CUVEwaters integrated water resources management

Rain- and Floodwater Harvesting –
Implementation Concept

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CuveWaters Papers, No. 13

Imprint

Prepared by
ISOE – Institute for Social-Ecological Research

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General Editor
CuveWaters research co-operation
www.cuvewaters.net

The joint project is funded as part of the "Integrated
Water Resources Management (IWRM) Including the Necessary
Technology and Know-How Transfer" programme that is sponsored by the Federal Ministry of Education and Research (BMBF).

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Frankfurt/Main, December 2015

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Abbreviations

BMBF	Federal Ministry of Education and Research
BMC	Basin Management Committee
CEB	Cuvelai-Etosha Basin
DAPEES	Directorate for Agricultural Production, Engineering and Extension Services
DoF	Directorate of Forestry at the MAWF
DRA	Demand Responsive Approach
DRFN	Desert Research Foundation of Namibia
DWSSC	Directorate of Water Supply and Sanitation Coordination (formerly Directorate of Rural Water Supply)
GIZ	Deutsche Gesellschaft für Internationale Zusammenarbeit GmbH
IFAT	Internationale Fachmesse für Abwassertechnik (the world's leading trade fair for water, sewage, waste and raw materials management)
ISOE	Institute for Social-Ecological Research
IWRM	Integrated Water Resources Management
MAWF	Ministry of Agriculture, Water and Forestry
NAD	Namibian Dollar
NamPower	Namibia Power Utility Company
NamWater	Namibia Water Cooperation
O&M	Operation and maintenance
PoN	Polytechnic of Namibia
RDC	Rural Development Centre
SAREP	Sustainable Agriculture Research and Education Program
SEIA	Social-ecological impact assessment
TA	Traditional Authority
TU Darmstadt	Technische Universität Darmstadt
UNAM	University of Namibia
USAID	U.S. Agency for International Development
WPC	Water Point Committee

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Objectives of the implementation concept

This implementation concept gives a (technological, institutional, social, economic and ecological) overview of the pilot schemes for rainwater harvesting and floodwater harvesting technologies (RFWH) in terms of their preconditions, procedural issues and results. The document informs in brief about these topics and refers to further publications for deeper insights. The implementation concept basically aims to:

1. support communication with the partners in Germany and Namibia
2. ensure strategic planning of sustainable implementation of the respective technologies in future
3. support internal work processes and knowledge management
4. refer to associated documents, products and results of the technologies

1. Initial situation

1.1 Original problem situation

In the Cuvelai-Etosha Basin (CEB) of central-northern Namibia, people depend on the rain-fed cultivation of crops such as pearl millet ('mahangu') and sorghum as well as on livestock farming. But rainfall only occurs during a certain time of the year, namely from October to March, and its variability is high. The CEB has a relatively reliable supply of drinking water, which is provided via interbasinal water transfer from the Kunene River in Angola. Despite this, the use of tap water for irrigation is limited for two main reasons: first, the local population cannot afford to buy this water for irrigation; second, the water supply network ends beyond the densely populated areas, and rural communities are not connected.

Farming and irrigation of high-value crops such as tomatoes and other vegetables are difficult in the CEB due to the unreliable water supply and the widespread lack of knowledge, which means that these types of crops are hardly grown at all. Rainwater harvesting (RWH) and floodwater harvesting (FWH) combined with capacity development measures were seen as good options with which to take advantage of the rains as irrigation water for growing high-value crops all year round. The options include supplemental irrigation in the wet season as well as new opportunities for irrigation during the dry season. Appropriate investment in rainwater harvesting tanks and associated infrastructure could have valuable effects on local food supply, boost the local economy and help Namibia to decrease its dependency from foreign food imports (Woltersdorf et al. 2014).

Despite its potential use for providing irrigation water, rainwater harvesting is not yet part of Namibia's National Water Supply and Sanitation Policy or the Namibian Water Act (Republic of Namibia 2004, 2008). The introduction of rain- and floodwater harvesting technologies by the CuveWaters project for the purpose of horticulture is the first approach in the region to provide irrigation water on a very small scale using local sources to increase self-sufficiency and develop opportunities for generating local income.

1.2 Political framework, governance and institutions

Namibia in general, as well as the project region in particular, has fairly good and stable political framework conditions, including those for the high-level water sector. However, the Basin and other regions all over Namibia possess a weak regional political framework for horticultural activities (especially small-scale businesses); their institutions in both the water and agricultural sectors are likewise weak. Namibia is currently undergoing a process of decentralisation. Several non-governmental stakeholders operating in the water sector as well as in the development sector are active in the CEB. For further information see Werner (2008) and Werner (2011).

A number of donor-funded Basin Management Committees (BMCs) were established until 2013, but with the withdrawal of the donor they lack government backup and support. In recent years, especially in the 1990s, several attempts have been made to implement small-scale gardening projects, most of which failed due to a lack of commitment on the part of the government or insufficient integration within local structures. The Ministry of Agriculture, Water and Forestry (MAWF) with its Directorate for Agricultural Production, Engineering and Extension Services (DAPEES) is the main governmental body responsible for agricultural development in Namibia and in the CEB. Other relevant regional stakeholders in the rural development and horticulture sector are the Rural Development Centres (RDCs) in Ongwediva and Okashana.

Further institutions are the Water Point Committees (WPC), the Constituency Councils as well as the Regional Councils and the University of Namibia (UNAM).

