TECHNISCHE UNIVERSITÄT DRESDEN

Faculty of Environmental Sciences Department of Hydrosciences

TRANSDISCIPLINARITY AS A MEANS FOR CAPACITY DEVELOPMENT IN WATER RESOURCES MANAGEMENT

TRANSDISZIPLINARITÄT ALS INSTRUMENT FÜR CAPACITY DEVELOPMENT IN DER WASSERBEWIRTSCHAFTUNG

Kumulative Dissertation zur Erlangung des akademischen Grades

Doctor rerum naturalium (Dr. rer. nat.)

vorgelegt an der Fakultät Umweltwissenschaften der Technischen Universität Dresden

von

M.Sc. Marco Leidel

geb. am 02.06.1979 in Fürth

GUTACHTER

Prof. Dr. Christian Bernhofer
TU Dresden, Institut für Hydrologie und Meteorologie

Prof. Dr. Peter Krebs
TU Dresden, Institut für Siedlungs- und Industriewasserwirtschaft

Prof. Dr. Guy Alaerts
UNESCO-IHE, Institute for Water Education, Professor of Capacity Building

Tag der Verteidigung: 19. Dezember 2017

Erklärung des Promovenden

Die Übereinstimmung dieses Exemplars mit dem Original der Dissertation zum Thema: „Transdisciplinarity as a means for capacity development in water resources management" wird hiermit bestätigt.

Ort, Datum

Marco Leidel

„It is not possible to step twice into the same river"
Heraclitus

Abstract

Water resources management has to deal with complex real life problems under uncertain framework conditions. One possibility for encountering such challenges is integrated water resources management (IWRM). However, IWRM is often understood as prescriptive manual, not acknowledging the need for adaptive solutions and capacity development (CD). These challenges demonstrate that sustainable water resources management requires transdisciplinarity, i.e. the integration of several scientific disciplines, as well as the collaboration between science and local actors. Transdisciplinarity is inherently related to CD since it facilitates collaboration and provides mutual learning and knowledge on complex interrelationships. This correlates with the evidence that CD can be seen as a key factor for water resources management (Alaerts et al. 1991, Alaerts 2009).

Consequently, the objective of this thesis is to strengthen water resources management by connecting processes of IWRM and CD in a transdisciplinary sense, i.e. (i) interrelating disciplinary research within an interdisciplinary research team that collaborates with local actors, and (ii) conducting a political process for knowledge and capacity development. Based on general insights, an embedded case study in the Western Bug River Basin, Ukraine, was conducted to evaluate the concept. It is shown that CD is essential for shifting from IWRM theories towards implementation and accordingly advantages of harmonizing CD into the IWRM process are presented (Leidel et al. 2012). Next to capacity issues, also other coordination gaps were assessed. River Basin Organisations are frequently proposed as a response to the administrative gap; however, coordination efforts cannot be simply reduced by transferring tasks from jurisdictional institutions to a river basin authority, because they will always need to coordinate with organizations from within or outside the water sector (von Keitz and Kessler 2008). Thus, coordination mechanisms across the boundaries of relevant policy fields are essential.

Therefore, a management framework is established linking technical development and capacity development that describes interrelations between environmental pressures and capacity and information gaps for different levels of water management (Leidel et al. 2014). The developed *model-based and capacity-based IWRM framework* combines model-based systems analysis and capacity analysis for developing management options that support water management actors. This is aligned with a political process for capacity development. It constitutes a *boundary object* for approaching cross-scale challenges that converges analyses, assessments and participation into one strategy. As concluded by Mollinga (2008), this can improve the performance of sustainable resources management by approaching transdisciplinarity. Within the model and capacity-based IWRM framework, the results of the integrated analysis are made explicit and transparent by introducing a matrix approach. Technical issues, institutional challenges, organizational and human resources development, and information needs are jointly assessed and interrelated by confronting pressures and coordination gaps on a subsystem basis. Accordingly, the concept supports a transparent decision making process by identifying knowledge and capacities required for the implementation of technical intervention options and vice versa.

The method is applied in the International Water Research Alliance Saxony (IWAS) model region 'Ukraine'. It could be shown that the approach delivers management options that are scientifically credible and also accepted by and relevant for the actors. The case study revealed that technical intervention measures for the urban and rural water management have to be jointly implemented with appropriate CD measures and an accompanying political process on (i) strengthening the institutional framework and interministerial collaboration, (ii) fitting RBM into the existing institutional framework, (iii) setting up prerequisites for realistic RBM (Monitoring, information management, legal enforcement), (iv) a revision of effluent standards and a differentiated levy system, (v) cost covering tariffs, (vi) association work. For the Western Bug River Basin (WBRB), the strengthening of the collaboration between actors on all levels has to be continued. For increasing the usability, the approach needs to be institutionalized and become more practice relevant, e.g. by extending it to a water knowledge management system. Developing a roadmap for establishing transboundary water management is a subsequent step.

For strengthening future water management actors, IWRM curricula development at universities in Ukraine was supported. And we developed the e-learning module *IWRM-education* that links interactively different aspects of water management to comprehend the complexity of IWRM (Leidel et al. 2013). The evaluation showed that participants understand the content, appreciate this way of learning, and will use this module for further activities.

The case study showed that technical cooperation can be a facilitator for political processes and that it can support decision making in a transparent way. Yet, it also showed that IWRM is highly political process and that the developed approach cannot cover all obstacles. In summary, exploring and reducing simultaneously environmental pressures and capacity and information gaps is essential for water sector evolution worldwide. Accordingly, transdisciplinarity as a means for capacity development can support the implementation of *real* integrated water resources management.

Kurzfassung

Wasserbewirtschaftung beschäftigt sich mit komplexen Problemen unter unsicheren Rahmenbedingungen. Eine Möglichkeit, diesen Herausforderungen zu begegnen ist integriertes Wasserressourcenmanagement (IWRM). Jedoch wird IWRM oft als Handlungsanweisung missverstanden, ohne zu berücksichtigen, dass adaptive Lösungen und Kapazitätsentwicklung (KE) notwendig sind. Diese Herausforderungen zeigen, dass Transdisziplinarität wichtig ist für IWRM, d.h. sowohl die Integration von verschiedenen wissenschaftlichen Disziplinen, als auch die Zusammenarbeit mit lokalen Akteuren. Transdisziplinarität ist inhärent mit Kapazitätsentwicklung verbunden, da es Zusammenarbeit fördert, und gegenseitiges Lernen über komplexe Zusammenhänge vorsieht. Das korreliert stark mit den Erkenntnissen von Alaerts et al. (1991) und Alaerts 2009, dass KE ein Schlüsselfaktor für die Wasserbewirtschaftung darstellt.

Die Zielsetzung dieser Dissertation ist daher IWRM Prozesse und KE auf transdisziplinäre Art und Weise zu kombinieren: disziplinäre Forschung innerhalb eines interdisziplinären Teams, welches mit lokalen Akteuren zusammenarbeitet, und der gleichzeitigen Durchführung eines Prozesses zur Wissens- und Kapazitätsentwicklung.

Es konnte gezeigt werden, das KE ein entscheidender Faktor ist für die Implementierung von IWRM und es somit wichtig ist, IWRM Prozesse und Prozesse der KE zu harmonisieren (Leidel et al. 2012). Es wurden auch weitere Koordinierungsprobleme berücksichtigt. So werden Flussgebietsorganisationen oft als Antwort gesehen zu dem Problem dass Flussgebiete und Verwaltungsgrenzen oft nicht übereinstimmen. Jedoch kann der Koordinierungsaufwand nicht einfach dadurch verringert werden, das Aufgaben auf eine Flussgebietsorganisation übertragen werden, denn Koordinierung innerhalb und außerhalb des Wassersektors wird immer notwendig sein (von Keitz und Kessler 2008). Daher sind Koordinierungsmechanismen zwischen Politikfeldern notwendig.

Hierfür wurde ein Managementrahmen etabliert, der technische Entwicklung und KE verbindet um die Wechselbeziehungen zwischen Umweltbelastungen und Kapazitäts- und Informationsdiskrepanzen zu beschreiben (Leidel et al. 2014). Der entwickelte Ansatz kombiniert modellbasierte Systemanalyse und Kapazitätsanalyse mit einem politischen Prozess zur Kapazitätsentwicklung. Dieser Ansatz stellt ein sogenanntes *boundary object* dar, welches Analyse, Bewertung und Partizipation in einer Strategie verbindet. Das kann nachhaltiges Ressourcenmanagement verbessern durch die Annäherung an Transdisziplinarität. (Mollinga 2008). Innerhalb des entwickelten IWRM Rahmens werden die Ergebnisse der integrierten Analyse eindeutig mit Hilfe eines Matrixansatzes dargestellt. Technische Aspekte, institutionelle Herausforderungen, Organisations- und Personalentwicklung und

Informationsdefizite werden gemeinsam bewertet und zueinander in Beziehung gebracht durch die Gegenüberstellung von Belastungen und Koordinierungsdefiziten auf Basis von Subsystemen. Daher unterstützt das Konzept eine transparente Entscheidungsfindung durch die Identifikation von notwendigen Kapazitäten für die Implementierung von technischen Lösungen und umgekehrt.

Die Methodik wurde in der Modellregion Ukraine der Internationalen Wasserforschungsallianz Sachsen (IWAS) angewendet. Die Fallstudie zeigte, das technische Lösungen für die urbane und ländliche Wasserbewirtschaftung gemeinsam implementiert werden müssen mit Maßnahmen zur KE und einem begleitenden politischen Prozess für: (i) Stärkung der interministeriellen Zusammenarbeit, (ii) Flussgebietsmanagement (FGM) in den institutionellen Rahmen integrieren, (iii) Voraussetzungen schaffen für realistisches FGM (z.B. Monitoring), (iv) Revision der Abwassernormen und ein differenziertes Abgabensystem, (v) kostendeckende Tarife, und (iv) Verbandsarbeit. Für das Einzugsgebiet des Westlichen Bugs sollte die Stärkung der Zusammenarbeit aller Akteure fortgesetzt werden. Um die Nutzbarkeit zu verbessern, muss der Ansatz institutionalisiert und relevanter für die Praxis werden, z.B. durch die Erweiterung zu einem Wasserwissensmanagementsystem. Die Etablierung von grenzüberschreitendem Wasserressourcenmanagement ist ein weiterer nötiger Schritt.

Um zukünftige Akteure der Wasserwirtschaft zu unterstützen, wurde die Integration von IWRM in Lehrpläne von ukrainischen Universitäten unterstützt. Darüber hinaus wurde zur Unterstützung der Implementierung von IWRM das e-learning Modul *IWRM-education* entwickelt, welches verschiedene Aspekte der Wasserbewirtschaftung interaktive verbindet (Leidel et al. 2013). Die Evaluierung zeigte, dass die Teilnehmer den Inhalt verstehen, diese Art des Lernens schätzen, und dieses Modul für zukünftige Aufgaben nutzen werden.

Die Fallstudie zeigte, dass technische Kooperation ein Vermittler sein kann für politische Prozesse und das es Entscheidungsfindung transparent unterstützen kann. Sie zeigte aber auch, das IWRM vor allem ein politischer Prozess ist, und das der entwickelte Ansatz nicht alle Probleme lösen kann. Insgesamt kann gesagt werden, dass die gleichzeitige Analyse und Reduktion von Umweltbelastungen und Kapazitäts- und Informationsdefiziten essentiell ist für die Entwicklung des Wassersektors. Dementsprechend kann Transdisziplinarität als Instrument für Kapazitätsentwicklung die Implementierung von realem integriertem Wasserressourcenmanagement unterstützen.

Contents

List of author's publications

The content of this thesis is based on two peer-reviewed journal publications (II; IV), one editorial board-reviewed journal publication (III), one peer-reviewed conference publication (I), two co-authored peer-reviewed book chapters (V; VII), and one co-authored peer-reviewed journal publication (VI):

I. **Leidel M**, Niemann S und Hagemann N (2010) Capacity Development for Integrated Water Resources Management (IWRM) in a transition country – Improving River Basin Management in the Western Bug Basin, Ukraine. In: Streusloff, H (Hrsg.), Integrated Water Resources Management (IWRM) Karlsruhe (2010) Conference Proceedings. *Karlsruhe, KIT Scientific Publishing: 382 – 388. ISBN 978-3-86644-545-1.*

II. **Leidel M**, Niemann S, Hagemann N (2012) Capacity development as key factor for integrated water resources management (IWRM)—Improving water management in the Western Bug River Basin, Ukraine. *Environ Earth Sci. doi: 10.1007/s12665-011-1223-5.*

III. **Leidel M**, Niemann S, Saliha AH, Cullmann J, Seidel N, Borchardt D, Krebs P, Bernhofer C (2013) IWRM- Education: E-Learning Module on Integrated Water Resources Management. *Environ Earth Sci. doi 10.1007/s12665-012-2059-3.*

IV. **Leidel M**, Hagemann N, Seegert J, Weigelt C, Zakorchevna N, Blumensaat F (2014) Supporting decisions in water management by exploring information and capacity gaps: experiences from an IWRM study in the Western Bug River Basin, Ukraine. *Environ Earth Sci. doi 10.1007/s12665-014-3863-8.*

V. Hagemann N, **Leidel M** (2014) Introducing river basin management in a transitional context: a case study about Ukraine. In: Huitema, D. and Meijerink, S. (Eds.) The Politics of River Basin Organisations. Coalitions, Institutional Design Choices and Consequences. *Cheltenham, Edward Elgar: 210-233.*

VI. Sigel K, Hagemann N, **Leidel M**, Niemann S, and Weigelt C (2014) Insights regarding transdisciplinarity and knowledge transfer gained from two case studies on integrated water resources management in Ukraine and Mongolia. *Interdisciplinary Science Review 39(4), 343-361.*

VII. Ibisch R, **Leidel M,** Niemann S, Hornidge AK, Goedert R (2016) Capacity Development for Integrated Water Resources Management: Lessons Learned from Applied Research Projects. In: Borchardt, D, Bogardi, J and Ibisch, R (Eds) Integrated Water Resources Management: Concept, Research and Implementation. Springer International Publishing. *ISBN 978-3-319-25069-4.*

1 Problem scope

Water is central to human well-being as well as central for a sustainable world. Already the Greek philosopher Thales of Miletus considered "water as the principle of all things". That means that human activities depend on the natural resource water and do have an influence on its quantity and quality and thus also on the proper functioning of ecosystems. Providing water in sufficient quantity and quality is thus essential for society and ecosystems. Water has to be managed therefore, and has been managed throughout history. As an example, already from 1000 BC onwards, so called *qanats* have been constructed in Middle East and Northern Africa, which are underground delivery systems for water (Chech 2010). Without much doubt, knowledge and capacities can be considered as essential factors already for the proper construction and management of this ancient water supply system. Current water resources management problems can be subsumed in terms of water quantity, water quality, drinking water and sanitation with its challenges to global change including climate and demographic development. The present and even increasing complexity of water resources management demands advanced knowledge and capacities. A considerable part of the current water resources management issues is related to governance and capacity challenges like the legislative system, effective institutions, organisational development, human resources development, and incentives.

1.1 Water quantity

Water quantity problems are related to a change in demand and/or supply. Water demand, i.e. consumption, for example for irrigation, has increased more than twice as fast as population growth (FAO 2012). And the supply of water resources decreases, because of an increase in contamination, as well as climate and land use changes. The intensification and acceleration of the future water cycle due to climate change will affect water availability and demand (IPCC 2007, 2014; EEA 2007). Vörösmarty et al. (2000) showed that the climate change impact on the relative change in demand per discharge leads to drier conditions particularly in poorer countries. Yet, Vörösmarty et al. (2000) also displayed that the population growth impact is more important than climate change impacts in terms of water demand. In terms of water quantity, hydrological extremes have to be mentioned as well, i.e. droughts and floods. Climate change is expected to increase intensity and frequency of floods and droughts, yet extremes are still characterized with large uncertainties (IPCC 2014).

1.2 Water quality

Water quality issues refer to the degradation of water resources, especially water bodies like rivers, lakes and groundwater. Pollution can be mainly ascribed to sewage, industry, mining, agricultural and urban runoff, and atmospheric deposition, with significant impacts on the environment and drinking water quality (point and nonpoint source pollution). It is a considerable challenge in water resources management, since every day, 2 million tons of sewage and waste are discharged into the world's water (UN WWAP 2003). Pollutants can be a surplus of nutrients (mainly NO3-N, NH4-N and PO4-P) potentially leading to eutrophication, fish kill and human health threats, microorganisms (e.g. cyanobacteria, fecal bacteria), inorganic chemicals including heavy metals and fertilizers, and organic chemicals including pesticides, herbicides and insecticides. To this group belong also persistent organic pollutants (POPs) like, Dichlorodiphenyltrichloroethane (DDT), Polychlorinated biphenyls (PCBs) or Dioxin[1]. The EU-Water Framework Directive (WFD), for instance, mentions (priority) hazardous substances. Hazardous substances are accordingly defined as "substances or a group of substances that are toxic, persistent and liable to bio-accumulate; and other substances...which give rise to an equivalent level of concern" (EU-WFD, Article 2).

1.3 Drinking water

Drinking water problems refer to the access of people to safe, reliable and sufficient drinking water, thus on the quality and quantity of drinking water. The Millennium Development Goals (MDGs) target on drinking water has been met, and 91% of world population use improved drinking water sources, i.e. that 2.6 billion people got access to improved drinking water since 1990 (UNICEF/WHO 2015). Yet, 663 million people are still without access, and hot spot regions as Sub-Saharan Africa will remain critical in this respect, as well as rural areas in general, where 8 out of 10 people without improved access live (UNICEF/WHO 2015).

1.4 Sanitation

Sanitation problems refer to safe removal of wastewater and hygienic conditions of human sanitation facilities. The lack of adequate sanitation contaminates water bodies worldwide and is one of the most significant forms of water pollution (WWDR 3). 2.1 billion people got access to sanitation since 1990; yet, the sanitation target of the MDGs was not met, since 68% instead of 77% of world population use improved sanitation facilities (UNICEF/WHO 2015). 2.4 billion people still lack improved sanitation facilities, in particular in

[1] The Stockholm Convention on Persistent Organic Pollutants from 2001 acknowledged the adverse effects on health and environment from twelve POPs, which became known as "the dirty dozen".

the least developed countries, and rural population is again more challenged, since seven out of ten people without improved sanitation facilities, and nine out of ten people doing open defecation live in rural areas (UNICEF/WHO 2015).

1.5 Climate variability and climate change

One of the most important drivers of changing conditions is climate variability and climate change with impacts on various levels and sectors like agriculture, hydropower, ecology, water resources management (cf. IPCC assessment reports [AR] 2007, 2014). Climate is defined as the average of weather events within a particular time period (e.g. decade) and *climate variability* is accordingly the change in the average between two observed time periods (Neelin 2011). Examples for this *natural* variability are ice ages and interglacial periods, e.g. due to volcanism, solar activity, or the El Nino/Southern Oscillation (ENSO). *Climate change* refers according to Neelin (2011) to human induced climate change, i.e. greenhouse gases (CO_2, CH_4, Halocarbons, N_20), and short lived gases (CO, NO_x) are emitted by anthropogenic activities. Anthropogenic effects on aerosols[2] and albedo change due to land use are also included (cf. IPCC 2013). The net balance of all radiative forcing compounds is positive, i.e. it leads to a heating up of the lower atmosphere (positive radiative forcing (W/m^2); IPCC AR4 2007). The increase in the atmospheric CO_2 concentration since the year 1750 is the largest contribution to total radiative forcing (IPCC 2013)[3]. Observed changes in the climate system show that the globally averaged surface temperature has warmed with 0.85°K[4] over the period from 1880 to 2012 (IPCC 2013). And the surface temperature change from the year 1901 to 2012 shows regional trends indicating that almost the complete world has experienced surface warming (Ibid.).

1.6 Impacts of climate variability and climate change on water resources

Impacts of climate change on the climatic water balance and the acceleration of the hydrological cycle are evident (cf. IPCC AR4 2007; Bernhofer et al. 2011; IPCC AR5 2014; Pavlik et al. 2014). Changes in temperature (T) and precipitation (P) result in a changing climatic water balance ($CWB = P - ET_P$), so that e.g. an increasing evapotranspiration (ET) due to rising T would lead to effects like reduced discharge within the catchment and con-

[2] Short lived gases contribute to the radiative forcing with carbon monoxide emissions having a positive radiative forcing and nitrogen oxides are likely to have a negative radiative forcing (IPCC 2013). Most aerosols have a negative forcing (e.g. sulphate aerosols), whereas black carbon aerosols contribute to a heating of the atmosphere.

[3] The net radiative forcing of aerosols, which includes cloud adjustments due to aerosols, is negative, and contributed essentially in offsetting the positive forcing effect from greenhouse gases (IPCC 2013). Yet, they also have the highest uncertainty interval of all radiative forcing components. Albedo change due to land use also shows a negative radiative forcing (IPCC 2013).

[4] The 90% uncertainty interval is [0.65 to 1.06] °C, i.e. 90% likelihood of covering the value that is being estimated (IPCC 2013).

sequently increased pollutant concentrations. Changes in the CWB impacts directly on the soil water storage and the recharge of aquifers or indirectly via a potential change of vegetation in the recharge area, which alters ET and consequently also aquifer recharge.

Additionally, extreme weather and climate events have changed in the last six decades (IPCC AR5 2014): Heat waves increased in some regions (e.g. Europe and Asia), and heavy precipitation events increased in more regions than decreased. With medium confidence, the fifth AR (IPCC 2014) states that increasing trends in extreme precipitation imply also a greater flood risk at regional scale. And the projected changes for 2081–2100 show that it is very likely that a higher frequency and longer duration of heat waves will occur (Ibid.). Moreover, the AR5 (IPCC 2014) reason that mean precipitation will likely decrease in many mid-latitude and subtropical dry regions, which will potentially increase the risk of droughts. The projected changes further show that the amount of heavy precipitation events is likely to become more intense and more frequent in a number of regions (e.g. mid-latitude regions), leading potentially to more floods (IPCC AR5 2014). This is also related to changing seasonality, i.e. a change in inter-annual variability of precipitation. In a case study in Western Ukraine, Pavlik et al. (2012; 2014) collected evidence that there will be a significant change in the precipitation distribution with drier summers and wetter winters.

The IPCC AR5 (2014) is medium confident that altered hydrological systems affect water resources in terms of quantity and quality. Accordingly, climate change and variability also have impacts on the *urban water management*, since storm events potentially lead to surcharge of sewers or the flood damage of wastewater treatment plants, so that mid and long-term infrastructure planning (e.g. wastewater treatment plants up to 30 yrs; reservoirs up to 100 yrs.) depends on reliable statements on future climatic conditions. Also combined sewer overflow pollution can be aggravated, since the infrastructure is often not designed for increased discharges. An increased frequency of storm events could also increase erosion and accordingly the sedimentation (and accompanying turbidity) in rivers, lakes or reservoirs could be compounded. In the latter case, a loss of reservoir storage is possibly conflicting with flood protection functions of the reservoir, as well potentially leading to increased water temperatures and thus higher evaporation and eutrophication.

Yet, also the duration of dry-weather conditions has impacts on urban water management, e.g. the reduced runoff into surface waters (quantity), which will also affect the quality by a reduced dilution as well as ecological problems (minimum ecological in-stream flow). The urban water demand also can increase due to dry spells and thus potentially leading to reduced groundwater levels for satisfying the water demand. In addition, drier conditions can reduce reservoir levels and thus raw water quality is impacted and the water quantity may not be sufficient for fulfilling all functions of the reservoir. According to the IPCC (2014), there is robust evidence that renewable surface water and groundwater resources in most dry subtropical regions will be reduced in future. And with a very high confidence, the IPCC (2014) states that the risks in urban areas will increase (e.g. heat stress, storms and extreme precipitation, inland and coastal flooding, landslides, air pollution, drought, water scarcity, sea level rise and storm surges. In rural areas it is projected that essential problems on water availability and supply, and thus food security will occur (high confidence).

Rising temperatures will lead to a higher potential evapotranspiration and thus an increased water demand of vegetation. This is also essential for the agriculture as the biggest water consumer with 70% on a worldwide basis. The water demand is potentially increasing in the agriculture because of more irrigated area, higher evapotranspiration, and an extended growing season due to warmer temperature and drier conditions. In addition, the IPCC AR 5 (2014) mentions with high confidence that projected climate change leads to negative impacts of climate change outweighing positive impacts in terms of crop yields. It will also challenge fisheries productivity due to global marine species redistribution and species loss, thus climate change is projected to undermine food security (IPCC AR 5 2014).

Several bacterial, viral and parasitic diseases are water borne diseases (e.g. Schistosomaisis, Giardiasis) impacting human health. They can potentially be aggravated by increased frequency of heavy rainfall events with resulting floods amplifying the risk of infection, which is encountered mainly in developing countries (Hunter 2003). And more favourable conditions (warmer climate) could also spread vector-borne diseases like malaria (Ibid.).

From an ecological point of view, climate change impacts directly terrestrial, freshwater and marine species that shifted inter alia their geographic ranges, seasonal activities, and migration in response to ongoing climate change as reported by IPCC (2014) with high confidence. There is a high confidence that manifold species face increased extinction risk in future and that many ecosystems (e.g. coral reefs) are highly vulnerable. A further indirect effect could be that reduced precipitation will not be enough to sustain the minimum ecological in-stream flow thus potentially leading to a different species composition. Additional ecological impact is due to the warming of rivers and lakes, i.e. a rising water temperature leads to higher evaporation and potentially to increased eutrophication and cyanobacterial blooms.

Last but not least, water resources management in coastal regions has to deal with storm surges that have increased since 1970, mainly as a result of rising mean sea level (IPCC AR5 2014). Moreover, there is the potential danger of saltwater intrusion into aquifers due to sea-level rise.

The IPCC AR 5 (2014) mentions with a very high confidence that the impacts from recent climate-related extremes (e.g. heat waves, droughts and floods) reveal significant vulnerability and exposure of some ecosystems and many human systems to current climate variability. By outlining these manifold potential impacts of climate change on water resources management, and by recognizing that competition for water among sectors may intensify (limited evidence, medium agreement; IPCC 2014), it becomes clear that collaboration and coordination in water resources management and adjacent sectors like agriculture is decisive for mitigation and adaptation of climate change risks.

1.7 Global change and uncertainties

In a nutshell, Vörösmarty et al. (2010) showed that for more than 80 % of the world´s population water security is endangered, and that within more than 60 % of the water bodies the aquatic biodiversity is endangered. The situation is however becoming worse under the conditions of the ongoing and future global change. It influences water management on the local, regional and national scale and vice versa. Global change includes inter alia climate change/ variability, land use change, loss of biodiversity, economic changes (growth, globalisation), population growth and movement (urbanization), as well as geo-political changes (Steffen et al. 2004). It is expected that human population grows from six millions in 1999 to nine billion before the year 2050, whereas this rapid growth is regionally different with exponential growth mainly in developing countries and a slow or even negative growth rate in many developed countries (Snider and Brimlow 2013). And more than half of the world's population (54%) is living in urban areas today and another 2.5 billion are according to UN-DESA (2014) expected by 2050 (66%). Thus, sustainable urban planning as well as integrated urban water management is needed. Urbanisation does have advantages, e.g. a centralized wastewater treatment for an urban area is normally more efficient than for a dispersed rural population, aside from decentralised wastewater treatment solutions.

Such current and future challenges lead to continuously changing conditions, so that the complexity of water resources management is even more aggravated by uncertainties about the future water resources and its management. Hereby, it is differentiated between aleatoric uncertainties, i.e. (statistical) uncertainties that are inherent within complex and nonlinear systems like water resources management within the man-environment system (cf. Schanze and Daschkeit 2013). Yet, there are also epistemic uncertainties that are due to a limited understanding of the behaviour of the system, which can be reduced by research (improving model-based approaches or enhancing data basis) or statistical processing (cf. Hense et al. 2010, Schanze and Daschkeit 2013).

1.8 Implementation of sustainable water resources management

Despite significant scientific achievements especially in terms of systems understanding, considerable need for action still exists in understanding responses of the water system to change and its interactions with governance and capacity aspects (e.g. OECD 2012). The latter point clearly shows that there is an urgent need for action in terms of operationalization of sustainable water resources management. Reasons for the fact that the practical implementation often does not meet expectations are manifold. Most importantly, water resources management is still fragmented in many parts of the world, following a sectoral approach that displays low cooperation and coordination with other policy areas within and across the water sector. It has to be acknowledged that water resources management need to consider people, as well as equity between different water uses (Agriculture, industry, and domestic use). For instance the interactions (nexus) between water, energy and food security need more consideration (Hoff 2011).

This includes that the different values of water (economic, environmental, cultural, and social) are accounted for within decision making processes. Furthermore, water related hazards like floods and droughts need to be considered within water management, i.e. that water management has to be aligned for instance with flood risk management. Actually, UN/ISDR has mentioned already in 2005 that it is necessary to integrate disaster risk considerations into sustainable development. In fact, impacts of global change and in particular the population growth/ urbanisation and the changing climate will lead to emerging challenges, that call for integrated approaches, e.g. integrated water resources management (IWRM), adaptive water management or integrated urban water management. Yet, in order to be successful, such approaches need to address the interactions between multiple levels and scales, respectively dimensions that exist within water management (Cash et al. 2006, Moss and Newig 2010; Gupta and Pahl-Wostl 2013). Manifold cross scale challenges, i.e. boundaries, exist for example between science and policy or between academic disciplines (cf. Mollinga 2010). Accordingly, interdisciplinarity is needed so that natural and engineering scientific factors have the same importance as socioeconomic ones. Additionally, further social actor groups must be integrated from the very beginning into the water management (transdisciplinarity). Cross-level challenges exist as well, for instance global policy agreements have to be adapted to national, regional and local characteristics and vice versa. Such challenges are aggravated if the management level is a transboundary river basin, where water has to be shared between states or countries.

However, even if all these points are addressed, positive incentives are needed for the implementing actors (organisations, humans), or at least negative incentives have to be absent, for implementation of actions (Alaerts 2009). Ostrom et al. (2001) discovered that collective-action problems are a major impediment for sustainable development and that appropriate *incentives* of actors are needed for developing sustainable solutions. Based on the comprehensive study of Ostrom et al. (2001) it can be concluded that their results are also applicable for implementing sustainable water resources management.

1.9 Governance, knowledge, incentives and capacities

The integration of multiple actors, tasks and sectors extends also the scope and the complexity of the system, raising additional challenges for planners, managers and decision makers (Leidel et al. 2014). In addition, coordination gaps exist such as inadequate governance structures, lacking capacities and insufficient knowledge that are needed for solving management tasks (OECD 2012). Furthermore, low motivation and/ or information asymmetry or missing of information may lead to incentives of actors of not solving a collective-action situation (Ostrom et al. 2001). Therefore, appropriate incentives are needed, as well as the reduction of information asymmetries. The latter shows that the access to necessary information and knowledge for all relevant actors and especially for the administration is decisive for a sound water resources management (WWAP 2012). Thus, information systems as well as decision support systems are needed that are adapted to the needs of the actors in order to make informed decisions. Since water resources management is complex and will become even more complex due to the above mentioned challenges, capacity development on the individual as well as organisational level is necessary (Alaerts 2009). A promising item for supporting capacity development is the application of *information and communication technology* (ICT) and accordingly the setup of learning management systems. For the governance deficits, also capacity development on the systemic level (enabling environment) has to be done (Alaerts 2009). Next to that, it is essential to set up and implement a context specific coordination mechanism between the different tasks and actors of water resources management for facilitating integration.

In summary, water management can be considered as a collective action situation and thus as a societal task that needs to integrate scientific, technical, social, economic and environmental aspects in order to sustain water for livelihoods and ecosystems. Appropriate governance structures, incentives, knowledge and capacities are needed for action. Approaches like IWRM or adaptive water management partly attempt to address such challenges. However, transdisciplinarity within water resources management, which could enhance actors' incentives and capacities and thus improve the sustainability of water resources management, is still in its infancy.

2 Research questions and hypotheses

1. How can the implementation of sustainable water management be supported? Is it possible to align IWRM with Capacity Development?

   Hypothesis: In order to be sustainable, a transdisciplinary approach is needed that aligns Integrated Water Resources Management (IWRM) with Capacity Development.

2. How to improve the transdisciplinary collaboration (Science-Policy-Interface)? How can the interlinkage between environmental pressures and capacity issues be improved? How can this interaction be made transparent and applicable for actors? How to close information and capacity gaps?

   Hypothesis: The implementation of IWRM needs a coordination mechanism between different actors, which addresses scientific work, capacity issues as well as the political process. Such a framework can support the cohesion between different organisations as for instance within a river basin. It improves the transparency and applicability and eventually constitutes the basis for closing information and capacity gaps.

3. What are the major challenges related to water resources management in the Western Bug River Basin and why are they not tackled? How is water management defined and conducted? How can the interaction between environmental pressures and capacity issues be assessed and how can the situation gradually be improved?

   Hypothesis: Water management related problems are manifold in the Western Bug River Basin, ranging from environmental and socio-economic pressures to coordination gaps within a difficult political situation (transition country). Aligning IWRM and CD within a concept that integrates scientific analysis, frameworks for science-policy interface and a political process can support understanding the complexity of the problem and can initiate a change process. The collaboration of all relevant actors is needed for a sustainable management in the region.

4. How can information and communication technology (ICT) and e-learning be utilized to support the implementation process of IWRM?

   Hypothesis: E-learning activities can support the implementation process of IWRM by improving individual and social learning, especially within a blended learning approach. ICT and e-learning can support the collaboration and coordination between actors.

The hierarchy of my research activities can be summarized in the following figure with slightly shortened research questions and hypotheses.

Figure 1: Hierarchy of research activities within the dissertation

Overarching topic: Capacity development for sustainable water resources management

Purpose: Support the implementation of integrated water resources management (IWRM)

Tackled research questions:

1. Is it possible to align IWRM with Capacity Development (CD)?
2. How to improve the transdisciplinary collaboration? How can the interlinkage between environmental pressures and capacity issues be improved? How to close information and capacity gaps?
3. What are the major challenges related to water resources management in the Western Bug River Basin and why are they not tackled? How can the interaction between environmental pressures and capacity issues be assessed and how can the situation gradually be improved?
4. How can ICT and e-learning be utilized to support the implementation process of IWRM?

Hypothesis:

1. In order to be sustainable, a transdisciplinary approach is needed that aligns IWRM with CD.
2. The implementation of IWRM needs a coordination mechanism between different actors, which addresses scientific work, capacity issues as well as the political process.
3. Environmental and socio-economic pressures and coordination gaps are the challenges in the Western Bug River Basin. Aligning IWRM and CD within a framework can support understanding the complexity of the problem and can initiate a change process.
4. E-learning activities can support the implementation process of IWRM by improving individual and social learning. It can support the collaboration and coordination between actors.

3 Conceptual framework

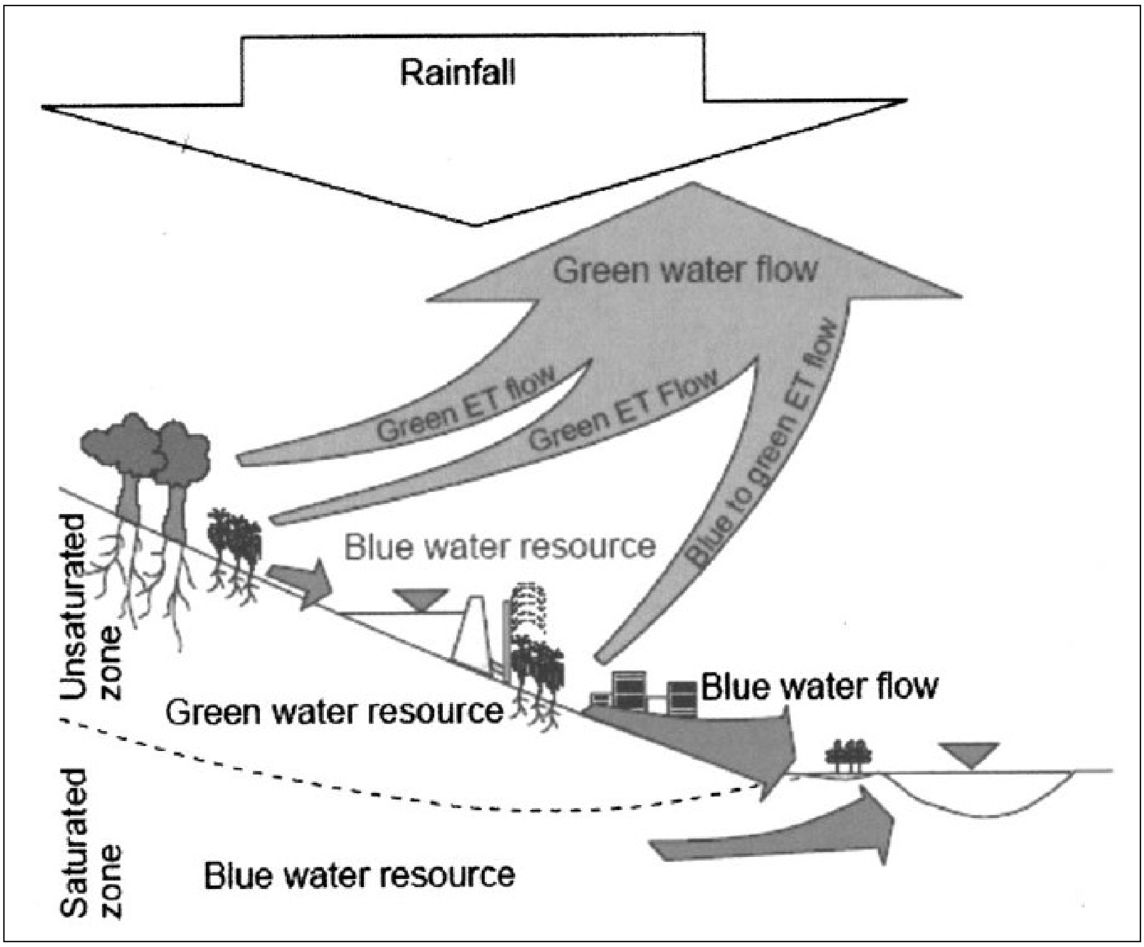
3.1 Sustainable water resources management

Before elaborating on sustainable water resources management, it is necessary to define the term water resources management and related terms in order to avoid misunderstandings.

3.1.1 Water resources

From a hydrological perspective, water resources are commonly defined as all occurrences of water within the hydrological cycle in liquid, solid, and gaseous states. It is divided into sea water, fossil groundwater, ice, active groundwater, lakes, soil moisture, atmosphere and rivers (Krebs 2012).This implies already that spatial and temporal scales are important factors for water resources. Derived from the water budget equation, water resources arebased

Figure 2: Green-blue approach to water resources management



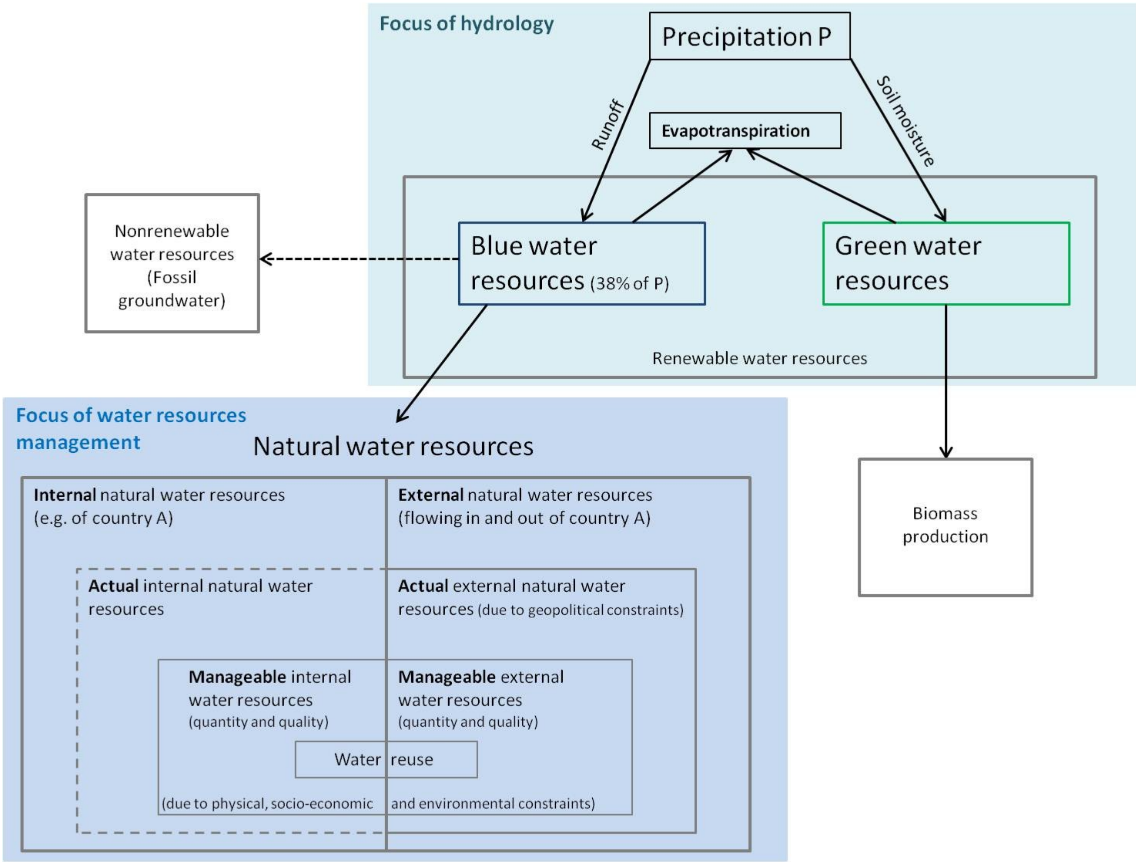
Source: Falkenmark and Rockström (2006)

on precipitation P as input equals the net storage change ΔS_w, runoff R and evapotranspiration E. For managing water resources, it is reasonable to differentiate between blue water and green water resources (Falkenmark and Rockström 2006; Figure 2): blue water is precipitation that flows into surface water (lakes, swamps, rivers,) and groundwater. Green water is precipitation that is either percolating into the unsaturated zone (soil moisture) and transpired by vegetation, or intercepted by the vegetation/ land cover and evaporated (evapotranspiration). Despite the fact that only 38 % of precipitation becomes blue water (Krebs 2012), traditional water resources management focuses on this part of the water resources (cf. Falkenmark and Rockström 2006; Figure 3). This indicates a huge potential for the management of green water resources in agriculture. Rockström (2003), for example, showed possibilities of minimizing non-productive evaporation by shifting it to productive transpiration through measures like intercropping, mulching or windbreaks.

Within water resources management, it is often differentiated between renewable and non-renewable water resources. According to the definition of the FAO (2003), "renewable water resources represent the long-term average annual flow of rivers (surface water) and groundwater, and non-renewable water resources are groundwater bodies (deep aquifers) that have a negligible rate of recharge on the human time-scale". Actually, green water is also a renewable water resource. However, from water resources management perspective, only blue water is considered as *renewable natural water resources* that potentially or theoretically can be used and managed (FAO 2003; Figure 3). Since water resources are often shared by several administrative units like districts or countries, next to hydrological boundaries (e.g. river basins), administrative boundaries need to be considered for water resources management (transboundary water management; q.v. chapter 3.1.4 on the problem of fit). In this case, natural water resources are further divided into *internal natural water resources*, i.e. precipitation within this administrative unit leading to blue water and *external natural water resources*, i.e. water resources that would *naturally* flow from an upstream administrative unit through rivers or aquifers (FAO 2003). *Actual water resources* take into account the resources that are shared for example with neighbouring countries (geopolitical constraints), e.g. through treaties on upstream water abstraction or a guaranteed minimum water flow to downstream riparian states (Ibid.). Here, it is distinguished between internal actual water resources, i.e. no constraints on use and external actual water resources, i.e. water resources that consider water reservation for neighbouring countries (Ibid.). Furthermore, water resources have to be distinguished whether they can be *exploitable or manageable* according to physical, socio-economic and environmental criteria (Ibid.). However, water resources can not only be defined according to flows and storage (water quantity), but also according to the water quality or a combination of both. That means that the constituents of water, its concentrations, respectively the loads (concentration of pollutants/

matter times water flow volume) have to be taken into account. Moreover, it has to be taken into account the reuse of water resources, for instance the reuse of wastewater for agricultural purposes. Figure 3 summarizes water resources concepts with focus on hydrological perspective and on water resources management perspective and its interactions.

Figure 3: Water resources concepts



Source: Based on definitions of FAO (2003)

It is evident from these explanations that there is a clear link to other natural resources, as well as to the socio-economic system and institutional, respectively political system.

3.1.2 Complexity of natural resources management system

Complexity is inherent to the system of natural resources management. Mollinga (2010) distinguishes between ontological, analytical and societal complexity. First of all, there is the ontological complexity, i.e. the system comprises a broad range of interrelated components depending on the existing issue. The natural resources like water, air, soil, vegetation with underlying physical and chemical characteristics, as well as human, ecological, socio-economic, political, organisational, infrastructural and technical components just to mention a few. Processes between those components can be linear and nonlinear and additional properties can emerge by interaction between different components of the system (qv. systems thinking). Related to the ontological complexity, is the analytical complexity, i.e. that not all processes and feedbacks within the system are known, so that the systems are difficult to understand from a scientific point of view (epistemic uncertainties). For reducing ontological and analytical complexities, interdisciplinary approaches are viable (chapter 4.2). Another type is the societal complexity, i.e. that manifold actor groups with varying and often conflicting perceptions and interests exist within natural resources management. Integrating societal complexities means that transdisciplinary approaches are needed (chapter 4.2). Consequently, conducting natural resources management successfully means to deal with all three types of complexity and thus applying transdisciplinary management. This includes according to Mollinga (2010) professional boundary management, i.e. to work on crossing the manifold boundaries within society, e.g. between science and policy or between scientific disciplines.

3.1.3 Systems thinking

Since this thesis is about water resources *systems*, it is worthwhile to discuss main features of *systems thinking*. The basic idea of systems thinking is that "the whole is greater than its parts", i.e. that emergence and interrelatedness are the essential characteristics (Floods 2006). An emergent property of a phenomenon developed from several interrelated items cannot be explained *only* by the interrelated items themselves. An overview of different traditions within systems thinking is provided by Floods (2006) and Ison (2008), whereas for the purpose of my work it is particularly important to focus on the differentiation between hard systems thinking and soft systems thinking as defined by Checkland (1983 in Checkland 2000).

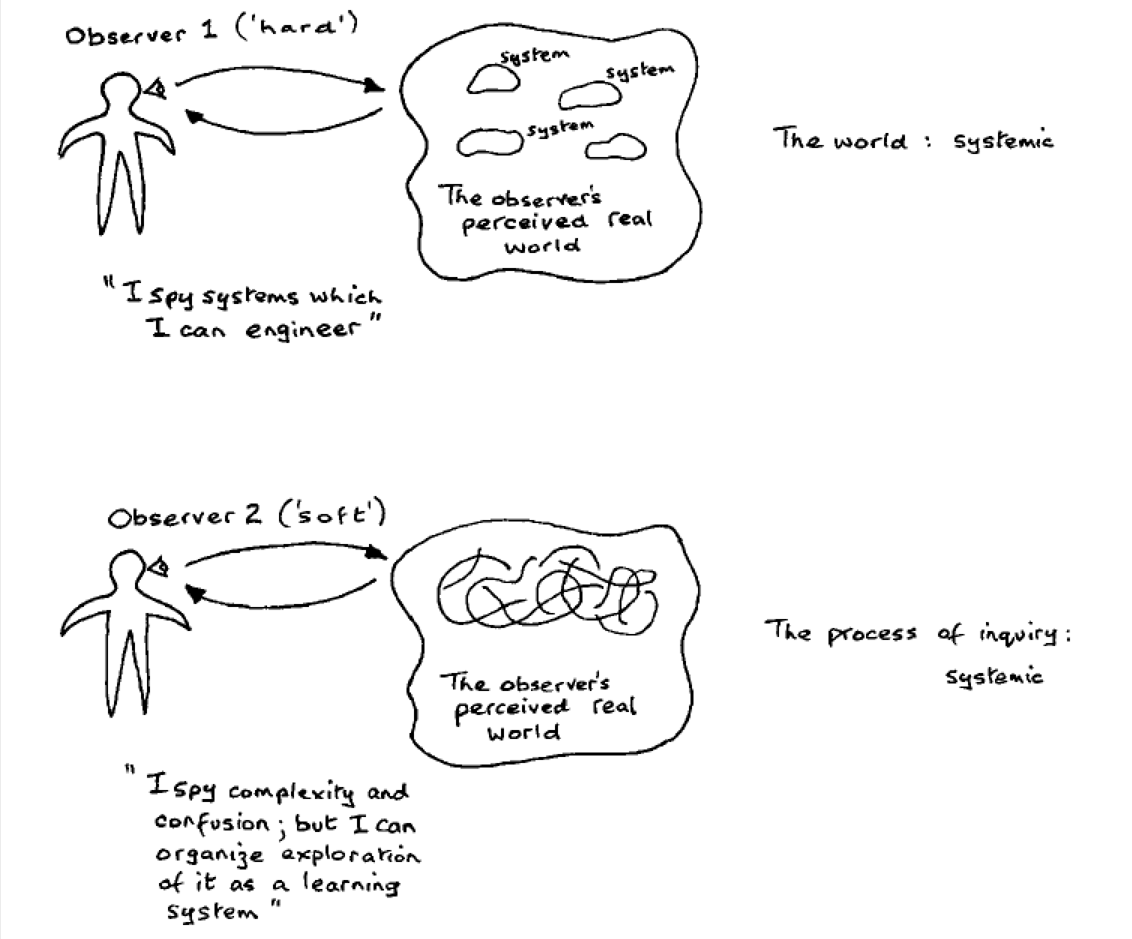
At the onset of systems theory, only hard systems thinking was recognized, i.e. a systems engineering approach with systems analysis and the potential use of qualitative and quantitative real world models for that, as for instance regional climate models or modelling nutrient emissions into rivers (technical world view). One of the first approaches of hard systems thinking in the context of environmental sciences was the famous work of Meadows et al. (1972) on the *limits to growth* prepared for the Club of Rome with the integrated global model named World3. Applying hard systems thinking for analysing natural and technical processes for reaching a defined objective is proven to be successful and reasonable; however, transferring this approach to complex human situations, where the system and the objectives are not easily definable e.g. the management of natural resources, is inappropriate (Checkland 2000). Rittel and Webber (1973) differentiate thus between "tame" problems and "wicked" problems, whereas the first means that problems do not change during the process and are agreed upon before the analysis starts, meaning that they can be solved by scientific approaches alone. Planning or policy problems are "wicked" problems, which are per se ill-defined problems i.e. that it is even difficult to agree on what the problem is. They cannot be solved by science and engineering alone, but in fact social problems can only be resolved (Rittel and Webber 1973). Poverty is provided by Rittel and Webber (1973) as a striking example for a wicked problem: What causes poverty? Low income- yes, partly. But what causes low income? Is it a problem of the regional economies, or a problem of skills and expertise? If the latter- is it a problem of the educational system or of personal motivation? Rittel and Webber (1973) therefore conclude that finding the problem and finding the solution is the same thing for "wicked problems".

Thus, soft systems thinking emerged that shifts from engineering approaches to a focus on multi-perspectives for instance political, legal or economic perspectives, i.e. modelling of how the world is viewed (Checkland 2000). Furthermore, soft systems thinking assumes that purposeful action of humans prevail in all complex situations, and that it is more about an inquiring and a learning process and about a problem situation instead of only seeing the problem, which requires solutions (Ibid.). Soft systems thinking is therefore a learning cycle between theory and practice with no permanent solution, so that it resembles the capacity development cycle, adaptive management cycle, or more generally the action research cycle (qv. chapter, 3.1.17, 3.2.4.3, 4.1).

In summary, Checkland (2000) mentions that within hard systems thinking, the world is perceived as systemic, i.e. that only those systems are recognized that can be engineered. Within soft systems thinking, he further argues that the world is perceived as a complex and confusing one, but it can be explored as a learning system, i.e. the process of inquiry is systemic (Figure 4). Yet, it has to be re-emphasised that systems engineering is a valid concept, if systems and objectives are defined, "tame" problems prevail and thus a systems optimisation is needed. Or as Checkland (2000) states that systems engineering is a specific case of the general soft systems methodology, which is relevant if the question is on *how* to do it, and not on *what* to do.

However, within (water) resources management "wicked" problem exists with frequently having "tame" problems integrated, so that hard and soft systems thinking needs to be aligned. Accordingly, the system elements are important, but also the interrelations between the elements are in focus, which is a characteristic of the *systems thinking*. This allows to identify critical linkages and thus to identify and prioritize points for policy leverage. Essential methods for identifying critical linkages are integrated assessment models, scenario analysis with the integration of stakeholders, and life cycle assessments.

Figure 4: The hard and soft system stances



Source: Checkland (2000)

Transdisciplinary research can be considered as a *system* as well, where the different elements of the system (researchers from various disciplines and other actors e.g. from government or private sector) interact and are transformed (Pohl and Hirsch Hadorn 2008; qv. Chapter 4.2). In the course of this work, I will substantiate that water resources systems and its management generates situations, where bringing together systems thinking, action and transdisciplinary research, capacity development and related concepts is highly valuable for developing sustainable outcomes.

3.1.4 Scale and level issues within man-environment systems

Systems thinking address multiple dimensions of a problem and the identification of critical linkages, so that the conjunction with scale and level issues is eminent. Accordingly, man-environment systems acknowledge the interactions and potential boundaries between environmental and human systems. Cash et al. (2006) depict that scale and level dynamics challenge the management of man-environment systems. For understanding and analysing such challenges, we refer to the definition of Gibson et al. (2000) with scale as a dimension for studying a phenomenon (e.g. spatial or analytical) and level as a position on the scale as unit of analysis (e.g. global or regional). Accordingly, interactions can be cross-level within a scale (e.g. local CO_2 emissions impact on global climate change) or cross-scale (hydrological and jurisdictional scale). We additionally conceive cross-scale challenges as *crossing boundaries* between different scales or dimensions, e.g. boundaries between different social worlds (e.g. scientist and layperson; qv. chapter 4.3). Respectively boundaries between the analytical dimensions (scales) for analysing water resources problems, namely the engineering and natural scientific dimension and the social scientific dimension. Multi-level and multi-scale means that several levels or scales are present (Cash et al. 2003). Figure 5 illustrates a selection of essential scales and levels within man-environment systems, whereas it has to be stressed that it is a selection of important ones. Depending on the particular study, other scales and levels can be considered, e.g. the scale of decision making authority with top (government), middle (region/state) and individual (human) level is generally important but not mentioned in Figure 5, or surface water-groundwater interactions are also not mentioned. We emphasize here the importance of knowledge being considered as scale ranging from an abstract level with general knowledge to a context-specific level with practical know-how. This is decisive for our transdisciplinary approach, which connects researcher from different disciplines and practitioners, and hence connects knowledge and action (qv. chapter 4.2.3). As a matter of fact, the study of water resources problems within the Ukrainian case study as described in chapter 7 and 8 crosses several scales and levels, with several emerging challenges. Cash et al. (2006) describes common scale and level challenges. A well-known problem within resources management is that scale and level interactions are not realized or even ignored, as for instance national legislation that impedes local policy making.

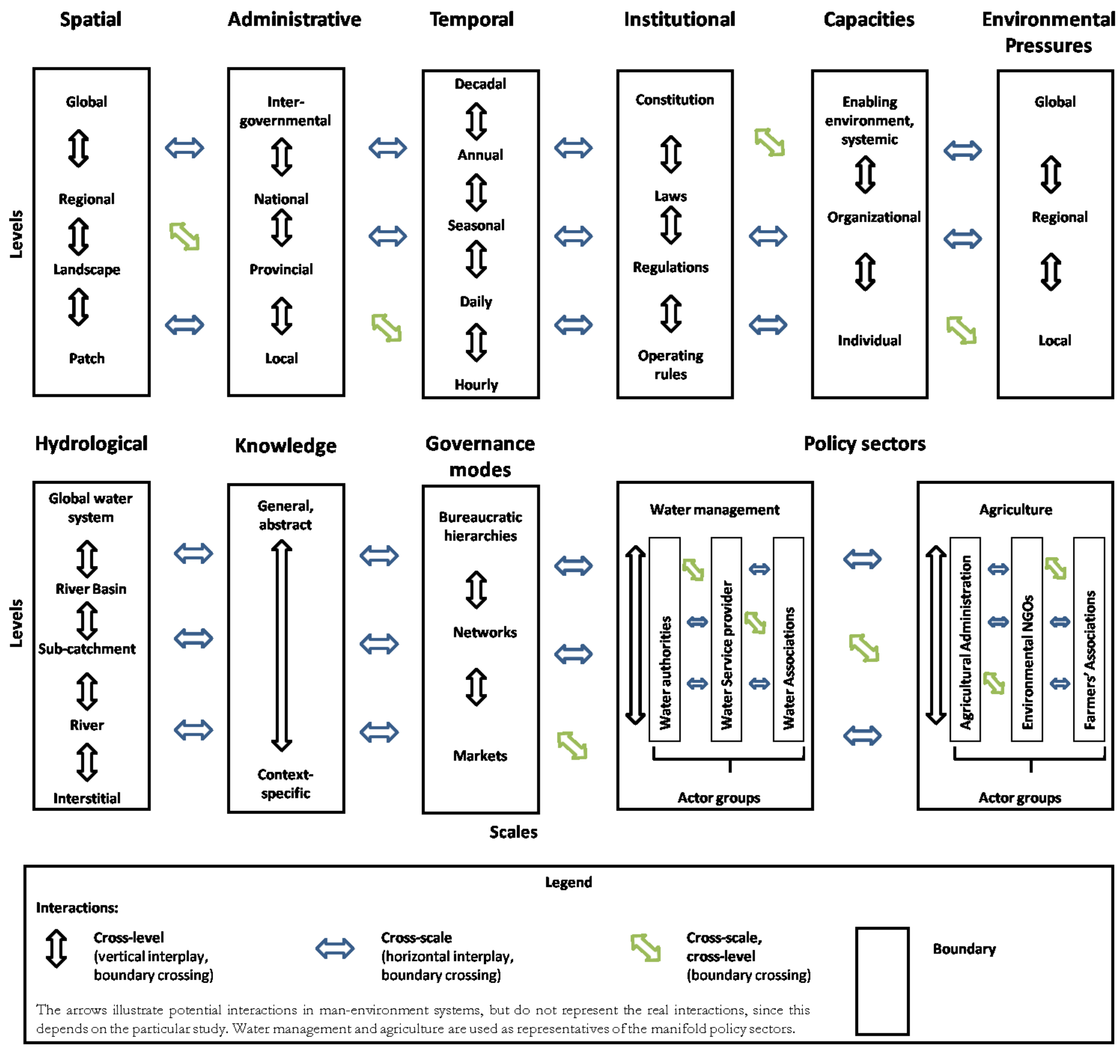
3.1.4.1 Problems of fit, interplay, and scale

Additionally, mismatches may occur, e.g. problems of fit, as well as problems of interplay and scale as described by Young (2002) and Moss (2003). Problems of fit describe cross scale challenges between the biogeophysical system and human institutions, and the problem of fit is generic, i.e. it always occurs when humans and environmental systems interact (Young 2002). An example is the incompatibility between a river basin and the jurisdiction, which is normally organised in administrative divisions or units. River basin management could be a response to problems of fit, because it is an approach to regionalize water management, i.e. it can internalize former external issues. The well-known upstream downstream problems could be internalized, for instance. One example, where river basin management within the boundaries of a river basin has been institutionalized is the EU-Water Framework Directive. However, new spatial misfits can emerge out of such a reorganisation, e.g. with other sectors like agriculture, which is not organized within river basins (cf. Moss 2012). And thus also problems of interplay, e.g. between water management and spatial planning as mentioned by Moss (2003), or problems of rescaling as named by Moss and Newig (2010) potentially evolve. Problems of interplay describe problems of interaction between different institutions, horizontally and vertically (Young 2002). Horizontal interplay is thus a cross-scale challenge related to the cooperation between policy sectors like agriculture, regional planning, transportation, nature conservation, industry, tourism, hydro-electric power and the cooperation between diverse actor groups like state ministries, local governments, industrial/ agricultural associations, public and private utilities, environmental NGOs, consumer associations. These explanations show that it is difficult to distinguish between the problem of fit and the problem of interplay. Vertical interplay is a cross-level problem.

Responses to problems of interplay are for instance co-opting policy instruments like agri-environmental measures within the EU, international commissions like the International Commission for the Protection of the river Rhine (ICPR), which are often the best and most resilient frame for effective management of transboundary water resources (Petersberg Declaration 1998; Wolf 2007) and/ or the concept of Integrated Water Resources Management (IWRM). Another example would be (administrative) cooperation through regional planning as within Germany with countervailing influence[5] and adaptation for vertical coordination between state planning, regional planning, and local planning. Problems of scale describe cross-level problems and are related to the spatial or temporal transferability of generalizations or causal inferences from one level to another (Young 2002), and to find the appropriate scale(s) and level(s) for analysis and action, called plurality challenge by Cash et al. (2006).

[5] (In German: Gegenstromprinzip)

Figure 5: Scales, levels and boundaries critical for man-environment systems



An example would be the up-scaling from the sub-catchment to an indicator at national level, or conflicts arising from different time periods, e.g. electoral period versus the return on investments or long term planning needs. For effective river basin management, an effective interplay between institutions at several levels is necessary, meaning that the problems of fit, interplay and scale are interconnected.

In summary, cross-scale and cross-level challenges (problems of fit, interplay and scale; boundary problems) are pervasive and cannot be avoided completely. For instance, Mitchell (2005) tellingly mentions that reorganisation moves boundaries but do not remove it and that each option of restructuring has advantages and disadvantages. Similarly, coordination efforts cannot be simply reduced by transferring enforcement tasks from jurisdictional institutions of water resources management to the river basin authority, because the river basin authority will *always* need to coordinate with other organizations from within or outside the water sector (von Keitz and Kessler 2008). And re-organizing water management within river basins instead of sticking to administrative units is also questionable in terms of democratic legitimacy and accountability. Local and regional government bodies within political-administrative jurisdiction are elected bodies, whereas established river basin councils are normally not elected and thus neither legitimated nor accountable to local and regional government bodies (Moss 2003; Pahl-Wostl 2007). Hence, political dependencies have to be clarified in order to avoid democratic deficits and to avoid that parallel structures (river basin authorities and traditional state authorities) coexist with the same responsibilities. Feasible is however, as done in Germany for the implementation of the EU-WFD, that river basin and jurisdictional institutions of water resources management coexist, where water management authorities plan around river basins, but implement in cross-sectoral collaboration (Hüesker and Moss 2014). Furthermore, transaction costs increase due to rescaling (Galaz et al. 2008; Roggereo and Fritsch 2010) because of an increasing amount of actors and scales and more interactions.

