research, attempts to create processes and systems that alleviate the problems.

Appendix B: Explanation of the Köppen-Geiger Climate Classification System

Köppen climate classification scheme divides the climates into five main groups and several types and subtypes (McKnight and Hess, 2000). Each particular climate type is represented by a 2 to 4 letter symbol:

GROUP A: Tropical/megathermal climates

Tropical climates are characterized by constant high temperature (at sea level and low elevations) — all twelve months of the year have average temperatures of 18 °C (64.4 °F) or higher. They are subdivided as follows:

- **Tropical rain forest climate** (*Af*): All twelve months have average precipitation of at least 60 mm (2.36 inches). These climates usually occur within 5-10° latitude of the equator. In some eastern-coast areas, they may extend to as much as 25° away from the equator. This climate is dominated by the Doldrums Low Pressure System all year round, and therefore has no natural seasons.
  Examples:
  Singapore
  Belém, Brazil.
  - Some of the places that have this climate are indeed uniformly and monotonously wet throughout the year (e.g., the northwest Pacific coast of South and Central America, from Ecuador to Costa Rica, see for instance, Andagoya, Colombia), but in many cases the period of higher sun and longer days is distinctly wettest (as at Palembang, Indonesia) or the time of lower sun and shorter days may have more rain (as at Sitiawan, Malaysia).
  - A few places with this climate are found at the outer edge of the tropics, almost exclusively in the Southern Hemisphere; one example is Santos, Brazil.
    Note. The term aseasonal refers to the lack in the tropical zone of large differences in day light hours and mean monthly (or daily) temperature throughout the year. There are annual cyclic changes in the tropics, not as predictable as those in the temperate zone, albeit unrelated to temperature but to water availability whether as rain, mist, soil, or ground water. Plant response (e.g., phenology), animal (feeding, migration, reproduction, et cetera), and human activities (plant sowing, harvesting, hunting, fishing, et cetera) are tuned to this *seasonality*. Indeed, in tropical South America and Central America, the *rainy season* (and the *high water season*) is called *Invierno* or *Inverno*, even though it could occur in the northern hemisphere summer; likewise, the *dry season* (and *low water season*) is called *Verano* or *Verão* and can occur in the northern hemisphere winter.

- **Tropical monsoon climate** (*Am*): This type of climate, most common in southern Asia and West Africa, results from the monsoon winds which change direction according to the seasons. This climate has a driest month (which nearly always occurs at or soon after the "winter" solstice for that side of the equator) with rainfall less than 60 mm, but more than (100 − [total annual precipitation

{mm}/25]).
Examples:
Conakry, Guinea
Chittagong, Bangladesh
Miami, Florida.

  - There is also another scenario under which some places fit into this category; this is referred to as the *trade-wind littoral* climate because easterly winds bring enough precipitation during the "winter" months to prevent the climate from becoming a tropical wet-and-dry climate. Jakarta, Indonesia and Nassau, Bahamas are included among these locations.

- **Tropical wet and dry or savanna climate** (*Aw*): These climates have a pronounced dry season, with the driest month having precipitation less than 60 mm and also less than (100 − [total annual precipitation {mm}/25]).
  Examples:
  Bangalore, India
  Veracruz, Mexico
  Townsville, Australia.
  - Most places that have this climate are found at the outer margins of the tropical zone, but occasionally an inner-tropical location (e.g., San Marcos, Antioquia, Colombia) also qualifies. Actually, the Caribbean coast, eastward from Urabá gulf on the Colombia–Panamá border to the Orinoco river delta, on the Atlantic ocean (ca. 4,000 km), have long dry periods (the extreme is the *BSh* climate (see below), characterised by very low, unreliable precipitation, present, for instance, in extensive areas in the Guajira, and Coro, western Venezuela, the northernmost peninsulas in South America, which receive <300 mm total annual precipitation, practically all in two or three months). This condition extends to the Lesser Antilles and Greater Antilles forming the Circumcaribbean dry belt. The length and severity of the dry season diminishes inland (southward); at the latitude of the Amazon river — which flows eastward, just south of the equatorial line — the climate is *Af*. East from the Andes, between the dry, arid Caribbean and the ever-wet Amazon are the Orinoco river' Llanos or Savannas, from where this climate takes its name.
  - Sometimes *As* is used in place of *Aw* if the dry season occurs during the time of higher sun and longer days. This is the case in parts of Hawaii (Honolulu), East Africa (Mombasa, Kenya) and Sri Lanka (Trincomalee), for instance. In most places that have tropical wet and dry climates, however, the dry season occurs during the time of lower sun and shorter days because of rainshadow effects during the 'high-sun' part of the year.

GROUP B: Dry (arid and semiarid) climates

These climates are characterized by the fact that precipitation is less than potential evapotranspiration. The threshold is determined as follows:

- To find the precipitation threshold (in millimeters), multiply the average annual temperature in °C by 20, then add 280 if 70% or more of the total precipitation is in the high-sun half of the year (April through September in the Northern Hemisphere, or October through March in the Southern), or 140 if 30%-70% of the total precipitation is received during the applicable period, or 0 if less than 30% of the total precipitation is so received.

- If the annual precipitation is less than half the threshold for Group B, it is classified as *BW* (desert climate); if it is less than the threshold but more than half the threshold, it is classified as *BS* (steppe climate).

- A third letter can be included to indicate temperature. Originally, *h* signified low latitude climate (average annual temperature above 18 °C) while *k* signified middle latitude climate (average annual temperature below 18 °C [64.4 °F]), but the more common practice today (especially in the United States) is to use *h* to mean that the coldest month has an average temperature that is above 0 °C (32 °F), with *k* denoting that at least one month averages below 0 °C.