1.3 Local demand

The project region of the Cuvelai-Etosha Basin is faced with high dependency on water from Angola and on agricultural products from South Africa. Furthermore, these products from South Africa are mainly consumed in and around the regional centres; they are not available in the rural parts of the region, where the supply with vegetables is insufficient. The local production of vegetables with the help of endogenous water resources could create a demand as well as enhancing the diet and health of the population. It could also create jobs in the agricultural sector and – if the technology spreads – opportunities in the construction sector too.

1.4 Analysis of local capacities

In the CEB, one finds a low level of education in general and a high rate of unemployment, especially among the younger people. Those who received either a higher level of education or vocational training often migrate to the urban centres or to the southern part of the country to try and find work there. Another general aspect is that poverty, malnutrition and poor health conditions have negative impacts on the regional economic development. People have little or no knowledge of how to grow vegetables and fruits. Another reason for the low capacity in this respect is that there is no cultural tradition of (small-scale) irrigation farming; this means that horticulture does not enjoy a very high status as an occupation. Nevertheless, it was shown during the construction of the pilot plants in Epyeshona and Iipopo that local knowledge is sufficient to develop basic construction and gardening skills.

1.5 Socio-economic aspects

Rain-fed agriculture, cattle herding and fishing during certain times of the year represent the main source of income for most rural residents. A high unemployment rate leads to migration to urban centres of the region or beyond, leaving behind mainly women, children and elderly people in the villages. Consequently, women play an important role in the society and are drivers of local economic development, while skilled male workers often work in mines or other industrial production far away from the region.

The health care situation in the region is very poor, with health issues such as HIV and malnutrition leading to stagnation in economic development. Malnutrition is mainly a consequence of low income and ignorance of how to grow vegetables and crops other than 'mahangu' (pearl millet).

2. Approach

2.1 Aim of implementation

The main goal is to enhance the livelihood of people in the CEB via the implementation of rain- and floodwater harvesting (RFWH). With the introduction of the proposed technologies, it is possible to increase the amount of water available for irrigation; this not only reduces the current poverty and deficits in food supply but also supports adaptation to climate variability and change by bridging temporary water shortages. An important way to sustainably implement RFWH is to establish technical know-how in the CEB while monitoring and analysing the impact of the technology.

The following positive impacts after the introduction of RFWH can be expected:

- More water available all year round
- Opportunity for irrigation all year round
- Generation of income from small-scale gardening and the sale of agricultural products
- Improved nutrition through small-scale gardening (subsistence and/or buying of additional products)
- Less dependency on Angola for water
- Less dependency on South Africa for food imports
- Job creation (small-scale gardening, landscaping, tank construction, selling produce at markets)
- Improved infrastructure in rural areas and thus reduced migration to cities
- Reduced evaporation and more productive use of water

There are also a few risks involved due to the innovative nature of the technology:

- Social cultural risks related to the joint management of communal plants
- Pollution risks of using pesticides
- Risk of salinisation due to irrigation with water from Ishana with moderate salt content
- Increase in agricultural production leading to a growing need for artificial fertilisers and pesticides which have to be imported from South Africa. It is therefore recommended to use

local manure, although this has the potential to conflict with manure needs for pearl millet farming.

- Initial malfunctioning of the RFWH technology, which may pose a problem for owners in financing maintenance and/or spare parts

Further details can be found in Jokisch et al. (2015a,b) and Liehr et al. (2015a).

2.2 Specification of the technology

The CuveWaters project introduced three different pilot options for rain- and floodwater harvesting (Table 1). The pilot plants are located in the villages of Epyeshona (RWH) and Iipopo (FWH) in the Oshana region in central-northern Namibia (Figure 1).

Table 1: Rain- and floodwater harvesting options implemented in central-northern Namibia

Water harvesting option (rain: RWH / flood: FWH)	**Catchment size $[m^2]$**	**Storage size $[m^3]$**	**Irrigation area $[m^2]$**
Option 1 (RWH, household level, roof catchment, Epyeshona)			
Ferrocement household tank	100	30	150 (90 net)*
Brick household tank	87	30	150 (90 net)
Polyethylene household tank	100	30	150 (90 net)
Option 2 (RWH, community level "green village", ground and roof catchment, Epyeshona)			
Concrete ground catchment and underground ferrocement tank	480	120	900 (540 net) outside garden and 160 greenhouse
Greenhouse roof catchment and pond with dam liner	160	80	
Green Village combined	640	200	
Option 3 (FWH, community level, storage of floodwater, Iipopo)			
Water harvesting from Oshanas with storage in two underground ponds and one ferrocement tank	Surface water from Oshana	400	1,000 (600 net) outside garden and 176 greenhouse

*'Net' refers to the fraction of garden area that receives irrigation

Figure 1: Research and implementation sites of CuveWaters in the Cuvelai-Etosha Basin. Floodwater harvesting is implemented at Iipopo while rainwater harvesting after its first implementation at Epyeshona has been replicated for example at the UNAM campus in Ongwediva (Source: Bischofberger et al., 2015). For implementation concepts for 'groundwater desalination' and 'sanitation and reuse' refer to Liehr et al. (2015b) and Zimmermann et al. (2015).

The first option includes the collection of rainwater from corrugated iron roofs and storage in a 30 m³ tank. For this option, three different materials for the storage tank were tested, namely ferrocement, bricks and polyethylene; corresponding prototypes were implemented at different households in the village of Epyeshona. Such tanks can be used for households and public buildings (schools, clinics etc.) and provide sufficient water to irrigate 60 m² to 90 m² of net garden area (up to 150 m² with pathways) (Fig. 2).

