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Manual on training in

"Extension services in horticulture and irrigation with special reference to rainwater harvesting in Namibia"

Training material and documentation

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All publications of this series:

Water Storage:

#1 Ferrocement Tank

#2 Rectangular Underground Tank

#3 Pond

Horticulture and related Infrastructure:

#4 Greenhouse

#5 Drip Irrigation

#6 Sustainable Techniques and Practices for Water Harvesting and Conservation and their Effective Application in Resource Poor Agricultural Production
(copy provided by the Water Research Commission South Africa)

Organisation and Extension Services:

#7 Proposal for a Rainwater Harvesting Builder's Yard

#8 Extension services in horticulture and irrigation with special reference to rainwater harvesting in Namibia

#9 Cost Sheets for Rain- and Floodwater Harvesting

Preface

„CuveWaters – Integrated Water Resources Management in central-northern Namibia” is a joint research project of German and Namibian partners funded by the German Federal Ministry of Education and Research (BMBF). Main research partners are the Institute for Social-Ecological Research (Frankfurt, Germany) and the Technische Universität Darmstadt (Darmstadt, Germany). Partners in Namibia are for example the Ministry of Agriculture, Water and Forestry (MAWF) and the Desert Research Foundation of Namibia (DRFN), the project furthermore closely cooperates with One World Consultants (OWC) from Kenya. CuveWaters has developed different technologies for water supply and sanitation in central-northern Namibia, ranging from groundwater desalination to rain- and floodwater harvesting (RFWH) as well as sanitation and water-reuse. Between 2009 and 2013 different pilot plants were constructed at different places all over central-northern Namibia.

This training documentation is part of a broad offer of information material on rain- and floodwater harvesting in Namibia. Beside this document, the “CuveWaters Rain- and Floodwater Harvesting Toolkit” promotes the extension of RFWH in northern Namibia and other water scarce regions. This manual succeeds a series of rain- and floodwater harvesting manuals for Namibia which form the basis for RWH extension:

<u>Water Storage:</u>

#1 Ferrocement Tank

#2 Rectangular Underground Tank

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For more information on organisational, institutional and other general aspects of rain- and floodwater harvesting please have a look in the "CuveWaters Rain- and Floodwater Harvesting Toolkit": http://www.cuvewaters.net/Toolkits.112.0.html

For more information on the CuveWaters project please visit http://www.cuvewaters.net

Alexander Jokisch

Technische Universität Darmstadt

Darmstadt, 21.10.2015

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About

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CuveWaters – Integrated Water Resources Management in Namibia

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This manual is also available on http://www.cuvewaters.net/Toolkits.112.0.html

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Table of Content

Introduction

The training course in "Extension Services in Horticulture and Irrigation with special reference to Rainwater Harvesting in Namibia" focuses on several aspects that shall be known, when rainwater harvesting (RWH) projects are promoted or facilitated. This manual is made for extension service officers of rural development centres (RDC) and agriculture development centres (ADC) as well as for anyone else, who already has knowledge in the field of agriculture and/or rural development and is interested in RWH. The training course was held the first time from April to June 2015 on UNAM Engineering Campus in Ongwediva as part of CuveWaters training. The training material provided allows for continuous training on RWH in the future to promote RWH in water scarce communities of central northern Namibia or elsewhere. Farmers and users of RWH will find manuals with focus on implementation and operation as part of the CuveWaters Toolkit (http://www.cuvewaters.net/Toolkits.112.0.html). Members of national and international institutions will find information more condensed in the CuveWaters policy papers (http://www.cuvewaters.net/Publications.111.0.html).

Important aspects to be examined in preparation of any RFWH project are the following:

- Identifying the need: Is RWH needed? Is the need articulated by the community?
- Benefits of the project: Is there a benefit of the project? Who benefits?
- Training components: Which kind of training is necessary to implement and sustain RWH?
- Technology choice: Which technology is affordable, sustainable, and appropriate for the users?
- Participation of beneficiary: How can beneficiaries be involved and participate in project planning and implementation?
- Sustainability of the project: How can sustainability be ensured (economics, ecology, social, operation)?
- Funding if the project: How can funds be acquired to implement RWH?

Each of the RWH components requires sufficient training of project members and RWH users to ensure optimal project planning and implementation as well as sustainable operation. Therefore this training course and additional information on RWH support the imparting of knowledge on RWH, tank construction, greenhouse construction, farm management, table banking, "Participatory Impact Management" (PIM) and concepts of governance and leadership. Each aspect of RWH has to be known by a RWH community to ensure successful extension of RWH.

1 Fundamentals of rainwater harvesting

Rainwater harvesting and the fundamental elements of it will be outlined to create a common basis for the rest of the extension training. This chapter therefore, gives a short overview on RWH and the CuveWaters project. Furthermore, benefits and effects of RWH are pointed out and key elements of CuveWaters RWH projects are described.

1.1 What is rainwater harvesting

Rainwater harvesting is a simple and in some regions also traditional technology to improve the water availability at household level. Rainwater can be harvested from many different kinds of surfaces, such as roofs, streets, fields, compacted soil, and concrete surfaces. Key is the guiding of rainwater from the catchment areas to be stored in reservoirs. The RWH system can be divided into four main components: catchment, delivery system, storage/reservoir and the final use. Harvesting and storing rainwater enables the user to use it later on for many different domestic uses. Depending on the water quality, purposes can be drinking, cooking, washing and cleaning, livestock watering, and horticulture. For horticulture, the component for final water use can be a greenhouse or a plot with several beds.

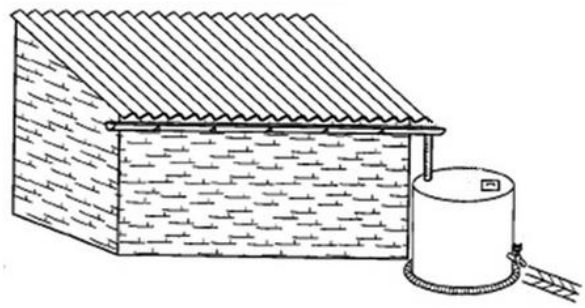

Figure 1: Sketch of RWH site.

Figure 2: RWH realized in central-northern Namibia.

1.2 What is CuveWaters

CuveWaters is a research project on Integrated Water Resource Management (IWRM) in the Cuvelai-Etosha Basin in central-northern Namibia with a subcomponent on RWH. Aim of the project is to examine several approaches of rainwater and floodwater harvesting to find the best options for the region's population from technological, economical, as well as socio-cultural point of view. The knowledge generated from CuveWaters shall be sustainably implemented to Namibia's Integrated Water Resource Management (IWRM) as well as to Namibian's everyday life. RWH and horticulture adhered to it furthermore, shall improve water and food security in central-northern Namibia and other water scarce regions.

1.3 RWH projects and benefits of RWH

Since decades RWH projects were performed in different African countries: Uganda, Ethiopia, Zimbabwe, Rwanda, Somalia, Ghana, Tanzania, and Yemen to mention some of them. Whereas, some RWH projects were stand alone projects, others were part of a region or country-wide RWH implementation and extension. To improve water availability in the project areas rainwater catchments and storage solutions were implemented. Furthermore, greenhouses were constructed to allow community level horticulture. Some projects additionally promoted the formation of Common Interest Groups (CIG) for microfinancing of RWH projects.

Lack of water for domestic use effects many aspects of everyday life in water scarce regions. Mostly, girls and women are responsible to bring water from sources which are far away from the households. Travelling between homestead and water source is a waste of productive time for the families and sometimes dangerous, especially at night. If water is not collected from piped sources, water quality may be inadequate for drinking and domestic purposes and consequently may lead to water borne diseases. Water recycling for multiple uses is often necessary to allow washing of family members followed of washing clothes, Furthermore, water scarcity often leads to conflicts at the communal water points and stresses communities' social cohesion. Helping at household level to bring water may force young girls to neglect their studies and to drop out of school.

RWH projects are aiming on the improvement of livelihoods by increasing water and food availability. Sustainable success requires community participation from the start. Participation from the start shall ensure that RWH projects come out of a response to a real need for additional water sources. Community participation is necessary in all project phases such as planning, implementation and operation and maintenance to ensure the RWH site fits the people's needs. Finally, participation creates a sense of pride and ownership and leads to success, sustainability and replication. The promotion of gender equality and empowerment of women increases the accountability of project members and ensures sustained operation of RWH sites, in addition. Horticulture as well as construction services offer business opportunities for the people in mostly remote rural areas. RWH combined with table banking activities may lead to transformation in rural and remote areas since microfinancing will support any good ideas for micro-businesses.

Figure 3: "Green Village" - Community garden for RWH and horticulture.

In general, all community members have to be trained adequately. Farmers have to be trained theoretically and practically to ensure good yields. Village executives are needed to support the sustained operation of RWH and manage extension of RWH within communities. Involvement of young people ensures the long term operation of RWH sites and the passing on of knowledge on RWH. For success of RWH training activities and RWH projects, the trainer has to become a part of the community. Each of the training participants or project members has to get to the same level and work up together. Information, mourning, laughing, dancing and crying have to be shared in the group. If one accepts the other as an equal member of the group, the desired results can be achieved.