3.1.4.2 Mechanisms for overcoming boundaries

Thus, it is evident from the discussion that boundaries of man-environment systems are difficult to define depending on the task and that boundaries cannot be removed. Accordingly we have to be aware that a perfect organizational structure does not exist. Instead, we have to work with and across the scales, e.g. by *cooperation and coordination mechanisms* across the boundaries of different policy fields and levels. Cash et al. (2006) shows three responses, namely institutional interplay, co-management and boundary organizations (qv. chapter 4.3 on the boundary crossing framework). Institutional interplay means to develop mechanisms for vertical interaction (cross-level) at the jurisdictional scale, co-management means to share power and responsibilities between the government and local communities thus addressing cross-scale and cross-level interactions (Cash et al. 2006). Boundary or bridging organizations have an intermediary function between several scales and levels for enhancing the coproduction of knowledge as well as mediating conflicting interests (Ibid.; qv. chapter 4.3 for details on boundary organizations and boundary management). We focus on boundary management within this work as a means for tackling scale and level problems as described above. That means that we capitalize ideas mainly from the concept of boundary organizations, but also from institutional interplay and to a smaller extent on co-management.

3.1.5 Water resources system

For the management and planning of water (resources) systems, it is evident that first of all, the system itself has to be defined, including subsystems, elements, processes, scales and levels, system boundaries and its functions, e.g. ecosystem services like self-purification of rivers, subsistence functions like traditional irrigation or commercial functions like hydropower generation (cf. Loucks 2005). One possibility to describe water resources systems is to apply and adapt the concept of a *man-environment system*. The interaction between human and environmental processes implies already to a certain extent the combination of hard and soft systems thinking. It consists of three parts, the natural system, the land use system and the socio-economic system that integrates again the socio-demographic subsystem, socio-cultural subsystem, political administrative subsystem as well as the economic subsystem (Messerli and Messerli 1979). Similarly, Loucks (2005) defined that a *water resources system* consists of the natural resources system (~supply), the socio-economic system (~demand) and the administrative and institutional system as the basis for the management of supply and demand. Instead of natural resources system, the term environmental resources system is used within this thesis, since the first term is regularly referred only to a direct economic use of the resources, whereas the latter is also integrating intrinsic and situational values and more intangible functions of the resources like ecosystem services, i.e. indirect benefits.

3.1.5.1 Environmental resources system

The environmental resources system includes in the context of this study land resources (terrestrial system) and predominantly water resources (aquatic system) as described in chapter 3.1.1 with its physical, chemical and biological components and processes (Limnology). That means that physical characteristics and hydro-meteorological processes that form the catchment and its rivers like current, flow velocity and discharge have to be taken into account as well as the geology and morphology, e.g. sediments or valley slope (hydromorphology). Furthermore, the chemical composition of the water resources with potential chemical pollutants and transport and sorption processes need to be considered including also matter cycling (e.g. nutrients). Biotic elements with all organisms and the resulting biodiversity are important parts of the environmental resources system as well. These abiotic and biotic elements and processes are interrelated and constitute the (aquatic) ecosystem. Solar energy is the main driver for energy and matter fluxes within the ecosystem. Ward (1989) has shown the four dimension of lotic ecosystems, which therefore also need to be considered within the environmental resources system. It includes (i) the banks and the floodplains/wetlands (lateral dimension), (ii) the interactions between the river and the groundwater in the river bed with the hyporheic and phreatic zone (vertical dimension), (iii) the upstream downstream linkages with nutrient spiralling, migration of species, erosion, transportation and deposition (longitudinal dimension; river continuum concept (Vannote 1980), (iv) the time scale which is relevant in terms of ecosystems as the range between evolutionary changes and behavioural response (Ward 1989). Furthermore, the (technical) infrastructure within the catchment has to be taken into account or defined as a separate system depending on the focus of the issues. Examples for water related infrastructure are waste water treatment plants and the sewer system, water supply system including wells, impoundments (reservoirs, barrages), hydropower plants, weirs, dykes and canals. The hydrological system boundaries are normally the water divides of the surface water (river basin) or of the underground water (aquifers), i.e. geographic boundaries. Yet, such system boundaries are scale dependent, i.e. depending on the existing problem. This shows that scales and levels of water resources systems are important for considering system boundaries, e.g. on the spatial scale from the regional level (river basin) to local level (e.g. sub-catchment) and down to analyses on the micro-scale (e.g. in the hyporheic interstitial). In any case, the system boundaries and its input-output relation (interdependencies) to the adjacent systems have to be defined. Boundaries could also exist due to administrative units, as described in the previous chapter on actual external natural water resources (Figure 3). However, often "mixed system boundaries" (geographic and administrative boundaries) are of relevance, as for instance the sewer system within a city or an irrigated agricultural site displaying a problem of fit. Therefore, also the socio-economic and governance system has to be taken into account.

3.1.5.2 Socio-economic system

The socio-economic system consists of the demand for water resources, i.e. water uses and other human related activities with both leading potentially to impacts on the environmental resources system. The main water uses/ relevant activities are agriculture, water supply and sanitation, flood control, industry and mining, environment, fisheries tourism, hydropower, transportation with all having varying fractions in different contexts. Yet, also other socio-economic influences need be considered as for instance demographic change, economic growth, livelihood, consumer behaviour, and innovations as for instance ICT. The system boundaries vary, depending on factors like the scope of the water use, management task, and relations to external regions with different socio-economic parameters. These points show again the scale and level dependencies.

Important in relation to the water uses is also the differentiation of water as an economic good. In terms of rivalry and excludability, i.e. depending on its use, water can be considered as a private good, a common good (common-pool resource), or a public good (Table 1). This serves also as basis for Ostrom's (1990) work on common-pool resource (CPR), in which she basically proves that no private property or state administration is necessary for the governance of CPR, but that common property regimes can prevent destruction/overuse. In chapter 3.1.15, the relation to motivation problems and incentives is shown.

Table 1: Rivalry and excludability of economic goods

	excludable	non-excludable
rivalrous	**Private goods** *drinking water*, food, clothes, cars	**Common goods (Common-pool resources)** *fish stocks, groundwater*, timber, mountain pasture
non-rivalrous	**Club goods** cinema, private parks	**Public goods** *flood control*, free TV, national defense

Some scholars also integrate the administrative and institutional system into the socio-economic system as for instance Messerli and Messerli (1979), yet, its importance for the water resources management cannot be overestimated (OECD 2011, WWAP 2006), so that it should be defined as a separate system.

3.1.5.3 Governance and capacity system

The administrative and institutional system as stated by Loucks (2005) refers to the legislation, administration and authorities that manage the water resources system. Yet, this view is comparatively narrow for managing water resources, therefore this thesis will stick to the more comprehensive term governance as explained in chapter 3.1.12, which additionally integrates cultural norms, traditions, interdependent individual and collective actors and the coordination between them (cf. Davis and North 1971, Benz 2010, Pahl-Wostl et al. 2013). In addition to Messerli and Messerli (1979) and Loucks (2005), also *capacities* need to be considered within man-environment systems, and especially within water systems, since they are pivotal means for context specific and thus sustainable water resources management (qv. chapter 3.2 on knowledge, capacity and capacity development). It has to be acknowledged that the development and management of water resources needs advanced knowledge and capacities (Alaerts 2009). Hereby it is distinguished between individual, organisational capacities and the enabling environment (van Hofwegen 2004, Alaerts 2009). The latter can be referred to governance capacities. The governance and capacity system provides the *coordination* with the other two systems, by "rules and means", e.g. legislation, policies, administration, information, capacities, funding, as well as displaying potential coordination gaps as described by Charbit (2011).

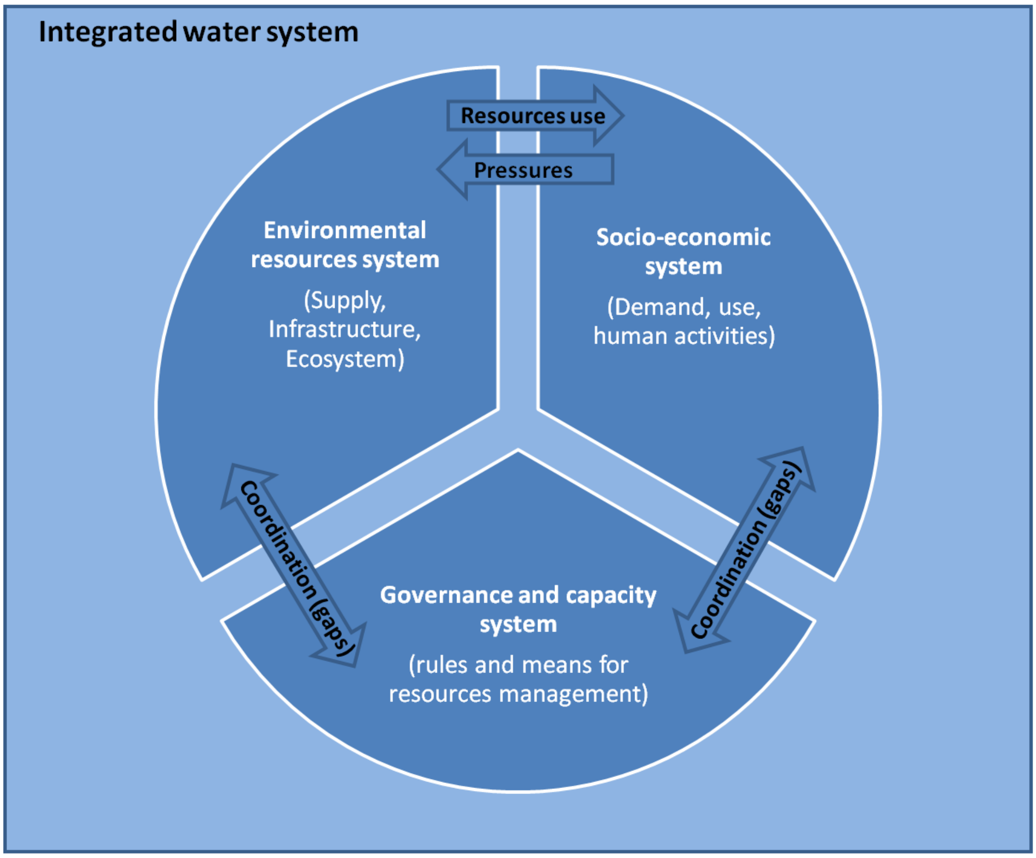
It is evident that the boundaries of the governance and capacity system vary according to the management task, from global to regional, national and local, and are frequently interdependent.

3.1.5.4 Integrated water system

The last chapters have demonstrated the complexity of water resources systems, especially because of the interdependency within the water sector and across other sectors as well as the integration of socio-economic issues. That means that frequently policy and planning problems ("wicked" problems) with underlain scientific problems ("tame" problems) need to be tackled.

Thus, based on the concepts of man-environment systems (e.g. Messerli and Messerli 1979) and concepts on water resources systems (e.g. Loucks 2005) and together with the above mentioned enhancements, I propose to introduce the term *integrated water system* (Figure 6).

Figure 6: Integrated water system



It is the appropriate term for acknowledging that both, hard systems thinking as well as soft systems thinking is necessary for (re-) solving water resources problems. It further is the appropriate term that acknowledges the equal importance of the hydrological perspective and the water resources perspective, as well as for emphasizing on the *interactions* between the environmental resources system and the socio-economic system (resources use and pressures). Furthermore, it admits the importance of the governance system and capacities for a sustainable management by providing rules and means for the management. Hence, the coordination of the environmental resources system as well as the socio-economic system, respectively the potential coordination gaps as stated by Charbit (2011) and OECD (2012) are taken into account. Accordingly, I will use the term *integrated water system* within this thesis. The systems analysis of the integrated water system, comprising of analysis of the three above mentioned systems and the analysis of the interdependencies, is depicted in chapter 7 and 8.

3.1.6 Integrated systems analysis and modelling

It is evident that an integrated systems analysis is needed for the analysis of integrated water systems. That means that the above mentioned systems (e.g. environmental resources system) and its interactions as well interactions within its subsystems (compartments, e.g. atmosphere/climate, catchment area/ land use, urban drainage system, WWTP, receiving water) have to be analysed. Modelling approaches are frequently used in water resources management and planning (e.g. the MONERIS[6] model developed by Behrendt et al. 2000, 2002; RWQM1[7] model developed inter alia by Shanahan et al. 2001), especially for modelling of water quality and quantity, as well as for climate change. Modelling is useful for systems understanding including the identification of pressures and thus impacts, as well as for describing potential future systems states. It can be also used for the evaluation of different rehabilitation measures. Modelling can be considered as integrated or coupled, if at minimum two compartments are considered sequentially, e.g. climate and surface waters.

One possibility for describing the interactions between society and the environment and thus for integrated analyses is the dynamic DPSIR framework (Driving forces, Pressures, States, Impacts, Responses) developed by the European Environment Agency (EEA 1997; EEA 2003). Social and economic developments (e.g. population growth, industrial production, consumption) are driving forces that lead to environmental pressures[8] (e.g. emissions, resources use), which consequently alters the state of the environment (e.g. increased CO_2-concentrations, changing water quality). As a result, the changed state leads to impacts, e.g. on ecosystems functioning (e.g. through fish kill) or human health (e.g. through more heat waves). Societal responses may occur, i.e. that the government or other actors attempt to encounter impacts (by prevention, compensation, adaptation, amelioration) that potentially influence driving forces and pressures (e.g. a behavioral change in resources use) or directly on the state or impact, e.g. revitalizing ecosystem services (Figure 7). Manifold approaches

---

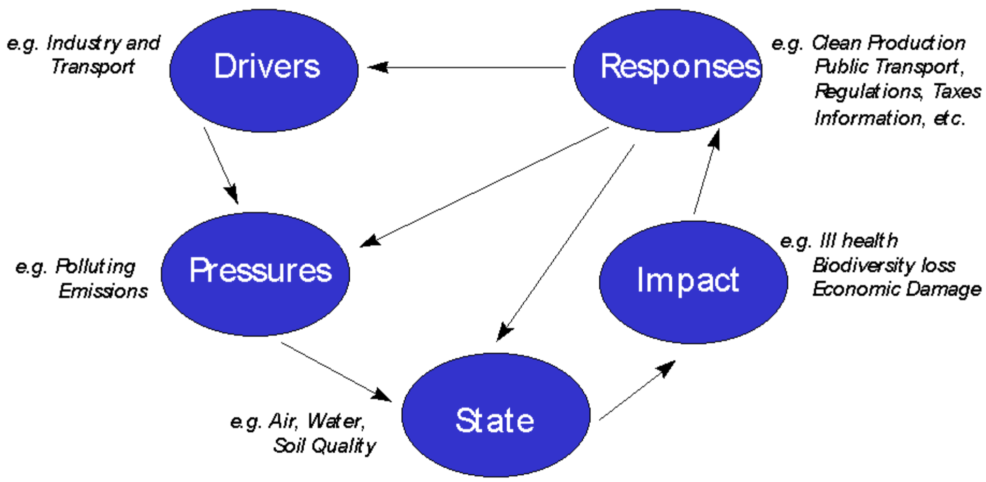
[6] The model MONERIS (Modelling Nutrient Emissions in River Systems) can estimate the nutrient inputs of point sources and diffuse pathways within river basins.

[7] The River Water Quality Model No. 1 describes significant processes for C, O, N and P cycling in rivers.

[8] In fact, driving forces can lead to an increase in pressures *or* to the mitigation of pressures (Responses acting on driving forces).

to systems analysis and modeling within water resources exist. One contemporary approach was developed within the IWAS project as described in chapter 6.1.4.

Figure 7: DPSIR Framework



Source: EEA 1997

3.1.6.1 Climate modeling for hydrological impact studies

The climate is determined by several essential climate state variables i.a. temperature, precipitation, wind, humidity and radiation, with mean and extreme values being of importance. Climate system observations show a change in means and variabilities of temperature, precipitation and CO_2 (IPCC 2013) leading not only to impacts on the water availability. Thus, current and future climatic conditions have to be analysed.

Projections of future CO_2 concentrations based on different scenarios also show rising concentrations (e.g. Legget et al. 1992; IPCC 1995, Special Report on Emission Scenarios (SRES) IPCC TAR 2001). Climate change depends on socio-economic and demographic development with associated emissions as mentioned above, and including also land use changes (e.g. deforestation), applied technologies, energy sources, lifestyles and (climate) policy. Hence, different scenarios have been developed based on different assumptions of the future within the SRES[9] (IPCC TAR 2001; IPCC AR4 2007). The sequential process of SRES has started with socio-economic scenarios and out of them developed emissions scenarios, radiative forcing and climate model scenarios, and finally to impact studies (Moss

[9] The Special report on Emission scenarios has different scenarios: A1 with subsets like A1B or A1T, A2, B1, B2.

et al. 2010). In the fifth assessment report from IPCC (2014), a major change occurred and SRES was replaced by the Representative Concentration Pathways (RCPs)[10]. Additionally, the sequential process of SRES is superseded by a parallel and coordinated process in which climate and integrated assessment will be elaborated simultaneously (Moss et al. 2010). This new approach starts with the more comprehensive radiative forcing characteristics, which integrates also land use changes and thus albedo changes (Moss et al. 2010; IPCC AR5 2014). This coordinated process should improve the interaction of climate relevant natural and anthropogenic processes and responses, i.e. the collaboration between research on climate and integrated assessment modelling, impacts, vulnerability, adaptation/mitigation is strengthened (Moss et al. 2010; IPCC AR5 2014).

The scenarios are used for simulating changes in future climatic conditions (surface temperature (T), precipitation (P) or other components like Evapotranspiration (ET)) within numeric climate models[11]. The models are based on physical equations describing properties (T, pressure, velocity, etc.), and thus processes in the atmosphere[12] and in the other compartments (Neelin 2011; IPCC 2013). General circulation models (GCM) are used for getting atmospheric variables at a global scale. Yet, water resources management needs a reliable *regiona*l analysis of the recent climate and possible changes that can be used for further hydrological applications (Bernhofer et al. 2011, Pavlik et al. 2012). Accordingly, global climate projections can be downscaled (statistical or dynamical) by regional climate models (RCM) to get information on regional climate conditions. A typical horizontal resolution of GCMs is circa 200km (2° in latitude and longitude; IPCC 2007), and downscaled horizontal resolution is between 50 and 7km, yet grid sizes getting regularly smaller. Pavlik et al. 2012, for instance, applied the CCLM as RCM for the IWAS model region Western Bug Basin with a horizontal resolution of circa 50 km and 7 km. Figure 8 shows the projected future change in average surface temperature and average precipitation for two scenarios as a projection for 2081–2100 relative to 1986–2005[13] for the whole world. In fact, all emission scenarios show a rising surface temperature (IPCC AR5 2014). Changes of precipitation are not equally distributed over the globe. For instance, in eastern parts of America, northern Europe and northern and central Asia, precipitation increased significantly (from 1900 to 2005; IPCC 4AR 2007). On the other hand, in the Sahel, the Mediterranean, southern Af-

---

[10] Four pathways are differentiated, RCP8.5, RCP6, RCP4.5, RCP2.6, where numbers refer to positive radiative forcing, i.e. a scenario family showing the energy surplus, in the year 2100 in comparison to the year 1850).

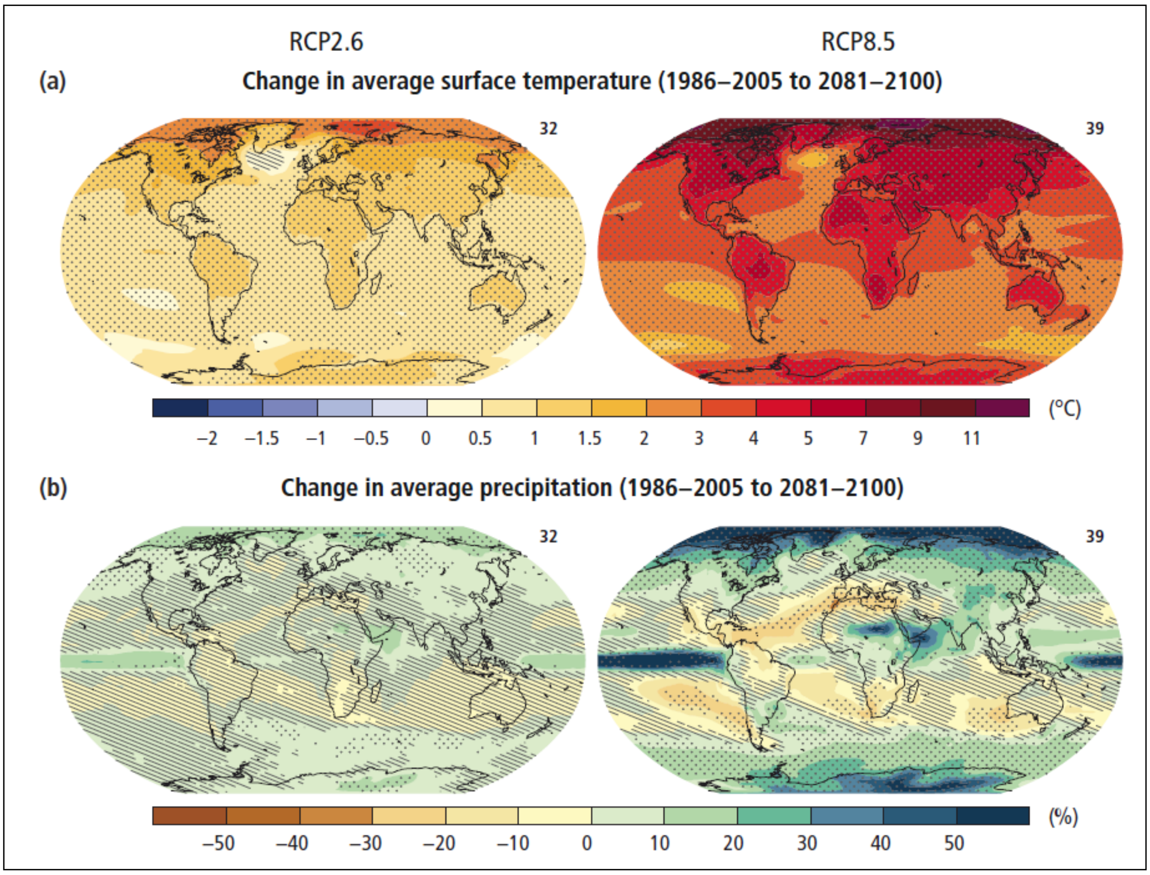
[11] Climate models can be also used for simulating current conditions.

[12] with internal time steps of 20 minutes (Neelin 2011).

[13] Within this chapter we always refer to the projection for the period 2081–2100 relative to 1986–2005 from the IPCC AR5 (2014) when using the terms *future change, future* or *projected change*.

rica and parts of southern Asia precipitation decreased in the same time period (IPCC AR4 2007). However, the AR5 (IPCC 2014) mentions that there is only a high confidence[14] for the increasing precipitation trends of the mid-latitude land areas of the Northern Hemisphere and for all other regions there is a low confidence of positive or negative trends.

Figure 8: Change in average surface temperature (a) and in average precipitation (b)



Based on multi-model mean projections for 2081–2100 relative to 1986–2005 under two RCP scenarios (see below for explanations). Number of models used is indicated in the upper right corner of each panel. Dots show regions where the projected change is large compared to natural internal variability and where at least 90% of models agree on the sign of change. Diagonal lines show regions where the projected change is less than one standard deviation of the natural internal variability.

Source: IPCC AR5 (2014)

Figure 8b displays the potential future change of precipitation, which will be not uniform meaning that some regions get drier and some wetter (IPCC AR5 2014). Moreover, changes in many extreme weather and climate events have been observed since about 1950 (IPCC AR5 2014), so that current and future impacts of climate variability and climate change on water resources have to be analysed.

It can be concluded that climate modelling delivers confident analyses of future mean values of the thermal components like T, ET, however, components like P, discharge Q, and

[14] medium confidence before the year 1951.

extreme events are still difficult to model. As Pavlik et al. (2012) mention for their study that model output in terms of precipitation cannot be directly used for hydrological impact studies, but that the data sets need to be post-processed (bias correction).

Yet, precipitation is an essential parameter for hydrological impact studies, e.g. for the urban wastewater system, since rainfall is essential for the steady state of the system, as well as for system dynamics in case of rain weather conditions (e.g. combined sewer overflow) or dry weather conditions. For describing theses dynamic conditions, long-term rainfall data over several years (>30 yrs.) with a temporal resolution of smaller than 5 minutes is necessary. Berne et al. (2004) demonstrated that precipitation data with a temporal resolution of 3 min and a spatial resolution of 2 km are needed for hydrological applications in urban catchments (100 ha). However, the temporal resolution of contemporary downscaled regional climate models is still too coarse (1-3 hours and daily output within the CCLM), as well as the spatial resolution (Pavlik et al. 2012) so that further approaches are needed (Maraun et al. 2010). Also for flood risk prediction, temporal high resolution precipitation data for forecasting and nowcasting[15] data are needed, as Wetterhall et al. (2011) showed that utilising sub-daily precipitation data in the calibration and initiation of hydrological models can strengthen forecasting of flood events. Spatially, high-resolution water balance and rainfall-runoff models work at a scale between 1 and 5 km grid scale, i.e. that hydrological forecasting input data are similarly needed at that scale, e.g. for the estimation of discharge for hydraulic models (25–100 m resolution) to approximate the potential flood inundation (de Roo et al. 2003). Also for the prediction of flash flood events, the spatial and temporal resolution of the precipitation data is essential because of the high space-time variability of both the precipitation as well as the response of the hydrological system (Creutin and Borga 2003; Sangati and Borga 2009). For simulating water quality of rivers, global radiation, temperature, relative humidity, wind speed and rainfall with a daily or hourly resolution are needed.

3.1.7 Management

The last chapters showed the importance of integrated systems and systems analysis with its various scales and levels. System understanding is a prerequisite for informed decisions and thus adequate management of any process or resource. Though, the term management has many different meanings, so that confusion between various actors exists, not only within the *management* of water resources. It has to be clarified, for instance, whether management means the business operations of a WWTP or the overall and long term manage-

[15] (precipitation data 0-1 hour).

ment of the water sector on the political level (~governance), or whether it is both. Since a common terminology is essential, we first describe the different meanings of management necessary for water resources management and its differences and interrelations to public policy and the policy cycle (qv. chapter 3.1.12 on governance).

3.1.7.1 Public policy and public management

Jänicke et al. (2003) emphasize that public policy together with public management constitute *modern policy*. They further state that the introduction of public management opened possibilities for reforming and modernization of the public sector, especially because of targeted action with performance review, so that the complete policy cycle can be optimized. The term *management* is a central part of environmental policy since the beginning of the 1990s (e.g. the Dutch Environmental Management Act as the central environmental law; Jänicke et al. 2003). The term originates from business administration and describes the targeted and efficient control of enterprises, which is extended also to the organization of administrations and even to social systems in general. Management comprises planning, organization, human resources, leadership, control and especially the improvement of organizational processes (Jänicke et al. 2003). And it has to be underlined that planning is a part of management, since there is frequently inconsistency about where planning is arranged within the policy cycle. (New) Public Management comprises inter alia privatization of state properties, deregulation of state control, as well as generally improving efficiency of policy.

Public policy refers to the execution of general rules (standards, subsidies, taxes), where instruments are more precisely defined than targets. In contrary, *public management* define specific objectives, manages more in terms of organisational activities than general rules do, and allows more flexibility in the utilisation of instruments (Jänicke et al. 2003). Consequently, public policy frequently controls only whether the policy has been implemented within the state mechanisms (state apparatus), i.e. whether the administration has implemented the necessary actions. Public management, in contrary, controls whether specific targets have been fulfilled, which needs a clear analysis of causal relations of the problem situation (Jänicke et al. 2003). Obviously, a consistent problem analysis will lead to the integration of further policy sectors and further stakeholders, so that it is connected to cooperative planning approaches (Ibid.). One of the oldest and overarching challenges of state systems that exist irrespective of a public policy or a public management approach is to have an effective relation between the policy (target setting; legislative power) and the administration as the executive power. In that sense, Ostrom (2005) stated that "...the worst of all worlds may be one where external authorities impose rules but are able to achieve only weak monitoring and sanctioning". There are manifold examples that many countries struggle in implementing policies. These mentioned points exactly represent the situation, which we find in terms of public policy and public management related to water resources and it shapes the way towards integrated water resources management. A summary on differences between public policy and public management can be found in Table 2.

Table 2: Differences between public policy and public management

Public policy	Public management
Control in terms of general rules, emphasis on implementation within state body	Control in terms of specific organisational activities; management by objectives and results
Main focus on ruling and execution	Main focus on target setting and control of success
Broad targets, precise instruments	Precise targets, flexible instruments (strategic approach)
Central and detailed budget (Fiscal accounting)	Decentralised responsibility for financial resources (Lump sum budgeting)
Formal democratic legitimisation	Legitimisation through consensus (stakeholder approach)
Motivation/action through hierarchy, formal orders, performing their respective duties	Motivation/action through decentralisation of power, specific facts of the case

Source: Modified and translated from Jänicke et al. (2003)

Examples of public management show that they can contribute to an improved environmental policy. However, public management theory is also criticised, because it assumes the full rationality of actors or the possibility of controlling complex systems (Jänicke et al. 2003). It can be reasoned that public management should not substitute public policy, but should support it towards what Jänicke et al. (2003) calls a "Public Environmental Policy and Management". This also implies that there is a double structure that comprises the hierarchic state as well as the cooperative state (Ibid.).

3.1.7.2 Normative and operative management

We further have to differentiate between two types of management (Grambow 2008): On the one hand, there is the *normative or strategic management*, i.e. long-term management on the societal and political level with principles, guidelines, rules of the game, etc. This type coincides with the term *governance*, which is used frequently to describe this type of management. Governance is about the fundamental rules and the legal system (Davis and North 1971), as well as cultural norms and traditions (qv. chapter 3.1.12). On the other hand, there is the *operative or functional management* on the level of authorities or companies, i.e. the implementation of normative decisions. Since also strategic decisions and management do play a role within the functional management, it can be stated that these two types interfere (Grambow 2008). Additionally, Grambow (2012) mentioned that normative *and* operative management exist on all levels, i.e. on the political and systemic level as well as on level of the concrete implementation. Different levels within management models for businesses and organisations are frequently found, e.g. the St. Gallen Management Model (Rüegg-Stürm 2002) with three levels: normative (general targets of the company, corporate policies), strategic management (to accomplish targets derived from normative management, business plan) and operative management (implementation of strategies, quality management, personnel management).

3.1.8 Natural resource management and nexus approaches

Increasing pressures on the natural resources system necessitates the management of theses renewable and non-renewable natural resources, like water, soil, energy, food or to certain extend waste. De Zeeuv (2000) classifies resources into: (i) non-renewable and non-recyclable resources (e.g. fossil fuels), (ii) non-renewable but recyclable resources (e.g. minerals), (iii) fast renewable resources (e.g. fish), (iv) slowly renewable resources (e.g. forests), (v) environmental resources (e.g. soil), and (vi) flow resources (e.g. wind energy). The Network of Heads of European Environment Protection Agencies (2006) defines natural resources as "all components of nature that offer direct benefits for humankind; e.g. raw materials, land, genetic resources. Natural resources also include services which nature indirectly provides for humankind, e.g. the absorption of emissions (sink function) and the maintaining of ecological biogeochemical systems." Thus, all ecosystem compartments are addressed (atmosphere, hydrosphere, pedosphere, lithosphere and biosphere) and interconnected within biogeochemical cycles of materials, mainly carbon, nitrogen, phosphorous and sulphur cycle. And this interrelationship has implications for the management of natural resources. In a general perspective, the management of natural resources is thus the sustainable utilization of natural resources, including its allocation and its protection for sustaining human livelihoods and biodiversity.

The interconnected biogeochemical cycles, the need to manage resources and other issues, like water, energy and food security led to the development of nexus discussions, as for instance the water, energy and food security nexus (Bonn Nexus Conference) as described by Hoff (2011), or the Nexus of Water, Soil and Waste as the central topic of the United Nation University Institute FLORES (Ardakanian et al. 2011). In fact, the intertwined processes within and between the compartments cause that many nexus approaches address similar issues, yet potentially having different foci (Figure 9). However, nexus approaches should be applied cautiously, since not all compartments and issues can be integrated and addressed simultaneously. This could lead to an unmanageable and too complex system leading to similar critique as already the IWRM concept encountered, e.g. "nirvana concept" (Molle 2008). Most important is a prioritization of issues, respectively management options and a functioning coordination mechanism, as we will show in chapter 7 and 8.

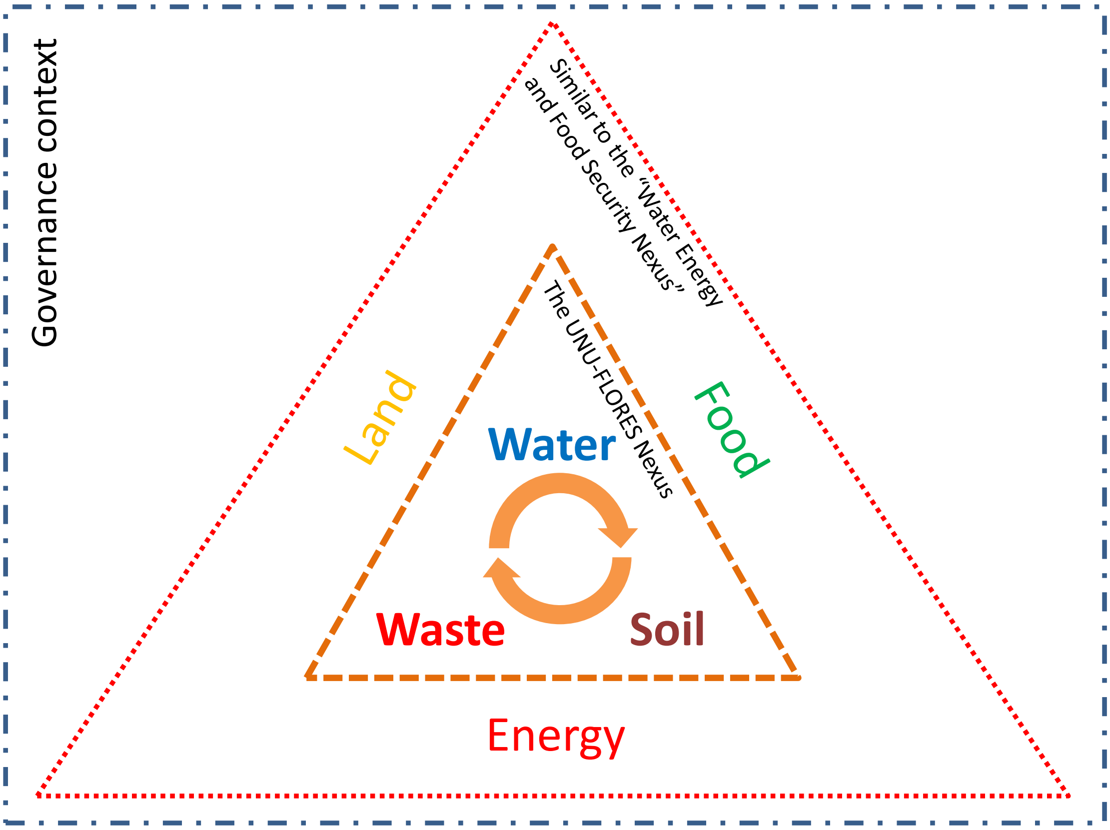
From a natural resources perspective, essential criteria for the nexus discussion are according to Bernhofer and Leidel (2014):

- energy efficiency, i.e. how much energy is required for water and waste management, as well as in soil uses like agriculture;
- land use efficiency, i.e. the required area for water, waste and land management;
- food production efficiency, i.e. the sustainable production of food under the constraints of area, water, nutrients and energy.

Underlying these three criteria is biodiversity for assuring adaptive capacity to environmental changes (Ibid.). Figure 9 displays the three criteria and its relation to two nexus approaches acting within the governance context.

From the definition of natural resources and the interconnected biogeophysical cycles, Bernhofer and Leidel (2014) state that fluxes form the "exchange currency" between the compartments and constitute the central element of nexus approaches (water, energy and nutrient fluxes). Taking nutrient fluxes as an example, phosphorus is on the one hand side the main factor for eutrophication of surface waters, and on the other side it is a non-renewable fertilizer needed for ameliorating agriculture, since it is one of the essential macronutrients (N, P, K). Several technologies for recovering P out of wastewater and recycling it for the application as fertilizer in agriculture are available as shown by Morse et al. (1998). E.g. the recovery of P from dewatered sewage sludge or as demonstrated by Franz (2008) from sewage sludge ash, which had an equal plant uptake efficiency as conventional phosphate fertilizer. This example already shows the huge potential to increase resource use efficiency, which needs to be an essential part of natural resources management, respectively of nexus approaches. Hoff (2011) summarizes that several opportunities for improving water, energy, and food security can emerge from a nexus approach, like increased productivity of resources, benefitting from ecosystems, waste as a resource, integrated poverty alleviation and green growth, stimulating development through economic incentives, governance and policy coherence or capacity building and awareness raising. Furthermore, Hoff (2011) states that transdisciplinary research on the nexus is needed, including integrated assessments of water, energy and food at all scales. The approach presented within this thesis goes in the same direction: transdisciplinary research with integrated assessment of the integrated water system. Yet, we are not drawing on energy and food security issues, but more on water resources management.

Figure 9: Interconnected nexus approaches



The inner triangle (water, soil, waste) displays the UNU-FLORES Nexus, the outer triangle (energy, food, land) are the central criteria relevant for UNU-FLORES Nexus and also stands for the context to the Water Energy and Food Security Nexus. Source: Bernhofer and Leidel (2014)

3.1.9 Water resources management

According to Lenton and Muller (2009), water resources management comprises the allocation and protection of the resource, incentives for efficient use, measures for regulating uses and conflict resolution, infrastructure development and last but not least the financing. Allocation of the resources means that water is distributed to the different water users, e.g. to agriculture or industry. This management task is according to Lenton and Muller (2009) a complex task due to the interrelated water cycle and subsequently the impacts that each use may have on other uses. Additionally, water resources management has to shift from focusing only on blue water towards managing all components of the water budget, i.e. the blue and the green water resources (cf. Falkenmark and Rockström 2006). That means that, for instance, water resources management is not only about allocating blue water to irrigation agriculture, but also about rain-fed agriculture, which is not common for traditional water resources management (qv. chapter 3.1.1). The importance of the latter is shown by

Falkenmark and Rockström (2006) that global food production needs 6800 km³ water per year, whereas "only" 1800 km³ is consumed by irrigation agriculture. Consequently, land use has to be taken into account in terms of water resources management. Having this example, also climate change related effects on water resources management have to be mentioned. Since higher temperatures in general lead to higher evaporation, water resources management has to deal with minimizing non-productive evaporation in (irrigation) agriculture (Bernhofer 2013). This is especially true if we consider the fact that hotter temperatures leads not only to more evaporation, but also to more vapour, since the saturation vapour pressure depends exponentially on temperature (Magnus equation). Consequently less rainfall may occur, since a sample of air with the same vapour pressure would reduce its relative humidity from 100%, i.e. the point where condensation and potentially cloud formation starts, to a lower percentage while temperature increases (Bernhofer 2013). This example shows that (i) integrated water resources management (IWRM) is necessary and (ii) that it has to take into account climate change effects (qv. chapter 3.1.11).

Later, I will discuss whether (integrated) water resources management should integrate the management of water uses as cross-sectoral integration as claimed by the GWP (e.g. 2000); or whether it should "only" focus on the management of the water resources where the emphasis should be on the coordination of water uses, i.e. looking at the impacts of water uses on water resources in terms of quantity, quality and allocation.

In Germany, water resources management (Wasserwirtschaft) is defined according to the DIN 4049[16] as the "systematic organisation of all human impacts on surface water and groundwater.[17] Accordingly, the German Working Group on water issues (LAWA 1996) describes that water resources management has been seen as the sum of all impacts on water resources with the main goals of (i) using the resources, (ii) defence against water related risks like flooding and (iii) reducing or mitigating water induced difficulties, e.g. land amelioration by draining marshes to transform it into agricultural land.

Other authors (e.g. Wolff and Gleick 2002, Gleick 2003) distinguish between a soft path and a hard path to water resources management, whereas the latter is about infrastructure development (e.g. dams, WWTPs) that should be *complemented* with a soft path including inter alia decentralised systems, improvement of water use efficiency, open and decentralised decision making, application of economic tools, and environmental protection. It is

[16] German Institute for Standardization (Deutsches Institut fuer Normung)

[17] In German: „Als Wasserwirtschaft wird nach DIN 4049 die zielbewußte Ordnung aller menschlichen Einwirkungen auf das ober- und unterirdische Wasser verstanden."

clearly stated by Gleick (2003) that centralised infrastructure development and management is still needed, yet it has to be complemented by the soft path. This includes the consideration of water resources management from the perspective of public administrations. Alaerts (2009), for instance, mentions that water sector management is part of the broader field of public administration.

Furthermore, water resources planning is part of water resources management. In order to reduce the confusion about water management, it is necessary to define the relationship between water planning, (integrated) water resources management, and water governance, which will be done in the following chapters. Moreover, water resources management needs to address existing coordination gaps (Charbit 2011; OECD 2012) and especially narrowing knowledge gaps by attaining, absorbing, and communicating knowledge, which can enhance human livelihoods (World Bank 1998). Next to addressing coordination gaps also the interlinked incentives have to be dealt with, which are as relevant for successful implementation of resources management.

In order to get a deeper understanding of the challenges of water resources management, the evolution of integrated approaches in water resources management will be explained.

3.1.10 Evolution of integrated approaches to water resources management

Integrated approaches to water resources management has evolved from traditional sectoral approaches to water resources management within the last one hundred years. It became necessary since the number of water uses was growing, resulting in an increasing pressure on the resource and thus also pressure on human livelihoods.

3.1.10.1 Early examples of integrated approaches

It is difficult to trace back the starting point of this evolution; a well-known and often cited example for the onset of integrated approaches is the Tennessee Valley Authority (TVA), USA, established in 1933. However, an even earlier pioneer in this respect is the German Ruhrverband (Ruhr River Association). It was established in 1913 as a response to severe water related problems in the Ruhr District based on the Ruhr pollution prevention act (Ruhrverband 2003). Due to the rapid increase in coal mining and the rise of heavy industry, water demand increased significantly as well as population growth, also leading to higher water demand and thus water scarcity. The river Ruhr was also used as raw water for the central waterworks so that also pollution of the river became an issue. The untreated wastewater also led to epidemics like typhus fever. Further conflicts about water and wastewater arose, e.g. water export to other regions leading to a reduced water flow in the Ruhr impacting for example hydropower stations. Since its establishment, the Ruhverband is responsible by law for the good water status of the river and its catchment and the compulsory members are the cities and districts, enterprises discharging wastewater and the waterworks (Ibid.). For the mentioned water quantity issues, the Ruhrtalsperrenverein (Ruhr reservoir association) was established also in 1913 based on the Ruhr reservoirs act, which was responsible for planning and constructing dams and reservoirs within the Ruhr catchment (Ibid.). Both associations were combined in the year 1938 into a single administrative unit (Ibid.). That means that the Ruhrverband is a public body with (i) the river basin as planning unit, (ii)specific legislation and authority for water management, and (iii) a balance of industrial development, drinking water supply and water quality. In summary, it can be said that the Ruhverband is by law the attempt to solve the multitude of pressing problems and conflicts between different water uses within a catchment. In the opinion of the author, this reflects the basic ideas behind integrated approaches like IWRM, so that the pioneering role of the Ruhverband can be justified.

3.1.10.2 Water on the international development agenda

In the international context, the evolution of IWRM can be traced back to the United Nations Water Conference (U.N.W.C.), in Mar del Plata in 1977. According to Biswas (1978) the conference had to address the "problem of ensuring that the world had an adequate supply of good quality water to meet the socio-economic needs of an expanding population". The *Mar del Plata Action Plan* contains several recommendations for all essential components of water management (UN DESI 1983):

A. Assessment of water resources
B. Water use and efficiency
C. Environment, health and pollution control
D. Policy, Planning and Management
E. Natural hazards
F. Public information, education, training and research
G. Regional cooperation
H. International cooperation

These recommendations and its further explanations resemble the current IWRM paradigm and basically combines all issues that are still today on the international water agenda, especially the integrated approach to the development and management of water resources. One output of the conference was the International Drinking Water Supply and Sanitation decade (1981-1990), in which some progress was observed according to Falkenmark (1997), for example sanitation improvements within developing countries, setting up of water authorities in some countries, revising legislation or improved pollution control in Western European countries. Yet, several aspects of the *Mar del Plata Action Plan* have not been addressed adequately, even if Falkenmark (1997) calls it an "excellent road map". So the question arises, why, almost forty years after this conference, the practical implementation of such recommendations is unsatisfying and still on the political agenda. Najlis and Kuylenstierna (1997) showed causes for the lack of progress in implementing the roadmap, namely external factors like population growth, decreasing economy, conflicts and rapid urbanization. They also depicted internal factors like (i) water pricing, (ii) no integrated approach to water, land and waste management, (iii) no sectoral integration, (iv) water quantity and quality aspects, and (v) local participation.

From the 1990s onwards, Integrated Water Resources Management (IWRM) was more and more recognized as a principle for implementing sustainable development in the realm of water resources management. One important step was in 1992 with the International Conference on Water and the Environment in Dublin (ICWE), as a preparatory meeting for the United Nations Conference on Environment and Development (UNCED, Rio Summit) in Rio de Janeiro. According to Biswas (2009), the Dublin conference was not based on the results and experiences from Mar del Plata Conference. Other critics like Muller (2010) mentioned that most of the participants were technical experts from governments of the developed world and NGOs. On the conference, the Dublin statement consisting of four guiding principles with explanations (so called Dublin principles, Figure 10) and an action agenda with several recommendations have been developed (ICWE 1992). The first principle is often considered as the basic requirement for integrated resources management in order to come to a sustainable utilisation and development of water resources (Solanes and Gonzalez-Villarreal 1999). It therefore includes the three parts of sustainability, namely economic development, social development and environmental protection as well as a river basin approach. Also aspects like water quantity and quality or water planning are read into the first principle. The explanation to the first principle resembles important parts of the GWP (2000) definition of IWRM. The Dublin conference claimed that centralized and sectoral approaches to water resources management are inadequate for solving local water management issues, so that local participation needs to be fostered by governments (Najlis and Kuylenstierna 1997). For the follow-up on action plans, the ICWE (1992) proposed inter alia to install a world water forum or council, which was subsequently founded in 1996. The World Water Council (WWC) organizes the triennial World Water Forum.

Members are intergovernmental organizations like UNESCO or World Bank, governments and government authorities like the French Environmental Ministry, private companies like Veolia Eau or Suez environment, civil society organizations like the International Union for Conservation of Nature (IUCN), professional associations and academic institutions like the Global Water Partnership, the International Water Resources Association or Alterra-Wageningen (WWC 2014).

Figure 10: Dublin principles

1. *Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment*

2. *Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.*

3. *Women play a central part in the provision, management and safeguarding of water*

4. *Water has an economic value in all its competing uses and should be recognized as an economic good*

Source: ICWE 1992

The WWC is criticized by several NGOs with some of them organising the Alternative World Water Forum. The main critics are that the WWC is dominated by private companies and is focused on privatizing water and sanitation services. They further state that the WWC has no legitimacy for developing international water policy (FAME 2012).

It is often criticised that the Dublin principles are too general and impossible to operationalise in terms of efficient water resources management (e.g. Biswas 2009). In addition, it is often mentioned that water as a social good is not considered. Yet, the explanations to the fourth principle state that "...it is vital to recognize first the basic right of all human beings to have access to clean water and sanitation at an affordable price." However, mentioning "social *and* economic good" within the fourth principle would have been reasonable, since the principles were promoted and became famous but not the explanations. In fact, the Dublin statement has been often reduced just to the Dublin principles, which are easily understandable, thus well-known and often repeated without explaining them correctly. Generalising the complexity of water resources management to four vague principles instead of promoting an agenda with a road map is the major drawback of the ICWE. This generalisation can be considered as the basis of unjustified as well as justified critiques of the Dublin statement.

The next important step was the UNCED (Earth summit) with the Rio Declaration on Environment and Development (Rio Declaration) incorporating 27 principles for supporting sustainable development (UNCED 1992). Furthermore, the Agenda 21 was enacted as the action agenda in terms of sustainable development. It acknowledges the importance of water in chapter 18 named "Protection of the quality and supply of freshwater resources: application of integrated approaches to the development, management and use of water resources". Within this chapter, water related programme areas are suggested:

a. Integrated water resources development and management;

b. Water resources assessment;

c. Protection of water resources, water quality and aquatic ecosystems;

d. Drinking-water supply and sanitation;

e. Water and sustainable urban development;

f. Water for sustainable food production and rural development;

g. Impacts of climate change on water resources.

These seven areas are comprehensively explained, mentioning all important points for sustainable water resources management. They are divided into basis for action, objectives, activities, and means of implementation as further explained in chapter 3.1.11. It can be seen that the focus is on development (referring to water resources as well as economic and social development), management and use of water resources and *not only* on management. It has to be noted that integrated water resources development and management (IWRDM) is one programme area next to the others like water resources assessment, which may lead to the misimpression that it is at the same level as the other programme areas. Yet, IWRDM incorporates the other six programme areas, as already implied in the title of the chapter, as well as explained within chapter 18 of Agenda 21. Another essential point is that chapter 18 clearly states that "effective implementation and coordination mechanisms are required".

Another important conference was the Millennium Summit in the year 2000, where the Millennium Declaration and the Millennium Development Goals (MDGs) were adopted. In terms of water resources management of special importance is goal 7 (ensure environmental sustainability) with four targets (UN 2013):

1. Integrate the principles of sustainable development into country policies and programs; reverse loss of environmental resources
2. Reduce biodiversity loss, achieving, by 2010, a significant reduction in the rate of loss

3. Halve, by 2015, the proportion of the population without sustainable access to safe drinking water and basic sanitation
4. Achieve, by 2020, a significant improvement in the lives of at least 100 million slum dwellers

At least since the World Summit on Sustainable Development in Johannesburg (2002), IWRM is considered as the basic concept for improving water resources management. Within the *Johannesburg Plan of Implementation*, one target is to "develop integrated water resources management and water efficiency plans by 2005…" UN-Water (2008) reported moderate progress in this respect with the percentage of developing countries having IWRM plans accomplished or under implementation has increased from 21% to 38%. The current status report from UN-Water (2012) indicates that on the one hand, significant governance improvements over the past 20 years can be reported, yet, on the other hand this process is for many countries still ongoing. However, the UN-Water survey from 2012 also showed that progress related to IWRM plans has slowed or even declined in developing and transition countries since the last survey in 2008. That means that the implementation of IWRM has started, but more efforts are still necessary to operationalise integrated approaches, especially for countries with a low Human Development Index (UN-Water 2012). One remaining question is, whether having IWRM plans in place is a good indicator for measuring the real implementation of IWRM at regional or local scales.

Efforts needed for implementation are manifold, yet improved education, knowledge and information about sustainable water resources management is evident. Therefore, the United Nations Decade of Education for Sustainable Development (DESD 2005–2014) demands an appropriate education in the field of hydrosciences in order to approach sustainable water resources management. Accordingly, the enhancement of academic and non-academic education and vocational training is a central part within the discourse on capacity development. This is also a central part in the current discussion on a new framework of international development (Sustainable Development Goals-SDGs) that should succeed the MDGs that will run out in 2015 (cf. Chasek et al. 2014). In the proposed SDGs, also IWRM is mentioned: "by 2030 implement integrated water resources management at all levels, including through transboundary cooperation as appropriate" (Chasek et al. 2014). There is currently the discussion on proposing a goal towards ensuring "...availability and sustainable management of water and sanitation for all" (Ibid.).

It would be important to further clarify issues concerning the international political agenda of water resources management. This thesis, however, attempts to shed some light on the development of a practical approach to support water resources management in implementing such theoretical (and often abstract) concepts and roadmaps. Thus, it is demonstrated how the implementation of global road maps can be supported for crossing boundaries on national, regional and local scales. The approach should form a vital piece to complete the jigsaw of implementing sustainable water resources management without having the hubris to think that this approach is a panacea for water resources management.

3.1.11 Integrated Water Resources Management (IWRM)

The IWRM concept is supported by several international organisations (e.g. GWP, UNESCO-IHP, UNECE, UNEP, GEF, UN-Water as inter-agency coordination mechanism for water related issues, WWC). Within the international development cooperation, IWRM is the prevalent principle for sustainable water resources management, e.g. Germany follows the IWRM model in all its development activities in the water sector (BMZ 2006), as well as the Agence Française de Développement (AFD 2012).

There are several definitions for the concept of Integrated Water Resources Management (IWRM), yet this thesis highlights similarities and differences between the definition of IWRM within Agenda 21 and the nowadays widely used definition of IWRM by the GWP.

3.1.11.1 IWRM within Agenda 21

A comprehensive definition of sustainable water resources management was developed within the Agenda 21 (UNCED 1992), emphasizing management *and* development *and* use:

"Integrated water resources management is based on the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization. To this end, water resources have to be protected, taking into account the functioning of aquatic ecosystems and the perenniality of the resource, in order to satisfy and reconcile needs for water in human activities. In developing and using water resources, priority has to be given to the satisfaction of basic needs and the safeguarding of ecosystems. Beyond these requirements, however, water users should be charged appropriately" (UNCED 1992).

It is further written within the objectives of chapter 18 (UNCED 1992) that "integrated water resources management, including the integration of land- and water-related aspects, should be carried out at the level of the catchment basin or sub-basin. Four principal objectives should be pursued, as follows:

a) To promote a dynamic, interactive, iterative and multisectoral approach to water resources management, including the identification and protection of potential sources of freshwater supply, that integrates technological, socio-economic, environmental and human health considerations;

b) To plan for the sustainable and rational utilization, protection, conservation and management of water resources based on community needs and priorities within the framework of national economic development policy;

c) To design, implement and evaluate projects and programmes that are both economically efficient and socially appropriate within clearly defined strategies, based on an approach of full public participation, including that of women, youth, indigenous people and local communities in water management policy-making and decision-making;

d) To identify and strengthen or develop, as required, in particular in developing countries, the appropriate institutional, legal and financial mechanisms to ensure that water policy and its implementation are a catalyst for sustainable social progress and economic growth."

These objectives are underpinned by means of implementation, whereas the most important one reflects a definition that "water resources development and management should be planned in an integrated manner, taking into account long-term planning needs as well as those with narrower horizons, that is to say, they should incorporate environmental, economic and social considerations based on the principle of sustainability; include the requirements of all users as well as those relating to the prevention and mitigation of water-related hazards; and constitute an integral part of the socio-economic development planning process. A prerequisite for the sustainable management of water as a scarce vulnerable resource is the obligation to acknowledge in all planning and development its full costs. Planning considerations should reflect benefits investment, environmental protection and operation costs, as well as the opportunity costs reflecting the most valuable alternative use of water" (UNCED 1992). Further means of implementation are about capacity development and human resources development and financing (Ibid.).

3.1.11.2 IWRM definition from Global Water Partnership (GWP)

One frequently used definition for IWRM is elaborated by GWP. IWRM is defined as "a process which promotes the coordinated development and management of water, land and related resources in order to maximise economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems and the environment" (GWP 2000). Within its work, GWP refers rather to the Dublin principles as important basics for IWRM, than to the Agenda 21. Even if the GWP Technical Advisory Committee refers in some publications to the principles of both Rio and Dublin conferences, and naming them seldom Rio-Dublin principles, they mostly mention in their documents the Dublin principles without explicit reference to Agenda 21. As a proof for the relevancy of the Dublin principles, GWP asserts that those principles have been restated at several conferences like the Rio+5 conference (UN 1997). However, those principles have not been mention explicitly within this conference; at best they can be found implicitly. Moreover, the Rio+5 conference (UN 1997) mentioned that water is a social and economic good, so drawing rather from the Agenda 21.

Interestingly, the Dublin principles and the term "IWRM" with its definition by the GWP (2000) has become accepted notwithstanding the fact that (i) the Dublin conference was a preparatory conference with limited participants, (ii) the Rio conference with the Agenda 21 was actually the legitimate intergovernmental agreement for setting the agenda on sustainable development based on the so called Brundtland report (Report of the World Commission on Environment and Development: Our Common Future). The term "integrated water resources *development* and management" disappeared from the political agenda during the 1990s, even if the United Nations Economic and Social Council reaffirms this term in its resolution 1996/50 (UN-DESA 1999). A Google search from 22/01/2015 showed 58.400 results for "integrated water resources *development* and management" and six times more results (383,000) for "integrated water resources management".

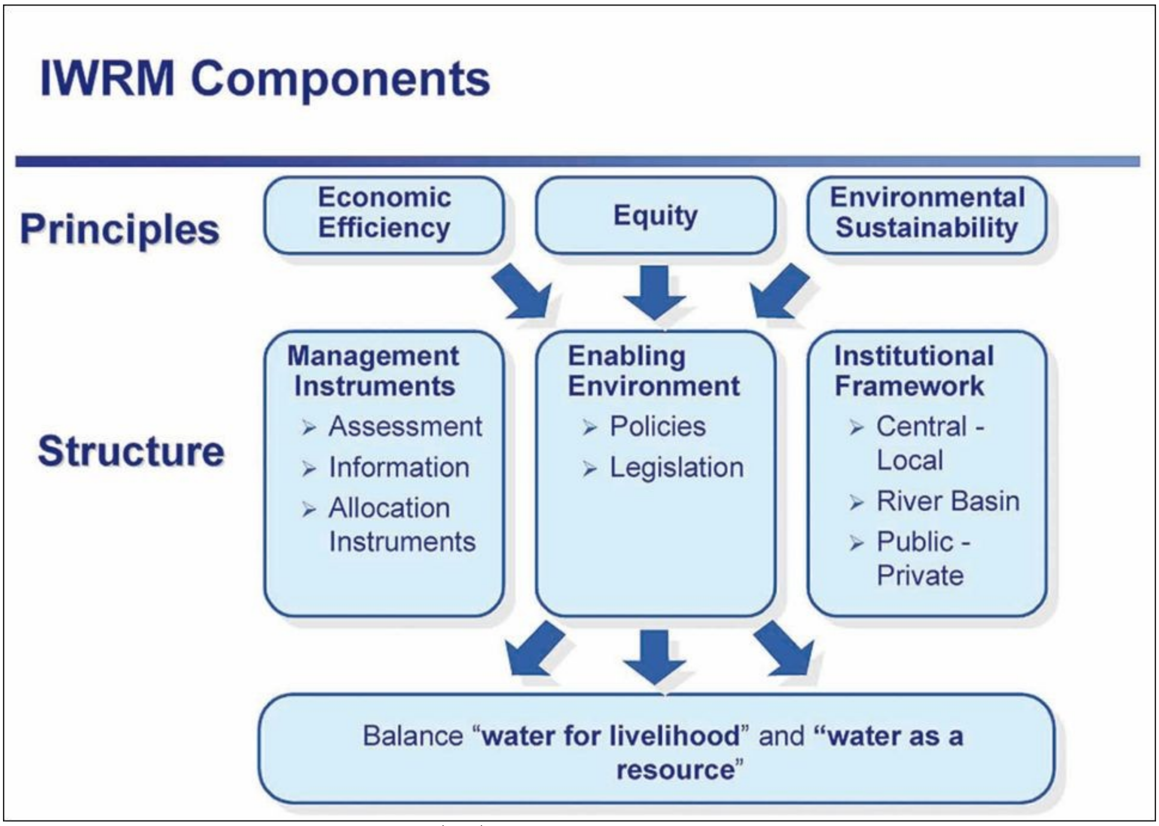
The question arises whether there is really a significant difference between those two terms and whether they reflect different approaches, namely IWRM= Dublin principles and IWRDM= Agenda 21. For Muller (2010) the Dublin approach to IWRM can be described as normative one, whereas the Rio approach is characterized as a pragmatic one. According to GWP-TAC (2000), the "M" in IWRM refers to both "development and management". Lenton and Muller (2009) attempt to bridge the gap between the Rio approach and the Dublin approach by summarizing both approaches and determining that "water is a public good with both social and economic values, and that good water resources management requires both a broad holistic perspective and the appropriate involvement of users at different levels".

3.1.11.3 IWRM components

Based on the concept of sustainability, IWRM focuses on three overriding principles, economic efficiency, equity and environmental sustainability (Figure 11). This should not be mixed up with the four "IWRM principles", promoted by GWP and which are basically the Dublin principles.

On the homepage of GWP, accessed on 28/01/2014, a fifth principle is laid down on "integrating three Es", meaning the above mentioned three objectives.

Figure 11: IWRM components



Source: GWP-homepage (accessed on 23/05/2012)

13 change areas have been identified by the GWP (2004), which are structured into the "three pillars of IWRM" enabling environment, management instruments and institutional framework (Figure 11; Figure 12). The three pillars with the change areas are listed in Table 3.

However, IWRM is no blueprint meaning that implementing IWRM is context specific, depending on several factors like (GWP-TAC 2000):

- character and intensity of water problems,
- human resources and institutional capacities,
- relative strengths and characteristics of the public and private sectors,
- the cultural setting,
- natural conditions

The challenge of IWRM is according to GWP-TAC (2000) to balance water uses between water for livelihood and water as a resource to maintain its functions and characteristics.

Table 3: Change areas within IWRM

Enabling environment	Institutional roles	Management instruments
Policies: setting goals for water use, protection and conservation	Creating an organizational framework: forms and functions	Water resources assessment: understanding resources and needs
Legislative framework: rules to follow to achieve policies and goals	Institutional capacity building: developing human resources	Plans for IWRM: combining development options, resource use and human interaction
Financing and incentive structures: allocating financial resources to meet water needs.		Demand management: using water more efficiently
		Social change instruments: encouraging a water-oriented civil society
		Conflict resolution: managing disputes, ensuring sharing of water
		Regulatory instruments: allocation and water use limits
		Economic instruments: using value and prices for efficiency and equity
		Information management and exchange: improving knowledge for better water management.

Source: Based on GWP (2004)

3.1.11.4 Meaning of integration within IWRM

Integration within IWRM can be categorized into natural system integration and human system integration, although it has to be acknowledged that integration between these two categories is also needed (GWP-TAC 2000).

Natural system integration

From the holistic nature of the water cycle, it is clear that the integration of land and water management is necessary, as well as the integration of surface water and groundwater management. Moreover, the quality of the resource is directly related to the quantity, so that both have to be managed simultaneously. Consequently, also upstream and downstream water uses have to be integrated, which clearly shows the interconnection to the human system integration. For instance conflicts and cooperation over upstream water pollution or abstraction are evident and therefore institutional mechanisms are needed that mirror and respect the upstream-downstream relationship (cf. van der Zaag 2005). Since rivers discharge into lakes and oceans, also the integration between water resources management and coastal zone management, respectively lake basin management, is needed. And it is necessary to integrate green *and* blue water as mentioned earlier.

A focus is also on integrating water and wastewater management, whereas the interaction of the natural system and the human system is obvious.

Human system integration

According to GWP-TAC (2000) the IWRM approach implies a *cross-sectoral integration* in national policy development meaning that water resources policies have to be integrated with other sectoral policies and financing priorities (Figure 12). That means that water related developments within other sectors like agriculture, energy or environmental protection must be in line with water resources development, water use and water risks (Ibid.). Vice versa, the management of water resources potentially has impacts on the society including economic activities, for example irrigation agriculture and thus food production. This implies also an integration of sectoral institutions and organisations (e.g. through River Basin Organisations), since there is a sectoral fragmentation of water policy across different authorities, as mentioned in chapter 3.1.4. This is also in accordance with van der Zaag (2005), stating that IWRM is mainly an institutional challenge, so that an institutional integration or a cross-sectoral integration is needed. Since decision making authority is according to Pahl-Wostl (2009) done within a nested hierarchy between top (e.g. national government), middle (e.g. regional administration) and individual (humans) level, also a vertical integration is needed (chapter 3.1.4).