The second option consists of a concrete ground catchment (480 m²) and an underground ferrocement tank (120 m³), with a roof made of shading net. This facility is connected to a greenhouse roof catchment (160 m²) and a pond (80 m³) sealed with dam liner and covered with shading nets. This pilot plant has a combined collection surface of 640 m² and a combined storage capacity of 200 m³. The stored water volume is used to irrigate up to six household gardens (90 m² of irrigated area each) and a greenhouse of 160 m² (Figs. 3a and 3b) that is shared by all six households in a community approach called 'green village'.

The third option collects floodwater from nearby Iishana (singular: Oshana) at the height of the rainy season when water quality is best and stores the water in underground tanks and ponds with a combined storage capacity of 400 m³ (Fig. 4). Oshanas are very shallow ephemeral rivers that drain the pilot region from north to south; they are generally difficult to use due to high evaporation rates which rapidly lead to quality degradation and thus salinisation of the water. The stored water is sufficient to irrigate 10 gardens of 100 m² area each (60 m² net) and a greenhouse measuring 176 m². The floodwater from the Oshana is collected using a petrol pump.

The potential length of time during which gardens can be irrigated with harvested rainwater depends on the extent of water-saving measures, cropping patterns, garden size and the duration of the respective rainy season. Considering these factors, the stored water is sufficient for the irrigation of one or two additional annual growth seasons depending on crop type. In most areas of Namibia, rainwater harvesting is applied to enhance water efficiency, i.e. through gardening activities, and not to serve as a substitute for drinking water. However, in remote areas far away from the existing pipeline grid, harvested rainwater could potentially be treated and serve as drinking water. Within the CuveWaters project, the option of using stored rainwater as drinking water was tested using different technologies such as ceramic filters and solar radiation for treatment. It is not recommended to use stored rainwater as drinking water without further treatment.

Fig. 2. Option 1: Rainwater harvesting with ferrocement tank (Epyeshona)

Fig. 3a. Option 2: Green village – concrete ground catchment and underground tank (Epyeshona)

Fig. 3b. Option 2: Green village – rainwater harvesting pond, greenhouse and garden (Epyeshona)

Fig. 4. Option 3: Flood water harvesting with storage of surface water from Oshanas in a combination of underground tanks and ponds (Iipopo)

2.3 Profitability analysis

Cost-benefit, financial and economic analyses of the different rain- and floodwater harvesting approaches were conducted during and after implementation at Epyeshona and Iipopo. Detailed information on investments, and operation and maintenance (O&M) costs at the pilot sites as well as financial options for the dissemination of the technology are presented in Chapter 4.

2.4 Stakeholders

The implementation of rain- and floodwater harvesting and associated gardening naturally involves a set of players. All relevant stakeholders were identified and their relationships mapped. In addition, the strategic networking and exchange with political institutions was started early and continued until the end of the project.

Most of the stakeholders are local. Here, the group of players includes the village residents, first and foremost the village committee and the headman. The main national stakeholders are the Directorates DWSSC, DAPEES and DoF of the MAWF. Community workshops were carried out in close cooperation with the Desert Research Foundation of Namibia (DRFN). See Chapter 1.2 for additional information.

2.5 Capacity development

Capacity development took place at local as well as regional level. Capacity at the local level helps to implement the technology within the village structures and enables subsequent maintenance and further tank construction in the village. Furthermore, it helps to create a sense within the village of owning the technology. For details see Chapter 3.3.1, Jokisch et al. (2015a,b) and Schulz et al. (2015).

2.6 Social embedding

The beneficiary communities of the villages Epyeshona and Iipopo were included in the planning process and the installation/operation of RFWH plants. This should increase the likelihood of the communities adapting to the new water source and the new occupation options, and taking over responsibility at a later stage, as well as further reducing the risk of vandalism or theft. The involvement of community members ensures the sustainability and the long-term success of the technology within the community.

A method to foster situation analysis and participatory planning was developed with the aim of devising a locally tailored operational concept. The demand-responsive approach (DRA, Fig. 5) includes methods from social sciences and participatory planning. The aim was to involve stakeholders and residents via community workshops, and the local and regional authorities via cooperation and exchange workshops.

Social aspects have to be addressed by means of participatory planning right from the beginning of the project in order to create a sense within the village of owning the technology and to prepare a later handing-over of the pilot plants. Such planning should consist of iterative discussion and adaptation of the technological solutions. Community workshops were held to consider the specific needs and opinions of the users.

The approach was successful in terms of weighing up demand and the optimal mode of operation within a specific local societal environment.

