Journal of Namibian Studies, 7 (2010): 55–84 ISSN: 1863-5954

The coexistence of traditional and large-scale water supply systems in central northern Namibia*

Martin Zimmermann

Abstract

Looking at recent research projects in the field of water resources management, it often seems that historical, social and cultural issues are not taken into account fully. In this paper, a methodology and its application are presented which address and overcome these shortcomings. Interviews with relevant regional stakeholders provide a deeper insight into the interrelations in the system. The area of investigation is the so-called Cuvelai-Etosha-Basin which is located in central northern Namibia. It is estimated that 1 million people live in this area, which is approximately half of the Namibian population. There are no perennial rivers within the region and groundwaters are saline. To supply the population with potable water, a large technical system has been established which is fed by the Namibian-Angolan border river Kunene. However, at the same time, traditional water supply techniques such as Oshanas and excavation dams (Ometale), shallow dug wells (Omuthima), dug wells (Oshikweyo), and rainwater harvesting play a considerable role. Preliminary results of the PhD project are presented in this article in the form of perceptions and opinions of the interviewees.

> *Central northern Namibia can be understood as a complex system of different interacting factors: urbanisation processes, livestock farming, crop production, water supply with its origin in Angola, subsistence economy, management at a customary level etc. Regarding this system, it is important not to look only at water but instead to look at the whole system. (Comment of a Namibian ministry official, 07a-AP-05)*

Introduction

The concept of Integrated Water Resources Management (IWRM) became more popular among engineers, planners, and scientists in the water sector as a result of the debate on sustainable development triggered by the United Nations at the beginning of the 1990s.[1] There is a broad consensus that the Global Water Partnership (GWP) provided the best definition of the approach so far:

---

* The research presented here has been conducted as part of a PhD project at the Chair of Water Supply and Groundwater Protection (Institute IWAR) at Darmstadt University of Technology. Doctoral supervisor is Prof. Dipl.-Ing. Dr. nat. techn. Wilhelm Urban. The completion of the thesis is expected in 2011.

[1] W.B. Snellen and A. Schrevel, *IWRM for Sustainable Use of Water – 50 Years of International Experience with the Concept of Integrated Water Management*, Wageningen, The Netherlands, Ministry of Agriculture, Nature and Food Quality, 2004: 6.

> IWRM may be defined as a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.[2]

Apart from aspects of administrative and spatial integration, sustainability, participation, and interdisciplinarity can be identified as some of the concept's theoretical core issues.[3] It can be assumed that the observed broad consensus among experts is only to the wide scope of interpretation of these notions.[4] When looking at recent research projects in the field of water resources management,[5] it often seems that these topics are not adequately dealt with. However, in the context of water projects in developing countries, the issues mentioned are crucial for the success and viability of proposed institutional or technological transitions. Furthermore, in the majority of cases, tools and methods are used that allow for a deductive model building for the problems tackled, which means that model structures are already defined in advance and in some cases, the assumptions made are not even verified. Such technocratic approaches may be sufficient for administrative purposes such as feeding databases but not for planning purposes where the aim is to secure water resources and supply and thus improve livelihoods in a development context. One major problem of technology-driven concepts is that they often neglect the influence or even existence of path dependencies. However, the awareness of historically grown interdependencies is essential for the understanding of the specific behaviour and the properties of a system which is to be managed. Furthermore, when assessing the sustainability of a large technical system like a supply infrastructure and seeking solutions for possible problems, experts are often inclined to focus on mere deterministic aspects and to exclude cultural and social implications. What is also often forgotten is that even the problems identified in an observed context are not necessarily evident or can be objectively verified. External experts perceive problems differently to internal stakeholders. Apart from that, resource and technology-driven perspectives often disregard traditional water supply techniques which may play an important role within a system as will be demonstrated later.

In this paper, a methodology and parts of its application will be presented which address and overcome the deficiencies described. In particular, interviews with relevant stakeholders allow an integration of issues that would otherwise be left unconsidered. Thus, the focus will be on some preliminary results of the interview evaluation. Before the approach is explained in more detail, the area of investigation in central northern Namibia and its characteristics are introduced.

---

2 Global Water Partnership (GWP), *Integrated Water Resources Management*, GWP Technical Committee (TEC) Background Paper No. 4, Stockholm, GWP, 2000: 22

3 International Conference on Water and Environment (ICWE), *The Dublin Statement on Water and Sustainable Development,* Dublin, Ireland, January 31, 1992.

4 A.K. Biswas, "Integrated Water Resources Management: A Reassessment", *Water International*, 29 (2), 2004: 248-256 (251).

5 UFZ – Helmholtz-Zentrum für Umweltforschung, *IWRM: Integriertes Wasserressourcen-Management: Von der Forschung zur Umsetzung*, 2009.

The Cuvelai-Etosha-Basin

The area of investigation is the so-called Cuvelai-Etosha-Basin which is named after the Cuvelai system of shallow and seasonally flooded rivers extending from southern Angola to northern Namibia which drain in some cases even into the Etosha pan. The area that was formerly referred to as "Owamboland" is located in central northern Namibia and consists of four of the 13 national administrative regions, namely Oshana, Oshikoto, Ohangwena, and Omusati (Figure 1). An estimated population of 1 million lives in this area, which is approximately half the population of Namibia, but the region comprises only about 7 % (approx. 56,000 km²) of the country's area (around 824,000 km²).[6] The population density amounts to about 17 inhabitants per km², whereas the population density of Namibia is less than 3 per km².

Oshakati is the regional capital of the Oshana region and was only founded in 1966.[7] During the Namibian war of independence from 1966 to 1988, the city served as an operational base for the South African Defence Force (SADF) in their fight against the South West Africa People's Organization (SWAPO). The northern region is almost entirely inhabited by the Owambo who make up half of the Namibian population. One of the outstanding processes that characterise the north is a rapid migration into the major cities which are Oshakati, Ongwediva, and Ondangwa, but also into Oshikango and Outapi for instance. According to its mayor, Oshakati has a population of around 45,000. Approximately 10,000 people each live in Ongwediwa and Ondangwa. This agglomeration forms the second largest concentration of population after Windhoek and is an important commercial centre for the entire north. At Christmas time and on other public holidays, the population is thought to triple due to family gatherings, thus posing an enormous challenge for urban supply and disposal systems. Nevertheless, the majority of the regional population lives in rural areas and in typical rural conditions. Here, people are often unemployed and practice subsistence economy, for instance rain fed crop farming and livestock farming.[8]

Namibia is the most arid country in sub-Saharan Africa due to its high evaporation rate which is, for example, around 2,500 mm per annum in the north.[9] The semi-arid region is characterised by high precipitation variability which ranges from 50 to 990 mm per

[6] T. Kluge, S. Liehr, A. Lux, P. Moser, S. Niemann, N. Umlauf, and W. Urban, "IWRM Concept for the Cuvelai Basin in Northern Namibia", *Physics and Chemistry of the Earth*, 33, 2008: 48-55 (51); S. Niemann, *Wasserversorgung und Wasserverwendung in Namibia. Nutzungstraditionen als Grundlage eines nachhaltigen Ressourcenverbrauches im ehemaligen Ovamboland*, Hamburg, Deutsches Übersee-Institut, Institut für Afrika-Kunde, 2000: 15.

[7] Niemann, *Wasserversorgung* : 108.

[8] A. Marsh and M. Seely, (eds.), *Oshanas – Sustaining People, Environment and Development in Central Owambo, Namibia*, Windhoek, Desert Research Foundation of Namibia, 1992; J. Deffner, C. Mazambani, P. Klintenberg, K. Nantanga, P. Moser-Norgaard, and M. Seely, *Selected Results from Socio-Ecological Participatory Situation Assessments in two Sites in Central Northern Namibia*, CuveWaters Paper No 3, Frankfurt a.M., Institute for Social-Ecological Research, 2008: 18.

[9] Kluge et al., "IWRM Concept": 51.

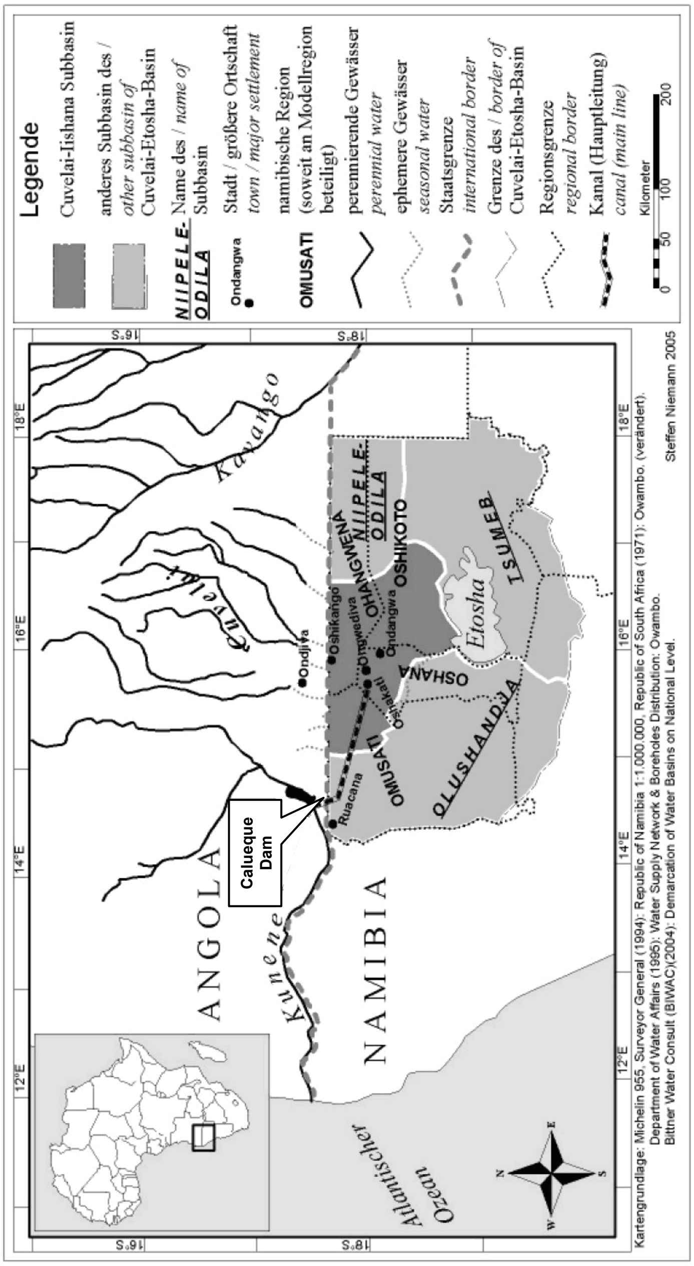

Figure 1: The Cuvelai-Etosha-Basin[10]