Another point raised by GWP-TAC (2000) is to influence economic decisions of sector actors, since such decisions potentially have impacts on water availability, quality and demand, as well as water-related risks. Therefore, economic decisions need to reflect the real value of water and to reflect the full costs of the consequences of their action on the environment and the society in order to make water sensitive decisions (internalising external effects).

Multi-stakeholder participatory process

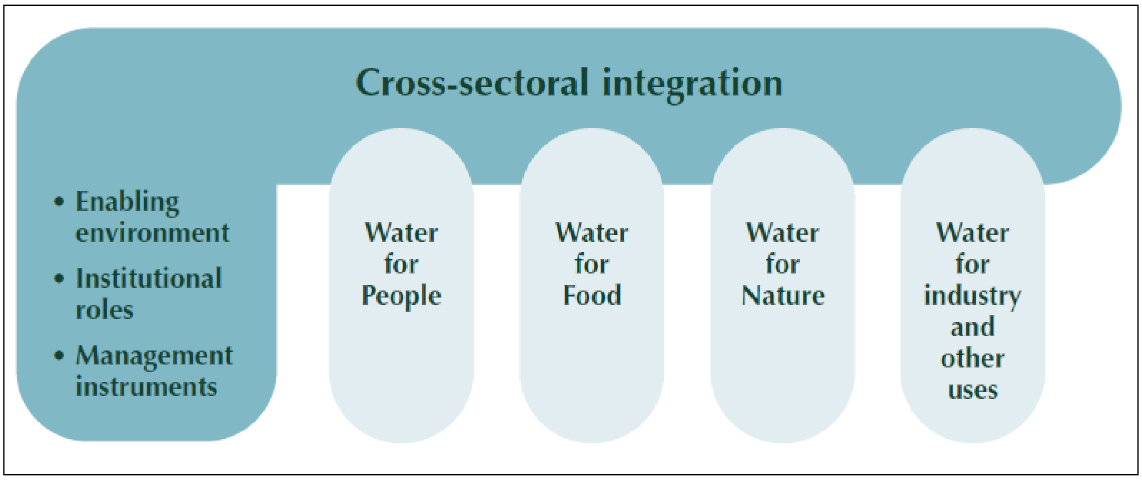
IWRM is about the integration among and between water users and the government (Van der Zaag 2005). Thus, the identification and integration of all stakeholders in the planning and decision making process is necessary (Ibid.). Yet, the integration of *all* stakeholders may increase complexity of the management process significantly, so that the integration of all *relevant* stakeholders seems more reasonable. It has to be carefully analysed who is needed in which phase of the decision making process on which level, following the principle of subsidiarity. It has to be assured that no relevant actor is omitted but also that negligible actors are not encouraged to participate. However, this differentiation is not always easy to be done, since sometimes the importance of some actors is only recognized during the development process.

Transparent decision making processes are essential based on real participation, implying that good governance is needed for IWRM as stated by Rogers and Hall (2003). Accordingly, the complex decision processes of IWRM need to be facilitated by water managers that have the skills and capacities to do that next to providing the necessary information to the participants of the decision making process (van der Zaag 2005).

Integration of development and environmental protection

There is a dilemma that development is often pitted against environmental protection, meaning that especially in developing and transition countries development is done at the expense of the natural resources.

Figure 12: IWRM and its relation to sub-sectors



Source: (GWP-TAC 2000)

Overall integration

In summary, it can be said that inter-sectoral (cross-sectoral) integration is needed (e.g. coordination between water for agriculture and water for domestic uses), as well as intra-sectoral integration (e.g. the coordination between different dischargers into the river) and the integration of actors at different levels of water management. Yet, problems arise from integration, namely the problem of fit, problem of vertical and horizontal interplay and the problem of scale, as described in chapter 3.1.4.1. This implies that coordination and collaboration are critical factors.

IWRM can be thus considered as a societal task steering the dynamic and diverse interdependencies between the biogeochemical processes and anthropogenic activities (Leidel et al. 2013). Many aspects of society like urban planning, vulnerability towards flooding or technological development for the utilization of water have to be taken into account. Thus, a transdisciplinary approach is needed, where natural and engineering scientific factors as well as socioeconomic factors need to be considered within a societal context (chapter 4.2 on transdisciplinarity). It has to be acknowledged that IWRM is not a concrete dogmatic manual, which integrates everything no matter what the situation is. Instead, it has to be seen as a conceptual framework that still has to be adapted to the societal and natural requirements within the geographic context of the conducted study (Leidel et al. 2012).

GWP-TAC (2000) acknowledges that human system integration is a complex task and perfect integration is unrealistic. For encountering this complexity, integrative and adaptive approaches are needed with multiple levels of analysis, assessment and management (e.g. Pahl-Wostl et al. 2007). This clearly shows that there is a distinct role for water governance in terms of implementing integrated water resources management.

3.1.12 Water governance

Before elaborating more on water governance, it is necessary to define some key terms that are essential for understanding the concept of water governance.

First of all, *stakeholders* are defined as an" individual, group, institution, or government with an interest or concern in a particular measure taken or a proposal made by an organization" (UNDP 2009). Accordingly, stakeholder analysis comprises "a mapping of key stakeholders and their position vis-à-vis an entity's objectives (degree of support, power etc.; UNDP 2009). Such an analysis is vital for identifying, the important stakeholders for the capacity assessment (qv. chapter 3.2.5). Somewhat differently, an *actor* can be defined as an individual or a group of individuals with regulated decision making, e.g. a government or a company (Ostrom et al. 2001). Even if there are slight differences in the definitions, we stick to Woodhill (2010) who uses both terms interchangeably by defining that "a stakeholder *or* an actor is an individual, organization or group who has a role to play and/or is affected by the outcome of an issue, situation or process". For Renn and Schweizer (2009), the term governance already implies that decision making of plural societies cannot exclusively be done by governments, but additionally economic players, scientists and civil society organizations are essential actor groups. Other experts use similar, but sometimes slightly different classifications of stakeholder groups, e.g. Woodhill (2010) emphasizes on citizens instead of scientists as fourth group. In the course of this thesis and thus for our analyses, we stick to the grouping of Renn and Schweizer (2009).

In terms of decision making and stakeholder participation, it is also vital to mention that inclusion (what and whom to include) and closure (what and how to select) are important parts of any decision making (Hajer and Wagenaar, 2003; Renn and Schweizer 2009). Inclusion means that the four main actor groups have to be included so that they can together work on the problem and options for solving them (Renn and Schweizer 2009; qv. Action research in 4.1). Closure means that a set of options is agreed upon, while other options or plans are not considered further, so that the actors are enabled to reach a joint statement or agreement (Ibid.). However, as mentioned earlier, the increasing integration of additional stakeholders with their different interests, values and standpoints makes it more difficult to reach a joint agreement or even a consensus (Ibid.). Nevertheless, Renn and Schweizer (2009) argue that *inclusive governance* is based on the assumption that all actors can contribute and are necessary for improving decisions instead of impeding the process or reducing the scientific quality, respectively the legitimacy. And stakeholder participation is clearly more than only a two-way communication process, but it is a process that needs to include technical expertise, public values and regulatory requirements, which can be brought into the decision making by the above mentioned four actor groups (Renn and Schweizer 2009). They further describe six concepts for organizing participatory processes, namely functional, neo-liberal, deliberative, anthropological, emancipatory and post-modern, and relate possible participatory methods and techniques to each concept like Delphi method or advisory committees to the functionalist concept (Renn and Schweizer 2009). However, it is important to mention in the context of stakeholder participation, water governance and power issues what Lewin (1946) called the "unwillingness to face reality" of actors in power positions, which can be found at any level of management (e.g. politics), i.e. it seems that they fear that they cannot proceed with what they want to do, if the facts are known.

Furthermore, it is essential to distinguish between organisations and institutions, since both terms are notoriously used interchangeably, which is however not correct. Organisations differ from institutions, since *organisations* are "groups of individuals bound by some common purpose to achieve objectives" (North 1990). Lusthaus et al. (2002) additionally mention that organizations are formalized entities and that "organizations both conform to and influence institutions". Many human activities are conducted within organisations and are categorized by Lusthaus et al. (2002) inter alia as private or public, for-profit or non-profit, governmental or nongovernmental. *Institutions* are the formal and informal rules by which stakeholders interact (Ibid.). Thus, institutions are the *rules of the game*, i.e. "the humanly devised constraints that structure political, economic and social interaction. They consist of both informal constraints (sanctions, taboos, customs, traditions, and codes of conduct) and formal rules (constitutions, laws, regulations, and property rights)" (North, 1991).

Governance itself is a term that became a well-known term in development cooperation, institutional economics and beyond, so that several different meanings and definitions can be found in literature. Pierre (2000) describes the basic meanings of governance; firstly, it refers to the adaptation of the state towards its external environment. Secondly, it refers to the coordination of social systems and the role of the state within the system (Pierre 2000). This second meaning can be further differentiated into two categories, whereas the first is about how the state steers and coordinates society and economy through developing policies, setting objectives and priorities, i.e. it is about the political and institutional capacities of the state and about the role of the state in relation to other influential actors (state-centred perspective; Ibid.). The second category is about coordination and forms of formal and informal public-private interactions and especially on the role of policy networks and partnerships, i.e. it focuses more on self-governance (society-centred; Ibid.). Chapter 3.1.16 describes how social coordination mechanisms function and explains main mechanisms relevant for water resources management.

An overview on governance definitions can be found in Roe (2013). Due to the manifold meanings and definitions, it is not surprising that the term governance it is often found in a compound with other terms, e.g. water governance, environmental governance, regional governance, inclusive risk governance, good governance and so forth.

And it has to be differentiated between governance and operational management as mentioned in chapter 3.1.7. Several authors (e.g. Grambow 2008) use the term *normative or strategic management*, instead of the term governance or interchangeably. Governance is about the fundamental rules and the legal system (Davis and North 1971), as well as cultural norms and traditions. In plain words, governance can be described as systems of rules for targeted activities; however, this is also true for government. So, a differentiation between governance and government has to be done. Rosenau (1992) describes government activities as backed by formal authorities and power to ensure the implementation of policies, whereas governance relates to activities backed by shared goals, which do not necessarily rely on power and formal authorities for compliance. Thus, governance "...is a more encompassing phenomenon than government. It embraces government, but it also subsumes informal, non-governmental mechanisms... And it is possible to conceive of governance without government...which function effectively even though they are not endowed with formal authority" (Rosenau 1992). He further states that governance can only function, if it is accepted by the majority, whereas government can function even if there is opposition to their policies (Ibid.).

Even if there are manifold meanings of governance, several core points of governance can be described as done by Benz (2010):

- Steering and coordination (also governing) with the objective of managing interdependencies between (usually cooperative) actors
- Steering and coordination is based on institutionalised rule system for enabling the action of the actors, which is usually a combination of different regulation systems (e.g. contractual regulations, supervisory power, negotiating rules, competency based rules, majority rule).
- Comprising various modes of interaction and collective action (e.g. networks, coalitions)
- Processes of steering, coordination and interaction crosses the boundaries of organisations, as well as the boundaries between society and state. Thus, policy processes are conducted by state actors and non-state actors, respectively between actors within and outside organisations.

Accordingly, a governance system consists of these above mentioned points and its interactions. If such a governance system is capable of setting a framework for reaching and enforcing defined targets the term good governance is frequently used. In terms of water resources management, however, usually diverging objectives of the different actors are in place, meaning that water resources management is related to power and interests, influencing also the governance system and eventually impedes good governance.

A common definition of water governance is put forward by Rogers and Hall (2003) that it "refers to the range of political, social, economic and administrative systems that are in place to regulate development and management of water resources and provision of water services at different levels of society." Huppert (2007) further emphasizes that for the integration within IWRM, mechanisms are needed that support the organisation of the relations between the different actors within and between the sectors. A wide range of such social coordination mechanisms are available and should be applied according to the context: legislation, hierarchical administrative mechanisms, market mechanisms, democratic mechanisms, formal and/or informal agreements (qv. chapter 3.1.16 on coordination mechanisms). It has to be mentioned that such coordination mechanisms are needed no matter how the water management is reorganized in terms of IWRM implementation. Whether a centralized organization is newly established during the IWRM process (e.g. river basin organization; water user association) or whether the existing sector organizations have to cooperate and coordinate with other sector organizations for implementing IWRM. Accordingly, Huppert (2007) adapted the governance definition of Williamson (1996) and defines water governance as "the means by which order is accomplished in the relation between the different stakeholders in the water sector in order to avoid potential conflicts and realize mutual gains in the context of IWRM".

3.1.13 River basin management

In the context of water resources management, we also have to discuss the relation to river basin management. IWRM from its definition (GWP 2000) does neither mention explicitly a geographical scale nor a jurisdictional one. River basin management (RBM) as its name implies focuses on a basin wide approach for managing water resources[18]. Already within Agenda21 as well as in several IWRM publications from organizations promoting IWRM, as for instance GWP or UN-Water, it is usually mentioned to conduct IWRM on river basin scale. That means that RBM is to be considered as means for implementing the IWRM principles on the ground. River basin management is, for instance, also a central part of the EU- Water Framework Directive, which states that water management should be conducted within its natural geographical unit, the river basin and that river basin management plans have to be set up.

And accordingly, river basin organizations[19] have been often proposed as organizations for implementing IWRM (e.g. GWP 2000). Details on the design and the different types of river basin organizations can be found in Huitema and Meijerink (2014), and the evolution including the different discourses towards RBOs are summarized in Jaspers and Gupta (2014). Interestingly, the EU-WFD has not forced the member countries to replace the existing water management authorities by establishing river basin organizations, but instead leaving this decision to the member countries by only regulating that there need to be one authority responsible for the coordination within the river basin. This led e.g. in Germany to the situation of parallel structures where the executing power is with the existing water authorities of the federal states and the planning is conducted within the river basin. This

[18] Sometimes also called *integrated* river basin management. Further used terms can be found in Downs et al. (1991).

[19] They are also called water agencies, basin agencies, basin department, basin commissions, water councils.

led according to Moss (2012) to high transaction costs due to coordination needs between authorities, but also avoided organizational restructuring and also forced authorities to co-operate with non-state actors.

IWRM is the overarching paradigm with general political objectives to be achieved, whereas RBM is considered as the concrete implementation and thus the operationalization and adaptation of the IWRM concept with "SMART"[20] objectives. Even if IWRM and the EU-WFD are stemming from different discourses, the EU-WFD can be considered as an example, where the concept of IWRM was transformed into law and was adapted to regional context specific conditions. E.g. gender issues have not been integrated into the EU-WFD, whereas it is a clear objective of the Dublin principles that women should have a central part in management of water. Yet, those issues are negligible in Europe, so that it is reasonable not to include it into the legislation and thus exemplifying the need of context-specific adaptations.

In fact, river basins are natural hydrological units, in which the precipitation on this area leads according to the water balance (i.e. net of ET and storage) to the discharge with the drainage divide as the natural borders of the catchment. However, even this supposed distinct border is sometimes not exact, e.g. within karstic catchments, drainage divides of the surface catchments are frequently not congruent to the borders of the underlying aquifers, i.e. that precipitation within one catchment could result in groundwater that eventually drains within the adjacent catchment. Similarly, man-made inter-basin water transfer also creates problems (Niemann 2005) for the water balance, and thus also questions the validity of having the basin as management unit instead of the jurisdictional unit.

Nevertheless, for hydrological analyses, and thus from a natural scientific and engineering scientific point of view, the river basin is the essential unit. All state-of-the-art analyses and modelling approaches are conducted within the river basin (qv. chapter 3.1.6 on integrated modelling). Thus, river basin management is a similar concept as water resources management that is described in chapter 3.1.9.

Some authors (e.g. Keitz and Kessler 2008) argue that even form an ecological point of view, river basin as boundaries are not relevant, because river basins do not constitute an ecological unit for species, apart from in stream species. They further argue that river basins are also from a socio-political point of view not fully reasonable (Ibid.). E.g. natural protection policies or agricultural policies are neither developed for, nor implemented in

[20] Objectives should be specific, measurable, achievable, realistic, time bound.

the river basin, but within the existing territorial, i.e. jurisdictional boundaries, e.g. supranational like the EU or national states and its sub-units like federal state or counties. In chapter 3.1.4 we described these problems of fit and interplay, and in fact, RBM is as Moss (2003) stated a classical approach of solving problems of fit.

There exist several different meanings of the functions of river basin management and which management tasks should be integrated. Downs et al. (1991) reviewed 21 approaches and provide a table listing all management components and its importance for developing as well as developed countries.

Table 4: Functions and tasks of river basin management

Main function	Function/Task	Description
Monitoring, investigating, coordinating and regulating	Data collection	Collecting, managing and communicating data regarding water availability, water demand (including environmental requirements), and water quality to support different basin functions
	Prevention, monitoring and enforcing	Monitoring and control of water pollution, salinity levels and ground water extraction – ensuring that they remain within accepted limits; and enforcing relevant laws and regulations to prevent degradation/overexploitation and to restore ecosystems
	Coordinating	Harmonizing policies and actions undertaken in the basin by state and non-state actors relevant to land and water management
	Resolving conflicts	Providing mechanisms for negotiation and litigation
Planning and financing	Water allocation	Defining mechanisms and criteria by which water is apportioned among user sectors, including the environment
	Planning	Formulating medium- to long-term plans for developing and managing water resources in the basin
	Mobilizing resources	Ensuring financing, for example, by collecting water user fees or water taxes
Developing and managing	Constructing facilities	Designing and constructing water infrastructure
	Maintaining facilities	Maintaining water infrastructure
	Operation and management	Ensuring that dams, navigation and water distribution infrastructure, and wastewater treatment plants are properly operated; that allocated water reaches its point of use; and that surface and ground water are conjunctively managed
	Preparing against water disasters	Protecting from floods and developing emergency works, flood/drought preparedness plans, and coping mechanisms (Flood and Drought Risk Management)
	Protecting and conserving ecosystems	Defining priorities and implementing actions to protect ecosystems, including awareness campaigns

Source: Modified from Molle et al. (2007) and GWP and INB (2009)

From that, Downs et al. (1991) conclude that RBM[21] comprises the following interrelated items, namely water management (water quality control, hydrologic regulation), river channel management (channel control), land management (land degradation control, land use regulation), ecological management (preservation, diversification) and human management (socioeconomic benefits). In a similar, but more detailed way, the essential functions of river basin management, which are partly or completely conducted in any river basin, have been described within the Comprehensive Assessment of Water Management in Agriculture by Molle et al. (2007) and have been subsequently slightly modified by other organizations, e.g. GWP and INBO (2009). Valensuela (2009) additionally lists the issues to be addressed at river basin level, as well as the various types of data and information needed. Table 4 shows the essential functions of river basin management developed by Molle et al. (2007) with modifications from GWP and INBO (2009). Other authors like von Keitz and Kessler (2008) argue that one should be cautious in conducting RBM and setting up RBOs and that integration should be "only" about (I) upstream/downstream issues, especially pollution, (ii) heat discharge regulations, (iii) regulations regarding flooding and low water levels. Graefe (2011) even states that the "river basin fetishism, the domination of the IWRM and governance concepts can be taken as a symptom of the depolitization of water management" and thus as "replacement of the polity by expert environmental administrators". Similarly, Swyngedouw (2009) mentions the depolitization of management, i.e. that the political is reduced to policy making and consensual governing. Graefe (2011) argues that the problems are not technical or hydrological, but political, so that the river basin as the planning unit is erroneous and naïve.

Interestingly, Gruenewald (2008) argues similarly that the problems are rather political than technical, but his deduction is completely different, since he states that therefore the river basin needs to be the planning unit. He further argues that not a restrictive river basin approach is needed, but a comprehensive one, especially regarding adaptation strategies, and strengthening the technical and natural scientific basis for integrated water resources management (Gruenewald 2008, qv. chapter 3.1.5.1). He proposes to establish water associations (i.e. RBOs) within river basins, forwarding good examples from several German federal states as for instance in Northrhine-Westfalia (Ibid. qv. Chapter 3.1.10.1 on the Ruhr River Association). There are pros and cons for both positions, however, the major points behind are that there are inherently misfits when dealing with challenges related to water resources management. As a matter of fact, from hydrological perspective water resources

[21] Downs et al. (1991) name it integrated basin management.

management has to be done on the river basin scale thus following Gruenewald (2008). In terms of legislation and implementation of management options, it is necessary to analyze and understand the institutional context conditions; i.e. also to check the historical arrangements towards water resources management. What is reasonable for Germany must not be reasonable for France or elsewhere. Nevertheless, the essential functions of RBM that have clear advantages have been described by von Keitz and Kessler (2008), and integrating additional functions should be a matter of discussion for each single river basin. And the form and the organizations need also to be in respect to the context, whereas it is more important to focus on coordination mechanisms between organizations for overcoming the boundaries between the different stakeholders. Last but not least, it has to be mentioned that river basin management is also a political process, i.e. that certain policy objectives are part of introducing RBM (e.g. RBM approach for industrializing agriculture), so that one has to be aware of hidden agendas of proponents of RBM (Moss 2006).

The increasing worldwide support for RBM in the last years shows that the scientific concept of RBM has been institutionalized (Moss 2006): On the one hand, RBM has become a guiding principle for water management worldwide (informal institution), and on the other hand it has been also operationalized within many countries (formal institution) since many years like the Ruhr River Association or within the implementation of the EU-WFD. As Alaerts (1999) mentioned, river basin organizations are important for implementing integrated water management, but should be limited to functions that complement the tasks of existing authorities, and thus have an added value for the water resources management. Furthermore, Alaerts (1999) states that institutional constraints like vested interests and a lack of confidence frequently impede basin management, even if basin management is in general a win-win proposition for all involved actors, at least in the long run.

3.1.14 Critics on IWRM

3.1.14.1 Critics on concept and terminology

Critics on the concept are manifold. Biswa (2004) for example doubts that one single paradigm can be valid for all regions and all the many contexts of the world. Biswas (2004), as one of the main critics on IWRM, further states that the concept sounds impressive, but the definition is vague and thus it does not provide assistance in implementing water resources management. As an example, Biswas (2004) mentions that it is impossible for water professionals to operationalise the claim from the definition to “maximize economic and social welfare”, since the relation between water management and economic and social welfare is still object of research. Another questionable point is that indicators are missing that are showing that a water resources system is working in an integrated manner, respectively moving towards an integrated system (Biswas 2004). He concludes that the IWRM definition by the GWP (2000) merely uses trendy words, but it is inconsistent and not implementable. Jonker (2007) argues similarly that the IWRM definition of the GWP does not provide a clear theory that is needed for practitioners for successful implementation. Van der Zaag (2005) calls the concept relevant but also elusive and fuzzy. He also stated that IWRM may be a buzzword, but *not* in the context of his research in South Africa (Ibid.).

Some ambiguity of the term IWRM is related to the fact that water resources management is understood differentially by several actors. The flexible or inconsistent use of terminology is a major problem for implementing IWRM. For instance, some actors perceive water resources management only as the optimisation of water uses, whereas water resources development, i.e. infrastructure development, is not included (cf. Muller 2010). Others describe IWRM predominately as a governance issue, i.e. focusing more on normative management. In addition, broad and vague approaches like IWRM are popular, especially because all stakeholders can identify with such broad definitions. Or as pointed by Biswas (2004) that stakeholders adhere to vague definitions because they can continue their work without the need of changing, but still claiming that they follow the “new approach”. Another critique towards the concept is that it does not integrate uncertainty (e.g. Pahl-Wostl (2005; qv. chapter 3.1.17).

3.1.14.2 Critics on integration

Manifold different integrations are described in literature so that it is not clear, what integration exactly means. Biswas (2004) presents a list of 35 different meanings of integration, whereas he doubts that it is feasible to integrate all these different issues and institutions. In terms of cross-sectoral integration (water, land and related resources), some actors derive from the IWRM definition a uniform (integrative) management of all relevant areas of water resources management or even a institutional reorganization with the rescaling of all management activities to new integrated water management institutions like river basin organizations. Biswas (2004) argues that such an entire integration and reorganization is not feasible, since

i. inter-ministerial and intra-ministerial rivalries usually exist,

ii. water ministries cannot execute such integration, as knowhow and/ or control is possibly limited,

iii. experts from other sectors may not want that water experts superimpose their views without consultation. The same would hold true for other sectors like agriculture, proposing concepts like integrated agricultural management.

iv. it is questionable, how these different integrations could be executed; respectively which processes for integration are necessary.

It can be also added that often different management cultures and attitudes and processes exist, leading, as Mollinga (2010) describes, to boundaries between different sectors and disciplines (cross-scale challenge). Overcoming such boundaries by setting up integrated institutions is difficult and other coordination mechanisms are more promising. Another argument in favour of other coordination mechanism instead of integration is about democratic participative processes. Biswas (2004) state that "different institutions have different stakeholders and interests, and this diversity is a part of any democratic process". The democratic legitimacy of RBO or similar integrated organisations can be also questioned (Dombrowsky 2005; Huitema and Meijerink 2014). Consequently, integration may lead to centralization, reduced responsiveness to needs and demands of the diverse groups of actors related to water resources management, and reduced transparency (Biswas 2004).

River basin organisations (RBO) that deal with a certain amount of water-related issues can contribute to successful operational water management. But even the well-reputed RBOs in France do not integrate all management activities of all water uses, but only the management of the water resources itself and in some cases the management of the irrigation water use (Huppert 2012). Tortajada (2002) mentions that the river basin may "not always be the best unit for water management", and thus RBOs might not always be the most appropriate body for coordination. And river basin management with or without integrated water management institutions like RBOs may lead to a parallel structure next to the existing administrative structure as observed in Germany during the implementation of the EU-WFD or as van der Zaag (2005) mentioned in South Africa. The same issue of parallel structures, which potentially lead to uncoordinated management of the water resources and competition in terms of management tasks, eventually aggravating already existing institutional deficiencies, was observed within the Western Bug River Basin, Ukraine (Leidel et al. 2012). Furthermore, rescaling of management activities can increase governance costs as shown by Roggero and Fritsch (2010).

3.1.14.3 Critics on missing governance and capacities

Several authors stated that capacities are insufficient for implementing IWRM. For instance, van der Zaag (2005) mentions that water managers that are capable of facilitating the IWRM processes are needed. Jonker (2007) similarly means that the implementation of IWRM is difficult because of missing human resources capacities. Also water institutions are often missing the capacities needed for water resources management in a rapidly changing and thus uncertain world. In chapter 3.2 we explain the importance of capacity and capacity development for water resources management. However, next to capacities, also incentives are decisive for sustainable water resources management.

3.1.15 Incentives for sustainable development outcomes

In their seminal work on development cooperation, Ostrom et al. (2001) demonstrated that major hindrances towards sustainable development results are *collective-action problems*. They occur in collective-action situations, i.e. that at least two actors work together for producing something beneficial, which can hardly be developed alone (Ostrom et al. 2001). Collective-action problems emerge, when low motivation and/ or asymmetry or missing of information lead to incentives[22] of actors of not (satisfactorily) solving a collective-action situation (Ostrom et al. 2001). Incentives can be material or nonmaterial, e.g. financial incentives (salaries, allowances), political incentives, moral incentives, personal incentives like career advancement, or coercive incentives like confiscating goods. That means that motivation and information problems (incentive problems) are rooted in goods and services that are often part of projects as well as actors' relationships to each other (Ibid.).

Motivation problems can be for instance the problem of *public goods*, which are non-excludable and non-rivalrous goods (Chapter 3.1.5.2; Table 1). Thus, individuals have the incentive to *free-ride*, i.e. the consumption of one public good without contribution, e.g. environmental protection (Ostrom et al. 2001). Another motivation problem is related to *common-pool resources* (e.g. groundwater), which are also non-excludable, but rivalrous, i.e. that the consumption of one actor reduces the availability of resources to other actors. If many individuals use the resources, an over-use of common-pool resources is expected as described by Hardin (1968) in his famous article *tragedy of the commons*. Hardin (1968) further argued that regulation (state) or privatisation (e.g. dividing farm land into several privately owned plots) is needed for encountering this problem; yet, Ostrom (1990) showed in her book on *governing the commons* that neither regulation nor privatisation is necessarily the best option of using scarce resources, but involving all actors in developing effective institutions for managing common pool resources. Another example for a motivation problem is the *Samaritan's Dilemma* (Buchanan 1975; Ostrom et al. 2001; Gibson et al. 2005): a situation, where a wealthy and cooperative actor (Samaritan) wants to support other (poorer) actors that are

---

[22] Incentives are rewards and punishments related to actions of humans (Ostrom et al. 2001).

in need of help (e.g. development cooperation). The Samaritan can decide to assist or not, and the recipients can choose the extent of their efforts. Game-theoretically, Buchanan (1975) has shown that for both, the active and the passive Samaritan's Dilemma, it is always the best strategy for the Samaritan to assist, but for the strategic acting recipients it is economically reasonable not to put high efforts into their work. This is clearly linked to moral hazard problems, which are described below.

Information problems emerge when there is an asymmetry of information or missing of information. Missing information means that actors may not know the complete situation or do not know possible actions and their linkages to results including payoffs (Ostrom et al. 2001). Asymmetry of information may create inappropriate incentives leading to several problems. First of all, *principal-agent problems* emerge when an employee has more operational knowledge than the supervisor, and when there are differing objectives between both, so that the subordinate may not act in accordance with the superior (Ostrom et al. 2001). Principal-agent problems occur frequently in social and economic exchange processes, e.g. potential intransparent transaction because of information asymmetry between a service provider (agent; e.g. a car mechanic) and a customer (principal; e.g. a car owner). Also the concept of boundary organisations draws from principal-agent theory as described in chapter 4.3 with the boundary organisation as agent being responsible and accountable for two or more principals (e.g. scientists and politicians).

Another example is *moral hazard problems*, i.e. information asymmetries exist between a provider (agent) and the receiver (principal) of services *and* additionally external influences on agent side occur, for which the agent cannot be held accountable within an intransparent exchange process and low accountability on the agent side (Huppert 2012). That means that the behaviour of the partners is uncertain and thus opens the door for opportunistic behaviour of the agent, corruption or rent-seeking (Ibid.). Ostrom et al. (2001) described another situation for a moral hazard problem, where, for example, a donor assures a benefit to a government based on a contract without having enforcement possibilities. That means the donor cannot force the government to implement the agreed reforms, e.g. the country's institutional system. The funding of the donor will create a moral hazard, because the government is not in need of changing their policies (Ibid.).

Therefore, appropriate incentives need to be developed within projects on sustainable development, "so that the time, skill, knowledge, and genuine effort of multiple individuals are channelled in ways that produce jointly valued outcomes" (Ostrom et al. 2001). Incentives are developed within institutions (Ostrom et al. 2001), i.e. within "the rules of the game" as described in chapter 3.1.12. Institutions therefore support tackling collective-action problems, whereas it has to be mentioned that solutions need to be adaptive due to ever changing conditions (Ostrom et al. 2001). This is in accordance with the concepts on adaptive management (Holling 1978; Walters 1997) or adaptive water management (Pahl-Wostl 2004).

It can be concluded that water resources management is a collective-action situation, where collective-action problems occur, since manifold studies have shown motivation and information problems within water resources management (e.g. OECD 2012). Especially in developing countries, the institutional context is often not powerful enough to overcome incentive problems like corruption, rent-seeking or fiscal illusion (Ostrom et al. 2001). That means that satisfactorily implementing sustainable water resources management needs to consider also institutions and actors' incentives. Or as Ostrom et al. (2001) put it in a nutshell that institutions that are capable of matching contributions with rewards are always needed. Thus, it has to be analysed whether governance systems support IWRM implementation or rather on the contrary. One method for that is the *Incentive Compatibility Analysis* (Fischer et al. 2004; Huppert 2007), which analyses whether the governance system provides incentives for implementing IWRM through carrots and sticks. This analysis is separated into (I) definition of IWRM targets, (ii) identification of main actors and determines essential services and the service relations between them, (iii) identification of the applied governance mechanism, and (iv) assessing effectiveness of governance mechanism in terms of incentives creation towards the developed targets (Fischer et al. 2004; Huppert 2007).

In chapter 7 and 8 it is discussed to what extent my developed transdisciplinary concept with the integrated coordination mechanism is capable of developing appropriate incentives for the actors.

3.1.16 Coordination mechanisms

If working within water resources management or other development activities one has to accept the inherent complexity and power asymmetries that exist according to McMahon (2010) due to the various actors involved with their different backgrounds, interests and power. This can potentially lead to conflicts, especially in terms of ownership, authority and the allocation of roles and responsibilities (McMahon 2010). Therefore, it is decisive to develop and maintain a relationship between actors, i.e. that collaboration and coordination between the actors is needed and thus also relational capacities of the actors.

Coordination is defined by the UNDP (2009) as "a technique of social interaction where various processes are considered simultaneously and their evolution arranged for the optimum benefit of the whole". That means that coordination is about solving problems by the coordination of the interactions between several actors, whereas Beetham (1996) distinguishes three types of coordination, namely markets, hierarchies and democracy.

In terms of water resources management, coordination mechanisms can be understood as coordination mechanisms on a global level between international organisation and within the UN system, e.g. UN-WATER, which can contribute according to Schubert and Gupta (2013) inter alia to agenda setting, knowledge sharing, or connecting stakeholders and experts. However, we conceive in the realm of this thesis coordination mechanism as tool for enhancing collaboration at national level, and especially at regional or local level between actors relevant for water management. And hereby it is not decisive whether there is a RBO or whether the integrated management is carried out by the existing organisations. In fact, a centralized single organisation is most likely not capable of managing complex basins on their own, even if they are strong organisations (Molle et al. 2007). Instead, it is important to coordinate government actors, user and community organisations and other actors at basin level (polycentric river basin governance), which according to Molle et al. (2007) perform better, but they also mention that the performance is especially effective in contexts where participation and democratic structures are well established.

Essential is thus for any organisational form to set up coordination mechanisms that support the joint water management and that organize and maintain the collaborative relations between the various stakeholders necessary for water resources management (Huppert 2007). This enhances the cooperation and allows for an appropriate balancing of conflicting interests (Huppert 2007). Thus, coordination mechanism should support the coordination of the functions and tasks that need to be conducted within water resources management, as e.g. data collection, planning, water allocation, construction of infrastructure (Table 4). However, the roles of and the responsibilities between the different involved authorities need to be clarified including the identification or assignment of one authority as responsible for the coordination and for assuring that the coordination mechanisms are set up and enforced. This can be executed by an existing authority if appropriate, by setting up a specialized organisation (RBOs etc.) or committees having sufficient level of authority. In the guidelines from UNESCO (2009), it is also proposed to take a third party (organization or individual) as coordinator that has no direct interest in the particular problem situation.

Cooperation mechanisms are basically about enhancing communication for joint problem solving, i.e. about initiating or strengthening a dialogue between stakeholders, so that collaboration is improved. Dialogue is "the art of thinking together" (Isaacs 1999 in McMahon 2010), and working through dialogue leads according to McMahon (2010) to self-reflection and shared learning, and thus leads to understanding rather than persuading. Yet, it is questionable, whether dialogue and thus voluntary cooperation always functions, especially where strong interests and power asymmetries prevail- the party with power will most likely resolve the conflict to its advantage. In fact, voluntary cooperation (bottom up cooperation) between authorities (or sectors with their administrations) or between authorities and NGOs for balancing interests is often difficult to reach, respectively is not functioning or not functioning well. And there is the potential danger of *coordination committees* that they are not able to accomplish their tasks, potentially because (i) every actor is part of the committee, thus decision making is difficult, (ii) donor driven and thus not integrated in the administrative system, and (iii) no or low support from higher level authorities.

Thus, stating coordination needs in the legislation as basis for top down approaches for setting up coordination mechanisms are frequently a feasible option for encountering uncooperative attitude. And it seems promising to combine top down approaches with bottom up activities. But it has to be stressed that this is not a panacea for resolving power asymmetries, since power relations prevail also in such situations, yet compulsory cooperation may lead to a real dialogue where stakeholders understand the views of the others and attempt to solve the problem situation.

As an good example, UNESCO (2009) describes the Yoshino River, where the different sectors were forced to work together (top-down approach), and a working group with representatives of the administration, as well as water user organisations and companies was set up for sharing data and eventually drafting in a collaborative sense the river basin management plan (bottom up activity).

Hence, examples for coordination mechanisms are working groups with regular consultations between the authorities, informal meetings for sharing information, mandatory information exchange, joint policy making, cross review of plans and policies and subsequent endorsement if possible. Another important point is a clear documentation of the joint work, which reduces the danger of misunderstandings, enhances transparency of the process and thus reduces the danger of conflicts. The documentation should include formal documents like agreements on collaboration like joint monitoring activities as well as more informal documents like joint protocols of meetings, schedules among other things. In fact, joint protocols can be considered as boundary object which facilitate cooperation (chapter 4.3). Collaboration can also be supported by knowledge networks like communities of practice (e.g. within water organisations) or global or regional networks. Knowledge networking can inter alia lead to (i) the creation of new knowledge and knowledge sharing, (ii) bringing the knowledge into policy and practice, and (iii) empower local communities (Luijendijk and Lincklaen Arriëns 2009). Yet, also knowledge networks need coordination mechanisms for being effective (chapter 3.2.2.1 on knowledge networking).

We consider the cooperation and coordination problems as *integration* problems that frequently occur in complex natural resources management that can be reduced by *boundary management*. Enhancing communication, but also mutual understanding and mediation can be reached with combining several coordination mechanisms in conjunction with organisational arrangements and knowledge networking. We argue that coordination mechanisms need to be embedded into a boundary management which follows analytical, assessment and participatory strategies as discussed in chapter 4.3. Indeed, this is the strategy that was developed for strengthening the collaboration within the water resources management in our Ukrainian case study (Chapter 7 ff).

In summary, it has to be underlined that sustainable river basin management requires collaborative relationships, which are based on existing organizations, customary practices, and administrative structures (Molle et al. 2007). And for managing these collaborative relationships, coordination mechanisms are needed that are adapted to the existing institutions, as well as to the current challenges of the particular basin. Hereby, also a certain amount of enforcement is needed. Above that, coordination mechanisms have to be adaptive to future changes. Yet, coordination mechanisms alone are not sufficient for collaborative relationships for sustainable river basin management. We propose and show that it requires integrating coordination mechanisms into a boundary management approach.

3.1.17 Adaptive water management

There exist many critics on IWRM and its difficulties in implementation as mentioned above. Scholars like Pahl-Wostl (e.g. 2005; 2007) or Petersen et al. (1997) argue that this is mainly due to the non-consideration of uncertainties within the system and within the management process. These uncertainties stem from global change and especially from climate change. Furthermore, it has been acknowledged that solving governance problems is often the key to more sustainable water resources management.

Pahl-Wostl et al. (2006) mention that a paradigm shift is needed for encountering the manifold problems of water management. Elements of such a change include according to Pahl-Wostl et al. (2006) and Pahl-Wostl (2008):

- Participatory management and collaborative decision making
- Integration of sectors and issues
- Management of problem sources instead of managing effects
- Decentralized and flexible management
- Soft measures for management of human behaviour
- Management goals integrating environmental goals
- Open information
- Iterative learning cycles included in management approach.

To meet these challenges, several authors (e.g. Pahl-Wostl 2008) propose to draw on the concept of adaptive management, which was introduced into ecology and environmental management by Holling (1978), and refined by Walters (1997) stating that ecological systems should be managed by a process of learning by doing. And Peterson et al. (1997) argue that the importance of the concept of adaptive management rises, because climate change and its consequences are inherently connected to other environmental and anthropogenic drivers, so that sustainable solutions for mitigation and adaptation are getting more complicated to achieve. Pahl-Wostl (2004) mentions that adaptive management is needed, because uncertainties and risks in the management of ecological systems exist, so that it is difficult to predict the behaviour and responses of the system in the future. And managing the water system includes even more complexities, so that the control of all relevant processes and to precisely predict the outcome of management decisions is difficult (Pahl-Wostl 2008).

Adaptive management reduces uncertainties continually by monitoring and assessing the system, which will gradually lead to an advanced and thus more adapted (management) system. Accordingly, management is considered to be rather a learning process instead of a mere control (Pahl-Wostl 2004) so that new insights probably will also lead to the adaptation of the goals and strategies of the management.

Generating different scenarios and hypotheses that are subsequently evaluated is one possibility within the learning process. The acquired knowledge from testing of the scenarios can be used to improve the system. A prominent example is the IPCC, which addresses uncertainties, uses scenarios and refine their statements on a regular basis, i.e. utilising an adaptive approach.

In fact, most of the current approaches within development cooperation, IWRM, capacity development, natural resources management reflect the ideas of adaptive management at least by having iterative policy cycles with goal setting, implementation, monitoring and evaluation and its recursion. This applies also for action research and transdisciplinarity, which also emphasize the iterative, cycling nature of all phases (qv. chapter 4.2.2).

Summarizing, adaptive management is an iterative process interrelating knowledge and implementation, or as Bormann et al. (1994) stated that "adaptive management is learning to manage by managing to learn". Pahl-Wostl et al. (2007) define adaptive management as a systematic process for strengthening management policies and practices by learning from the outcomes of already implemented management strategies. Adaptive water management can be accomplished through social learning (Pahl-Wostl et al. 2007), or as Mostert et al. (2008) mentions that social learning is the key to IWRM.

Accordingly, adaptive and integrated water management is decisive for sustainable water resources management since it can increase the adaptive capacity of water systems (Pahl-Wostl 2008). Structural changes are needed for real innovations in water management, i.e. that it is more important to initiate changes than developing new models towards best water regimes (Pahl-Wostl 2008). For the process of change and for the learning in operational adaptive water management, Pahl-Wostl (2008) suggests linking actor platforms and learning cycles to existing water management structures. She further states that methods and tools are needed that "help navigation in a fast changing and uncertain world" (Ibid.). And Pahl-Wostl (2008) concludes that there are no panaceas, but also not only unique cases- so it has to be assessed, what can be generalized.

We developed a similar approach, by including the capacity development process into the management process (Leidel et al. 2012) and by developing an e-learning platform for facilitating learning for several levels of integrated water resources management (Leidel et al. 2013). However, Pahl-Wostl follows more the research direction on social learning within water resources management, whereas my study follows more the research direction of transdisciplinary methods for water resources management. Yet, during the course of this thesis it becomes clear that apart from different focal points, both research directions interfere and have similar approaches.

Accordingly, due to the manifold uncertainties and vulnerabilities within the water sector, adaptive water management (AWM) is a reasonable extension to the paradigm of IWRM. Yet, in my opinion, there is no need to change the IWRM to AWM or another concept that will potentially rise in future (e.g. water security). It is irrational to change every couple of years the paradigm, even if some new facts have been manifested- just after the non-scientific stakeholders have been convinced that the presented concept is the *right* concept for future water management. I met a person from an African NGO on the World Water Forum in Marseille in 2012, and she complaint that she just has convinced decision makers that IWRM is a sound concept for approaching their water issues- and now the IWRM concept should be old-fashioned. My firm conviction is that IWRM should be considered as an overarching paradigm[23] that has to be adapted to the needs of the particular problem situation, or as Mollinga (2006) mention that IWRM should be considered as boundary concept, in which different interest and perceptions have to be negotiated (qv. chapter 4.3.1). This directly leads to a first synthesis about rethinking IWRM.

3.2 Knowledge, capacity and capacity development (CD)

The importance of knowledge, capacities and capacity development for sustainable resources management and especially for water resources management cannot be overestimated, if we think about the unprecedented challenges like climate related hazards and its resulting need of having an adaptive and resilient society for tackling such problems.

The international development cooperation has been using the concept of capacity and capacity development since the late 1980s (Baser and Morgan 2008). The origins of capacity development within the development cooperation are summarized in Table 5 from Pearson (2011). Within the water sector, the concept's importance raised due to the experiences of the 1980s (International Drinking Water Supply and Sanitation decade) that technological approaches and infrastructure alone are not sufficient for solving water related problems, but that the development of institutions and human resources is as decisive (Alaerts et al. 1991; Alaerts 2009). The water sector was therefore one of the first sectors with a practical definition of capacity development for improving the sustainability of development programmes (Alaerts et al. 1991). The concept became particularly important after the *Delft declaration* in 1991 (Alaerts et al. 1991), and the 1992 UNCED in Rio (qv. chapter 3.1.10 on the history of water resources management). Furthermore, capacity development was focused on within the Paris Declaration on Aid Effectiveness (OECD

[23] A water management paradigm is according to Pahl-Wostl (2008) a set of assumptions that are shared by a community of water actors and is manifested in items like planning approaches or engineering practices.

2005) and the subsequent Accra Agenda for Action (OECD 2008) attempting to improve the quality of aid and its impact on development. Both documents highlight the importance of country ownership and leadership, and correspondingly that capacity is considered an endogenous process[24]. Thus, there should be a shift from donor-driven approaches (i.e. introducing own initiatives) to support countries in their own development activities. That means that technical cooperation from donors should be used for supporting locally driven capacity development. And capacity development continues to be on the international agenda and within the water sector. Inter alia in the *Sustainable Development Goals* it is mentioned in target 6a to enlarge international cooperation and capacity development support to developing countries in water and sanitation related activities and programmes[25].

Additionally, there is a clear need for a knowledge-based society to advance sustainable development. Correspondingly, a close link between knowledge and capacity development exists, so that e.g. Alaerts et al. (1991) described that both issues have to be addressed coherently.

[24] Endogenous process means that countries or societies guide their development process themselves locally (e.g. Ubels et al. 2010).

[25] In fact, capacity building is mentioned several timers in the SDGs, e.g. in target 13.3 it is mentioned to "improve education, awareness-raising and human and institutional capacity on climate change mitigation, adaptation, impact reduction and early warning", in 13.b to "promote mechanisms for raising capacity for effective climate change-related planning and management in least developed countries and small island developing States", as well as several times in target 17 (www.sustainabledevelopment.un.org).

Table 5: History of development approaches and capacity development

<table>
<tr><th>Development approach</th><th>Practices</th><th>Started</th><th>Assumptions</th><th>Results</th></tr>
<tr><td>Development Aid
• Developed countries lend or grant money to developing countries</td><td>Institution building
• Objective was to equip developing countries with the basic inventory of public sector institutions that are required to manage a program of public investment
• Focus was on the design and functioning of individual organizations, not broader environment or sector
• Imported or transplanted models from developed countries were often used</td><td>1950s and 60s</td><td>• Developing countries need money</td><td>• Greater focus on investment and reporting than on results
• Mounting debt
• Dependence on foreign aid
• Projects end when money runs out</td></tr>
<tr><td rowspan="3">Technical Assistance
• Foreign experts come in to operate their own projects, which they expect to yield similar results to those seen in developed countries

Technical Cooperation
• Greater emphasis on training, transferring knowledge, based on national policies and priorities</td><td>Institutional strengthening/ development
• Shift from establishing to strengthening institutions
• Focus was still on individual institutions and not a broader perspective
• Tools were expected to help improve performance</td><td>1960s and 70s</td><td rowspan="3">• Developing countries should just model themselves after the developed ones
• Few or no resources available locally
• Developing countries should partner with developed ones</td><td rowspan="3">• Projects launched, but disconnected from local goals or priorities
• Dependence on foreign experts
• Expertise not always transferred from foreigners to locals
• The externally driven models often ignore local realities
• Idea of ‘assistance’ highlights unequal relationship between developed and developing countries
• Local expertise enhanced
• Projects somewhat more in line with local priorities and goals
• Driven by outside forces, opportunities missed to develop local institutions and strengthen local capacities
• Expensive</td></tr>
<tr><td>Development management/ administration
• Objective was to reach special public or target groups previously neglected
• Focus was on delivery systems of public programs and capacity of government to reach target groups</td><td>1970s</td></tr>
<tr><td>Human resource development
• Development is about people
• Stressed the importance of education, health, population
• Emergence of people centred* development</td><td>1970s and 80s</td></tr>
</table>

	New institutionalism • Focus was broadened to sector** level (government, NGO, private) including networks and external environment • Attention given to shaping national economic behaviour • Emergence of issue of sustainability and move away from focus on projects • Rooted in field of institutional economics • Set the scene for the emergence of the 'governance' focus that is now prominent	1980s, and 90s		
Capacity Development • A focus on empowering and strengthening endogenous capabilities	**Capacity development** • Emerged in the 1990s as an aggregate of many other development approaches • Re-assessed the notion of technical cooperation (TC) • Stresses importance of ownership and process • Has become "the way" to do development	Late 1980s and 1990s	• Developing countries should own, design, direct, implement and sustain the process themselves	• Makes the most of local resources (people, skills, technologies, institutions) and builds on these • Favours sustainable change • Takes an inclusive approach in addressing issues of power inequality in relations between rich and poor, mainstream and marginalized (countries, groups and individuals) • Emphasizes deep, lasting transformations through policy and institutional reforms • Values 'best fit' for the context over 'best practice'; as one size does not fit all

*Some of this change was influenced by political emancipation frameworks and the emergence of 'participation' as a concept and practice for development.
** The word sector usually refers to functions (education, agriculture) but in this context the word was used to denote types of organisation and institution.

Source: Pearson (2011) based on Lusthaus et al. (1999) and UNDP (2009)

3.2.1 Data, information and knowledge

Innovations and inventions and thus knowledge were and are an essential production factor for any development process, not only in terms of industry, but for all sectors and societal processes. The World Development Report from the World Bank (1998) has already emphasized that knowledge is development. In fact, it is almost a truism now that "knowledge-intensive societies" become even more important in managing the increasingly complex, competitive and changing environments. Accordingly, also public administration and thus also water sector organisations need to focus on continuous knowledge development for facing emerging challenges (cf. Alaerts 2009). Expressions like knowledge-based economy, knowledge-intensive industries, knowledge worker or knowledge-intensive business services show an indication that we are in the fifth Kondratiev wave (cycle), in which information and communication technology (ICT) and knowledge as a strategic resource prevail.

The basis for any informed decision is the availability of data and information and its aggregation to knowledge (cf. Zins 2007 or Rowley 2007 on the data–information–knowledge–wisdom hierarchy). And its importance is also acknowledged in the discussion on the Sustainable Development Goals to increase significantly the availability of high-quality, timely and reliable data by the year 2020 (Chasek et al. 2014).

Therefore, we have to define what data, information and knowledge is about and it has to be emphasized that knowledge is not the same as data or information. However, they are interrelated within a hierarchy, i.e. knowledge is derived from information, which itself is created from data (Rowley 2007). Yet, there is a diversity of interpretation of this interrelationship and the meaning of data, information and knowledge as presented by Zins (2007), who made a critical Delphi study on these expressions under 57 scholars working in concerned academic fields. For a detailed and comprehensive discussion with different perspectives on data, information and knowledge it is thus referred to Zins (2007). For the realm of this study, we refer mainly to the concepts of data, information and knowledge from Davenport and Prusak (1998), Polanyi (1966), Nonaka and Takeuchi (1995) and the integration of the discussion on knowledge into the water sector as described by Alaerts et al. (1991), and Alaerts (2009).

Data can be defined as an objective fact about a situation or a process with no inherent meaning, and without giving an additional value like interpretation or judgement (Davenport and Prusak 1998). The basis of data is measurements or observations leading to raw material stored in records or transactions out of which the information is developed. Thus, information can be defined as data that has meaning, purpose and relevance (Ibid.). *Data is transformed into information*, if value is added, as for instance by:

- Contextualisation; i.e. the purpose of the data is known
- Categorisation, i.e. the units of analysis or key components are known
- Calculation, i.e. the data is analysed, e.g. statistically or mathematically
- Correction, i.e. errors are deleted
- Condensation, i.e. the data is summarized

(Davenport and Prusak 1998).

Furthermore information is stored in a message and always needs a sender and a receiver and therefore the receiver decides, whether the message really informs the receiver, i.e. a real information is derived out of the data (Davenport and Prusak 1998). It has to be underscored that the medium for transmission (e.g. the internet) is not the message, i.e. the information itself is more important than the information technology (Davenport and Prusak 1998). This is also essential in terms of using new media for information transmission within e-learning environments. Having a learning management system with state-of-the-art functionality like synchronous and asynchronous communication tools will not guarantee good teaching (qv. chapter 9.1 for details about the developed e-learning module on IWRM).

It is not trivial to define knowledge, which can be substantiated by the fact that there is a scientific debate on knowledge and its meaning pervading the history of philosophy. Many definitions exists, as for instance the definition of Howell (2013, who states that "knowledge incorporates our stock of explanations and understanding of why reality and the truth and theories that reflect this are as they are; knowledge involves interpretations of facts derived from data as well as abstract comprehensions of phenomenon". For the purpose of this thesis, however, we will stick to the apt working definition by Davenport and Prusak (1998): "Knowledge is a fluid mix of framed experience, values, contextual information, and expert insight that provides a framework for evaluating and incorporating new experiences and information. It originates and is applied in the minds of knowers. In organisations, it often becomes embedded not only in documents or repositories, but also in organisational routines, processes, practices, and norms". This definition makes no differentiation between object (known) and subject (knower) and reflects therefore, according to

Nonaka and Takeuchi (1995) more the Japanese tradition than the Western philosophical tradition. *Knowledge is derived from information* by

- Comparison, i.e. the situation is compared to previous known situations
- Consequences, i.e. what implication has the information for decisions or actions
- Connections, i.e. how does this information relate to other kinds of knowledge
- Conversation, i.e. what do other persons think about this information

(Davenport and Prusak 1998). Knowledge is acquired through other humans or through organisational routines and is exchanged e.g. via books or documents, conversations or apprenticeships (Davenport and Prusak 1998). The invaluable advantage of knowledge is that it is close to actions and decisions (Ibid). Therefore, knowledge is an important part of action research and transdisciplinary research as a means for societal changes as describe below.

3.2.1.1 Explicit and tacit knowledge

The discussion about the *kinds of knowledge*, its development and its transfer or exchange, originated in the 1960s and is often traced back to the work of Polanyi (1966), who stated that "we can know more than we can tell". The work of Polanyi is frequently considered as cornerstone for knowledge management, yet he has not participated in research towards establishing knowledge management as an academic discipline (Lehner 2012). Polanyi (1966) distinguishes between *explicit* and *tacit* knowledge, whereby explicit means that the knowledge can be expressed in numbers or words, explained and the information transferred. For instance factual knowledge like the properties of water (melting point, specific heat capacity, etc.) or the understanding of a phenomenon like the hydrological cycle, can be explained but also shown in an equation (water budget equation[26]). Tacit knowledge is not as easily articulated and not easily transferred within a "classical learning situation" as for instance a university lecture, because it is hidden, implicit knowledge. That means it is more based on experiences and on context, more related to personal opinions and intuition, value systems, and thus more about the development of skill and attitudes. Polanyi (1966) gives a striking example for tacit knowledge: If a person knows the face of someone else, s/he can recognize it under millions of humans without knowing why s/he recognizes the face. Similarly, Nonaka and Takeuchi (1995) distinguish within tacit knowledge between a technical and a cognitive dimension. The former describes for example the know-how of

[26] Precipitation= Net Storage + Evapotranspiration + Runoff.

a carpenter gained within years of experience but often being unable to explain the technical principles behind. The cognitive dimension expresses the mental models, beliefs and perceptions that frame our reality and the vision for the future (Nonaka and Takeuchi (1995). Based on that, Nonaka and Takeuchi (1995) developed a knowledge management model explaining how to make tacit (implicit) knowledge explicit in organisational development. They explain the exchange of knowledge with the SECI-Model which stands for Socialization, Externalization, Combination, and Internalization (qv. Next chapter on knowledge management). The differentiation between explicit and tacit knowledge is similar to the notion of Fowler and Ubels (2010) who state that capacity can be tangible (e.g. individual skills or organisational structures) and intangible (attitudes, values, cultural background). These points imply that tacit knowledge is important for solving societal problems, as described in Schön's (1983) reflection-in-action process.

Yet, for explaining successful development outcomes sufficiently, Sveiby (1997 in Alaerts 2009) mentions that instead of knowledge alone it should be referred to "capacity-to-act" or "competence". Alaerts (2009) concludes that an interaction between problem solvers and problem bearers for adapting and enhancing the knowledge of practitioners is worthwhile. This is also in accordance with Schön (1983), who states that reflective practitioners are needed, i.e. a process between action and reflection or as Alaerts (2009) similarly states a process between knowledge and questions (qv. chapter 4.1.1). These points clearly show the connection between knowledge and capacities (Alaerts et al. 1991), which is further described in the following chapters.

3.2.2 Knowledge management

Existing knowledge within organizations is often not used completely for decision making, since it is not known, which knowledge is available. Moreover, the exchange of employees often leads to a loss of knowledge. And frequent changes within the staff is particularly a problem in developing countries ("brain-drain") and thus also in their water management. On the other hand, an information overload exists nowadays that leads to stress within employees reducing quality of work and job satisfaction. Massive and uncontrolled data and information acquisition does not necessarily lead to an improved knowledge base (Davenport and Prusak 1998). In fact, employees could be unable to act, if too much information is available and not structured. Therefore, appropriate knowledge management is needed that facilitates and structures the handling of data, information and knowledge, as well as the transformation from implicit to explicit knowledge as for instance described by Nonaka and Takeuchi (1995) in the SECI-Model. However, several other knowledge management concepts exist, inter alia the knowledge management cycle from Probst et al. (2003).

The interrelation between data, information and knowledge is also mirrored in the advancement from data organization to database management to information management and decision support systems (DSS) and eventually to knowledge management as described in various articles (e.g. Bullinger et al. 1997 in Lehner 2012).

Knowledge management (KM) supports organizations in acquiring, developing, processing, sharing, storing and application of knowledge and thus strengthens learning processes within organizations (Lehner 2012). Important processes are the multiplication of knowledge, i.e. the exchange of experiences (lessons learnt) and disseminating existing knowledge (best practice) as well as innovation, i.e. the development of new knowledge. KM can be regarded from various different disciplines, as for instance a technical perception would be more about information or knowledge management systems, whereas a human centred perspective would focus on improving organizational issues, e.g. for facilitating knowledge exchange of employees by initiating a "culture of knowledge sharing". According to Lehner (2012), *integrative approaches* that combine the technology oriented and the human oriented approaches are promising and several concepts for aligning both are developed in recent years (e.g. Probst et al. 2003, Nonaka 1991, Nonaka and Takeuchi 1995, in Lehner 2012). That means that human abilities for handling knowledge have to be combined with information technologies. According to Lehner (2012), however, no solutions for real integrative KM are available up to now.

One challenge for KM is the organizational structure, i.e. processes and regulations structuring working processes within an organization. They can be hierarchical and functional or more cooperative and thus less hierarchical. However, it has to be mentioned that organizations always have a functional and a political dimension, as well as an internal and external dimension (EC 2011, Table 6). That means that formal organizational structures are in place, but that informal structures often play an important role, as for instance the official supervisor versus an informal leader that may even have higher influence than the official leader. Another example is the difference between working through official channels and informal ways. That means that formal organizational structures as well as informal procedures have to be taken into account when developing KM. A "culture of knowledge management" has to be established within the organization. Without such a culture, the application and constant utilization of technical solutions like information systems cannot be guaranteed.

Table 6: Dimensions of organisations

	Internal Dimension	External Dimension
Functional Dimension	e.g. strategies, management instruments, structures, work processes, hierarchy	e.g. legal framework, formal accountability requirements, timeliness of data
Political Dimension	e.g. leadership, rewards, sanctions, conflicts, incentives, vested interests	e.g. political governance, pressure from public, media attention, vested interests

Source: Based on EC (2011)

Thus, the development process of information or knowledge management systems needs to involve the relevant employees and departments from the very beginning so that they concern themselves with the topic and integrate their suggestions.

3.2.2.1 Knowledge networking

Knowledge networking is a human collaboration process that supports social learning, and especially the horizontal learning between peers (Parcell 2010). Social networks were always important, however, due to improved ICTs their significance skyrocketed and simultaneously collective wisdom becomes more important as described in Surowiecki (2004). Knowledge networking is therefore not only about individual learning but more importantly about connecting many people so that they exchange knowledge and thus mutually developing capacities by joint learning (Parcell 2010). Knowledge networking can be therefore considered as a CD technique, which can have advantages in terms of costs, speed and scale compared to other methods like training or expert advice (Parcell 2010). Effective knowledge networks need three dimensions (Parcell 2010):

i. a community of people that work together and develop mutual commitment. Important is diversity of group members as well as trust as the basis for knowledge exchange. Trust is needed because humans are reluctant to admit that they have difficulties in solving a problem or some people think that their experiences are not worth sharing them. Above that, reciprocity is an important attribute, i.e. that network members share knowledge and do not expect a reward apart from honouring their contribution and validation of their knowledge;

ii. a focused topic of knowledge that correspondents to the goals of the participants. The topic should not be too general, and the community establishes what is already known and what *should* be known, e.g. by doing self-assessments (qv. chapter 3.2.5 on capacity assessments);

iii. organizational processes to connect members so that they can collaborate (qv. co-ordination mechanisms, chapter 3.1.16). That means defining schedules for regular interactions (face to face and virtual), how to package the available knowledge and how to navigate through it, defining a facilitator and the life cycle of the network, clarifying "rules of the game" and the purpose of the network.

Parcell (2010) further states that knowledge networks capture not only the understanding of the knowledge, but also the application of the knowledge, i.e. the experiences. Thus, explicit as well as tacit knowledge is available and can be distributed between the participants. This dispersion of knowledge is facilitated by improved communication means, as for instance social networks like Facebook or LinkedIn that permeate humans' lives. Yet, Parcell (2010) demonstrated that there are also obstacles that impede knowledge networking, as for instance hierarchy and organisational issues, actors' unwillingness to learn and change, time constraints, or considering knowledge as power.

The importance of communities of practice and knowledge networks within the water sector is described by Luijendijk and Lincklaen Arriëns (2009), highlighting that it can support knowledge generation and sharing, as well as capacity development (qv. chapter 3.1.16).

3.2.3 Knowledge management systems

Knowledge management systems (KMS) are the ICT support for the above described knowledge management within organizations. As a matter of fact, ICT supports new forms of organizations and its structure, yet, the technology alone is not sufficient. According to Lehner (2012), KMS differ from information systems, if they integratively combine and attune the following points:

- Adaptation to current and future socio-economic developments
- Output of goods and/ or services
- Communication with the exchange of relevant information
- Motivation of humans for target-oriented behaviour

3.2.4 Capacity and CD

As mentioned above, CD emerged as new development approach within the development cooperation in the late 1980s (Table 5) and is since then a widely used term; yet, its exact meaning is still unclear for some actors despite the manifold definitions as described in Table 7. Uncertainty and confusion around this term still exists and it has been often misinterpreted as being only about training and education for individual humans. Yet, the understanding of the concept of CD is gradually shifting and it is nowadays more and more considered as a comprehensive concept that deals with societal and political challenges (ECDPM 2009; Ubels et al. 2010a, b) on several levels often differentiated into individual level, organisational level and enabling environment/ system level (Lopes and Theisohn 2003, Alaerts 2009; Visser 2010; qv. chapter 3.2.4.2). Current developments show that some authors extend that approach and integrated civil society as additional level (Alaerts and Kaspersma 2009; Wehn de Montalvo and Alaerts 2013). Furthermore, capacity development has to distinguish not only between levels of human organisation, but also between geographic, respectively administrative levels, e.g. communities, districts/provinces, and nation state (Visser 2010).