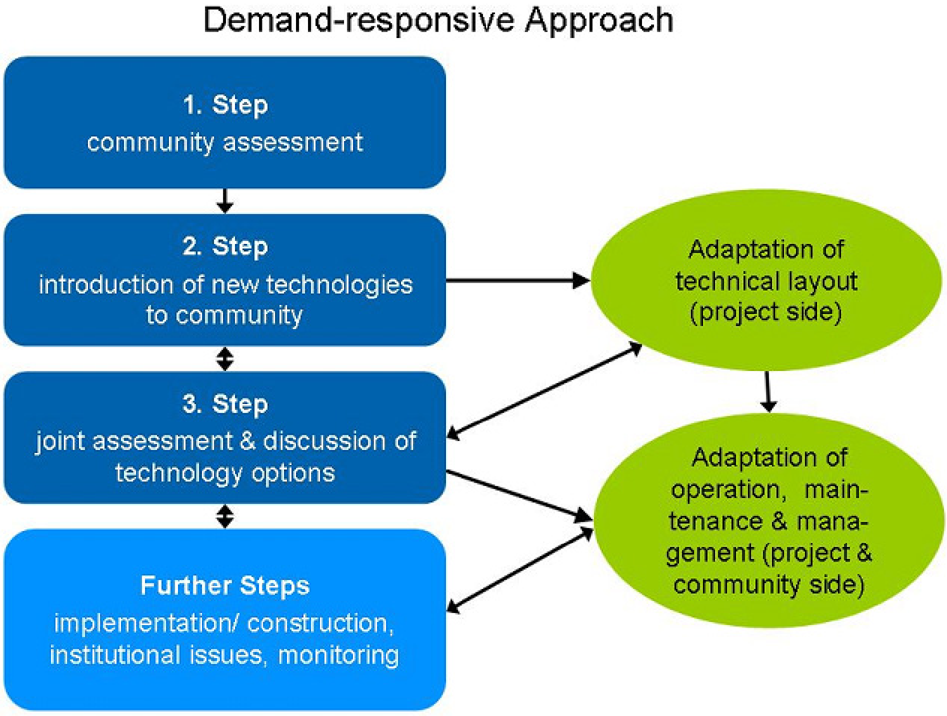

Fig. 5: Demand responsive approach developed within the CuveWaters project (Source: Deffner/ Mazambani 2010)

2.7 Impact

The positive impact of a more reliable and readily available supply of irrigation water on the well-being and livelihoods of the farmers, their families and the communities was assessed during the pilot phase (Woltersdorf et al. 2014). Social-cultural monitoring and a social-ecological impact assessment (SEIA) were conducted to evaluate the effects of introducing the RFWH technology, looking also at the potential environmental impact for the case of a regional dissemination of the technology. For details of the SEIA see Chapter 3.3.2 and Klintenberg et al. (2012).

3. Implementation

3.1 Work packages and time schedule

The implementation of RWH in Epyeshona and FWH in Iipopo started with a local demand analysis, followed by the construction of pilot plants and implementation of capacity development measures. Years later, a sustainable structure had been reached to assure the continuity of the projects, and having secured agreement on support from local to national administration, the plants were finally handed over to the local communities. With a view to spreading the technology, the experience gained by CuveWaters in this implementation process is written down in the present implementation concept for RFWH. It is dedicated to support future projects in achieving the desired results more effectively and within a shorter period. The ‘raw’ time schedule for implementing the respective activities is presented in Table 2. All phases have to be supported by ongoing monitoring and evaluation processes and the development of information material as well as a Technology Toolkit.

The question of whether to implement rainwater or floodwater harvesting technology (or a combination of both) depends mainly on the local environmental situation and whether there is an Oshana for FWH. On the other hand, any household in rural northern Namibia with a corrugated iron roof meets the preconditions for RWH. It is important to distinguish between the individual household concept (RWH) and the community approach (both RWH and FWH possible). Each household can be equipped with a tank for the irrigation of a household garden which would primarily be used for personal consumption of fruits and vegetables. The community approach is intended first and foremost for market gardening, and one facility should be constructed per village. To ensure that there is a market for these products, the facility should not be too far away from urban centres such as Oshakati, Okahao or Onaanda.

Table 2: Implementation phases and time schedule for the implementation of the CuveWaters RWH and FWH plants

Implementation phase	Activities	Time schedule
1	Demand analysis and demand responsive approach (DRA)	Workshop (1 day)
2	Development of individual village concept	Workshop (1 day)
3	Construction and capacity development	Depending on extent of implemented technologies (10 days for household approach, 20 days for communal approach)
4	Training in gardening, management and bookkeeping	20 days spread over a full growing season (4 months)
5	Start of operation and handover	½ year after Implementation Phase 1
6	Intensive assistance in first year of operation	Every two weeks over one year
7	Continuous support and monitoring (evaluation)	Once a month over three years

3.2 Operational concept

The operational concept was developed for the community and the household approaches. The household approach places responsibility for the day-to-day business of water and garden management with the household; minor repairs are done by technicians who were trained during the construction phase and who live in the villages. The headmen are well connected to those running the rainwater harvesting approach.

In the case of the community approach for RWH and/or FWH, six to ten selected users run the plants together; this involves water management, gardening (to some extent), bookkeeping and table banking. The groups of farmers hold meetings on a regular basis. Each user has his/her own allotment in the outdoor garden, while in the greenhouse the workloads as well as the revenues are shared.

Financial support is necessary to fund investment costs for more major infrastructure such as drip irrigation. The main support for both communal facility projects (communal approach of RWH and FWH) was received from the local councils, which financed facilities such as a tap connection for both Iipopo and Epyeshona in order to cope with drought in the rainy season. The users of the two plants were also very successful in raising further funds from public donors (Chinese Embassy) and private donors (NAMPower). Both approaches call for a backup unit to support the operation of the plants; this is currently organised jointly by DAPEES and the RDC Ongwediva.

Rain- and floodwater harvesting is associated with very low running costs (which are mainly associated with gardening). Garden output for some crops is restricted to a certain time of the year (during harvesting), while input (seeds, fertiliser, pesticides) is necessary during other times of the year. This makes savings necessary and requires some knowledge of bookkeeping, table banking and calculation for both the household and the community approaches.