[10] Based on T. Kluge, S. Liehr, A. Lux, S. Niemann, and K. Brunner, *IWRM in Northern Namibia – Cuvelai Delta*, Frankfurt a.M., ISOE, 2006.

year (Figure 2), including consecutive droughts. However, the average annual rainfall is at about 450 mm per year.[11] Furthermore, there are seasonal alternations of a dry period during winter from May until September and heavy rainfall during summer from October until April (Figure 3), which occasionally bring severe flooding as happened at the beginning of 2008.

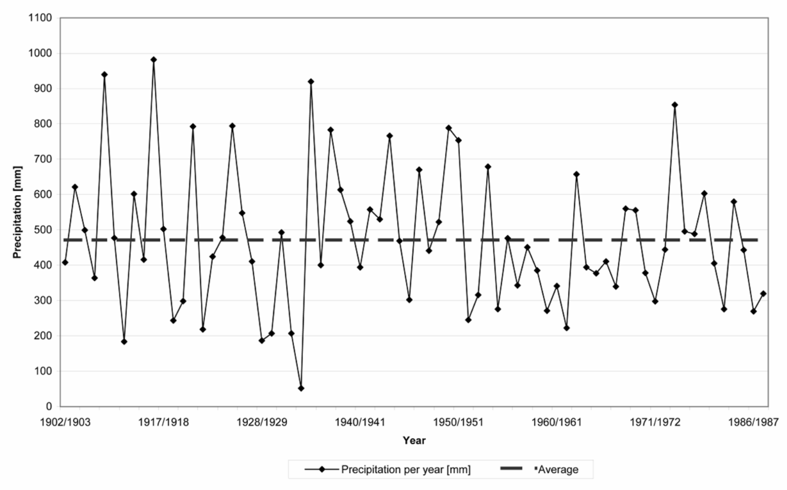

Figure 2: Annual precipitation in Ondangwa 1902-1988
(based on data of the Namibia Meteorological Service)

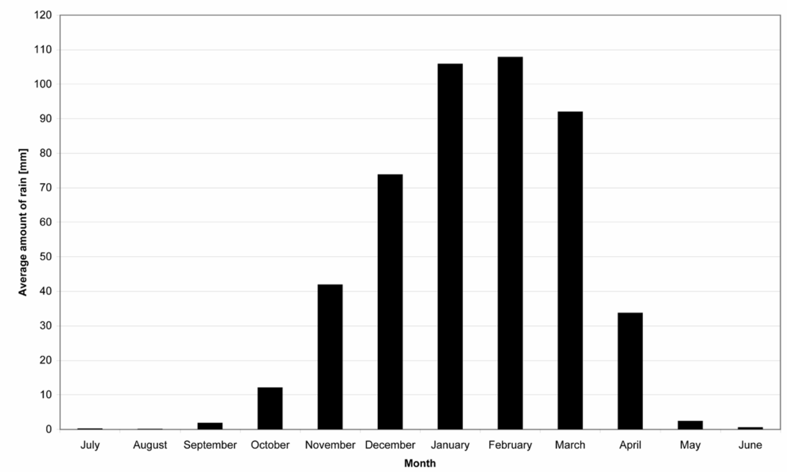

Figure 3: Seasonal distribution of precipitation in Ondangwa 1902-1988
(based on data of the Namibia Meteorological Service)

[11] M. Sturm, M. Zimmermann, K. Schütz, W. Urban, and H. Hartung, "Rainwater harvesting as an alternative water resource in rural sites in central northern Namibia", *Physics and Chemistry of the Earth*, 34, 2009: 776-785 (778).

The absence of any perennial rivers within the region and the salinity of groundwater aquifers are further serious problems. The national water supply utility's limits on the conductivity of water are often exceeded which poses increased health risks. Thus, supplying water is extremley challenging because demand greatly exceeds the supply by local water resources. Since the early 1970s, a large technical system has been established which initially served to supply SADF military camps.[12] It consists of a 150 km long open canal and a pipeline grid with an overall length of about 2,000 km.[13] This system is fed by water from the Namibian-Angolan border river Kunene which is abstracted at Calueque dam on Angolan territory (Figure 1) and distributed all over the region by the Namibia Water Corporation Ltd. (NamWater). The utility was set up in 1997 as a commercialised water corporation under the supervision of the Ministry of Agriculture, Water and Forestry (MAWF). Nevertheless, population growth, urbanisation, and the rising withdrawal of Kunene water on the Angolan side might increase the demand for water and jeopardise supplies.

Empirically grounded modelling as a new methodological approach

When dealing with such a set of interdependent problems, conventional methodologies used by water engineers and planners are not appropriate. The question now is: Which requirements should an adequate methodology meet? First of all, it should be grounded in social-empirical terms in order to take relevant social and cultural processes into account. At the same time, the method should be capable of modelling systemic interdependencies. Only in very few cases will both aspects be completely combined, which is why corresponding interfaces have to exist that allow for a seamless integration of social-empirical data and modelling. In the following pages the methods available will be discussed.

There is a limited number of approaches that can be referred to as holistic due to their integrative character. For instance, Peter Checkland's Soft Systems Methodology, Jac Vennix' Group Model Building, and Roland Scholz' Transdisciplinary Case Study Approach can be subsumed under these kinds of methodologies.[14] They all have in common that so-called messy or ill-defined social problems are tackled by making use of group interviews, some kind of systems analysis, and an assessment of scenarios to

---

[12] Niemann, *Wasserversorgung* : 108.

[13] M Zimmermann and W. Urban, "Wasserversorgungstechnische Lösungsansätze innerhalb des IWRM im Norden Namibias", in: H.J. Linke, (ed.), *1. Darmstädter Ingenieurkongress – Bau und Umwelt, 14. und 15. September 2009, Tagungsband*, Darmstadt, Technische Universität Darmstadt, 2009: 124.

[14] P. Checkland, "Soft systems methodology: a thirty year retrospective", *Systems Research and Behavioral Science*, 17, 2000: 11-58; J.A.M. Vennix, "Group model-building: tackling messy problems", *System Dynamics Review*, 15 (4), 1999: 379-401; D.F. Andersen, J.A.M. Vennix, G.P. Richardson, and E.A.J.A. Rouwette, *Group Model Building: Problem Structuring, Policy Simulation and Decision Support*, 2006; R.W. Scholz, D.J. Lang, A. Wiek, A.I. Walter, and M. Stauffacher, "Transdisciplinary case studies as a means of sustainability learning – Historical framework and theory", *International Journal of Sustainability in Higher Education*, 7 (3), 2006: 226-251.

achieve desired transition management.[15] However, the group-oriented approach in the integration of stakeholders often brings many problems and disadvantages. These mainly centre around group-dynamic processes which bias or, at worst, annul the validity of the collected data. For example, groups tend to discuss in an unstructured or inaccurate manner[16] or they try to avoid any conflicts, which leads to a lack of critical reflexion on the topics discussed,[17] and finally, the participants often adopt a defensive position to prevent a loss of face, which also leads to a negative interview quality.[18] Furthermore, the opinion leadership of individuals or factions within the group, and power constellations based on gender, age, ethnicity, religion, or traditional hierarchies play a major role. This is why the application of group interviews in the context of developing countries is limited and, in the particular Namibian case, rejected, because local traditional authorities can influence and bias the discussion.

Individual interviews can be distinguished methodically as well as in terms of their scientific-theoretical approach. Centralised top-down approaches are deductive and thus don't meet the requirements of participatory research which are of critical importance in a development context. Hence, inductive methods have to be considered which allow for a direct and systematic derivation of hypotheses, theories, or models out of the underlying data. One of the most prominent representatives of inductive social-empirical methods is the so-called Grounded Theory.[19] This approach was developed by the sociologists Barney Glaser and Anselm Strauss in the 1960s.[20] Although quantitative data can also be used in principle, only qualitative data was recorded in the present example. Several qualitative social-empirical methods are available, such as structured, focused, or semi-structured interviews. By systematic evaluation or so-called theoretical coding, codes or concepts can be identified in the interview transcripts which are empirically grounded and not biased by preconceived assumptions. These codes are topics or problems that have been mentioned by the interviewees repeatedly, and can be analysed for example for ambiguities or heterogeneities. Through an iterative and recursive procedure, it also ensures that no relevant aspects are omitted. In so doing, it is possible to create a verbal model of the system which allows for the description and

---

[15] M. Zimmermann, "Modellierung für eine nachhaltige Wasserversorgung im Norden Namibias". in: Verein zur Förderung des Instituts IWAR, (ed.), *Neue Herausforderungen und Chancen in der Wasserversorgung. Seminar des Fachgebiets Wasserversorgung und Grundwasserschutz im Rahmen des 1. Darmstädter Ingenieurkongresses Bau und Umwelt am 14. und 15.09.2009*, Darmstadt, IWAR, 2010: 137-148 (140).