- *Examples:*
  Yuma, Arizona (*BWh*)
  Turfan, Xinjiang, China (*BWk*)
  Cobar, New South Wales, Australia (*BSh*)
  Murcia, Spain (*BSh*)
  Medicine Hat, Alberta, Canada (*BSk*),
  Enna, Italy (*BSh*)
  desert areas, situated along the west coasts of continents at tropical or near-tropical locations, are characterized by cooler temperatures than encountered elsewhere at comparable latitudes (due to the nearby presence of cold ocean currents) and frequent fog and low clouds, despite the fact that these places rank among the driest on earth in terms of actual precipitation received. This climate is sometimes labelled *BWn* and examples can be found at Lima, Peru and Walvis Bay, Namibia.

- On occasion, a fourth letter is added to indicate if either the winter or summer is "wetter" than the other half of the year. To qualify, the wettest month must have at least 60 mm of average precipitation if all twelve months are above 18 °C, or 30 mm (1.18 inches) if not; plus at least 70% of the total precipitation must be in the same half of the year as the wettest month — but the letter used indicates when the *dry* season occurs, not the "wet" one. This would result in Khartoum, Sudan being reckoned as *BWhw*, Niamey, Niger as *BShw*, El Arish, Egypt as *BWhs*, Asbi'ah, Libya as *BShs*, Ömnögovi Province, Mongolia as *BWkw*, and Xining, China as *BSkw* (*BWks* and *BSks* do not exist if 0 °C in the coldest month is recognized as the *h*/*k* boundary). If the standards for neither *w* nor *s* are met, no fourth letter is added.

GROUP C: Temperate/mesothermal climates

These climates have an average temperature above 10 °C (50 °F) in their warmest months, and a coldest month average between −3 °C (27° F) and 18 °C (64 °F).

Some climatologists, particularly in the United States, however, prefer to observe 0 °C (32 °F) rather than −3 °C (27 °F) in the coldest month as the boundary between this group and Group D; this is done to prevent certain headland locations in New England — principally Cape Cod — and such nearby islands as Nantucket and Martha's Vineyard, from fitting into the Maritime Temperate category noted below; this category is alternately known as the *Marine West Coast* climate, and eliminating the aforementioned locations indeed confines it exclusively to places found along the western margins of the continents, at least in the Northern Hemisphere. This also moves some mid-latitude areas - such as parts of the Ohio Valley and some areas in the Mid-Atlantic States - from humid subtropical to humid continental.

- The second letter indicates the precipitation pattern — *w* indicates dry winters (driest winter month average precipitation less than one-tenth wettest summer month average precipitation; one variation also requires that the driest winter month have less than 30 mm average precipitation), *s* inidicates dry summers (driest summer month less than 30 mm average precipitation and less than one-third wettest winter month precipitation) and *f* means significant precipitation in all seasons (neither above mentioned set of conditions fulfilled).

- The third letter indicates the degree of summer heat — *a* indicates warmest month average temperature above 22 °C (71.6 °F), *b* indicates warmest month average temperature below 22 °C , with at least 4 months averaging above 10 °C (50 °F), while *c* means 3 or fewer months with mean temperatures above 10 °C.

- The order of these two letters is sometimes reversed, especially by climatologists in the United States.

- Group C climates are subdivided as follows:

- **Mediterranean climates** (*Csa*, *Csb*): These climates usually occur on the western sides of continents between the latitudes of 30° and 45°, though on the west coast of North America, they occur in small patches as far north as 48°. These climates are in the polar front region in winter, and thus have moderate temperatures and changeable, rainy weather. Summers are hot and dry, due to the domination of the subtropical high pressure systems, except in the immediate coastal areas, where summers are milder due to the nearby presence of cold ocean currents that may bring fog but prevent rain.
  Examples:
  Split, Croatia (*Csa*)
  Gaziantep, Turkey (*Csa*)
  Madrid, Spain (*Csa*)
  Marseille, France (*Csa*)
  Yalta, Ukraine (*Csa*)
  Los Angeles, California (*Csa*)
  Barcelona, Spain (*Csa*)
  Perth, Australia(*Csa*)
  Risan, Montenegro (*Csb*)
  Porto, Portugal (*Csb*)
  San Francisco, California (*Csb*).

  - **Humid subtropical climates** (*Cfa*, *Cwa*): These climates usually occur in the interiors of continents, or on their east coasts, between the latitudes of 25° and 40° (46°N in Europe). Unlike the Mediterranean climates, the summers are humid due to unstable tropical air masses, or onshore Trade

Winds. In eastern Asia, winters can be dry (and colder than other places at a corresponding latitude) because of the Siberian high pressure system, and summers very wet due to monsoonal influence.
Examples:
Houston, Texas (*Cfa — uniform precipitation distribution*)
Milan, Italy (*Cfa — uniform precipitation distribution*)
Brisbane, Queensland, Australia (*Cfa — uniform precipitation distribution*)
Atlanta, Georgia (*Cfa — uniform precipitation distribution*)
Porto Alegre, Brazil (*Cfa — uniform precipitation distribution*)
Luodian, Guizhou, China (*Cwa — summer wetter than winter*).