Figure 4: Community supported construction.

Figure 5: Children showing motivation for ownership and operation of RWH.

2 Specifics of rainwater harvesting

Successful extension of RWH requires imparting of more detailed information on RWH to project members and users. The following part of this documentation summarizes the specifics of RWH that are to be known for successful project planning and implementation.

2.1 Stakeholder

RWH projects include many stakeholders of different authority levels and institutions as well as community members of different social classes. Governmental stakeholders are the employees of responsible ministries as well as of companies for water provision and regulation. Furthermore, regional and local authorities are important stakeholders in RWH activities. Beside authorities and office holders, all other community members are important participants. Other important stakeholders in RWH campaigns and projects may be donors, NGOs, and entities of the United Nations (e.g. UNICEF or UNEP).

To achieve fewer conflicts during RWH extension and single RWH projects, the aims of each of the stakeholders have to be discussed early in time. Furthermore, the scope of involvement and the degree of contribution of stakeholders should be clear from the beginning. Successful projects require coordination and in many cases balancing of interests. Beyond the scope of interests and involvement, project parameters such as funding and timing have to be coordinated between the stakeholders to avoid a fail of a project halfway.

2.2 Benefits of RWH

Benefits of RWH for individuals, which are the project members and users of RWH, are the improvement of water and food availability. Water is available close to a household or horticulture plot and no or less travelling to other water sources is necessary. Furthermore, RWH is comparatively simple to construct, install, operate and to maintain. In general, households and communities have full control over their RWH systems. While water quality may differ from one RWH site to another, the quality is in generally adequate for watering plants and animals. Finally, income can be generated by selling vegetables on local markets, if horticulture leads to a surplus of vegetables.

Benefits for local and regional communities, as well as for the national economy as a whole, are job creation for often disadvantaged rural communities due to increased water supply and food security, increased possibilities for employment and business as well as increased incomes. The communication and cooperation across social or economic classes, furthermore, strengthen the cohesion of the society.

2.3 RWH technologies

The components of a RWH system can be realized using different technologies. In general, each of the technologies leads to a functioning RWH system. Nevertheless, for each project it has to be evaluated which technologies are best for the particular users, with regards to affordability and with regards to sustainability.

Depending on scope of a RWH project and the circumstances present at the RWH site, it has to be evaluated whether roof catchments or ground catchments are more suitable. Roof catchment can be made of corrugated steel roof, plastic sheeting, concreted or tile covered roofs. If RWH shall be implemented on household level and roofs are already covered with any of the above mentioned, the preconditions partly determine the configuration of the RWH system. Storage of rainwater can be done in many different types of reservoirs. In general, tanks can be made of bricks, steel, plastic, clay, concrete or ferrocement. CuveWaters research found tanks made of ferrocement the most suitable options for RWH in central-northern Namibia. Ferrocement tanks allow for long operating life expectancies with low effort and cost for maintenance.

Figure 6: RWH from corrugated iron roof to polyethylene tanks (left).

Figure 7: Ferrocement tank for rainwater storage (right).

For community level RWH, the CuveWaters research project showed that one suitable possibility is rainwater harvesting from greenhouse roofs covered with plastic sheeting. In this case, storage of rainwater can easily done in ponds in the ground and lined with dam liner. Another option is the use of a concreted ground catchment and a corresponding underground tank. Underground tanks can be made of concrete or bricks to withstand the loads of the water stored.

When harvested rainwater is used for horticulture on household level or in community gardens, there are several irrigation methods possible for farming. Using RWH to improve water availability in water scarce regions requires water efficient irrigation methods. Traditional irrigation methods, such as flood, furrow and overhead irrigation are not suitable. The preferred irrigation is drip irrigation which comes with a high efficiency and reduces losses of water due to evaporation.

Figure 8: Greenhouse used as a roof catchment and storage in pond (left).

Figure 9: Drip irrigation for open field horticulture (right).

2.4 Costs and economic benefits of RWH

Costs and benefits of RWH may vary from one site to another. Nevertheless, experiences from former projects can be used for demonstration of cost and benefits of a RWH and horticulture on household level. Costs of RWH can be assigned either to project implementation phase or to RWH operation phase. Investment during implementation is considerably high due to the built infrastructure needed for a running RWH system. This requires financial resources for material and labour for construction. During operation phase of RWH, running costs are relatively low. Ferrocement tanks, gutters and other RWH components are long lasting and do not come along with high maintenance costs. However, seeds, fertilizers, and other material for regular use on RWH sites lead to running costs as well.

Following, an exemplary calculation of costs and benefits shows in simplified terms the potential of RWH:

Ferrocement tank for household use (30m³)	
Investment	N$ 9,000
Operation & Maintenance (per year)	N$ 75
Garden with drip irrigation (90m²)	
Investment	N$ 2,000
Operation & Maintenance (per year)	N$ 375

Revenues from one garden (90m²)	
Tomatoes or Spinach (per year)	N$ 2,700 – 5,400
Recovery of investment and O&M cost within 3-5 years.	

Table 1: Cost and Benefits of RWH

2.5 Criteria for technology selection

Technology selection for each RWH site is driven by several main aspects. Three questions guide the project planner and future users through the selection process:

1. Is it sustainable?
2. Is it affordable?
3. Is it appropriate?

Sustainability of a RWH project and the components to be used has to be discussed in the light of technical, social, environmental, and educational aspects. Technically, sustainability describes durability of the various parts of a RWH system as well as the functional interaction of all parts. In addition it is essential, that a system is easy to maintain and spare parts are available for all components. Sustainability with regards to the environment includes the suitability of a system to the terrain and climatic conditions it is exposed to. The RWH systems shall be sustainably in operation and therefore presumed environmental and climatic changes have to be included into technology selection process. Finally, social and educational sustainability of a RWH system refer to the point whether users can operate all parts of the system on their own or if external service is needed constantly. Furthermore, experienced users should be able to train new users to allow continuous operation of RWH systems and RWH should be flexible enough (technically and concepts of ownership and operation) that they can be adapted to social changes in communities.

Affordability of RWH systems is also an important aspect to be considered when technologies are selected. First, technologies used for RWH determine initial investment and running costs of the system. Both have to suit the users' or household's financial situation, which means, invests and loans may not overstress the household's budget. RWH systems may be affordable for a wider group of people when local, regional, national or international support schemes are available. For each RWH project the availability of support schemes or incentives has to be checked. Furthermore, RWH may support low-income groups extraordinarily, if the initial investment is supported. Finally, RWH material and components, which are already available locally or can be produced locally can increase affordability as well.

Figure 10: Bucket harvesting as an "easy to implement" option for RWH (left).

Figure 11: RWH with small ferrocement jar for storage (right).

Beside sustainability and affordability, the usability of RWH is an important criterion for technology selection. Preferably, RWH systems are easy to construct and maintain and labour is available locally or work is done by the users themselves. Quality of harvested water and required water quality for a specific use must match to ensure user-friendliness and appropriate use of water. Finally, RWH or specific technologies of it have to be accepted in the cultural environment where it is planned to be installed. Furthermore, management of community RWH has to fit into socio-cultural patterns.

2.6 Scope of RWH projects

Scale of RWH projects can differ largely from one site to another. As mentioned above, major determinants of size and scope of a RWH project always are the need of households and the capabilities in financial terms and regarding usability. Consequently, micro scale bucket harvesting on household level can be an adequate RWH project as well as medium scale community gardening with greenhouse and pond can be a suitable solution for another RWH project site. Tanks can be purchased, if steel or polyethylene is used. Otherwise, construction of brick or ferrocement tanks can be part of a RWH project. If brick tanks are constructed, also brick making can be part of the overall RWH project which has to be considered during project and material planning and additionally requires labour during implementation phase. Scale of tanks may differ from 5m³ to 160m³ depending on the need and overall scale of the project. Furthermore, tank capacity can be increased when additional storage solutions like ponds are installed.

Figure 12: Brick making.

Figure 13: Construction of 160m³ underground tank for community RWH.

Figure 14: RWH on household level.

Figure 15: Micro-scale greenhouse for horticulture.

Beside the technical scope of a project, also the focus of a RWH project may be different from one site to another. In some cases, RWH projects may support especially the rural poor population. In other cases, RWH projects may focus on training of women, on promotion of gender equality, or on business and job creation. Anyway, the extent of planning, construction, and management activities which accompany a RWH project are divers: tank excavation and/or construction, excavation and lining of ponds, construction of greenhouse and preparation of beds, farming activities, trainings for technicians, users and village executives and many more. Finally, outlook to ownership and coverage of real needs will secure continuous motivation of project participants.