[16] C.R. Rogers and F.J. Roethlisberger, "Barriers and gateways to communication", *Harvard Business Review*, November-December, 1991: 105-111 (107); Vennix, "Group model-building": 385.

[17] I.L. Janis, and L. Mann, *Decision Making – A Psychological Analysis of Conflict, Choice and Commitment*, New York, The Free Press, 1977; Vennix, "Group model-building": 385.

[18] Klimoski, R.J. and B.L. Karol, "The impact of trust on creative problem solving groups", *Journal of Applied Psychology*, 61 (5), 1976: 630-633 (632); C. Argyris, "Good communication that blocks learning", *Harvard Business Review*, July-August, 1994: 77-85 (80); Vennix, "Group model-building": 386.

[19] B.G. Glaser and J. Holton, "Remodeling Grounded Theory", *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, 5 (2), 2004: Art. 4.

[20] B.G. Glaser and A.L. Strauss, *The Discovery of Grounded Theory*, New York, Aldine de Gruyter, 1967.

explanation of the systemic interdependencies while comprising also the worldviews or perceptions of all stakeholders.

The main drawback of verbal models is their poor operability. Simulations for the construction of scenarios can only be run verbally but not in a system-analytical or methodically grounded way. This is why it seems reasonable to integrate the described method in systemic and cybernetic modelling approaches. The Grounded Theory meets the necessary requirements for combination with such methods. These include for example System Dynamics[21] which are purely quantitative and are based on cybernetic systems theory.[22] Since in this case the data is almost entirely qualitative, the Sensitivity Model is preferred to the former.[23] This approach allows for the construction of a model of the deterministic system and comprises descriptive, analytical, as well as explanatory elements. More details on the Sensitivity Model will be provided in the section on 'List of system variables and next steps'.

The sample of the empirical survey consists of more than 60 interviews with 53 interviewees. During a field trip in 2007, 36 interviews with 28 interviewees were conducted.[24] In a second field trip in 2009, 25 interviewees were questioned. In the last case, the interviewees were accompanied by the interviewer for a period of roughly two months. Hence, a participant observation could also be carried out to identify and analyse the routines and perceptions of the water users. All relevant stakeholders of the region were interviewed. The interviewees can be assigned to different areas, but the focus is on representatives of the water sector. In addition, officials from ministries, administration and politics, of national and international governmental and parastatal organisations as well as NGOs and scientific institutions were surveyed. Consulting engineers, traditional authorities and other individuals such as water users themselves were also questioned. Without these, insights, especially into rural conditions, would not be possible. The broad spectrum of interviewees ensures that the points of view of those who make policies and influence the system as well as of those who are affected are included.

The discussions were conceived as semi-structured or focused interviews to meet the requirements of the inductive approach. Contrary to structured interviews, no preconceived questionnaires were used, thus the conversation was kept thematically open as long as possible which allows for an unaffected integration of the interviewees'

---

[21] J.W. Forrester, *Industrial Dynamics*, Waltham, Pegasus Communications, 1961.

[22] E.g. N. Wiener, *Kybernetik – Regelung und Nachrichtenübertragung im Lebewesen und in der Maschine*, Düsseldorf, Econ, 1965; L. v. Bertalanffy, *General System Theory. Foundations, development, applications*, New York, Braziller, 1976.

[23] F. Vester, *Neuland des Denkens – Vom technokratischen zum kybernetischen Zeitalter*, Stuttgart, Deutsche Verlagsanstalt, 1980.

[24] These interviews were partly conducted together with Dr. Stefan Liehr from the Institute for Social-Ecological Research in Frankfurt a. Main (Germany) within the research project "CuveWaters – Integrated Water Resources Management in the Cuvelai-Etosha Basin (Central-Northern Namibia)" which is funded by the German Ministry of Education and Research.

worldviews. The only guideline for the conduct of the interviews and for the evaluation of the data was the focus on the provision, acquisition, and utilisation of water, including all impacts, effects, requirements, and constraints on the system which were observed and identified. These interdependencies comprise technological, ecological, social, economic as well as political and institutional aspects. Furthermore, the observed interrelations were explored in terms of time and space, for instance with regard to past and assumed future development. In this context, path dependencies are of particular interest. For the spatial dimension, the differentiation between urban and rural structural classes is crucial. An analysis of the involved actors and stakeholders was also conducted. Not only was specific information about these groups recorded, but also details of their relationships to each other as well as constellations within the network of actors. Thus, their perceptions of problems, goals, interests, influence, power, expectations, and options for action could be identified as well as how they were affected by systemic impacts and/or actions. This implies a clear distinction between a deterministic system of entities, which is described with the system variables above mentioned, and a contingent system of actions.[25] The deterministic interdependencies are of course ambiguous since only the perceptions of the interviewees can be identified and analysed. Although there are some approaches, the system of actions will not be modelled in terms of causal relations.[26]

Regional water supply techniques

In our case, the terms 'technique' or 'technology' refer to all observed kinds of acquisition, treatment, and delivery of drinking water. Hence, this implies a broad understanding of the notion of technology. According to theories of the sociology and philosophy of technology technologies range from material artefacts to the mere (immaterial and maybe even implicit) knowledge of, for instance, water sources and qualities.[27] Furthermore, the term 'drinking water' is not specified more precisely since waters of differing qualities are used for drinking purposes.

In the following, the interview statements are presented unless otherwise stated. Scientific expertise was only made use of if necessary, i.e. if statements were obviously wrong. Ambiguous or contradictory statements by the interviewees are also indicated. The contents are arranged in topics according to the above mentioned codes or system

---

[25] G. Ropohl, *Eine Systemtheorie der Technik: Zur Grundlegung der allgemeinen Technologie*, München, Hanser,1979: 104.

[26] E.g. P.W.G. Bots, M.J.W. van Twist, and J.H.R. van Duin, "Designing a power tool for policy analysts: dynamic actor network analysis", in: J.F. Nunamaker and R.H. Sprague, (eds.), *Proceedings of the Thirty-second Annual Hawaii International Conference on System Sciences*, vol. 6, Los Alamitos, IEEE-Press, 1999: 6029.

[27] W. Rammert, and I. Schulz-Schaeffer, "Technik und Handeln – Wenn soziales Handeln sich auf menschliches Verhalten und technische Abläufe verteilt", in: W. Rammert and I. Schulz-Schaeffer, (eds.), *Können Maschinen handeln? Soziologische Beiträge zum Verhältnis von Mensch und Technik*, Frankfurt a.M., Campus, 2002: 11-64.

variables. When referring to the 'supply side', officials and experts of the supply utility as well as authority representatives of the corresponding administrative bodies including politicians are being referred to. Experts comprise external consultants and scientists.

According to observations made by the author, five spatial categories can be roughly distinguished in the region. They refer to differing settlement structures found in the urban centres and remote peripheral areas. This is particularly important in terms of the allocation or mapping of certain phenomena to these spatial classes. Basically, the categories are subdivided into developed and undeveloped areas, where developed, in the following, means that an area is supplied with tap water and/or electricity and streets. The spatial categories are as follows:

- Developed urban space, e.g. central districts close to a main road in cities like Oshakati or Ondangwa which are usually connected to a sewage system.
- Informal urban space, like in the nine informal settlements of Oshakati in which 65 to 75 % of the city's population lives.
- So-called 'locations' in rural areas, which are predominantly characterised by retail, services, crafts, and Cuca shops (Shebeens or public bars) and usually but not necessarily developed. In general, locations are along tarred roads but can also be in rural village centres.
- Developed rural space as well as
- Undeveloped rural space which are both mainly characterised by (subsistence) agriculture.

Large-scale water supply

The first system variable is the large technical water supply scheme which is of course a central, if not the most important, system element. The water supply infrastructure is seen as the one with the highest priority compared to traffic or other infrastructures, especially by authority representatives. Thus the supplier says that the system's benefits outweigh the negative impacts by far. The water supply in the region depends mainly on surface water. Most of the domestic demand is met by pipeline water. The large technical supply scheme is fed by the water of the Kunene River. Around 80 to 90 million cubic metres of water are officially withdrawn per year from the Kunene runoff at an extraction point close to Calueque dam on Angolan territory. However, this is just a fractional amount in comparison to the total runoff but we will come back to this issue again later. As usual for a surface water source, treatment is necessary to achieve drinking water quality standards. This is accomplished by four treatment plants of which the Oshakati water treatment facility has the largest output of tap water with about 1,400 to 1,600 m^3/h. In total, around 3,300 m^3/h of raw water are treated by the four regional plants according to Namwater. The pipeline water is of comparatively high quality.

The water pipeline scheme covers nearly the whole region and provides a tight network of pipes as well as public and private water points. According to NamWater, the infrastructure takes the tap water as far north as Oshikango, as far south as Omapale, and as far east as Omutsegwonime. Depending on the radius around a water point, the percentage coverage of the large technical water supply ranges from 75 – 80 % according to the Ministry of Agriculture, Water, and Forestry (MAWF) up to even 90 % according to the Department of Rural Water Supply (DRWS). So it is said that only a low percentage of the population remains without access to tap water. But this is not seen as a serious problem since the expansion of the pipeline branches is continuing. The completion of the Ruacana south and the Amanzi schemes will increase the coverage so that the whole region is served with potable water. The situation of the population is considered good by the representatives on the supply side due to the available access to the improved water source.