- **Maritime Temperate climates or Oceanic climates** (*Cfb*, *Cwb*): *Cfb* climates usually occur on the western sides of continents between the latitudes of 45° and 55°; they are typically situated immediately poleward of the Mediterranean climates, although in Australia this climate is found immediately poleward of the Humid Subtropical climate, and at a somewhat lower latitude. In western Europe, this climate occur in coastal areas up to 63° latitude. These climates are dominated all year round by the polar front, leading to changeable, often overcast weather. Summers are cool due to cloud cover, but winters are milder than other climates in similar latitudes.
  Examples:
  Limoges, France (*Cfb — uniform precipitation distribution*)
  Langebaanweg, South Africa (*Cfb — uniform precipitation distribution*)
  Curitiba, Brazil (*Cfb — uniform precipitation distribution*)
  Prince Rupert, British Columbia, Canada (*Cfb — uniform precipitation distribution*)
  Bergen, Norway (*Cfb — uniform precipitation distribution*)
  Cfb climates are also encountered at high elevations in certain subtropical and tropical areas, where the climate would be that of a subtropical/tropical rain forest if not for the altitude. Bogotá, Colombia and Crkvice, Montenegro (*Cfsb —perhumid Mediterranean mountain climate without summer dryness*, Crkvice on Orjen holds also Europe's precipitation record - averaging 4927 mm/m² 1931-1960) are perhaps the best examples.
  Cwb is found only at higher altitudes, without which the climate would be tropical wet and dry.
  Examples:
  Addis Ababa, Ethiopia
  Mexico City, Mexico
  Campos do Jordão, Brazil)
  In parts of the Pacific Northwest of North America and parts of south-western South America, *Cfb* climates are also sometimes similar to Mediterranean climates in that summers are relatively dry. Examples include:
  Seattle, Washington (*Cfb*, sometimes *Csb*)
  Victoria, British Columbia, Canada (*Cfb*, sometimes *Csb*)
  Puerto Montt, Chile (*Cfb*, sometimes *Csb*).

- **Maritime Subarctic climates** or **Subpolar Oceanic climates** (*Cfc*): These climates occur poleward of the Maritime Temperate climates, and are confined either to narrow coastal strips on the western poleward margins of the continents, or, especially in the Northern Hemisphere, to islands off such coasts.
  Examples:
  Punta Arenas, Chile (*Cfc — uniform precipitation distribution*)
  Monte Dinero, Argentina (*Cfc — uniform precipitation distribution*)
  Reykjavík, Iceland (*Cfc — uniform precipitation distribution*)
  Tórshavn, Faroe Islands (*Cfc — uniform precipitation distribution*)
  Harstad, Norway (*Cfc — uniform precipitation distribution*).

GROUP D: Continental/microthermal climate

These climates have an average temperature above 10 °C in their warmest months, and a coldest month average below −3 °C (or 0 °C in some versions, as noted previously). These usually occur in the interiors of continents, or on their east coasts, north of 40° North latitude. In the Southern Hemisphere, Group D climates are extremely rare due to the smaller land masses in the middle latitudes and the almost complete absence of land south of 40° South latitude, existing only in some highland locations in New Zealand that have heavy winter snows.

- The second and third letters are used as for Group C climates, while a third letter of *d* indicates 3 or fewer months with mean temperatures above 10 °C *and* a coldest month temperature below −38 °C (−36.4 °F).

- Group D climates are subdivided as follows:

  - **Hot Summer Continental climates** (*Dfa*, *Dwa*, *Dsa*): *Dfa* climates usually occur in the high 30s and low 40s in latitude, and in eastern Asia *Dwa* climates extend further south due to the influence of the Siberian high pressure system, which also causes winters here to be dry, and summers can be very wet because of monsoon circulation.
    Examples:
    Boston, Massachusetts (*Dfa — uniform precipitation distribution*)
    Chicago, Illinois (*Dfa — summer wetter than winter*)
    Santaquin, Utah (*Dfa — summer drier than winter*)
    Seoul, South Korea (*Dwa*).
    Dsa exists only at higher elevations adjacent to areas with hot summer Mediterranean (*Csa*) climates, such as Cambridge, Idaho and Saqqez in Iranian Kurdistan.

  - **Warm Summer Continental or Hemiboreal climates** (*Dfb*, *Dwb*, *Dsb*): *Dfb* and *Dwb* climates are immediately north of Hot Summer Continental climates, generally in the high 40s and low 50s in latitude in North America and Asia, and also in central and eastern Europe and Russia, between the Maritime Temperate and Continental Subarctic climates, where it extends up to high 50s and even lowest 60 degrees latitude.
    Examples:
    Moncton, New Brunswick, Canada (*Dfb — uniform precipitation*

distribution)
Minsk, Belarus (*Dfb — summer wetter than winter*)
Revelstoke, British Columbia, Canada (*Dfb — summer drier than winter*)
Fargo, North Dakota, (*Dfb — winter drier than summer*)
Vladivostok, Russia (*Dwb*).
Stockholm, Sweden (*Dfb — winter somewhat drier than summer*)
Dsb arises from the same scenario as *Dsa*, but at even higher altitudes or higher latitudes, and chiefly in North America since here the Mediterranean climates extend further poleward than in Eurasia; Mazama, Washington is one such location.

- **Continental Subarctic or Boreal (taiga) climates** (*Dfc*, *Dwc*, *Dsc*):*Dfc* and *Dwc* climates occur poleward of the other Group D climates, mostly in the 50s and low 60s North latitude, although it might occur as far north as 70° latitude.
  Examples:
  Sept-Îles, Quebec, Canada (*Dfc — uniform precipitation distribution*)
  Anchorage, Alaska (*Dfc — summer wetter than winter*)
  Mount Robson, British Columbia, Canada (*Dfc — summer drier than winter*)
  Irkutsk, Russia (*Dwc*).
  Kirkenes, Finnmark, Norway (*Dfc - summer wetter than winter*)
  Dsc, like *Dsa* and *Dsb*, is confined exclusively to highland locations near areas that have Mediterranean climates, and is the rarest of the three as a still higher altitude is needed to produce this climate. Two examples are Zubački kabao, Montenegro (*Dfsc* perhumid Mediterranean snow climate) and Galena Summit, Idaho.

- **Continental Subarctic climates with extremely severe winters** (*Dfd, Dwd*): These climates occur only in eastern Siberia. The names of some of the places that have this climate — most notably Verkhoyansk and Oymyakon — have become veritable synonyms for extreme, severe winter cold.