3 Farm management, greenhouse and open field farming

Small scale horticulture as well as greenhouse farming offer users vast opportunities to increase their food security and also to generate income when surplus is produced and can be sold on local markets. Using RWH in combination with horticulture on household or community level demonstrates low cost effective technologies of agriculture to promote self help on household, group, or community level. Furthermore, minimum use of chemicals and a consistent soil improvement reduce the risk of soil and water degradation over time.

3.1 Introduction to farm management and greenhouse farming

CuveWaters implemented small scale horticulture on household level as well as medium scale greenhouse farming on community scale. In both cases, water supply for farming activities was secured by RWH components such as catchment and storage tanks. In any case, the amount and the varieties to be grown have to be adequate for the water available from RWH activities.

Greenhouse farming in particular, comes with some major benefits for the farmer. Since a greenhouse is covered and fenced by shade net, adequate temperatures for growing are present earlier than on open fields. Usually, crops grow earlier and with an enhanced growing rate which finally leads to higher yields. Furthermore pest infestation is reduced and costs for pest control are less. Depending on the irrigation method, greenhouse irrigation can be done more water efficient than traditional irrigation. Finally, temperature and light control is possible in a certain range which allows for a better and easier management of farming activities in a greenhouse.

Key tasks which enable greenhouse farming are:

1. Construction of a greenhouse.
2. Soil treatment and bed formation.
3. Installation of a drip irrigation system.
4. Seeding and Planting.
5. Training, monitoring, and evaluation.

Figure 16: Training of farmers.

Figure 17: Example of good farm management.

3.2 Seedlings, direct seeding and nursery beds

In general, some thoughts on the varieties to be grown should be discussed before the farming activities start. The questions guiding the way to a good start for farming activities are:

- What are the most economical seedlings to grow?
- Is it intended to plant seedlings into a greenhouse or on open field?
- What is the planned area of planting and which is the area demanded by each plant?
- How much water is needed for raising seedlings and growing vegetables?
- When is it best to start raising the seedlings in the course of the year and regarding the farming activities already going on?
- What method of sowing is intended to be used?

After decision was made, which plants and varieties to grow, a suitable place to grow seedlings has to be found. Preferably, the place for raising seedling is bright and airy, sheltered from harsh sun, from other strong weeds as well as from heavy rain.

Raising seedlings and growing plants can be started using different methods. Direct seeding to the beds is possible for most vegetables, like spinach, cabbage, tomato, green pepper and onion. While direct seeding does not require additional efforts for transplanting of seedlings, the water demand in general is higher, due to evaporation and drainage. Nevertheless, for some vegetables direct seeding does not work well and leads to small yields only. Examples which do not grow well with direct seeding method are butternut, water melon, and cucumber. Another method for seeding vegetables is the nursery beds method. Some special beds, called nursery beds, are prepared. Soil is treated and enriched with manure or compost to ensure sufficient nutrients and a good draining of water and ventilation of soil. Vegetable seedlings are raised in the nursery beds with special care. When seeds were germinating and seedlings are ready, the plants are transplanted to the beds. However, transplanting the seedlings is the crucial point. Damages of roots and sprouts may lead to die-off of up to 50% of seedlings. Finally, seedlings can also be raised in seed trays. Seed trays allow a very special care for the seeds during germination. The trays can be made of various materials, but in any case need drainage holes to allow excess water to run off. As long as sufficient light hits the trays, they can be stored vertically in racks in a certain shed or micro-greenhouse which reduces the space required.


Figure 18: Seeding to a seed tray.


Figure 19: Seedlings in a nursery bed.

Transplantation of seedlings from trays is easier than from nursery beds, because roots are densely packed in the soil bales and damages occur less often. Transplanting usually is done 3 to 4 weeks after seeding, depending on the type of vegetable. Best time for transplanting the seedlings is in the evening, when the temperatures are lower. This reduces the risk of water stress for seedlings and ensures plants can adjust to the new environment overnight.

Independent from the seeding method used, the seeds have to be covered with 5 to 15mm of soil. Irrigation should not be done directly to the seed, but in close proximity to not rinse or splash away soil and seeds. Furthermore, soil has to be kept damp but not wet to ensure proper germination of seed and growing of seedlings. Watering twice a day is a good start and can be adjusted according to specific conditions at a horticulture site. Some vegetable seedlings grow better, when foliar feed is applied. Always observe seedlings and plants for fungal infections or pest infestations.


Figure 20: Tomato seedling (direct method).


Figure 21: Drip irrigation of tomato seedling.

3.3 When to plant certain vegetables in Namibia

When to plant certain vegetables in Namibia always depends on local climatic conditions. Nevertheless, the following table is a good reference to start from. Furthermore, greenhouse farming allows planting activities more early in time than open field farming does. Monitoring of temperatures and plant growth allows for an optimization of planting schedules from one year to another. Most vegetables do well after July, when the cold season is over. Nevertheless, water melon and butternut will not grow well, when there is too much water.

In general, growing vegetables all year long is possible in a greenhouse, but increases the effort and management required. Temperature and light control is more challenging, as well as usage of larger amount of fungicides and pesticides may be necessary. In total, production cost for vegetables increase and have to be considered.

Vegetable	J	F	M	A	M	J	J	A	S	O	N	D
Tomatoes	✓	✓	✓	✓	(✓)	(✓)	(✓)	✓	✓	✓	✓	✓
Cabbage			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Onions	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	
Green Pepper	✓	✓					✓	✓	✓	✓	✓	✓
Spinach	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Water melon	✓	✓	✓						✓	✓	✓	✓
Butternut	✓	✓						✓	✓	✓	✓	✓
Carrots	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Table 2: General guide when to plant vegetables in Namibia.

3.4 Greenhouse tomato farming

To begin with, there is no single best way for growing tomatoes. Many techniques are possible and may lead to good results. Each individual grower must experience tomato farming on his own to find the best and most economic techniques for his or her greenhouse. Nevertheless, greenhouse tomato farming comes with the advantage, that tomatoes can be grown in the cold season as well. Farming in cold season comes with higher farm management effort, but reduced availability of vegetables leads to higher market prices which can compensate the expenses. As a rough estimation, greenhouse tomatoes need 3 month for growing flowering and formation and fruits. The harvest period is at least 4 month long.

3.4.1 Light and temperature control

For optimum growth of tomatoes, the grower must keep the greenhouse in the right temperatures. A thermometer is required in the greenhouse to ensure temperature can be monitored continuously. In warm or hot outdoor conditions, greenhouses must be ventilated to keep temperatures below 40°C. Too high temperatures not only affect the leaves and fruits of a tomato plant, but also reduce root growth and impair the yield for the whole lifecycle of a plant. Furthermore, too high temperature leads to abortion of flowers which from fruits when pollinated. In general, the construction method with a plastic sheet covering the greenhouse and shade net forming the sidewalls of the greenhouse ensures sufficient ventilation during hot periods.

Nevertheless, growers may be forced to increase ventilation manually or by temporary opening of roof or sidewalls. As high temperatures harm the tomato plants, also too cold temperatures affect tomato growth negatively. If temperatures are below 20°C constantly, plants stay little, flower formation and pollination is reduced and fruit development is sparse. In case of low temperatures in cold season, sidewalls can be improved with additional plastic foils. Helpful internet links can be found in Part A.2 of the CuveWaters Toolkit (http://www.cuvewaters.net/Toolkits.112.0.html). Weather forecasts can be found for example on http://www.namibiaweather.info.

3.4.2 Sowing and transplanting

As mentioned above, three main methods are possible for sowing and raising vegetable seedlings. For tomato farming the nursery bed method and direct seeding are most suitable and should be preferred. Transplanting of seedlings from the nursery bed should be done approximately 2 weeks after sowing. This short period in the nursery bed reduces the risk of damaging roots and sprouts of the seedlings while transplanting. Space between one plant and another in the greenhouse should be 40 cm in a row and between two rows. Beds of 1m width, which allow for two rows, offer sufficient space for pest control and de-suckering and hence offer a good management.

For direct seeding, the spacing of tomato plants is the same. Seeds are placed into holes dug into the beds where plants are to be grown. Since no transplanting is necessary, a damage of seedlings is very unlikely. If some seeds did not germinate sowing can be repeated at these places after two or three weeks.

Figure 22: Bed preparation for greenhouse farming.

Figure 23: Transplanting tomato seedlings from nursery.

3.4.3 Pruning and de-suckering

Pruning and de-suckering are essential components of tomato farming. Tomato plants grow best and give good yields, when each plant is pruned to a single stem. Pruning ensures, that the plant growth upwards which is necessary to give enough space to the fruits. De-suckering means the removal of

lateral branches and suckers. Suckers growing between the main stem and already existing branches with leaves or flowers are typically for tomato plants.

Nevertheless, these branches reduce the growth of the plant in height and the formation of fruits and therefore have to be removed. When pruning and de-suckering is done, always handle the plants with care and make sure the correct branches and suckers are removed. Removing branches which carry flowers or removing the main stem will strongly reduce the yield.

Figure 24: Suckers of tomato stem.