In rural areas, several public water points as well as private taps are connected to each pipeline branch. Water points are located at every 3 to 5 km at least. In the village of Epyeshona, which lies in the Okatana constituency around 5 km north of Oshakati and which has been one of the major locations of the author's field trips, there are three public water points to which nobody has to walk more than 1 km. These water points belong to the Ekuku-Amatanga branch line which in total has seven public taps. Foreign experts are astonished by the high density of water points and consider this unusual for Africa. The Epyeshona water point No. 3, for instance, is used by about 15 households whereby each so-called homestead consists of between five and 15 inhabitants. Water point No. 2 is used by approximately seven households or around 40 people. The usage of communal taps is not very popular since the water has to be carried in buckets to the users' homesteads. Currently the majority of households, around 80 %, are using private taps as far as this is affordable and the number is increasing on this branch of the pipeline.

Limits to the water supply system are not dictated merely by hydrological water availability as we will see later but in the capacity of the purification plants, the canal, and the pipeline grid itself. The main limit, however, is not the treatment capacity of the plants themselves since these could be upgraded but rather the availability of water. Thus, the canal capacity is the main limiting factor. According to NamWater, this stands at approximately 2,880 m^3/h at the Oshakati treatment plant, which is where the canal ends. Although a concrete projection has not been made yet, government representatives state that the limitations of the water supply system and its capacity can already be seen:

> The [water] supply system is constructed for too few people taken population growth into account. (MAWF official, 07a-WM-08)

Other officials say that the water supply is not the critical factor in the region. An increase in water abstraction from the Kunene River is not expected in the future and the capacity of the canal is sufficient. Challenges such as a growing demand can be dealt with with technical solutions, e.g. an upgrade of the treatment plants or the expansion of the pipeline system.

The expansion of the pipeline network is an ongoing process especially in rural areas but also in informal settlements around the major cities of the region. The construction of new pipelines is seen as a necessary measure by the supply side due to increasing demand caused by population growth. Generally, new pipelines and an increase in the number of water points seem to have only positive connotations and their benefits are emphasised. New water points through grid extensions are supposed to reduce the pressure on the existing water points. In the first years of the water supply system, in the mid 1970s, the pipeline was only built along and to existing agglomerations and infrastructure, such as roads, schools etc., which caused an acceleration in the concentration processes. After this phase, the pipelines also spread into less populated areas which slowed down those processes. This also complies with governmental policies to control urbanisation and migration. The only limits to an extension of the network are seen in conservancies or nature reserves. However, the priorities of the supply side is to reach total coverage so that

> […] soon everybody will be served with tap water. (Official of the Ministry of Regional Local Government, Housing & Rural Development, 07b-AP-01)

> [The goal] is reached when everybody has access to water. (MAWF official, 07a-WM-08)

Technical problems with the large-scale water supply system

The second technical system variable deals with problems within the large scale water supply system. These comprise system inherent water losses and problems with maintenance and repair. The total systemic water losses (including distribution losses) based on estimates of the author are at least 70 %, realistically at 75 % or even more, in which losses due to evaporation and leakages in the open canal account for roughly 65 %.

> Problems of the supply system are leakages and evaporation at the canal part of the system. (Official of the Iishana Basin Management Committee, 07a-WM-05)

According to officials, there are 25 % losses between Calueque and Olushandja and then another 30 % by Oshakati. Consultants state in studies of water losses in the system which were conducted at the beginning of the 2000s that the point will be reached when this cannot be continued anymore. These losses are not only due to evaporation and leakages but also due to illegal abstraction for irrigation purposes on the Namibian as well as on the Angolan side of the border, vandalism, and other forms of misuse.

> There are a number of damages of the canal walls; […] parts of the concrete wall of the canal are sometimes used as walls for Cuca shops. (Official of the Directorate of Rural Water Supply (DRWS), 07a-WM-07)

Despite the problems, it could be observed that even at the end of the dry season, the canal was still well filled. At some sections, the water level was even above the canal wall. The same applies to Olushandja dam and Calueque dam.

The first installations of the pipeline scheme date back about 35 years which makes maintenance and repairs necessary. These comprise the modification of structural elements or the replacement of parts of it by new material. It is said that there are a lot of ongoing rehabilitation projects but they face several problems and this is seen as a serious danger for the complete supply system.

> The main threat for the water supply system is […] the lack of maintenance of the technical infrastructure. (MAWF official, 07b-WM-04)

In technical terms, maintenance is problematic due to the length of the pipeline. Furthermore it is stated that the value and lifespan of the infrastructure is declining. Representatives of the supply utility complain that new pipelines, which are supposed to have a lifespan of 30 years, in reality only last 15. Another problem is the availability of spare parts. The construction materials used often have to be delivered from Windhoek and technicians complain that they have to wait for two weeks on deliveries. The maintenance required due to the aging of the pipeline is very cost intensive. Officials state that the utility lacks money for these purposes, which can sometimes make maintenance impossible.

Finally, problems are also seen in the water treatment processes. The purification of surface water makes flocculation and disinfection chemicals necessary, the transport, deposit, and handling of which can be difficult, if not dangerous. For instance, the chlorination process is complicated because the production of undesired carcinogenic disinfection byproducts must be avoided. As a result of these problems, calls for alternatives have become louder.

> The water supply is in danger and it is the basis for everything. (DRWS official, 07a-WM-07)
>
> Alternative sources of water […] are needed to reduce the stress for the pipeline. (DRWS official, 07a-WM-07)

Oshanas and excavation dams (Ometale)

The region actually has another water supply system, the so-called Oshanas. Once a year this ephemeral and intermittent river system, the Cuvelai system, brings the surface runoff of southern Angola's precipitation into the region. The water from the Oshanas can be used directly during the rainy season but it is also possible to retain it with excavation dams, so-called 'earth dams' or Ometale (singular: Etale). They usually, though not necessarily, lie within the Oshanas or are nearby and, in this case, are fed by a hand-dug canal. Ometale have been an important part of the water supply system since the 1960s and can be found everywhere, especially in rural areas so that the region is almost littered with them. Earth dams are mostly built by using construction machinery, for instance as a side effect of road works where sand is needed as an aggregate. Rural communities have been known to try to build Ometale manually but generally, funding, knowledge, and appropriate machines are necessary. This is also the reason why earth dams are rarer in remote peripheral areas of the region. Ometale vary considerably in size depending on the design but the surface areas can be up to 1-2 ha.

Their depth can reach 4.5 m at the end of the rainy season and is around 2 to 3 m during the dry period. It is common to call Ometale 'earth dams' but in fact they are excavation dams since no dam or weir is built but the bottom of the reservoir is excavated and deepened.

> There have been lots of earth dams in the past but they have been pushed away by the pipeline. (NamWater official, 07a-WSU-01)

Ometale served for decades as water sources but they are not supposed to play an important role anymore because of the availability of tap water. Some authority representatives even state that earth dams therefore need to be protected. In the last few years the usage patterns of the Oshana water have changed. While in the past, people could use the water from January until October, it is said that this is not the case anymore. However, it could be observed that even at the end of the dry period, the Ometale were still well filled. Locals also say that there is no real scarcity of water. The water is mainly used for watering livestock. In the rainy season this is done directly at the Oshanas, whereas during the dry season the livestock are driven to the Ometale. Nevertheless, the water is also used for human consumption, even as drinking water especially in peripheral areas and/or by the poor. While experts know that dams and lakes are polluted and might harbour severe health risks, the ordinary population is not aware of this. Other usages include brick-making, the brewing of traditional drinks, or laundry. Oshanas and Ometale also contain fish which are caught at the beginning of the rainy season.

The main problem of Ometale beside their water quality is the high evaporation rate which can be up to 2,500 mm per year in central northern Namibia.[28] However, the sheer size of the earth dams makes up for this. Another negative aspect is the drain on resources caused by the planning and financing of such projects. In ecological terms, Ometale water is always said to be saline. Representatives of the supply utility claim that the Ometale are only suitable for cattle but land has to be cleared for cattle-raising and this leads to deforestation and land degradation. It is also said that there are cases where the authorities have had to compensate for the loss of available land. Furthermore, earth dams can cause problems for downstream ecosystems. In general experts state that this source is very unreliable and unpredictable due to rainfall variability. Building activities upstream, like roads or shopping centres built across or in the middle of Oshanas, can also prevent runoff from the north reaching the earth dams.

One of the major advantages of Ometale is that they are of benefit to an entire community and not just individual households. The idea that, for instance, the Iishana Basin Management Committee (IBMC) should build earth dams around villages in the dry period even meets approval among some politicians. In particular, the rural population desperately wishes to receive support for the construction of Ometale and expressed this at every opportunity. More Ometale would considerably reduce the walking distance to this water source. Foreign experts were astonished that there is still so much water in

[28] Kluge et al., "IWRM Concept": 51.

the dams at the end of the dry season despite the huge evaporation rate. One of the main reasons for this is loamy and silty layers of soil which can be found throughout the region just below surface. These layers mean that hardly any water seeps into the ground. Rural inhabitants report that Ometale only fall completely dry during severe droughts, which occur roughly every 10 years. Some government representatives even argue that high evaporation rates are advantageous as they lead to more precipitation. Another important reason why the population asks for more Ometale is that tap water is perceived as too expensive, especially for purposes other than drinking. Even though earth dams are not promoted by officials from the supply side, politicians concede that Ometale would be beneficial for livestock farming. Furthermore, the population does not consider growing livestock numbers a major risk. Earth dams are also essential for the survival of livestock during the dry season. Apart from that, more Ometale would contribute to improving the nutrition of the population by adding fish to the diet. One of the greatest potential benefits of Ometale is seen in using its water for irrigation purposes. Some consultants state that the installation of a low cost drip irrigation system would require around 600 litres of water per week which could, in theory, be transported by donkey carts.