GROUP E: Polar climates

These climates are characterized by average temperatures below 10 °C (50 °F) in all twelve months of the year:

- **Tundra climate** (*ET*): Warmest month has an average temperature between 0 °C (32 °F) and 10 °C (50 °F). These climates occur on the northern edges of the North American and Eurasian landmasses, and on nearby islands; they also exist along the outer fringes of Antarctica (especially the Palmer Peninsula) and on nearby islands.
  Examples:
  Iqaluit, Nunavut, Canada
  Provideniya, Russia
  Deception Island, Antarctica.
  Longyearbyen, Svalbard

ET is also found at high elevations outside the polar regions, above the tree line — as at Mount Washington, New Hampshire.

- **Ice Cap climate** (*EF*): All twelve months have average temperatures below 0 °C (32° F). This climate is dominant in Antarctica (e.g., Scott Base) and in inner Greenland (e.g., Eismitte or North Ice).

- Occasionally, a third, lower-case letter is added to *ET* climates if either the summer or winter is clearly drier than the other half of the year; thus Herschel Island ('Qikiqtaruk', in Inuvialuit) off the coast of Canada's Yukon Territory, becomes *ETw*, with Pic du Midi de Bigorre in the French Pyrenees acquiring an *ETs* designation. If the precipitation is more or less evenly spread throughout the year, *ETf* may be used, such as for Hebron, Labrador. When the option to include this letter is exercised, the same standards that are used for Groups C and D apply, with the additional requirement that the wettest month must have an average of at least 30 mm precipitation (Group E climates can be as dry or even drier than Group B climates based on actual precipitation received, but their rate of evaporation is much lower). Seasonal precipitation letters are almost never attached to *EF* climates, mainly due to the difficulty in distinguishing between falling and blowing snow, as snow is the sole source of moisture in these climates.

Plant Sign Up List

Each plant costs $10. We will bring manure in to use when we plant in this area. This list leaves enough space for what is available right now.

Mango:

1.
2.
3.
4.
5.
6.
7.
8.
9.
10.

Cashew Nut:

11.
12.
13.
14.
15.
16.
17.
18.
19.
20.

Lemon:

21.
22.
23.
24.
25.
26.

Wild Olive:

27.
28.
29.
30.
31.

False ebony:

32.
33.
34.
35.
36.

Celtis Africana (White Stinkwood)

37.
38.
39.
40.
41.

Rhus

42.
43.
44.
45.
46.

Albezia Anthelmetica

47.
48.
49.
50.
51.

Grapes:

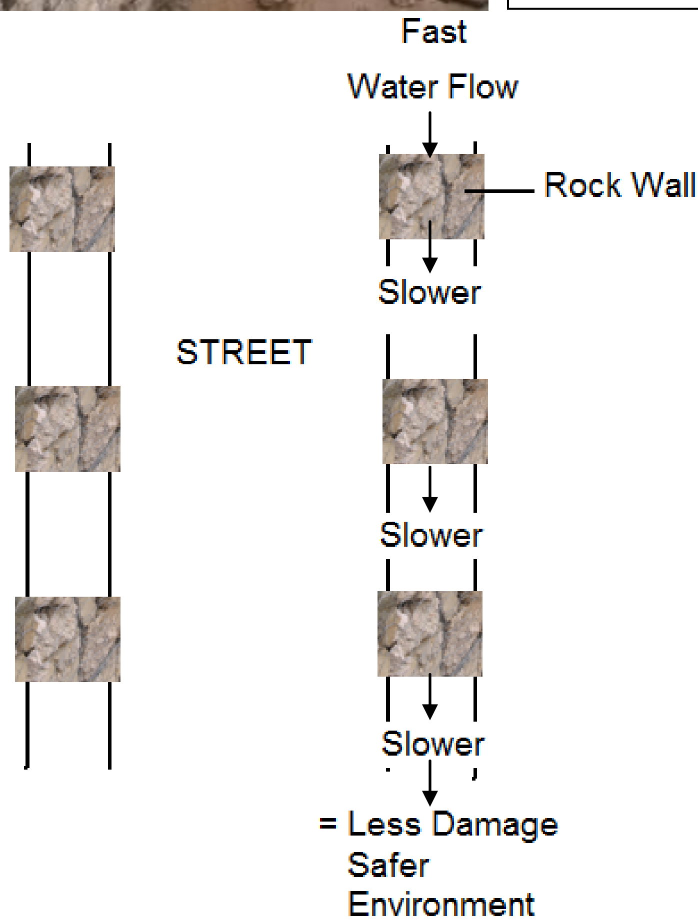
52.
53.
54.
55.

Tire Wall

This can be used to make the water scatter instead of making large streams. The water will move slowly through the tires.

Rock Walls

This can be used to slow the flow of water. This may be useful along the street.



Runoff Dispersement Tire System

This can be used to slow the flow of water. The water will have to go around the tires. The rocks between the tires will also slow the water.

Rooftop Collections

Placing rocks below your rooftop will help with flooding problems. It may also help to form gardens by slowing the water.

Appendix E: Importance of Stormwater Management Pamphlet

Rocks

Large rocks and stones may be placed next to houses to absorb some of the energy from falling water. This will help to stop the water from digging the soil away from the side of your house.

Look at the way the water falls off of your roof and place rocks directly where you think it will fall.

Rooftop Rainwater Management

Collecting water from your roofs is a good way to help stop erosion. It also creates another source of water which can be used for things such as cleaning and watering plants.

WPI IOP 2008

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Marissa Olay, Jennifer Keating, Jocelyn Moody, & Daniel Irwin

Methods for Stormwater Management

Erosion & Flooding—Control & Prevention

WPI IOP 2008

The Importance of Stormwater Management

Stormwater during the rainy season in Namibia affects most people living in the settlements of Windhoek. Both flooding and erosion are commonly faced community problems. Fast flowing rainwater often causes large channels and holes to be carved into the soil – which can be dangerous to the children and elderly people of communities.