Figure 25: De-suckering tomato plants

3.4.4 Plant support

Greenhouse tomato farming requires plant support to ensure plants collapse under the weight of their fruits. In general, plant support is realized from above. Steel ropes are stretched above the rows in sufficient height (minimum 2m). Where plants are growing in the bed, a sisal rope is attached and hangs down. The plants have to be clipped to the rope or twined around it to guide them upwards in the beginning and support the plant's and their fruits' weight later on. A yield of 10 to 20kg can be expected per plant which makes obvious that plant support is required and has to be strong enough to

carry the load of all plants. Every 6 to 10 days clipping to or twining around the support string should be repeated. The plant support starts when the plants are about 25cm high.

Figure 26: Support string attached to steel ropes.

Figure 27: Tomato plants supported by sisal strings.

3.4.5 Flower pollination

Flower pollination is a key element when growing tomatoes. Tomato plants form fruits only from flowers which were pollinated during flowering period. The pollination of tomato flowers is comparatively easy. Plants can pollinate their own flowers (self-pollination) and do not need an exchange of pollen from one plant to another. For this reason, pollination usually happens with the wind. In addition, pollination can easily be supported by shaking the plants with care. Pollination by insects or by usage of brushes is possible as well but does not give a guarantee in the one case or is extremely time consuming in the other case.

3.5 General recommendations for a greenhouse

Some general recommendations for greenhouse farming are provided below. These are guidelines which have to be adjusted according to experiences gathered at a specific site and for specific vegetables and varieties.

1. Side wall ventilation must be provided for to allow for best air movement and reduce amount of heat inside the Green house.
2. The type of structure being build should support the tomato crop based on the orientation of the plant rows.
3. Install the drip irrigation system for water efficient use. Filters must be incorporated in the system to prevent clogging. Obtain a thermometer to regularly check temperatures. 20°C minimum to 40°C maximum are the best temperatures for tomatoes growing. The temperatures can be regulated by putting water in buckets inside the green house.
4. Make sure that the greenhouse is well ventilated. Abortion of flowers happens when the green house is too hot.
5. Be sure the necessary supplies are on hand, e.g., manure, fertilizer, insecticides, fungicides, string, labels, marketing containers and spraying equipment.
6. Green house tomatoes seed can be sown at any time of the year. This is in consideration that greenhouse tomatoes can be harvested for at least 6months. However, one can time to have the pick of harvesting in the rainy months of November, December, January and February when prices are high.
7. Growing medium temperature should be maintained at 30 to 40°C during germination. Seedlings can be transplanted to holes at about 2 weeks later. Seedlings will tolerate the high temperatures in summer and may require water twice a day. Apply fertilizer, 50ppm, about a week after transplanting.

8. Spacing of tomatoes is 40cm by 40cm from one plant to the other and as well as between the rows. The beds are 1m wide and the length should be the size of Green house. Two lines are advisable for easier management. Thoroughly water each plant daily until the roots are established in the soil. Water the plants thoroughly 1-2 times per day.
9. Fertilize the tomato plants immediately after transplanting and continue once every week. Apply NPK fertilizer once every month.
10. Plants grow rapidly by the third month producing large leaves and lateral branches. Large individual leaves indicate that the plants are growing normally and a good indicator of the quality of plant care.
11. The first flowers will appear by the end of the first month. Be sure the flowers are pollinated properly. This is a significant part of the fruit yield.
12. Remove suckers and tie-up the plants weekly to make sure the plants are properly supported. Be extremely observant of the location of lateral branches or suckers. It is easy to mistakenly remove the main stem rather than a sucker. If you remove the main stem, you could cut fruit yields in half. Watch for aphids, whiteflies, red spider mite, bollworm, armyworms and caterpillars of all types in the plant canopy. Do not allow the plants to wilt at any time. Fruit will be damaged if the plants do not get enough water and fertilizer regularly.
13. Monitor greenhouse temperatures closely. Night temperatures should not fall below 20°C while pollination is occurring. Be sure the air circulation inside the greenhouse is working properly.
14. There must be an assured continuous source of water. An example is constructing a dam, pond or underground tank next to the green house where water can be harvested from and stored. The capacity of such reservoir is designed to cater for the longest period of the dry spell. If the grower manages watering and manure and fertilizer application well, then a good crop is assured.


Figure 28: A well managed greenhouse.


Figure 29: Ripening tomatoes in a greenhouse.

4 Soil improvement, diseases, pesticides and irrigation

Farm management and vegetable growing comes along with the need for soil improvement, diseases control and hence application of pesticide. In addition, well managed irrigation is a key element of any successful farming business. In the following, some information on these specific farming activities is given. This information gives a proper advice for a good start of farming and has to be adjusted to each site according to experiences made by a user.

4.1 Soil enrichment, fertilizer application

Soil enrichment is essential to ensure vegetables grow well and have sufficient nutrients for proper fruit formation. Soil improvement already begins with the bed preparation and has to be continued consistently. Manure application, compost making and application, as well as use of fertilizers are activities which belong to the term "soil enrichment" and for this reason have to be known. Manure is natural side product of livestock farming. Manure e.g. from goats or chicken is high in nutrients and therefore perfect for soil enrichment. Compost is a good way to transform biodegradable waste into a useful addition for farming activities. Compost making can be done on a pile or in a pit. In any case, biodegradable waste from other plants or food preparation is layered with manure and soil and turned over every 2 weeks. After approximately 6 weeks the biological process turned the organic waste into usable compost.

Manure and compost are to be added when beds are prepared. Compost supplies nutrients to the soil and improves ventilation and run-off properties of the soil. Manure adds nutrients only and can be taken if characteristics of soil are already good. Manure and compost application is to be continued during growing and harvesting period of vegetables. Use of fertilizers is determined by the vegetables grown and by the amount of manure and compost available and used. Some vegetable are light feeder, which do not need many nutrients to grow optimal. Others are heavy feeder, which require a good supply with nutrients and therefore require fertilizer application more often. Heavy feeders, such as tomatoes require around 10kg of manure per m² and month. The following table shows what fertilizers are preferable in which stage of plant growth. Generally, fertilizers for tomato farming shall be moderate in nitrogen and high in phosphorus, potassium, calcium, and magnesium.

Stage of Tomato Growth	Planting	Flowering	Fruiting	Harvest
Fertilizer	2 : 3 : 2	Calamabon, Ammonium Phosphate	Calcium, Potassium, Calamabon	

Table 3: Fertilizer use for stages of tomato growth.

4.2 Pest control, pesticides and fungicides

Pests and fungal infections of vegetables can lead to loss of high percentage of the crop. For this reason, regular inspections of plants for pest infestations or fungal infections have a high priority. Although, greenhouse farming reduces the risk of pest infestations, monitoring has to be done carefully. Pest and disease controls should be started on week after transplantation of seedlings or as soon as seeds germinate in the beds. The interval of inspections should be 7 to 10 days, to avoid intense infestations. Preventive use of pesticides and fungicides can help to avoid infestation and fungal infections at all, but amount of pesticides and fungicides used has to be as low as possible to protect the soil and to ensure best quality possible of vegetables.

Usage of pesticides and fungicides comes with some important recommendations which shall be understood. First, not more than three chemicals should be used at the same time. Application of chemicals always stresses plants and soil as well and mixture of too many kinds of chemicals may lead to unfavourable effects. Furthermore, product labels and instructions should be read carefully and followed. Moreover, do not mix solid or powder chemicals with liquid chemicals.

Figure 30: Examples of early blight infestation.

Figure 31: Example of a caterpillar.

Caution: Working with pesticides, fungicides, and other chemical may be toxic or at least harmful to humans' health! Special care is needed, when these substances are prepared for use or applied to the plants. Read carefully the instructions which come along with each of the pesticides or fungicides and follow the safety recommendations. General safety and sanitation instructions for horticulture were exemplarily made for Outapi irrigation site and can be found in CuveWaters publications (http://www.cuvewaters.net/fileadmin/edit/Downloads/Publications/Cuve-Sanitation-Safety-Instructions_100315.pdf).

Figure 32: Example of safety instructions for preparation and use of harmful pesticide.

Figure 33: Example of safety instructions for preparation and use of toxic pesticide.

Successful pest control requires the knowledge of the different kinds of pests and how to fight them. The table below shows a selection of pesticides and fungicides which were used at the CuveWaters pilot plants. Furthermore, the table describes symptoms of specific pests and how long fruits cannot be harvested and consumed after the application of a pesticide or fungicide.

	Pesticide / Insecticide / Fungicide	Controls Problem / Disease	Symptoms	Spray Intervals	Withdrawal from Eating
1	Odeon and Folicar	Early Blight, Fungal Diseases	Patterned Leaf Spots, Stem Lesions, Fruit Rot	14 days	7 days
2	Cyprin	Lawn Caterpillar, Beetles, Termites, Ants	Insects on leaves, chomp marks		7 days
3	Buldock	Cutworm	Insects on leaves, chomp marks	14 days	7 days
4	Comite	Red-spider Mite	Insects on leaves, chomp marks	14 days	7 days
5	Biomectin	Insects	Insects on leaves, chomp marks	14 days	7 days

Table 4: Selection of helpful pesticides and fungicides.