3.2.4.1 Concept and definition of capacity and CD

A variety of different definitions for capacity and capacity development exists depending on the different theoretical or political backgrounds or the different foci of the authors or organisations towards the different aspects of capacity. The different perspectives as well as similarities can be seen in Table 7 and Table 9. However, most of the definitions have in common that they refer to the ability of human systems with several levels to perform well for achieving objectives. Some authors (e.g. Morgan 2006; ECDPM 2009a) state that capacity is an emergent property, i.e. that capacity is more than its elements and that it emerges out of uncontrollable and hardly predictable processes (qv. chapter 3.2.4.3 on CD processes). Of course, the definitions of capacity as displayed in Table 7 are interrelated with or extended by the definitions of capacity development as summarized in Table 9. As mentioned above, the water sector was one of the first sectors with a practical definition of capacity and capacity development, which acknowledged also the entity of capacity and knowledge (Alaerts et al. 1991). Correspondingly, this thesis refers to the definition and work of Alaerts (2009) and Alaerts and Kaspersma (2010) which is particularly apt for the context of water resources management: "*Capacity* can be defined as the capability of a society or a community to identify and understand its development issues, to act to address these, and to learn from experience and accumulate knowledge for the future." We utilised this definition also for the capacity development process in our Ukrainian case study, as for instance during our capacity assessments and translated it into Ukrainian language. There are different *types of capacities*, with several existing classifications, as for instance the differentiation in hard and soft capacities or technical/functional and social/relational capacities as described by Pearson (2011).

Table 7: Selection of capacity definitions

Capacity definitions	Author/organisation
"Capacity comprises well-developed institutions, their managerial systems, and their human resources, which in turn require favourable policy environments, so as to make the [water] sector effective and sustainable"	1991 Delft declaration (Alaerts et al. 1991)
"An organisation with capacity has the ability to function as a resilient, strategic and autonomous entity"	Kaplan (1999)
"Capacity is potential to perform"	Horton et al. (2003)
"Capacity represents the potential for using resources effectively and maintaining gains in performance with gradually reduced levels of external support"	LaFond and Brown (2003)
"The ability of individuals, institutions and societies to perform functions, solve problems, and set and achieve objectives in a sustainable manner"	OECD (2006)
"Capacity is that emergent contribution of attributes that enables a human system to create development value"	Morgan (2006)
"Capacity as that emergent combination of attributes, assets, capabilities and relationships that enables a human systems to perform, survive and self-renew"	Baser and Morgan (2008)
"The availability of resources and the efficiency and effectiveness with which societies deploy these resources to identify and pursue their development goals on a sustainable basis"	Otoo et al./ WBI (2009)
"Capacity can be defined as the capability of a society or a community to identify and understand its development issues, to act to address these, and to learn from experience and accumulate knowledge for the future."	Alaerts and Kaspersma (2010) based on Alaerts (2009)
"Capacity comprises the sum of the capabilities of a group, organisation or network; the ability of the group or organisation to learn and adapt, and the performance of the organisation in delivering good research and having an impact on policies and practice"	DFID (2010)
"Capacity is the ability of human system to perform, to sustain itself and self-renew"	Ubels et al. (2010)
"The ability of individuals, institutions, and societies to perform functions, solve problems, and set and achieve objectives in a sustainable manner"	UNDP (2010)

Another classification is into visible and invisible capacities, as e.g. done by Kaplan (1999), where visible relates to materials, skills, or organizational structures, and invisible means that this type of capacity can be only observed through effects, e.g. vision or strategy of an organisation. Fowler and Ubels (2010) classify capacities into tangible and intangible capacities, mentioning that only a small part of capacity is tangible, for instance individual skills or organizational structures. A much larger part of capacity is intangible, for example attitudes, values and cultural backgrounds. Additionally, Lopes and Theisohn (2003) emphasize that underlying capacities as for instance ownership, leadership, knowledge networking exist that are needed for improving the overall effectiveness of CD. Even if there are slight differences between these classifications, I will subsume them for the sake of clarity into *hard capacities* comprising categories like technical, functional, visible and tangible, and *soft capacities* comprising social, relational, intangible and invisible differentiated on the respective level of capacity (Table 8). Within hard capacities also explicit knowledge is subsumed and implicit knowledge into soft capacities. Obviously, a combination of both capacities (hard and soft) is needed for long lasting and sustainable capacity development.

Table 8: Types of capacity

Level of capacity	Hard capacities	Soft capacities
Individual	Hard skills and competencies	Interpersonal and relational skills (soft skills): Leadership, ownership, facilitation, team-work, effective communication, decision-making, problem solving, networking
	Explicit knowledge	Implicit knowledge (know-how), experiences, attitudes, values
		Adaptive capacities (self-reflection, learning from experiences)
Organisational	Organisational structures and strategies	Culture and values
	Human resources	Adaptive capacities and change management (analyse and adapt)
	Management with planning, action, monitoring and evaluation	Knowledge networks
	Materials as support for capacity (Infrastructure like monitoring systems, DSS or KMS, or analytical apparatus, equipment)	Vision
Systemic	Legislation, policies	Cultural backgrounds, adaptive capacities (participation, empowerment)

A generally accepted universal definition for capacity development is not available. Fowler and Ubels (2010) accentuate that capacity is about real-life issues and about fostering the livelihoods of humans. This demonstrates that it is questionable, whether a general definition is essential at all, since capacity development is always context-specific and therefore also the definition should reflect that. Yet, most capacity development definitions have in common that they refer to endogenous processes at multiple societal levels for reaching development objectives (Table 9). Within this thesis, we stick to the UNDP (2009) defining that CD "refers to the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time".

Table 9: Definitions of Capacity Development

Definitions of Capacity Development	Author/organisation
The processes whereby people, organisations and society as a whole unleash, strengthen, create, adapt and maintain capacity over time.	OECD (2006; 2010) adopted inter alia by GIZ, ADB, FAO
"Refers to the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time".	UNDP (2009)
"Approaches, strategies, or methodologies used by USAID and its stakeholders to change, transform, and improve performance at the individual, organizational, sector, or broader system level"	USAID
A locally driven process of learning by leaders, coalitions and other agents of change that brings about changes in socio-political, policy-related, and organizational factors to enhance local ownership for and the effectiveness and efficiency of efforts to achieve a development goal.	Otoo et al./ WBI (2009)

Furthermore, there is also a wide range of theoretical propositions and methodologies that correspond to principles and processes of capacity development, yet they do not use explicitly this terminology. One example would be the concept of transdisciplinary research, which subsumes interdisciplinary research that is jointly conducted together with stakeholders within a research project for achieving knowledge exchange and development (Pohl and Hirsch Hadorn 2007, Mollinga 2010, Hornidge et al. 2010; qv. chapter 4.2). In fact, transdisciplinarity is a means for capacity development (Scholz 2011).

3.2.4.2 Multi-level approach

In terms of the manifold problems that are faced today, organisations and people working within organisations are part of the problems as well as part of the solutions. Literature on organisation development and changes in the workplace are often based on the work of Kurt Lewin on action research (Bradbury et al. 2008; chapter 4.1), as well as on Schön's (1983) reflection-in-action. Bradbury et al. (2008) further describe the consensus statement of a meeting with representatives inter alia from universities, NGOs, World Bank, UN that dealt with the question, how the way of organizing work together can be changed for a sustainable future. Two out of the five main statements are that social change has to: "address immediate needs, linking them to larger, systemic issues and raise awareness of how social systems support and resist change" (Bradbury et al. 2008). These points clearly imply that multiple levels (e.g. individual, organisational) are needed for successful social change, as well as to relate single problems to contextual factors and the system level.

Therefore, contemporary CD focuses on individual competencies, but also on organizational development and the enabling environment, i.e. applying a multi-level approach (Lopes and Theisohn (2003); van Hofwegen (2004); OECD (2006); Alaerts (2009); Visser (2010). We stick to the multi-level approach without explicitly using civil society as a fourth level as proposed by Alaerts and Kaspersma (2009) or Wehn de Montalvo and Alaerts (2013). The importance of the civil society justifies the explicit mentioning of this level, yet it is according to our perceptions already integrated in the level of the enabling environment as suggested by Alaerts (2009). Within this multi-level approach, the different levels are mutually interdependent as indicated by the grey shaded arrows in Figure 25 in chapter 7. CD on the individual level is further not just about water management competencies, but also emphasis on the relationship to government processes as well as underlying capacities ("soft skills") like leadership development, trust generation or negotiation skills. And as van der Zaag (2005) mentions that a new generation of water managers need to be educated. For that, also new teaching techniques are needed. In terms of organisational level, water related organisations need CD in order to get the capability to adapt and self-renew (Baser and Morgan 2008), i.e. that these organisations are resilient towards emerging problems and consequently are able to continuously develop solutions to encounter such challenges. And it is also important to improve the societal and system level, i.e. the enabling environment, or as Lusthaus et al. (2020) clearly state that organisations do not act in vacuum. And also Ernstorfer and Stockmayer (2009) emphasize the need of capacity development for good governance. Chapter 7.3.2 describes the multi-level approach in detail.

3.2.4.3 Process of CD and its implementation

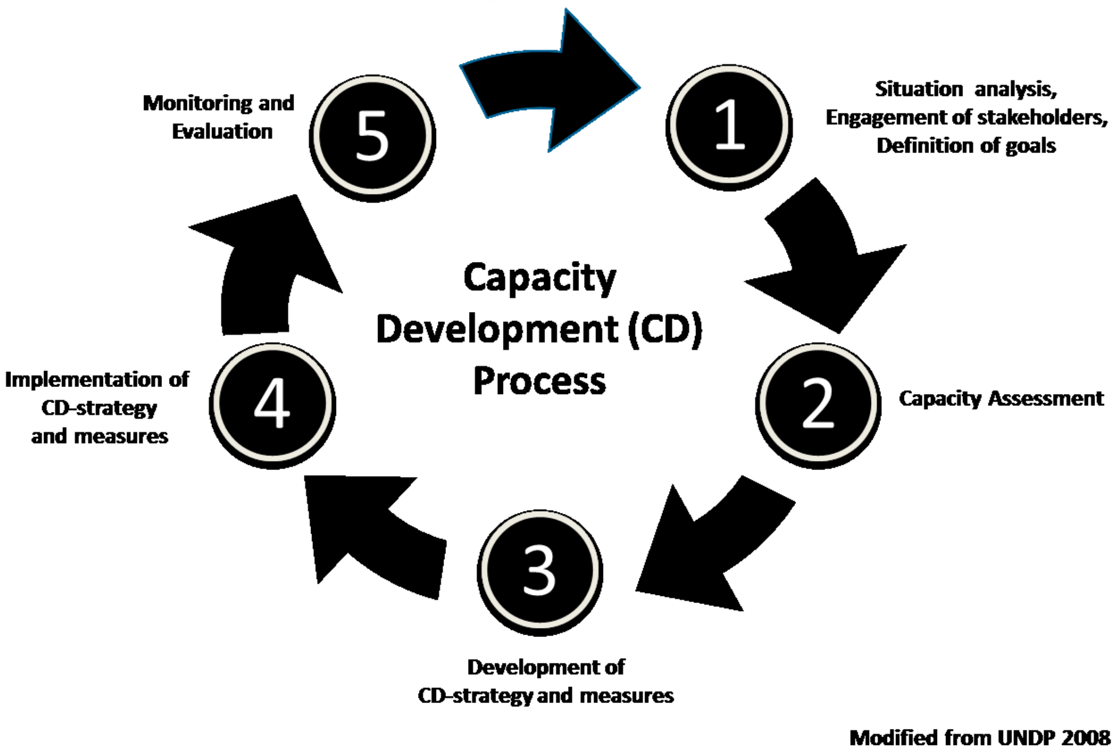
Capacity development is about shifting from one state of capacity to another state, thus it is as Baser (2009) describes about the "dynamics of change- organisational, institutional, personal, political and logistical". This clearly shows that CD has to be considered as a process. Three approaches to CD are stated in literature, planned approaches, incremental approaches and emergent approaches (Baser 2009; ECPDM 2009). The first means that CD is precisely planned with clear steps to be executed and results being evaluated against explicit objectives. It is a reasonable approach, when goals and means are clear to all involved stakeholders and when they all have the capacities to implement solutions (Land et al. 2009). But natural resources management, especially in development cooperation, is often complex and characterized by uncertainty, and potentially by low capacities and weak institutional structures so that goals and means frequently remain unclear at the beginning. In such situations, Land et al. (2009) argues that the CD approach may need to be more incremental or emergent. The emergent approach is based on the assumption that capacity development can hardly be planned and thus objectives cannot be set. But instead, capacity develops out of unplanned and complex processes like networking (Baser 2009). Incrementalism combines characteristics from the planned as well as from the emergent approach (Land et al. 2009). It considers objectives and the strategy more as guidelines for structuring the implementation of the capacity development without defining explicit objectives, but being flexible and adaptive within implementation (Bea and Haas 2005: Baser 2009)[27]. As Baser (2009) mentioned, each approach can be useful in specific circumstances, but one approach alone has not the power to change complex systems so that a combination is frequently more effective. Thus, change processes within complex situations need to be of an adaptive and cycling nature and have to be integrated into local development plans. Accordingly, we, i.e. the IWAS team, basically used a strategy that is based on an incremental approach. An example for emergent properties of our approach can be displayed by CD measures like seminars on wastewater tariffs that were planned and conducted for several water service providers in Western Ukraine. Through this CD measures also networking capacities emerged among the water service providers with exchange of experiences. We took this up, adapted our strategy (incremental approach) and further facilitated this process by strengthening their association, e.g. through supporting working groups on various topics, as well as through strengthening their political clout on national level, e.g. through initiating a working group with the responsible ministries. This was also supported through high-level meetings between German and Ukrainian government representatives, where the

[27] A football match is a striking example in favor of incrementalism: If the team has a predefined exact strategy and plans the whole game without adapting to changes (e.g. tactics of opposing team or a dismissal), its chances of winning the match are certainly reduced.

German actors emphasized the needed strengthening of the wastewater sector as well as the sector associations.

Our approach is based on the CD process from UNDP (2008; 2009: Figure 13) for structuring the capacity development, which is described in detail in chapter 7.3.3, as well as below. Within the Ukrainian case study, we developed a joint CD process together with regional and national stakeholders that was based on the UNDP approach (Figure 21) and which was gradually modified during the course of the project and eventually aligned with the IWRM process in Ukraine. In fact, the CD-strategy was considered as guideline with objectives that structures the implementation of the capacity development, but being flexible for reacting on changes (incremental approach).

Figure 13: Modified UNDP capacity development process



3.2.5 Capacity assessment

In general, assessments are reasonable as a basis for making sound decisions, respectively to improve decisions, which will eventually also improve the performance. Assessments are thus the basis for evolving from a current state to a desired state, and accordingly, assessments describe the baseline against which performance improvement can be measured. As a matter of fact, development cooperation or any other wanted improvement needs to be based on the existing capacities in order to develop adequate and effective assistance without negatively influencing the existing system. As shown in Figure 13, the assessment is conducted after the engagement of stakeholders and the definition of goals and *before* the planning, implementation, monitoring and evaluation.

Capacity Assessment is defined by UNDP (2009) as an "analysis of desired capacities against existing capacities and offers a systematic way of gathering critical knowledge and information on capacity assets and needs." Furthermore, they define that capacity assets refer to existing capacity "in a given system, organization or unit that can be strengthened, built up on and optimized" (UNDP 2009). The gap between existing and desired capacities is thus identified according to gathered information and should not be based on assumptions or preconceived solutions. The gap describes the needs, which have to be balanced with the wants of the stakeholders, e.g. their preferred methods or solutions. As an example, during the capacity assessments within the case study, actors from monitoring authorities wanted to have a fully automated online monitoring system for the water quality in the Western Bug River. Yet, during the discussions it became clear that this is neither a feasible option, nor a necessary one at that moment, since other issues are more urgent, as for instance the intercalibration of measuring methods.

Concurrently, a CD strategy has to be developed with the identification of possible solutions and instruments for reaching them (e.g. training, knowledge exchange or technical equipment). According to the CD-process from UNDP (2008), the strategy development is already a proceeding step; yet, real capacity assessments conducted in the field, commonly comprise the assessment as well as the strategy and solutions development. Potential solutions should be evaluated according to their political, social, financial, economic and environmental feasibility. Additionally, it is essential to draft a work plan including schedule and commitment of stakeholders. It has to be noted that the described procedure for capacity assessment suits best for planned or incremental CD approaches.

Instead of capacity assessment, also *needs assessment* is frequently used as a term for assessing capacities. Another term, though rarely used, is gap analysis; yet it is rather a method for conducting capacity assessments. Needs assessment is defined by Rossett (1987, in Watkins et al. 2012) as "The systematic study of a problem or innovation, incorporating data and opinions from varied sources, in order to make effective decisions or recommendations about what should happen next." Needs assessments are according to Watkins et al. (2012) important for interdisciplinary and combined solutions to complex problems, since underperforming organisations are mostly the result of multiple problems or causes. He further argues that "through their processes, needs assessments encourage you to identify, compare, and- when appropriate- combine the activities that will best accomplish the desired results". These definitions clearly show similarities, however the definition by UNDP (2009) focuses more on assessing the gap between desired capacities and existing capacities, and the definition by Rossett (1987, in Watkins et al. 2012) also emphasizes that the assessment is the basis for decision making. Thus, the two concepts complement each other.

The content and the scope of capacity assessments obviously depend on the project and its objectives. Yet, it should normally mirror the above mentioned multi-level approach for getting a holistic view on the situation. Capacities reside within individuals or within organisations, but they are also shaped by the context, which is related to the above mentioned enabling environment. Thus, it is always essential to consider the context that provides positive and negative incentives to act, i.e. either fostering development or productivity and others fostering passivity or decline (European Commission 2007).

Detailed descriptions on how to conduct capacity assessments are provided by UNDP (2007) as well as Watkins et al. (2012).

3.2.5.1 Stakeholder analysis

The basic first step within, respectively *before* a capacity assessment is a stakeholder analysis (Step 1 in Figure 13), i.e. according to Morgan and Taschereau (1996) to identify relevant stakeholders and analyze their relative power, influence and interests so that the importance of each stakeholder towards the development outcomes can be assumed, respectively assessed. Hereby, additional institutional or governance analyses are often necessary. Especially important is to identify stakeholder that have high power and high interests towards the development, since they can be the "game-changer" needed for successful projects.

The advantages of stakeholder analyses are that (I) it is a relatively simple process, (ii) it can support project design and identify potential proponents and opponents of the project, (iii) it can support the identification of appropriate forms of stakeholder participation and (iv) ownership of actors is potentially created and analytical capacity is strengthened if the analysis is conducted with local partners (Morgan and Taschereau 1996). Additionally, it assures that no key actor is left out and it facilitates actors' commitment to project implementation. Yet, disadvantages are that (I) stakeholders as well as their influence, power and interest can change, (ii) assessing the influence of stakeholders is difficult, and (iii) covert interests and hidden agendas are difficult to discover (Ibid.). Stakeholder and institutional analyses are essential, because they facilitate the identification of the necessary scope of the capacity assessment for reaching the goals. Another challenging question is about who should participate, i.e. being invited, in the capacity assessment. On the one hand side, the participation of all relevant actors assures transparency, the inclusion of all topics, and it could enhance the commitment for change. On the other hand, broad stakeholder participation (or the participation of upper *and* lower management) may lead to the avoidance of sensitive problems or to escalating conflicts. Participants may also expect that being involved in the assessment means to be involved in the further CD process and that CD measures are developed for them. But the results of a capacity assessment might suggest that there is no priority of capacity development for a specific actor group.

Worth mentioning is also that broad participation is frequently a lengthy process, especially if many conflicting interest emerge. Thus, additional costs for resources occur (time, staff). It can be concluded that the decision on whom to integrate into capacity assessments is a vital one, which can have positive or negative implications for the whole project, so that this decision has to be carefully taken.

3.2.5.2 Methods and tools for capacity assessment

There are many methods tools available for conducting capacity assessments. Watkins et al. (2012) describes tools and techniques for needs assessment and subdivides them into tools for data collection and tools for decision making, which is similar to the subdivision I have done for our methods in chapter 5.8 into data collection and data analysis methods. That means it is important to use first information gathering tools and then tools for data analysis and prioritisation, and eventually techniques for decision support. And for each part, multiple tools and methods should be used, and triangulated as described in chapter 5, so that the validity of the results can be improved. The choice of methods and tools that are reasonable for a particular capacity assessment depends on many variables like the experiences of the team, available resources, small or large groups, qualitative and/ or quantitative results needed, etc. That means it is not an easy task and "more of an art than a science" as mentioned by Watkins et al. (2012). Examples for tools that can be used are found in Table 10 and are described in Watkins et al. (2012) including the purpose, application possibilities, advantages and disadvantages and how to conduct them. The methods and tools that have been used for our case study are described in detail in chapter 5.8.

Table 10: Tools for capacity assessment

Information-Gathering Tools	Decision-Making Tools
Document or Data Review (review existing sources, e.g. documents, reports, data files for collecting independently verifiable data and information)	**Nominal Group Technique** (a Group Consensus-Building and Ranking Technique; used to engage in consensus planning for prioritizing issues and making decisions)
Guided Expert Reviews (reviews by expert to provide valuable external perspectives that can inform decisions and to provide balanced perspectives)	**Multicriteria Analysis** (systematically provide a quantitative comparison across multiple options; assigning and weighing quantitative values to potential options and measures)
Management of Focus Groups (collect information from a small group in a systematic and structured format; designed around a clear goal; participants interact with a facilitator to gain valuable information related to both current results and desired results)	**Tabletop Analysis** (discussion-based activity in which a group of participants works with a facilitator identifying gaps in performance at several levels, e.g. individual, unit, organizational, systems; can identify, analyze, and evaluate potential solutions to a performance problem)
Interviews (collect information from a single person; structured, semi structured and unstructured; often provide in-depth context, stories, and discussion)	**Pair-Wise Comparison** (used for priorization of multiple options by narrowing the options according to a set of agreed criteria; may be used to prioritize or rank needs or possible solutions; less complex than MCA)
Dual-Response Surveys (collect information on current and desired performance)	**2 × 2 Matrix Decision Aids** (to examine multiple perspectives on issues identified during a needs assessment)
SWOT+ (define relationship among strengths, weaknesses, opportunities, and threats and to assign values to each of the items)	**Fishbone Diagrams** (cause-and-effect diagram that can be used to identify the potential/ actual causes for a problem; providing a structure for a group's discussion about the potential causes; illustrating and communicating the relationships among causes)
World Café (collaborative conversations designed to get insights into pressing collective issues; participants circulate in the room and building upon one another's suggestions)	**Scenarios** (exploring potential strengths and weaknesses of different combinations of interventions; comparing benefits and risks of alternative scenarios for recommendations; most useful where number of possible directions is large or high uncertainty)
Delphi Technique (to get insight from a group of experts in a structured way, reveal the areas where experts have consensus and to lead to a group decision, e.g. making recommendations; iterative process; can be used for data collection and decision making)	**Root Cause Analysis** (tool for examining the contributing factors that are preventing current achievements from matching your desired accomplishments; determines which processes, procedures, tools, or policies (or combination) are limiting performance)

3.2.6

Performance Observations (document the steps, procedures, tools, and decisions used to accomplish current performance)	**Fault Tree Analysis** (step-by-step procedure to identify, evaluate, and quantify potential problem causes for a failure in a system and to determine strategies for preventing these causes; visual representation identifying causes, the relationships between the causes, and the prioritized prevention strategies.)
Task Analysis (hierarchical or sequential, if–then, and model-based; systematically describe, document, and analyze activities, procedures, processes, and resources that are used by individuals or groups to accomplish current results; a task analysis process parallels the performance analysis process although the former begins with the results currently being achieved, whereas the latter begins with the desired results that should be accomplished)	**Future Wheel** (to assist participants analyze and explore effects of a trend, future event or issue; useful tool for conducting structured brainstorming, determining needs, planning strategically, and building consensus; it is a graphic depiction with the future event in a circle in the center, the first-order effects in the first circle out from the event, the second-order effects in the second circle out from the event, and so on; last circle is about implications and opportunities)
Cognitive Task Analysis (focus on the psychological processes underlying the completion of a task; define the decision requirements and psychological processes used by expert individuals in accomplishing results)	**Concept Mapping** (visual representation, i.e. a map, of concepts or ideas and to illustrate their relationships; especially useful when complex relationships exist between elements; also called mind map)
	Performance Pyramid (ensuring that all aspects of the performance system are considered; to provide structure when identifying/ analyzing needs, and deciding what to do to improve performance)

Source: Assembled based on Watkins et al. (2012

3.2.7 Frameworks and models for assessing capacities

There are several frameworks and models available for assessing capacities in the academic and non-academic fields of capacity development, e.g. the Community Development Resource Association's approach (Kaplan 1999), outcome mapping (Earl et al. 2001), the framework for organisational assessment by the Inter-American Development Bank (Lusthaus et al. 2002), the 5Cs framework to assess organisational capacity (ECDPM; Baser and Morgan 2008), the World Bank capacity development and results framework (CDRF) (Otoo et al. 2009), the adaptive capacity wheel (Gupta et al. 2010), the UNDP approach to measuring capacity (Lopes and Theisohn 2003; UNDP 2008; 2009), the Capacity Development Strategic Framework developed by the African Union (AU)/New Partnership for Africa's Development (NEPAD 2009) are only some approaches to assess capacity. However, Kaspersma (2013) stated that scientific and development challenges still exist in the assessment of capacity development. Important is also to differentiate between the assessment of capacities *within* a capacity development process (capacity assessment) and the assessment of an *overall* capacity development process.

A literature review on the different available approaches showed that many approaches exist that are operational but having a simplified view on capacities (e.g. focusing on training), or approaches that are more holistically describing the complex reality, but are difficult to implement. Lusthaus et al. (2002), for instance, developed a framework for in-depth organisational assessment based on (i) measuring organizational performance, (ii) understanding the organization's external environment, (iii) determining organizational motivation, and (iv) examining organizational capacity. The approach is appropriate for organisational capacity assessment, but it seems less appropriate for a profound assessment of individual and systemic capacities, which is, as mentioned above, essential. Kaspersma (2013) provides a good summary on existing models for capacity assessment and describes pros and cons of the different approaches. In the following, I draw on capacity assessment frameworks that influenced our work on capacity assessment within the realm of this thesis.

As *conceptual basis* for our capacity development activities, we applied the KCD conceptual model developed by Alaerts and Kaspersma (2009) and adapted by Kaspersma (2013) and based on previous work by Alaerts, e.g. Alaerts et al. (1991), Alaerts (1999). The approach explicitly focuses on applying a multi-level approach, as well as clearly describing the sequences for the nested levels. That means that each particular level is related to the specific "nature" of knowledge and capacities (e.g. skills), how they can be developed with tools and mechanisms (e.g. training or change management), the indicators or attributes for assessing them (e.g. technical competences), as well as the outcomes of the development process, e.g. new individual capacities (new skills). Since this is a nested model, the model specifies the (simultaneous) outcomes for each level that are the basis for the overall (water) sector performance.

3.2.7.1 Capacity development process from UNDP

The *concrete process* for implementing CD was done in accordance with the above mentioned CD process from UNDP (2008; 2009). The process was slightly modified (Figure 13), yet, this is in accordance with the UNDP capacity assessment methodology that explicitly demands to adapt the process to the context. The process starts with

- a situation analysis (stakeholder and institutional analysis),
- engagement of stakeholders (participation and commitment of key stakeholders, i.e. ownership and accountability) and strengthening the relational capacities of stakeholders
- setting/ priorization of preliminary targets.

The next step is the capacity assessment. It is a systematic method for identification of existing and missing capacities and constitutes the baseline for measuring progress. It is an essential step for delineating a CD strategy and measures and for the prioritisation of capacity needs and measures. Essential for a sound capacity assessment is the participation of key stakeholders in defining the scope of the assessment, its implementation as well as the analysis of the findings (UNDP 2009). The UNDP capacity assessment framework consists of technical and functional capacities (e.g. capacity to evaluate) and three points of entry, mirroring the multi-level approach, which allows the combination with the above mentioned KCD conceptual model of Alaerts and Kaspersma (2009). The UNDP framework also consists of *core issues* (institutional arrangements, leadership, knowledge, accountability). *Institutional arrangements* relate to the (i) institutional context within which an organization works, as well as to the (ii) internal challenges of an organization. The first (i) addresses thus policies and procedures needed for organizations to work. Furthermore it comprises the organizational role within the public sector architecture including coordination mechanisms with other organizations. The latter (ii) deals with internal issues like human resources management (including motivation through direct and indirect incentives for staff) or financial and technical management, i.e. it deals with the organizational effectiveness

(UNDP 2009). Hence, the core issue *institutional arrangements* resemble the organizational level *and* the enabling environment of the KCD model from Alaerts and Kaspersma (2009). *Leadership* is another core issue, which is decisive for achieving development objectives. Leadership development should be aligned to other development activities and should also reflect the multi-level approach, including vision development, hands-on activities, mentoring, career management and continuous learning (UNDP 2009). *Knowledge* as the third core issue is the basis of capacity. Alaerts (1999), for instance, acknowledges the high relevance of knowledge by introducing the term *knowledge and capacity development* (KCD). Knowledge can be improved through training, education and exchange of experiences, resembling the individual level of the KCD model. But also education policies have to be assessed and potentially rearranged, which is part of the systemic level of the KCD model. Additionally, knowledge sharing mechanisms and access to knowledge is of outmost importance for CD. *Accountability* as core issues is important, since it can lead to better performance and effectiveness by helping to monitor and adapt the behavior of systems, organizations and individuals (UNDP 2009). Accountability means that individuals and organizations are held responsible for executing their work correctly, whereas vertical and horizontal accountability exists. Vertical accountability means that state actors are accountable to the citizen e.g. through elections or an active civil society. Horizontal accountability means that government organizations are checked by other government agencies as for instance by the jurisdiction or auditing agencies. In terms of development cooperation this can include accountability between donors and receiving countries. Also internal accountability of organizations is an important factor. Accountability is often impacted by corruption or power asymmetries. Development measures could include the strengthening of monitoring and evaluation, developing enforcement mechanisms, participatory planning, enhancing access to information and other measures for strengthening civil society (UNDP 2009).

After the assessment, the next step is to formulate a CD strategy and measures[28]. They have to be based on existing capacities and should include short- and long term responses. Measures should reflect the above mentioned core issues and an increased effectiveness can be assumed, if combined *across* core issues and levels of capacity (UNDP 2009). Additionally, it is important to calculate required funding, be transparent while delineating measures, as well as developing indicators for measuring progress.

[28] CD measures are called CD responses within the UNDP approach. UNDP (2009) defines a capacity development response as “an integrated set of sequenced actions embedded in a programme or project to address one or more capacity development core issues.” We use the term capacity development response synonymous to measures.

The proceeding step is the implementation, which should not be a parallel process, but instead should be embedded into the overall project process, and implementation should be done through national systems and processes (UNDP 2009). And it has to be underlined that implementation of responses means change and change means threats as well as opportunities, so that political dynamics and relationships have to be considered (UNDP 2009).

The last step is the evaluation of the capacity development, which is necessary for learning and thus adaptation and performance improvement, as well as improving accountability (UNDP 2009). Measurement of capacity development is more than an evaluation of input resources (e.g. human or financial resources). Improved capacity is reflected by changes in the core issues; yet, it is difficult to establish a direct cause and effect relation between a particular CD measure and a change in the core issues. And some capacities are difficult to measure at all or data are not available, e.g. on leadership development. An evaluation framework has to be designed in such a way that it respects the (un-) availability of data, and the available capacities and resources for using it (UNDP 2009).

A detailed description of the single steps and how to conduct them in the field is available within the capacity assessment user guide from UNDP (2007).

4 Theoretical framework

The full range of theories, which are relevant for the topic of the dissertation include individual theories (e.g. learning, behaviour, etc.), group theories (e.g. formal and informal networks, rent seeking), organisational theories (e.g. organisational structures, performance, interorganisational cooperation), social theories (e.g. administrative science, systems theory, cultural, political, market economy), as well as theories that integrate several theories of the above mentioned like theories on decision making or theories on capacity development.

It would go beyond the scope of this work, to explain all theories that are touched within this doctoral thesis. Therefore, only the essential theories will be explained in depth. If further explanations are needed, they are mentioned directly where the theories are touched upon. And as Hartley (2004) mention, an initial theoretical framework is necessary, however during the course of the research, it may be modified due to new insights.

4.1 Action Research

There are different approaches to research namely qualitative, quantitative, and mixed methods (qv. chapter 5.1) which basically try to describe, explain or explore the world (events, situations, and context). However, most of those approaches do not emphasize that research should be connected to action. Since I assert that successful and sustainable research within real world settings should be always related to action, stakeholders need to be integrated into the research process instead of seeing them merely as "research subject". Therefore, my thesis will draw on the ideas and theories form action research.

The groundings of action research were developed by Lewin's (1946) seminal work on action research, in which he reasoned that it is not sufficient that universities create new insights, but that research should lead to social action: "No action without research, no research without action" (Lewin in Adelman 1993). However, Lewin (1946) clearly stated that this does not imply that the needed research is less scientific compared to "pure science", even in contrary. He called for an integrated approach to social research thus setting the scene for mixed methods research as outlined in chapter 5.3. Lewin (1946) argues that realistic fact finding and evaluation are preconditions for any learning and that management should therefore be composed of a circular process of planning, action, and the evaluation of the results. Importantly, experiences convinced Lewin (1946) to consider "action, research and training as a triangle", because trained researcher are needed for improving action. He mentioned that one of the most important prerequisites towards progress in the management of intergroup relations is to have scientists that can handle scientific issues, but also can work in teams with practitioners (Lewin 1946; qv. chapter 4.2 on transdisciplinarity). This challenge of having this kind of trained personnel is more than ever an issue as described in this study. Action research should also overcome scientific "technocracy", i.e. that scientists should not tell the stakeholders exactly what they should do and what not to do (Ibid.). Moreover, action research must include the active participation of stakeholders (Lewin in Adelman 1993). Therefore also the term participatory research is used for action research (Adelman 1993; Reason and Bradburry 2008). Argyris et al. (1985, in Adelman 1993) underline the interrelationship between science and social practice, especially the relation between science and learning within the action context.

Kemmis and Mc Taggart (1988 in Kemmis 2008) correspondingly define action research as "a form of collective self-reflective enquiry undertaken by participants in social situations in order to improve...their own...practices, as well as their understanding of these practices and the situations in which these practices are carried out." Reason and Bradburry (2008) similarly define "action research is a participatory process, concerned with developing practical knowing in the pursuit of worthwhile human purposes. It seeks to bring together action and reflection, theory and practice, in participation with others, in the pursuit of practical solutions to issues of pressing concern to people..." Action research projects are conducted in cycles of action and reflection, where action means to test ideas and collect evidence and reflection means to think collectively about the results of the action and to develop further actions. Thus, the interactions between ideas and practice lead to improved results.

Action research is only possible with, for and by stakeholders and should ideally include all stakeholders within the research planning as well as in the action (Reason and Bradburry 2008). Action research is a development process, in which actors develop skills and gain new (practical) knowledge and in which actors develop new abilities to generate knowledge (Ibid.). This clearly links to the concept of capacity and capacity development and to the concept of adaptive management as described in the previous chapters 3.2 and 3.1.17.

Reason and Bradburry (2008) argue that normal academic institutions focus on pure research without practical questions. However, I think that this shows bias and that there are more and more academic institutions that direct their research to practical questions. Reason and Bradburry (2008) further hold that the primary purpose of action research is not "to produce academic theories based on action...nor is it to produce theoretical or empirical knowledge that can be applied in action; it is...the search for a better, freer world". Besides that this seems to be a deliberate provocation, indeed, I consider those points as essential for conducting sustainable research, which iterates between theories and practice as described in chapter 5.3 on mixed methodology, as well as in the above mentioned definitions. I even advocate that the combination of a profound scientific process with a participatory process and linking scientists with stakeholders will deliver results that are credible, relevant and accepted (Leidel et al. 2014), which is actually the purpose of this thesis.

The root of action research is participation; however this potentially also leads to challenges. Especially if many stakeholders are involved as for instance in water resources projects, participation may become difficult (qv. 3.2.5.1). Questions arise concerning the engagement of stakeholders and to keep them in the continuous process of planning, action and evaluation (Reason and Bradburry 2008). Another challenge can be about drawing generalisations from action research, since action research depends to a good portion on the interdependency between research and active participation of other actors (Gustavsen et al. 2008).

4.1.1 Reflection-in-action

One seminal work on action research is Schön's (1983) *reflective practitioner*, where he described the reflection-in-action process. Similarly to Lewin (1946), he supposes that universities are not devoted to produce and share knowledge in general and that there is a gap between research and practice. He clarifies the difference between academic and professional knowledge and assumes that competent practitioner normally know more than they can describe their work. According to Schön (1983) practitioner show a mostly tacit "knowing-in-practice" with a capacity to reflect their own know-how, which can be and is sometimes used for coping with uncertain or complex situations occurring in practice. Schön (1983) further mentions that the importance of such intuitive knowing within practical situations increases in future[29], e.g. to reduce uncertainty to manageable risks or complex situations to manageable plans or defining the "right" problem. Those challenges are manifested in water resources management, so that Schön's theory should be applied for improving this sector.

Thus essential know-how and competencies have to be taught, coming "from technical rationality to reflection-in-action" (Schön 1983). Within technical rationality that is based on a positivist world view[30], it is attempted to solve practical problems merely with scien-

[29] Schön (1983) even considers this as art and that practitioners show artistry in their work.
[30] Explanations on the positivist world view can be found in chapter 5.2

tific theory and techniques. The limitations of this approach to solve societal problems became obvious through the dilemma of rigor or relevance (Schön 1983). Knowledge lies in action, e.g. the tacit knowledge of a practitioner who recognizes a phenomenon, without being able to provide a comprehensive description[31] (qv. chapter 3.2.1 on the differentiation of tacit and explicit knowledge; Schön 1983). Those practitioners frequently reflect on the understanding of the actions, i.e. they think about what they do (Schön 1983). And this can also occur during the action (e.g. musicians improvising during a jam session), i.e. reflection-in-action. Summarizing it can be stated that reflection-in-action research therefore means to reflect a surprising, uncertain or complex phenomenon *and* to reflect the researcher's implicit existing understanding of it. Subsequently, research and action is carried out that leads to new theories of understanding the phenomenon and to a change in the situation, i.e. that inquiry and implementation are coupled.

Technical problem solving should not be expelled; however, it is necessary to embed it into a reflection-in-action process, as described by Wilson (in Schön 1983). That means to combine the technical analysis with an intervention in the real world, i.e. having a socio-technical system or more comprehensively a man-environment system as described in chapter 3.1.5 on (integrated) water resources systems. Yet, Schön (1983) reasons that reflection-in-action may be difficult for organisational development, since organisational inquiries are guided and limited, e.g. by regulations. It may be difficult and risky for managers to reflect on these existing theories, i.e. to question them. That means the focus should be on reflecting the organisational learning system. In fact, reflection-in-action of managers within the organisation would be needed for organisational learning, yet, it is also a threat to the stability of the organisation (Schön 1983). That means that capacities for reflection-in-action-processes are needed, which can be developed by action research. A *reflective practitioner* is needed, i.e. a professional who (i) integrates his expertise into a context, (ii) acknowledges that different meanings of action are possible, (iii) discover and explain these different meanings, (iv) may reconstruct his or her expertise, (v) attempts to discover limits of his or her expertise by reflection (with the client), and (vi) is technically competent, but instead of being a black box, s/he makes understanding accessible for the client and remains open for his inquiries and his or her learning process (Schön 1983). A *reflective researcher* could have the role as consultant for the practitioner, and reflective research, which requires a partnership between researcher and practitioner, can become a part of further

[31] Polanyi (1966), the inventor of the term tacit knowledge gives a striking example for it: If a person knows the face of someone else, s/he can recognize it under millions of humans without knowing why.

education for practitioners (Schön 1983). This implies that contemporary water-related academic education also needs to integrate more skills that facilitate this partnership in addition to the subject itself, e.g. hydrology. As for instance suggested by the T-shaped model of Uhlenbrook and De Jong (2012) or the umbrella concept for an IWRM course elaborated within this thesis in the Ukrainian case study.

Also, implementation is directly incorporated in reflective research, from which practitioners get insights from participating in this process (Schön 1983). These points clearly show the interlinkage with the concept of capacity development (qv. chapter 3.2 on knowledge and CD; cf. Alaerts 2009) and transdisciplinarity.

Accordingly, we draw on action research and on the reflection-in-action research for our theoretical framework. Especially, we refer to a cycling spiral with planning, action, reflection in terms of results and action, so that we can generated improved results based on the interactions between theories and practice and the continuous learning within the process.

4.2 Transdisciplinarity

Transdisciplinarity and thus transdisciplinary research deals with real life problems, i.e. it supports the preventing, mitigating or solving of such problems by developing descriptive, normative and practice-oriented knowledge (Pohl and Hirsch Hadorn 2008). According to Pohl and Hirsch Hadorn (2007) transdisciplinary research is reasonable, if (i) uncertain knowledge within a societal relevant problem field (e.g. environmental pollution) prevails, (ii) the nature of the problem is diffuse and controversial, and (iii) the stakes are high for the actors concerned by the problem and a social interest exists in approaching the problem (socially relevant).

However, in order to define transdisciplinarity and transdisciplinary management, it is important to explain first disciplinary, multidisciplinary and interdisciplinary research. Disciplinary research obviously means to conduct research within one academic discipline or specialisation with no or little connection to other disciplines. Multidisciplinary research means that several disciplines are, for example, working within the same research project on the same problem, but with no significant collaboration between them. Many problems can be adequately solved by disciplinary or multidisciplinary research. Interdisciplinary research is commonly conducted when the collaboration between different disciplines is the *only* possibility of solving a problem, as for instance frequently within environmental sciences. Interdisciplinary research consists of coordinated and joint research activities (joint problem definition, research planning, design, research questions, and implementation) of several academic disciplines or specialisations (cf. Pohl and Hirsch Hadorn 2007; Jahn 2008; Bergmann et al. 2012).

Transdisciplinarity is characterized by joint activities between scientists from different academic disciplines (as within interdisciplinary research) and practitioners within a project for solving a societal problem (e.g. Pohl and Hirsch Hadorn 2008, Scholz 2011). That means that *transdisciplinarity* needs cooperation between scientific fields relevant for the societal problem *and* societal actors with relevant practical knowledge for transforming societal problems into scientific problems (Jahn 2008). Häberli et al. (2001) similarly define *transdisciplinary research* as taking up "concrete problems of society and works out solutions through cooperation between actors and scientists". *Transdisciplinary research* is according to Scholz (2011) research that is related to and conducted within transdisciplinary processes. Lang et al. (2012) define *transdisciplinarity* as a "reflexive, integrative, method-driven scientific principle aiming at the solution or transition of societal problems and concurrently of related scientific problems by differentiating and integrating knowledge from various scientific and societal bodies of knowledge".

From these definitions it becomes clear that a distinct differentiation between transdisciplinarity and transdisciplinary research is difficult to draw, since science and, thus, also research is an inherent part of transdisciplinarity, at least in the way as it is used within this thesis. Some scholars define transdisciplinarity and transdisciplinary research differently, which can be often considered simply as applied research, or some define the difference in such a way that transdisciplinary research is controlled by researchers as described within Scholz (2011). In fact, there is a risk that transdisciplinary research projects are excessively research driven (Roux et al. 2006). Being aware of that, for the objectives of this thesis it is, however, not necessary to differentiate between both terms. We stick to these above mentioned definitions and use both terms interchangeably as done by several authors like Lang et al. (2012).

According to the above mentioned definitions, transdisciplinary research crosses both, the *boundaries* between different academic disciplines needed, as well as the *boundaries* between science and practice (Cash et al. 2003; Jahn 2008; Mollinga 2010), which we will pick up in the following chapter on *boundary management*. This implies also that researchers within transdisciplinary research (TR) need cognitive skills for understanding and integrating (i) the methods and knowledge applied by different disciplines involved, as well as (ii) applied knowledge of other actors involved and (iii) the interaction between scientists and other actors (e.g. Truffer et al. 2003). This also includes the capabilities of mutual learning and exchange of experiences. Furthermore this interaction between researcher and other social actors calls for social competence and communication skills. Consequently, several scholars (Bammer 2005 and Wiesmann et al. 2008, in Pohl and Hirsch Hadorn 2008) propose a transdisciplinary specialisation. However, it has to be stressed that "transdisciplinary research is not meaningful without sound disciplinary contributions and it has the potential to stimulate innovations in participating disciplines" (Wiesmann et al. 2008, in Pohl and Hirsch Hadorn 2008). Accordingly, transdisciplinary research can be considered as a *system*, where the different elements of the system (researchers from various disciplines and other actors e.g. from government or private sector) interact and are transformed within a problem field like poverty (Pohl and Hirsch Hadorn 2008). In fact, all actors within a TR process do have their specific knowledge, whether it is e.g. results derived from model-based frameworks of some research disciplines or hands on experiences of practitioners. Renn and Schweizer (2009) advocate for participation of all societal systems, since economy contributes efficiency, scholars and experts deliver know-how on effectiveness, political institutions bring in the legitimacy and the inclusion of social actors is needed for reflection on the values and the common good (qv. chapter 3.1.12). These different knowledge bases have to be connected through the problem field, which will obviously lead to some methodological challenges (Pohl and Hirsch Hadorn 2008). The interrelation and transformation of the actors during the research process means to discuss the issues at stake, or to discuss targets and what the common good is (see below), as well as deriving measures (Ibid.). But it has to be ensured that each stakeholder is able to provide his or her expertise into the process, so that e.g. technical expertise is not replaced by fuzzy public perceptions or the other way around that experts impose their view and judgements (Renn and Schweizer 2009). The actors collaborate because they have a shared concern of solving a particular problem within a problem field (Ibid.). Therefore, Wiesmann et al. (2008, in Pohl and Hirsch Hadorn 2008) further conclude that peers are needed that are "able to bridge disciplinary and transdisciplinary specialisation".

Pohl and Hirsch Hadorn (2007) consider transdisciplinary research as a synthesis of various other research fields e.g. the above mentioned uncertainty and the social relevance is related to the field of *post-normal science*[32], as proposed by Funtowicz and Ravetz (1993, in Pohl and Hirsch Hadorn 2008). Furthermore, Pohl and Hirsch Hadorn (2007) define that TR requires to be conducted within a problem field so that

---

[32] see below for further examples, e.g. drawing on the field of systems theory.

i. the complexity of problems is understood,

ii. the diversity of perceptions towards problems is acknowledged (diverse scientific *and* diverse real life opinions),

iii. case specific and abstract knowledge is connected,

iv. it supports the "common good", i.e. that it supports the welfare of all humans, respectively the agreed common interests.

Out of the literature on transdisciplinary *processes*, which frequently have similar properties (e.g. Lang et al. 2012; Pohl and Hirsch Hadorn 2007), we stick to the TR process with the phases *problem identification/structuring, problem analysis* and *bringing results to fruition* from Pohl and Hirsch Hadorn (2007).

4.2.1 Challenges of transdisciplinarity

The above mentioned requirements for TR (i-iv) make clear that manifold challenges, especially methodological ones, have to be tackled for conducting TR.

4.2.1.1 Complexity and integrating multiple perspectives

The first point (i. complexity of problems) means that the various and partially dynamic factors that set up a problem (e.g. technical, social, legal, environmental, economic, etc.) need to be interrelated and subsequently integrated, so that a comprehensive understanding of the problem can be reached and possible solutions can be derived. This clearly shows the systemic character of transdisciplinarity, since not only the elements are important, but the interrelations between the elements are in focus, which is a characteristic of the discipline of *systems theory* (e.g. Jantsch 1972; in Pohl and Hirsch Hadorn 2008; Checkland 1981 in Checkland 2000; qv. chapter 3.1.2). Checkland's (1983 in Checkland 2000) differentiation in hard and soft systems thinking is necessary. Yet, we reason that both, hard systems thinking, i.e. an engineering perspective *and* soft systems thinking, i.e. focusing on multi-perspectives, is necessary for addressing complex problems. Thus, for a sound handling of problems, disciplinary perspectives (scientific knowledge) as well as perspectives of other actors (contextualised or traditional knowledge) have to be integrated as mentioned in the next point.

4.2.1.2 Collaboration and integrating diverse perceptions

The second point deals with the diversity of perceptions, i.e. that all actors have different perceptions towards the problem, its causes and its potential solutions. They are formed inter alia by the academic background of scientists, context and role of actors, the relation towards the problem, as well as the conditions of the specific situation (Pohl and Hirsch Hadorn 2008). Therefore, actors' relevance of the problem varies, and the diversity of perceptions and knowledge derived from them has to be acknowledged and subsequently explored and clarified (e.g. Giri 2002). This shows that *participatory research* (e.g. Renn 2005; Renn 2009), *action research* (e.g. Kemmis and Mc Taggart 1988, in Kemmis 2008) and *interdisciplinary research* (e.g. Constanza 2003) is needed. Especially for exploring the different knowledge bases and perceptions of the different actors, it is reasonable to apply and relate quantitative and qualitative social science methods (Pohl and Hirsch Hadorn 2008). Yet, using several methods concurrently or sequentially without reducing the scientific rigor is not trivial. A sound way of integrating various applied research methods, e.g. qualitative and quantitative ones, under the constraints of scientific validity, is mixed methods research (e.g. Creswell 2008, Tashakkori and Teddlie 2010). For that reason, my research within the Ukrainian case study is subject to mixed methods as described in the methodological framework in chapter 5.3. Another challenge related to the understanding and the subsequent integration of the manifold perceptions is that the actors are members of different "cultures", communities, or in different *social worlds* as described by Star and Griesemer (1989). Those social worlds have their own specific jargon, knowledge, beliefs and practices, which makes the integration of knowledge and perceptions from different social worlds difficult. However, this integration lies at the centre of transdisciplinarity, since it should support solving the problem and to define the common good (Pohl and Hirsch Hadorn 2008). Hence, for successful integration it is necessary that the different social worlds respect each other (Giri 2002), and to "specify and combine means of integration with forms of collaboration" (Pohl and Hirsch Hadorn 2007). They mention three forms of collaboration within a team:

- common group learning (integration via learning processes of the *entire* group),
- deliberation among experts (experts or actors separately analyse the part of the problem in which they are specialist; integration via exchange between experts),
- integration by a subgroup or individual

(Pohl and Hirsch Hadorn 2008).

And the means of integration are according to Pohl and Hirsch Hadorn (2008):

- *Mutual understanding*, i.e. that all involved actors "speak the same language" and thus know the terms used by the community of each other (Cash et al. (2003) appositely call this translation). Issues of mutual understanding can be solved, e.g. by using every day language or developing a glossary of used terms.

- *Theoretical concepts*, i.e. (i) concepts are transferred between disciplines, or (ii) different concepts are mutually adapted and relate to each other, or (iii) new bridge concepts are developed that merge different scientific perspectives and different actors' perspectives.
- *Models*, i.e. quantitative "hard" models that use parameters from different disciplines for integration, or qualitative "soft" models representing different perceptions for developing a joint understanding or for mutual learning (qv. chapter 3.1.2 on hard and soft systems thinking; Checkland 2000). Also, scenario development could be a means of integration.
- *Products*, e.g. frameworks, technical devices, databases, maps, or plans like water resources plans. If the main rationale of the product is for joining different interests, and if the content of the product is not contested, than Pohl and Hirsch Hadorn (2008) reason that this integration approach can be termed "boundary object" as introduced by Star and Griesemer (1989). Correspondingly, within this study a boundary object is applied as described later (chapter 4.3, as well as within the case study in chapter 8.3.4).

The chosen form of collaboration and means of integration determines the degree of integration between the involved actors (Pohl and Hirsch Hadorn (2008). Within our study, we apply all *four* means of integration, as we assume that this enhances the integration of the diversity of actors' knowledge bases. A bridge concept was developed that integrates hard and soft models, and products (framework as a boundary object), which supports mutual understanding and altogether the knowledge integration.

4.2.1.3 Integration of abstract and general knowledge

Another challenge is to connect case specific and abstract, respectively scientific knowledge, since both are necessary for transdisciplinarity, and especially for TR in the field of natural resources management. That means that there is an interaction between theoretical know how and context-specific know how, which clearly shows the need of iterative (recursive) approaches instead of linear approaches. Schön (1983) circumscribes this with the dilemma of rigor or relevance and the question whether to stay on *solid grounds* (i.e. practicing with technical rigor), or to go to the *swamps*, i.e. tackling the real and most relevant problems.

As I mentioned in chapter 4.1.1, technical rigor should not be expelled, but should be embedded into a reflective and iterative process and to combine the technical analysis with an intervention in the real world. Moreover, the complexity of the problem and the manifold perceptions makes it necessary to iterate. Such iterative approaches have been developed for instance within *action research* (e.g. Schön's (1983) reflection-in-action), as well as the iteration between deductive and inductive approaches within mixed methods research (Tashakkori and Teddlie 2010). Yet, also policy sciences are important in the context of real world research, as for instance within resources management (e.g. Clark 2002).

Hereby it has to be mentioned that TR is more than consulting since the nature of all kinds of research is to generalise or transfer results from one study to another. Remarkably for TR is that it does not generalise based on standard conditions, but it validates the developed theoretical models within concrete real world conditions (Pohl and Hirsch Hadorn 2008). As a result, knowledge exchange and integration needs to be based on action research, real world experiments or adaptive management (Ibid.).

4.2.1.4 Developing the common good

Knowledge development should support the "common good", i.e. that TR is oriented to real life problems, which are incorporated in a framework that constitutes the common good (Pohl and Hirsch Hadorn 2007; Pohl et al. 2008). Obviously, policy sciences and especially policy sciences in respect to natural resources management often deal with questions and definitions of the common good (e.g. Clark 2002). The common goods are defined as the welfare of all humans, respectively the agreed and demanded common interests of the majority of a community (Clark 2002). This clearly implies that the common good cannot be defined by a single actor, but that it has to be deliberated by all concerned stakeholders.

The specification of the common good in relation to the regarded problem is, therefore, a central part of transdisciplinary projects (Pohl and Hirsch Hadorn 2008). The same holds true for proposed solutions, which need to be in accordance with the common goods, and thus has to deal potentially with opposing opinions from the diversity of actors. I admit that these conflicting interests are not easily resolved, if at all possible. Yet, Renn and Schweizer (2009) draw from their experiences that it is possible to reconcile and integrate scientific expertise, rational decision-making and public values if it is seriously attempted.

Thus, for reducing these contestations, several concepts for stakeholder participation with different participatory methods are available for knowledge production and integration between actors, e.g. Delphi method, round tables, mediation, focus group discussions, panel discussions, hearings, advisory committees (e.g. Renn and Schweizer 2009; qv. chapter 3.1.12 on participation and water governance).

4.2.1.5 Principles of transdisciplinary research

Addressing all mentioned requirements for TR is fraught with risk of ending up in a mess, so that Pohl and Hirsch Hadorn (2007) propose four principles, which sum up the above mentioned items:

i. *"Reduce complexity by specifying the need for knowledge and identifying those involved."* Therefore, systems knowledge (causes and possible developments of the problem), target knowledge (explaining need for change/ better practice and determining goals), as well as transformation knowledge (how to change from current to target state; development of laws, technologies, capacities), which are mutually dependent, is needed. It is further necessary to involve not all, but all relevant actors and how they can contribute.

ii. *"Achieve effectiveness through contextualisation"*. TR focuses on having societal impacts so that it has to be assured that the research is within the real world context. And thus, also the results have to be made accessible for the stakeholders, which mean that the results need to be provided in such a form that they are understandable and fit to existing agendas. As important is, to place and link TR in the context of state-of-the-art science.

iii. *"Achieve integration through open encounters"*. Effective collaboration depends significantly on openness, i.e. that the diversity of perceptions is acknowledged. The use of different forms of collaboration and means of integration (e.g. boundary object) determine the degree of reflection on perspectives and the intensity of collaboration (chapter 4.2.1.2).

iv. *"Develop reflexivity through recursiveness"*. Acknowledging that within complex situations not all issues can be recognized instantly, a recursive (iterative) process is suitable for gradually improving the knowledge base. That means that a reflection on preliminary results leads to an adaptation by targeted learning.

4.2.2 Transdisciplinarity and action research

From the above mentioned requirements of transdisciplinarity, the similarities to action research, as described in the previous chapter, become obvious. Not only the connection between case specific and abstract knowledge relates to action research, but also the diversity of perceptions is addressed within action research, as well as supporting the common good as described in the above mentioned definition of action research from Reason and Bradburry (2008). However, a major difference is the focus of TR on transforming social problems into scientific problems, the emphasis of interdisciplinarity *and* integration of stakeholders, as well as the application and combination of the systems, target and transformation knowledge. Another similarity between action research and transdisciplinary research is the "cycling nature" with similar phases, namely planning, action, reflection within action research, and problem identification/structuring, problem analysis and bringing results to fruition within TR. Both emphasize the iterative nature (or as termed within TR: recursiveness) of all phases of research. Furthermore, both concepts call for reflective actors that do need expertise, but should integrate this know how into the real life context. However, also specialised transdisciplinary researcher or knowledge broker are needed with the capacities as described above (e.g. understanding and integrating knowledge from different disciplines and different practitioners).

4.2.3 Transdisciplinarity, IWRM and capacity development

IWRM deals with highly complex, controversial and socially relevant real life problems with high stakes of many actors and potentially uncertain framework conditions. Furthermore, case specific and abstract knowledge has to be linked for successful IWRM and it refers to the common good, which are the common interests that are widely acknowledged within the targeted social group. As a matter of fact, the perception of what the common good is, has to be discussed and developed by all the involved actors themselves (cf. Pohl and Hirsch Hadorn 2008), meaning that this discussion has to be negotiated within IWRM processes as well. Thus, IWRM resembles the above mentioned requirements for transdisciplinarity. Another challenge is that IWRM research is often conducted within joint research teams of several disciplines and local actors, thus having a high degree of academic diversity, as well as a high cultural and social diversity with the local actors. That makes clear that not only the implementation of IWRM (qv. chapter 3.1.14) is challenged, but also the IWRM research *itself*. This demonstrates that projects in the realm of sustainable water resources management can be identified as requiring TR approaches and thus IWRM can be considered as a transdisciplinary problem field. In fact, Scholz and Marks (2001 in

Scholz 2011) have declared that transdisciplinarity is the appropriate framework for investigating sustainable development, and Kabisch (2014) concluded that it became a mainstream topic within environmental sciences. Accordingly, several projects applying transdisciplinary research within natural resources management exist. One example under several is the *follow the innovation* approach (Hornidge et al. 2009) and its application in the project “Economic and Ecological Restructuring of Land and Water in the Khorezm Region of Uzbekistan” carried out by the Center for Development Research (ZEF), University of Bonn, in cooperation with UNESCO, the State University of Urgench and the German Aerospace Center (DLR) at the University of Würzburg (Hornidge and Ul Hassan 2010; Ul Hassan et al. 2011, Hornidge et al. 2011).

Since we consider IWRM as a transdisciplinary problem field, its success depends on the application and combination of systems, target and transformation knowledge as described by Pohl and Hirsch Hadorn (2007) for TR. However, a real integration is frequently impeded by various issues, e.g. by the division of work, which normally occurs in practice, and the potentially resulting disciplinary and/or political differences. That means that the integration of the three types of knowledge is obstructed by *boundaries*, e.g. between disciplines, but also between science and other stakeholders and decision-makers (qv. next chapter). However, we should not neglect the other boundaries relevant for IWRM as physical, administrative, and sectoral boundaries. All these mentioned integration problems are particularly relevant for IWRM. As described earlier and by many authors (e.g. Hooper et al. 1999; Falkenmark et al. 2004; Mostert et al. 2008) a full integration of all water related tasks within an “IWRM body” is not feasible, but instead, cooperation across the ever existing boundaries should be realized. There exist several concepts for implementing cooperation, e.g. the concept of social learning and its integration into adaptive water management as described by Pahl-Wostl et al. (2007), social learning as key for IWRM as reasoned by Mostert et al. (2008), transdisciplinary concepts as mentioned above (Pohl and Hirsch Hadorn 2007), or boundary crossing frameworks for natural resources management based on transdisciplinarity (Mollinga 2008; Hornidge et al. 2009). We refer to the insights of the seminal work by Pahl-Wostl and colleagues (qv. chapter 3.1.17 on adaptive management); however, we focus more on cooperation as one part of boundary management within a transdisciplinary concept. Drawing on experiences from transdisciplinarity for IWRM studies seems worthwhile, because (i) resolving integration problems is central to transdisciplinarity (Jahn 2008), and (ii) transdisciplinarity includes boundary management (Mollinga 2010).

Additionally, transdisciplinarity is inherently related to capacity development since it facilitates collaboration, provides mutual learning of actors and it provides knowledge on complex interrelationships. For Scholz (2011) transdisciplinarity is a means for capacity development. And he even mentions that capacity development[33] is the key function of transdisciplinarity (Scholz 2011): There is knowledge exchange between scientists (theoretical know-how) and practitioners (applied know-how and experiences), it can improve environmental awareness, and it combines learning and research. This correlates with the evidence that capacity development can be seen as a key factor for natural resources management, and especially for water resources management as reasoned by Alaerts et al. (1991), Alaerts (2009), Salamé and van der Zaag (2010), Leidel et al. (2012), Wehn de Montalvo and Alaerts (2013) and others authors.

Consequently, connecting IWRM and capacity development under a "transdisciplinary umbrella" is promising for strengthening sustainable water resources management. Thus, the IWAS project did research on how to strengthen IWRM by disciplinary research within an interdisciplinary research team that strongly works together with local actors and conducting capacity development and knowledge exchange. Consequently examining how transdisciplinarity can improve IWRM in general, as well as conducting an embedded case study in the Western Bug River Basin, Ukraine.

In a first step, IWRM and capacity development concepts were analysed and linked together (Leidel et al. 2012). Based on that and studies in Mongolia, we derived first insight regarding transdisciplinarity and knowledge transfer gained from the two case studies on integrated water resources management in Ukraine and Mongolia (Sigel et al. 2014). After having first empirical results, the second step was to address the challenges of transdisciplinary integration in detail. One feasible solution within literature on transdisciplinary research is to develop a boundary crossing framework including boundary objects, concepts and settings for facilitating the crossing of different types of boundaries (Mollinga 2010). Accordingly we developed such a framework for IWRM within chapter 8, respectively within Leidel et al. (2014).

[33] Scholz 2011 uses the term capacity building. However, we stick to the nowadays frequently used term capacity development (qv. chapter 7.3.1).

4.3 Boundary management

Boundaries are manifold in resources management and are described by several scholars (Guston 2001; Cash et al. 2003; Mollinga 2008; Mostert et al. 2008; Mollinga 2010)[34]. Obviously, there are the natural boundaries e.g. between surface water and groundwater, or between land and water resources, as well as administrative boundaries, e.g. between government levels and political boundaries between different policy sectors. And there can also be boundaries between different spatial and temporal scales and levels as described in chapter 3.1.4. Further boundaries are the cognitive boundaries between different scientific disciplines, between experts and decision-makers, between experts and laymen or between scientists and practitioners. This is related to boundaries between knowledge and action, as well as to socio-economic boundaries as for instance between different actor groups (e.g. between government and NGOs, trade unions, etc.). The number and kind of boundaries depends on the conducted project.