3.3 Framing activities

3.3.1 Capacity development

A concept for capacity development was set up: it addresses technical skills for gardening, marketing (selling of produce), management and bookkeeping, which ensures the sustainability of the gardening initiatives both at community and household level (Zimmermann et al. 2012). Training on a regional scale is intended to spread the know-how required to construct tanks. To this end, a 'train-the-trainers' concept on tank construction and maintenance was set up in collaboration with UNAM and other partners in northern Namibia. After five weeks of training, the participants become certified tank- building trainers. Among the media used for the training sessions is a RFWH Toolkit, developed within the CuveWaters project (Schulz et al. 2015). It contains material to facilitate the selection of a locally adapted technology option, along with visualisation material for the steps involved in constructing tanks and gardens. The Toolkit can be used in local campaigns for RFWH and during the construction process to inform the local population and guide new local workers. Furthermore, a 'train-the-trainers' course for agricultural extension staff was initiated together with UNAM, the MAWF and the RDCs. In six weeks of training, the participants learned all skills necessary to support farmers in all aspects of horticulture, irrigation and rainwater harvesting. The training was conducted at the Rainwater Harvesting Field Laboratory that was established during the 'train-the-trainers' session on tank construction at UNAM campus Ongwediva in central-northern Namibia. In addition to this, framework conditions were created to enable Namibian institutions to conduct similar training courses in future, to which end several training manuals as well as the Toolkit mentioned above were handed over.

3.3.2 Social-ecological impact assessment

The social-ecological impact assessment (SEIA) measures the effects of the newly introduced technologies on the social setting, the hydrology and the ecology of the surrounding area. The aim of the SEIA is to analyse especially negative impacts and propose solutions. In the case of rain- and floodwater harvesting, the SEIA has shown that no major negative effects are related to the technology as long as one does not install too many floodwater storage tanks along a certain Oshana. Detailed results given in Klintenberg et al. (2012) indicate that in a scenario whereby all households in the region take part in rainwater harvesting, only 0.2% of the total rain volume would be harvested from the roofs of buildings and stored in tanks. Most of this small amount would have evaporated when falling on bare ground instead of being captured. Floodwater harvested from the Oshana near the pilot area Iipopo would be 1.65% of the total discharge in the worst case scenario. This scenario assumes that discharge only develops locally during dry years. In the case of small Iishana, salinisation and impact on the fish population are only likely to arise when extracting a considerable percentage.

3.4 Ownership

With the household approach, ownership is linked to individual households. The household members own the plants attached to their houses. The plants were officially donated to the respective households in November 2015.

In the case of the community approach, a legal framework for ownership was developed in the third project phase. The structures drawn up by the groups of users were improved in conjunction with the project partner Legal Assistance Centre (LAC) in Windhoek.

The plants of the communal approach were not donated to the participating private households for two main reasons:

- The plants were constructed on communal land and therefore the user group did not have the land rights.
- The users of the communal plants rejected the idea of taking over full responsibility and ownership privately.

The latter point of view was also supported by other village residents, as the implementation of the technology was intended to benefit the whole community. Users of the plants as well as other village residents agreed to hand over the plant to the respective headman so that he would be able to decide on their behalf. As the headman is not a legal entity and only represents the Traditional Authority (TA), the plants were officially handed over to the TA (in Iipopo in April 2015, in Epyeshona in November 2015), with the headman as the local representative of the TA. Contracts were signed that guarantee that the current users remain the main beneficiaries of the plants.

For all plants, agreements were signed with the MAWF to ensure that the users receive assistance from Agricultural Extension staff.

3.5 Services and products

The main aim of the project, namely to enhance the use of rains and floods to enable gardening activities for food supply and job creation, was achieved during the pilot phase. Additional services and achievements of the project include the experience gained with small-scale rain- and floodwater harvesting plants under challenging conditions, and the enhancement of skills and capacities at local, regional and national level.

Further products are:

– construction, training and management manuals
– fact sheets on rain- and floodwater harvesting
– GIS maps
– RFWH Technology Toolkit

– training courses
– monitoring reports
– evaluation report based on monitoring
– SEIA synthesis report
– policy briefs and policy papers
– long-term experience with plants
– handover contracts
– scientific publications

A number of these products are available for download at www.cuvewaters.net or in scientific journals.

3.6 Sustainability assessment

To ensure sustainability, the local communities were included in all aspects of the project, from concept tuning to the development of the technologies and plant construction, down to the running and management of the plants. All construction was done by local people trained by technicians from Kenya, and all materials were bought in Namibia or South Africa.

The production of vegetables is for self-consumption and for the local market only, which strengthens the local economy. The use of artificial fertilisers and pesticides is reduced to the lowest possible level and people were trained in careful application of pesticides. The water consumption of irrigation horticulture is far below that of livestock farming.

Project controlling was supported by continuous monitoring and an evaluation of the technology (Deffner et al. 2010). The key issue concerning sustainability is the operation and maintenance of the plants. A more comprehensive assessment of the sustainability is still under preparation.

3.7 Variance of implementation and challenges

The initial plan underwent the following main changes:

- RWH and FWH called for considerably more work and effort than was initially expected in order to develop gardening capacity and secure the facility management process (as well as the learning process for the group).
- FWH pilot plants were constructed to far smaller specifications than initially planned because research has shown that this makes them easier for the users to manage and that parts of the technology can be adapted from RWH. This also meant that construction could be carried out using local labour.
- The communal approaches to RWH and FWH involved the laying of emergency pipeline connections to the public water supply grid. This is due to the situation in the drought year 2013, when it became obvious that with an annual rainfall of lower than 200 mm (which happens every one in ten years on average), gardens had to be abandoned. In the long term this could lead to failure of the initiative because no income could be generated for a full year. The tap water is only intended for use in times of extreme drought or towards the very end of the dry season, and in very little amounts as users have to pay for the water.