Ometale are organised by traditional authorities. Usually the headman of a village manages the usage of the earth dam's water. For community members, access to Ometale and withdrawal of water are not restricted. The headman represents the interests of the village vis-à-vis the regional councillor and is responsible for expressing the community's wishes, for example, for a new earth dam. The government also promotes and organises the construction of earth dams to create jobs, as well as to assist rural communities, mainly in watering their livestock but also for household purposes and even irrigation. Hence, research has been carried out in the past to determine optimal sizes and structures of excavation and storage dams with regard to evaporation, depth, volume, and fluctuation of rainfall as crucial parameters. Nevertheless, one major problem is that government and communities' definitions of earth dams differ. The former generally thinks of large-scale solutions, whereas rural communities think of smaller installations at specific locations due to their knowledge of local geological conditions. Even among government representatives it is not clear which strategy to pursue. While some say that it would be very helpful for the people if the earth dams were upgraded by removing sediment and deepening them, others state that this is no solution due to the salinity of groundwaters. However, there is considerable support for Ometale across different stakeholder groups on the grounds that earth dams provide a good solution and an alternative source of water.

The situation in periurban informal settlements is somewhat different. Since the settlements are much more densely populated, there is a lack of space for earth dams but still some lakes can be found, e.g. in Oshakati's suburb of Pohamba. These lakes are also often a result of mechanical excavations during construction activities and are fed directly by precipitation and/or surface waters of Oshanas. Informal settlements are already populated by the poor and the poorest of them have to consume water from this source although it is of lowest quality according to municipal officials.

> The people cannot afford paying for the tap water and many unemployed people fetch water from the lake. In the future this will be even worse. (Traditional authority, 07a-WU-01)
>
> This is also a severe health threat because the people drink lake water. (Local politician, 07a-AP-01)

Shallow dug wells (Omuthima)

A traditional water supply technique which has been used for generations and is still in use are Omuthima. These are shallow dug wells that are mainly used for the storage of Oshana runoff which is why they are also mostly located within the riverbed. Similar to the Ometale, there are also examples where they lie outside and are fed by hand dug canals. Omuthima are 4-5 m in diameter and have a depth of 8-9 m. Local people say that this technique has not been in use for at least 15 years. It is also said that this is mainly due to the expansion of the pipeline system. Steps are usually built into the soil of the walls like a spiral staircase for the user to reach the water table. Depending on the time of the year, the water level can be at the very bottom where sometimes an additional wooden ladder even leads further downwards. In almost all observed cases, the Omuthima were not maintained and were completely filled with sediment so that they were inoperable.

The water from Omuthima has been used for human consumption as well as livestock watering in the past. Nowadays they serve at best for brick making or washing if they contain water at all. The rural population even drinks the water although it has the poor quality of surface water, but it is said that it has never harmed anybody. Usually, the sediments that are spilled into the well with every flood have to be removed each year. Every Omuthima typically has an owner but every community member who helps to shovel out the deposits is then allowed to extract water.

Omuthima can be found in developed rural areas and close to cities as well as in remote peripheral parts of the region. One of their major advantages is their depth. Compared to Ometale, Omuthima have a much smaller surface to depth ratio which reduces evaporation. However, they still fall dry much earlier due to the smaller volume of water stored. Omuthima never contain water throughout the whole dry season. Furthermore, the water can be saline depending on their location.

For instance in the village of Epyeshona, at least five Omuthima can be found directly within the local Oshana but all of them have been abandoned and are no longer maintained. The same applies to further observations in the region. This can be seen as a clear indication that the Omuthima as a traditional water supply technique is dying and that water scarcity is not perceived as a problem by the rural population. Among government representatives and officials from the supply side, Omuthima play also no role.

Dug wells (Oshikweyo)

Another traditional water supply technique is the so-called Oshikweyo which are usually hand dug wells with a depth from 2-3 m up to 5-9 m. This is the most common method of making use of groundwater resources and can mainly be found in undeveloped rural areas, less often in peri-urban areas. For instance in the Okatana constituency, it is said that there is only one such well. In the majority of cases, the wells are not protected which means that they have neither roofing nor brick walls nor an apron. Oshikweyo are often equipped with a winch and a simple bucket-and-rope-system for lifting the water. Sometimes ladder rungs are attached to protected walls to allow for maintenance.

In the past, dug wells have been mainly used for human consumption but also for watering livestock. Nowadays this is only the case in peripheral areas of the region where there is poor access to pipeline water. Especially in the southern parts of the region, it is said that there is a large number of wells, e.g. at Oponono, because the land is used for grazing cattle herds. In other areas, wells are also used as an additional water source. The main problem with the groundwater quality is the high level of salinity throughout almost the entire region.

> In the 1970s and 80s the water wasn't that saline as today. (Local Water Committee member, 07a-WU-02)

Authority representatives say that this is one of the main reasons why Oshikweyo are hardly used. Since fresh water aquifers are mostly shallow, they dry out quickly according to government officials, and deeper aquifers have the problem of salinity. Another challenge is that groundwater tables are sinking. Local communities report that it is no longer possible to reach the groundwater with hand dug wells anymore. By October, which is the end of the dry season, up to 70 % of the wells had been abandoned according to experts. However, the Oshikweyo the author saw still contained water at the end of the dry period. This was confirmed by the owners, as was the fact that the water was not saline. This may, however, have been an exception. Another water quality issue arises because Oshikweyo for watering livestock have a well mouth which is large enough for cattle to enter. For this reason people say the water is usually cleaner in the morning. Apart from that, there are also typical problems connected with unprotected wells, for instance animals falling into the well and drowning. Several experts state that dug wells were more sustainable than the pipeline water or Ometale since Oshikweyo limited the problem of overgrazing in the past. This has again to do with access to water sources and the pressure on farmers to move on to other places.

In the past the people used to have their own boreholes. Usually, Oshikweyo are used exclusively by the homestead's inhabitants who own them. Nowadays, dug wells are not very sought after by the population of developed rural areas. Basically, there are two reasons why Oshikweyo are rejected. This is due firstly to the financial resources of the inhabitants. It is said that to dig a well and to arrange for its protection is too expensive. This doesn't sound very plausible considering the costs of alternatives. Secondly, there is a cultural issue which means that in areas where tap water supply is provided, the reputation of traditional techniques is lower. This might even be the major reason.

If one has a tap, nobody wants wells anymore. (MAWF official, 07a-WM-09)

A possible option to cope with the salinity of groundwaters which was discussed by the interviewees is to apply desalination technologies. It was agreed that treatment is necessary to achieve drinking water quality. Some government officials say that desalination could be a solution to this problem and that it also wouldn't have significant negative effects. However, most representatives say that it would be very optimistic to believe that such technologies could be sustainable. Only if the technique is simple can it also be viable, but desalination is complicated and expensive. This applies especially to processes of reverse osmosis and, to some extent, also to solar-thermal ones, according to interviewees from the water utility. Examples of experiences with existing cases were given that highlighted several maintenance problems like missing spare parts and the lack of technical know-how or the inadequate yield of such facilities which could only meet the water demand of single households but not of communities, let alone livestock. Futhermore, it is said that such technologies would stimulate the people's demand for more services of this kind which is not wanted by officials on the supply side due to the related costs. Some of these representatives said desalination is completely inadequate for the level of technology in the region and thus not viable. This solution lacks technical robustness as well as trained technicians or caretakers and is too expensive, they state. Another criticism is that an ecologically important issue like the disposal of the brine has not yet been addressed.

Rainwater harvesting

Rainwater harvesting (RWH) is a technique which is known to most of the population. Usually three components are needed for the purpose of collecting the precipitation, namely a catchment area, a delivery system, and a reservoir. Theoretically, roofs as well as ground areas can be used as catchments. Corrugated iron roofs which are very common in periurban and developed rural areas are ideal for the purpose of RWH. Traditional thatched roofs can be found in rural areas but these are less suitable due to problems with runoff, water quality, and shape. It can thus be assumed that rainwater collection has only become widespread since the introduction of corrugated iron roofs. However, many interviewees do remember precipitation being harvested during their childhood.

Rainwater can be channelled via more or less sophisticated installations using gutters and downpipes but this is not very common. Experts state that there is far too little RWH being carried out in the region. In the majority of cases, cooking pots, buckets, and sometimes oil drums are used to collect the runoff directly from the roof without guttering. This is, according to the local population, due to lack of financial resources and technical know-how. Furthermore, there are no traditional methods to store the rainwater apart from the containers mentioned and these are wholly inadequate. Only a few people can afford plastic tanks for this purpose. Precipitation in this semi-arid region is roughly 450 mm per year.[29] However, during the rainy season up until March in particular, it is possible to harvest a considerable amount of rainwater. As the local people report, rainwater is mainly used for domestic purposes like washing laundry, cooking, personal hygiene, but also for drinking. The harvested water is not usually treated with filters or the like.

Some representatives on the supply side state that RWH could be useful since nobody knows what consequences a pipeline breakdown would have, whereas others say that there are no advantages at all. The majority of the interviewees are critical of the technique. One major drawback is the relatively small quantity of mean annual rainfall, according to officials on the supply side and other experts. This, combined with the high evaporation rate, is said to limit yields too such an extent that RWH doesn't make sense anymore. Another problem is seen in the lack of suitable roofs according to other government representatives and experts. Although the author has seen evidence to the contrary corrugated iron roofs are supposed to be almost completely absent from the region. Furthermore, it is stated that they are mostly owned by middle income households and that the poor may not be able to afford them, which is an aspect which has to be considered in any plans to promote RWH. The share of the population who do not have the means to pay for such roofing is estimated at about 1 % compared to 99 % who do, according to government officials. Furthermore, some experts say that dust and sand being blown onto the roofs by the wind can adversely affect water quality. Generally, quality aspects are considered to be very important since insufficient care for and maintenance of catchments and reservoirs can quickly lead to the collected water being contaminated. Interviewees from the supply side compare quality of the rainwater unfavourably with that of potable water.