These boundaries have to be crossed for sustainable resources management, i.e., in a figurative sense, bridges or gateways are needed. We perceive boundaries as cross-scale challenges, which can be approached according to Cash et al. (2006) by "bridges" like institutional interplay, co-management and/ or boundary organisations.

Boundaries mirror the above mentioned challenges of integration within transdisciplinarity (e.g. different "languages", different expectations, perceptions, and objectives; chapter 4.2.1). As a matter of fact, transdisciplinarity attempts to cross the boundaries between different disciplines and between science and practice. That means that boundaries have to be managed ("boundary work"), and especially that they have to be managed in such a way that salience, credibility and legitimacy of the exchanged and developed knowledge are simultaneously improved (Cash et al. 2003). *Credible* means that the information is scientifically relevant, *salient* means that the action is relevant to the stakeholders, and *legitimate* means that the knowledge has been produced by acknowledging all different perceptions of the different stakeholders and an unbiased balancing of interests (Ibid.).

The function of boundary management is to reduce the integration problems of transdisciplinarity within man-environment systems as described in chapter 4.2.1. This can be done by enhancing the communication, translation (mutual understanding) and mediation between separated groups with boundary spanning institutional mechanisms like organisa-

[34] Boundary and boundary crossing are frequently used metaphors (e.g. Gieryn 1983; Star and Griesemer 1989; Klein 1996; Mollinga 2008)

tional arrangements and procedures (Ibid.). Yet, the essential question is, *how* such a boundary crossing can be realized. Examples from literature are arranged around boundary objects introduced by Star and Griesemer (1989) that should facilitate the collaboration between two parties. Guston (2001) argue that additional opportunities and incentives for the development and use of boundary objects are important, so that he proposes to develop boundary organisations that have rules and procedures for carrying out their tasks at the interface between social actors. Mollinga (2008) reasons that boundary objects and conditions and arrangements for its use, and in particular for the complete boundary management, are needed (boundary settings). But additionally, he mentions that boundary concepts are needed, and he refers to the interaction between boundary objects, boundary settings and boundary concepts as boundary work (Mollinga 2008). This triad is according to Mollinga (2010) essential for dealing with the complexities of natural resources management. This emphasizes that crossing boundaries is not happening automatically, but on the contrary, it needs significant efforts and work (Mollinga 2008; 2010).

4.3.1 Boundary concept

A boundary concept is a concept that refers to the same object or process within different actor groups or disciplines, but with different dimensions and thus meanings of the object or process (Mollinga 2010). Thus, it is essential to analyze interdisciplinary the different dimensions of the object and to understand the interrelationship between these dimensions and the different meanings within the different actor groups. Examples are the concepts of risk and vulnerability, ecosystem services or capacity development. Mollinga (2003) mentions *water control* as a prime example, since there are different yet interrelated dimensions with different meanings about the term. It can be understood as technical control of physical processes, as organizational control of water related management activities, or as political and socio-economic control of water related social processes. A boundary concept thus facilitates the re-integration of the different abstractions and allows the reasonable utilization of these different meanings (Mollinga 2008). Boundary concepts can also be used within policy making for integrating different aspects, e.g. IWRM. The different perceptions towards IWRM must not be seen as a disadvantage, but rather as an advantage, because it can be negotiated how these different meaning can be operationalized (Mollinga 2006). So, IWRM is a flexible concept as well as a flexible framework and not a dogmatic manual at the operational level (Leidel et al. 2012). The relevancy of IWRM lies in the constructive interaction between different interests, where in each case a negotiation process leads to the tailoring of a context-specific concept. Obviously, different stakeholders will have different perceptions about IWRM and perceiving their opinion as the proper understanding of IWRM, leading to boundaries (Mollinga 2006).

4.3.2 Boundary object

In order to forward scientific knowledge to decision-makers, procedures have to be elaborated that support the integration of knowledge into the decision making process for approaching inter- and transdisciplinarity, i.e. in plain words, how to make the knowledge work in practice. One possibility is the use of boundary objects.

Boundary objects are situated between different social worlds as a "means of translation" between them, i.e. that it is adaptable to the purposes of *all* involved actors without losing their identify (Star and Griesemer 1989). Boundary objects can be abstract or concrete and are items for crossing boundaries, e.g. procedures, institutions, organisations, (technical) devices, computer programmes, people and organisations. A simple but striking example is provided by Guston (1999 in Guston 2001), who mentions that a *patent* can be a boundary object, since it serves the scientist in fostering his research and it also serves the politician to measure research productivity.

Further concrete examples for boundary objects related to natural resources management are reports, models, scenarios, frameworks, joint protocols, indicators, maps, databases, decision support systems (Cash et al. 2006) and should provide "the knowledge for doing" Mollinga (2010). Boundary objects improve (i) credibility by contribution of several experts, (ii) salience, because the practitioners are present from the very beginning thus collaborating in describing objectives and needed information, and (iii) legitimacy, because it makes the information generation more transparent to the stakeholders (Cash et al. 2003). However, simultaneously addressing all three factors adequately represents still a challenge (Ibid.). Turnhout (2009) argues in a study on ecological indicators as boundary objects that boundary objects can only connect social worlds that are similar, i.e. share common values and preferences. Likewise, boundary objects rely on voluntary collaboration between the different actors, so that boundary objects appear to be essential but not sufficient for a comprehensive boundary management that improves the integration between different stakeholders.

Mollinga (2008; 2010) mention that there are typically three strategies associated with boundary objects i.e. means for developing a boundary object:

- analytical route with models as boundary objects

- assessment route with frameworks as boundary objects
- participatory route with processes and people as boundary objects

4.3.2.1 Analytical route

The analytical route applies analytical methods and uses modeling approaches for understanding the behavior of complex systems. The basic idea behind modeling in natural resources management is to represent and simulate the components of a system like a river basin. Eventually, "if-then" questions can be asked to evaluate for example the impacts of certain activities or interventions (e.g. the different impacts of human activities on groundwater pollution). This strategy is widely used in science, and especially in natural and engineering disciplines for disciplinary as well as interdisciplinary studies. Models are eventually utilized as decision support systems including scenario development and to simulate different scenarios (e.g. several different options for improving the cleaning capacity of WWTPs). Yet, several authors (e.g. Stephens and Middleton 2002; Guipponi et al. 2007; Mollinga 2008; Diez & McIntosh 2009; Stewart 2014) mention that not many developed DSS are used in practice at least in developing countries, especially because the model development process is frequently science driven and not user driven. Diez & McIntosh (2009) identified best predicting factors for the usefulness of information systems which are user participation, user perceptions/ intentions, user computer experience, top management support, support and training, external pressure, professionalism of the information system unit, and the availability of external sources of information. Thus, it can be concluded that the credibility of the models and DSS is assured (scientific output); yet, salience and legitimacy are not considered adequately. And especially scientists often consider models as neutral and objective devices, which is, at least for models used at the interface between science and policy, not valid. There, models should be rather considered as mediators, i.e. boundary objects, according to Mollinga (2010), because they integrate different types of knowledge and (policy) objectives for solving complex and contentious issues within the decision-making process. And Cash et al. (2003) show that one function of effective knowledge systems is negotiation and mediation. This view implies that also participatory processes need to be integrated for assuring salience and legitimacy as explained below in the assessment and especially in the participatory route.

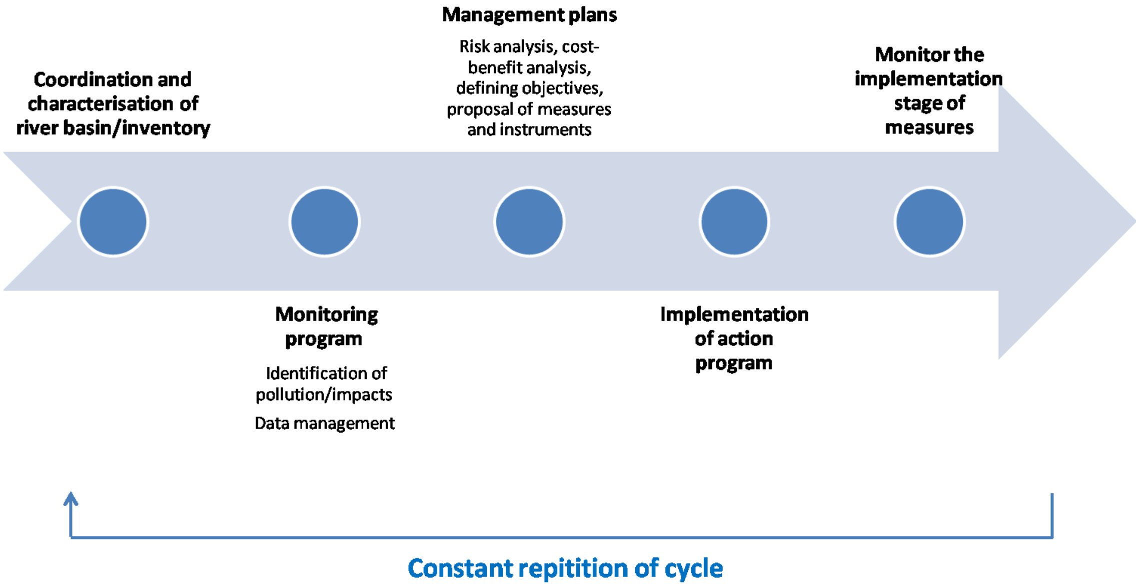
It can be seen that the analytical route including modeling is a valuable component delivering credible scientific results that can be used for decision making and for closing the gap between science and policy. Yet it is frequently not a sufficient component for integrating knowledge into the decision making process, because the uptake of scientific knowledge by other actors (or users of a DSS) is often limited. Hence, for overcoming these obstacles other strategies are necessary.

4.3.2.2 Assessment route

Within the assessment route, (assessment) frameworks serve as boundary objects, which is a very common strategy for realizing integration in natural resources management (Mollinga 2010). Frameworks can be considered as means and tools for several activities towards problem solving, like the support of data collection and analysis, assisting in planning and decision making (together with the participatory strategy), or for learning and knowledge exchange.

Instead of trying to fully represent all processes as normally within a scientific model, frameworks attempt to simplify the relations by only showing the main characteristics and processes. Hence, they are generic concepts that are not particularly used for improving scientific credibility, but they are especially used for supporting the understanding of complex relationships (learning) and for decision making. Accordingly, frameworks have black-boxes as e.g. all the points and interactions mentioned within the simplified process scheme we used for the national decision makers within the Ukrainian case study for explaining in principle the necessary generic steps of river basin management (Figure 14). Further, more detailed frameworks have been elaborated within the case study for different purposes (e.g. Figure 25: Multi-level approach of capacity development Figure 28).

Figure 14: Process of river basin management



Frameworks have to be tailored to the involved actors and have to be as simple as possible; however, it has to be as scientific as necessary, so that all disciplines and actors can work with this abstraction. Their function is therefore to link different kinds of knowledge and different actors (e.g. science and policy) so that frameworks constitute typical boundary objects (Mollinga 2010).

Frameworks or assessment frameworks can be considered as practical tools for supporting decision making, as e.g. environmental impact assessments often use a framework as boundary object including protocols, procedures, indicators and matrices for considering various types of information (Mollinga 2010). Frameworks are appealing for decision makers because of their simplicity, but this simplicity also has the disadvantage of potentially having a bias and they do not assure necessarily the participation of all relevant actors.

4.3.2.3 Participatory route

Thus the third strategy, the participatory route, focuses more on social processes for knowledge integration into the decision making process meaning that processes and actors (and the organizations and institutions they form) are considered as boundary objects (Mollinga 2008; 2010). The development of knowledge has to focus explicitly also on social learning and negotiations, respectively mediation between conflicting parties (Pahl-Wostl 2002). Yet, this part is often lacking in the other analytical and assessment strategies, where the knowledge is developed externally *before* the decision making starts (Mollinga 2010). In the participatory route, the knowledge is generated *within* the decision making as a process of continuous and mutual learning (Mollinga 2010). This continuous learning and adapting is essential, since the man-environment system is constantly changing with manifold inherent uncertainties. Therefore, capacities are essential, respectively need to be developed, so that the societal actors can address and resolve future issues. The capacities needed include human, organizational and governance capacities, as well as information (generation). The objective is to develop transformation knowledge, i.e. to have the know-how to change existing practices and to have institutions in place that allow responding adequately to emerging challenges. It is accordingly related to action research, transdisciplinarity as well as capacity development concepts and adaptive management (qv. chapter 3.2.4 and 3.1.17).

Several methods and procedures (qv. Coordination mechanisms, chapter 3.1.16) are available for facilitating participation and for mediating between different interests, inter alia round table discussions, focus group discussions, empowerment, dialogue, participatory workshops, capacity assessment workshops, (river basin) councils, hearings, working or steering groups, (regional) conferences. In this respect also participatory modeling should be mentioned, i.e. that models are developed jointly by scientists and users, respectively that model building tools are available that facilitate the use of models for the stakeholders without needing programming skills. Such a joint development of models or databases will increase users' confidence in the model and its results, because the users know the system and its limitations, so that ownership towards the model will be high. Yet, as mentioned in Leidel et al. (2014), the integration of actors into the model conception and the model-based systems analysis may be a difficult task (especially in short term projects up to 3-5 yrs.), depending on the existing modeling know how of the actors and depending on the complexity of the issue, the modeling software and the data processing.

4.3.2.4 Boundary object for transdisciplinary management

All three strategies have their disadvantages if used as stand-alone strategy, but could benefit from each other, so that converging the three routes seems plausible according to Mollinga (2008). The convergence of the three strategies is a reasonable way of merging credibility, salience and legitimacy of the exchanged and developed knowledge.

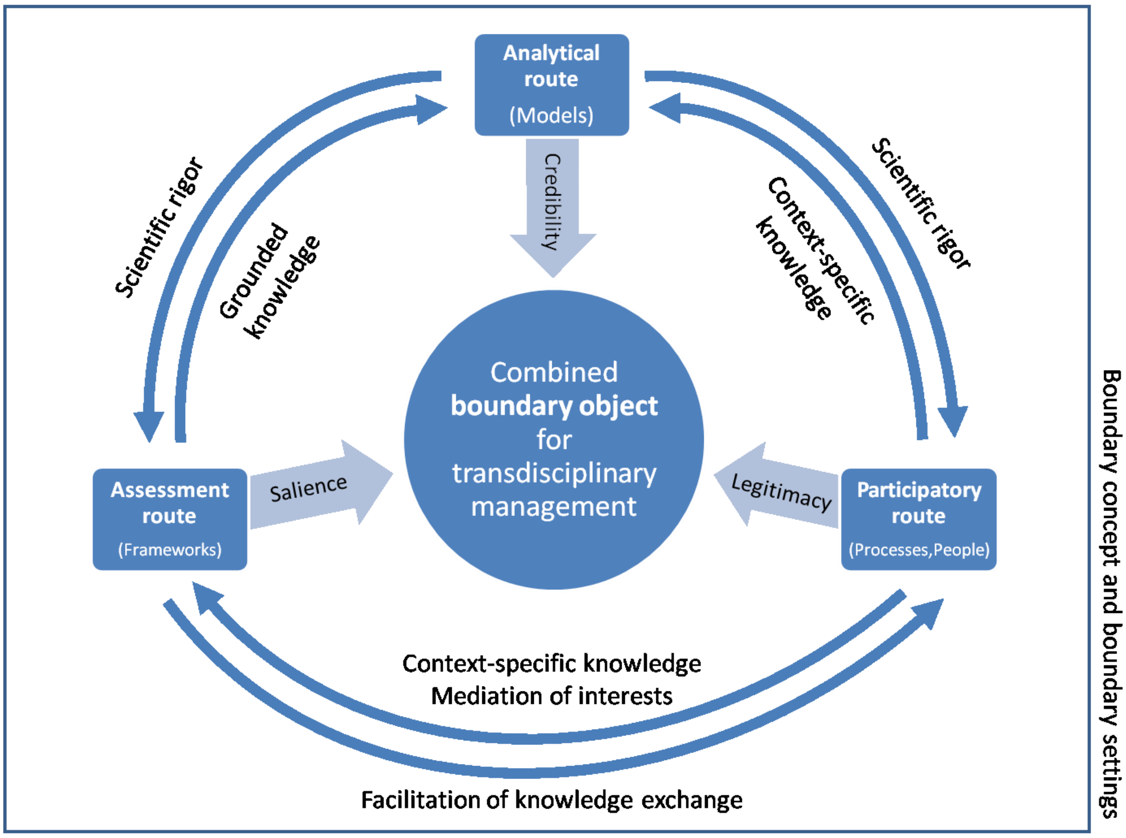
The assessment and participatory route could benefit from insight into the complex processes of the natural resources systems (credibility), which can be generated within the model-based systems analysis of the analytical route (Mollinga 2008). It can further support the other two strategies by generating results for different scenarios and thus demonstrating scientific credible results to other actors within decision making, e.g. the impacts of certain activities or interventions on the trophic state of a lake. Mollinga (2008) further mentions that the participatory strategy can support the assessment route by integrating all relevant actors with their context-specific knowledge and by negotiation and mediation between different perceptions and conflicting interests. This strengthens salience and legitimacy of the knowledge development. The participatory and the assessment routes can strengthen the analytical route by providing context specific grounded knowledge as mentioned by Mollinga (2008), which can support and extent the analysis by additional data and information, and eventually improving the performance of the model. And it allows verifying whether analysis goes in the "right" direction, meaning to focus on relevant objectives that are legitimated. This again strengthens salience and legitimacy.

Yet, the three strategies are associated with different policies, disciplines and attitudes, which makes the convergence difficult according to Mollinga (2008). Also Cash et al. (2003) mention it is still a challenge to address credibility, salience, and legitimacy simultaneously and adequately. However, overcoming such obstacles is the task of transdisciplinary management. We attempt with our approach to combine the three different strategies into one boundary object, so that credibility, salience and legitimacy are assured and eventually the water resources management is strengthened (Figure 15).

4.3.3 Boundary settings

Boundary settings basically describe that project settings as well as favourable governance conditions are additionally important for addressing credibility, salience, and legitimacy within resources management (Mollinga 2008; 2010). The first describes how a project is organized including descriptions of and separation into work packages, and how project internal communication between participants assures interdisciplinary work. The latter relates to the conditions and institutional arrangements of the enabling environment towards successful boundary management, e.g. the access to information. Three factors are needed, namely treating boundary management seriously, accountability to all parties across the boundaries as well as the utilization of boundary objects (Cash et al. 2003).

Figure 15: Boundary object for transdisciplinary management



Mollinga (2008) argues that boundary management is no automatic process, but it needs a considerable amount of work and careful design of the procedures and structures. Therefore, institutions like boundary organizations or other kinds of boundary managers could be a reasonable support.

4.3.3.1 Boundary organisations

Boundary organisations are organisations, persons or other institutional mechanisms acting at the interface between two scales as science and politics (Guston 2001). Boundary organisations

(i) provide opportunities and incentives for the development and use of boundary objects and facilitate that information is coproduced by different actors from both sides of the boundary within the boundary object,

(ii) involve actors from different sides of the boundary and mediating actors for managing the boundary,

(iii) exist at the interface between two different social worlds of politics and science, but which are accountable to each other (Guston 1999, 2000 in Guston 2001; Cash et al. 2003).

These points show that leadership is a key function of boundary organizations, i.e. that facilitation and coordination skills are highly necessary for boundary management (Cash et al. 2006). Well-functioning boundary organisations develop rules, procedures and norms for accomplishing their tasks (Cash et al. 2003).

It is also necessary for a functioning boundary organisation that authority is delegated from the actors across the boundaries to the boundary organisation, thus, drawing on the principal-agent theory and its resulting problems as described in chapter 3.1.15. Accordingly, the boundary organisation is responsible and accountable to all principals it has, yet addressing issues differently towards each principal (e.g. science and policy).Therefore, boundary organisations display, in a figuratively positive sense, a Janus-faced[35] process meaning that several perspectives can be considered simultaneously.

A boundary organisation provides the possibility to the parties on both sides of the boundary to participate and to shape the joint process according to their perspectives (Guston 2001). Since a boundary organisation is responsible to all involved parties (principals), the interests are balanced, and the risk that one party considers the boundary organisations prejudicial is reduced (Guston 2001). Summarizing, boundary organisations favour coproduction, i.e. the simultaneous production of knowledge and social order (Jasanoff 1996 in Guston 2001), by bringing together scientists and non-scientists and generating boundary objects (Guston 2011). Thus, they stabilize the relationship e.g. between science and policy. Boundary organisations can be designed as a specialised intermediary organisation (e.g. a river basin organisation or international commissions; a decision centre as describe by White et al. (2008) for the water management in Phoenix, USA) or integrated into a broader organisation. But investigations from Cash et al. (2003) showed that they do not necessarily be formal organisations or a unique organisation, but can also be individuals or several organisations that conduct boundary functions. It is conceivable that e.g. working groups between authorities or informal groups take over boundary functions, yet legitimacy has to be ensured. A challenge in this respect is to evaluate the boundary management potential of organisations, groups and individuals. Especially scientists, however, often underestimated the workload of the boundary management, i.e. that they (i) attempt to do the boundary work next to their research activities, and thus (ii) often take boundary management not seriously (enough).

[35] Janus is the Roman god of transition, often depicted with two faces opposing each other, meaning that an issue is considered from different perspectives. Janus-faced is nowadays often a symbol of ambivalence and used in a somewhat negative sense.

Successful boundary management depends therefore not on the organisational form but according to Cash et al. (2003) on how the three following factors are carried out. Most importantly, the boundary management has to be taken seriously, i.e. communication, mutual understanding and mediation have to be done continuously and frequently so that credible, salient and legitimate knowledge is produced. A positive example for that is the boundary organisation Pacific ENSO[36] Applications centre (PEAC) that connected inter alia climatologists, water management, and agriculture and coordinated the development of forecasting tools linking global climate models with e.g. hydrological models (Cash et al. 2003). A negative example of the same field is the Southern African ENSO forecasting system, in which no boundary organisation was created, but in which the coordination was distributed between several agencies resulting in lower communication, translation, and mediation and consequently also in less effective model coupling and forecasting tools (Cash et al. 2003). Furthermore, the accountability of the boundary managers to the actors on both sides of the boundary is also important; since it assures that the interests of both actors are respected (Ibid.). And as mentioned above, it is essential to use boundary objects for developing jointly knowledge based on insights from both sides of the boundary, e.g. scientists and practitioners.

Therefore, *effective* boundary organisations facilitate what the multiple actors involved in sustainable resources management perceive under credibility, salience and legitimacy (Cash et al. 2003).

4.3.4 Transdisciplinary management

As mentioned, the function of boundary management is to reduce the integration problems of transdisciplinarity within man-environment systems (integrated water systems). Therefore, we propose to define and use the term transdisciplinary management that integrates the concepts of transdisciplinarity, boundary management with a converged boundary object and capacity development. First of all, transdisciplinary management instead of transdisciplinary research is preferable, because it acknowledges that the transdisciplinary process should not be fully science driven.

Transdisciplinary management is an adaptive process that facilitates sustainable natural resources management, e.g. the management of integrated water systems, on several levels of management (local, regional, national). It emphasizes the integration of scientists, practitioners and other relevant actors and thus that knowledge from several sources is the basis for

[36] ENSO stands for El Niño/Southern Oscillation.

management options. It acknowledges that crossing boundaries (scales) for knowledge integration is an active work, which needs adequate boundary concepts, boundary settings and especially boundary objects integrating analytical, assessment and participatory strategies. This assures that the developed options are scientifically robust, context-specific and can support decision making and capacity development.

5 Methodological framework

Methodology is the general research strategy that describes how research is conducted and it constitutes the basis for the methods to be used. Corbin and Strauss (2008) define methodology, in a somewhat social science oriented sense, as "a way of thinking about and studying social phenomena". I will stick to the more striking definition by Morgan (2007), a proponent of pragmatic approaches, that the methodology "connects issues at the abstract level of epistemology[37] and the mechanical level of actual methods". This implies that the methodology is the interface between the theoretical and the conceptual framework *and* the methods needed for implementation of research. Accordingly, this thesis differentiates between methodology and methods, with the first comprising the complete research set-up and the latter being the means for gathering and analysing data.

This thesis is embedded within a research project (International Water Research Alliance Saxony-IWAS; funded by the German Federal Ministry for Education and Research), where basic research and applied research is combined, however the focus lies on applied research.

5.1 Methodology of applied research

Basic research means according to Hedrick, Bickman and Rog (1993) that universal knowledge is developed (knowledge production), where usually mono-disciplinary statistically significant effects are discovered (focus on research purposes). Applied research uses knowledge and attempts to understand, address and contribute to solving problems and thus discovering practically significant relationships (Hedrick, Bickman and Rog 1993). Maxwell (1998) similarly states that the focus of applied research lies on practical purposes (e.g. goal achievement), yet research purposes are a necessary precondition for understanding the issue. Since applied research often approaches several questions simultaneously, both, statistically *and* practically significant effects are essential, and therefore it is often conducted within a multidisciplinary research team as emphasized by Hedrick, Bickman and Rog (1993). However, the interdisciplinary collaboration between different scientific disciplines still needs to be strengthened, especially because of difficulties in combining different research methodologies, e.g. case-based research versus experimental research (cf. Mollinga 2008; Lang et al. 2012). Actually, even within social sciences, the application and purpose of existing research methods like experiments, surveys, case studies, or history is

[37] Epistemology is a Greek term and means "study of knowledge". That means it deals with questions about the nature of knowledge, as well as about how to generate knowledge. For example the verification of hypotheses can be considered, in plain words, as the epistemology of natural sciences.

heavily discussed. In former times, some social scientists have been under the misconception that case study research is only possible for exploratory purposes and doubt that case studies can be used for descriptive and explanatory studies (Yin 2009). Despite this, Yin (2009) made a good case for the possibility of using all methods for the three research purposes namely exploratory (what questions), descriptive (what, how many) and explanatory (how/why questions).

Hedrick, Bickman and Rog (1993) further state that the research focus and criteria for the practical significance within applied research needs to be discussed with the actors that have a stake in the research outcomes. Thus, applied research wants to deliver results that are of societal importance. Nevertheless, a major question is still *how* to interact effectively with these actors and *how* to approach social importance. Accordingly, the concept of **transdisciplinary research** and the concept of **boundary objects** is utilised within this thesis as a theoretical framework for the developed methodology (chapter 4).

Applied research is often conducted in a complex environment, which makes it difficult for researchers to analyse causal relations. Some scientists contest that causal explanations can be derived by qualitative methods, yet, an increasing number of researchers (e.g. Miles and Huberman 1994, Mohr 1996 in Maxwell 1998) acknowledge qualitative analysis as credible method for identifying causal relations having the same validity threats as quantitative research. Furthermore, such an open environment can be challenging, because it cannot be controlled by the researcher, so that problems e.g. concerning data acquisition or the exchange of responsible persons in the government may impede research activities as for instance within the case study on the river basin management in the Western Bug River Basin (chapter 7 and 8). Bickman and Rog (1998) further state that "theoretical opportunism" is a characteristic of applied research, meaning that only such theories are used that will most likely deliver practical results, as well as combining several theories, if it seems useful. In the realm of this thesis, several theories have been considered and combined in order to obtain realistic results. Moreover, for applied research it is more important that the outcome is valid. This is evident, because it is mostly impossible to identify the independent cause from other causes in analysing societal problems (Bickman and Rog 1998). E.g. within a study on the effects of a development project for improving water quality in the effluent of a WWTP, it is difficult to isolate single aspects of the project that are responsible for the outcomes, like leadership training for WWTP operators. Above that, Bickman and Rog (1998) mention that for describing a societal complex problem in a realistic and credible way, not only self-reports and simple evaluation forms of stakeholders are necessary, but more important also real-world measures directly related to the problem like the analysis of the interaction between stakeholders or institutions. Hence, multiple levels of analysis prevail, e.g. on individual, organisational and societal level as inter alia described for capacity development by Lopes and Theisohn (2003) and Visser (2010), respectively for integrated water systems by Alaerts (2009) and Alaerts and Kaspersma (2009).

5.2 Qualitative and quantitative research

Research is often distinguished between *qualitative and quantitative analysis* in natural sciences and especially in social sciences. Denzin and Lincoln (2000) describe that qualitative research is "cross-cutting disciplines" and a "complex family...of terms, concepts". Corbin and Strauss (2008) for instance, define qualitative analysis as "a process of examining and interpreting data in order to elicit meaning, gain understanding, and develop empirical knowledge". Qualitative methods are frequently related to the collection and analysis of written and oral data or the observation of situations without quantifying the studied phenomena statistically. Qualitative research is therefore described by Cassell and Symon (1994) as having "a focus on interpretation rather than quantification; an emphasis on subjectivity rather than objectivity; flexibility in the process of conducting research; an orientation towards process rather than outcome,..., an explicit recognition of the impact of the research process on the research situation." However, qualitative research is often contested and considered as "soft science" in comparison to "hard sciences" like physics, and it is considered subjective or even unscientific by positivistic academic disciplines (Denzin and Lincoln 2000).

Quantitative analysis refers to numeric data and is according to Cassell and Symon (1994) based on the assumption that an objective reality exists, which can be analysed by scientific methods in order to develop systematic and statistical relationships between variables. According to Tashakkori and Teddlie (1998, 2010) there is an ongoing debate since decades between the positivist/ empiricist paradigm with underlying quantitative approaches and the constructivist/ phenomenological paradigm with the underlying qualitative approach. This debate also includes the thesis that quantitative and qualitative methods are incompatible, because of the fundamental differences between the underlying paradigms, i.e. positivism versus constructivism (Tashakkori and Teddlie 2010). The positivist approach is characterized by deduction, i.e. testing hypotheses for generating theory, the major epistemology of natural sciences. The constructivist approach is characterized by induction, i.e. theory is developed based on collecting and analysing quantitative data, as for instance the grounded theory by Glaser and Strauss (1967). Cassell and Symon (1994) tellingly mention that quantitative analyses are good at assessing changes that occurred, but for analysing how changes occurred (involved processes) as well as why (stakeholder, context) qualitative research is needed.

5.3 Mixed methodology

Tashakkori and Teddlie (2010) reject that it is inappropriate to mix quantitative and qualitative analysis. Instead, they state that there is a growing amount of scientists (e.g. Yin 2009), who demonstrate the compatibility between both approaches and refer to this new paradigm as pragmatism. Already Burgoyne (1994), for instance, mentions that next to qualitative approaches within stakeholder analysis, also quantitative methods could be used, since it is reasonable "to count the countable". In fact, Tashakkori and Teddlie (2010) call for paradigm pluralism, i.e. that divers paradigms can constitute the basis of mixed methods research. They further state that there is no "either-or" between paradigms, but that they can be used continuously and they call for a cooperation instead of confrontation between the different methodological communities. Thus, mixed methodology or mixed methods emerged that contain qualitative and quantitative analyses (e.g. Patton 1990, in Tashakkori and Teddlie 1998). Johnson et al. (2007) compared meanings of several experts working in mixed methods research (MMR) and composed a definition out of it: "mixed methods research is the type of research in which a researcher or team of researchers combines elements of qualitative and quantitative research approaches…for the broad purposes of breadth and depth of understanding and corroboration". Johnson and Onwuegbuzie (2004) define MRR similarly, but emphasize that techniques, methods, approaches and concepts are mixed within a single study. In fact, already Lewin (1946) in his seminal work on action research called for an integrated approach to social research that includes e.g. surveys and interviews as well as laboratory and field experiments, thus setting in my opinion the groundings for MMR. Yet, Lewin (1946) further stated that diagnosis (e.g. surveys) does not suffice, but action and eventually evaluation about the results is needed, i.e. research must lead to action. This exactly delineates the transdisciplinary framework of my research of combining MMR in a case study with action research.

Several authors like Johnson et al. (2007) realise the importance of mixed methods research and proposed that it is the third research paradigm next to qualitative and quantitative research.

5.3.1 Characteristics of mixed methods research (MMR)

A characteristic shown by Tashakkori and Teddlie (2010) is about the diversity of MMR, i.e. that conceptual as well as empirical research can be conducted and MMR can address several research questions simultaneously, e.g. exploratory and explanatory ones. They further state that MMR stems partially from triangulation literature (convergence of evidence), yet, it is also essential to acknowledge that divergent results from combining data from different sources is important, since it can deliver interesting insights in complex conditions. Greene et al. (1989) explain that there are five purposes of MMR, (i) triangulation (seeking convergence), (ii) complementarity (analyse overlapping and differences of a phenomenon for enriched understanding and clarification), (iii) initiation (discovering contradictions leading to modified research questions), (iv) development (using methods sequentially to develop or inform the following method), (v) expansion (expand range and breadth of research by using different methods for different inquires). Consequently, mixed methods are particularly suitable for addressing complex research questions (Yin 2009). Tashakkori and Teddlie (2010) argue that mixed methods means that the "best" methods should be chosen for the research questions, yet, they emphasize that purely qualitative or purely quantitative research are reasonable research strategies depending on the focused research question. Notwithstanding, using a single method within applied research may not cover the full complexity and thus may deliver, in the worst case, wrong results (Mertens 2007). One very essential characteristic of MMR is its iterative, cyclic nature including both, deductive and inductive logic in the same research study (Tashakkori and Teddlie 1998; 2010). That means that research cycles from empirical results (e.g. from interviews) through induction to inferences about theory or generalisation, then from theory through deduction to tentative hypotheses or predictions of events or results (Tashakkori and Teddlie 2010). It is not important, where the research starts, either starting with theories or with data collection/ observations, yet, Tashakkori and Teddlie (2010) assume that MMR cycles fully at least once.. These deductively and inductively emerging findings are the starting point for another research cycle, where deeper understanding of the phenomena is explored (Tashakkori and Teddlie 2010).

Johnson and Onwuegbuzie (2004) reason that MMR also uses abductive logic, which is the third type of logic next to deductive and inductive logic. Abduction is mainly based on ideas of Peirce (1974), who argues that observed (surprising) events should be attempted to explain by the development of hypotheses. This third logic is contested; however it is integrated in pragmatism as for instance in Morgan (2007).

The central question of MMR is how to combine quantitative and qualitative analyses. Teddlie and Yu (2007) distinguish five types of mixed methods (MM) sampling strategies for a MMR design based on a review of studies that used MM:

- basic MM sampling strategies (e.g. purposive random sampling)
- sequential MM sampling (information from first sample is required for second sample, sequential use of quantitative and qualitative analysis or vice versa)
- concurrent MM sampling (simultaneous use of quantitative and qualitative analysis, yet both sampling procedures are independent and allows to triangulate)
- multilevel MM sampling (common for examining nested units of analysis as e.g. in organisations. An example from my study would be the analysis of the following nested levels: national water legislation and administration, water authority, employees of the authority)
- sampling using multiple MM sampling strategies (the four above mentioned types are a simplification, since frequently a mixture of these types occur. E.g. sequential MM sampling does not describe the unit of analysis, respectively the potential application in multiple units; in contrast, multilevel MM sampling focuses on multiple levels of analysis, yet it is not based on the differentiation between quantitative and qualitative analysis).

Creswell (2008) mentions another mixed method strategy next to sequential and concurrent MM, namely transformative mixed methods, which can use a sequential or a concurrent approach. The difference is that transformative approaches have an overarching theory that constitutes the framework for topics, methods and anticipated changes of the study (Creswell 2008). Moreover, Creswell (2008) mentions that *multiphase combination timing* exists, i.e. that multiple phases (sub-studies) of a project exist that combine e.g. concurrent and sequential elements.

One critique of MRR is that mixing should be done only *within* a paradigm. However Morgan (2007) deconstructs the term paradigm and suggests a *pragmatic approach* with the methodology at the centre. Morgan (Ibid.) further states to apply pragmatic concepts like abduction instead of deduction/induction or transferability instead of context/generalisation. Furthermore, there are different paradigms or conceptual stances within MRR, e.g. the *a-paradigmatic stance* that assume that paradigms are unimportant for applied research in real world context or *substantive theory stance* that supposes that theoretical frames are more important than philosophical paradigms (Tashakkori and Teddlie 2010). Another example would be the *complementary strengths stance* that assumes that MMR is feasible, but that the different methods must be kept separate as much as possible so that the paradigmatic strength of each method can evolve *or* the *dialectic stance* that assumes that the use of several paradigms improves understanding (Ibid.). The *alternative paradigm stance* as for instance pragmatism emphasizes the mix of methods and is particularly not convinced of any incompatibility between paradigms (Ibid.).

5.3.2 Cross-disciplinary applications of MRR

MMR can be therefore used for cross-disciplinary applications as substantiated by Tashakkori and Teddlie (2010). Interesting mixtures can occur, as for instance mixing GIS and qualitative software (Fielding and Cisneros-Puebla 2009). Yet, apart from this example, the application of MMR as interdisciplinary methodology between natural sciences and social sciences is not common. Creswell (2010) sees an emerging trend in using MMR within several disciplines and across disciplines, however, in his "mapping of the MMR landscape" no further example in the field of environmental sciences is depicted, apart from the GIS-example from Fielding and Cisneros-Puebla (2009). One similar example is from Nightingale (2003), where she uses on the one hand aerial photo interpretation, triangulates results with vegetation inventory (quantitative analysis), and on the other hand oral histories that are triangulated with data from participant observations (qualitative data). In accordance with the purposes of MMR from Greene et al. (1989), Nightingale (2003) mentions that both research strings do not have to be triangulated necessarily for the interpretation of the overall results, but that one result can inform the other result for comparison or contradiction.

Mertens (2007) strikingly demonstrates the strength of combining qualitative and quantitative methods within research that is both, conducted in difficult socio-economic and political context and should potentially constitute the basis for sustainable change. As an example, she describes that qualitative analysis is needed to collect the perspectives of actors at each stage of the research process, while the quantitative dimension delivers outcomes that are credible for the actors (Ibid.). That means that mixed methods are essential for understanding complex settings and for delivering credible results to the involved local actors as well as involved scientists. Mertens (2007) *transformative paradigm* of using MMR shows strong relations to transdisciplinary approaches, as well as to action research, e.g. in terms of integrating stakeholders and their knowledge into the research, relationship and trust between researchers and stakeholders, addressing power issues or in fully understanding the complex reality. Mixed methods potentially improve trust generation, since researchers are more responsive to the needs of the actors, and the actors recognize the strength of quantitative and qualitative evidence (Ibid.).

5.3.3 Application of MMR within this thesis

Since not many MMR examples from environmental studies exist, it would be worth developing further projects that utilise mixed methods research as it is intended with this thesis. My approach attempts to integrate various methods, data and inferring results, which is legitimized within MMR and needed for transdisciplinary research (qv. chapter 4.2 on transdisciplinarity). By means of MMR, the different perceptions and knowledge bases of the actors in my case study were explored.

Furthermore, MMR is used within this study for the integration of qualitative observations with quantitative structured data like outcomes from model-based analysis. My study is based on mixed methods, because the different methods should be used for converging evidence, as well as for complementarity (cf. Yin 2009). The methods are used simultaneously and sequentially, where the preliminary analysis of the different inquires is conducted independently. Findings of all applied methods are merged together gradually and continuously for getting a final analysis that integrates all evidence. However, it has to be underlined that the qualitative and quantitative components are not separated processes that are only merged at the end of the study, but that they inform each other during the whole research process and are thus used for adaptation. This is essential for having a mixed methods study instead of a multiple methods study as described by Tashakkori and Teddlie (2010). The qualitative analysis is needed in my study to collect the perspectives of actors and to describe the context, which is also necessary for shaping the quantitative analysis. The quantitative analysis delivers outcomes that are credible and useful for actors, e.g. water quality parameters, which is also necessary for the focus of the qualitative analyses.

5.4 Methodology of case study research

Case studies are frequently regarded as only being a research method, i.e. for collecting and analysing data. Yet, several annotations (e.g. Yin 2009) lead to the conclusion that case study can be considered as a methodology. This is substantiated by the following chapter, starting with a definition by Yin (2009), who states that "case study is an empirical inquiry that

- investigates a contemporary phenomenon...within its real-life context, especially when
- the boundaries between phenomenon and context are not clearly evident."

Case studies can cope with situations, where "more variables of interest than data points" (Yin 2009) are available. Consequently, case study research relies on and utilises many different sources of evidence (data sources), especially documents and archival records, direct and participant observations, and interviews (Yin 1998; 2009). These multiple sources of information have to converge towards the same issue so that a fact can be established, i.e. data triangulation (cf. Patton 2002) has to be carried out with at least three different sources of data (Yin 1998; 2009; qv. chapter 5.8 on different triangulation possibilities; Figure 16). For establishing a reliable and robust fact (finding) of the case study, the evidence of the three applied methods needs to correspond to each other (Yin 2009). Triangulation[38] exists, if the multiple sources are analysed together and address the same fact based on the same research questions, whereas a separate analysis of multiple sources with different research questions in sub-studies is not triangulation but a comparison between different facts and findings of the sub-studies (Yin 1998). Furthermore, case study research emulates approaches from natural sciences, e.g. preferring theory driven inquiries or to establish facts objectively, which strengthens the conclusions in terms of positivism[39] (Yin 1998). In fact, theory development is an important feature within case study research for guiding data collection as well as for generalisation. The objective of case studies is to generalise theories (analytical generalisation) instead of generalising to populations (statistical generalisation[40]), i.e. the developed theory is used for comparing with empirical results from the case study (Yin 2009).

Even if case study research is often considered as a qualitative research design (Denzin and Lincoln 2000), case study research can include qualitative and quantitative evidence (Yin 2009; qv. chapter 5.3). This shows the proximity of case study research and mixed methods

---

[38] Triangulation is a metaphor imported from Geodesy. In my opinion this is not a particularly adequate metaphor, since triangulation in a surveying sense is different and means the determination of a point by using two known points, measuring angles and having one baseline. However, in a social science sense, triangulation is meant to establish a fact by data from at least three sources, so that a more convincing metaphor would be needed. The triangulation in a social science sense is, to stay in metaphors, more like a *position vector (vector analysis)*, which exactly defines an n-dimensional point. In a 3-dimensional space, one would need 3 coordinates for exactly describing the point.

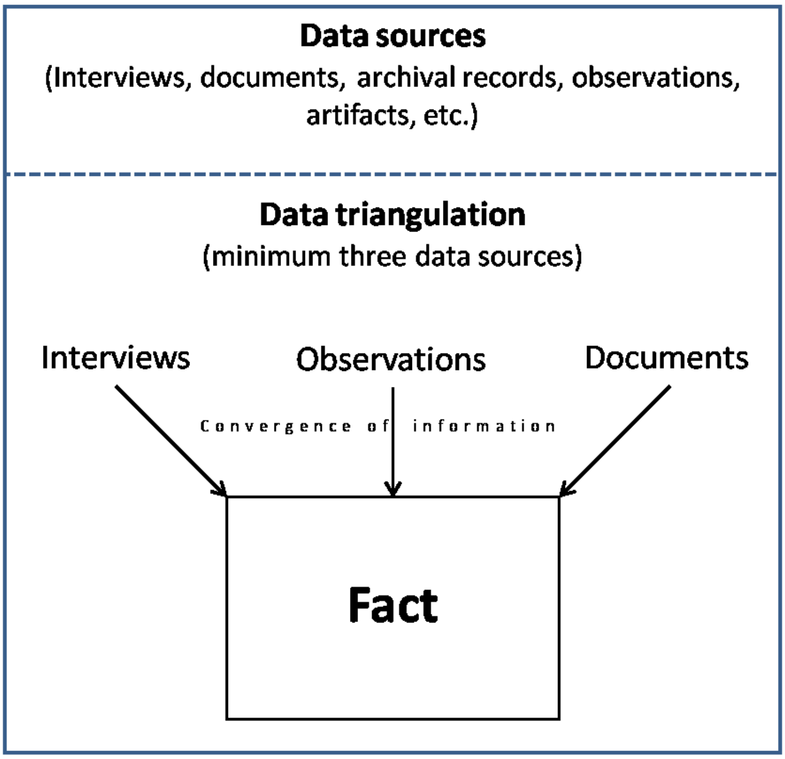
[39] That means verification of hypothesis as the epistemology of natural sciences. For the debate on the falsification of hypotheses, it is referred to Popper (1974).

[40] Case studies are not representative for the population (no random sampling).

research. Yet, mixed methods research, clearly emphasize an iterative and cycling nature between deductive *and* inductive reasoning.

Accordingly, this strategy is particularly suitable for my research, because it fits to objectives of my study and the overarching purpose of river basin management with its natural and engineering scientific basics embedded in a societal context and thus encouraging the stakeholders' trust towards the research and its results.

Figure 16: Convergence of information from multiple sources



That means that it resembles a transdisciplinary process, for which according to Scholz (2011) an embedded case study design is appropriate. MMR is needed within the study, because results from one research string can inform the other result for comparison or contradiction.

Yin (2009) further explains that case study is the appropriate research method, if

(i) it is about more explanatory "how and "why" research questions

(ii) the focus is on current issues within a real life context, and

(iii) the researcher has little control concerning the situation.

These mentioned points are applicable for my thesis, so that case study as a method was adopted for dealing with the complexity of the encountered problem situation in Ukraine, and for evaluating whether the developed framework is valid and transferable (construct and external validity). The encountered situation in Ukraine will first be described and then explained in detail for the water resources management. Since I also integrate exploratory "what questions" into my thesis, next to the cases study method also methods like surveys and archival analysis are applied (MMR).

These mentioned methods are valid for the first part of the research strategy, i.e. the situation analysis. Yet, my work was not limited on reporting of the results, but went on with developing recommendations and measures together with the stakeholders. In fact, stakeholders were included from the very beginning of the research so that scientific and context-specific knowledge could be combined, resembling action research and transdisciplinary research.

5.5 Transdisciplinary research strategy of the thesis

We draw on the previously described theoretical framework (chapter 4) with *action research* (e.g. Schön 1983), *transdisciplinary research* (e.g. Pohl and Hirsch Hadorn 2008), and *boundary management* (Mollinga 2008; 2010). These theories are aligned with the methodological framework, i.e. with MMR and case study research.

Within the IWAS project, quantitative and qualitative analyses are conducted (MMR), whereas my focus is on qualitative research and its interaction with quantitative research. Natural scientific quantitative data ("hard facts", e.g. measured and modelled water quality parameters) that are (i) the basis for any river basin management, and (ii) sometimes have a greater credibility within engineering science and some societal groups (e.g. authorities) are combined with results from qualitative social scientific data. The latter generates outcomes that are credible, but also understandable, because they analyse and describe in detail how the situation is and which processes are of importance (Maxwell 1998). Thus, qualitative research is particularly suitable for cooperation and collaboration with practitioners or other stakeholders (Ibid.), i.e. important for transdisciplinary research.

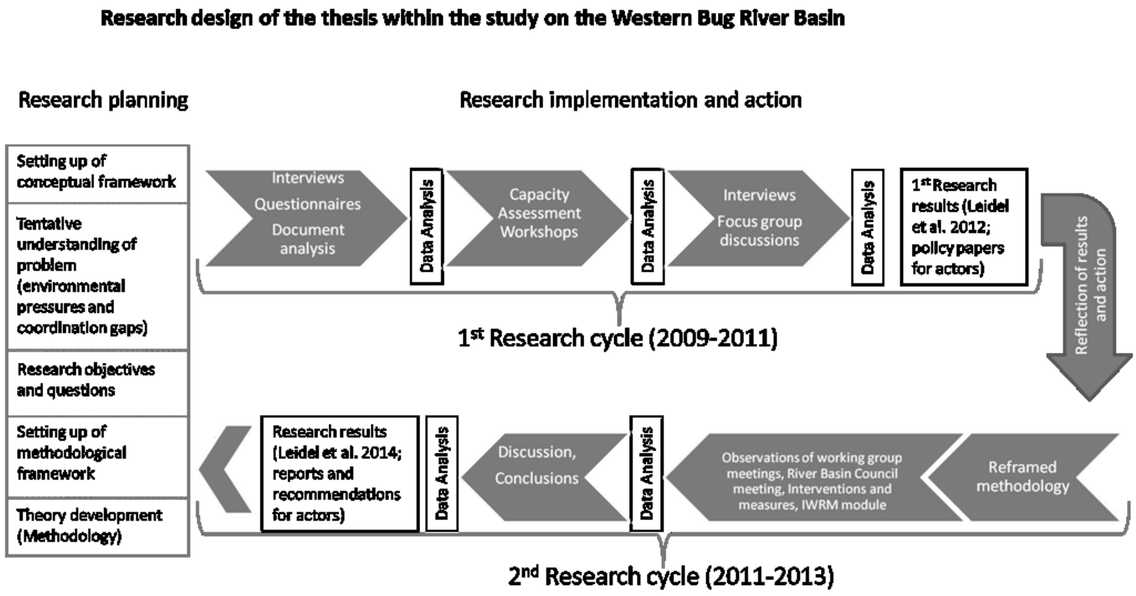
That means that our project has research purposes ("understanding") as a basis for our practical purpose ("action and improvement"). The research purposes within the IWAS project were (i) to understand the context (governance and capacities) in which our project is carried out, (ii) to understand processes and causal relations in terms of natural and engineering science within the river basin, (iii) to understand (socio-economic and governance) processes that lead to outcomes of events and actions (social science perspective), and (iv) to understand the interdependencies between (i)-(iii) and thus developing causal relationships between those factors. This is arranged following MMR within a case study, i.e. we applied research cycles of deduction and induction, i.e. between theory building and empirical results.

Based on that, the practical purposes of the IWAS project were to overcome water related pressures within the Western Bug River Basin, as well as coordination gaps (Governance capacities, organisational capacities, individual capacities and information). We refer to a cycling spiral with planning, action, and reflection in terms of results and action (action research). Thereby, we can generate improved results based on the interactions between theories and practice and we can pursue a continuous learning within the process.

According to the principles of action research and transdisciplinarity, relevant stakeholders have been identified, consulted and integrated into research and practical purposes at the appropriate level from the very beginning of the project. Yet, the amount of relevant stakeholders increased within the first two years of the project. This was due to improvements in our network activities and the resulting identification of further necessary actors, as well as due to extending our research to the national Ukrainian level.

As mentioned by Hartley (2004), the theoretical framework may underlie changes during the course of the research, because of exploring new areas or the construction of new theories. It is supposed that rational planning approaches, i.e. first designing the process and the outcomes, is not always realistic, respectively not always leading to the desired results (cf. Forester 1989). But rather incremental approaches that combine strategic intent with flexibility (cf. ECDPM 2009) are assumed to be more promising. Accordingly, my research plan was to develop an initial framework as described in chapter 7 (Leidel et al. 2012), which was gradually adapted and amended by further theories and insights from the case study mirroring the action research cycle, as well as the iterative and cycling nature of mixed methods research. Eventually this led to an emerging methodology for an integrated analysis of environmental pressures and capacity gaps. In chapter 8 (Leidel et al. 2014) this management framework for combining quantitative and qualitative analyses (MMR) as well as for the interaction between different academic disciplines and other actors is provided, so that an integrated analysis of environmental pressures and capacity gaps is feasible. Teddlie and Tashakkori (2009) mention that "researchers will think of data less in terms of words or numbers and more in terms of transferable units of information that happen to be initially generated by in one form or the other". Taking this into account, we developed the Subsystem-Pressure-Coordination-matrix as information units, based on the conjoint systems and capacity analysis with mixed methods results (Leidel et al. 2014; chapter 8.4). The outline of my thesis research with the two research cycles can be seen in Figure 17. It has to be stressed that feedback loops exist between the single phase of the research cycles and the parts of the research planning (e.g. methodological framework or theory development).

Figure 17: Research design of the thesis



5.6 Research planning

First of all, it has to be acknowledged that applied research is an iterative process, because the research questions are normally not static (Bickman and Rog 1998, Maxwell 1998). Iterations within the research design and implementation is an essential factor for improving the quality, credibility and responsiveness of the research project, because of changes of the research environment, like improved knowledge, unanticipated challenges, or contextual shifts (Bickman and Rog 1998).

Yin (2009) states that case study research follows an iterative process with the following parts: designing case study, data collection, data analysis and reporting. Within the design phase, Yin (2009) subsumes research questions, theoretical propositions, units of analysis, a logic to link data and propositions as well as criteria for interpreting outcomes. Maxwell (1998) suggests a research design approach with five components that are not linear or cyclic, but have an integrated relationship between each other:

- study focus (purposes, goals and focus of the study, motives)
- conceptual framework (theories, conceptual context, literature, personal experiences, i.e. existing theory as well as developing and connecting theories for research setting)

- research questions (what should be understood by this study, how are questions related)
- methods (what approaches and techniques; how are they connected to induce an integrated strategy)
- validity (what are plausible other explanations; validity threats to conclusions)

Research questions are the central element of MMR as described above (Tashakkori and Teddlie 1998) and the advantage is that the design and methods can pragmatically be selected on "what works" (Plano Clark and Badiee 2010). Scholars like Maxwell (1998), Maxwell and Loomis (2003) or Tashakkori and Teddlie (2010) emphasize that research questions are *interdependent* with the focus of the study and the conceptual framework on the one hand side, and on the other side, they are *interrelated* with methods and validity, i.e. they propagate a more interactive model. My research also refers to this explanations and the integrated relationship between the research components. The advantage is that the integrated character of MMR is acknowledged more with such an interrelated concept, since it does not dogmatically stick to a linearity in research which is often not valid and it also better acknowledges the influences of the context on the research (cf. Maxwell and Loomis 2003; Plano Clark and Badiee 2010). Thus, the importance of context, purposes and political agenda for mixed methods research questions has evolved (e.g. Mertens 2007) and accordingly we also stick to an interrelated research design with its obvious interdependencies to context and political agenda as shown.

5.7 Research Design

Research design is according to Yin (1998; 2009) a logical process or an action plan that connects the research questions to the outcomes and vice versa. Choosing a research design therefore depends on the research questions and whether it is quantitative or qualitative research or mixed methods. Types are for instance experimental research designs, or descriptive research designs. Yet, as outlined in Bickman, Rog and Hedrick (1998), often a hybrid is used, especially within dynamic research conditions with multiple questions to be answered.

One feature of the research design of normative studies, for instance, is to identify which variables need to be compared to "standards", and it has to be analysed which standards are appropriate (Ibid.). Within my research, standards are the state-of-the-art in sustainable water management (e.g. EU-WFD), as well as international conventions (e.g. UNECE-

Convention on the Protection and Use of Transboundary Watercourses and International Lakes) and national legislation, i.e. in my case Ukrainian legislation. My design comprises descriptive, correlative, and normative questions.

Furthermore, the level (unit) of analysis has to be defined so that consequently also the boundaries of the study can be defined (Bickman, Rog and Hedrick 1998; Yin 1998; Yin 2009). Additionally, the level of precision and the key variables have to be selected, i.e. the variables that are useful for the research task (Bickman, Rog and Hedrick 1998).

Validity is a central criterion of research design, and Bickman, Rog and Hedrick (1998) mention the importance of the representativeness of data sources, i.e. how they are selected (universe, random sample, nonprobability sample, etc.). They further mention the importance of the measurement time frame (e.g. one shot, cross-sectional or longitudinal study). Important is to be aware of the *reflexivity*, i.e. the mutual interactions between the researcher and the stakeholders as research participants (Maxwell 1998) and its potential threats to validity. He further states that the researcher has to think about the relationship s/he wants to have with the actors and how to establish it, especially if action research or collaborative research is conducted.

5.7.1 Case study design

Case study research design can be explanatory, descriptive or exploratory (Yin 1994). Within my thesis, I focus mainly on an explanatory and descriptive research design, which interacts with the engineering and natural science research as well as further social science research of colleagues. Case studies can be designed as single or multiple cases, whereas multiple cases can enhance analytic generalisations by having evidence from several cases in terms of literal and theoretical replication (Yin 1998). Yet, as mentioned above, a sample is still needed for inferring to the population.

Within case study research, a unit of analysis can be an individual person, group of persons or organizations, decisions, programmes, implementation process or organisational change, i.e. the case needs to be a real life phenomenon (Yin 1998; 2009). There can be also embedded units of analysis, i.e. a main unit exists with several subunits, where analysis has to be done on all levels (Yin 1998). The embedded design belongs also to the major mixed methods types of design as described by Creswell (2008) next to convergent parallel design, explanatory sequential design, exploratory sequential design, transformative design and the multiphase design. Important to note for the embedded design is that the analysis within the subunits can involve other methods than the case study method, e.g. using archival data, so that Yin (1998) argues that the overall case study could be based e.g. on quantitative analysis at subunit level and qualitative analysis within the main unit. Consequently the case study would be qualitative and quantitative (Chapter 5.3). It should be attempted to distinguish between the unit of analysis (the topic of the case study) and the context (Yin 2009), thus constituting the scope of the study. Furthermore, boundaries of the case have to be defined, e.g. temporal, spatial or concrete ones like parts of a management cycle (Ibid.). However, boundaries between case and context are often diffuse and contextual conditions possibly change over to be part of the case (Yin 1998). Within the case study on the Western Bug River, for instance, the national Ukrainian environmental legislation and the environmental ministry were considered to be part of the context at the beginning of the research, but later on turned out to be a key part for my case study. This describes the advantage of case study research that the research is permitted, even if exact boundaries are not known at the beginning (Yin 1998). In fact, case study research wants to explore the relationship between the context and the case (Yin 2009). Therefore, the case study method, and especially the embedded design, is particularly apt for structuring transdisciplinary processes (Scholz 2011) so that I have chosen this design for my research.

Summing up, there are four types of case study designs, (i) single-case study with single (main) unit of analysis, (ii) single-case study with embedded units of analysis, (iii) multiple-case study with single (main) unit of analysis, and (iv) multiple-case study with embedded units of analysis (Yin 1998).

5.7.2 Design of the study in the Western Bug River Basin (WBRB)

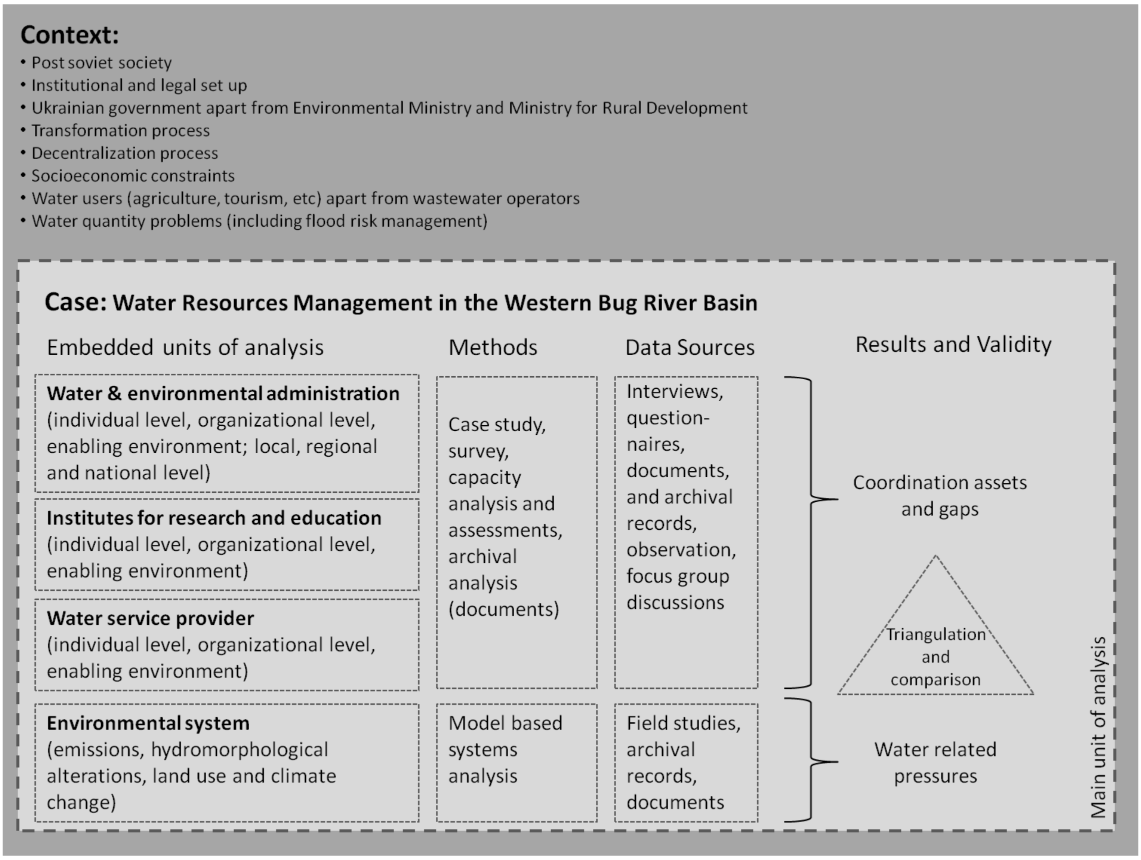
Within my case study on the WBRB, a single case with embedded units of analysis was chosen, in order to improve the opportunities for in-depth analyses and thus avoiding that only abstract analyses were conducted (cf. Yin 2009).

This design further allows improving the focus of the case study inquiry to the research questions (Yin 2009). Within my inquiry, the embedded units that are necessary for studying water resources management with a focus on water quality problems were selected based on experiences and the analysis of previous investigations, theory development, and thus on the research questions (Figure 18). The main unit of analysis (the case) is the water resources management in the Western Bug River Basin as man-environment system. A single case design is justified, since my study represents a critical case, i.e. the case is used for testing and potentially adapting my developed theory (cf. Yin 2009).

5.7.3 Study focus and conceptual framework

The first part within the research planning is to define the purpose or the *focus of the research*, i.e. that the problem has to be understood, e.g. by analysing literature, obtaining experts' and stakeholders' opinions, or field trips to get a realistic and context-specific impression (Bickman, Rog and Hedrick 1998).

Figure 18: Embedded single-case design of the study in the Western Bug River Basin



Next to that, a *conceptual framework* has to be developed and iterated with the problem understanding, i.e. which theories and key factors are used for the study, respectively in more policy or programme related studies also guidelines, concepts or expectations can be integrated into the conceptual frame (Ibid.). Such theories should assist in assessing the purposes of the study and to develop realistic and relevant research questions and consequently methods and to check validity threats (Maxwell 1998). An underlying (hypothesized) logic (model) is useful for the conceptual framework, respectively for theory development (Rog 1994; Yin 1998). That means that the interactions between frameworks, goals, activities and outcomes have to be comprehensible, which is especially important in terms of policy or programme research, so that interventions can be developed in a structured way and thus potentially reducing "ill-defined interventions" (Rog 1994). Such "ill-defined" interventions lack both, a sound problem understanding as well as a sound conceptual and logic framework and often occur under politically and socially intricate conditions (Ibid.). Besides, transdisciplinary approaches also reduces the danger of "ill-defined" interventions. The development of the conceptual framework is more than "literature review", since it is constructed by the researcher who provides the coherence between the single pieces of theories (Maxwell 1998). For setting up a conceptual framework[41], Maxwell (1998) describes the following possibilities:

- experiential knowledge, i.e. the incorporation of the researcher's existing experiences. Yet, "critical subjectivity" is needed, i.e. to be conscious about the personal bias *and* use it as part of the research process (Reason 1988 in Maxwell 1998).
- existing theories and research, which can give justifications for the study by discovering unsolved issues or it can reveal challenges of the research concept. And it can be used for generating new theory and for validating the developed concepts.
- pilot and exploratory studies for testing methods or for developing grounded theory by induction. Very important for developing conceptual frameworks is to comprehend the meaning that the developed concepts have for the stakeholders, as well as their perspectives towards the concepts. These insights can be provided by pilot studies.
- Thought experiments to answer "what-if" questions, e.g. to test the current theory for logical implications.