Please have in mind that other concepts of pest control do exist as well. Organic farming for example does work without pesticides, fungicides, and other chemicals. Unfortunately, this manual cannot describe different concepts of farming and their use of chemicals.

4.3 Crop water demand and watering

Different varieties of vegetables have a different water demand for growing and formation of fruits. The amount of water per watering and times of watering per day also depend on the type of soil. If drainage of soil is low, water is stored temporarily and plants have to be watered less frequent. In general, make sure there is enough water available for a whole crop lifecycle from sowing until end of harvest period. Make sure water is available all the time, since shortages have negative impact on plant growth and fruit formation, as well as on taste of vegetables. For example, water shortages make salads be in bloom early and taste bitter/acerbic. The water demand for tomato plants is shown exemplarily. However, the amount of water needed is dependent on many factors and therefore experiences have to be made for each single site.

Stage of Tomato Growth	Planting	Flowering	Fruiting	Harvest
Watering	2 litres /day	1 litre / day	1 litre / day	1 litre / day

Table 5: Water demand of Tomato Plants per Stage of Growth.

Most of the vegetables will do well after July when the cold season is over. But, during dry season crops need in general more water to grow. Water melon and butternut will not do well when there is too much water. Also note that many vegetables can be planted any time of the year. The challenge comes on management of growing. If it is too cold, more fungicides may be required. If it is too hot, more water is required.

Watering of seedlings has to be done with special care. Seeds shall not be splashed away from water. Furthermore, the soil around the seeds and seedlings has to be kept damp continuously. After seedlings were transplanted, an efficient watering technique shall be used for irrigation. If drip irrigation or microjets are used, watering should be done close to the plants root zone. As an example, tomato plants have space of around 40cm between each plant. Drip outlets can be positioned in a distance of 15 to 25cm from one to another, when each plant shall be irrigated by two drip emitters. To maximize the efficiency of irrigation, watering should be done in the early morning or late in the afternoon, when sun is harsh. Nevertheless, some vegetables do not tolerate late watering and fungal diseases will occur. Finding the optimum way and a good balancing of efficiency and plant health requires gathering of experiences and ongoing optimization.

4.4 Drip irrigation and other irrigation techniques

Drip irrigation is the preferred irrigation technique in CuveWaters RWH projects. Drip irrigation is a simple, effective, and water-saving way to reliably irrigate gardens. Water is guided through feeder and submain lines from the intermediate tank to the beds. Since the tank is lifted to approximately 2m height, the water flows by gravity. Drip lines finally provide the water along the rows to the plants. Drip lines can be either made with internal or with external drip emitters which ensure consistent and reliable leaking of water droplets which soak into the soil. With proper handling and filters, used for processing of irrigation water, drip lines can reach lifetimes of about 5 years. However, mechanical stress may cause damages earlier.

Main advantage of a drip irrigation system is the high irrigation efficiency of approximately 90 to 95%. This means, only 5 to 10% of water used for irrigation does not reach the plant. Furthermore, the system can be set up very simple. No continuous pumping is needed during irrigation. Only pumping of water from a reservoir to the intermediate tank has to be done, which can also be done with mechanical and hand operated pumps. Finally, the investment needed for installation of a drip irrigation system is moderate, whereas advantages are high. Unfortunately, drip irrigation is still new to many farmers and hence initial training is necessary to set the system up successfully and guarantee proper operation.

Figure 34: Technicians installing drip irrigation.

Figure 35: Drip lines in bed of tomato plants.

Traditional irrigation techniques are furrow irrigation, flood irrigation, and overhead irrigation. Furrow irrigation can be used to grow any vegetables of any kind. The disadvantage compared to drip irrigation is the high amount of excess water used. Additionally, furrow irrigation consumes more energy e.g. for continuous pumping. More time and effort for repositioning of irrigation lines are required as well. Flood irrigation is good for animal fodder and rice farming. The flood irrigation technique can also be used to grow maize. The disadvantage of flood irrigation is the enormous water use for flooding whole beds. If water has to be supplied with pumps, this leads to high energy consumption. When water is not available in large amounts and has to be paid for, this entails additional cost as well.

Finally, overhead irrigation is the technique used the most. Sprinklers distribute the water to the plants through the air. This method can be used for many vegetables such as onions, carrots and maize. But, overhead irrigation does not work for tomatoes, since wet on the leaves of tomato plants leads to mildew and other fungal infections. In general, the overhead irrigation method requires more water than drip irrigation due to higher evaporation rates. Furthermore, areas where no plants have to be watered may be irrigated as well. Usage of microjets, which is still overhead irrigation, reduces the

downsides of this technique and can be an adequate solution for horticulture on household or community level as well.

Figure 36: Drip Irrigation

Figure 37: Traditional overhead irrigation with watering can.

5 Harvesting, marketing, and record keeping

In general, small scale farming and horticulture on household or community level can lead to several advantages for the people and over large scale farming. Horticulture as part of RWH allows for integration of cost effective methods of production which result in high yield output to meet the food and nutrient requirements of the communities. Furthermore, horticulture provides communities with alternative sources of income through sale of surplus vegetables. CuveWaters demonstrated low cost effective technologies of agriculture to self help groups, youth groups and the community at large. In addition, small scale farming activities come with minimum use of chemicals and hence a lower intake of chemicals which leads to good health.

To achieve the above mentioned advantages it is necessary to continue the good care during sowing and growing of vegetables during harvesting period. Additionally, continued monitoring is essential to ensure horticulture activities can be optimized within a growing season and from one season to another. Farming without good record keeping puts the business at risk.

5.1 Harvesting and expected yields

Which vegetables can be grown at which time of the year is already shown in Table 2: General guide when to plant vegetables in Namibia. (in Chapter 3.3). In general, harvest is possible as soon as fruits formed and ripened (e.g. for tomatoes, cucumber and green pepper) or when vegetables grew to a sufficient height or leaves are large enough, but short before flowering (e.g. spinach, carrots). In some cases, the die-off of leaves indicate, the beginning of the harvest period (e.g. for onions).

For greenhouse tomatoes, period of growth and ripening of fruits usually is 75 to 90 days. The harvest period is about 4 month long. In this period tomato plants flower and form fruits several times. Depending on the variety grown, the average weight of total fruit harvest is 15 to 20 kg per tomato plant. The average amount of fruits per plant (at a time) is approximately 20 fruits. In a greenhouse of 120 m² as built during CuveWaters demonstration phase, has enough space for 400 plants which can lead to a total yield of 6,000 to 8,000 kg if no fruits are lost due to pests or mismanagement. During harvest period, harvest ripe fruit every 3 days. Weigh and package fruits appropriately for the market or per demand in the market

When using pesticides and fungicides have the period of withdrawal from harvest and eating that is shown in Table 4: Selection of helpful pesticides and fungicides. (chapter 4.2) in mind. Usage of chemicals and direct harvest and eating may be hazardous to health.

Figure 38: Tomatoes short before harvest.

Figure 39: Tomatoes at a wholesale distributor.

5.2 Marketing and economics

The market for greenhouse tomatoes is quite good. Tomatoes can be sold directly from the greenhouse at retail prices or sold to wholesale distributors, supermarkets or restaurants at wholesale prices.

Green house tomato farmers have an upper hand to those growing outside. The Greenhouse farmers can grow tomatoes in all seasons including winter. This makes greenhouse farmers a reliable supplier on the one hand and allows for cost recovery of increased management efforts during winter. The average tomato sale from greenhouse is 5-10 N$ per kg. Nevertheless, market prices can vary seasonal as well as regional depending on supply and demand.

Following, economics for greenhouse tomato farming are shown exemplarily in the case that all tomatoes harvested are sold to the market a) at an average price of 5 N$ and b) at an average price of 10N$.

Size of Greenhouse	Number of Plants	Yield per Plant	Total Yield	Sales Price per kg	Total Revenue
120 m²	200 - 400	10-20 kg	2,000 – 8,000 kg	5 N$	10,000 – 40,000 N$
120 m²	200 - 400	10-20 kg	2,000 – 8,000 kg	10 N$	20,000 – 80,000 kg

Table 6: Economics of Greenhouse Tomato Farming.

The example above does show the possible revenue only for an experienced farmer. This is assuming that yields are good, all tomatoes are sold at the market and nothing is kept or used for personal needs. In addition, the revenues do not show the expenses of greenhouse tomato farming. Costs for construction of greenhouse, payments for loans, costs for seeds, fertilizers and pesticides are to be considered to calculate whether farming activities led to a profit in the end. To be able to calculate costs and revenues correctly, a good record keeping is necessary in the course of the year. Furthermore, loss of fruits can occur in single years, which should be considered as a share of additional cost in each year.