There are many ways to help stop homes from flooding and to reduce the amount of erosion in communities. One way to help with these problems is to create systems that redirect and slow runoff water, as well as help the soil to soak some of the water up. Some of these systems are:

- Gabions
- Tire walls
- Half-tire walkways
- Spillways
- Mulch pits
- Vegetation

Vegetation

Vegetation can be very helpful in reducing the speed of water flowing downhill, as well as the amount of water which flows down the hill. It absorbs water. You can plant vegetation to stabilize the soil and decrease the amount of erosion in the area.

Mulch Pits

Mulch pits can be used to enrich the soil so that plants may grow more easily than they usually do in arid areas.

Tire Walls

Tire walls can be used to slow water flow in steep areas. Setting up a system like this will make water which was once in large streams scatter and go

Spillways

The purpose of the spill way is to direct the flow of water into a specific area. You can use a spillway to direct water into a mulch pit or garden. When enough water has been directed to your area of interest any excess water will spill through the system and continue down the hill.

Half-Tire Walkways

These can be used to slow the flow of water. The water will have to go around the tires. The rocks between the tires will also slow the water.

Rotse

Groot rotse en klippies mag kan langs die huise neer gesit word om energie van vallende water op te suig. Dit sal hulp om water wat an die kant van die huis in die grond in grou te stop.

Kyk op die manier die water van die dak aaf val en dan sit die klippe reg waar jy dink dit sal val.

Dak water opvang

Om water van die dak te op te vang is n goeie manier om erosie te hulp stop.

WPI IOP 2008

WPI PAKH Team 2008
Marissa Gray, Jennifer Keating, Jonathan Moody, & Daniel Swan

Leiding van Stormwater

Erosie & Vloede

WPI IOP 2008

Leiding van Stormwater

Vloedwater gedurende die reenseison in Namibia benadeel die lewens van baie mense in die nedersettings. Beide vloede en erosie is algemeen ondervind gemeenskaplike problem. Vinnige reen water veroorsaak gereeld groot hoeveelheid kanale en gate in die grond. Wat baie gevaarlik is vir die kinders en bejaardes in die gemeenskap.

Daar is baie maniere om die voorkoming dat huise verspoel en die vermindering van erosie in die gemeenskap. Een van die maniere om te help met die problem is om 'n stelsel te installeer wat die water nastuur en stadig afloop van die water. Sommige van die metodes is:

- -Skanskorf
- -Tyre muur
- -Halwe tyre loopban
- -Stroomis dekblare put
- -Mus pit
- -Plantegroie

Vegetasie

Plante groei kan baie hulp saam wees in die afwaardse water vloei verminder asook die hoeveelheid water wat afwaards vloei. Plante groei absorber water. Om plante te plant om grond te stabiliseer en die vermindering van erosie in die omgewing.

Mus pit

Mus pitte kan gebruik word om die grond te verryk sodat die plante makliker kan groei anders as dit in dor area.

Tyre muur

Die kan gebruik word om die water te laat spat in plus van groot strome te maak. Die water sal stadig deur die tyres beweeg.

Spillways

Die reede van die stroomis dekblare put is om vloei van die water in n spesifieke deeling in te lei. Jy kan n stroomis dekblare put ook gebruik om water in n muspit of tuin in te lei. Waaneer genoeg in jou gebied van fokus gelei is sal enige meer water uitspoel deur die systeem en verder van die heuwel aaf.

Halwe tyre loopban

Die kan gebruik word om die water stadig te laat vleoi. Die water sal om die tyres moet gaan. Die klippe tussen die tyres sal ook die water stadiger laat vloei.

Kyk op die manier die water van die dak aaf val en dan sit die klippe reg waar jy dink dit sal val.

Appendix F: How to Build a Tire Wall Pamphlet

Tyre muur

Die kan gebruik word om die water te laat spat in plus van groot strome te maak. Die water sal stadig deur

die tyres beweeg.

Hierso is somige tyre mure wat mense van Otjomuise gebou klaar gemaak het.

Dimbokro Str., Otjomuise

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How to Make a Tire Wall

Hoe om n stortente tyre muur te maak

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Tire Walls

Tire walls can be used to slow water flow in steep areas. Setting up a system like this will make water which was once in large streams scatter and go through the tires.

These are some tire walls that the people in Otjomuise have already made.

Dimbokro Street, Otjomuise

How to Make a Tire wall

1. Dig a hole where the tires will be placed.
2. Place the bottom row of tires in the hole
   -Make sure to place them close to each other

3. Fill inside side-walls with large stones

4. Fill center with soil and stones

5. Build another row on top of the bottom

-Build the row slightly off center
-Use the hill to support the wall

Hoe om n stortente tyre muur te maak

1. Gat te grou waar die tyres sal gesit word.
2. Sit die onderste ry van tyres in die gat
   -Maak seker om hulle naby ann mekaar nee rte sit

3. Vul in tussen kant muure met groot klippe

4. Vul middle met sand en klip

5. Bou ander ry op die onderste

-Bou die lyn skyns van die middle
-Gebruik die heuwel om die muur support.

Appendix G: How to Build a Tire Walkway Pamphlet

Halwe tyre loopban

Die kan gebruik word om die water stadig te laat vleoi. Die water sal om die tyres moet gaan. Die klippe tussen die tyres sal ook die water stadiger laat vloei.

Hierso is somige halwe tyre loopban wat mense van Otjomuise gebou klaar gemaak het.