At the same time *research questions* and the *scope of the study*, together with the relevant stakeholders, need to be identified and eventually refined or clarified. Such a research agenda should be as comprehensive as possible, i.e. it should be attempted to integrate all stakeholders' objections in order to avoid that it is considered as biased (Bickman, Rog and Hedrick 1998; qv. chapter 4.2).

5.7.4 Research questions and hypotheses

Some scholars advocate a linear approach, i.e. that research questions are the central starting point for mixed methods research and that they "dictate" the methods to be used (e.g. Johnson and Onwuegbuzie 2004). However, we stick to the opinion of scholars like Maxwell and Loomis (2003) or Tashakkori and Teddlie (2010) who acknowledge also the centrality of the research question, yet, they emphasize that research questions are *interdependent*

[41] One technique of organising, representing and developing a conceptual framework with all interactions between the different concepts and theories is concept mapping (Novak and Gowin 1984; Novak and Canas 2007).

with all other parts of the research design, i.e. they should not be determined at the beginning of the research, but should be adaptable to changes as mentioned above (inductive nature of applied research). They should be specified and finalised only after clarification of goals, focus and conceptual frame of the study, meaning that sometimes a good portion of research has to be done before knowing the "right" research questions (Maxwell 1998). Yin (1994) states that the identification of research questions is already an important achievement in conducting case studies. "Good" research questions should assist in focusing research, how to implement the study, relate to purposes and context and should be answerable by the study in mind (Ibid.). The strength of qualitative approaches is to ask "how" and "why" research questions focusing on the process how things happen, instead of variance questions like "to what extent" or "whether", which focus on difference and correlation (Ibid.). Thus, Maxwell (1998) advocates to develop questions about *what* is the meaning of actions to the stakeholders involved and *what* are the influences of the physical and social context towards these actions and *how* the meaning and the influences are involved in these actions. Mixed methods research can address several research questions simultaneously (Tashakkori and Teddlie 2010). Yet, units of analysis that should be triangulated, as for instance in an embedded design, need to be based on the same research question (cf. Yin 1998).

Additionally, Yin (1998) highlights the importance of developing theoretical propositions/hypothesises (theory development) as a blueprint for designing the study, which should also include rival theories, e.g. for testing the targeted theory. As we set up a mixed methods research design, we agree with Yin (1998), however, we utilise both, theory development and empirical results within an iterative cycle. Thus, exploratory as well as explanatory research questions are used for exploring the "relationship between entities, the process that underlies these relationships and the context of these occurrences" (Tashakkori and Teddlie 2010).

In summary, research questions describe what the researcher is interested in, *and* hypotheses focus on what should be studied, thus supporting the search for evidence.

5.8 Methods

According to Corbin and Strauss (2008), methods are "techniques and procedures for gathering and analysing data". Maxwell (1998) defines, in a more comprehensive way, methods as "...the *means* to answering your research questions...", e.g. questionnaires for a survey need to be developed in such a way that they reveal the information necessary for answering the research questions. A selection of methods can be found in Table 11.

Yin (2009) demonstrates that for choosing the proper method, three conditions are decisive: (i) type of research question (e.g. what, who, how, why), (ii) extent of control that the researcher has over the events and (iii) focus on contemporary events (Table 11). This shows that the choice of methods depend on and interrelate with the other components of the research design and obviously on the studied object. Important is to anticipate or test (e.g. pilot studies) how the data collection strategy will work in reality (Ibid.). Maxwell (1998) states that methods need to be prestructured, i.e. a data collection plan is necessary.

Table 11: Conditions for using different methods

Method	Type of research question	Likely purpose of study*	Control of event needed?	Focus on contemporary events?
Experiment	how, why	exploratory, explanatory	yes	yes
Survey	what, who, how much, how many	exploratory, descriptive	no	yes
Archival analysis	what, who, how much, how many	exploratory, descriptive	no	yes/no
History	how, why	exploratory, explanatory	no	no
Case study	how, why	exploratory, explanatory	no	yes

*All methods can be used for the three different purposes, yet some are more advantageous for a specific purpose, thus more likely to be used.

Source: Modified after COSMOS Cooperation in Yin (2009)

Yin (2009) further mentions that there are no clear borders between the methods and that it is possible to use multiple methods within a study, e.g. a survey within a case study. Since my research is within real-world settings with several research questions, the integration of multiple methods is justified (cf. Bickman and Rog 1998). In fact, utilisation of data from diverse methods potentially improves the confidence (validity) of the results, respectively makes valid results more likely, because it potentially reduces biased outcomes due to specific methodically inherent problems. In addition, using multiple methods is a practicable way if random sampling is not possible as in my case.

We apply not only multiple methods, but we also use mixed methods as described in chapter 5.3. That means that qualitative data are interpreted and qualitative data are statistically inferred, but the two parts are not separated and only merged at the end of the study, but that they inform each other as far as feasible during the whole research process as described by Tashakkori and Teddlie (2010).

The process of integrating different methods is called *triangulation* (Bickman and Rog 1998, Maxwell 1998). Denzin (1978 in Janesick 1998) and subsequently Patton (2002) differentiate four types of triangulation, (i) methodological, (ii) data, (iii) theory and (iv) investigator. In fact, methodological triangulation usually implies that also data triangulation is elaborated. A fifth type, the interdisciplinary triangulation, was introduced by Janesick (1998). Accordingly, I applied a methodological, data and interdisciplinary triangulation between quantitative research from natural sciences and the social scientific qualitative research as shown in the developed model-based and capacity-based IWRM framework for seeking convergence, especially for improving the comprehensiveness of measurements, as well as resulting management options (qv. chapter 8).

Yet, triangulation is only one out of five purposes of mixed methods research (Greene et al. 1989; chapter 5.3.1). Since I conduct a mixed methods study, the applied methods are not only used for converging evidence (triangulation), but also for complementarity and expansion. The methods are used simultaneously and sequentially, where the preliminary analysis of the different inquires is conducted independently. Findings of all applied methods are merged together gradually and continuously for getting a final analysis that integrates all evidence. This is also in accordance with findings of implementation research, where quantitative and qualitative methods are applied simultaneously or sequentially for reaching similar results by inter alia (i) converging results from different sources, (ii) using the two different approaches for explaining the results from each other (iii) using one set of methods for developing a focused application of the other methods (Palinkas et al. 2011, 2013).

As mentioned above, case study is used as a method within this thesis, as well as further qualitative research methods like surveys, capacity assessments, and archival analysis (documents and materials) for gathering and analysing data within the socio-economic and governance system (Water and Environmental Administration, Institutes for Research and Education, Water Service Provider, Figure 18). Data sources, i.e. *sources of evidence*, are interviews, questionnaires, documents, archival records (e.g. legal documents, socio-economic data), focus group discussions, and observations. The quantitative analysis of the environmental system applied a model based systems analysis as method with field studies and archival records inter alia of hydrological, meteorological, and water quality parameters, as well as documents (laws, ordinances, and monitoring reports) as data sources (chapter 5.7.2). I conducted the analyses together with colleagues from the IWAS consortium, whereas my study focus was on the qualitative research parts as well as its interaction with the analyses of the environmental system, but not on the analyses of the environmental system itself. The results led to several scientific publications as described in the case study in chapter 7 and 8.

5.8.1 Sampling

My research attempts to understand the complex situation of the water resources management within the Western Bug River Basin, what influences exist, how different aspects are related, and what the stakeholders' perception towards these problems is. Therefore, purposive sampling[42] as a nonprobability sampling technique was applied, which is common in case study research (Maxwell 1998, Patton 2002, Bernard 2011). Purposive sampling means that not random samples are selected but sample units (e.g., individuals, events, institutions) are selected on purpose based on researcher's knowledge that the chosen samples hold information that cannot be gained from other sources for answering research questions (Maxwell 1998, Patton 2002, Teddlie and Yu 2007, Bernard 2011)[43]. From the broad range of purposive sampling techniques (e.g. Henry 1998, Patton 2002, Teddlie and Yu 2007), two sampling techniques have been chosen, namely expert/ stakeholder sampling (Bernard 2011describes this as critical cases sample,) and snowball sampling. We identified regional and national Ukrainian experts, as well as the major stakeholders that are relevant for the research questions and that potentially have different perceptions about the causes of water pollution (Authorities, NGOs, water service provider, universities and research facilities). The identification was elaborated based on local knowledge (through a German consulting company named DREBERIS with an office in L'viv, Ukraine), literature, documents, legislation, regulations and later also based on snowball sampling, i.e. existing informants have been asked for further accessible knowledge sources (Individuals, legislation, procedures). One success factor of the data collection for my study was to gradually improve the relationship with local actors, which started with establishing contacts to staff of

[42] Sometimes also called judgment sampling (e.g. Marshall 1996) or qualitative sampling (e.g. Teddlie and Yu 2007).

[43] Bernard (2011) put it in a nutshell: "It would be pointless to select a handful of people randomly from a population and try to turn them into trusted key informants."

local and regional authorities, NGOs and universities within the oblasts[44] L'viv and Volyn. They gradually provided contacts to the middle level management, the senior management level/ faculty councils and the directors/ professors. Consultations and open interviews with the directors have been used for clarifying the research interest, the advantages for their organisation in participating, and to overcome concerns towards their participation. With all stakeholders, written agreements have been signed that described the research co-operation and the responsibilities of both parties (memorandum of understanding, treaties; included in doctoral thesis data base, e.g. treaty between Technische Universität Dresden and the Western Bug River Basin Department in agreement with the Ukrainian State Committee of Water Management and the German Ministry of Environment-BMU). However, developing personal contacts was the key to get data and information. The sampling of the first research cycle on the regional level was done until no additional substantive information could be identified. However, within the second, iterative cycle of my research, it became evident that for further investigations and measures more information from the national level and a central (national) approval is needed, i.e. it became necessary to establish profound contacts to the national Ukrainian level (Ministries, NGOs, associations, experts).

As Bernard (2011) mentions, identified participants need to have the necessary knowledge, but also the willingness and ability to participate and communicate and to be reflexive about expertise and experiences. All enquiries have been accepted by the participants, yet, there was a varying degree of willingness to participate as well as the ability/willingness to communicate critical issues. Through the creation of trust during our frequent field trips, this reticence could be reduced (qv. the case study in chapter 7 and 8 for details and results of the data collection and analysis).

In order to increases the external validity, a broad and comprehensive approach was chosen. As proposed by Glaser (1978 and Bernard 2002 in Palinkas et al. 2013), my sampling strategy was to start with sampling for breadth (variation) followed by an in depth sampling of specific components. However, due to limited resources, this chosen comprehensive approach has the disadvantage that the depth of some measures is limited, i.e. a reduced level of precision.

5.8.2 Data collection

Within this study, several forms of data as sources of evidence have been used:

[44] The first level of Ukraine's administrative division is called oblast (province).

- self report data based on interviews and questionnaires (surveys) and assessment workshops
- archival records: extant databases and (online) information systems (e.g. hydrolog-cial data, meteorological data, water quality, land uses, census, demography, various maps)
- observational data of issues, events, and actions
- documents (administrative documents like legislative text, regulations, by-law, strategies, reports; reports of former projects; minutes and written reports of meetings and events; personal documents like notes and e-mails)
- maps and geospatial data

5.8.2.1 Self report data

Self report data have been laborious to collect in the case of assessment workshops with previously sent questionnaires (survey) as written corroboration that have been used as basis for the workshop (chapter 6.2). One major challenge towards obtaining reasonable results was the language issue, which could be solved by simultaneous translation of the interactive assessment workshop, as well as a German and a Ukrainian facilitator, who jointly conducted the workshop. Another challenge was to get all relevant stakeholders to the workshop and that they do not prevent an open discussion.

Interviews are an essential source of information for case studies as well as surveys (Yin 2009). According to Bickman, Rog and Hedrick (1998), semi structured and unstructured (open) interviews are appropriate for descriptive and exploratory research within new circumstances. Hence, we conducted such types of interviews in the beginning of my research for getting insights into the complex situation. During the course of the research project, further semi-structured interviews were conducted (Hagemann and Leidel 2014, Hagemann et al. 2014a, b). Yin (2009) distinguishes between in-depth interviews and focused interviews. The first type is characterized by several sittings with key persons in which they describe the facts as well as their opinion and insights, where the interviewee potentially converts into a key informant (Ibid.). Key informants are often decisive for the success of a case study, because they can provide deep insights into the situation and they can provide additional data sources or additional interviewees (snowball sampling; Yin 2009). Yet, key informants can be also biased or may have a hidden agenda, so that Yin (2009) advices to corroborate or contradict such information by other data sources. Within the Ukrainian case study, for my personal research focus, three interviewees turned into key informants, one senior expert from the regional environmental administration in the WBRB, and two senior experts currently working as environmental consultants within Ukrainian water related projects but having long standing work experiences within the environmental Ministry and thus good contacts.

Within the second type, focused interview, the actor is interviewed for a shorter time period, e.g. one hour, often with the purpose of corroborating facts (Yin 2009). Hereby, attention should be given not to use leading questions and secondly, when different respondents give the same answers, it should be checked, whether this is really corroboration or conspiracy (Yin 2009). In our survey, for instance, two respondents from two different regional authorities answered the same facts and opinions about the situation. My investigations discovered that there is an informal connection between the two persons, where apparently one person influenced the other one so that I did not use the data for corroboration.

Surveys have a structured questionnaire (can be also executed as interview) and deliver quantitative data, e.g. within an embedded case study (Yin 2009). If opinions or attitudes of respondents are corroborated with each other, the study is a survey, whereas in interviews opinions or attitudes are considered definitive (Yin 1998; 2009). Yet, interview data reporting behaviour needs to be corroborated (Yin 1998; 2009). In our study, a questionnaire for the relevant stakeholders in the WBRB was developed with open-ended question. Within the evaluation of the e-learning module, questionnaires with closed and open questions were developed (qv. chapter 9.2).

5.8.2.2 Documents and archival records

Documents are an important source of evidence, since they are independent from the case study, can be repeatedly analysed, and are normally exact in terms of names, event description, and often cover a broad field needed for the investigation (Yin 2009). However the researcher has to be aware that they are potentially (i) difficult to find or be accessed, (ii) biased by the author, or (iii) selectively biased, if not all relevant documents are collected (Yin 1998; 2009). Nevertheless, documents are essential for making inferences and corroborating information from other data sources (Yin 1998). Within my case study, some documents could be obtained from homepages of Ministries, authorities, and previous research and development cooperation projects. Yet, not all information needed were available, respectively the search was also impeded by language difficulties. Therefore, also bilingual Ukrainian scientists were employed that screened the internet for further relevant documents and databases and for translating those sources into English or German. This in-depth search can reduce the selectivity bias. Additionally, documents and data from extant databases were obtained directly from several regional authorities, which was often a lengthy and difficult process, since trust generation was the precondition and only reached by frequent meetings.

Data from archival records have the same advantages and disadvantages and they are normally precise and of quantitative nature (Yin 2009). Within the case study in the WBRB, the information from databases (e.g. water quality parameters) was often not consistent and reliable. Beyond that, the data was sometimes expensive (qv. chapter 8 for details on data collection).

5.8.2.3 Observational data

Observational data can be separated into direct observations and participant observations, whereas the first one is conducted by field visits delivering additional information, e.g. observation of meetings, the conditions of infrastructure and facilities, or curricula (Yin 1998). As proposed by Yin (1998) we increased the reliability of direct observational data by regularly having several observers. The peculiarity of participant observations is that the researcher is integrated and participates in the events s/he is concurrently observing (Yin 1998). The enormous advantage is that the researcher gets access to situations that are otherwise impossible to study, respectively to get insights from an insider perspective, which is often argued to be invaluable for analysing the case study accurately (Yin 2009). Only participant observations allow for manipulating events, e.g. organizing a meeting for gathering data (Ibid.). However, there are disadvantages as well, mostly related to potential bias of the researcher due to the limits of not being an external observer or the researcher becomes even a supporter of the studied group (Yin 2009). In the WBRB case study, participant observations were a major source of evidence. To confront the disadvantages, the rules of good scientific practice have been obeyed stating that advocacy roles for any party involved should not be taken. Researcher bias and reactivity varies, however it is always existent in qualitative research and thus affect data collection and validity of the study results (cf. Maxwell 1998 and the chapter 5.9 on validity). Another practical problem can be that the researcher's role as participant is so stressful that there is only limited time for the role as observer (Yin 2009). Therefore, always several colleagues were present in the events of our case study and data was analysed jointly, so that both roles could adequately be fulfilled.

5.8.2.4 Process of data collection

The process of collecting observational data was a long term process over five years between 2009 and 2014 with several events and actions (e.g. Table 15). Minutes of the events were prepared as observational recording form for documenting the information (qv. doctoral thesis database). Observations were manifold and included conditions of infrastructure, e.g. waste water treatment plants and sewer system, curricula and teaching arrangements at universities, meetings.

Data has to be accurate, reliable and valid, i.e. (i) it has to be asked whether we measure what we wanted to measure (construct validity), (ii) it has to be checked whether databases are consistent, and (iii) whether errors are sufficiently small (Bickman, Rog and Hedrick 1998).

Within the data collection process, also a *case study protocol* should be elaborated, which assures the reliability of the research (Yin 1998; qv. Table 12). It should include an overview of the study (objectives, background information), field procedures (e.g. access to organisations, schedule, workarounds for unanticipated incidents), which are important because the researcher works in real world settings as opposed to the controlled environment for data collection within other methods like experiments (Yin 2009). Within my case study, I was developing a case study protocol, where, e.g. the overview of the study was also used as introductory text for the invitations of interviewees or survey participants. The field procedures included the "logistics" of the field study in Ukraine, i.e. questions concerning the availability of translators, schedules for interviews with buffer time for staying in the schedule, and being creative about workarounds for frequent unanticipated incidents like traffic jams, changing schedule for interviews because of interviewee's rearrangement requests. Moreover, they incorporate the adaptation of "tactics" how to approach the different stakeholders.

Another essential point in this respect is described by Yin (2009) that case studies often have to differentiate between the unit of data collection and the unit of data analysis. Within my case study, for instance, the unit of data collection was frequently individual persons (e.g. interviews), but the unit of data analysis was the water resources management with its organisation and politics. That means that my conclusions cannot be drawn completely from the individuals acting within the water resources management, but have to be based also on other data sources like documents on administrative work and results, strategy papers, so that I gain information about the water resources management and not only about the individual opinion of actors within water resources management. Accordingly, the case study questions were about water resources management and not about the individual actor. Last but not least, the protocol should integrate a guide for the case study report (Yin 2009). In my example, it was clear that a doctoral thesis should be developed out of my personal case study results, next to a final project report within the IWAS project for the funding German Federal Ministry for Education and Research (BMBF). Additionally, a final project report specifically tailored for the actors within the Ukrainian case study, incorporating all results from the different IWAS working groups within the Ukrainian case study, was planned. In fact, it was one explicit aim of the study to transfer research results to various stakeholders varying from specialists to laypersons, which is a strength of case study research (cf. Yin 2009), in different formats namely narratives, but also lectures at Ukrainian universities as well as e-lectures within an e-learning module (qv. chapter 9 for details on the e-learning module).

This thesis is written in the style of a classical single-case study (mixed method study), i.e. a single narrative is used for describing and analysing the case including figures (Yin 2009). It is elaborated in a linear-analytic structure, i.e. starting with the problem, literature review, used methods, findings, conclusions and implications (Yin 2009), because this is the most common way of arranging a report for an academic audience and most researchers, especially from natural and engineering sciences, are used to this well-proven style.

Furthermore, a case study database should be developed to organise the evidence, which is not only a collection of materials, but should also include emerging narratives (Yin 1998). That means that the evidence from the various data sources is incorporated in the database and not only the single sources separately (Ibid.). A database supports data analysis and it improves the reliability of the research, since it enables other researchers to review how the conclusions were developed out of the raw data (Yin 2009). The data within the database has to be stored and classified in a way that facilitates retrieval, e.g. according to the major topics as described in the case study protocol. The following data should be integrated (Yin 2009): case study notes, case study documents, tabular materials (e.g. survey data), and narratives.

Last but not least, a chain of evidence should be maintained, i.e. a sequence from research questions to the conclusions, where each single step of research can be identified (Yin 1998). It is related to the construct validity.

5.8.3 Data analysis

Data analysis has to start right after the first data collection has been finished e.g. the first interview (Maxwell 1998), or as Yin (1998) mentions that triangulation of evidence occurs during data collection and can be considered as a first analysis. Accordingly, I also have analysed the data successively after the data collection/ events. Neuman (2000) mentions that first analyses can deliver necessary information for further steps of the research process. Accordingly, the directly analysed data was frequently used immediately afterwards for focusing further data collection and shaping the participatory process with the stakeholders. The (preliminary) analysis of data from the first day of the capacity assessment workshop, for instance, was used to frame the discussions on the second day. After the field trips, the single preliminary analyses were summarized. The main analysis starts after the data collection is finished, i.e. the collected evidences are manipulated (e.g. categorizing or tabulating) to address the hypotheses of the study (Yin 1998).

Maxwell (1998) describes three main strategies for qualitative analysis, namely

- categorizing (especially coding), i.e. cracking the data and rearrange it into categories (from existing theories or grounded theory), which supports organizing the data, its comparison and thus a general understanding;
- contextualizing (e.g. narrative analysis, case study), i.e. to understand the data in the whole context;
- memos and displays, i.e. to make analyses visible and top support thinking about relationships in the data. Displays (e.g. matrices, concept maps, networks; cf. Miles and Huberman (1994)) are suitable for data reduction and presentation/ analysis that facilitate the holistic understanding of the data.

Maxwell (1998) emphasizes that these three strategies should be combined for delivering the essential data. Software packages can assist in qualitative data analysis, however, computerized tools cannot readily utilise the multiple sources of evidence, which are necessary for real life conditions of case studies (Yin 2009).

A possible starting point for data analysis is to "play with the data", e.g. a matrix of categories and evidence, flowcharts or chronological sequence of data (cf. Miles and Huberman (1994). Yet, Yin (2009) argues that analytic strategy is needed, because otherwise it has more the character of a haphazard process. Four strategies that can be used are proposed by Yin (2009): First of all, the most important strategy is, obviously, to stick to the theoretical propositions (hypotheses). Secondly, a descriptive framework for organising the study can be developed. Thirdly, a strong strategy would be to use qualitative and quantitative data jointly, as described above for the embedded case studies. Fourthly, rival explanations can be defined and tested and used together with the other three strategies, e.g. rival hypotheses/ theory or rival descriptive frameworks. Yin (2009) lists a set of rival explanations and emphasizes that the more rivals are addressed and rejected the more confident are the results.

5.8.3.1 Analytic techniques

An important technique for strengthening internal validity is pattern matching, i.e. that an empirically based pattern is compared with a predicted one (Yin 2009). Another technique is explanation building, which is, similarly to the pattern matching, mainly used for explanatory case studies. Yet, it can be also used for exploratory case studies, i.e. hypothesis generating as stated by Glaser and Strauss (1967), which, however, does not focus on concluding a study but on developing new ideas (Yin 2009). Explanation building often occurs in narrative form for explaining the how or why of something and, in the best case, reflects the theory (Ibid.) Time series analysis is another technique for analysing data over time, which is normally always possible when events are observed over a time period (Ibid.). Yet, also causal propositions or hypotheses are necessary, i.e. the observed time series is compared to a theoretical trend or a rival trend (Ibid.). A specific case would be a chronology, or if no proposition is available, it is called chronicle, i.e. it is a description but no causal inference (Ibid.). A further technique is a logic model, which combines pattern matching and time series analysis, i.e. a complex sequence of linked events over a period of time (Yin 2009). Again, empirically observed data is compared with predicted theoretical events (Ibid.). That means that a logical model should be defined before the data collection, followed by testing how well the empirical information fits to the logic model (Yin 2009).Within an embedded unit of analysis, also quantitative links can be used for a logic model (Yin 2009) Logic models are graphically often described in a linear sense, but real life processes are often not linear but more dynamic and continuous so that, Yin (2009) suggests using an alternative. All activities/events are mapped and appear on "growth rings of a tree" with the centre being the "best" condition for change, so all activities have to be aligned there. Each "trunk cross section" displays a period of time, thus several "trunks" can show the chronology.

Finally, the purpose of data analysis is to make inferences, i.e. making sense of the results. Especially important is the question on how to elaborate inferences that are based on qualitative and quantitative analysis as within MMR (Tashakkori and Teddlie 2010). Teddlie and

Tashakkori (2009) mention inter alia to focus on the research question, since inferences should answer them. Moreover, inferences should explain situations and events, so that conclusion can be drawn ranging from global and abstract explanations to more concrete ones that explain specific situations (Ibid.). Results from the qualitative and quantitative data analysis within MMR are compared and contrasted continuously and eventually integrated to get a more general answer (Tashakkori and Teddlie 2010).

5.9 Validity

A research design needs to be credible and therefore the quality of the research has to be tested; correspondingly e.g. Cook and Campbell (1979 in Bickman, Rog and Hedrick 1998) mention four types of validity

- internal validity (credibility) as the extent to which a causal conclusion can be soundly established,
- external validity as the extent to which the research results are generalizable from the context of the study to other settings, meaning inter alia that researchers have to convince decision makers that the results are useful for them and applicable for the encountered problem.
- construct validity as the extent to which the conceptual framework can be operationalized in the study
- Statistical conclusion validity, as the extent to which statistical appropriate measures are used to detect effects.

Yin (1998, 2009) mentions another type, reliability, which demonstrates that the study can be repeated and leads to the same results, i.e. protocols and databases for auditing should be used. Although all types are essential, they have a relative importance according to the research questions and the research design (Bickman, Rog and Hedrick 1998). Impact studies focus more on internal and statistical validity (Ibid.), which is also true for the natural and engineering research perspective on the impact studies elaborated within the IWAS project (e.g. validating mass balance modelling results). Yin (2009) argues that internal validity is mainly important for explanatory studies and is not applicable for descriptive and exploratory studies. Similarly, Bickman, Rog and Hedrick (1998) mention that descriptive researches design would focus more on external and construct validity. Internal validity is related to the overall problem of making inferences and the question whether the inference is correct (Yin 2009; qv. case study tactics in Table 12). Generalisation of population, geography and time is an essential factor for external validity, i.e. that all relevant locations, time periods and actors have to be studied; if not possible, sampling of a subset has to be conducted from which is generalized to the complete set (Bickman, Rog and Hedrick 1998). Within case study research, external validity is about analytic generalisation (generalise to theory) and not about statistical generalisation (Yin 2009).

Yin (1998, 2009) mentions that within case study research, the design should be tested according to the above mentioned validity types, apart from statistical conclusion. Yin (1998, 2009) suggests applying case study tactics that correspond to the different tests, which will significantly improve the quality of the case study research and will overcome the criticism that case study research is weak (Table 12).

Table 12: Case study tactics for testing quality of research design

Tests	**Case study tactics**	**Phase of research in which tactic occurs**
Construct validity	• Use multiple sources of evidence • Establish chain of evidence • Key informants reviewing draft case study report	• Data collection • Data collection • Composition
Internal validity	• Do pattern matching • Do explanation building • Address rival explanations • Use logic models	• Data analysis • Data analysis • Data analysis • Data analysis
External validity	• Use theory in single case studies • Use replication logic in multiple-case studies	• Research design • Research design
Reliability	• Use case study protocol • Develop case study database	• Data collection • Data collection

Source: Yin (1998; 2009)

For improving validity and thus credibility of the outcomes, several further validity tests are available that usually do not verify the conclusions but test the validity and search for potential threats (Miles and Huberman 1994, Maxwell 1998): Either there is evidence that is contesting the research results (alternative explanations) or there is evidence that the potential threat is implausible. Within this thesis, the following tests have been applied, respectively are inherent part of the developed methodology. First of all, it has to be assured that both, supporting and ambivalent arguments are carefully assessed; since Miles and Huberman (1994) explain that ambivalent evidence regularly do not have the same significance as supportive data. Triangulation is the most important applied test in this thesis, since no method is free of validity threats (Fielding and Fielding 1986 in Maxwell 1998). E.g. interviews and questionnaires potentially have self report bias, i.e. that another method is needed that is not having the threat of self report bias[45] (Maxwell 1998).

Furthermore, feedback (within and outside of research setting) can be used to test validity related to problems within the developed theory, applied methods or propositions (Ibid.). Seeking feedback from participants of the study (member checks; Miles and Huberman 1994; Maxwell 1998) concerning the conclusions is according to Maxwell (1998) the "single most important way" to expel misinterpretation of participants meaning. Above that, collecting "rich data" is essential for reducing biases, e.g. detailed notes of observed events or verbatim transcripts of interviews (Maxwell 1998). Detailed notes of the events observed in the case study on the Western Bug River were collected, yet, verbatim transcripts of the interviews and consultations (e.g. from audio recording) were impossible due to my assumption and experiences that most interviewees, at least from authorities, will be reluctant in telling the *real* truth about this critical situation and will only explain the "official" and legal meaning when there is a concrete evidence of what issues they raised. Respondents stated, some clearly and some implicit, that it is difficult for them to break cover, since the consequences go as far as dismissal. So, in order to generate trust with the stakeholders for obtaining a complete picture of the situation, and thus also getting rich data, e.g. details not only on the formal settings, but also on informal issues, no audio recording was done but protocols of the interview were elaborated right after the execution of the interviews. Another test is the so called quasi-statistics, i.e. deriving simple numerical results from the analysed data (Maxwell 1998). Qualitative studies frequently have a quantitative part, e.g. the assertion that something happens regularly or rarely is already a quantitative proposition (Ibid.). Comparison is according to Maxwell (1998) a further essential test, e.g. improving generalizability through multiple-cases studies (Miles and Huberman 1994; Yin 2009) or comparison within single case studies, which was applied in this study, e.g. through comparing contemporary legal Ukrainian documents with international conventions for evaluating the appropriateness of the Ukrainian documents.

Generalization of quantitative studies is based on probability sampling of a population to which the results of the study can be universalized (Maxwell 1998). In contrast, generalization of qualitative studies normally means to develop a theory that can be transferred to other cases (e.g. Ragin 1987 in Maxwell 1998, Yin 2009), so that Guba and Lincoln (1989 in Maxwell 1998) propose to use transferability instead of generalizability. This indicates also

[45] However, this method could have other specific threats, which, again, can be triangulated by additional methods (Maxwell 1998).

that extrapolating of qualitative studies is not as accurate as quantitative studies (Maxwell 1998).

According to Tashakkori and Teddlie (2010), the conclusions need to correspond to the initial research questions and they emphasize that it has to be assessed how good the different parts of the study have been integrated so that a more holistic and advanced understanding of the investigated phenomenon can evolve.

There are several important threats to validity, inter alia researcher bias, which describes the distortion of results by researcher's perspectives and applied theories (Maxwell 1998). Another threat is reactivity, i.e. the influence of the researcher on the research setting (Maxwell 1998). This effect varies, however it cannot be eliminated entirely, e.g. the answers of an interview always depend on the questions and the interviewer itself, even if countermeasures like avoiding leading questions are used (Maxwell 1998). Therefore, it has to be understood how bias and reactivity affect data collection and thus the validity of the study results. Last but not least, high quality research should be always attempted, i.e. to integrate all evidence, address all essential rival interpretations, focusing on the most significant issues, and use personal expert knowledge (Yin 2009).

6 Case study: Western Bug River Basin, Ukraine

6.1 Introduction to the case study region Ukraine

Ukraine is a country in Eastern Europe with an area of 603,628 km^2, and a population of 44.5 million. The political situation is unstable since November 2013, when citizens started to protest against President Viktor Yanukovych's decision to postpone the EU-Ukraine Association agreement. The people's movement is called Euromaidan and violence escalated mid of January 2014 culminating in riots mid of February with more than hundred dead persons. President Viktor Yanukovych flew out of the country and was impeached by the parliament. Eventually the new president Petro Poroshenko was elected in May 2014, and the EU-Ukraine Association Agreement was signed in June 2015. Yet, the political situation is still unstable due to the civil war in the Eastern part of Ukraine (Donbass region, i.e. oblast Donetsk and Luhansk) in the aftermath of Russia's intervention to annex Crimea. Accordingly, Ukraine's economy is in a recession with a GDP of 0% in 2013, so that the country depends at the moment on international support from IMF, World Bank, EU/ EBRD to stabilize the financial system. Yet, the support is also connected to policy reforms, especially stopping dubious governance practices, in particular the omnipresent corruption.

Environmental problems and in particular water pollution are a big challenge for Ukraine, not only since the political crisis. According to OECD (2006), all Ukrainian river basins are polluted or heavily polluted. The outdated industries and infrastructure as a Soviet legacy contribute significantly to the pollution, as well as large amounts of chemical residues, mine drainage and agricultural runoff. Yet, the structural changes after the fall of the iron curtain led to the collapse of many industries and the agriculture production of the state-owned farms declined due to a severe financial crisis in the agricultural sector (FAO 2005), which resulted in reduced water pollution. Another legacy of the Soviet times is the wastewater system, which was constructed according to the state-of-the-art at that time. Since investments into operation, maintenance and modernisation were constantly insufficient, the infrastructure is today on the brink of collapse, in particular the WWTPs, and thus water quality is deteriorating. 97.2% of the cities are connected to centralized wastewater system, 57.6% of urban settlements and 2.6% of villages. According to the association Ukrovodokanalecologia, the costs for wastewater disposal varies in Ukraine between 0.075 €/m^3 and 0.48€/m^3 (2013). In terms of water supply, 99.6 % of the cities, 72.2% of the urban settlements and 24% of the villages are connected to a centralized water supply system.

40.7% of the supplied water is lost due to leaks and unrecorded expenses according to Ukrovodokanalecologia (2013). The costs for water supply vary between 0.16 €/m^3 and 0.53 €/m^3 (Ukrovodokanalecologia 2013). Next to physical deterioration of systems, the water sector in Ukraine is also impacted by weak public financing, (incomplete) devolution of responsibility to municipal level, and weak management capacity (Hall and Popov 2005).

6.1.1 Key legislative provisions of the water sector

The key legislative provision for water resources management is the Water Code of Ukraine (213/95-BP) ratified in 1995 and further specified by several by-laws. Article 13 of the Water Code calls for the introduction of RBM,[46] yet it does not specify how implementation should be conducted. In Law No. 2998-III (2002), the State Programme for the Development of Water Management is approved emphasizing the need to establish water management and planning on the level of river basins and calling for the establishment of river basin councils (RBC) and river basin organizations/river basin administration (RBA) for all Ukrainian river basins. In fact, having basin management agencies (so called BUVR) for specific river basins was a policy already during Soviet times, but without conducting river basin management planning as it is perceived nowadays.

The State Programme of 2002 is not specifying competencies and responsibilities of the new institutions, in particular not how to cooperate with the existing authorities, which were responsible for water management until then. The State Programme for the Development of Water Management until 2020 was approved in 2009 stating that river basin management plans (RBMP) need to be used as an operational tool. Apart from some elements of river basin plans that have been developed within projects of technical assistance, no profound river basin management planning has been conducted. The Tisza river basin is the only Ukrainian river basin for which a complete and feasible RBMP has been developed, the so-called Integrated Tisza River Basin Management Plan with assistance of the other riparian states and the ICPDR in 2010.

The Law of Ukraine "On Fundamental Principles (Strategy) of the State Environmental Policy of Ukraine for the Period until 2020" which entered into force in 2010 is the key environmental document and it underscores the importance of RBM.

In 2008, the State Agency for Water Management has developed and approved a regulation (Nakaz No. 56) that provides advice on how to design RBCs and RBAs and defines the

[46] Article 13: 'The state management of water resources use, protection, and restoration is carried out according to the river basin principle on the basis of national, international, and regional programs for water resources use, protection, and restoration.'

principles and the content of RBMPs (Table 13). RBCs comprise representatives of the state, the local governments, water users and NGOs, and the RBAs are considered as secretariat to the council (Figure 20). The objectives of the Nakaz are to improve the status of water resources, e.g. reduction of pollution, reduced flood risk, ecosystem protection and the sufficient allocation of water, yet no explicit or time-bound targets are stated. The functions of RBCs are also laid down in Nakaz No. 56, namely (i) to develop RBMPs and implement programmes of measures, (ii) making decision on water resources management, and (iii) conflict resolution between water users. The RBMP should be designed for 10-15 years and need to be developed two years before the scheduled implementation start. Yet, the Nakaz is not describing detailed procedures about the plan preparation, approval process, methods to be used, and the collaboration with other actors in the river basin.

The underlying principles for the preparation of RBMPs are (I) to reflect EU principles (WFD) in the Ukrainian system, (ii) the financing of the plans and measures should be gradually diversified, i.e. state and local budgets should be substituted more and more by water use and pollution fees, financing of international donors and other sources, and (iii) coordinated and gradual implementation of RBM first within two or three river basins.

The current degree of implementation of RBMPs varies across the Ukrainian RBs but as mentioned earlier, only one RB has an adequate state-of-the-art RBMP at the moment, and it is not clear how RBCs fulfil their tasks. Incentives for progressing are not offered, political pressure towards implementation is not carried out and politicians or directors of authorities within the RBC do not champion RBM. The ratified association agreement between EU and UA might increase incentives for strengthening RBM, since it is stated in chapter 6 to improve the cooperation in environmental protection and especially in Article 363 it is mentioned that a "gradual approximation of Ukrainian legislation to EU law and policy on environment shall proceed...". Annex XXX even explicitly mentions to implement main parts of the EU-WFD (2000/60/EC), e.g. to establish programmes for monitoring water quality within 6 years (as Art. 8 of EU-WFD), as well as the EU Floods Directive (2007/60/EC), e.g. preparation of flood hazards maps and flood risks maps within 6 years (as Art. 6 of EU Floods Directive). However, the current political instability of Ukraine makes it difficult to estimate future progress related to transforming environmental legislation or the adequate adaptation of EU directives.

Table 13: Content of river basin management plans according to Nakaz No. 56

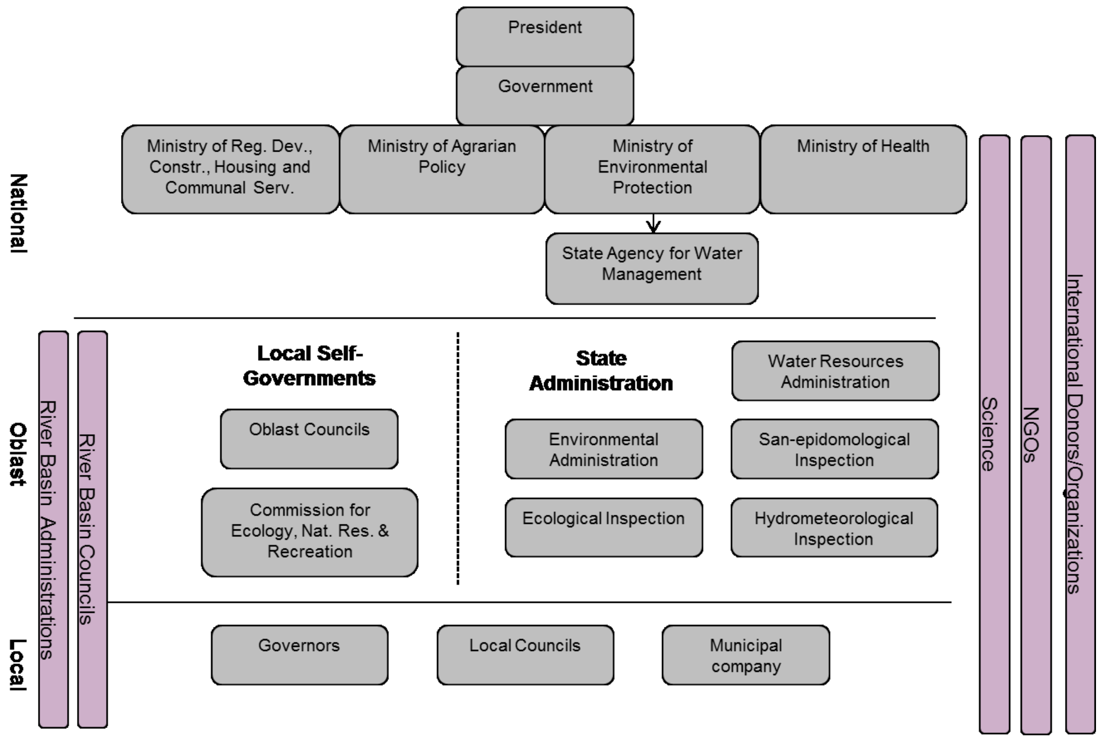
Analysis of river basin district	
Surface water	mapping of the location & boundaries of surface water bodies
	mapping of ecoregions and types of water bodies within each river basin
	mapping of reference conditions for the water bodies defined
Groundwater	mapping of the location & boundaries of groundwater bodies
List of different kinds of anthropogenic impact	
surface water and groundwater	assessment of point-source pollution
	assessment of diffused pollution, including information on land use
	assessment of pressures on the quantitative status of water, including abstractions
	analysis of other anthropogenic impacts on water status
Identification and mapping of protected areas	
Map of monitoring network and information on results of monitoring programme	
Surface water	Ecological and chemical
Groundwater	Chemical and quantitative
Protected areas	
List of environmental objectives for surface water, groundwater and protected areas	
Summary of feasibility analysis of water use	
Summary of programmes of measures	
-	summary of the measures required to implement EU legislation on water protection
-	measures taken to apply the principle of recovery of the costs of water use
-	summary of the measures taken to protect drinking water bodies
-	summary of measures for the control of water abstraction and impoundment
-	summary of measures for the control of point-source discharges & other activities with an impact on the water status
-	identification of the cases where direct discharges to groundwater were authorized
-	summary of the measures taken to reduce discharge of priority substances and thereafter
-	summary of the measures taken to prevent or reduce the impact of accidental pollution
-	summary of the measures taken for water bodies which are unlikely to achieve the environmental objectives
-	details of additional measures aimed at attaining the environmental objectives established
-	details of the measures taken to avoid increase in pollution of sea waters
Register of any detailed programmes and RBMP for a river basin district dealing with particular sub-basins, sectors, issues or water types, including a summary of their contents	
List of competent authorities	
Contact sources and procedures for obtaining background documents, information and monitoring data	
Table compiled and translated by N. Zakorchevna, national IWAS coordinator and governance expert	

6.1.2 Key institutions of the water sector in Ukraine

An overview of the key institutions relevant for the water sector is shown in Figure 19, whereas it has to be mentioned that the administration in Ukraine is characterized by a plethora of committees/ agencies, coordination bodies, and ministerial departments, where tasks and responsibilities, e.g. on surface water monitoring, are not always clearly delineated.

The main player for water resources and river basin management are the Ministry of Environmental Protection (MOE[47]) and the State Agency for Water Management, which is coordinated by MOE, and their local bodies. MOE is mainly responsible for water protection, development and enforcement of environmental legislation, e.g. Water Code, ecological inspection/ monitoring and permitting water uses. The regional environmental administration and ecological inspectorates are responsible for local water abstraction, emissions permits, control and enforcement of environmental legislation, control of industry, monitoring of surface waters (chemical parameters) including laboratory for chemical analysis.

Figure 19: Institutions in the Ukrainian water sector



Source: Dombrowsky et al. 2014

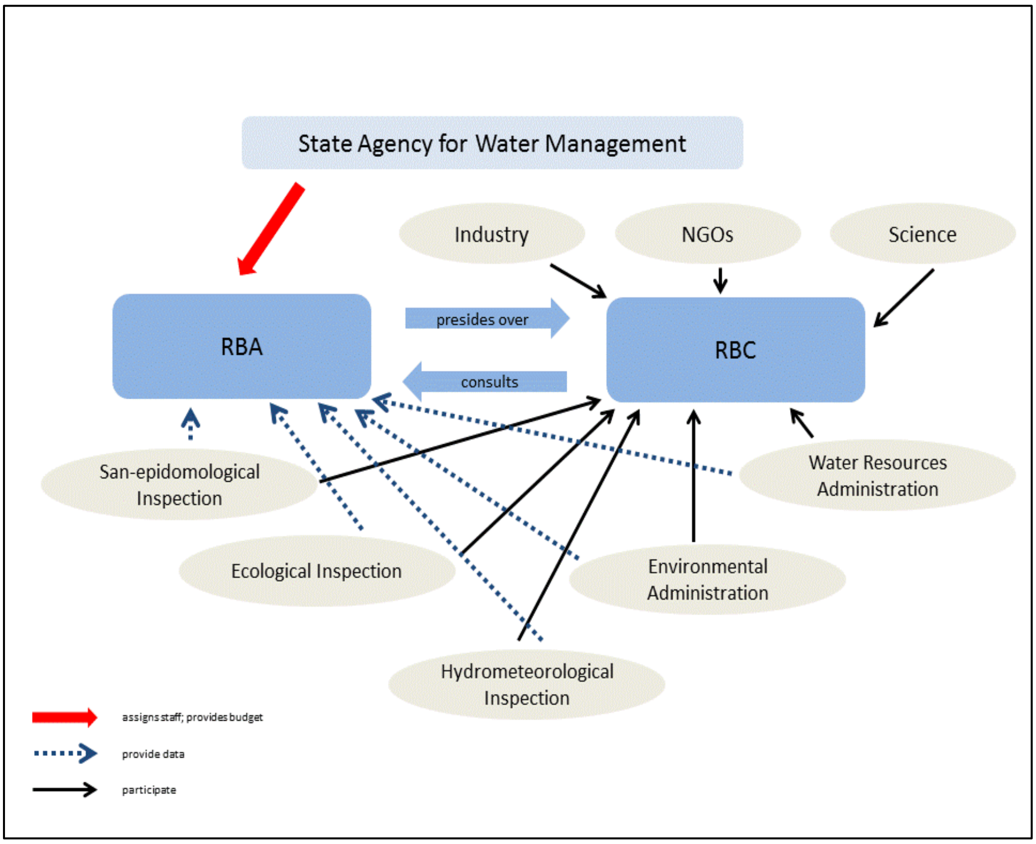
[47] Names of Minsitries change frequently in Ukraine and the MOE is called now Ministry of Ecology and Natural Resources of Ukraine.

The State Agency for Water Management is responsible for the river basin management, execution of water management including water allocation and abstraction, the water use cadastre, the supervision and operation of reservoirs and water supply systems, collecting data on capacities of WWTPs and partly for the chemical surface water monitoring. The RBAs as well as the local water resources administration are subordinated to the State Agency for Water Management.

Another important institution is the Hydro-meteorological Service which was subordinated to the MOE, but since 2005 is subordinated to the Ministry of Emergency Situations. Their responsibility comprises the hydrological and meteorological monitoring, as well as chemical and biological monitoring of surface waters. The San-epidemiological inspection is subordinated to the Ministry of Health and is inter alia controlling hygienic quality of drinking and bathing water and water discharged into natural water bodies.

Civil society actors like NGOs are part of the RBCs, yet their political clout is low. In terms of public participation and involvement of stakeholders, Sigel et al. (2014) mention that post-socialist transition countries still struggle with it, even if e.g. the Law of Ukraine on Local Self-Government (1997) explicitly refers to the right of citizens' participation. More details on the governance system and especially on the institutional design of the water sector with an emphasis on RBCs and RBAs can be found in Hagemann and Leidel (2014).

Figure 20: Organization of river basin management in Ukraine



Source: Hagemann and Leidel (2014)

6.1.3 Western Bug River Basin

The Western Bug originates east of the city of Lviv (Western Ukraine) and flows from oblast Lviv northwards to oblast Volyn where it becomes a border river with Poland and later with Belarus. It is a tributary of the river Narew, which drains into the river Vistula and finally into the Baltic Sea, thus it is a transboundary river. The total basin area is 39,420 km², with 27.4% belonging to Ukraine. Approximately 2 million people live in the Ukrainian part of the basin (>50% of the total population of the basin), and circa 1 million in the agglomeration of Lviv. Investigations within the IWAS project concentrate on the catchment upstream of the reservoir Dobrotvir which covers an area of 2,616 km².

The Western Bug is a lowland river which is meandering from the highlands through flood plains and swamps, with only marginal amelioration in the Northern part of the catchment. A quaternary aquifer underlying the catchment is intensively used for public water supply.

The region is characterized by a temperate climate. Yet, it is climatologically in a transition zone between cold continental climate and western maritime climate. Annual precipitation is circa 650-700 mm and the annual mean temperature is around 7.0-7.6°C (Lipinskyy et al. 2003).

Hydrological pressures within the Western Bug arise from discharge variations and extremes (floods and low flow). Floods during spring and early summer and low water levels in summer are typical characteristics of the river. Mean low, mean and mean flood discharge at the gauge Kamianka-Buzka are 7.6, 17.4 and 73.6 m^3/s, respectively (period 1980-2008; qv. Pluntke et al. 2014).

Water abstraction and flow regulation have minor roles, apart from one barrage (Reservoir Dobrotvir). Nutrients, organic compounds, and heavy metals are the main pollutants within the river system. These compounds are emitted into the river by diffuse sources (e.g. erosion from agriculture, leading to sediment and N, P emissions), and point sources (mainly WWTPs, industrial dischargers, landfill sites and mining) leading to N, P organic compounds and heavy metals (qv. Helm et al. 2012, Ertel et al. 2012, and chapter 8.5.2). As a result of anthropogenic activity, antibiotic resistance in aquatic bacteria is manifested (Ertel et al. 2012, Lupo, Coyne and Berendonk 2012). The major point source is the WWTP of the city of Lviv (~715000 inhabitants). In fact, the river Poltva, a tributary to the Western Bug, originates in the WWTP of Lviv and according to TACIS (2001), two thirds of the Poltva inflow consists of (treated) sewage. The wastewater of the city of Lviv is the major source of pollution of the Western Bug. In summary, the Western Bug and its tributaries are heavily affected by anthropogenic interventions affecting physical, chemical, biological and morphological characteristics.

The institutional set up of the water sector in the Oblast Lviv and Volyn, respectively in the Western Bug River Basin follows the above mentioned organization with their local bodies and the Western Bug Basin Department of Water Resources as RBA, which was established in 2005; details are explained in the upcoming chapters.

6.1.4 Modelling approach within IWAS

Many approaches to systems analysis and modeling within water resources management exist, yet model coupling is still cutting edge research (chapter 3.1.6). The IWAS project attempted to apply a coupled modeling approach focusing on climate modeling aspects, land use modelling and its interaction with water quality and water quantity modeling. An integrated analysis of the catchment (with natural and anthropogenic items) and the river system is conducted. That means emissions from the catchment (pressures) are analyzed and set in relation with an analysis of the water quality (state) of the river system for exploring system deficiencies. The applied methods were (i) analysis of existing data (e.g. hydrological, meteorological, water quality parameters, soil, land use), (ii) measuring campaigns for gathering data, (iii) material flow analyses, (iv) conceptual modeling, as well as (v) numerical modeling. In particular, water and mass balance models were applied (SWAT[48]; MONERIS, Behrendt et al. 2000) and the urban sewage model SWMM (Storm Water Management Model; developed by the U.S. Environmental Protection Agency) and RWQM1 (Shanahan et al. 2001[49]), which is compatible with the ASM (Activated sludge model; first version developed by Henze et al. 1987). For the land use, the model PWF-LU was used. The future projections of the regional climate were modeled by dynamic downscaling of global projections with the regional climate model COSMO-CLM (CCLM; Rockel et al. 2008; Pavlik et al. 2012). For details on the model approach and caveats to coupling, it is referred to the publications of the IWAS consortium, e.g.: Blumensaat et al. 2012; Blumensaat et al. 2013, Ertel et al. 2012, Helm et al. 2012; Schanze et al. 2012; Scheifhacken et al. 2012, Pavlik et al. 2012; Pavlik et al. 2014;).

Next to the integration of different compartments, the objective was to elaborate a conjoint systems and capacity analysis, so that an integrated analysis of the integrated water system can be realized. The following chapter describes the conducted capacity assessment as part of the integrated analysis. The framework for the integrated analysis with the model-based and capacity-based systems analysis and its description is elaborated in chapter 8 and in Leidel et al. (2014).

6.2 Capacity assessment

Based on literature review for capacity development, IWRM in general, as well as existing knowledge on the situation of the water resources management in Ukraine, we decided that we need an approach that (i) is capable of assessing and eventually developing the capacities of *all* capacity levels, (ii) can be operationalised and implemented within the complex political situation of Ukraine, (iii) allows for adaptation, i.e. to change the focus level of CD during the implementation, and (iv) is suitable for overview as well as in-depth assessments. Therefore, we developed a capacity assessment approach which is based mainly on the multi-level approach and the KCD model (Alaerts 2009, Alaerts and Kaspersma 2009) and the UNDP approach to CD (2008; 2009). The detailed capacity assessment approach is delineated in chapter 5.8 and 7.4.

---

[48] The Soil and Water Assessment Tool (Arnold et al. 1998) is mainly applied within meso-scale catchments, and it is a semi-distributed, process-oriented model for simulating the transport of water, nutrients, sediments and pesticides.

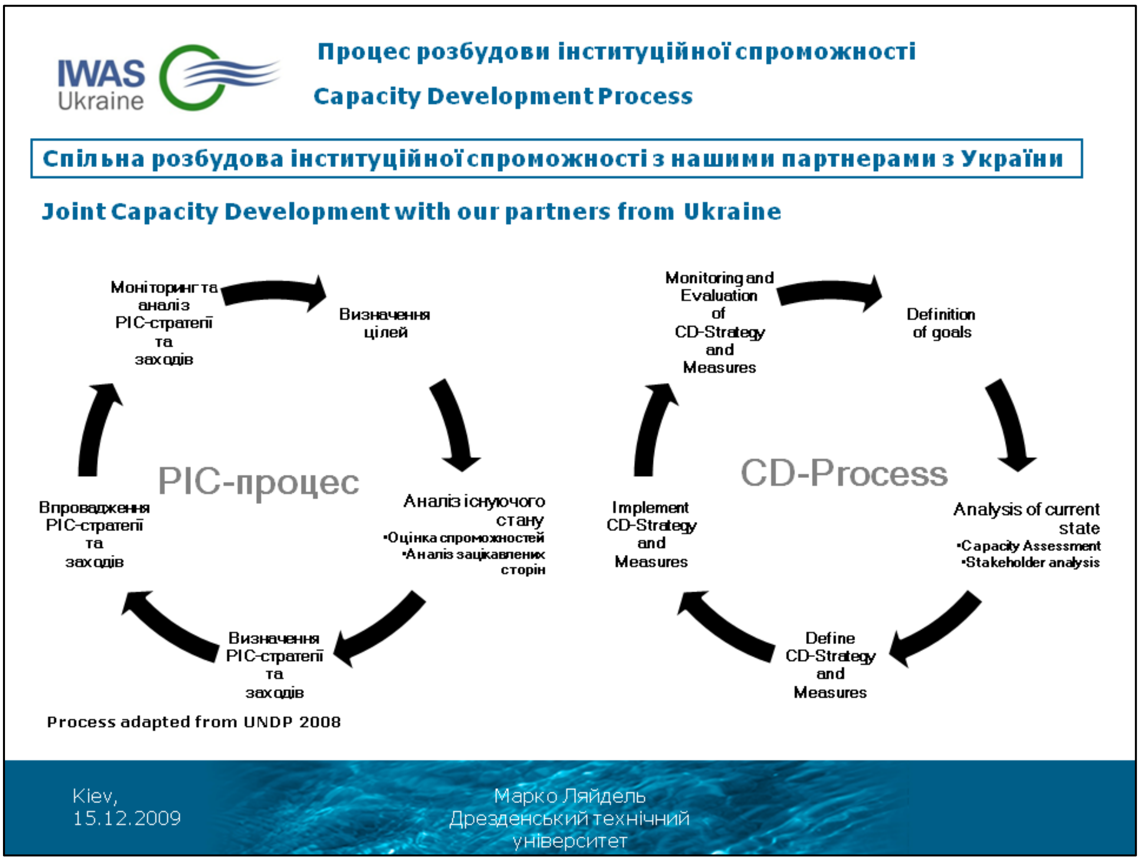
Our main assessment objective at the beginning of the project was to get an overview of the whole water resources sector on the national level, and how it is interrelated with the regional level. The first analyses thus described the institutions and organizations of the sector on the national, as well as on the regional level. Hence, our assessment of each single organisation was not a comprehensive organisational assessment as described by Lusthaus et al. (2002). The focus at this early stage was more on the interdependencies between the organisations, and on the main organisational issues that influence the performance of water resources management in the Western Bug River Basin as well as the organisational output (e.g. monitoring results), thus we were extracting appropriate items from the framework of Lusthaus et al. (2002). This is also in accordance with the European Commission (2007) recommending that the organisation should be considered *at the beginning* as a "black box", i.e. focusing on inputs (e.g. finances) and outputs (e.g. services) of organisations and the context in which it works. They further argue that it is reasonable to assess the quality and quantity of the existing outputs of the relevant organisations, since outputs are good proxies for capacity (Ibid.). But it has to be underscored that a full-fledged water sector reform is a highly complex task ranging from political to organisational and technical issues that need complete in-depth assessments as e.g. described by Lusthaus et al. (2002).

Capacity assessments are sensitive issues, so that their implementation should be done cautiously, especially if it is conducted by external persons. Within the Ukrainian case study, the capacity assessment was conducted by the German IWAS team with support from Ukrainian collaborators and in consultation with actors form authorities for trust generation. It can be reasoned that this strategy, together with focusing more on a broader understanding and not explicitly on internal affairs of a specific organisation, is a viable and non-encroaching approach for starting a CD process.

We utilized the CD approach from UNDP (2008; 2009: Figure 13; chapter 3.2.4.3) and adapted it to our needs (Figure 21). Within the capacity assessment, difficulties as well as existing and missing competencies and knowledge can be identified. Such capacity assessment exercises have to be elaborated together with the relevant stakeholders to get more in-depth information about processes from the stakeholders themselves as well as to get to know the needs of the actors e.g. towards monitoring procedures. We analysed, which competencies in the field of river basin management (RBM) exist, which additional ones are needed for improving current water management, and which challenges towards RBM lie within the identified target groups. Eventually CD strategies that are tailored to the requirements of the stakeholders were developed and discussed. Capacity assessments have been done for:

- public authorities (Environmental administration and water authorities of the oblasts L'viv and Volyn, Western Bug Basin Department of Water Resources)
- science community (on national and catchment level)
- economic sector (municipal water and wastewater companies)

Figure 21: Capacity Development process within IWAS Ukraine



6.2.1 Capacity assessment for public authorities

For the public authorities a profound capacity assessment was carried out (Figure 22). The participants were selected based on observations, document review and purposive sampling techniques, especially expert sampling and snowball sampling (e.g. Henry 1998; chapter 5.8.1). We identified regional and national experts, as well as the major stakeholders that are relevant and that potentially have different perceptions (authorities, NGOs, water service provider, universities). Based on that the major target groups for our study were selected, representing the relevant actors for the mentioned water quality issues in the Western Bug River Basin.

Figure 22: Capacity assessment workshop (Kiev 2009)

6.2.1.1 Survey

In a first step, questionnaires were sent to relevant stakeholders within the Western Bug River Basin. The questions and the structure of the survey were developed and iterated together with Ukrainian actors. Eventually, the 82 questions were structured into the following chapters reflecting the applied multi-level approach:

- institutional and financial aspects (Інституційна сфера, qv. Figure 23)
- technical and organisational aspects (data and information management, planning, monitoring; Технічні питання)
- human resources development (Розвиток персоналу).

Figure 23: Extract from capacity assessment questionnaire

IWAS Ukraine

Анкета для аналізу існуючих або необхідних компетенцій стосовно інтегрованого менеджменту річкового басейну

1. Інституційна сфера:

У цій частині анкети йдеться про інституційну сферу управління водними ресурсами в басейні Західного Бугу. Тобто тут обговорюються організаційні та правові основи інтегрованого менеджменту річкового басейну, а також співпраця і розподіл повноважень між установами та всередині цих установ.

Крім того, у цьому розділі анкети йдеться про фінансові питання, а саме про наявність фінансових механізмів для управління водними ресурсами.

1. Інституційна сфера	Ні	Скоріше ні	Скоріше так	Так	Не знаю
Інституційні та правові рамки інтегрованого менеджменту річкового басейну					
1.1 Чи існують правові основи для реалізаці Інтегрованого управління водними ресурсами (ІУВР)?					
1.2.1 Чи існують постанови про впровадження ІУВР в Україні?					
1.3.1 Чи є на Вашу думку структура управління у басейні Західного Бугу прийнятною для інтегрованого менеджменту річкового басейну?					
1.3.2 Де ви бачите проблеми всередині адміністративної структури?					

From 12 forwarded questionnaires, 6 were sent back. An extract of the Ukrainian version of the questionnaire can be seen in Figure 23. The complete questionnaire as well as the answers of the participants and a summary of the answers can be found in anonymized form in the Doctoral Thesis Database in German and Ukrainian language.

6.2.1.2 Capacity Assessment Workshop

The results of the survey were integrated into the discussions at the capacity assessment workshop and they constituted the framework for the workshop. As mentioned above, IWRM processes and CD processes have to be aligned; therefore we were using the (preliminary) findings from the situation and system analysis (Assessment of natural and technical processes, stakeholder and institutional analysis) for the capacity development process. To account for the holistic IWRM approach, participants of that workshop were from all relevant authorities, national and international scientists and experts and from NGOs.

22 Ukrainian actors were invited, from which 12 confirmed their coming and participated in the workshop (Table 14). Yet, the directors of the authorities neither confirmed nor cancelled the invitation at the beginning, but promised to try to come and they agreed that the invited department heads are allowed to come. Just shortly before the workshop, all directors cancelled their participation. We assume that this was due to the list of confirmed participants, i.e. that maybe not enough high officials from the national level were invited, respectively not enough professors from our side (only one professor confirmed the participation, next to one PhD). However, looking retrospectively at the workshop, we concluded that the open discussions with the profound ideas and results were only possible because they directors were not present. From the IWAS team, six persons participated, with one Ukrainian scientist who is bilingual (German Ukrainian).

Table 14: List of invited and participating stakeholders for the capacity assessment

Stakeholder	Organization	Invitation	Participation
Dr. Kovalchuk Oksana	State administration of environmental protection, L'viv	Yes	Yes
Matolych Bogdan (Director)	State administration of environmental protection, L'viv	Yes	No
Bodnarchuk Tetyana	State Inspectorate of environmental protection, L'viv	Yes	Yes
Jahotskyy Oleh (Director)	State Inspectorate of environmental protection, L'viv	Yes	No
Kinder Oleg	State administration of environmental protection, Wolyn	Yes	No
Myrka Wolodymyr	State administration of environmental protection, Wolyn	Yes	No
Bondaruk Viktor (Director)	Western Bug Basin Department	Yes	No
Serhushko Oleksandr Hryhorovych	Western Bug Basin Department	Yes	Yes
Babych Mykola	State Water Resources Agency of Ukraine,	Yes	No
Chayka Maryna	State Water Resources Agency of Ukraine, L'viv regional management of water resources	Yes	Yes
Mr. Kosak (Director)	State Water Resources Agency of Ukraine, L'viv regional management of water resources	Yes	No

Roman Pavliv	San-Epedem. Service	Yes	No
Buzhak Ihor Vasyly-ovych	Ministry of Environmental Protection of Ukraine	Yes	Yes
Dymitro Rushak	UNDP-GEF Dnipro River Ecological Program; UNOPS	Yes	Yes
Anna Tsvetkova	MAMA-86 (NGO)	Yes	Yes
Myroslav Saplatyn-skyj (Director)	Vodakanal L'viv (Water service provider)	Yes	No
Dr. Demydenko An-driy	Global Water Partnership Ukraine, IWRM-expert	Yes	Yes
Prof. Kovalchuk Ivan Platonovych	National University of Life and Environmental Sciences of Ukraine, Kiev	Yes	Yes
Melen Olha Mary-anivna	NGO "Environment-People-Law"	Yes	Yes
Cholovska Nataliya Valeriyivna	LMHO "Ekoterra"	Yes	Yes
Dr. Nataliia Zakor-chevna	Mott MacDonald water resources expert	Yes	No
Zakorko Olena Pav-livna	State Institute for Administration and Man-agement of water resources (Further education institute)	Yes	Yes
Prof. Peter Krebs	Technische Universität Dresden	Yes	Yes
M.Sc. MarcoLeidel	Technische Universität Dresden	Yes	Yes
Dipl. Hydrol. Jörg Seegert	Technische Universität Dresden	Yes	Yes
Dr. Herwig Unnerstall	Helmholtz Centre for Environmental Research	Yes	Yes
Mag. Lesya Gram-Radu	Helmholtz Centre for Environmental Research	Yes	Yes
Mag. Nina Hagemann	Helmholtz Centre for Environmental Research	Yes	Yes

Participating stakeholders are written in green.