5.3 Record keeping

Book keeping is essential for knowing costs and benefits of farming activities. Keep records for water used for irrigation. Most interesting information is volume of water used and cost (if supplied from elsewhere or repayment of loans for RWH are ongoing). The amount and cost of fertilizers, fungicides, and pesticides used is to be known as well. In addition, keep records for the total yield per variety, the average yield per crop or m², and for each variety. Other important information, which allows optimization of farming activities, is the sales price of vegetables grown on weekly and monthly basis. The records allow for an unprejudiced calculation of profits of horticulture activities. Furthermore, records allow for optimizing farming activities from one year to another.

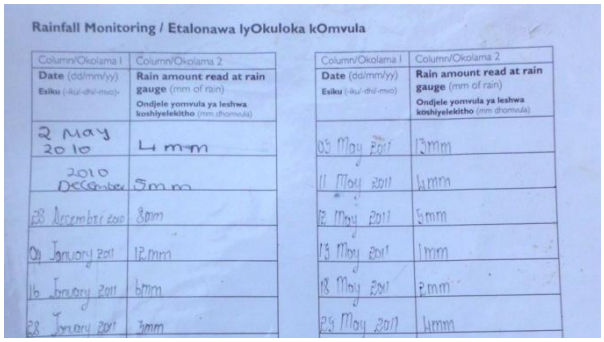

Figure 40: Record of rainfall.

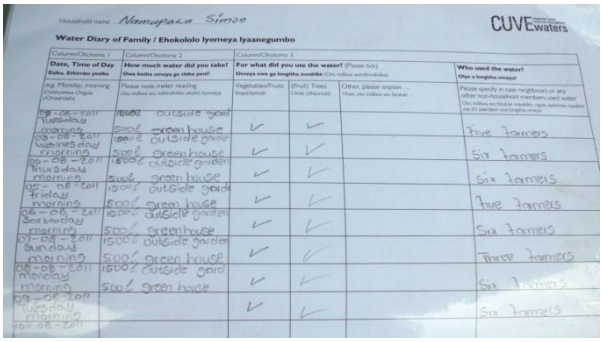

Figure 41: Record of water usage.

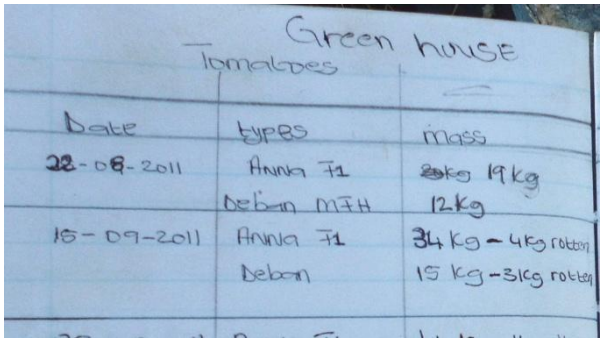

Figure 42: Record of yield.

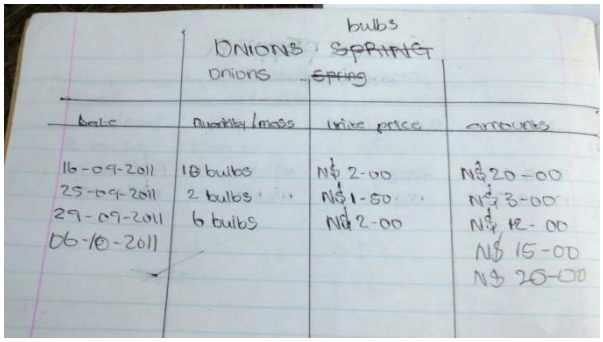

Figure 43: Record of sales.

6 Table banking, microfinance and by-laws

Construction of RWH facilities requires financial resources as initial investment for material, tools, labour and seeds to start farming. Mostly, initial investment is too high for single households. Mostly, business in horticulture on household level, does not qualify for credits and loans at acceptable rates. For this reason, other support and financing schemes have to be introduced to provide loans with appropriate interest rates who serve micro-scale businesses. Table Banking, also called Microfinance, is such a financing scheme and proofed to be a suitable solution to lacking initial investment for RWH projects.

6.1 The idea of table banking

The idea of table banking is easy to comprehend and based on community cohesion as well as individual profit for each of the participants. Table banking is formed of a community of participants, of whom each saves a certain amount of money on a regular basis. The savings are put to a community account and each of the inputs is recorded. The aim is to support projects from community members financially with acceptable interest rates.

The specific conditions of saving, lending and repayment can be aligned to the community's needs when table banking by-laws are established.

6.2 Examples for table banking by-laws

In the following, it is shown exemplary how table banking can be set up. First, qualifications for participation in the table banking community have to be defined. Following characteristics can be defined to allow for membership in the table banking community and later on to apply for a loan:

- Age over 18 years.
- Origin or residence of the same area.
- Ability to read and understand, as well as abide to laws set by the group.
- Must be a member of the registered table banking group (for application for a loan).
- Must be a regular saver (for application for a loan).
- Must have a bank book of the table banking project.
- Must be a guarantor to all members of the group i.e. this is to avoid defaulting by members who may break the laws.

After certain rules for participation are defined, the processes of saving, lending and repayment have to be determined. An example which can be adjusted to a specific table banking community's needs is the following:

1. Members meet once a month to contribute savings where a minimum amount is set and members are encouraged to save as much contribution; the money is put on the table and reconciled (hence the name table banking).
2. The contributions are recorded and announced to all members.
3. If there is any expenditure for the day, it is deducted.
4. Member's then requests how much she/he wants to borrow in terms of an advance loan. This could be either short term or long term depending on a level of the group. A member must understand the loan is repayable in either 1, 3, or 6 months depending on the group by/laws. The interest rates range between 1% and 10% per month.
5. All members requesting for long term loans must apply through a written document committing themselves on repayment and must abide by the laws that states borrowing is times three of one's savings.
6. The written document must be signed by the group leaders (officials) on behalf of other members.
7. The long term loan must be used for the proposed project and the officials must make a follow up.
8. All members qualifying for loans must be advised on a simple drafted monthly repayment schedule.
9. The money is then loaned to members as requested and considering the availability.
10. After loaning is done, the transactions are recorded in the right books for future and follow up reference. E.g. loan forms, group secretary performance book known as group monthly statement, facilitator monthly record and member pass book.
11. The money must also be insured through a contribution of a minimum amount by all members of the group. The money either can be ploughed back all a bank account opened where money is saved in-case of death eventuality.

When it comes to loans, there are two different repayment modes possible. Advanced loans are short term loans which have certain characteristics:

- Advance loan is borrowed times two of the total savings a member has banked.
- Must be repaid with one month and a maximum of 3 months with an interest of 10%. Unless a member is sick, or have a reason of not paying and must be discussed by all members of the group. She/he is given an allowance of 2 extra month of repayment. This is not very common.
- The loan is not drafted a repayment schedule.
- A member request with no written document.
- It is recorded on advance loan side and how much she/he must refund the next month.

The second type of a loan is a long term loan which comes along with a longer period of payback:

- Long term loan is borrowed times three of the total savings a member has banked.
- Must be paid within 6 to 12 monthly instalment with an interest of 1% per month.
- Member must write a document (inform of a simple proposal) showing commitment and the project she wants to start. In case of any change of the project proposed she should inform the group to discuss and advice.
- Members are given monthly repayment schedules.

7 Participatory Impact Monitoring

Participatory Impact Monitoring (PIM) is a process which can help to achieve optimum results from a project. PIM is not a new invention, but consolidates things that are part of everyone's daily life and draws attention to the advantages of conscious actions and decisions in a project. Main aspects of PIM are monitoring and the execution of the project cycle, also known as "Plan Do Check Act"-Cycle (PDCA).

7.1 Monitoring

First, the definition and meaning of the term "monitoring" has to be clear. Monitoring is the overseeing and implementation of plans and the identification of obstacles. It is also the collecting, analyzing, keeping, and sharing of information. Monitoring further can be described as decision making and revisiting of objectives as well as the developing of indicators for decision making. Even though, some of the descriptions are rather based on monitoring and results from monitoring, the broad meaning of the term "monitoring" indicates its high importance for everyday life as well as for special projects.

Monitoring requires clarity about what is the aim of an action or project and which ways may lead to success. Furthermore, obstacles that may occur on the way shall be expected as early as possible. Nevertheless, unexpected obstacles may arise and require alignment. Monitoring always needs some indicators to be monitored. For example, monitoring the weather can be done by use of temperature, atmospheric pressure and precipitation as indicators. Everyone monitors the things that affect his or her life by use of certain indicators. If one stops monitoring, failure is most likely.