> Collected rainwater is of bad quality. The Kunene has the purest water, so there is no advantage of having rainwater harvesting. (MAWF official, 07b-WM-04)

Another point of criticism is the cost of RWH systems. They are said to be economically inefficient, particularly due to the construction materials needed for the storage tank. Depending on the type of reservoir, e.g. made of ferro-cement or bricks, materials like sand, cement, and reinforcing steel are necessary. These may be available locally but vary in quality and price. There is a wide range of opinions among the experts regarding the availability and quality of local construction materials. Some say that it is completely impossible to use the local sand for instance, whereas others claim that there are no problems at all with it. Furthermore, self-made gutters and downpipes could be used instead of ready-made ones to reduce costs, but investigations showed that the saving potential is rather low. In socio-cultural terms, there is a problem in remote peripheral areas where RWH could be a valuable additional source. Here, the mobility of the population is said to be higher due to the transhumance, i.e. the seasonal movement of the people with their livestock. This is not reconcilable with the settled lifestyle that is required for a RWH facility, according to representatives from the supply side.

---

[29] Sturm et al., "Rainwater harvesting": 778.

Interviewees gave examples that show how projects run by development organisations have failed. It was reported that RWH facilities at schools in the region which were built by a European development agency, did not work properly at first and broke down later. Thereafter, frustration led to vandalism of the tanks. In another example, it was reported that tanks originally intended for the purpose of storing rainwater were used for the storage of all kinds of food and goods since the RWH system was inoperable after some time.

On the question of the possibility of using ground areas as catchments for the collection of precipitation mentioned above, opinions also vary. So-called ground catchments are difficult to construct and require a lot of maintenance, according to officials on the supply side. It is also said that they are cost-intensive due to the materials, tools and machinery required, and thus are not viable.

> These technologies [RWH using ground catchments] only mean more investments. Still the people are not able to survive droughts or to feed their cattle. (MAWF official, 07a-WM-10)

Interestingly, another traditional technique exists which is quite similar to the use of ground catchments. The clay layers mentioned above which can be found in the soil of the region are traditonally used to thresh the Mahangu which is a widely cultivated pearl millet and the key element of the population's nutrition. For this purpose, the upper sandy layers of soil are removed to uncover a plain and firm pan-like area of several square metres. In these 'Odobes', the accumulation of rainwater during the rainy season is a side effect and the accumulated water remains there until May at least, according to the local population. Experts say that the water from these ponds is used for household needs and also for livestock watering. As explained earlier, the clay catchments hold the water due to reduced infiltration and percolation.

> Alternative technologies like rainwater harvesting are needed. (Municipal technician, 07a-AP-02)

Nevertheless, the interviewees did see some potential for RWH. Government officials as well as experts state that on a household level the stored rainwater could be used for irrigation. Rural dwellers also expressed the wish to use rainwater to practice gardening. They say that small-scale agriculture or horticulture could improve their situation and would be appreciated by the people. This approach could be very promising especially in schools and kindergartens according to experts and villagers, although the idea has already been investigated and attempted. Schools usually have teaching gardens for the students to learn about gardening but in the majority of cases, they lack rainwater harvesting facilities. Rural people support the idea that the learning of these basic techniques and other issues surrounding sustainable water usage could be addressed in schools and that these skills could be implemented at grassroots level and in a practical way. On the other hand officials from the supply utility object that RWH might be sufficient for domestic purposes but would not suffice even for small-scale irrigation purposes in terms of quantity. Other representatives of the suppliers state that urban gardening could even be practised using RWH, but the town councils are allegedly not interested in projects like these, especially in informal urban settlements where investors are preferred.

Apart from that, climate change is expected to have a negative effect on the use of RWH according to experts, since more droughts and less rain are real possibilities in the future. This aspect is particularly interesting as several interviewees state that climate change might pose a threat to large-scale water supply systems and that this is one of the main reasons for calling for alternative water sources and techniques. Finally, another opportunity is seen in the combined usage of RWH and groundwater sources. Water authority officials believe that the mixing of brackish groundwater with fresh rainwater could be useful.

As fas as the RWH system with ground catchments is concerned, local experts argue that they could be viable and beneficial. Even representatives of the supply side state that the collected water would be cheaper than the tap water and could be used for the livestock during the approximately four months of water scarcity in the dry season. In addition, it is said that ground catchment facilities would reduce the risk of overgrazing if enough of them are available. It is also thought that the making of bricks could reduce land degradation and deforestation since less wood from local trees would be used by the population to build their houses. Apart from the benefits of irrigation mentioned above which are also associated with ground catchment systems, water authority officials believe that RWH on a larger scale could lead to a growth of towns.

Finally, it can be said that NamWater especially plays a crucial role when it comes to promoting or impeding a technique like RWH. Several representatives of the utility explain that NamWater as a bulk water supplier does not want to be involved in RWH and that it does not belong to their strategic goals. Nevertheless, they would give assistance and support to any attempts to establish the method as long as it is sufficient and beneficial for the population. Water authority officials also confirm that the government is considering supporting RWH but that the main criteria for the assessment of options remain simplicity as well as costs of construction, operation, and maintenance. Other experts are quite pessimistic and say that RWH has been tried in the past and that it would not be reasonable to reconsider it since it has already failed before.

Sanitation

The examination of regional water regimes would not be complete without a brief look at the issue of sanitation. The distribution and types of sanitary facilities in the region vary considerably depending on the spatial category. Water authority officials report that, nationwide, the coverage on the supply side is at around 90 %, whereas on the sanitation side it is at around 60 %. This also applies to central northern Namibia. Government officials report that sanitary reticulation systems only exist in central areas of the regional cities. In Oshakati for instance, only half of the households are connected to the central sewage system according to municipal engineers. The sewers are connected to so-called oxidation ponds, of which there are two in the city. Here, the waste water evaporates, whereupon the solid waste is deposited. Several interviewees were critical of these huge evaporation losses saying the water should be recycled and reused in a region which is mainly supplied by and dependent on external water sources.

In the periurban informal settlements of the cities, the situation is quite different. Here, some inhabitants can afford a pit latrine on their plot. In most of the cases, these latrines were built with the assistance of several development projects, according to local people. They also report that the most common method, which is used by around 60 % of the people, is the so-called flying toilet which means nothing more than using plastic bags and going into the bushes. The latter also applies to rural areas since they too are not served by a sanitary system. Although pit latrines can occasionally be found here, they are the exception according to local people.

Municipal officials consider the sanitary conditions as the major problem of the regional cities, especially in terms of risks for health and ecosystems. With regard to the centralised sewage system, interviewees mainly criticise the high water losses from the oxidation ponds, technological problems in operation and maintenance, security issues, high costs, a foreseeable capacity shortfall and also organisational aspects. This is why even high-ranking water authority representatives ask which technologies might be appropriate in this case. According to supply side officials who are not even responsible for these issues, simple and decentralised solutions like pit latrines have to be promoted, especially in periurban informal settlements as well as in rural areas. However, these techniques are also said to have their disadvantages which revolve mainly around problems of construction, investment, and groundwater contamination. A major reason why it is difficult for the poor to set up a pit latrine is that there is nowhere to obtain loans, according to the local population.

List of system variables and next steps

The topics that have been discussed so far represent only one of five analytical dimensions, namely the technological one. The evaluation of the interviews continued according to the other dimensions. Eventually, the set of system variables comprised 38 elements which are shown in Table 1. Although these variables are identified by theoretical coding, problems arose in understanding the issues of livelihoods, poverty, subsistence etc. on the one hand and organisation, management, decentralisation, participation etc. on the other, as well as in assigning them to a certain analytical dimension. This is due to the fact that the topics are distributed over several analytical dimensions and/or related to different stakeholders. However the perspectives of both the supply as well as the demand side have always been taken into consideration as far as possible.

Table 1: The full set of system variables

Dimension	No.	Name
Technological dimension	1.	Large-scale water supply
	2.	Technical problems with the large-scale water supply system
	3.	Oshanas and excavation dams (Ometale)
	4.	Shallow dug wells (Omuthima)
	5.	Dug wells (Oshikweyo)
	6.	Rainwater harvesting
	7.	Sanitation
	8.	Other water supply techniques
Political, institutional, and organisational dimension	9.	Governance and management problems
	10.	Water supply and sanitation policies
	11.	Land policies
	12.	Integration and decentralisation
	13.	Inter-regional conflicts
	14.	Attitudes and distribution of power
Ecological dimension	15.	Availability of water resources
	16.	Salinity of groundwaters
	17.	Floods, droughts, and climate change
	18.	Quality and availability of grazing land
	19.	Soil Degradation
	20.	Deforestation
	21.	Environmental pollution and risks for biodiversity
Social and cultural dimension	22.	Population growth and Migration
	23.	Urbanisation
	24.	Rural concentration and Immobility
	25.	Health
	26.	Disparities and exclusion
	27.	Level of education and understanding of water issues
	28.	Perception of water prices
	29.	Organisation and participation of users
	30.	Misuse and vandalism
	31.	Security of water supply
	32.	Security of food supply
Economical dimension	33.	Subsistence and poverty
	34.	Traditional crop farming
	35.	Traditional livestock farming
	36.	Lack of irrigation and horticulture
	37.	Regional economic state
	38.	Angolan water demand

As indicated in the methodological explanations, the codes or concepts of the Grounded Theory are nothing but the system variables of the Sensitivity Model which are crystalised by theoretical coding so to speak. Hence, Vester's method can be applied based on this set of system elements. Besides the identification of relevant system variables, the other main components of the approach are the analysis of their interdependencies and the characterisation of their respective roles within the system.[30] The elements can be examined in terms of their specific properties as well as of relations and connections to other variables. These interdependencies represent flows of matter, energy, or information and can be assessed based on empirical data from the interviews by using a cross-impact matrix. In so doing, it is possible to interpret and categorise system variables based on their character or function within the system which is an essential result of this method. According to four fundemental types, which are active, passive, critical or reinforcing, and buffering, ordinal rankings of the variables can be created. Thus, it is possible to identify outstanding variables (codes) which are essential for the understanding as well as for the sustainability of the system since not only weakest links but also driving forces, destabilising elements, systemic stabilisers, and indicators are revealed. By-products of this analysis are visualisations of the observed system and its sub-systems which are relevant for subsequent steps like simulations and policy tests.