At the beginning of the workshop, it was defined what capacity and capacity development is (Figure 24). From that assessment, possible solutions were identified, i.e. different options were analysed according to their financial, environmental and political feasibility. Finally, the project identified and proposed both prioritized CD measures, responsibilities and a schedule was adopted.

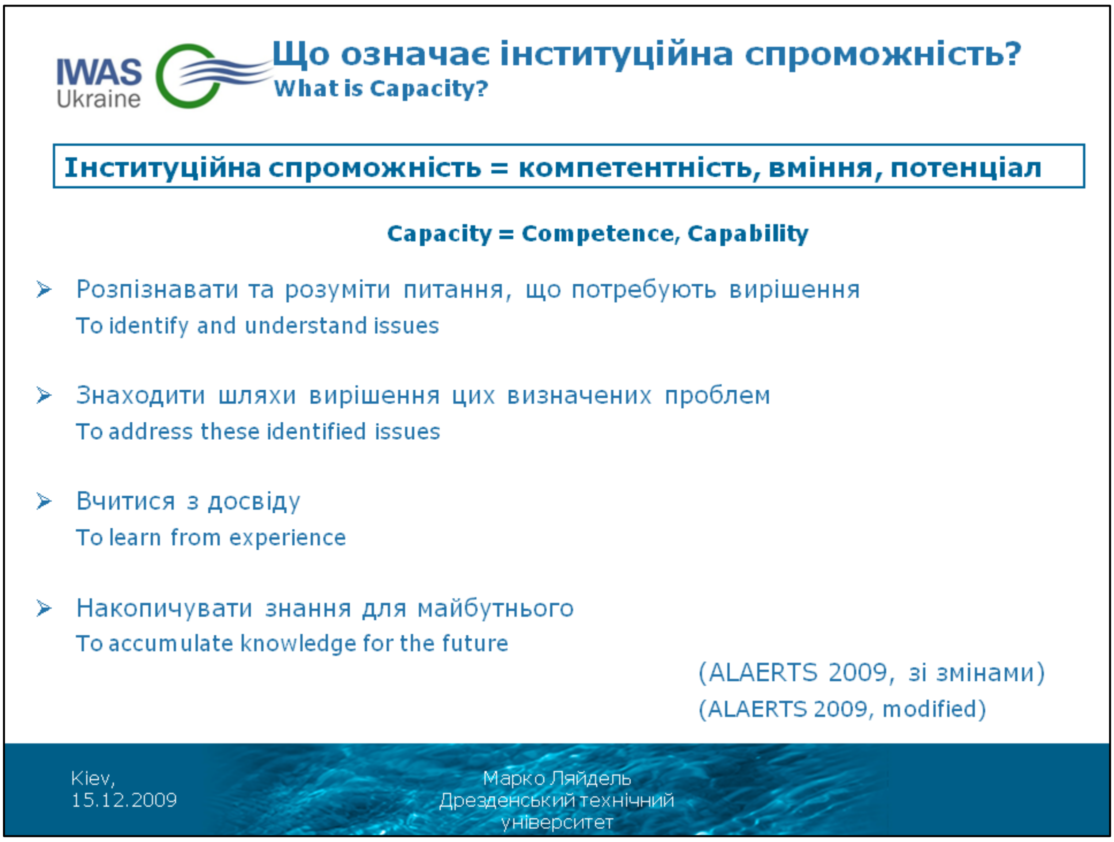
In detail, the capacity assessment workshop was executed in the following way:

- Identify future desired status of the water resources management
- ➢ Desired capacities in the institutional domain
- ➢ Desired capacities in the technical domain
- ➢ Desired capacities in the human resources development
- Analysis of available capacities of the water resources management
- ➢ Available capacities in the institutional domain

- ➢ Available capacities in the technical domain
- ➢ Available capacities in the human resources development
- ▪ Development of CD strategy, identification of possible solutions including the analysis of their feasibility (political, financial, environmental)
- ▪ Develop and prioritize CD-Measures (legal, institutional, technical, management)
- ▪ Drafting of a work plan including schedule, commitment of stakeholders

The capacity assessment showed the importance of the challenges within the institutional framework and political process of river basin management in Ukraine. The workshop contributed well to the understanding of the governance system of Ukraine in respect to water resources management. Apart from that, it evolved that the authorities consider the areas of data management/ collaboration, water monitoring, water modelling and human resources development as highly important (Leidel et al. 2012). The programme of the workshop, an introduction to the workshop, a summary of the results as well as the Capacity Development schedule can be found in the Doctoral Thesis Database in German and Ukrainian language. The results are further described in depth in chapter 7.4.2.2.

Figure 24: Capacity definition for the capacity assessment



6.2.1.3 Political process for knowledge exchange and CD

The process of knowledge exchange and capacity development with the public authorities on regional and national level started at the very beginning of the IWAS project. The major activities and milestones of this political process within IWAS Ukraine are listed in Table 15. In March 2009, several Ukrainian stakeholders from universities as well as from the administration came to Dresden for starting the information exchange and starting the collaboration. Most important first step was the field trip to the model region from 19/04-24/04/2009, where interviews and discussions with the stakeholders were conducted. From the interviews and discussions it can be summarized that the quality of the available data is problematic, especially the data of the river water quality, because four different organizations are conducting water monitoring: State Inspectorate of Environmental Protection, State Water Resources Agency of Ukraine, Lviv regional management of water resources, San-epidemiological service, and Hydro-meteorological service. The analyzed parameters, the measuring points and the measurement points in time vary between the four organizations. The measurement interval is still unclear, quarterly or monthly. The hydro-meteorological service conducts 13 measurements per year. The measured values are forwarded to the monitoring department of the state administration of environmental protection, Lviv, *and* to the Western Bug River Basin department (WBRBD), whereby it is unclear, whether the mean values or the raw data are forwarded. The interview with Mr. Bondaruk (director of the WBRBD) conducted by some IWAS scientists, led to the impression that only data from oblast Volyn are further processed.

Accordingly, the major problem within water monitoring is an institutional one. Verifying the consistency of the monitoring data and recommendations for an improved monitoring system seem to be necessary. Concrete measures could be to enhance the collaboration and the data management among data collecting authorities and between them and data processing authorities by CD measures. Due to the significant differences in the measured parameters, a quality assessment within the frame of an intercalibration could be worthwhile. Furthermore, interviews on different occasions with Ms. Kovalchuk from Lviv, and Ms. Maturova (National Academy of Sciences of Ukraine, Institute of Hydrobiology) that the enforcement of the planned policies and measures is necessary, but hardly done, especially because fines are not available, too low or not enforced at all.

In addition, the available river water data are not sufficient for realistic and reasonable modeling. The data on the wastewater discharge from 2003 to 2009 in the oblast Lviv could be obtained from Ms. Bodnarchuk. Data on the wastewater quantity can be obtained from Ms. Chayka. Meteorological data are available, but only in analogue form. A soil map of the catchment in the scale 1:10.000 is digitally available. Due to the sparse data availability, it was proposed to conduct an intensive and profound measuring campaign with Ukrainian and German scientists and students.

It was also frequently mentioned that there is only a lack of funding, which constrains water monitoring. For instance Mr. Myrka Wolodymyr from the state administration of environmental protection, Wolyn, mentioned in the interview that we (IWAS) should provide financial resources, and then the administration is capable of fulfilling all monitoring needs. I encountered that there are potentially also other issues that are not directly related to a lack of funding (e.g. intransparent organizational procedures), respectively that it may be useful to analyze whether the available financial resources are used in an efficient way. Since more financial resources are not per se improving the efficient use of the funds.

The capacity assessment was an essential milestone, where important knowledge about the Ukrainian system in respect to water management and to the peculiarities of the Western Bug River Basin could be developed. The follow up on the results of the workshop started immediately afterwards. However, the Ukrainian presidential election in 2010 brought a political change with an exchange of most key actors on all national administrative levels, so that it was necessary to modify the capacity development schedule. This influenced also our regional activities, even if only minor changes occurred on the regional level. In spite of that, we proceeded with strengthening RBM in the Western Bug River Basin and, as agreed within the capacity assessment, started with planning of the meeting of the WBRB Council. Although all preparations were done jointly together with the WBRBD, the council meeting and the workshop were cancelled only one week before the scheduled date by the director of the WBRBD with no plausible reasons. The major lessons from this setback were that (I) a stronger involvement of the national level is needed, even if regional authorities claim to have full authority on the RBM process, and (ii) more coordination is needed on the regional and national level. In the second phase of IWAS, the working group on capacity development focused on a dialogue with the key national actors, and we established one coordinator on national level and one on regional level. The strategy was to discuss RBM with the national level, and only after getting the commitment of the major national actors to collaborate, we proceeded with the process in the WBRB. Accordingly, an inter-ministerial workshop for river basin management was held in February 2012 with 36 participants from various ministries and civil society actors (Table 15). All participants underlined the importance of RBM for Ukraine and decided to establish a working group on *integrated water resources management* that should develop a strategy for introducing RBM in Ukraine and to have the WBRB as a pilot basin for integrated RBM. The working group's major achievements were (I) realizing the meeting of the WBRB council, which adopted also a work plan for 2012-2103, (ii) an accompanying workshop on river basin management for the regional actors in the WBRB, (iii) a policy paper on *Strengthening Implementation of Integrated Water Resources Management (IWRM) in Ukraine*, and (iv) initiating a follow up on the IWAS activities, with an emphasis on twinning activities. Therefore, additional funding was secured (*National Dialogue for grouping capacities-Integrated river basin management in Ukraine),* that facilitated the discussion between German/ EU representatives and the Ministry of Ecology and Natural Resources of Ukraine on possibilities of cooperation. The potential topics for a twinning arrangement were discussed as well as the procedure to apply for a twinning project with the EU. A project proposal was developed named *Capacity Development for strengthening water monitoring as a contribution to river basin management*. The project purpose is to contribute to the improvement of the water administration in Ukraine by advancement and harmonization of water monitoring according to EU water related aquis communautaire. Another focus, next to the strengthening of water monitoring system, should be on the development of human and institutional capacities. Due to the escalating violence of the Euromaidan movement in February 2014, however, no responsible person within the Ministry of Ecology and Natural Resources of Ukraine was able to hand in the finalized proposal before the deadline of the EU. Several other options for financing an EU-UA partnership in the water sector were investigated; especially arguing on a *window of opportunity* for collaboration after the new Ukrainian government was established. Yet, the situation until mid of 2014 was that German/ European decision makers opted for not financing any major activities due to the instable and unpredictable political situation.

.

Table 15: Timeline of political process within IWAS Ukraine

Date	Place	Main topics	Participants
30/03/2009-02/04/2009	Dresden	• Meeting with Ukrainian actors; information exchange - Dr. Kovalchuk provides us overview of measured parameters (river water quality), measuring points, metadata, concrete data from emitter - GIS based on mapinfo - Interested in cooperation - No financial allowances mentioned - Ms. Chayka manages data from wastewater discharger - Mainly voluntary responses/disclosure from discharger - Database, but not available for IWAS; database queries possible - Will send us offer for sub-catchments as well as a sample (discharges into Poltva, Western Bug until Dobritvir as well as until Sokal for 3 respectively 10 yrs.)	- Dr. Oksana Kovalchuk, head of monitoring department; State administration of environmental protection) - Ms. Marina Chayka (State Water Resources Agency of Ukraine, Lviv regional management of water resources) - Mr. Bondaruk (Director Western Bug River Basin Department) - Prof. Hirol (NUWMNRU in Rivne)
21/04/2009	Lviv	• Meeting and interviews with members of Ivan Franko National University Lviv (IFNU Lviv) - Discussion about scientific collaboration (e.g. integrated soil management; climate change) - Availability of meteorological data of the Western Bug River Basin - Discussing about study programmes at IFNU Lviv and TUD - Student exchange and advertising TUD's Hydro Science and Engineering study programme - Collecting funding possibilities for UA students - Joint development of lectures - Discussion on measuring campaign; definition of parameter that should be assessed - Signing of letter of Intent with Vice rector for international relations Prof. Volodymyr Kyrylych	- Prof. Kovalchuk (National University of Life and Environmental Sciences of Ukraine, formerly IFNU Lviv) - Prof. Kit (IFNU Lviv) - Ms. Olga Pylypovych (IFNU Lviv) - Ms. Kuvcanevic (IFNU Lviv) - Mr. Leidel (TUD) - Mr. Pluntke (TUD) - Ms. Tavares (TUD) - Ms. Lobandska (IFNU Lviv; doctoral candidate) - Wolodya Motyl (DREBERIS)
21/04/2009	Lviv	• Meeting and interviews with members of Lviv Polytechnic National University (PNU Lviv) - Discussion about potential scientific collaboration; Dr. Oksana Kovalchuk is scientist at Prof. Malyovanyy's department (and head of monitoring within regional environmental administration) - Discussing about study programmes at PNU Lviv - Student exchange is possible	- Prof. Yuriy Rashkevych, Vice-Rector of International Relations of PNU Lviv - Prof. Malyovanyy, Director, Department of Ecology and Sustainable Nature Management, PNU Lviv - Prof. Zhuk, Head of Department of Hydraulics and Sanitary Engineering, PNU Lviv; now

			deputy head - Mr. Leidel (TUD) - Ms. Weigelt (DREBERIS)
23/04/2009	Lviv	• Making contact with Bohdan Matolych Head of State administration of environmental protection	- Mr. Bohdan Matolych - Ms. Oksana Kovalchuk - Mr. Marco Leidel - Ms. Leysa Gram-Radu
23/04/2009	Lviv	• Interview and discussion with Dr. Oksana Kovlachuk, head of monitoring department; State administration of environmental protection - Cooperation agreement with state administration of environmental protection in Lviv oblast is important basis for collaboration in the Western Bug River Basin - TACIS I: Set up of monitoring - TACIS II: Western Bug River Basin Council, river basin management and monitoring established (since 2006) ➔ 15 Persons that are trained in monitoring activities - Oblast Lviv only region with monitoring activities - TACIS: training seminars up to 1 month, e.g. EU-WFD has been explained to 50 persons ⇨ But: not relevant for employees, because WFD is no legal requirement in UA ⇨ But directors and decision makers have no idea about WFD ⇨ two problems/ tasks in Ukraine: 1. directors and decision makers need to know about the importance of the WFD; 2. middle management need tools for data management - Many different data are measured, but no management - Hierarchy within administration important in Ukraine; we have to consider the different levels (Head and upper management, middle management [Ms. Chayka, Ms. Kovalchuk, Ms. Bodnarchuk], working level) - Head and upper management only interested in CD measures if instructions are received from higher levels, if they cannot hide (e.g. send them to Dresden), or if you pay them. - Middle management should educate working level, but also German experts; training of trainers - Ms. Kovalchuk will provide list of most important contacts - Cooperation agreements should explicitly mention that all levels of administrations have to take part in further education	- Dr. Oksana Kovalchuk - Mr. Marco Leidel (TUD) - Ms. Leysa Gram-Radu (UFZ) - Ms. Anna-Maria Ertel (TUD, Institute for Hydrobiology) - Dr. Susanne Rollinski (TUD, Institute for Hydrobiology)

	- Advantages of vocational training has to be made clear
	- Results from laboratory are going directly to water resources department, with which she has no contact
	- Proposal to have basic introduction to IWRM/ EU-WFD for all actors, followed by specific topics like data base management, methods ➔different courses for different experts; joint development with Ukrainian stakeholders
	- integrated monitoring stations necessary , i.e. that not four administrations measure parameters, but only one.
	  ⇨ Cannot be done by IWAS; but IWAS can support it; target can be to improve communication between data collecting and data processing administrations;
	  ⇨ Ultimate goal: information system
	  ⇨ Implementation has to be done by UA
	- CD-concept for Ukraine needed: Harmonization of data, data management, and communication between authorities
	- Intercalibration of monitoring sites within measuring campaigns (Ms. Kovalchuk can advise the four authorities to measure)	

24/04/2009	• Interview and discussion with Environment People Law (EPL)
	- Making contact
	- Working in CD (workshops etc.)
	- legal expertise (environmental law)
	- project on pesticides; principal is State Environmental Inspectorate, financed by EU
	- EPL has filed several lawsuits against State Environmental Inspectorate
	- 1/3 of their work are lawsuits
	- He does not know the Western Bug River Basin Council
	- Access to environmental information is regulated by law
	  ⇨ normally, the state has to provide the information; only if information is a state secret, then it is allowed to refuse the delivery
	  ⇨ in oblast Lviv almost all data considered as top secret
	  ⇨ reformed law not implemented yet
	- Preparing legislation: NGOs are heard but do not play a role in weighing of interest
	- Role of NGOs in UA undervalued
	- It has to be clarified, whether they can be experts for CD measures
		- Mr. Lohzan (EPL)
		- Mr. Marco Leidel (TUD)
		- Ms. Leysa Gram-Radu (UFZ)

31/08-07/09/2009	Lviv, Lutsk	• Preparation of capacity assessment; interviews with key stakeholders • Preparation of measuring campaign	- Mr. Viktor Bondaruk - Dr. Oksana Kovalchuk - Mr. Marco Leidel
07/09/-20/09/2009	Western Bug River Basin	• Measuring campaign - 4 working groups: Urban Water Management, Hydrology and Meteorology, Hydrobiology, Site Ecology - Tasks (Selection): longitudinal section measuring with sensors, chemical analysis, sediment, phytoplankton, macrophytes, urban discharge balance, measuring of quality parameters in a longitudinal section of the Poltva for the identification of dischargers, installation of rain gauges, measuring flow rate, land use mapping, etc. - In average 25 German scientist, 4 Ukrainian scientists (including one from National Academy of Sciences of Ukraine), 2 employees from Western Bug River Basin Department, 20 German students, 8 Ukrainian students	-
03/10-09/10/2009	Kiev, Lviv	• Preparation of capacity assessment; interviews with key stakeholders from national level. - Discussion and interview with Dr. Demydenko, water expert, on the issue of thresholds: unrealistically low in UA, exact knowhow on limits still missing, shift from controlling to managing; BUT: State Environmental Inspectorate benefits from low limits. - NGO Mama-86 on the main challenges of Ukrainian water management - UNDP Ukraine • Preparation of capacity assessment; interview with regional stakeholder	- Dr. Andriy Demydenko - Ms. Ana Tsvetkova (NGO Mama-86) - Dr. Oksana Kovalchuk - Mr. Marco Leidel
14/12-16/12/2009	Kiev	• Capacity Assessment Workshop • See chapter 6.2.1 and 7.4.2	- see Table 14
01/2010-12/2010	Lviv, Lutsk, Dresden	• Regular meetings and telephone conferences for implementing results of Capacity Assessment Workshop, especially on the agreed reactivation of the river basin council meetings as a start for improving RBM: - Strengthening RBM in the Western Bug River Basin, e.g. working on reinstalling the meetings of the Western Bug River Basin Council. Discussions on regional level with Mr. Bondaruk and Ms. Kovalchuk; - Our partners in authorities (especially Ms. Kovalchuk) demanded for the planning of workshops on integrated river basin management for directors, upper and middle management. Including participants from German authorities and analyzing possibilities for twinning. - Major distortions due to Ukrainian presidential election (17 January and 7 February 2010) with a political change from "orange revolution" to Viktor Yanukovych; many	- various

		partners in Ministries were exchanged, so that the capacity development schedule was modified - Planning of training measures (e.g. modeling, statistics) - Strategic discussions on how to proceed (stronger integration of stakeholders, etc.) - Preparing application for second phase of IWAS	
06/2010-08/2010		• Planning of programme and logistics for meeting of the Western Bug River Basin Council and the workshop on integrated RBM - Discussion on strength of council and the members, funds - Discussion on the still not finished management plan - Clarification who has power to convoke the meeting=> Director Western Bug Basin Department - strategy for the meeting, translation during meeting - which content - who must/should speak, - how to integrate IWAS in the official meeting; Project leader Prof. Krebs as scientist on water modeling as tool for strategic river development - scheduled for 8/11-9/11/2010, then rescheduled in mid of August due to the request of Mr. Bondaruk to 02/12-03/12/2010 - invitations for meeting done by basin department • Agreement that the council meeting and the workshop on integrated RBM will be done jointly by the Western Bug Basin Department and IWAS	- Mr. Viktor Bondaruk - Mr. Marco Leidel
02/12-03/12/2010		• Planned meeting of the Western Bug River Basin Council and the workshop on integrated RBM - The meeting and workshop was agreed upon with the Ukrainian authorities, especially with the Director of the Western Bug Basin Department - High-ranking German representatives from the environmental administration accepted the invitation - Because of the new political situation and the decreasing support from the Western Bug Basin Department, the council meeting and the workshop were **cancelled** only one week before.	-
16/12.-17/12/2010	Dresden	- Final IWAS-I Ukraine Workshop	-
01/2011		The second phase of the IWAS project starts (01/2011-07/2014)	-

04/2011- 12/2011		• Establishment of one coordinator on national level (Ukraine) and one on regional level (Western Bug River Basin), restarting discussions on how to improve river basin management	-
06/02/2012	Kiev	• Inter-ministerial workshop for river basin management • Results: Setting up an inter-ministerial working group that develops a strategy for introducing RBM, first in the Western Bug River Basin and potentially also in other RBs of Ukraine: - The WBRB as pilot river basin for RBM in UA; authorities should use IWAS data/ recommendations; monitoring as basis for decisions - Developing a management plan/ measures for the WBRB - Reestablishing river basin council meetings in the WBRB; - Strengthening of monitoring and collaboration within the WBRB - Strengthening of (tertiary) water education	- 36 participants from various ministries (Environment, Economy, Education, Agriculture, Civil protection) and agencies (water resources, environmental inspection, geology, forestry, land use), Council for National Security, IWAS, GIZ, NGOs (list of participants can be found in database of the doctoral thesis).
18/04/2012	Germany, Ukraine	• Discussion paper for the setting up inter-ministerial working group to strengthen river basin management in Ukraine - Strategy to strengthen RBM in Ukraine - Preparation of river basin council meeting - Content-related milestones for RBM to be developed by working group	- Draft by M. Leidel (can be found in the database of the doctoral thesis)
23/04/2012	Kiev	• 1st meeting of the Inter-ministerial working group "Integrated water resources management" - Discussion on the contents and program for river basin council meeting and accompanying workshop for capacity development	- List of participants can be found in the minutes in the database of the doctoral thesis
19/06/2012		• Meeting of the River Basin Council and Workshop Adopted a work plan for 2012-13 for the Western Bug Basin Department of Water Resources	- List of composition of WBRB Council participants can be found in the database of the doctoral thesis, as well as minutes and work plan
01/11/2012	Germany, Ukraine	• Strengthening implementation of Integrated Water Resources Management (IWRM) in Ukraine- Policy paper for inter-ministerial working group "Integrated water resources management"	M. Leidel and J. Schanze within the Dresden-Leipzig water science cluster/IWAS results

07/11/2012	Kiev	• 2nd meeting of the Inter-ministerial working group "Integrated water resources management" for discussing policy paper for inter-ministerial working group "Integrated water resources management"	List of participants can be found in the minutes in the database of the doctoral thesis
10/07/2013	Kiev	• Final IWAS conference	List of participants and presentations can be found in the database of the doctoral thesis
11/2013–02/2014		• National Dialogue for grouping capacities-Integrated river basin management in Ukraine (Project funded by the German Federal Ministry fort the Environment, Nature Conservation and Nuclear Safety with means of the Advisory Assistance Programme for Environmental Protection in the Countries of Central and Eastern Europe, the Caucasus and Central Asia, supervised by the Federal Environment Agency)	
11/12/2013	Kiev	• Workshop "National Dialogue for grouping and developing capacities in the water sector	Participants of the workshop were from the Ministry of Ecology and Natural Resources of Ukraine, the State Agency for Water Resources, the Ministry of Regional Development, Construction, and Communal Living of Ukraine, as well as from scientific organizations, water service providers and NGOs (Mama-86); TU Dresden, German representative to the EU-Common Implementation Structure (CIS)
02/2014		• Proposal for a EU-UA twinning project: Capacity Development for strengthening water monitoring as a contribution to river basin management	Representatives of Ministry of Ecology and Natural Resources of Ukraine, Stephan von Keitz (German representative to the EU-Common Implementation Structure, CIS), Marco Leidel (TU Dresden), Natalia Zakorchevna (Consultant)

6.2.2 Capacity assessment for academic education in the water sector

For the science community the capacity assessment was based on several discussions and meetings with Ukrainian scientists from various universities, Ukrainian water experts, as well as employees of the Ministry of Education (Milestones can be found in Table 24). This was corroborated with the analysis of curricula in water management. Within the situation analysis, the Ukrainian academic education in the field of water sciences was analysed.

The prevailing engineering approach to water management in Ukraine is also mirrored in academic education focusing on water engineering. The education in the field of water sciences is strongly focusing on natural sciences and engineering sciences, i.e. it focuses on training on hydraulic construction and infrastructure. IWRM related topics of social sciences are largely missing. Consequently, no interdisciplinary courses on IWRM are available at Ukrainian universities (Demydenko and Leidel 2010). Furthermore, the research is in some cases not state of the art in water sciences, e.g. modelling of water quality and quantity or biological monitoring is not common. For reaching a vast amount of future decision makers in the field of water resources management, IWRM and RBM should be integrated in curricula of universities in Ukraine.

An important role within the Ukrainian academic water education plays the National University of Water Management and Nature Resources Use (NUWMNRU) Rivne, since many engineers and future decision maker within the water sector are educated there (80% of the directors of the Ukrainian vodokanal companies are educated in Rivne according to Prof. Sapsay, vice-rector for research, education and international relations of NUWMNRU). The faculty of water resources at the NUWMNRU has 9 chairs, 11 professors and 83 doctors with 800 full time students and 500 part time students. The disciplines of the faculty are inter alia hydrogeology, use and protection of water resources, ecology, hydraulics, meteorology, nature protection, and monitoring methods. The study courses are divided into bachelor programmes (4 yrs.) followed by programmes for "specialists" (75% of students; 1 year) or programmes for "masters" (25% of students; 1 year but more credits needed compared to "specialists"), and also PhD programmes are available. Since Ukraine is part of the Bologna-process, it is planned to change completely to the B.Sc. /M.Sc. system. In 2011 three new specializations for the "masters" were proposed to be integrated into the master's programme of the faculty of water resources, namely (i) water management and natural building, (ii) hydrotechnics and (iii) rational use and protection of water resources.

A current list from the year 2013 of all available courses at the NUWMNRU can be found in the doctoral thesis data base.

The NUWMNRU in Rivne is not within the Western Bug River Basin but in its vicinity and there were already studies done within this catchment, which was another argument for integrating the NUWMNRU into our activities.

Yet, the assessment and the collaboration focused also on universities in the catchment of the Western Bug River. This is reasonable, since we wanted to cooperate with universities having local context specific knowledge. The Ivan Franko National University Lviv (IFNU Lviv) plays an important role not only within the catchment of the Western Bug River. There, the Department of geography is working on various aspects (planning, hydrology, meteorology, flood assessment) related to the Western Bug. Accordingly, professors, PhDs, doctoral candidates as well as students have been intensively integrated into IWAS activities. The Lviv Polytechnic National University (PNU Lviv) plays a significant role in Western Ukraine, since it has a study course on Ecology and Environmental Protection and the University has close connections to the Department of Environment and Natural Resources of Lviv Regional State Administration. Therefore, the IWAS project developed together with the NUWMNRU, PNU Lviv and IFNU L'viv a postgraduate module on IWRM (chapter 9.3).

Apart from universities, we were also screening the educational landscape for IWRM courses in Ukraine. E.g. GWP Ukraine was organizing once a seminar with five lectures in the realm of IWRM for representatives of river basin management (RBM) authorities. Furthermore, the ministry of Environment as well as the Water Agency have academies for advanced training. The latter is offering inter alia IWRM courses for staff of Water Agency and RBM authorities. Yet, according to one national water expert, the courses are called IWRM, but they are not focusing at all on IWRM. This could not be corroborated by further sources of evidence, since course outlines and course descriptions could not be made available.

6.2.3 Capacity assessment for economic water sector

For the economic water sector, the assessments were done for municipal water and wastewater companies, most of them in the Western Ukraine. In order to get a more holistic picture of the situation for wastewater companies in Ukraine, also the national association Ukrovodokanalecologia was integrated into the assessments. This NGO was established in 1995 with the objective of providing methodological and organizational support for their members in the field of water management. The association represents 70 municipal water management companies ranging from small companies with less than 30000 customers to huge companies with more than one million customers, and also organizations like universities are members (Table 16: Member structure of UkrovodokanalekologiaTable 16). Next to training, conferences and knowledge exchange between members, the association focuses on cooperation with the national political level in questions related to water management, e.g. standard setting. Another focus of the association is to reduce the energy consumption of water management companies, since this represents a major cost factor, especially for the wastewater companies. Therefore an energy-efficiency center was established in 2009.

Table 16: Member structure of Ukrovodokanalekologia

Amount of customers	Amount of municipal water management companies
<30,000	6
30,000-50000	13
50,000-100,000	10
100,000-200,000	20
200,000-500,000	11
500,000-1,000,000	7
>1,000,000	5

Source: Data from Ukrovodokanalekologia

In depth assessments of the water quality parameters of the inflow as well as the effluent were conducted for several companies throughout Ukraine under the auspices of the Stadtentwässerung Dresden (Wastewater company of the city of Dresden, Germany) as IWAS member. This was also conducted for the city of Lviv within the Western Bug River Basin. In contrast to the other cities, a holistic assessment of the capacity gaps was also conducted including the governance context (8.5.1). During the course of the IWAS project, additionally an assessment for a smaller city within the Western Bug River Basin was started namely Chervonograd and conducted predominately by the Institute for Urban Water Management of the TU Dresden as well as the company DREBERIS. The city was chosen, because it resembles 47 cities within Ukraine with a population between 50,000 and 100,000 with ailing infrastructure, inadequate financial means and an unsatisfying wastewater system in the adjacent rural areas. This work resulted eventually in another project funded by the German Federal Environmental Foundation.

7 Capacity development as a key factor for integrated water resources management (IWRM): improving water management in the Western Bug River Basin, Ukraine

The following chapter is a citation of the original published peer reviewed manuscript:

Leidel M, Niemann S, Hagemann N (2012) Capacity development as key factor for integrated water resources management (IWRM): improving water management in the Western Bug River Basin, Ukraine. *Environ Earth Sci. DOI: 10.1007/s12665-011-1223-5.*

7.1 Abstract

There is growing consensus in the global water community that the concept of Integrated Water Resources Management (IWRM) is only the starting point in the IWRM implementation process. This paper proposes that special attention should be drawn to well-elaborated and adapted Capacity Development (CD). It is argued that measures for solving existing water problems can only be sustainable and effective, if the knowledge generated about possible solutions is deeply rooted within the originating region. General guidelines for CD and knowledge transfer are elaborated, and these constitute the basis for region-specific CD strategies as exemplified in the Ukrainian Western Bug River Basin, one of five model regions within the International Water Research Alliance Saxony (IWAS). As a first step towards improving river basin management, situation analysis and capacity assessment are undertaken to evaluate social and political circumstances, identify relevant stakeholders, existing competencies, and anticipated difficulties in establishing an operational IWRM and appropriate tailor-made measures are proposed. The experiences gained during this process indicate that neither IWRM nor CD can be expected to stand alone when considering sustainable development in water resources management.

7.2 Introduction

The paradigm of Integrated Water Resources Management (IWRM) has been generally accepted and is the basis for improving management in the water sector worldwide[50].

IWRM deals with complex and dynamic adaptive systems that comprise political, economic, social, environmental and technical factors and their interactions (cf. definition of IWRM, GWP 2000). Shifting towards sustainable water management practices, the concept

[50] IWRM is a general principle of international development cooperation, e.g. Germany follows the IWRM model in all its development activities in the water sector (BMZ 2006).

emphasizes a process of permanent change without prescribing a “perfect” system to be implemented at once.

Biswas (2004) and García (2008) doubt that the implementation of IWRM is possible at all. As an overarching concept, however, IWRM is not a concrete dogmatic manual at the operational level or a rigid series of steps to be followed. Instead, it should be seen as a flexible conceptual framework based on the principles equity, efficiency and sustainability—a general guideline for a more efficient water management that needs to be customized for the unique requirements of the region concerned (UN-Water 2008). In a global perspective, the current implementation status of the IWRM process is still dissatisfying according to UN-Water (2008).

Since the late 1980s, the concept of capacity and capacity development (CD) has been in general use for international development cooperation as well as in the water sector in particular (Alaerts et al. 1991, Baser and Morgan 2008). It is increasingly recognized that inadequate governance structures and especially the gap between existing and necessary capacities, rather than technical challenges, are constraints for enhanced water resources management (cf. Alaerts 2009).

The International Water Research Alliance Saxony (IWAS) is dedicated towards improving water management in several world regions, inter alia Eastern Europe/Ukraine, and the concept of IWRM constitutes its framework (cf. Leidel et al. 2010; Kalbus et al. 2011).

Shifting the focus from theory towards implementation, a key objective of IWAS is to evaluate the influence of capacity development on the implementation of IWRM, especially in the challenging political environment of transition countries. This paper demonstrates the importance of CD for this purpose by showing the advantages of harmonizing CD into the IWRM process, as exemplified within the Western Bug River Basin, Ukraine.

7.3 Capacity development for integrated water resources management

Although the global water community does incrementally acknowledge the importance of IWRM as major concept for improving water management[51] and thus for creating sustainable livelihoods, there is growing consensus that the concept of IWRM is only the starting point. UN-Water and Global Water Partnership (2007) claim that a roadmap accompanying

[51] On the World Summit for Sustainable Development in Johannesburg in 2002 it was decided to regard the development of IWRM as a major step in the process towards achieving the Millennium Development Goals (MDGs).

established national water plans will be needed, in order to focus not only on planning, but also on a concrete mechanism for implementation.

According to UNESCO (2009), the application of IWRM principles at the river basin level is increasingly accepted as means for IWRM implementation. From a spatial perspective, the overarching concept of IWRM is represented in the river basin approach, i.e. managing water within the geographical and hydrological unit of the river basin[52]. Concentrating on river basin management, all issues in IWRM may not be covered but a crucial area is discussed.

River basin management (RBM) and the establishment of river basin organisations (RBO) that deal with all water-related issues can contribute to successful operational water management. The river basin may, as Tortajada (2002) put it, “not always be the best unit for water management”, and hence RBOs might not always be the most appropriate body for coordination[53]. Yet, from a scientific point of view, the river basin is the common unit for all water and substance balances, and basins have to be managed either by a formal organisation, by official working groups between the responsible authorities or by informal groups (GWP & INBO 2009).

In order to perform RBM properly, there is a need for data, information and knowledge about water-related issues, e.g. about the water management itself, but also about land and forest management or rules and regulations (Valensuela 2009). In addition, issues about the basin organisation itself need to be addressed, inter alia about the organisational structure and statute or the role in the institutional context (Ibid.)[54].

What is often not adequately reflected in respective policies in many parts of the world is that RBM does not merely mean the establishment of RBOs—it is much more than that, it implies a change in the general approach towards water management. Consequently, a major obstacle to successful RBM implementation is that the capacities needed are often not well developed. In order to overcome this shortcoming, the elaboration of a profound capacity development concept identifying the needs of the RBM is required.

52 CAP-NET (2008) states that the river basin is the logical geographical unit for implementation of IWRM.
53 Horlemann and Dombrowsky (2011) elaborate on the challenges to manage water resources at the level of river basins.
54 Salamé and Van der Zaag (2010) present a good overview of the wide topical range in necessary knowledge, skills and tools for water managers.

7.3.1 Capacity and capacity development

Even though the concept of capacity development is one of the cornerstones of development cooperation, uncertainty and confusion about its exact meaning is still common. In fact, CD has often been misinterpreted as (i) acting only at the individual level and (ii) doing so predominantly by training and education activities. This opinion is gradually shifting towards the understanding that CD is a much broader concept dealing with societal and political challenges (ECDPM in Blokland et al. 2009; Ubels et al. 2010a, b)[55]. Currently, instead of one, commonly accepted, universally valid definition of CD, a wide range of definitions focusing on different aspects of CD is available. Prior to elaborating on the concept of capacity development, the meaning of capacity should be addressed.

From a multitude of definitions in the literature (e.g. Lopes and Theisohn 2003; Alaerts 2009; and Ubels et al. 2010a, b) the authors regard the definition proposed by Alaerts (2009) that capacity is the "capability of a society to identify, understand and address problems, to learn from experience and to accumulate knowledge for future issues", as being particularly apt.

Additionally, (Fowler and Ubels 2010, in Ubels et al. 2010a) emphasize that capacity is about real-life issues and about improving the livelihoods of people. They state that capacity is tangible and intangible; only a small part of capacity is tangible, for instance individual skills or organizational structures. A much larger part of capacity is intangible, for instance attitudes, values and cultural backgrounds[56].

Capacity is multi-dimensional, i.e. it has manifold elements[57], actors and levels[58] (Ibid.). Five core capabilities of capacity[59] are differentiated in the European Centre for Development

[55] Lopes and Theisohn (2003) argue that underlying capacities (e.g. ownership, leadership, knowledge networking, etc.) exist that are needed for supporting this broader view and thus improving the overall effectiveness of CD.

[56] As a consequence of this, successful capacity development has to look "behind the scenes" of tangible capacities.

[57] Elements of capacity are particularly addressed in the Community Development Resource Association's approach. This South African NGO describes them as conceptual framework, vision, strategy, culture, structure, skills, material resources (Kaplan 1999). Addition- ally, it emphasizes capacities' status as being "(in-)visible". Visible does, in this context, apply to materials, skills, organizational structure, whereas invisible means that it is only observable through effects, e.g. vision or strategy of an organisation (Ibid.).

[58] Visser (in Ubels et al. 2010a) distinguishes between levels of human organisation (individual, organization, sector/national institutions) and geographic, respectively administrative levels (communities, districts/provinces, nation state).

[59] Capability to act and self-organize, capability to generate development results, capability to relate, capability to adapt and self-renew, capability to achieve coherence (Baser and Morgan 2008).

Policy Management's concept (Baser and Morgan 2008)[60]. Further important frameworks are, for instance, the Capacity Development Strategic Framework developed by the African Union (AU)/New Partnership for Africa's Development (NEPAD 2009, 2010), or the approach towards capacity development from the UN Development Programme (UNDP 2008, 2009), which is expanded upon later.

Derived from these characteristics of capacity, according to UNDP (2008), capacity development refers to "the process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time".

Capacity development is a broad concept encompassing several issues, not limited to development of individual skills but, more importantly, addressing relational capacity, i.e. the interface between actors (Woodhill 2010 in Ubels et al. 2010a, b). Societal negotiation processes, e.g. to shift water management practices, always include a multitude of actors (Multi-stakeholder processes), so that, according to Woodhill (2010) (in Ubels et al. 2010a, b), connecting and engaging actors is a vital aspect of change processes. Capacity development is therefore a highly political pro- cess, always being about power, politics and interests (cf. Fowler and Ubels 2010, in Ubels et al. 2010a, b).

The following section elaborates these themes further examining the main characteristics and multi-dimensional nature of CD.

7.3.2 Multi-level approach of capacity development

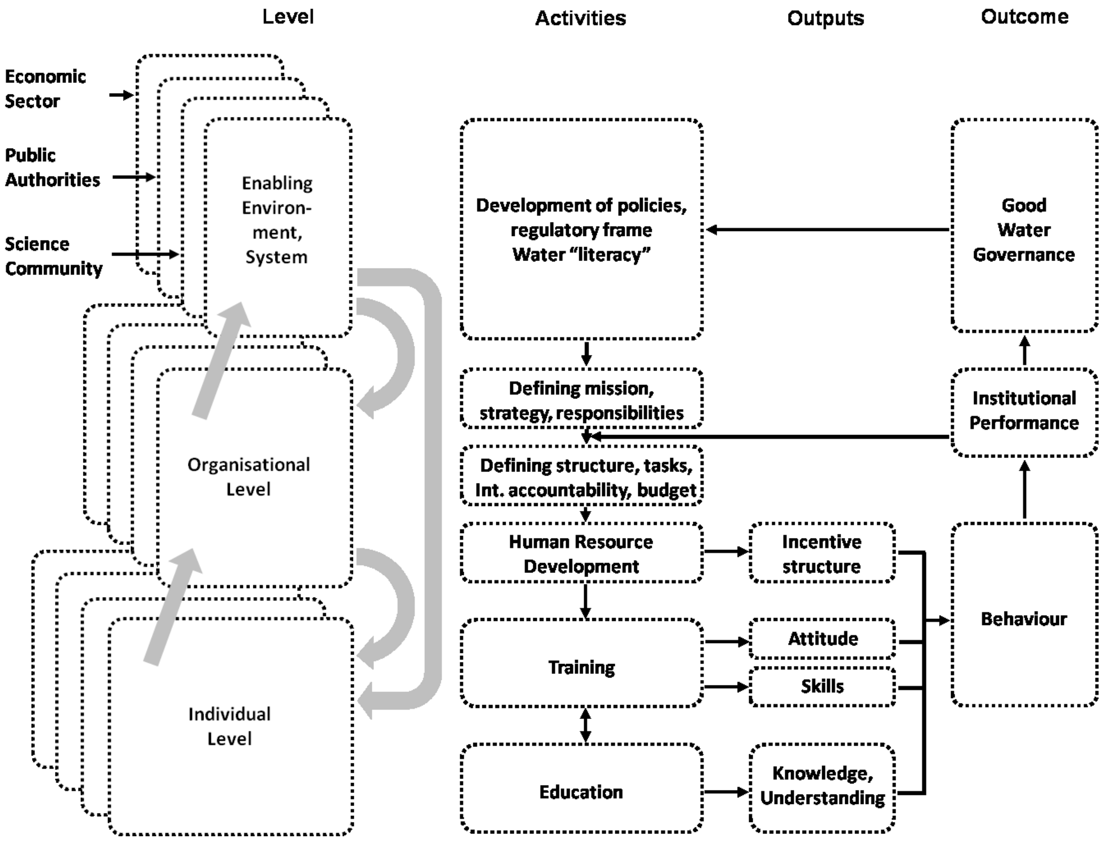
One major characteristic of CD is the fact that it addresses a multitude of different levels. In international CD research, this concept is commonly referred to as the "multi-level approach" (Lopes and Theisohn (2003); van Hofwegen (2004); OECD (2006) 5th World Water Forum (2009) and Alaerts (2009); Visser (2010); Figure 25). It distinguishes between different levels of CD measures; the individual, organisational and enabling environment levels. Lopes and Theisohn (2003) circumscribe this by asking the question "Capacity for whom"?

The human individual level is predominantly addressed by training and education activities. In order to attain the maximum possible success at the individual level, measures attempt

[60] Fowler and Ubels (2010), in Ubels et al. (2010a) elaborate similarities of (i) this widely recognized framework and (ii) the one from Community Development Resource Association (see above), both addressing the multiple dimensions of capacity.

to serve all three aspects of learning; knowledge, skills and attitude. If properly executed, such measures result, not only in better trained actors, but also in a changed behaviour and also influence the other two levels.

The organisational level includes all activities that improve the processes within organisations, for instance defining a mission and strategy, or internal/external accountability and responsibilities. As shown in Figure 25, human resources development belongs to the organisational level, yet, it obviously has a strong link to the individual level. The overall outcome of measures at this level is improved institutional performance; this is considered as an important step towards good water governance. As Earle et al. (2010) put it, there is “a distinct role for the development of knowledge and capacity to strengthen […] water management institutions”.



Modified after van Hofwegen (2004), 5th World Water Forum (2009 and Alaerts (2009)

Figure 25: Multi-level approach of capacity development

The third level, the enabling environment, includes all legislative, administrative, judicial and organizational issues influencing the performance of the individual and organisational levels. Such issues can be the development of policies or administrative regulations and ordinances but also the fiscal frame.

It should be emphasized that, as indicated above, the three levels are not independent of each other, but are intertwined in many ways[61]. Hence, measures addressing one particular level often include and integrate consecutive influences on the others.

The target group for CD is society as a whole, comprising specific societal groups like the scientific community, public authorities, the economic sector or the public in general, as differentiated in Figure 25. Each level has relevance for each target group. Ideally, any focus on a particular target group, or the break-down into lower levels, should be appropriate to the prevalent CD strategy, if one exists, and CD measures and especially the focus on special groups have to be demand driven according to the needs of the respective society. These two perceptions coincide with the results of World Bank's (2008) project-based training activities' evaluation that CD measures are insufficiently targeted to needs, and inadequately incorporated in broader CD-strategies.

Based-on these observations, the process of capacity development and, in particular, its application in transition countries is examined in the following sections.

7.3.3 Process of capacity development

Lopes and Theisohn (2003) stated that there are no blueprints for capacity development. CD is an adaptive process[62] that has to be customized to the respective goals and necessities of the region concerned. It is worth emphasizing again that CD is also an endogenous process; a process that is self- guided by the respective societies (Ubels et al. 2010a, b).

Due to the complex and uncertain nature of capacity development processes, the ECDPM (2009a, b; in Blokland et al. 2009) considers capacity as an emergent property (i.e. that properties like capacity emerge from unplanned and uncontrollable processes) and conclude that the concept of complex adaptive systems (CAS)[63] thinking is valuable for capacity development processes. Consequently, the authors from ECPDM propose a shift from exclusively planned approaches towards more incremental[64] or emergent approaches, were appropriate.

---

[61] Visser (2010) elaborates that such "nested systems" are interdependent, meaning that one level cannot perform well without the other levels.

[62] Earle et al. (2010), for instance, do, referring to Salamé and van der Zaag (2010), state that "the process of developing capacity is as important as the type of knowledge introduced"

[63] In brief, CAS means that organisations and systems are like living organisms that adapt and change continuously and unpredictably (ECDPM 2009a, b).

[64] Incremental approaches combine strategic intent with flexibility (ECDPM 2009a, b). Incrementalism is, according to Bea and Haas (2005), the strong interlocking between the formulation/set up of a strategy and its implementation without defining explicit targets.

Thus, CD concepts and strategies need to be developed for the individual situation based on an evaluation of, and continuous adaptation to, local circumstances. Leidel and Niemann (2009) assume that measures for solving existing water problems can only be sustainable if the knowledge generated is deeply rooted in the particular region. As the authors have elaborated at the beginning of this article, this also refers to IWRM—and again, a general concept needs to be broken down and customized for the specific regional and/or cultural conditions. Indeed, the issue of regional adaptation is, as demonstrated later on, not the only similarity of IWRM and CD.

The widely applied CD approach from UNDP (2008) also follows the multi-level approach and comprises a process with five steps per iteration cycle: engage stake- holders on capacity development, assess capacity assets and needs, formulate a capacity development response, implement the response and evaluate capacity development. Core issues assumed to have the greatest influence on capacity development are institutional arrangements, leadership, knowledge and accountability (UNDP 2009). According to UNDP (2009), an effective CD process has to be incorporated into national development plans.

Considering the CD process from the UNDP (2008), a profound analysis or at least a screening of the societal and political situation including the identification and engagement of the relevant stakeholders should be conducted first (stakeholder and institutional analysis). This goes hand in hand with the definition of overarching and general targets for the CD. The definition of general targets along with stakeholder and institutional analysis can be seen as a preliminary step for capacity assessment (current state analysis). According to such an assessment, anticipated difficulties as well as existing and missing competencies can be identified and, hence, minimize transaction costs for implementation later on in the process. Furthermore, capacity assessments support efficient resource allocation, since capacity development responses are identified according to their priority. Such capacity assessment exercises have to be elaborated together with the relevant stakeholders. This will also help to minimize transaction costs, and stakeholders will be better informed and feel more integrated and accepted in the process. In addition, opposition to certain measures is less likely. Thus, it can be expected that measures based on such an assessment maximize CD impact. The Independent Evaluation Group of the World Bank (2008) showed that most training activities led to individual stakeholder learning, but only improved the capacity of their institutions in half of the cases, one reason being that the institutional context in which the training took place was not considered thoroughly.

Overarching targets that have been set in the first step of the CD process should be broken down into a CD strategy. Ideally, a time frame for further steps in the CD process would be elaborated and CD measures and responsibilities for mile- stones identified. This would secure a stringent CD process, as well as growing the accountability of local stakeholders. The next step is implementation, monitoring and evaluation of the proposed CD measures; this in turn leads, as required, to the adaptation of the CD strategy, which is an iterative and adaptive process often based on a combination of planned and incremental approaches with numerous steps that are (i) intertwined and (ii) driven by additional external factors. Examination of the CD process from the UNDP (2008) with its continuous sequence of measures, evaluation and respective modification of future strategies and measures reveals additional similarity to IWRM and CD.

7.3.4 IWRM and capacity development

Integrated water resources management in a truly sustainable manner requires far more than merely linking different facets of water management. An additional and essential factor for successful implementation is good governance. Water governance, i.e. the interdependence between governance and water, has become more and more important at the international level (Baum et al. 2009, p. 30). The term "good water governance" includes several aspects: "democracy and participation, transparency, decentralization, modern public administration management, the rule of law, coordination of state, civil society and private sector, etc." (Ibid. p. 31). Lopes and Theisohn (2003) explain the inherent and direct interdependency between governance and capacity development by the fact that capacity development is about society's ability to frame its own future. Beyond this, Woodhill (2010) (in Ubels et al. 2010a) states that real capacity development relates to processes of governance, because a large part of good governance depends on relationships between actors, and thus relational competencies are needed for improving development processes. Considering these points, it becomes clear that in our context CD has to focus not only on improving water management competencies, but also on improving governance for enabling IWRM. The institutional basis for good governance[65] is, however, often missing and can be enhanced by well-tailored CD especially in transition countries.

[65] A discourse on institutionalizing IWRM in transition countries can be found in Horlemann and Dombrowsky (2011).

It should be restated that CD has been recognized as one important factor for the implementation of IWRM.[66] In the IWRM Guidelines at River Basin level (UNESCO 2009), for instance, CD is taken into consideration. Within those guidelines, the IWRM process is illustrated by a spiral, showing the assumed progress of IWRM. This spiral loops the IWRM process starting with the phase of recognizing and identifying, whereby CD is a part of this phase. The second phase is about conceptualizing, i.e. that the situation should be understood and future actions towards IWRM should be developed. The following phase deals with coordinating and detail planning. Concepts from the previous phase are finalized and coordinated with the stakeholders. The last phase of the IWRM process is about implementing, monitoring and evaluation. Eventually another cycle of the IWRM spiral will start again at the first phase.[67] Recalling the previously discussed CD process, it becomes obvious that both the IWRM process and the CD process have similar phases.

CD is, as mentioned above, nevertheless, restricted to the first phase of the IWRM process from UNESCO (2009). Yet, the authors propose that CD should rather be seen as an accompanying process during all phases of the IWRM process, since knowledge and capacity for starting and maintaining the IWRM-process is often not adequate. Local stakeholders, therefore, have to be trained and educated during the complete IWRM process in order to play an active role. Furthermore, the improvement of the institutional structures and the enabling environment is one indispensable part of the IWRM process since otherwise the knowledge gained by the stakeholders may not be applied and implemented. Thus, institutional capacity development has to be a part of all phases of the IWRM process, or at least taken into account. Consequently, we propose to merge the IWRM process with the CD process, meaning that the phases of CD will be aligned and harmonized with the phases of IWRM (Figure 26).

This proposal is substantiated by the following considerations. In phase one of the harmonised process, recognizing and identifying the problems in the river basin is the main point in this IWRM process stage (UNESCO 2009). Within the first phase of the CD process a profound analysis or at least a screening of the societal and political situation according to problems identified, including the identification and engagement of the relevant stakeholders, should be conducted (stakeholder and institutional analysis).This goes hand in hand with the definition of overarching and general targets for CD and is in alignment with

[66] Salamé and van der Zaag (2010).
[67] For a detailed explanation of the IWRM spiral it is referred to UNESCO (2009)

the IWRM phase. This harmonisation supports IWRM actors in recognizing the right problem and estimating the accurate state of the problem.

The second phase within the IWRM process (conceptualizing) assesses the structure of the problem in greater depth, conceptualizes feasible solutions and draft planning (UNE- SCO 2009). The second phase of the CD process supports this, since the current state analysis (capacity assessment) identifies the gap between existing and missing competencies towards an operational IWRM. This is an essential point for endogenous and adaptive development processes like IWRM. Solutions have to take into account the level of available capacities in order to create “best fit” solutions.

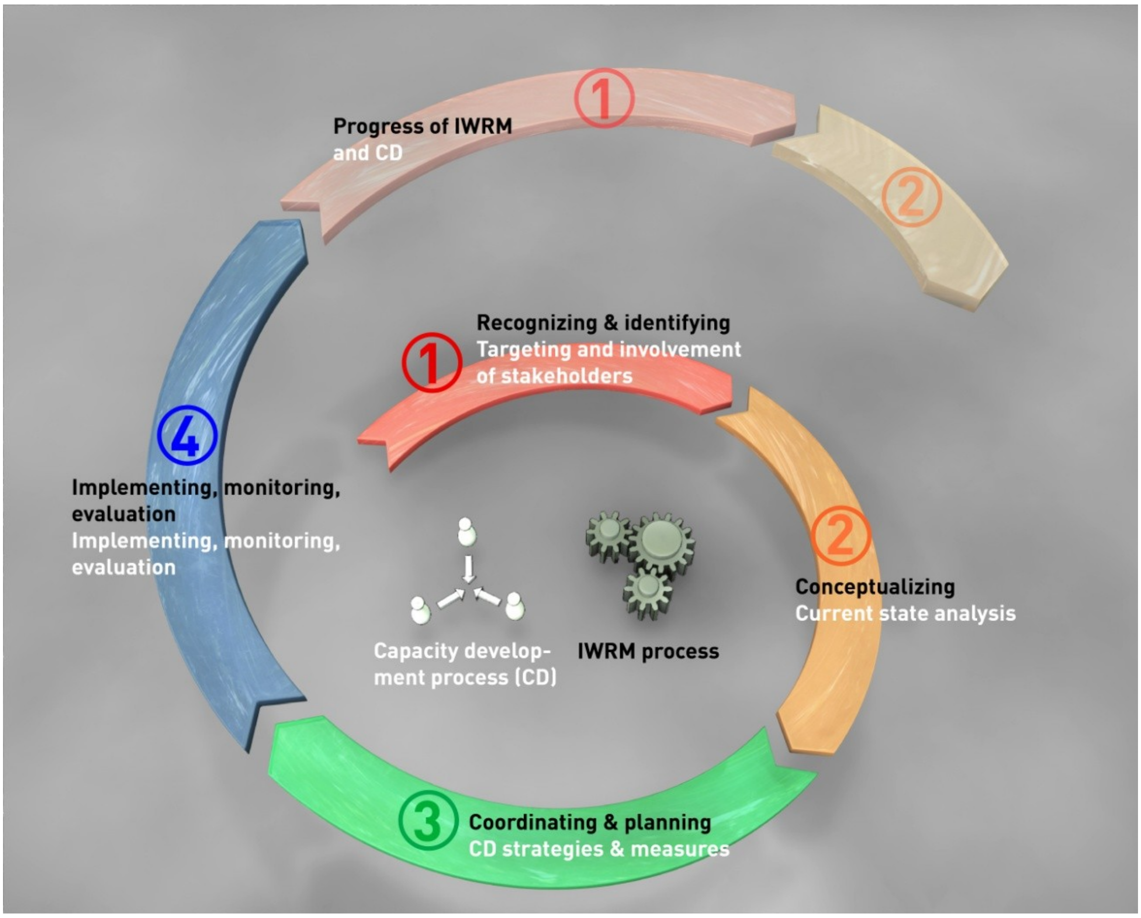


Figure 26: Combined and harmonized IWRM and CD Processes

Consequently, the third point within the CD process establishes a CD strategy including planning of adequate CD measures. This compliments the third point of the IWRM process, where coordination with stakeholders and eventually the draft plan is finalized (UNESCO 2009). The advantage of harmonising CD strategy and the final IWRM plan is that capacities essential for the IWRM implementation plan may not yet be available, but can be developed accordingly. This means that it assists in prioritizing the required capacities of stakeholders for IWRM implementation and is thus resource efficient.

The next step is the implementation, monitoring and evaluation of the IWRM plan and the CD strategy. The evaluation should then, if necessary, lead to the adaptation of the IWRM approach and the CD strategy. Eventually another iteration, i.e. another combined IWRM and CD cycle has to proceed, progressing IWRM and CD. This is indicated by the upwardly spiralling arrows in Figure 26, which shows the proposed combination of harmonised IWRM and CD processes (based on UNDP 2008; UNE- SCO 2009). The arrows indicate that the actions mentioned within one phase, but also between the phases are intertwined and no sharp boundaries exist.

In the context of sustainable development, the authors are convinced that IWRM and capacity development are mutually dependent—or, to put it plainly: IWRM is, to a very large extent, capacity development.

7.4 Capacity development for IWRM in transition countries

7.4.1 Institutional setting and transformation process in Ukraine

The following section focuses on institutional preconditions for implementation of an IWRM concept (and especially the role of CD in this respect) in post-soviet countries, taking the example of the Western Bug Basin in Ukraine.

The Western Bug River is a transboundary river and therefore not only affects Ukrainian territory but also influences the water quality on the Polish and Belorussian sides and the Baltic Sea. In addition, Ukraine is trying to amend its legislation to European standards. If Ukraine gains a closer relationship with the EU, they will have to adopt the EU WFD. Given that the Western Bug Basin crosses administrative boundaries, capacity development for RBM can be regarded as essential.

It is a given fact that the initial conditions for transformation and the application of strategies for the transformation process differ widely between the East European countries. A major difference can be observed between countries that joined the European Union (EU) and EU neighbouring countries that have currently no plans to become a member state of the EU. The new EU member states had strong economic and financial incentives to restructure their economic and political system and they were able to enforce structural changes with the main argument being for individual and economic prosperity after joining the EU. The transformation process took more time in Ukraine and as a result it entered a "third way" of transformation between capitalism and communism by establishing "social democracy" but at the same time securing "national protectionism of the state producers" (Stadnytskyi and Nobis 2008, p. 33). Old elites, which are still part of the political and economic arena, contribute to the development of informal structures. The institutional setting in Ukraine is still quite weak and several democratic institutions and procedures are not taken seriously and are played with (BOS 2010). In some cases informal structures as well as personal relationships have more power than legal structures and the required resources are concentrated within the executive (Ibid, p. 79). Major problems in legal and political terms are the allocation of competencies for certain duties and responsibilities of different administrative units. Actors at the local and regional level are not used to independent decision making. Even though they have been assigned some competencies, in several cases they can be overruled by higher level decisions as a result of overlapping and not well-defined responsibilities.[68] This also has implications for the establishment and functioning of IWRM concepts, CD and the establishment and functioning of river basin management.

Special features in transformation processes are the involvement of civil society and the right of political participation. Van Zon (2002, p. 404) criticises the absence of societal grounding for decisions in the Ukraine: "No polity has been created that is a reflection of society and that could adapt political structures to changing social needs, creating preconditions for evolutionary institutional change". To summarize this, (i) awareness raising by information distribution is one of the major challenges when trying to set up a CD strategy and (ii) the rule of law is not fully applied which means that in theory certain competencies might be assigned to authorities but in practice these competencies are overruled by higher level authorities. Institutions and especially local organisations and administrations, therefore, have to be assessed in detail regarding their capacity and competencies towards water management. Instruments have to be developed to strengthen their power and influence towards independent local decision-making. They have to be tailored according to the specific Ukrainian, and in many cases, more regional circumstances.

7.4.2 Capacity development for river basin management in the Western Bug River Basin, Ukraine

7.4.2.1 Recognizing and identifying/targeting and involvement of stakeholders

[68] For more information on the decentralization process and short- comings regarding the assignment of competencies see Unnerstall and Hagemann (2011).

When following the consecutive steps elaborated in the combined IWRM and CD process (Figure 26), recognition and identification of status quo and respective challenges is the first step to be taken. The Western Bug River originates in the West Ukrainian oblast L'viv[69] and is a transboundary river, bordering Poland and Belarus and entering the European Union (EU), where it becomes subject of the EU Water Framework Directive (WFD).

Current and ongoing studies show that the hydromorphology of the Western Bug River and its tributaries are along many stretches only slightly to moderately anthropogenically modified (Scheifhacken et al. 2011), but they contain high levels of organic and inorganic pollution (Ertel et al. 2011). Such pollutants are from point sources like out-dated and deteriorated municipal and industrial waste water treatment plants and diffuse sources like eroding agricultural/fallow land, pesticide waste sites, mining activities and wastewater from rural communities that are not connected to the sewer system (Ibid.).

The stakeholder and institutional analysis revealed that there is currently no external pressure on Ukraine to implement legislation for sustainable water management and especially not for designing and implementing a RBM concept. The two most important Ukrainian regulations with regard to water protection, the Water Code of Ukraine and the Law on Potable Water and Potable Water Supply, however, claim the adaptation of EU principles regarding the protection of waters from pollution (Kuhrt 2008). Regarding River Basin Management, Article 13 of the Water Code of Ukraine reads as follows: "The state management of water resources use, protection, and restoration is carried out according to the river basin principle on the basis of national, international, and regional pro- grams for water resources use, protection, and restoration". This regulation is not further defined, but despite this fact, six river basins have been defined for Ukraine, under the auspices of the State Committee of Ukraine for Water Resources, and one of them is the Western Bug River. This means that there is no legislation providing guidelines on how river basin councils have to be organised and how programmes have to be set up and implemented. These decisions are left to basin authorities that lack the back- ground and experiences to fulfil their duties.

[69] The first level of Ukraine's administrative division is called oblast (province)

In the case of the Western Bug, two TACIS[70] (EU 2006) projects were set up with the aim of establishing a RBM concept, with the main aim of establishing cooperation of organisations across administrative borders, which is a novelty in Ukrainian local governance. The Oblasts L'viv and Volynska were asked to set up a joint river basin council[71] and furthermore, a river basin department was installed.[72] This was quite successful in the beginning because actors succeeded in setting up a river basin council of 50 members with representatives from the Regional State Administrations, public bodies, NGOs, scientists, consumers, bodies of local and regional councils, public bodies and the Western Bug Basin Department of Water Resources (Zingstra et al. 2009, p. 27). In addition, the respective administrations of both Oblasts were asked to cooperate especially regarding data exchange which— according to personal statements—did not work out the way it was supposed to. Data are gathered and stored within one authority, but the data are incomplete and/or measured with different techniques and are therefore sometimes not comparable. Besides missing data and some data exchange problems, financial provision and transfer to the local level is an obstacle to an adequate RBM approach.