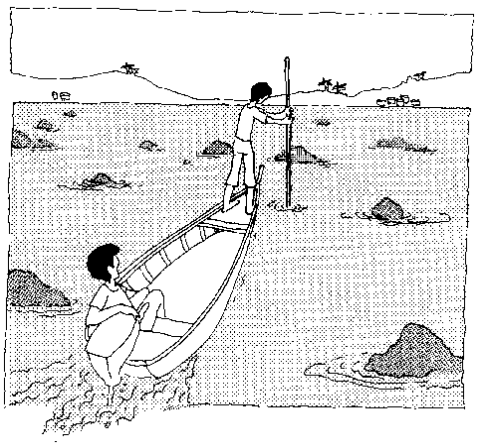

Figure 44: Illustration of monitoring as a part of project management. (Source GIZ)

7.2 Project cycle

The sum of all stages of a project usually are called a project cycle. A project cycle can be divided into 5 stages:

Figure 45: Illustration of a project cycle.

As the term cycle indicates, the project does not come to an end. Usually, evaluation is passing on to survey stage and the cycle starts from the beginning. In each of the phases monitoring is essential for success. Monitoring ensures, all necessary information is present and comparison of target and actual can be done. The availability of information and the comparison of target and actual are basis for good decision making. Advantages of monitoring and the use of project cycle further improve the basis of information when all stakeholders of a project are involved from the beginning in every stage of the project. Early involvement of all stakeholders ensures that all demands are known, understood and considered from the beginning. This reduces the risk that a project fails at a later stage.

7.3 Introduction to and application of Participatory Impact Management

PIM is a guideline, which brings together the ideals of monitoring and project management using project cycles. In addition, PIM underlines the high importance of participation of all stakeholders when projects are to be executed with success. Thereby, PIM does focus on early and complete participation of stakeholders of all levels, i.e. end users as well as technical experts. In general, projects, with a high number of people involved, need extra management efforts to ensure, all participants act coordinated according to agreements.

Furthermore, monitoring of use of goods and materials as well as monitoring of progress and results is necessary to avoid chaotic interaction.

Preconditions for success of PIM are the willingness to promote people's participation in a projects and mutual trust and transparency between an organization executing a project and all other stakeholders, such as a group of users or a community. All parties of a project using PIM need to be willing to adapt plans to the people's needs and to invest additional time for monitoring, analyzing, discussing and decision taking. Successful management of projects with PIM starts with the discussion of individual needs and aims and the agreement on common/shared aims which lead to benefits for all stakeholders.

Important questions which guide through the PIM are:

- WHAT should be monitored?
- HOW can it be monitored?
- WHO should watch it?
- HOW can results be documented?
- WHAT was observed?
- WHY these results?
- WHAT action has been / can be taken?

For monitoring, the right indicators are essential. Indicators show the actual situation and the direction a person, car, or project is heading in. Furthermore, indicators allow for evaluation of the gap to intermediate results and overall project goals. A broad variety of indicators can be used for monitoring and project management. Nevertheless, each indicator has to add information crucial to good decision making and is obsolete, if no or unimportant information is added.

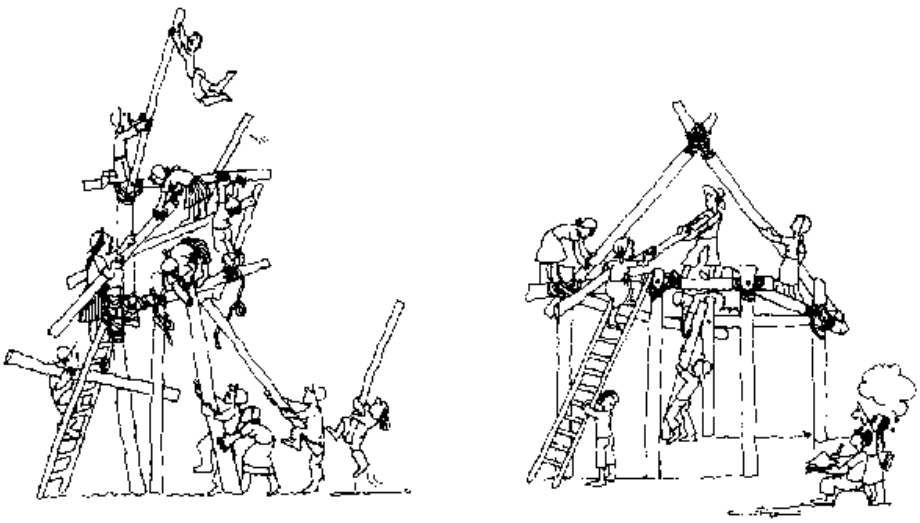

Figure 46: Illustration of uncoordinated project implementation (left) and successful project management with PIM (right). (Source: GIZ)

8 Good governance and leadership

RWH projects – as any other project – is depends on good governance during project planning and implementation but more crucial during operation. Governance is the process of decision-making and the process by which decisions are implemented (or not implemented). Governance is also described as a set of values, policies and institutions by which a society manages its social, political and economic process through interactions among government, civil society and private sector. That means every type of social interaction is governance, only on different levels (e.g. family, local and community level, government, private sector and civil society).

8.1 Concept of governance

The concept of governance as such only refers to the fact that social interactions of individuals and groups is somehow organized and structured. The term "good governance" is going beyond this fundamental concept and introduces a judgment based on criteria and values agreed upon in society.

Governance is "good" when it ensures that political social and economic priorities are based on a broader consensus in society, and that the voices of all are heard in decision-making over allocation of resources. Principles of good governance are:

1. Participation
2. Rule-of-law Principle
3. Transparency
4. Responsiveness
5. Consensus Orientation
6. Equality and Inclusiveness
7. Effectiveness and Efficiency
8. Accountability

Participation of both, men and women forms a key cornerstone of good governance. Types of participation can be direct or through legitimate intermediate representatives or institutions. The rule of law principle is based on fair legal frameworks that are enforced impartially. It also requires full protection of human rights, particularly those of minorities. Transparency means that as much information as possible is proved and provided to public in an easily understandable form and media. Good governance requires responsiveness, which means, that institutions and processes shall try to serve all stakeholders within a reasonable timeframe. Consensus orientation and mediation of the different interests in society is necessary to reach a broad consensus in society on what is in the best interest of the whole community and how this can be achieved.

A society's well-being depends on ensuring that all its members feel that they have a stake in it and do not feel excluded from the mainstream of society. Good governance therefore is based on the principles of equality and inclusiveness. Finally, governance shall be efficient and effective to produce results that meet the needs of society or stakeholders and accountability of any person in charge for his or her decisions made.

8.2 Dependency

Dependency is one of the obstacles to good governance and community development. Dependency is defined as a situation or condition when someone or a community wholly or solely relies on another individual, group, organization, or institution to provide solutions to their problems. Causes of dependency can be self-imposed or imposed from other individuals, groups, organizations, institutions or society as a whole. Examples of causes for dependency are laziness, lack of skills or initiatives, programs that promote hand- outs, natural or man-made disasters as well as illiteracy or ignorance.

Several ways can reduce dependency, but none guarantees sustained improvement when individuals, groups, and society do not transform. Dependency can be minimized, when capacity building is performed effectively and empowerment is promoted. Raising awareness on the ills of dependency at least may reduce the self-imposed dependency and foster individual initiative of persons affected. Finally, creation of livelihood opportunities can improve a social or age group's situation and reduce their dependency. Nevertheless, dependency on external assistance can undermine sustainable development. Communities must practice doing things for themselves since assistance will one day be removed. Therefore training and other capacity building opportunities offered to them must be well embraced and taken very seriously by communities themselves.

8.3 Leadership

Leadership as governance is a concept of social interaction of individuals or groups. Leadership describes the ability to guide individuals' behaviour and actions to a certain aim. The concept of leadership can be based on different types of legitimating, such as democratic elections or autocracy backed up by armed force.

"Good leadership" again refers to certain values and the idea of leadership serving the majority of people and promoting benefits for as many individuals possible. Good leader is characterized by many traits. Good leaders are respectful, supportive, visionary, able to delegate, tolerant, fair and impartial, open and accommodating, empathic and sympathetic, transparent, responsible in behaviour, consultative, accepting faults, are flexible but firm, and are decisive. The long list of attributes of a good leader illustrates how complex leadership can be and which broad skills a leader has to have.

Depending on the level of leadership and the background, some of the characteristics can be more important than others, e.g. for success of a certain project.

In general, leaders can be classified according to their leading behaviour. Dominating leaders, usually, take all activities of a group and does not give others a chance to share in decision making. Democratic or participatory leadership is based on discussion of group members and common decision making. Dictatorship is a very the most narrowed form of leadership. The leader makes all decisions and members have no say. They are commanded to follow orders. Another unfavourable approach is passive leadership. The leader gives no guidance to group members, which leads to individual actions and loss of coordination of people. Finally, confusion and competition may undermine the community and put goals at risk. In general, democratic leadership is most favourable to ensure community participation is possible and benefits for a majority of people can be achieved. Nevertheless, democratic leadership requires additional efforts for discussion and balancing of interests. Finally, keep in mind that finding a good leader is a hard task.