Conclusions

With the evaluation of the interviews, it was possible to describe the world views, perceptions, and opinions of all stakeholders questioned. In so doing, issues relevant for the attribution and assessment of the statements could be identified, e.g. dissensions, contradictions, agreements, valuations, priorities, and of course also unmentioned topics. Several aspects are striking, for instance, the clash of diametrically opposing views on large-scale water supply systems. Some interviewees take a rather sceptical view of technology while others remain technocratic. Interestingly, this is not influenced by their affiliation to a specific stakeholder group. Similar attitudes can be observed with regard to alternative or traditional water supply techniques. Mostly, this ties in well with the known controversy and argumentation patterns. Many interviewees emphasise the chances or risks of the various options as they perceive them. In some cases, however, rather negligible or obviously wrong arguments were put forward like the supposed bad quality of harvested rainwater. Even more precarious is the fact that the rural poor do not have the required knowledge about more or less sophisticated alternative small-scale techniques which is why their statements simply do not appear in this context. Some options are even ignored by the interviewed as well, like for instance, the artificial recharging of aquifers or so-called subsurface water storages as currently discussed by scientists in the water sector. The identification of such deficits in the world

[30] F. Vester, *Die Kunst, vernetzt zu denken. Ideen und Werkzeuge für einen neuen Umgang mit Komplexität*, Stuttgart, DVA, 2000: 194.

views of the interviewees – whether deliberate or accidental – as well as the conclusions that can be drawn from them are among the major upcoming tasks of the project. The interviewees' most important contribution, however, was highlighting the relevance of traditional water supply techniques as well as the significant role they play as supplements to the piped schemes. Not only were the differences in their specific properties and present usages demonstrated, but also their historical development and change of use. Furthermore, concepts for traditional techniques were explained that might even have the potential to improve rural livelihoods such as in the case of the utilisation of Ometale water for irrigation purposes. Some of the interview statements also showed how changing usage patterns of such technologies can indicate a change in supply regimes and routines as well as in the level of water requirements as in the case of the abandoned Omuthimas. Further examination of this data will also have to incorporate these findings into a detailed analysis of the prevailing policy and decision-making processes. In this context, the role of power structures and, especially, the distribution of power among the stakeholder groups are of particular interest to uncover who is able to influence decisions or to foster systemic transformations and who not.

As described above, the interview codes or system variables identified will serve as a basis for the modelling process. Modelling, by itself, is still the method of choice in water planning and management, but whether a model gives us a true picture or can offer any explanations depends on several factors. What is sometimes overlooked is that it is of crucial importance who is constructing the model since the model-builder decides what is constructed and how it is constructed. These issues will be discussed in the concluding remarks.

The identification of the main problems of a given system is not evident and at the same time crucial for the understanding of the system since they indicate the relevant aspects that have to be considered. In this context, customary top-down approaches in engineering sciences tend to focus on problems that are quantifiable or that seem to be objective. However the specific problem perceptions of all stakeholders have also to be integrated because they take decisions based on these perceptions and thus act according to them. This can only be done in a participatory way. In this specific case, empirical methods of qualitative social research, like interviews and participant observation, have been applied to understand and construct a model of the perceived world views. In so doing, one can avoid implementing inappropriate standard solutions to a given problem context. In fact, it is possible to address core problems, requirements, and needs in specific cases.

Furthermore, the proposed modelling concept is interdisciplinary. Contrary to traditional approaches to water management it refers not only to natural sciences and engineering. By combining methods of qualitative social-empirical research and systems analysis, forms of knowledge and theories of both scientific cultures, social as well as engineering sciences, can be integrated. Otherwise it would not have been possible to identify cultural topics like the importance of traditional water supply techniques, the users' perceptions of water prices, their willingness to pay for the services, their understanding of the water supply system, and their traditional handling of water resources, crops, and livestock etc. At the same time, the interface between the two methodological parts allows for a seamless transfer of social-empirical data into the qualitative model. In particular the processing within the systems analysis ensures the operability of the approach which is essential for further steps of the project as we will see below.

Both of the aspects mentioned make a significant contribution to understanding completely the concept of sustainability. It includes not only ecological, economical, and technological dimensions but also the social one which is often not given sufficient attention in resource-oriented approaches. The methodological and theoretical integration is of vital importance for the coverage of issues of social sustainability such as securing basic needs, poverty alleviation, generational equity, gender equality, access and exclusion, power structures etc.

Another important finding refers to the scope of the observed system. When dealing with such systems as the one described, which are intensely interrelated with historic path dependencies as well as traditional and cultural entities, the question of their boundaries arises. As we saw, it is not sufficient to analyse the large technological system alone, not to mention the mere water utility, in order to understand and assess the current water supply regime without considering alternative and traditional techniques. The scope of the examination has to be widened to the environment of the observed system since both are highly interrelated. This makes the water supply regime a subsystem of the natural as well as of the social environment which can be seen as the higher-level systems. Any reflections on sustainable planning and management issues will not be valid and comprehensive if these interdependencies are not taken into account and if environmental variables are not included in the set of system elements. Furthermore, these explanations show that the system scope can only be determined a posteriori during the participatory process of data collection and analysis.

In the course of the research project and based on the described model construction, alternative water supply scenarios are discussed. By using simulations and sensitivity analyses, the role of decentral and traditional water supply techniques within the system is examined in more detail. These scenarios represent different supply modes that range from centralised to decentralised and from large to small-scale. To appraise the system's viability, vulnerability, and resilience, methods of systemic sustainability assessment will be applied.[31] Thus, based on this identification of desired water supply regimes, adapted strategies for action can be devised that allow for corresponding systemic transformations which fulfil all goals of sustainable development. The proposed methodology ensures that these options for action refer directly to the empirical data which should be more promising than approaches that lack such a foundation.

[31] C.S. Holling, "Resilience and stability of ecological systems", *Annual Review Ecological Systems*, 4, 1973: 1-23; H. Bossel, *Indicators for Sustainable Development – Theory, Method, Applications – A Report to the Balaton Group*, Winnipeg, International Institute for Sustainable Development (IISD), 1999; J. Jörissen et al., "Ein integratives Konzept nachhaltiger Entwicklung", *Technik und Umwelt, Wissenschaftliche Berichte, FZKA 6393,* Karlsruhe, Forschungszentrum Karlsruhe, Institut für Technikfolgenabschätzung (ITAS), 1999.

Bibliography

Interviews

The interview transcripts were rendered anonymous and codes are used for each interviewee. The first section of the code refers to the phase of data collection. The interviews of the 07a phase were conducted together with Dr. Stefan Liehr from the ISOE whereas the 07b and the 09 phase interviews were carried out by the author alone. The second section relates to the stakeholder group of each interviewee. WM comprises representatives of the Ministry of Agriculture, Water, and Forestry as well as its Directorate of Rural Water Supply. Officials of NamWater are assigned to the group WSU. Representatives of other ministries as well as of administration and politics in general are subsumed under AP. The group WU comprises individuals, especially (rural) water users but also traditional authorities. Officials of national and international governmental as well as parastatal organisations are assigned to EI. Interviewees from scientific institutions and also consulting engineers are subsumed under SC and from non-governmental organisations under NGO. The third section of the code is the consecutive number of the interviewee. However, in some cases more than one code refers to the same interviewee as in the case of 09-SC-01 and 07b-SC-03; 07a-WM-02, 07a-WM-03, and 07b-WM-01; 07a-WM-01, 07a-WM-10, and 07b-WM-04; 07a-WSU-01 and 07a-WSU-02. This is due to the fact that either the interview was conducted in a different context or the contents of an interview necessitated a separate entry.

Code of interviewee	Date of interview	Place of interview
07a-WM-01	17.8.2007	Pfungstadt
07a-WM-02	29.8.2007	Windhoek
07a-WM-03	30.8.2007	Windhoek
07a-WM-05	3.9.2007	Oshakati
07a-WM-06	4.9.2007	Oshakati
07a-WM-07	4.9.2007	Oshakati
07a-WM-08	10.9.2007	Windhoek
07a-WM-09	10.9.2007	Windhoek
07a-WM-10	13.9.2007	Windhoek
07b-WM-01	2.8.2007	Windhoek
07b-WM-02	6.8.2007	Windhoek
07b-WM-03	7.8.2007	Windhoek
07b-WM-04	9.8.2007	Windhoek
07a-AP-01	4.9.2007	Oshakati
07a-AP-02	5.9.2007	Oshakati
07a-AP-03	5.9.2007	Oshakati
07a-AP-04	7.9.2007	Oshakati
07a-AP-05	13.9.2007	Windhoek
07b-AP-01	10.10.2007	Windhoek
07a-WU-01	5.9.2007	Oshakati