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How to Make a Half Tire Walkway

Hoe om n halwe tyre loopban te maak

WW IQP 2008

Half Tire Walkway

These can be used to slow the flow of water. The water will have to go around the tires. The rocks between the tires will also slow the water.

These are some half tire walkways that people in Otjomuise have built already.

How to make a half tire walkway

1. Cut tires in half

2. Dig two small holes for each end of the tire

3. Place the half-tire in the holes

4. Fill the surrounding area around the tire with soil and small pebbles.

Hoe om n halwe tyre loopbaan te maak

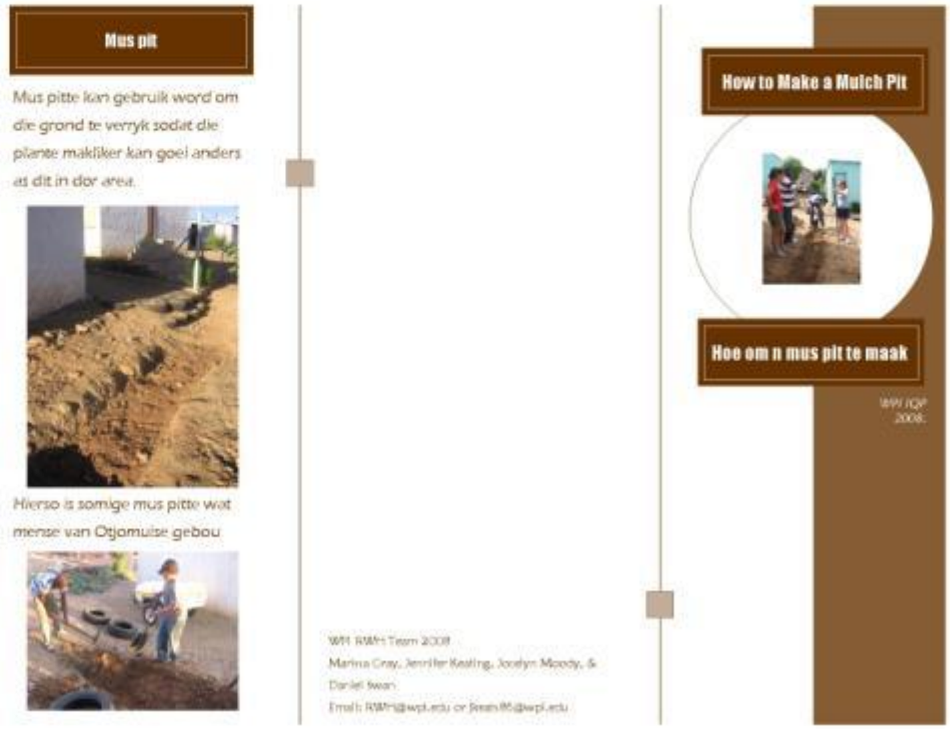
1. Sny die tyres in die heelfte

2. Grou twee klein gate vir elke einde van die tyre

3. Sit die halwe tyre in die gat

4. Vul die omgewing van die tyre met sand en klien klippies.

Appendix H: How to Build a Mulch Pit Pamphlet



Mus pit

Mus pitte kan gebruik word om die grond te verryk sodat die plante makliker kan goei anders as dit in dor area.

Hierso is somige mus pitte wat mense van Otjomuise gebou

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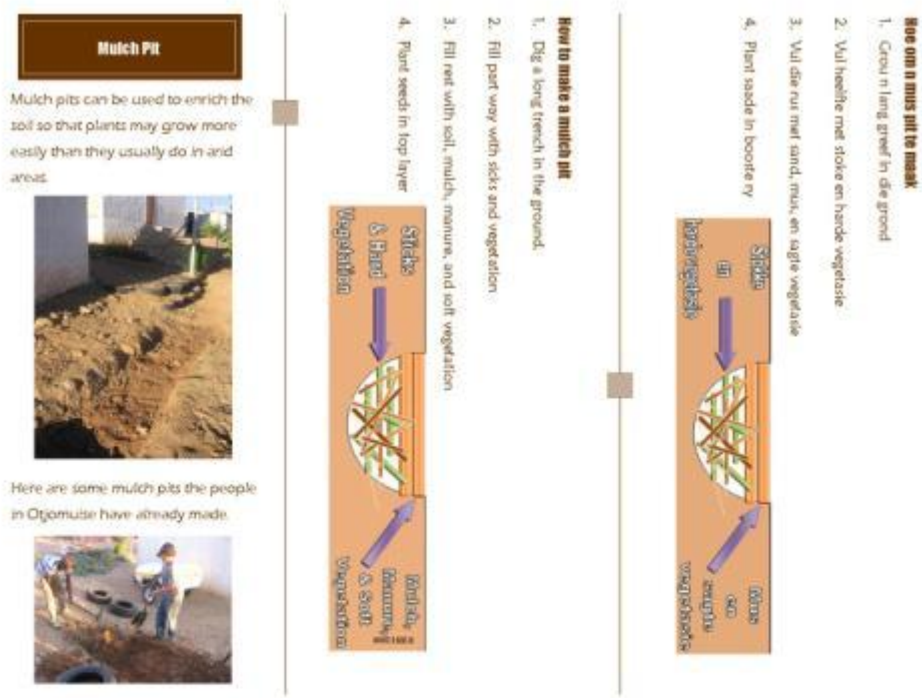
How to Make a Mulch Pit

Hoe om n mus pit te maak



Mulch Pit

Mulch pits can be used to enrich the soil so that plants may grow more easily than they usually do in arid areas.

Here are some mulch pits the people in Otjomuise have already made.