8.4 Community participation

Participation is a process of joint dialogue, sharing and learning about situations to obtain consensus towards action and change. Participation is an active process by which community people influence the direction and implementation of a development project. Participation includes the involvement of people in decision-making processes, implementation, sharing of benefits and cost, and taking part in the project and activities evaluation.

Factors hindering community participation therefore are when members of community are not involved at all stages of the activity. Furthermore socio-cultural conflicts in the community, poor leadership, political interference, ignorance coupled with illiteracy, lack of commitment and contribution, as well as stereotypes about participants (e.g. woman, youth, and disabled person) hinder successful community participation.

Figure 47: Scoping workshop to discuss needs of community (left).

Figure 48: Community workshop for planning of RFWH construction (right).

8.5 The role of a leader

The role of a leader is closely linked to the expectations of a leader. The different leadership approaches (dominating, participatory, dictator like, and passive) were describe above. Key elements for successful leadership are the knowledge and the abilities of a leader. A leader should have an understanding of the role of group and community members as well as of belief and value behaviour at various ages in the community. Roles and positions of people, as well as their belief and values they follow determine their behaviour and expectations, and thus have to be understood. A leader should understand norms of behaviour, acceptable and unacceptable practices in a community. Additionally, interests, needs, expectations and aspirations of the majority of the group members should be known to make process of participation and finding a consensus easier. Finally, a leader should understand the economic and environmental conditions of a group and its members, since these factors may hinder or promote cohesion of a community.

Besides the understanding of circumstances, a leader should be able to handle people gently but also to address people effectively. Collection and use of information is as important as pursuing and convincing people to accept and follow ideas. In addition, a good leader shares duties and tasks with other members, while following up the implementation of agreed tasks and being a counsel of members to help solving problems. All this can be realized by listening to the thoughts, ideas, and fears of the other group members, as well as by observation of group member's non-verbal behaviour.

Figure 49: Tasks of a leader – give advice and instruction to other project members (left).

Figure 50: Training village executives in RHW management.

The behaviour of a good leader should be honest, committed, and focusing on benefits for the whole community. Honesty is required especially, when a leader handles resources of group members, such as finances, materials and time. When becoming a leader, commitment to the role of a leader is a key to underline the responsible acting and avoid competition. Good leadership requires focusing on the welfare of the community and not on self-interest. In general, the behaviour of a leader should be an ideal to others, which means harsh or rude language is avoided; teachings of other people are faced sensitively; and showing biased judgment as well as backing opposing groups or individuals is avoided.

A leader is expected to listen to and accept other people's views, show perseverance and patience when problems arise, be approachable and inviting, be hard working, and to be observant and analytical. Finally, the leader should understand how and why things happen and show initiatives to solve problems arising or promote progress.

Different roles of within a group require certain level of leadership and consequently persons which have the above mentioned understanding, skills, and behaviour. The chairperson of a group for example has to organize the group and keep it moving along a project or process path. The chairperson should encourage participation of members and – at the same time – direct the group to follow certain rules and maintain the discipline within the group. Finally, the chairperson has to coordinate the members' views and ideals, guide and summarize discussions, define and clarify problem areas, as well as reconcile conflicting views. In a group or community meeting, the chairperson has to keep the time and advice the group on its progress and points already agreed on. Encouraging contribution of group members, as well as delegating work and assignments, maintain harmony in a group and represent the group's ideals and aims at meetings with others are other tasks of a chairperson. The Treasurer is leading a group's financial assets. The person has to keep financial records, inform the group members on their financial situation and advice them how to use their financial resources. Furthermore, the treasure has to establish and maintain a close contact to all stakeholders, which means group members as well as external supporters, institution or benefactors. Finally, the treasurer ensures financial records are open to members and checked by appointed bodies regularly. Summarizing the duties of the treasurer, he is safeguarding and managing the group's money. When group saving or table banking is done, he furthermore gives receipts for money received. The management committee can be established as a body of a community to prepare and schedule meetings as well as to make suggestion to the group regarding specific issues or problems. The committee promotes decision making and participation by delegation of tasks. Further, it follows up on implementation of tasks and progress of a project and reports the status. Finally, the management committee organizes trainings for group members, helps to solve problems and represents the group towards external institutions or other groups. A group's hierarchy can be set up like shown in the example below:

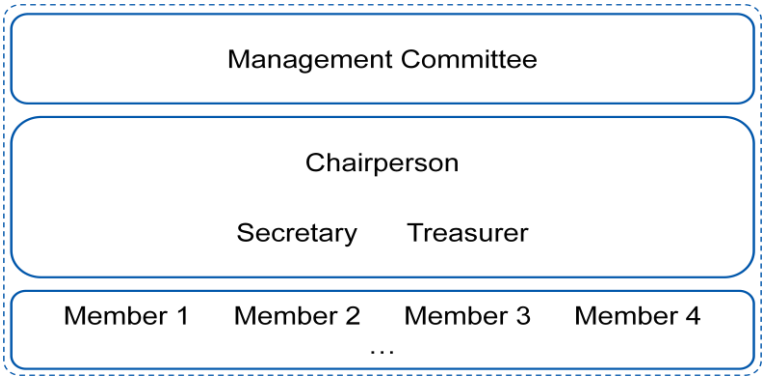

Figure 51: Example of a group's hierarchy.

Despite the spreading of duties and responsibilities as shown above, it may be required to share roles and leadership between group members from time to time. Taking over leadership may be required, when contribution to discussions is necessary to provide experience and skills. Furthermore, giving opinions and ideas which help the group may be necessary to ensure progress. Additionally, leaders for certain activities or sub-committees may be appointed.

8.6 Conflicts resolution

Conflict resolution is the most critical aspect of leadership, since impartiality is tested and skills as well as ideal behaviour are to be used to achieve conflict resolution. Conflict resolution always should focus on the problem and the person. Responses in conflict resolution may be withdrawal, which means, individuals choose to say or do nothing about their problem and give up. Use of force (verbal and non-verbal, economic, or armed) may be a response as well, in which one individual or a group pursue their own goals by intimidating others. Compromise is the response to conflict, which results from negotiations and bargain of benefits. In many cases, the compromise is not satisfactory to any of the parties which reduce the commitment to solutions agreed upon. Co-operation is the most favourable response in conflict resolution. Co-operation involves taking both personal relationship and goals very significant. It is believed that people can find new and imaginative solutions to conflict that lead to both sides winning, while wining does not mean others have lost. When conflicting groups or people sit together to discuss their needs / goals, they often realize their needs have changed. Nevertheless, a final remark is appropriate: No single response to conflicts is the right one and each depends on the circumstances and the particular relationship of conflicting parties and individuals. However cooperating holds the greatest promise for all.

Third parties may support the resolution of conflicts. They can act as fact finders, which includes gathering and working up of information from all sides. This information is summarized in a list of key issues and shall focus the process of conflict resolution to the most important aspects. A third party can also be a facilitator, which helps both sides to schedule and facilitate meetings for discussion of a problem. However, the facilitator has no power to make decisions. Taking over the role of a broker, a third party gives views on some of the issues and pursues to fit the outcome of discussion to his views. Acting as an arbitrator comes with the highest level of power and responsibility at the same time. The third party is under the obligation to listen to the evidence of all conflicting parties or individuals. Finally, all aspects of the conflict have to be balanced and a decision has to be made that all sides must accept. The role as a police officer comes with the duty to remind conflicting parties of rules, regulations, and laws to be observed. In case of violation of rules the third party may force people to obey the law. A final role for a third party may be the role as a judge. Thereby the decision

made is not lead by certain circumstances of the conflict and the conflicting parties, but according to law only.

9 Conclusion and Outlook

The training in "Extension services in horticulture and irrigation with special reference to rainwater harvesting in Namibia was held the first time from April to June 2015 and showed how knowledge on RWH can be transferred to people already familiar with agriculture or rural development. Successful dissemination of RWH technology and sustained application and operation of it, require the establishment of a bigger community of users and participants. Hence, the first training session can be a starting point only and more training courses have to follow for other people interested in RWH. This manual and documentation, as well as the other documents of the CuveWaters toolkit give all information at hand to those who are interested in RWH planning, training, and implementation and operation.

The CuveWaters project team was giving advice for a defined timeframe only and leaves behind Namibian institutions and individuals, which are able to further pursue the roll-out of RWH as part of an IWRM in Namibia. From a technological perspective, RWH proofed to be a suitable solution for reduction of crop water scarcity in central-northern Namibia and consequently for improvement of food security and living conditions. The participatory demand-responsive approach used for scoping and planning of RWH sites during the CuveWaters research project encouraged local communities and individuals to contribute. Furthermore, early and continuous participation led to a takeover of responsibilities for the facilities and their operation after ownership transferred formally.

The continuing extension of RWH promoted by RDCs and ADCs and as part of a Namibian rainwater harvesting policy gives the chance to many household and communities in central-northern Namibia to improve their living conditions by increased food security and creation of small businesses. CuveWaters wishes success to all future RWH planers, users, and trainers.