- The households where private tanks were implemented are linked to the pipeline grid anyway and therefore have water in times of extreme drought.
- As described in Chapter 3.4 the communal plants were officially handed over to the responsible TA with the local headman as the representative. Private tanks were given as a donation to the respective households. For all private and communal plants, agreements with the MAWF were signed to guarantee support for the farmers by the Agricultural Extension Officers. The Extension Officers of the RDCs also inform informal support.

4. Economic considerations

4.1 Investment

Investment costs for RWH and FWH depend on the materials selected for water storage (tanks and ponds of different materials and sizes) and whether the greenhouse option is chosen. Cost-benefit and sustainability analyses showed ferrocement tanks to be the most appropriate option at the household level, and greenhouses with ponds at the communal level.

Table 3 gives an overview of the investment costs for the most appropriate options for the project's RWH pilot plants and for a future roll-out. Table 4 summarises the investment costs for the different options for FWH at the pilot plants and for a future roll-out. For more detailed information, see Jokisch et al. (2015a,b) and Pfeifer (2014).

Table 3: Infrastructural investment costs for rainwater harvesting in N$

Type of costs	**Household approach**		**Communal approach**	
	Material costs for pilot plant	Calculated costs for roll-out	Material costs for pilot plant	Calculated costs for roll-out
Investments for construction				
Infrastructure (tank 30m³, gutters, downpipes)	12,000-18,000	9,000		
Infrastructure (ground catchment, underground tank 120 m³, shade net covered pond 80 m³, gutters, downpipes)			110,000	82,000
Garden (90 m²), drip irrigation system	2,700	2,000		
Garden (750 m²), greenhouse (160 m²), drip irrigation system			40,000	30,000

Table 4: Infrastructural investment costs for floodwater harvesting in N$

Type of costs	Material costs for the pilot plant	Calculated costs for roll-out (per plant)
Investments for construction		
Underground tank (130 m³)	42,000	32,000
Shade net covered pond (135 m³)	23,000	20,800
Corrugated iron covered pond (135 m³)	31,000	24,500
Garden (1,000 m²), including drip irrigation	47,000	35,250
Greenhouse (176 m²), including drip irrigation	43,000	30,000

4.2 Operation and maintenance costs

The maintenance costs are low for both rain and floodwater harvesting infrastructure, and higher for gardening infrastructure due to the shorter lifetime of materials (drips, greenhouse materials). Maintenance can be organised within the village by people trained during the construction phase. If several tanks are to be constructed, this task can be institutionalised and undertaken by a company specialising in tank construction on a larger scale. Tables 5 and 6 give an overview of the operation and maintenance costs for RWH and FWH, respectively.

Table 5: Operation and maintenance costs for rainwater harvesting in N$

Type of costs	Household approach		Communal approach	
	Material costs for pilot plant	Calculated costs for roll-out	Material costs for pilot plant	Calculated costs for roll-out
Operation & minor maintenance (per year)				
Infrastructure (e.g. tanks, fences)	100	75	1,000	750
Garden (drip irrigation system, seeds, fertilisers, pesticides)	500	375	2,000	1,500

Table 6: Operation and maintenance costs for floodwater harvesting in N$

Type of costs	Material costs for the pilot plant	Calculated costs for roll-out (per plant)
Operation & minor maintenance (per year)		
Infrastructure (e.g. tanks, ponds, fences)	1,500	1,125
Garden (drip irrigation system, seeds, fertilisers, pesticides)	2,500	1,875

4.3 Cost-benefit analysis

As rain- and floodwater harvesting necessitates a certain amount of financial investment, gardening with the harvested water is a good option to recover costs through the sale of garden produce. So far only a fraction of vegetables sold in the region is produced locally, while most fruits and vegetables are imported from South Africa. Long distances lead to very high prices, and local producers can take advantage of this fact. Furthermore, especially remote villages such as the pilot village of Iipopo far away from urban centres have no local production of vegetables as yet. This indicates very good opportunities for vegetables produced with water from rain- and floodwater harvesting. The cost-benefit analysis shows very promising results in terms of the net present value achievable within the service life of the plants constructed. For details see Woltersdorf et al. (2014 and 2015) and Pfeifer (2014).

4.4 Financing options

The initial investments required for such kinds of infrastructural development cannot be made by single households or a group of farmers in Namibia. Therefore financing has to be initiated by government agencies. Several policies exist that are linked or can be linked to rainwater harvesting and which could form the framework for financing mechanisms. Regarding operation and minor maintenance costs (without renovation), it is fair to say that farmers are able to cover these costs with revenues from selling the agricultural produce at market. The following financing options are possible under the circumstances indicated:

- Microfinancing, possibly only for gardening infrastructure and the cost of maintaining gardens and rainwater harvesting infrastructure; not suitable for the investment costs required for a rainwater harvesting facility.
- Several donors and development aid companies are active in Namibia, some of them also in the water sector. These institutions could provide funding for tank infrastructure, which could also be combined with the microfinancing of gardening infrastructure and running costs.
- The funding of infrastructure by the government would be another option, for example as support for economic development in rural parts of the country.
- Private investment or bank loans could also be an option, especially for public buildings with returns (such as clinics) or households with a stable income from other jobs in urban or peri-urban areas.