How to make a mulch pit

1. Dig a long trench in the ground.
2. Fill part way with sicks and vegetation
3. Fill rest with soil, mulch, manure, and soft vegetation
4. Plant seeds in top layer

Hoe om n mus pit te maak

1. Grou n lang greef in die grond
2. Vul heelfte met stoke en harde vegetasie
3. Vul die rus met sand, mus, en sagte vegetasie
4. Plant saade in boonste ry

Appendix I: Design Plan for Otjomuise

Appendix J: Plants Available for Sale

Plants Obtained at the National Forestry Research Center – Directorate of Forestry

Mango (10)

Cashew Nuts (10)

Lemon (6)

Wild Olive (5)

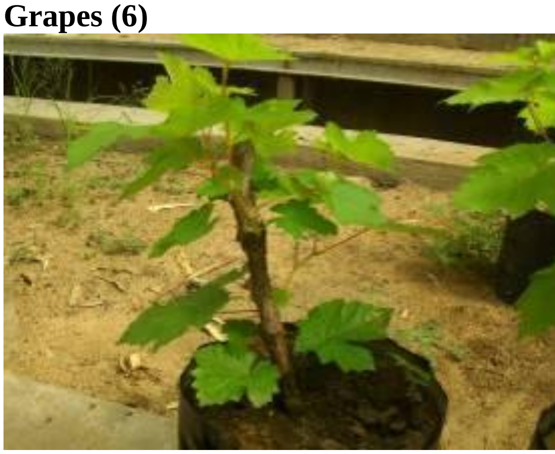

False Ebony (5)

Celtis Africana (White Stinkwood) (5)


Rhus (5)

Albezia Anthelmetica (5)

Grapes (6)



Appendix K: Plant Care Booklet

Celtis africana

Height: 12-25m
Description: Mature trees will have a single, straight trunk branching to form a circular, thick canopy. The trunk has smooth, gray to white bark which may be loose.
Growth: Easy to grow, reasonably drought resistant. Best with rich, deep soil and plenty of water but will grow in arid regions as well. Nice shade tree when planted on the northern or western side of the house. The seeds may germinate easily and it is best to take seeds directly from the tree, not the ground where they are most likely to be infested with bugs. The seeds should be spread in a thin layer and covered with a layer of soil and compost and should be planted in a shady area. Germination will take place between 15 to 30 days. After this time the seeds will be ready for transplanting and should grow 1 to 2 meters per year.

Albizia adianthifolia

Height: Max height of 40m
Description: Canopy takes the shape of a flat crown. Bark is reddish brown and has a rough texture. The flowers are large and the petals are white or greenish white. The tree flowers in the spring during the months of September to November. The trees are not threatened at the moment but are increasingly being exploited for their medicinally important bark.
Growth: Usually grown in tropical areas although they can be grown in more tropical areas. If planting by the seeds, soak seeds in warm water overnight to allow water to seep into the leathery seed coat. Then plant in a mixture of soil and compost. Transplant seedlings quickly as they immediately form strong, deep roots. Grows the best in humus-rich, sandy soil and should be watered every second or third day. Not frost resistant.

Grapes

Type: Perennial
Height: According to surroundings
Description: Spherical shaped fruit are grown on a woody vine and is usually green or red. The leaves are large and glossy.
Growth: Usually grown in a warm climate with adequate rainfall but may survive in arid temperatures if watered. The soil should be fertile, deep, and well drained, and should be 1 meter deep. The plants should be spaced 1.5 meters apart. Unpack vines in the shade and plant ASAP. Do not expose the roots to the sun or wind. Plants from a nursery should be planted at the depth in which they came in. Grapes need water in the spring when growing but they do not need as much water while the fruit is ripening. After the fruit has been harvested the vines need to be watered again to rebuild reserves. In the summer the plants should be watered every 3-4 weeks. The plants should be grown with fertilizer.

Melons

Type: Annual
Description: Vine plant that spreads along the ground. Produces large, round fruit of usually two varieties: Musk/Netted Melons or Cantaloupes/Winter Melons

Growth: Melons require a considerable amount of attention and fare best in light to medium soils that have been improved. They should be planted l meter apart and holes should be well dug, treated with compost, and 30-45 cm in diameter. The best time for direct outdoor sowing is from September to early December. Watering melons is extremely critical at all stages of growth. As plants develop and weather is warmer, they should be watered twice a week. Harvest fruit when color changes are visible or when the blossom ends of the melon yield when pressed by a thumb.

Pumpkins
Type: Annual

Description: Vine plant that spreads along the ground and produces large greenish white or orange fruit.
Growth: Pumpkins are warm weather crops and can be easily damaged by even light frosts. They demand a moderate level of soil fertility and respond to liberal amounts of manure and compost as well as adequate soil drainage. They are not suitable for small gardens because of their widespread growth and require ample space.

Gooseberries

Type: Perennial
Description: Blossoms into a bush with round yellow fruit enclosed in an outside sheath. Berries can be eaten raw, made into jam, bottled or stewed, and popular in pies.

Growth: In frost free areas gooseberries can be a winter crop but in frost areas they are typically a summer crop. Seeds should be sown from August to September in frost areas. They thrive in practically any type of soil as long as it is well drained. Soil that is too rich results in rapid growth and poor fruit development. For best results the plants should be spaced 600mm apart and rows should run north to south. Seedlings should be planted regularly until they are established. After, the plants need water after 2-3 weeks in dry weather. The fruit is ripe for picking when the outside coating is biscuit colored and almost dry while the berried inside should be yellow.

Citrus Fruits such as Lemons and Oranges

Height:

Growth: Citrus fruits are prone to frost so if planted in frost areas, they should be covered and treated in the winter. The trees should be planted near the house so as to protect them from both hot and cold winds which are both damaging to the plants. Trees should be planted at least 5 meters apart and should get plenty of sun. They can be planted at any time throughout the year but for cold areas, they should be planted in the spring to the trees a full growing season before winter. The soil should be moist before planting and the tree should also be planted with a mulch compost mix. Citrus trees need regular watering when flowering and when fruit develops, from June to March. The trees do not need regular

Description: These trees provide large fruit that is yellow and orange in color and also has rough skin. The trees have an attractive round shape with small green leaves and are normally grown on a large scale, although single trees are an excellent addition to your home.