07a-WU-02	6.9.2007	Oshakati
09-WU-01	21.11.2009	Oshakati
09-WU-02	26.10.-30.11.2009	Epyeshona, Oshakati
09-WU-03	26.10.-29.11.2009	Epyeshona
09-WU-04	8.11.2009	Etunda
09-WU-05	26.10.-29.11.2009	Epyeshona
09-WU-06	9.-29.11.2009	Epyeshona
09-WU-07	9.-29.11.2009	Epyeshona
09-WU-08	9.-29.11.2009	Epyeshona
09-WU-09	9.-29.11.2009	Epyeshona
09-WU-10	26.10.-30.11.2009	Epyeshona
09-WU-11	21.11.2009	Amutanga
09-WU-12	24.11.2009	Epyeshona
09-WU-13	18.11.2009	Oshakati
09-WU-14	2.-30.11.2009	Epyeshona
09-WU-15	26.10.-30.11.2009	Epyeshona
09-WU-16	22.11.2009	Ondiri Nawa
09-WU-17	26.10.-28.11.2009	Oshakati
09-WU-18	6.11.2009	Epyeshona
09-WU-19	13.11.2009	Epyeshona
07a-WSU-01	3.9.2007	Oshakati
07a-WSU-02	6.9.2007	Oshakati
07b-WSU-01	21.8.2007	Windhoek
07a-EI-01	11.9.2007	Windhoek
07b-EI-01	15.8.2007	Windhoek
07a-SC-02	13.9.2007	Windhoek
07a-SC-03	17.9.2007	Windhoek
07b-SC-01	16.8.2007	Windhoek
07b-SC-02	16.8.2007	Windhoek
07b-SC-03	21.8.2007, 20.9.2007	Windhoek
07b-SC-04	18.9.2007	Windhoek
07b-SC-05	18.9.2007	Windhoek
07b-SC-06	18.9.2007	Windhoek
09-SC-01	25.10.-6.11.2009	Oshakati
09-SC-02	29.10.2009, 3.+7.11.2009	Oshakati
09-SC-03	28.10.2009	Ondangwa
09-SC-04	3.11.-29.11.2009	Oshakati, Epyeshona
09-SC-05	8.11.2009, 15.11.2009	Olushandja
07a-NGO-01	14.9.2007	Windhoek

Books and Articles

Andersen, D.F., J.A.M. Vennix, G.P. Richardson, and E.A.J.A. Rouwette, *Group Model Building: Problem Structuring, Policy Simulation and Decision Support*, 2006, http://www.albany.edu/~gpr/JORS06.pdf (accessed on September 5th, 2008).

Argyris, C., "Good communication that blocks learning", *Harvard Business Review*, July-August, 1994: 77-85.

Bertalanffy, L. v., *General System Theory. Foundations, development, applications*, New York, Braziller, 1976.

Biswas, A.K., "Integrated Water Resources Management: A Reassessment", *Water International*, 29 (2), 2004: 248-256, http://www.adb.org/Documents/Books/AWDO/2007/dp05.pdf (accessed on August 5th, 2009).

Bossel, H., *Indicators for Sustainable Development – Theory, Method, Applications – A Report to the Balaton Group*, Winnipeg, International Institute for Sustainable Development (IISD), 1999.

Bots, P.W.G., M.J.W. van Twist, and J.H.R. van Duin, "Designing a power tool for policy analysts: dynamic actor network analysis", in: J.F. Nunamaker and R.H. Sprague, (eds.), *Proceedings of the Thirty-second Annual Hawaii International Conference on System Sciences*, vol. 6, Los Alamitos, IEEE-Press, 1999: 6029.

Checkland, P., "Soft systems methodology: a thirty year retrospective", *Systems Research and Behavioral Science*, 17, 2000: 11-58.

Deffner, J., C. Mazambani, P. Klintenberg, K. Nantanga, P. Moser-Norgaard, and M. Seely, *Selected Results from Socio-Ecological Participatory Situation Assessments in two Sites in Central Northern Namibia*, CuveWaters Paper No 3, Frankfurt a.M., Institute for Social-Ecological Research, 2008, http://www.cuvewaters.net/ftp/cuve_3_deffner.pdf (accessed on May 14th, 2009).

Forrester, J.W., *Industrial Dynamics*, Waltham, Pegasus Communications, 1961.

Glaser, B.G. and A.L. Strauss, *The Discovery of Grounded Theory*, New York, Aldine de Gruyter, 1967.

Glaser, B.G. and J. Holton, "Remodeling Grounded Theory", *Forum Qualitative Sozialforschung / Forum: Qualitative Social Research*, 5 (2), 2004: Art. 4.

Global Water Partnership (GWP), *Integrated Water Resources Management*, GWP Technical Committee (TEC) Background Paper No. 4, Stockholm, GWP, 2000.

Holling, C.S., "Resilience and stability of ecological systems", *Annual Review Ecological Systems*, 4, 1973: 1-23.

International Conference on Water and Environment (ICWE), *The Dublin Statement on Water and Sustainable Development,* Dublin, Ireland, January 31, 1992, http://www.un-documents.net/h2o-dub.htm (accessed on May 14th, 2010).

Janis, I.L. and L. Mann, *Decision Making – A Psychological Analysis of Conflict, Choice and Commitment*, New York, The Free Press, 1977.

Jörissen, J. et al., "Ein integratives Konzept nachhaltiger Entwicklung", *Technik und Umwelt, Wissenschaftliche Berichte, FZKA 6393,* Karlsruhe, Forschungszentrum Karlsruhe, Institut für Technikfolgenabschätzung (ITAS), 1999, http://www.itas.fzk.de/deu/Itaslit/joua99a.pdf (accessed on August 4th, 2010).

Klimoski, R.J. and B.L. Karol, "The impact of trust on creative problem solving groups", *Journal of Applied Psychology*, 61 (5), 1976: 630-633.

Kluge, T., S. Liehr, A. Lux, S. Niemann, and K. Brunner, *IWRM in Northern Namibia – Cuvelai Delta*, Frankfurt a.M., ISOE, 2006, http://www.cuvewaters.net/ftp/iwrm_final_report.pdf (accessed on May 14th, 2009).

Kluge, T., S. Liehr, A. Lux, P. Moser, S. Niemann, N. Umlauf, and W. Urban, "IWRM Concept for the Cuvelai Basin in Northern Namibia", *Physics and Chemistry of the Earth*, 33, 2008: 48-55.

Marsh, A. and M. Seely, (eds.), *Oshanas – Sustaining People, Environment and Development in Central Owambo, Namibia*, Windhoek, Desert Research Foundation of Namibia, 1992.

Niemann, S., *Wasserversorgung und Wasserverwendung in Namibia. Nutzungstraditionen als Grundlage eines nachhaltigen Ressourcenverbrauches im ehemaligen Ovamboland*, Hamburg, Deutsches Übersee-Institut, Institut für Afrika-Kunde, 2000.

Rammert, W. and I. Schulz-Schaeffer, "Technik und Handeln – Wenn soziales Handeln sich auf menschliches Verhalten und technische Abläufe verteilt", in: W. Rammert and I. Schulz-Schaeffer, (eds.), *Können Maschinen handeln? Soziologische Beiträge zum Verhältnis von Mensch und Technik*, Frankfurt a.M., Campus, 2002: 11-64, http://www2.tu-berlin.de/~soziologie/Crew/schulz-schaeffer/pdf/TechnikUndHandeln.pdf (accessed on July 8th, 2009).

Rogers, C.R. and F.J. Roethlisberger, "Barriers and gateways to communication", in: Harvard Business Review, November-December, 1991: 105-111, http://sbuweb.tcu.edu/pwnuss/Foundations_Materials/Barriers%20and%20Gateways%20to%20Communications.pdf (accessed on August 4th, 2010).

Ropohl, G., *Eine Systemtheorie der Technik: Zur Grundlegung der allgemeinen Technologie*, München, Hanser,1979.

Scholz, R.W., D.J. Lang, A. Wiek, A.I. Walter, and M. Stauffacher, "Transdisciplinary case studies as a means of sustainability learning – Historical framework and theory", *International Journal of Sustainability in Higher Education*, 7 (3), 2006: 226-251.

Snellen, W.B. and A. Schrevel, *IWRM for Sustainable Use of Water – 50 Years of International Experience with the Concept of Integrated Water Management*, Wageningen, The Netherlands, Ministry of Agriculture, Nature and Food Quality, 2004.

Sturm, M., M. Zimmermann, K. Schütz, W. Urban, and H. Hartung, "Rainwater harvesting as an alternative water resource in rural sites in central northern Namibia", *Physics and Chemistry of the Earth*, 34, 2009: 776-785.

UFZ – Helmholtz-Zentrum für Umweltforschung, *IWRM: Integriertes Wasserressourcen-Management: Von der Forschung zur Umsetzung*, 2009, http://www.wasserressourcen-management.de/_media/IWRM_Broschuere_BMBF_19_03_2009.pdf (accessed on May 15th, 2009).

Vennix, J.A.M., "Group model-building: tackling messy problems", *System Dynamics Review*, 15 (4), 1999: 379-401.

Vester, F., *Neuland des Denkens – Vom technokratischen zum kybernetischen Zeitalter*, Stuttgart, Deutsche Verlagsanstalt, 1980.

Vester, F., *Die Kunst, vernetzt zu denken. Ideen und Werkzeuge für einen neuen Umgang mit Komplexität*, Stuttgart, DVA, 2000.

Wiener, N., *Kybernetik – Regelung und Nachrichtenübertragung im Lebewesen und in der Maschine*, Düsseldorf, Econ, 1965.

Zimmermann, M. and W. Urban, "Wasserversorgungstechnische Lösungsansätze innerhalb des IWRM im Norden Namibias", in: H.J. Linke, (ed.), *1. Darmstädter Ingenieurkongress – Bau und Umwelt, 14. und 15. September 2009, Tagungsband*, Darmstadt, Technische Universität Darmstadt, 2009.

Zimmermann, M., "Modellierung für eine nachhaltige Wasserversorgung im Norden Namibias". in: Verein zur Förderung des Instituts IWAR, (ed.), *Neue Herausforderungen und Chancen in der Wasserversorgung. Seminar des Fachgebiets Wasserversorgung und Grundwasserschutz im Rahmen des 1. Darmstädter Ingenieurkongresses Bau und Umwelt am 14. und 15.09.2009*, Darmstadt, IWAR, 2010: 137-148.