An overview of national and international financing options for RFWH is given in Table 7. For further information see Liehr et al. (2015a), Zimmermann/Lorek (2014/2015).

Table 7: Financing options for water storage and reuse (with Namibian and German examples). Possible forms of financing are budget allocation, (micro-) credits, subsidies or grants. Particularly for international institutions, the opportunities for financing very much depend on the strategic fit regarding target country, technology and recipient.

	RFWH financing option
National	Private/households Regional councils Ministries (e.g. MAWF-DAPEES) National (development) banks (e.g. DBN) Government investment programmes (e.g. EIF)
International	Development cooperation (e.g. GIZ) Development banks (e.g. AfDB, KfW) European Union (EU), European Development Fund (EDF) Green Climate Fund (GEF) New Partnership for Africa's Development (NEPAD) Seed Initiative (funded 2002 by UNDP, UNEP, IUCN)

The primary partner for the implementation of rain- and floodwater harvesting is the Ministry for Agriculture, Water and Forestry (MAWF) with its Directorate for Agricultural Production, Engineering and Extension Service (DAPEES). In terms of financing the storage tanks, possible partners would be the Agribank (which typically finances agricultural projects in Namibia), FIDES (which is already active in the field of microfinancing in Namibia), the Rural Development Centre (especially for capacity development but also for the supply of materials, and probably also for taking over responsibility), the Millennium Challenge Account, the UN (e.g. within the scope of the Green Climate Fund), or other ministries/governmental institutions. For further information, see Zimmermann/Lorek (2014/2015).

5. Transfer/dissemination

5.1 First transfer projects

Research has shown both the household and the communal approaches to be successful and generate sufficient income to cover the cost of vital farming inputs such as seeds, fertilizers and pesticides. They do not generate sufficient funds for larger investments, which must therefore be financed by the government. Along with the other positive effects on the regional economy, namely a supply of vegetables for rural villages and the effects on the job market, there is a huge potential for both technologies in rural parts of the region as well as for other rural and marginalised regions of Namibia. This has also been proved by several private initiatives that have implemented communal rainwater harvesting plants or are planning to do so.

One example is a self-financed tank constructed in a pilot village. Based on the experiences of the first farmer groups, several people in the pilot villages started gardening with tap water or Oshana water in their backyards.

In 2012 and 2013, the project received some enquiries from Namibia Development Trust, GIZ, SAREP, USAID, and several private enquiries from neighbouring villages as well as from the region at large (gathered mainly at conferences and trade fairs).

In January 2013, the Rural Development Centre Okashana financed the construction of a community approach plant for rainwater harvesting in the village Onamishu (Oshikoto region). The plant consists of a ferrocement tank, pond, greenhouse and open garden area, and is run by a group of 20 people from the local community. One World Consultants were responsible for construction, and people from the village were trained in both construction and management.

In August 2013, the Regional Council of the Oshikoto region decided to build a plant similar to that in Onamishu close to the town of Omuthiya. Construction management was again undertaken by One World Consultants, including training the local people and incorporating them into the construction process. Each of the plants is worth approximately 20,000 Euros.

August and September 2014 saw the construction of another two tanks, a greenhouse and an open garden area with drip irrigation on the UNAM Engineering campus in Ongwediva. This serves as a research facility for the students at UNAM University and is financed by the GIZ. During the process of setting up the site, people were trained in tank construction and some aspects of construction site management and organisation.

5.2 Demand analysis

An impact assessment of rain- and floodwater harvesting on the regional economy in central-northern Namibia was conducted in project phase III. The report assesses the potential impacts on the economy of central-northern Namibia, assuming that the penetration and use of rain- and floodwater harvesting for horticulture is substantially up-scaled. Summarising the results it can be stated that rain- and floodwater harvesting for the irrigation of private gardens and communal facilities generally offer considerable potentials for up-scaling. Numerous economic benefits across central-northern Namibia could be created. Despite this it has to be noted that the complexities and cost of any large-scale roll-out of water harvesting at household or communal level are considerable, and should not be underestimated. For further information see von Oertzen (2015).

In addition, the dialogue and cooperation with the MAWF/DAPEES was continued, in which the dissemination and decentralised supply of small villages was discussed. By the end of the CuveWaters project, three further replications will be finished and five requests for plant construction have been placed at different ministries. In addition, there is an exchange with non-governmental organisations to explore the potentials for further dissemination of the technologies.

5.3 Marketing

Since construction of the first pilot plants, the technology has received a lot of local, regional and media attention and has been shown twice on Namibian TV news. In project phase III, the pilot plants were upgraded to demonstration plants. Regular visits to the plant sites from Oshakati, along with supporting publications in regional and national newspapers, provided further publicity. Furthermore, project members presented the RFWH approach and products at local and regional trade fairs (Ongwediva Trade Fair, Olufuku Festival Outapi), at fairs and conferences in SADC (e.g. IFAT Johannesburg) and at Technology Roundtables organized by CuveWaters in 2015. An ongoing task is the strengthening of cooperation with NGOs from all over southern Africa (but especially within Namibia) and with the Basin Management Committees (BMCs). Further important marketing strategies include close cooperation with local industries such as with hardware shops in central-northern Namibia, strategic networking with key institutions, and knowledge transfer. The CuveWaters film is already part of the marketing.