Mangoes

Height: 10m
Description: The mango tree produces oblong shaped, red and purple skinned fruit. It also has large, glossy leaves and can grow to be quite large.

Growth: These trees should be planted at least 10m apart in regular soil at least 2m deep. Mangoes like light soils which allow them to be dry from May to July for good fruit development. Mangoes do not thrive in soils that are not drained properly. To plant, the soil in containers must be moist. Dig a hole larger than the container, place plant in it, pack the soil around the tree and water thoroughly. The best time to plant is from December until the end of February, during the rainy season. Fertilizer should be used every 4 months and the trees do not require pruning. The trees are self-fertile and fruit can be picked when the skin is well colored.

Cabbages

Type: Annual
Description: Cabbages are widely grown because they will grow in a wide range of climates and soil conditions. A cabbage plant, when fully grown, is a full head of large, green, edible leaves that can be eaten raw or cooked.

Growth: Cabbages rely on soils that are rich in organic matter like compost and manure, like those of a mulch pit. Seeds can be planted throughout the year and are placed in little holes and covered with about 8-10mm of soil and packed down. The plants should receive a lot of sun and should be spaced anywhere from 35-60 cm apart. The plants are likely to thrive in a soil with adequate moisture but the plants do not need as much water when the cabbage heads are firm. Too much water can cause damages to the heads. Cabbages can be harvested when the heads are firm and should be cut with 2 or 3 outer leaves. The stumps should then be removed.

Swiss Chard (Spinach)

Type: Annual

Description: Swiss Chard is a large, leafy, dark green plant. It has a broad leaf stalk with dark, crumpled leaves.

Growth: Can be grown in a variety of different soils and grows best in manure or compost treated soils. To plant, the soil should be raked and the seeds should be planted in shallow holes about 35-45cm apart. During hot weather, the seeds should be covered with a layer of grass for protection. The best time to grow Swiss Chard is form May to July although it can be planted in many months throughout the year. Leaves can be picked about 8 weeks after planting and when they are large. Leaves must be picked quickly or else they will be tough and discolored. They should be removed through a twisting action, not being cut with a knife.

Sweet Corn (Maize)

Type: Annual

Description: Tall Stalks with long and narrow green leaves produce cobs of small, edible, yellow kernels. These cobs or ears of corn can be harvested, cooked, and eaten.

Growth: Corn is a warm weather crop and needs full sunlight. It grows best in deep, fertile soil and should be planted from September to December. Seeds should be planted in rows 25-30cm apart and should be covered with 4-5 cm of soil. Cobs are picked when the kernels are plump and full and when the silks are very dry. Most types of corn take 2-3 months to get to this stage. Cobs are removed by pulling downward and the husks and silks can be easily peeled off the kernels.

Granadillas

Type: Perennial
Description: Produces large, round, purple skinned fruit that has a unique sub-acid flavor. The leaves of the long vines are small and green.

Growth: Grows best in frost free areas but can be grown in frost areas if plants are well protected when they are young. They will grow in nearly all types of soil, and when planted the vines should be at least 3m apart. Vines usually need something to climb so plant granadillas along posts or walls for best results. When planted, water plants thoroughly but after they mature plants can be planted once a month during winter months and twice a month after August. After they have finished bearing fruit in January and July, plants should be pruned back so they can produce again. The fruit should be picked when it has turned purple but keeps well even when shriveled.

Pears

Type: Perennial
Description: Pear trees produce large, pale green fruit with a narrow top and a large bottom. The leaves of a pear tree are small and dark green.

Growth: Pears grow best when the winters are very cold but the summers are cool. They grow in almost all soil types but sandy soils must be supplemented by organic material and fertilizer. Trees grow large and should be planted with the soil from the nursery or store. Trees should be watered every 3 weeks in the winter and spring until the summer rains begin. In the winter, the trees should be watered during long dry spells. Pears can be shaped and pruned to about 2.4m tall. Pears can be picked before they are ripe and they should not be dropped. Fruit should be stored in dark cupboards.

Rhus lancea (Karee)

Height: 8m high with a 5m spread
Description: The Rhus tree has a weeping shape with dark bark and long, thin, dark green leaves that grow in groups of 3. It produces small yellow flowers and small, flat, yellow-green fruits which attract birds.

Growth: This tree is frost hardy and drought resistant so it can grow in almost any environment. It should be planted in a hole slightly deeper than the soil contained with the tree when taken from the nursery and watered thoroughly. The tree is a great shade tree and can be planted near houses. It can be grown in almost any soil but favors areas rich in lime.

False Ebony

Height: 5-7m
Description: Small tree with shiny leaves that when they are young are purple-pink in color. The fruit is round, fairly large, and light green with a dark brown powder on the surface.

Growth: Grows in many different environments around the world. May adapt to poor soil conditions and should be protected from frost when young. They should be planted in a hole the size of the container in which it came. The fruit are yellow when ripe with a sweet yellow flesh.

Wild Olive

Height: 5-10m
Description: This tree often has more than one stem and has a round top. The leaves are greenish-gray and shiny and darker on the underside. Wild olive trees produce small olive-like fruit that is much smaller, about 8mm wide. The fruit is mature in the winter and is black.

Growth: When the tree is young it is fast growing and is resistant to frost and drought conditions. Wild olives can grow in almost any soil but should be watered thoroughly when planted. It should be planted in a large hole about the size of the soil in which it came. The fruit is produced in the winter and provides food for many birds. Little care is needed for the wild olive.

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