5.4 Networks and partners for dissemination

Regular meetings between TU Darmstadt and ISOE ensure ongoing discussion on further implementation. What is more, a regular exchange between CuveWaters and the main Namibian partner (MAWF) allows a rapid response to any changes that arise in the work process. The rainwater harvesting plant and garden at the UNAM campus in Ongwediva serve as a centre for capacity development and for technical studies.

The potentials of a know-how transfer on rainwater harvesting to neighbouring countries in southern Africa were explored by Müller et al. (2015). South Africa, Botswana, Lesotho and Swaziland have reached different levels of integration of rainwater harvesting in national policies. This opens the potential for an exchange. CuveWaters experiences in terms of technology, social aspects and organisation as well as economies and policy adjustments could be helpful for stakeholders in the neighbouring countries.

Possible partner organizations in the SADC region for further projects are the MVULA Trust (familiar with rainwater harvesting in South Africa), RAIN (Rainwater Harvesting Implementation Network, working all over Africa) or the WRC SA (Water Research Commission of South Africa).

RAIN is an international network, which was founded in 2003 and is based in Amsterdam. It develops, spreads and implements RWH systems, especially for areas which lack sufficient and safe water sources, and cooperates with as many parties as possible (donors, NGOs, companies, government and individuals). Three services it offers are: advice, intelligence & know-how, and implementation. Its projects are based in: Mali, Burkina Faso, Uganda, Ethiopia, Kenya and Nepal. There are no activities in the SADC region as yet.

MVULA Trust is South Africa’s largest water and sanitation NGO, established in 1993 and based in Johannesburg (Head Office). The main focus is on water service and sanitation as well as services for developing capacity within the water services sector. The Trust tries to improve the health and welfare of poor and disadvantaged South Africans in rural and peri-urban communities by increasing their access to safe water. Its projects are spread over most South African provinces but not outside South Africa; this restricts cooperation to an exchange of technical and organisational know-how. As part of its rainwater harvesting activities, the MVULA Trust supported the Limpopo Regional office in providing 76 underground masonry tanks and 159 above-ground rainwater harvesting systems to rural households by the end of 2009/10. Another 192 households were provided with rainwater harvesting systems as part of a livelihood and food security programme in two villages (North West). In Mpumalanga, 800 rainwater harvesting tanks were provided to communities.

WRC SA: The Water Research Commission South Africa is based in Pretoria and was founded in 1971 as a dynamic hub for water-centred knowledge. It focuses on meeting South Africa’s societal needs as well as needs in the water sector by providing leadership for research and development (funding). Solving water-related problems by engaging stakeholders and partners is also part of its mission. Its projects are all located in South Africa and its mandate is to look at

South Africa, although its research has an African and global focus as well. Rainwater harvesting activities: The WRC SA funded a project whereby a team of researchers from the Stellenbosch University (Department of Microbiology and the Department of Sociology and Social Anthropology) studied the quality of water from a community with rainwater harvesting tanks, and gathered information on how this water was being used. They tested the chemical and microbial quality of the water and in addition investigated the acceptance and perception of domestic rainwater harvesting tanks.

An important partner for the implementation of rainwater harvesting will be **One World Consultants** (OWC) from Kenya. OWC was already involved in the construction of almost all rain- and floodwater harvesting infrastructure constructed in project phase II and in the technical training provided in project phase III. Other important partners in implementation will be the BMCs, the Rural Development Centres in Ongwediva and Okashana as well as the regional councils which were also involved in the activities at both pilot villages during project phase II.

5.5 Intellectual Property Rights-Management

Intellectual Property Rights Management is not a concern for RFWH, as the network of project partners (no industry partners) does not fall under the relevant provisions.

5.6 Success factors

In project phase III, a continuous assessment of the opportunities for diffusing the technology on a nationwide basis was carried out. Discussions with key stakeholders were continued in order to explore possible opportunities and risks, for example at the workshop held in 2012 with representatives of Namibian Ministries, NGOS, and Universities. In addition, these issues have been investigated during research carried out in partial cooperation with Namibian universities. Risks of failure or possible restrictions on implementation were identified, and the implementation concept and activities adapted in order to avoid such risks. The results are described in this implementation concept. See also Liehr et al. (2015a) and Liehr et al. (in press).

Aspects identified as critical factors for the successful implementation of RFWH plants can be grouped into the four categories ‘starting point’, ‘social and organisational factors’, ‘technical factors’ and ‘external support’.

- Starting point: There must be a demand within the local population for additional water with which to engage in local small scale irrigation farming, as well as sustained interest within the community to build and run rainwater harvesting tanks and gardens.
- Social and organisational factors: Ongoing training and long-term guidance of the farmers is needed in all activities, including group management and firm rules for common tasks, working times and product marketing. Further success factors are the combining of different age groups of women and men to promise continuity, and women taking over full responsibility as farmers (which has to be supported by the community). A key to successful knowledge transfer is communication with the local group members in their native language.
- Technical factors: A step-by-step training programme over at least one growing period enhances knowledge about and application of fertilisers, pest control, fencing and daily maintenance. Additionally, assistance is needed with accounting/bookkeeping and product

marketing. Training in the long-term maintenance of tools and other facilities is crucial if one is to avoid extensive repairs and failure of the project.

- External support: Outside technical support from agricultural and technical Extension Offices must be provided to solve technical problems and advise on production within the limits of a given soil quality. Finally, guaranteed access to materials and spare parts in the region is paramount.

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