Those issues identified constrain the sustainable utilisation and conservation of water resources, impacting not only the ecosystem itself, but also the livelihoods of the people within the Western Bug River Basin. Because of the high degree of pollution and the institutional deficiencies, efficient improvement of surface water quality with a holistic approach towards water resources management is of utmost importance. Respective activities were elaborated in close accordance with the general national Ukrainian water policy, e.g. the National Targeted Program for Water Management Development up to 2020.[73] According to that program and the aforementioned regulations, the Ukrainian government intends to enhance water management by, among other measures, approaching international standards like the EU-WFD. Eventually, the principles of IWRM, in the respect of RBM should be implemented in the Western Bug basin.

7.4.2.2 Conceptualizing/current state analysis

---

[70] Technical Assistance to the Commonwealth of Independent States; foreign assistance programme implemented by the EU (1991–2007).

[71] Hence, we are not talking about a transboundary river basin approach between Ukraine, Belarus and Poland, but a national one, even though strong cooperation with the Polish and Belorussian authorities exists and a platform for information exchange is provided.

[72] Called Western Bug Basin Department of Water Resources.

[73] In 2009, this programme was revised and it now contains the "introduction of a system of integrated water management according to the basin principle"; yet, it is only declarative.

Within the phase of conceptualizing and current state analysis, the status of the problems within the Western Bug River Basin would be scientifically substantiated, for instance, by applying the knowledge gained from phase one in order to identify, issues for water users. As pointed out earlier, a capacity assessment is the condition sine qua non for effective CD measures. Therefore, capacity assessment exercises must be elaborated.[74]

Based on system analyses and identified pressures on the water resources, the key issue within the second phase of the combined IWRM and CD process was to identify problems that constrain the implementation of an efficient RBM. The project analysed, which competencies in the field of integrated RBM are already available, which additional ones are needed for improving current water management, and which challenges towards integrated RBM lie within the identified target groups, public authorities (Environmental administration and water authorities of the oblasts L'viv and Volyn, Western Bug Basin Department of Water Resources), science community (on national and catchment level) and the economic sector (municipal water and wastewater companies).

As mentioned earlier, the capacity development process in the Western Bug River Basin follows a multi-level approach. The enabling environment, organisational, individual levels have, therefore, been considered for all three target groups within the capacity assessment. From that assessment, possible solutions were identified, i.e. different options were analysed according to their financial, environmental and political feasibility. It was clearly highlighted that the difficulties in implementing capacity development responses will increase from human resources development to the system level. Finally, the project identified both prioritized CD measures and responsibilities, securing the accountability of the actors.

For the public authorities, at least three essential, but lacking factors for sustainable water monitoring and transparency of executed monitoring activities were identified, whose improvement is feasible within a reasonable amount of time:

(i) robust and reliable data as fundamental basis for water monitoring and thus awareness raising. As mentioned previously, however, measurement methods, for instance, for water quality parameters, partially vary between authorities in the river basin;

(ii) exchange of data and information within and between authorities, which is still not working properly between the authorities in the Western Bug basin; and

[74] E.g. one workshop was executed in coordination with Global Water Partnership (GWP) Ukraine in the role of the authorities involved in the water management of the Western Bug river basin.

(iii) modelling of water quality and quantity, which is still in its infancy in the region.

The assessment of the economic sector showed that the sewage system is, as mentioned above, in ailing condition. In fact, the problems are not exclusively related to the available technical know-how, but instead a multitude of reasons are responsible (the weak institutional framework, no cost-efficient prices, little networking between waste- water companies, little vocational training and inadequate rules and standards).

Within the scientific community, the assessment revealed that the prevailing engineering approach to water management in the Ukraine is also mirrored in academic education that focuses on water engineering. Consequently, no interdisciplinary courses on IWRM are available at Ukrainian universities (Demydenko and Leidel 2010). Furthermore, research is not state of the art in water sciences, e.g. modelling of water quality and quantity or biological monitoring is not common.

7.4.2.3 Coordinating and planning/CD strategies and measures

The situation analysis and the capacity assessment showed that there are already competencies available for integrated RBM, e.g. the existence of the Western Bug Basin Department, but the authors found certain capacities to be absent, e.g. data management, and water monitoring and modelling. It became obvious that the process of introducing, respectively, continuing the RBM approach and thus the IWRM process, is in direct connection to CD. Thus, a capacity development strategy including the identification of (short and intermediate term) feasible and fitting CD measures was elaborated for improving river basin management in the Western Bug Basin.

Capacity assessment for public authorities resulted in measures for (i) enhancing communication between authorities (relational capacity development to enhance cooperation and build trust), improving the data basis, i.e. by measuring campaigns and intercalibration of different measuring methods and (ii) the development and enhancement of data base systems and training of government employees for such systems was also proposed. Additionally, it is planned to (iii) inform the decision makers within this basin about the advantages of modelling for integrated RBM.

The measures for the wastewater companies contain the development of concepts for strengthening of communal companies, technical and vocational education and training (TVET), the development and organization of rules and standards and strengthening the network of Ukrainian wastewater companies.

In order to shift sectoral water education, curricula for academic courses on IWRM are developed and tailored for participating universities so that future water professionals are familiar with this holistic view during their studies. Furthermore, research in IWRM and especially modelling will be strengthened, i.e. through networking between Ukrainian universities and with the Technical University of Dresden, thus bringing the Ukrainian universities closer to the European Research Area (ERA).

The last phase of the harmonized IWRM and CD pro- cess (Implementing, monitoring, evaluation) has started in the Ukrainian case study, meaning that the proposed CD measures for the mentioned target groups are gradually implemented. Subsequent steps are the scientific monitoring and evaluation of the measures, focusing on their strategic impact on water management.

The authors have showed that system analysis is an important step towards implementation of an improved RBM. The example presented here, however, also demonstrates the added value of CD as an integral part of implementing RBM and thus approaching IWRM. The authors are convinced that only the combination of both approaches will increase the chances of success of improving management of the Western Bug river basin.

7.5 Discussion

This article demonstrates that capacity development is a key factor for Integrated Water Resources Management. As a matter of fact, CD is not a new concept within water management theory; however, it is often regarded as only one piece of the puzzle and not as an integral and inherent part of IWRM, or RBM. At best, it is seen as a supplementary process accompanying development processes in the water sector. Within this paper, the authors emphasize the high relevance of harmonizing the concepts of IWRM (at the river basin level) and CD for supporting the implementation of improved water resources management. Thus on the basis of recent literature this article demonstrated the complex nature of capacity and its emergent development by means of incremental approaches. Con- temporary CD not only focuses on individual competencies, but also on organizational development and the enabling environment. CD is further not just about water management competencies, but also emphasis on the relationship to government processes as well as underlying capacities ("soft skills") like leadership development, trust generation or negotiation skills. These last two points are more easily said than done. Actors within development processes often want to see fast results, which can be only accomplished by tangible measures like training activities or improving technical capabilities. From such capacity development responses, usually no fundamental changes can be expected. On the other hand, focusing only on long- term and intangible interventions, e.g. developing strategies for organisations or strengthening ownership and leadership, may reduce actors' incentives for participating in development processes.

In order to foster sustainable development, long-term and intangible approaches are indispensable, especially in transition countries like Ukraine. Another danger for long- term capacity development activities is political instability with associated institutional shortcomings. The current political situation in the Ukraine has to be taken into account for CD as a legacy of the still not completed transformation process. For practical application this means that actors, especially at the political level, are exchanged frequently. This restricts the sustainability of CD actions. In addition, the implementation and targeting of measures is in some cases difficult, because the responsibilities of authorities are unclear—implemented measures might be reversed at the whim of a higher level authority. The approach in the Western Bug Basin focuses therefore on a mixture of short- and intermediate-term measures that are in accordance with overall and long-term capacity development targets of establishing efficient river basin management. The first experiences show that elaboration of functioning networks is crucial to success, that is, in developing relational capacities of actors as the basis for trust generation and thus for healthy collaboration. However, a scientifically sound monitoring and evaluation approach has to be developed, in order to better assess the impact of the implemented CD measures on improving the water management.

The implementation deficits of RBM structures in the Western Bug River Basin are a further obstacle for CD, because the Bug River Basin Council in particular is a unit where information exchange and distribution is settled and several different stakeholders are involved. Furthermore, the advisory function of the body to the Western Bug Basin Department of Water Resources is an essential instrument for integrating local knowledge and experiences into the process of setting up a river basin management plan.

It should be acknowledged that capacity development is a lengthy process, with significant results possibly only showing after decades.

7.6 Summary and outlook

The concept of IWRM is the current frame for water management worldwide. Irrespective of the fact that it might be barely feasible to fully implement the approach in countries with well-established water management systems, transition countries such as Ukraine are often lagging even farther behind.

Although good water governance and thus a strong civil society are important factors for making IWRM operational, many countries struggling for the implementation of IWRM do, to a certain extent, lack such factors. The respective society, therefore, needs these capacities, in order to start such processes and keep them running.

Despite obstacles for the enhancement of RBM in Western Ukraine, a combined approach of IWRM and CD has a high chance of success. The analysis of the current state of the natural conditions and the governance analysis can be seen as essential, yet preliminary steps towards improving water management. According to those analyses, implementing tailor-made and targeted measures is possible. This strong emphasis on CD assures a long-lasting improvement by achieving good governance and thus enhancing prevailing sectoral water management. Further sustainable interventions should also aim at the general public, including school education.

Another important future development, that would be a significant step towards more sustainable water management for the Western Bug Basin, is the establishment of transboundary water management with all neighbouring countries, i.e. Ukraine, Belarus and Poland and possibly modelling existing international bodies such as the International Commission for the Protection of the Rhine (ICPR).

Hence, when talking about sustainable and long-lasting development, IWRM and capacity development cannot stand alone—or, to put it more plainly, the successful implementation of IWRM depends, to a very large extent, on capacity development

Acknowledgments

The graphic representation of Figure Combined IWRM and CD Processes were created by Mr. Sander Münster, M.A., Media Center, Department Media Design, Technische Universität Dresden, Germany. This work was supported by funding from the German Federal Ministry for Education and Research (BMBF) in the framework of the project "IWAS—International Water Research Alliance Saxony" (grant 02WM1027 & 02WM1028).

7.7 References

Alaerts GJ (2009) Knowledge and capacity development (KCD) as tool for institutional strengthening and change. In: Alaerts GJ, Dickinson N (eds) Water for a changing world—developing local knowledge and capacity. Delft

Alaerts GJ, Blair TL, Hartvelt FJA (eds) (1991) A strategy for the water sector capacity building. International Institute for Hydraulic and Environmental Engineering IHE/UNDP, Delft/ New York

Baser H, Morgan P (2008) 'Capacity, change and performance: Study report', Discussion Paper 59B, European Centre for Development Policy Management (ECDPM), Maastricht

Baum I, Renger J, Werchota R (2009) Good governance in the water sector. In: Ernstorfer A, Stockmayer A (eds) Capacity development for good governance. Nomos, Baden–Baden, pp 30–44

Bea FX, Haas J (2005) Strategisches management. UTB, Stuttgart

Biswas AK (2004) Integrated water resources management: a reassessment. A water forum contribution. Water Int 29(2):248–256

Blokland M, Alaerts G, Kaspersma J, Hare (eds) (2009) Capacity development for improved water management. CRC Press, London

BMZ- German Federal Ministry for Economic Cooperation and Development (2006) Water Sector Strategy. Strategies 152. Bonn

BOS E (2010) Stabile Instabilität, dynamische Blockade. Das politische System der Ukraine. In: Osteuropa 2–4: 77–88

CAP-NET (2008) Integrated water resources management for river basin organisations. International network for capacity building in IWRM

Demydenko A, Leidel M (2010) Education as a key for integrated water resources management (IWRM) and adaptation to climate change. In: Proceedings of International conference global and regional climate changes. Kiev. Ukraine

Earle A, Jägerskog A, Öjendaal J (2010) Introduction: Setting the scene for transboundary water approaches. In: Earle A, Jägerskog A, Öjendaal J (eds) (2010) Transboundary water management. London, Washington DC: 1–10

Ertel A-M, Lupo A, Scheifhacken N, Bodnarchuk T, Manturova O, Berendonk TU, Petzoldt T (2011) Heavy load and high potential. Anthropogenic pressures and their impacts on the water quality along a lowland river (Western Bug, Ukraine). Environ Earth Sci. doi:10.1007/s12665-011-1289-0

European Centre for Development Policy Management (ECDPM) (2009a) Capacity change and performance. Capacity development: between planned interventions and emergent processes- Implications for development cooperation. (Policy Management Brief No.22). Maastricht. ECDPM

European Centre for Development Policy Management (ECDPM) (2009b) Capacity change and performance-insights and implications for development cooperation. In: Blokland M, Alaerts G, Kaspersma J, Hare M (eds) Capacity development for improved water management. CRC Press, London

European Union (2006) Management of the Bug, Latoritza and Uzh River Basins Ukraine: EuropeAid/114957/C/SV/UA Report on Project Component 3 Upper Tisza/Western Bug. Challenges and management requirements

Fowler A, Ubels J (2010) The multi-faceted nature of capacity: two leading frameworks. In: Ubels J, Fowler A, Acquaye-Baddoo N-A (eds) Capacity development in practice. Earthscan, London

García LE (2008) Integrated water resources management: a "small" step for conceptualists, a giant step for practitioners. Water Resour Dev 24(1):3–23

Global Water Partnership (GWP) (2000) Integrated water resources management. TAC Background papers, No.4. Stockholm

Global Water Partnership (GWP) and International Network of Basin Organizations (INBO) (2009) A handbook for integrated water resources management in basins

Horlemann L, Dombrowsky I (2011) Institutionalising IWRM in developing and transition countries—the case of Mongolia. Environ Earth Sci. doi:10.1007/s12665-011-1213-7

Kalbus E, Kalbacher T, Kolditz O, Krüger E, Seegert J, Teutsch G, Borchardt D, Krebs P (2011) IWAS—integrated water resources management under different hydrological, climatic and socio- economic conditions. Environ Earth Sci. doi: 10.1007/s12665-011-1330-3

Kaplan A (1999) Organisational capacity: a different perspective, development Dossier No. 10, Non-Governmental Liaison Service. United Nations, Geneva

Kuhrt W (2008) The adaptation of Ukrainian legislation to the law of the European Union with regard to environmental protection. In: Roth M, Nobis R, Stetsiuk V, Kruhlov I (eds) Transformation processes in the Western Ukraine. Weißensee Verlag, Berlin, pp 509–521

Leidel M, Niemann S (2009) Internationale WasserforschungsAllianz Sachsen (IWAS)—Capacity Development Leitlinien. http://www. iwas-sachsen.ufz.de/data/IWAS-CD-Leitlinien11658.pdf. Accessed 10 Sep 2010

Leidel M, Niemann S, Hagemann N (2010) Capacity development for integrated water resources management (IWRM) in a transition country. In: Steusloff H (ed.) Integrated water resources management (IWRM) conference proceedings. KIT Scientific Publishing, Germany, pp 382–388

Lopes C, Theisohn T (2003) Ownership, leadership and transformation. Can we do better for capacity development? Earthscan, London

NEPAD capacity development programme (2009) Capacity Development Strategic Framework (CDSF). http://www.oecd.org/dataoecd/1/11/43508787.pdf. Accessed 12 Mar 2011

NEPAD capacity development programme (2010) Capacity development strategic framework.http://www.nepad.org/system/files/NEPAD%20CDSF%20Brochure%20final%20FN%20LN%20060710.pdf. Accessed 2 Mar 2011

Organization for economic cooperation and development (OECD) (2006) The challenge of capacity development: working towards good practice, OECD, Paris

Salamé L, van der Zaag P (2010) Enhanced knowledge and education systems for strengthening the capacity of transboundary water management. In: Earle A, Jägerskog A, Öjendaal J (eds) Transboundary water management. London, Washington DC pp. 171–186

Scheifhacken N, Haase U, Gram-Radu L, Kozovyi R, Berendonk T (2011) How to assess hydromorphology? A comparison of Ukrainian and German approaches. Environ Earth Sci. doi: 10.1007/s12665-011-1218-2

Stadnytskyi Y, Nobis R (2008) Special problems of transformation in the Ukraine. In: Roth M, Nobis R, Stetsiuk V, Kruhlov I (eds), Transformation processes in the Western Ukraine. Weißensee Verlag, Berlin 31–41

Tortajada C (2002) Workshop on integrated water resources management for South and South-east Asia. Conference report. Bangkok, Thailand, 2–4 December 2002. http://www.thirdworldcentre.org/bangkok.pdf. Accessed 19 Aug 2010

Ubels J, Fowler A, Acquaye-Baddoo N-A (eds) (2010a) Capacity development in practice. Earthscan, London

Ubels J, Fowler A, Acquaye-Baddoo N-A (2010b) Learning about the field of capacity development: characteristics, practitioner challenges and future perspectives. In: Ubels J, Fowler A, Acquaye- Baddoo N-A (eds) Capacity development in practice. Earthscan, London

UN development programme (2008) Capacity development practice Note

UN development programme (2009) Capacity development: a UNDP primer. New York

UNESCO (2009) IWRM guidelines at river basin level. Part 1 and part 2.1

Unnerstall H, Hagemann N (2011) Analysing the shortcomings of the Ukrainian urban waste water sector—Institution options for modernisation. In: Theesfeld I, Pirscher F (eds), Perspectives on institutional change—water management in Europe. Studies on the Agricultural and Food Sector in Central and Eastern Europe 58, pp. 35–54

UN-Water and GWP (2007) UN-water and global water partnership (GWP) roadmapping for advancing integrated water resources management (IWRM) processes

UN-Water (2008) Status report on IWRM and water efficiency plans for CSD16

Valensuela D (2009) Knowledge and capacity development at river basin level. In: Blokland MW, Alaerts GJ, Kaspersma JM, Hare M (eds) Capacity development for improved water management. Delft, Bonn

Van Hofwegen P (2004) Capacity-building for water and irrigation sector management with application in Indonesia. FAO Water Reports 26. FAO, Rome

Van Zon H (2002) Alternative scenarios for Ukraine. In: Futures 34: 401–416

Visser H (2010) Capacities at multiple levels and the need for connection: a Bhutan example. In: Ubels J, Fowler A, Acquaye- Baddoo N-A (eds) Capacity development in practice. Earthscan, London

Woodhill J (2010) Capacity lives between multiple stakeholders. In: Ubels J, Fowler A, Acquaye-Baddoo N-A (eds) Capacity development in practice. Earthscan, London

Zingstra H, Simeonova V, Kitnaes K (2009) The Bug River. Corridor in the Pan European Ecological Network. A Feasibility Study. BBI-Matra Project 1006/015. http://www.cdic.wur.nl/NR/rdonlyres/DFDA8928-9664-4EF3-A593-C5 E3023 D3164 /85640/FinalReportBugRiver.pdf. Accessed 3 Sep 2010

8 Supporting decisions in water management by exploring information and capacity gaps: experiences from an IWRM study in the Western Bug River Basin, Ukraine

The following chapter is a citation of the original published peer reviewed manuscript:

Leidel M, Hagemann N, Seegert J, Weigelt C, Zakorchevna N, Blumensaat F (2014) Supporting decisions in water management by exploring information and capacity gaps: experiences from an IWRM study in the Western Bug River Basin, Ukraine. *Environ Earth Sci. doi 10.1007/s12665-014-3863-8*.

8.1 Abstract

Key problems of Integrated Water Resources Management refer to interactions between various *levels, scales* and existing coordination gaps, such as inadequate governance structures and insufficient knowledge and capacities. In this study we describe a management framework that aligns model-based systems analysis with capacity assessments suggesting a concept for improving cross-scale interactions and thus for overcoming both, water-related pressures and coordination gaps. In the study we (i) identify the missing link between technical development approaches and capacity development, (ii) outline interrelations between environmental pressures on aquatic systems and capacity and information gaps in a transparent way, and (iii) introduce a practice-relevant method to combine model-based system planning with capacity assessments for deriving management options that support water management actors in reducing pressures and gaps. The results of the integrated analysis are made explicit by introducing a matrix approach that is inspired by an existing framework to systematically differentiate water quality-related pressures (cf. Blumensaat et al. 2013). The approach confronts pressures and gaps and so jointly addresses technical issues, institutional challenges, organizational development, information needs, and human resources development. The concept supports a transparent decision making process by identifying knowledge and capacities required for the implementation of corresponding technical intervention options and vice versa. The application of the method in the International Water Research Alliance Saxony model region 'Ukraine' is illustrated to demonstrate the added value as a *boundary object* between *scales* that is supporting actors in stream-lining model-based planning and capacity development.

8.2 Problem scope

Implementing the concept of Integrated Water Resources Management (IWRM; e.g. GWP 2000) in practice is still a considerable challenge (e.g. Biswas 2004; Medema et al. 2008).

Key issues refer to interactions between various *levels* and *scales* (Moss and Newig 2010; Gupta and Pahl-Wostl 2013). Existing coordination gaps such as inadequate governance structures and missing capacities need to be adapted to IWRM requirements—according to the OECD (2012) the lack of *capacities* is the second most important issue in water management after financial constraints.

The IWRM concept furthermore implies the joint consideration of various technical aspects, whereas 'technical' is here defined as 'pertaining to different technical disciplines'. This extends the scope and the complexity of the system to be analysed as such that planners often face the challenge to answer increasingly complex questions in a minimum of time, with least effort and information. A number of different approaches, such as substance flow balancing and integrated process-based modelling are being used to handle this increased system and problem complexity and to consider different issues in a conjoint, integrative manner (e.g. Benedetti et al. 2005; Blumensaat et al. 2009; Dietrich et al. 2012). However, very often this type of systems analysis has been considered mostly detached from the examination of governance and capacity related aspects. But as a matter of fact, the IWRM theory demands covering alike pressures causing impacts on the environment *and* governance/capacity issues (cf. GWP 2000; UNESCO 2009).

Our main research questions are therefore:

(i) how to improve the interlinkage between technical planning aspects and capacity issues, and

(ii) how to make this complex interaction transparent and applicable for participating actors.

Within this context, all actors involved in the management process must understand that technological solutions may be less efficient without systematic (model-based) analysis (e.g. as exemplified by Blumensaat et al. 2013), modelling results are less reliable with inadequate input/ reference data, and data stays inconsistent with unsystematic environmental monitoring programmes or lacking resources and capacities.

Thus, a third key question is (iii) how to strengthen the interdisciplinary collaboration between different scientific disciplines and, in particular, how to address the difficulties in combining different research methods (e.g. comparative vs. case-based research: cf. Mollinga 2008; Lang et al. 2012).

In this paper we propose a management framework that aligns model-based systems analysis with capacity analysis. We focus on the influence of model-based planning and capacity development approaches for knowledge exchange within the IWRM process and thus on the development of tailoring management options.[75] By exploring capacity and information gaps, cross-scale (e.g. science-policy) and multi-level challenges are resolved to approach transdisciplinarity (cf. Pohl and Hirsch Hadorn 2008) for real-world implementation of IWRM.

8.3 State of the art

8.3.1 Governance and capacity development

Within the literature on capacity and capacity development, the governance context—consisting of fundamental rules and the legal system (Davis and North 1971), cultural norms and individual as well as collective actors (Pahl-Wostl et al. 2013)—is often integrated in the multi-level approach of capacity development, next to organizational and individual level (van Hofwegen 2004; Alaerts 2009). Despite the fact that governance is an important issue, we refer to the capacity development literature (e.g. Lopes and Theisohn 2003; Alaerts and Kaspersma 2009) and do not repetitively mention governance explicitly, but consider it as a part of capacity and capacity development. For a discussion on capacity development we refer to Lopes and Theisohn (2003), Alaerts (2009), Ubels et al. (2010) and Leidel et al. (2012).

8.3.2 Coordination gaps in water resources management

The OECD multi-level governance framework describes key challenges on a broader basis as interrelated coordination gaps in water resources management (Charbit 2011; OECD 2012; see Table 17). Yet, in this study we focus on information and capacity gaps, since exploring and reducing these gaps are decisive factors for systems understanding and thus serve as a basis for elaborating upon other coordination gaps. Hooper et al. (1999), for example, underline the need for integrating information and competencies in river basin management (RBM). The *information gap* refers to the asymmetry of information between individual and collective actors that are involved in water policy making and is thus con-

[75] We define management options as a combination of 'technical intervention options'/rehabilitation measures, such as the implementation of innovative treatment technology at a wastewater treatment plant (WWTP) with capacity development measures, for example the establishment of training courses for operating personnel.

nected to the capacity gap[76]. It can be about the quantity, quality and type of information. There is either a general lack of appropriate information for the management at the relevant level, or the information is not or hardly shared by the responsible authorities. The information gap can occur between different levels of a government branch (e.g. within one ministry), between different government branches (cross-scale, between different ministries) as well as cross-scale between different stakeholders (authorities, NGOs, public). Timmerman et al. (2010) define the water information gap as the gap between information producers and users (science-policy), and describe a method for improving the communication between them. That means that this gap strongly influences decision making in the realm of water management.

Gap	Explanation
Information gap	Asymmetry or lack of information
Capacity gap	Missing capacities and knowledge
Administrative gap	Misfit between hydrological and administrative boundaries (problem of fit)
Policy gap	Sectoral fragmentation of water policy across different authorities (horizontal interplay)
Funding gap	Finances for fulfilling responsibilities missing or not regularly enough paid
Objective gap	Contradicting targets, e.g. flood control versus nature protection
Accountability gap	Lack of transparency within water policy

Based on Charbit 2011, OECD 2012

Table 17: Coordination gaps in water resources management

The *capacity gap* refers to missing capacities and knowledge. This comprises as commonly defined (i) individual capacities, i.e. skills, attitude and knowledge of water actors (e.g. sewage engineering technician), as well as (ii) organizational capacities, i.e. available technical infrastructure such as laboratories for ensuring the responsibilities (e.g. of authorities for water quality monitoring). The latter also comprises capacities towards organizational processes, for example how to do water quality monitoring, how to fulfil reporting commitments or collaboration with other authorities. There can also be a capacity gap within the governance context, for instance concerning laws relevant for organizing water management, environmental legislation, policies, regional planning, municipal economy, and tariff regulations.

[76] Asymmetry of information is a general problem in environmental policy making (Krutilla and Krause 2011).

Gaps exist at various levels and scales and thus are often associated with cross-level and cross-scale challenges (cf. Figure 27) so that the question arises how to handle such challenges.

8.3.3 On the role of scales and levels in IWRM

IWRM has to be implemented at multiple levels and scales in order to be sustainable. It is therefore decisive to identify and understand relevant scales and levels within water management and its interactions (cf. Moss and Newig 2010; Gupta and Pahl-Wostl 2013). Environmental researchers commonly use the terms 'scale' and 'level' for spatial and temporal dimensions. We draw on the definition of scale and level from Gibson et al. (2000) and Cash et al. (2006) in which scale is referred to as a *dimension for analysing challenges*, for example spatial, temporal, institutional or managerial, and level as a *position on the scale*. Cash et al. (2006) showed that cross-scale and cross-level interactions are evident in man–environment systems.[77] According to the authors, a major challenge for resources management lies in the mismatch between research and scientific knowledge at a global (and therefore abstract) level and applied, often empirical know-how on a local and context-specific level. Global concepts (e.g. the general IWRM concept) are hardly applicable for regional decision makers and local knowledge is often disregarded, i.e. not communicated and scaled up to higher levels (e.g. how to operate a wastewater treatment plant under financial constraints). The importance of a cross-sectoral analysis for an integrated and adaptive management (cf. Pahl-Wostl et al. 2012) is an implicit part of the mentioned cross-scale interactions and its application for relevant actors. This clearly underlines that identifying and understanding all relevant cross-scale and cross-level interactions is as important as developing technically efficient management options. In fact, interactions between scales and levels within IWRM are still insufficiently explained which contributes to the confusion about IWRM. Vreugdenhil et al. (2010) conclude that flexibility in scaling and scale use is an important factor for successful management, i.e. "looking outside existing boundaries". One question is therefore how to overcome boundary problems for improving cooperation between scales.

[77] Young (2002) and Moss (2003) describe these interactions as problem of fit, vertical and horizontal interplay.

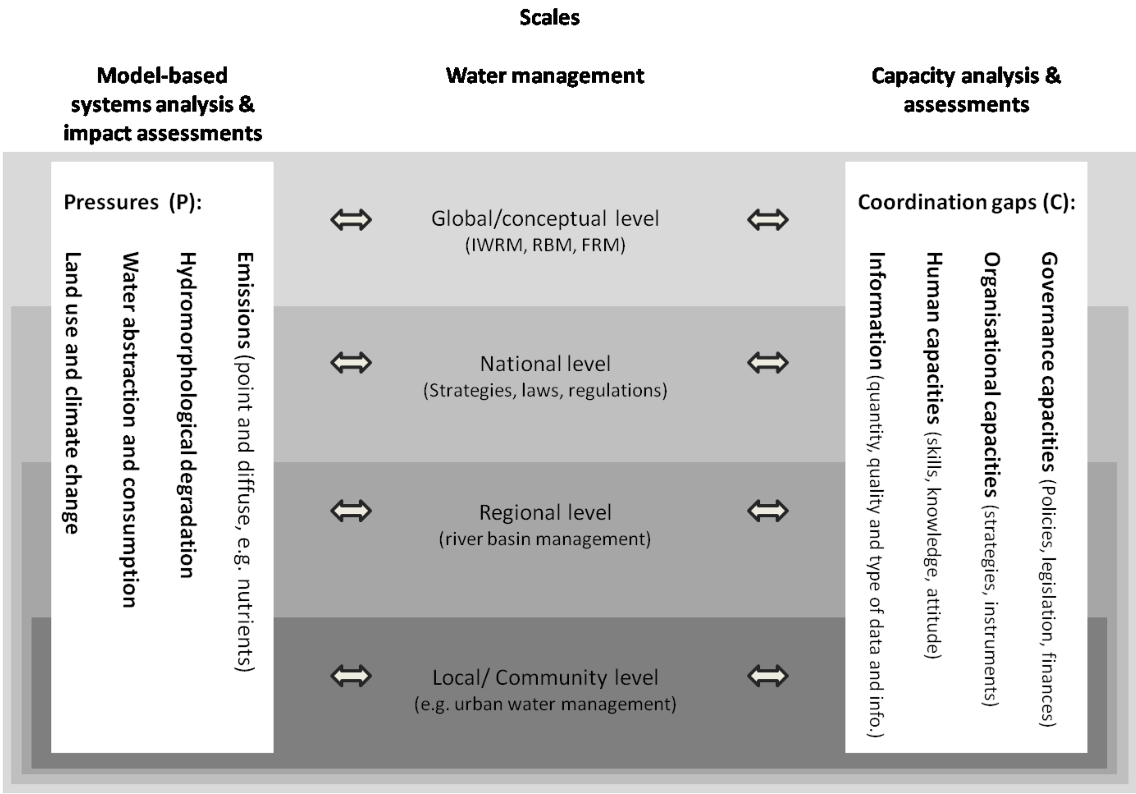


Figure 27: Underlying framework illustrating 'scale' and 'level' challenges

8.3.4 Boundary objects to approach cross-scale interactions

Boundaries, i.e. *cross-scale* challenges, are manifold according to Mollinga (2010), for instance between different academic disciplines, sectors or experts and laymen. Simultaneously, knowledge and capacities are often unevenly distributed between water actors, so that a need arises for an institutional framework that deals with *cross-scale* dynamics for facilitating cooperation and knowledge exchange. Cash et al. (2006) propose responses such as institutional interplay, co-management or boundary organizations as described by Guston (2001). Mollinga (2008) argues that boundary concepts, boundary settings and *boundary objects* are required. Acknowledging their importance, this study focuses on *boundary objects* to approach *cross-scale* challenges. The concept of *boundary objects* was introduced by Star and Griesemer (1989) as a "means of translation" between different social worlds. Boundary objects should provide the "knowledge for doing" (Mollinga 2010) potentially through maps, reports, frameworks, scenario development, models, and decision support systems (Cash et al. 2006). Mollinga (2010) describes three strategies, i.e. distinct routes to develop *boundary objects*:

(i) the analytical route: applying analytical methods, models to understand complex systems. Knowledge is developed "externally" for example by scientists and then transferred to the decision-making process.

(ii) the assessment route: building a link between different disciplines or different actors, for example by developing suitable frameworks to clarify complex issues. The frameworks facilitate *cross-scale* knowledge transfer (e.g. between science and policy), which is appealing for decision-makers (Mollinga 2008).

(iii) the participatory route: emphasizing social learning[78] and political negotiations as a continuous social process for knowledge development within the decision making process, for example through putting forward round table discussions with participating actors at an early stage. This contributes to promote river basin management by exchanging knowledge and mutual learning.

Mollinga (2008) discusses obstacles for all three routes, concluding that converging the three routes into one strategy can improve the performance of sustainable resources management by approaching transdisciplinarity. To adapt regularly to changing conditions, Mollinga (2008) further concludes that information generation and iterative learning are essential for resources management.

8.3.5 The harmonized IWRM and capacity development concept

Based on Mollinga's work on *boundary objects* (2008, 2010) and findings by other authors (e.g. Salamé and van der Zaag 2010) it can be concluded that capacity development (CD) has to be on a par with other IWRM related processes. Hence, Leidel et al. (2012) suggested harmonizing IWRM and CD processes. This approach enables CD measures to be selected that fit with the overall IWRM process. Yet, the specific interaction with the model-based systems analysis and the resulting rehabilitation measures are not taken into account completely.

8.3.6 The model-based IWRM planning framework

Modelling approaches for the quality and quantity of water resources are widely used in water management (i) to increase systems understanding, (ii) to identify relevant pressures and impacts and (iii) to assess the performance of (technical) rehabilitation measures. They can be further used to describe future conditions especially within a globally changing envi-

[78] Social learning is according to Reed et al. (2010) defined as (i) a change in understanding in the individuals, (ii) goes beyond individual learning and is within wider social units and (iii) change occurs through interactions between actors within a social network (meetings, media, Web 2.0).

ronment. Blumensaat et al. (2013) proposes a model-based IWRM planning framework for identifying impacts on river water quality that reduces complexity by differentiating pressures (P) within different subsystems (S) and introducing the S/P matrix. Within this approach a variety of models of different complexity, different spatial and temporal *scale* can be applied. Within the multi-objective evaluation, relevant stakeholders are already integrated for identifying a ranked list of potential rehabilitation options. Yet, the concrete interactions with capacity analysis are just taken into account in the final phase, i.e. the resulting management options are based on systems analysis without assessing the capacities from the very beginning.

8.3.7 Synopsis

Considering current practice in water management, we can conclude that:

(i) ambiguously used terminology impedes integrative water management across *scales*,

(ii) technical optimization is often carried out without considering capacities,

(iii) coordination gaps hamper the successful implementation of intervention options,

(iv) global and abstract approaches are inefficient to resolve problems at a local *level*,

(v) *boundary objects* that combine the analytical, the assessment and the participatory strategy help improve water resources management.

8.4 Methodology

In this study we develop a framework for an integrated analysis, i.e. a combination of model-based systems analysis and capacity analysis as a basis for developing sustainable management options. It is based on the joint examination of the three scales outlined in Figure 27.

8.4.1 Framework overview

At the centre of Figure 27, the water management *scale* is shown with its different *levels*. It follows a nested approach starting with abstract concepts at a global level (e.g. flood risk management-FRM) and gradually becoming more context-specific by going down to the national, regional and local *level*. Each single *level* of water management consists of an interacting man–environment system (e.g. urban and rural entities: water and related resources), as well as the socioeconomic system with a governance context and its actors (e.g. authorities). The water management *scale* interacts with the pressures resulting from human activities and the coordination gaps (*cross-scale* interactions). For instance, at the local *level*, the water management consists of adjacent river sections as (natural) subsystems (S) with pressures (P), for example pollutant emissions exerted on them. It also consists of local water service providers (local wastewater operators) and local authorities (municipal environmental inspections) as subsystems (S) with potential coordination gaps (C) such as a lack of information on the surface water quality due to inefficient monitoring programmes. As indicated by the nested boxes in Figure 27, *cross-level* interactions potentially occur. For instance, decisions at the regional level also have consequences for urban water management at the local *level* and vice versa.

8.4.2 Model-based systems analysis and impact assessments

On the left hand side of Figure 27 the pressures on the man– environment system are shown. The analysis of the pressures results in deriving potential rehabilitation and optimization measures. Hence, it interacts across the *scale* with water management. Integrated modelling has become an important part for supporting decisions in water management. Yet, the selection of the appropriate modelling approach is always conditional upon the availability of data and information. In fact, river basin management strongly depends on consistent and reliable field observations, which are organized and documented through adequate data management. Various studies have shown at different geographical *scales* (Dietrich et al. 2012; Blumensaat et al. 2013) that modelling of different levels of complexity can significantly contribute to a water management planning. Modelling that successfully supports decision-making is credible, but also legitimate (accepted) and salient (relevant)—cf. Mollinga (2010). This in turn means the modelling approach must be objective-driven and adapted to the perceptions, needs and capacities of the involved actors. Therefore, the *scale* of model-based systems analysis has to interact with the *scale* of capacity analysis and assessment.

8.4.3 Capacity analysis and assessment

On the right hand side of Figure 27, coordination gaps are shown, namely the governance, the organizational and the human capacities[79] as well as the information sub-scale. There is an evaluation of which type of capacity and information is available and what is required for each level of water management. Several methods for analysis are available: for example reviewing documents, stakeholder analysis, institutional analysis, SWOT analysis, capacity

[79] This reflects the aforementioned multi-level approach. Yet, we turn it upside down for the sake of clarification and define it as sub-scales.

assessment workshops, focus group discussion. The information assessment refers to the quantity, quality and type of data. This comprises information on the environmental and technical system, as well as socioeconomic data and aggregated information, for example on flood risks. These four *sub-scales* are interrelated and interact with the water management *scale* by deriving potential capacity development (CD) measures.

It has been recognized in several studies (e.g. Speed et al. 2013) that the complexity of proposed water management approaches is often too demanding for the available capacities. Therefore, the *scale of capacity analysis and assessment* has to interact with the *scale of model-based systems analysis*.

8.4.4 Detailed description of the model-based and capacity-based IWRM framework

It appears essential to balance technical management with available and developable capacities. Consequently, we propose a *boundary object* that consists of a management framework with model-based systems analysis, capacity analysis and a political process for capacity development and social learning (see Figure 28). This strongly corresponds to Mollinga's approach (Mollinga 2008, 2010) that suggests converging the three 'routes' into one boundary *object*. As a structuring element the so-called S/P/C matrix is introduced to confront Pressures and Coordination gaps on a Subsystem basis making results transparent and explicit.

8.4.4.1 Systems analysis

Systems analysis consists of a conjoint systems and capacity analysis (see Figure 28). It starts with the screening, in which system scope, drivers, potential pressures and coordination gaps are compiled, giving first insights into impacts for delineating the objectives (step 1 in Figure 28). The developed method can be used for all *levels*, for example at the local *level* for the optimization of the urban wastewater management of a particular city (see Example 1), as well as for other *levels* such as the regional *level*, for example for a river basin management with manifold problems (see Example 2) and also for *cross-level* analysis.

Gradually developed results from the systems analysis of the environmental and technical system are used for governance and capacity analysis and vice versa. To obtain operational solutions, it is important to integrate the stakeholders' knowledge as well as the governance context during the initial step. Thus, a capacity analysis starts with the identification of existing information and capacities for the particular problem to be tackled. Concrete inquiries for required information from relevant authorities can be addressed, which are then used for the further identification of pressures and subsequent rehabilitation measures. To handle the complexity, we differentiate potential coordination gaps (C_m) within subsystems (S_n). Coordination gaps and the scope of subsystems vary according to the identified impacts and study objectives (see Table 19). The conjoint systems analysis thus leads to the holistic identification of the current status of the water management, technically and capacity-wise. This relationship can qualitatively be expressed as follows:

$$W_{local} = \sum_{1}^{m} \boldsymbol{P}\, river\ section\ S_1 + \ldots \sum_{1}^{m} \boldsymbol{P}\, river\ section\ S_n + \sum_{1}^{m} \boldsymbol{C}\, actor\ S_1 + \cdots \sum_{1}^{m} \boldsymbol{C}\, actor\ S_n$$

where W_{local} is the local water management level, P represents pressures and C represents coordination gaps. River sections and actors represent the subsystems ($S_1 \ldots S_n$).

8.4.4.2 Deficit analysis

The second step comprises an in-depth analysis of deficits that constrain efficient water management. Deficits are defined according to the state-of-the-art in sustainable water resources management as well as according to national legislation and international conventions. Driving factors ('pressures') leading to ecological and technical deficits (i.e. aspects of public life which may have an impact on the environment) are differentiated. At the same time, institutional deficits are assessed including financing and funding, as well as organizational and individual gaps. Thus it is necessary to know the desired future state of the water management which has to be elaborated together with relevant stakeholders. The comparison of required and available capacities and information leads then to clear description of capacity and information gaps (deficits).

8.4.4.3 Comparative assessment

Comparative assessment provides a qualitative synthesis of relevant deficits to see how the single pressures and gaps interact and contribute to the corresponding deficits. Within a comparative analysis of S/P/C matrix, a first evaluation of the relevance of each single pressure and gap on the complete system is carried out qualitatively (interaction across the boundaries of *scales*). Comparing both matrices shows which levels and which subsystems are involved. The national subsystem within the S/C matrix may interact, for example via water legislation, with the *local* subsystems of the S/P matrix—this comparison exhibits *cross-level* and *cross-scale* interactions.

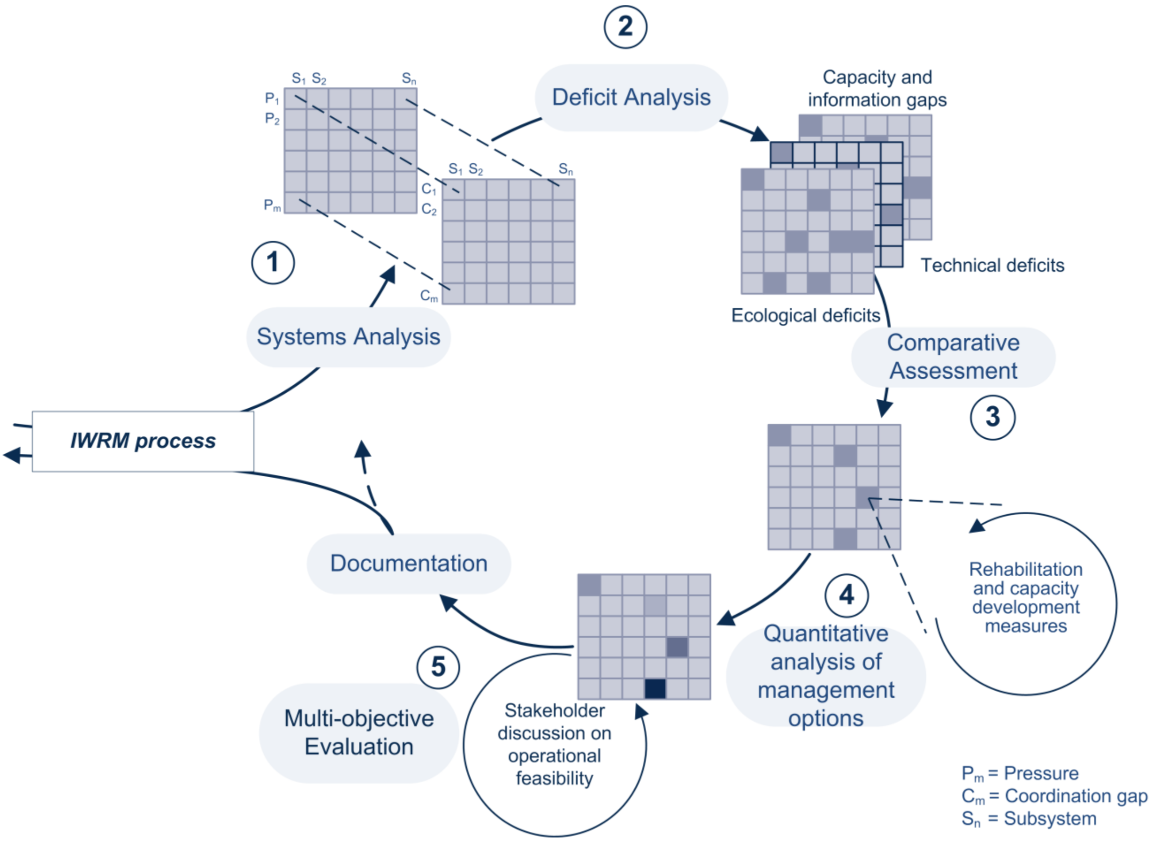


Figure 28: Model-based and capacity-based IWRM framework

Ultimately, all relevant pressures and gaps in relevant subsystems at corresponding levels are brought into context, and integrated management strategies (technical rehabilitation and CD measures) may qualitatively be identified.

8.4.4.4 Quantitative analysis of management options

The effect of the identified management strategies on different system (state) variables is quantified. Methods used for effect quantification need to be selected according to the availability of required data as well as the capacity of users. Single management options, i.e. technical rehabilitation measures should correspond to capacity development measures possibly differentiated on the governance, organizational and human resources sub-scale. This reveals whether the available information and capacities are:

(i) already sufficient, (ii) to be developed in a short term, (iii) in a medium term, (iv) in a long term, or (v) if no capacity development is feasible.

8.4.4.5 Multi-objective evaluation

Within this final step, potential management options are integratively evaluated according to their technical, ecological, economic and institutional efficiency—the overall feasibility of implementation is assessed. Different temporal horizons of implementing rehabilitation and CD measures and the corresponding availability of information are harmonized towards a sound integrated implementation strategy. The time and effort required to implement CD measures at an institutional level may often exceed the period of realizing a technical rehabilitation measure. Hence it needs to be made transparent to decision makers how long the development of capacities and implementation of rehabilitation measures will take and how they may influence each other. It may be necessary that CD measures have to be executed prior the actual rehabilitation measure, for example developing organizational capacities which are indispensable for technical implementation. Ultimately this process leads to a prioritization of management options for different planning horizons (short-, medium-, long-term) addressing the objectives of different stakeholders in an adequate manner.

8.4.4.6 Knowledge exchange and capacity development

To increase awareness regarding the complexity of water resources management among decision makers, a participatory approach is applied so that technical understanding and social learning increases. This corresponds to the participatory route of the *boundary object*. Hence, the overall development is accompanied through continuous knowledge exchange and capacity development with the relevant actors, for example through political negotiations that support all the above-mentioned phases.

8.5 Application in Western Ukraine

Within the International Water Research Alliance Saxony (IWAS), the foremost research question was how to effectively support the implementation of IWRM through an adequate rehabilitation of environmental and technical systems along with corresponding capacity development to address pressing water resources problems in different regions worldwide (Kalbus et al. 2012). The conjoint consideration of technical and socioeconomic issues was particularly paid attention to in the IWAS model region in Eastern Europe, the Western Bug river basin (WBRB) in Ukraine.

Based on the approaches from Leidel et al. (2012) and Blumensaat et al. (2013) we apply a *boundary object* combining the *three routes* so that the analysis of pressure and coordination gaps goes along with reducing them by delineating management options and improving the science-policy-interface through CD and policy advice. We exemplify it at local and regional *levels*, and for both cases we discuss their dependence on available information and capacities from the local, regional and national *level* perspective.

8.5.1 Example 1: Wastewater management in the city of Lviv

8.5.1.1 Systems analysis

A model-based systems analysis was conducted for the WBRB including model coupling (Ertel et al. 2012; Blumensaat et al. 2012; Schanze et al. 2012). It pinpoints the desolate surface water quality issue in the reaches of the Upper Western Bug basin due to inefficient wastewater treatment. Wastewater discharges from the city of L'viv appear to be the most significant pollution sources for the river Poltva, the main tributary of the Upper Western Bug. In an initial step, mass balance models were used, while field studies provided additional data to narrow down the information gaps. Simultaneously, the technical expertise of the water service providers is evaluated through questionnaires and interviews. The analyses reveal considerable pollution through

(i) continuous emissions due to discharge of poorly treated WWTP effluent, and

(ii) highly dynamic emissions due to combined sewer overflow during rainy weather.

This results in environmentally critical pollutant concentrations of varying dynamics (increased pollution levels, concentration peaks) in the rivers Poltva and Western Bug. Obvious pressures that were identified are compiled in the S/P matrix (Table 18). Considering the weak legal situation on the other hand, regulatory shortages become obvious: while no WWTP effluent standard regarding phosphorous is defined, the national NH4-N WWTP effluent standard is extremely strict. Further coordination gaps within subsystems on local, regional and national *level* (national politics, authorities at various *levels*, water service providers, water associations, and science) were analysed through capacity and governance analyses, accomplished through questionnaires and expert interviews (Leidel et al. 2012; Hagemann and Leidel 2014; Hagemann et al. 2014a, b; Sigel et al. 2014), assessment workshops (Blumensaat 2010) and negotiations (Leidel et al. 2012). They reveal a weak institutional framework, insufficient cooperation between authorities, inconsistent data basis and information management and an inadequate monitoring. The state (Oblast[80]) authorities are at their limits concerning budget and staff (Hagemann et al. 2014a).

8.5.1.2 Deficit analysis

An in-depth analysis of the urban wastewater system (WWTPs and the sewer system) in L'viv reveal manifold deficits: (i) a significant overload of and the absence of loading control regimes for treatment facilities, (ii) out-dated, energy-intensive and deteriorated treat-

[80] The first level of Ukraine's administrative division is called oblast (state).

ment technology and infrastructure, and (iii) inadequate storm water treatment, i.e. management strategy. Ecological deficits are abundant: nearly oxygen-free conditions (long-term mean concentration in 2009–2010: 1.1 mg L-1) and increased nutrient concentrations (NH4-N: 6.0 mg L-1, PO4-P: 1.1 mg L-1) in the river Poltva. By comparing existing/ required information and capacities, gaps are identified and made explicit in the S/C matrix

Subsystem/ Pressure	Local		Regional
	Poltva	Upper Western Bug River	Western Bug River
Emissions due to continuous discharge of poorly treated treatment plant effluent	High	Low	Moderate
Emissions due to combined sewer overflow during rain weather	High	Low	n.a.
Discharge of untreated industry wastewater to municipal transport and treatment units	High	Moderate	Moderate
Increased diffuse nutrient emissions due to agriculture	Low	Moderate	Moderate
Particle-bound heavy metal loads in river sediments due to historical pollution through sludge disposal	High	Low	Moderate
Hydromorpological constraints	Moderate	Low	Moderate

Table 18: Results of model-based systems analysis compiled in S/P matrix

(Table 19). Main capacity deficits are: the weak institutional framework, no cost-covering tariffs (an Ukrainian-wide analysis show that in average only 85 % of the cost for operating municipal WWTP is covered[81]), little networking between wastewater operators (neighbourhood assistance), little vocational training, outdated and yet to be revised water quality standards based on former Soviet legislation (dating back to 1973 and 1982). Despite the fact that the Ukraine aims to implement RBM and first steps are being made towards reforming legal basis for standards (Hagemann and Leidel 2014), Ukrainian environmental standards are still incompatible with European directives.

[81] http://krogerc.info/ua/tarifs/bycapital/sink.html (in Ukrainian; accessed 29/10/2014).

Ukraine's existing system of emission standards is rather ambitious, covering hundreds of pollutants and mandating very low concentrations of contaminants (e.g. NH4-N, heavy metals), making it very difficult for WWTP operators to comply with. On the other hand, Ukrainian water quality standards are for a number of parameters less strict (e.g. nitrate or phosphate), see Ertel et al. (2012). The standardized set of Ukrainian emission and immission standards is however inconsistent regarding an environmental assessment that identifies the actual impacts of the pollutants on water bodies. The corresponding ecological status of water bodies remains additionally ambiguous, because biological and hydromorphological indicators are not a legal requirement (Scheifhacken et al. 2012). The water service providers responsible for water supply and sanitation as well as their sector association "Ukrvodokanalekologia" have little influence on the development of a water sector strategy, water sector state regulation, technical and environmental standards as well as tarification and corresponding revenues. The analysis of the national level showed that all effective and necessary sector strategies and programmes consist of long-term actions with significant costs, whereas these proposals are usually not approved by the Ministry of Finance.

8.5.1.3 Comparative assessment

All technical, ecological, governance and capacity deficits of the relevant subsystems are synthesized. That means that at a local level the deficits from the wastewater system of L'viv causing pressures on the Poltva and Upper Western Bug River are brought into context with the capacity and information deficits at local, regional and national *levels*.

Full compliance with effluent standards regarding nitrogen according to Ukrainian environmental legislation can only be reached with fully functioning nitrification–denitrification treatment. On the other hand the analysis shows that sanctions for exceeding effluent standards are not differentiated according to their environmental relevance. This can be exemplified for nitrogen emissions: the discharge of NH4-N loads (increased environmental relevance) into the receiving water would ultimately lead to the same sanction as the discharge of the same load of NO3-N (moderate environmental relevance). Eventually, vague negotiations between environmental authority and wastewater operator are the usual practice to arrange the final effluent requirements—the only rational option to avoid a 'blunder' in the inspection-treatment practice. Financial incentive mechanisms to encourage investments into more efficient treatment technology, such as reduced penalties, are presently irrelevant. In addition, the municipal utility companies operating WWTPs pay the environmental taxes (levy) for the discharge of treated and untreated wastewaters in natural bodies, since the polluter-pays-principle is integrated in Ukrainian legislation and WWTPs are considered as environmental protection enterprises that have to pay the same taxes as other industrial companies. Yet, such taxes are considerable and in order not to increase the wastewater fee for the public, the local authorities reduce the amount of taxes for municipal WWTPs. The missing amount is normally absorbed by the local environmental budget. The dilemma is that, in most cases, the environmental budget is not used to develop the treatment plants but is collected to the budget itself. Thus, water tariffs and wastewater fees are fixed by the local municipal authority and do not reflecting the economic value of the treated water. In particular, industrial dischargers are not charged adequately. Consequently, the incentive, i.e. the motivation to invest in improved wastewater treatment, is reduced to a minimum; no mitigation of ecological deficits is reached. For the urban wastewater system of L'viv this means: sustainable management strategies are only possible if the pressingly required rehabilitation measures are jointly implemented with appropriate capacity development measures and an accompanying political discussion about a revision of current tariff principles, a serious implementation of the polluter-pays-principle, a revision of WWTP effluent standards and general environmental compliance.

8.5.1.4 Quantitative analysis of management options

Effects of discussed rehabilitation measures have been quantified using a process-based numerical model that describes the urban wastewater management of L'viv, comprising the urban drainage system and the two municipal WWTPs. Results clearly show that treatment efficiency, i.e. carbon removal and nitrification, could already be improved without treatment capacity extension but by intensifying and optimizing the aeration process including a simultaneous pre-treatment of industrial wastewater. Modelling results further show that an integrated pollution load control concept that harmonizes treatment plant loading and storm water conveyance would significantly reduce the total emissions released into the river Poltva.

Identified capacity development measures included revision of environmental legislation to better reflect the current situation. It has to be acknowledged at the national *level* that a differentiated levy system for effluent standards needs to be legally enforced. Above that, emission standards must be carefully revised in relation to the best available technology, toxicological and environmental studies, and changes in the consumption market. The command and control approach has to be supported by a management oriented approach that takes local conditions and interests into account, which will gradually improve water quality by setting up an agreed schedule for emission reduction.

Subsystem/ Coordination gaps		Local		Regional	National		
		Water service provider (Lvivvodokanal)	Municipality (Lviv)	Authorities (Environmental Administration and Water Authorities of oblasts Lviv and Volyn, Western Bug Basin Department of Water Resources)	Government/ Ministries (Ministry of Ecology and Natural Res., State Agency of Water Resources, Ministry of Regional Develop., Construction, Housing and Communal Services)	Association (Ukrvodokanalekologia)	Universities (NUWMNRU Rivne , Lviv PNU, IFNU Lviv)
Information		- inconsistent and little reliable information on: • wastewater quantity and quality (no continuous monitoring of influent and effluent, only random sampling) • loads and concentrations • wastewater composition • dimensioning and operation of WWTP • sludge parameters (e.g. dry matter content) • capacity of activated sludge tanks/oxygen distribution and availability • no metering of water consumption	- little information for public	- inconsistent data series - lacking essential parameters - moderate hydromorphological data - authorities monitoring water quality with differing methods - no comparison of differences and similarities of methods (e.g. sampling or analytics) - no coherent method for data exchange - data and information has to be exchanged upon request - little exchange of experiences - few enforcement instrument, e.g. in terms of data delivery - no modelling of water quality/ quantity - geodata base from RBA, yet data are not all open access (no information platform) - little information of public	- reasonable indices missing - information on current legislation incoherent or not available for public - poor or outdated socio-economic data - little exchange of data between ministries - no data/ information platform - little knowledge transfer measures - data management and collaboration guidelines missing - little exchange of experiences with other countries	- no consistent information platform	- difficult to get data from authorities and water service providers - no modelling of water quality and quantity
Capacity	**Individual**	- little state-of-the-art know-how/ skills on: • technical, e.g. sludge recycling • environmental standards • customer relations • cost and tariff regulations	- little know-how on: • technical issues • private sector involvement	- little state-of-the-art know how on: • RBM, water monitoring, coordination and cooperation in RBs • technical solutions	- moderate state-of-the-art know how on: • RBM, coordination and cooperation in RBs - little knowledge about interdependencies	- insufficient communication and cooperation skills for political influence	- interdisciplinary knowledge on RBM/IWRM missing - no trainings on biological monitoring
	Organizational	- little vocational training - little maintenance - little state-of-the-art know-how - missing strategies for modernisation of facilities - little public relations - measuring and regulation technology is outdated (e.g. online measurement of oxygen in activated sludge tanks, air distribution)	- no incentive systems for outstanding debts	- water monitoring and data management not state-of-the-art - lacking regular and standardised internal quality management - few guidelines on technical, organisational issues and education and vocational training - informal rules play an important role - RBA's coordination role unclear - No regular coordination meetings - No mechanism for continuous adaptation and learning	- law enforcement and compliance missing - water competences/ existing capacity development measures are not bundled - no common strategy	- unclear role and tasks of the association - low collaboration and commitment of member companies - no scientific institutions and commercial companies	- focus on natural sciences and engineering sciences - no interdisciplinary courses on RBM/ IWRM - context-specific (e-) learning materials on IWRM missing - no inter- and transdisciplinary research approaches
	Governance context	- no incentives for investments - no cost-efficient prices - little networking with other wastewater companies - depend on national regulator for tariff revenues - little know how on state-of-the-art operation and business administration	- little resources to fulfil tasks - little budget for investments - no cost covering tariffs - no metering of water and wastewater	- environmental legislation not adequate (limits, intervals) - no efficient law enforcement - responsibilities and competencies are ambiguous and often unclear (e.g. river basin management planning) - RBA and RB Council (RBC) often lack power and experience to carry out tasks - not all actors are participating in RBC - little public participation - little spirit of cooperation between the members of the council	- common definition of RBM missing, overlapping legal guidelines - Nakaz No. 56 regulation is not specific enough for implementation of RBM - laws/ ordinances concerning nutrient pollution not state of the art - strict thresholds for total N and Nitrate - low inter-ministerial collaboration - little cooperation with NGOs, science - no schedules for plan approval and achievement of goals - regulations for Private Public Partnerships difficult - little investment security, implementation gap - Instable political and economic conditions - administrative system inappropriate, e.g. roles and responsibilities of actors	- insufficient collaboration with ministries and science - little influence on: • development of sector strategy • sector state regulation • technical standards • environmental standards and norms - not recognized by political and national/regional stakeholders	- difficult funding possibilities - low collaboration with ministries, NGOs, associations - big science-policy gap - research is in some cases not state of the art in water sciences, e.g. modelling of water quality and quantity - biological monitoring is not common

Table 19: S/C matrix for case study in the Western Bug River basin (Ukrainian part)

Equally important is an intransigent and persistent process to enforce the polluter-pays-principle so that ultimately tariffs fully reflect the costs for refinancing wastewater infrastructure. To support this approach it is important to strengthen the sector association "Ukrvodokanalekologia" and to pool competencies at the appropriate levels. In addition, reforms to amend Ukrainian environmental and water quality standards requires political will, but also financial resources and capacity development of state authorities (Hagemann et al. 2014a).

8.5.1.5 Multi-objective evaluation

Two round-table discussions between involved stakeholders (city council of L'viv including the mayor, environmental authority, wastewater operator 'LvivVodokanal') have been exerted to evaluate results of the analysis regarding the different interests of the stakeholders. Different management options have been evaluated according to their technical, ecological, social and economic efficiency. In a first step this led to a public commitment of the city council to make the modernization of the municipal wastewater treatment a top-level priority. However, the acquisition of funding to finance prioritized measures is still difficult, also due to the confusion regarding previous international funding initiatives and the corresponding historic burden impeding new initiatives.

8.5.1.6 Process for knowledge exchange and capacity development

Central within the capacity development process is the establishment of a national working group between the Ministry of Regional Development, Construction, Housing and Communal Services of Ukraine, the National Com-mission for the regulation of communal services, the sector association "Ukrvodokanalekologia" and IWAS. It helped to start a dialogue and thus to discuss results, especially on cost and tariff regulations as well as on standards and standard settings. In addition, several working groups were created within "Ukrvodokanalekologia" dedicated to technical issues of sanitation and environmental standards as well as economic questions such as cost and tariff calculation. This strengthens the association so that its role is enhanced in the national water sector reform process.

8.5.2 Example 2: nitrogen loading in Western Bug River

Model-based systems analysis (1) and deficit analysis (2) have shown that the nutrient load in the Western Bug River is moderate to high (Ertel et al. 2012), while hydromorphological conditions vary between unmodified, i.e. natural to heavily modified river sections (Scheifhacken et al. 2012; see S/P matrix, Table 18). Mass balance modelling revealed that the vast majority of the nitrogen pollution stems from the L'viv wastewater system (NH4-N) and from agriculture and groundwater (NO3-N) (Helm et al. 2012). Furthermore, climate and land use changes have to be taken into account (Roth et al. 2008; Pavlik et al. 2012; Schanze et al. 2012). The capacity analysis has shown that there is a lack of consistent and reliable data due to methodological differences between monitoring authorities (e.g. different monitoring protocols) as well as other restrictions (e.g. low amount of monitoring sites, low monitoring intervals, finances). Thus, data are missing or are inconsistent. Information asymmetries occur predominantly between authorities at a regional *level*, as well as between ministries at the national *level* and between state actors and the public. A river basin management plan for reducing the deficits has to be developed and implemented according to Ukrainian water law. However, the responsible Western Bug Basin Department of Water Resources has not put it in operation so far, which can be ascribed, at least partially, to the above mentioned deficits.

The *quantitative analysis of management options* revealed that rehabilitation measures need to include the improvement of rural sanitation in the Western Bug River Basin, for example by installing decentralized wastewater treatment facilities. Measures should also improve the scientific basis of monitoring, for example inter-calibration of different measuring methods and improving research.[82] A coordination approach based on the existing administrative structures and capacities as well as the assignment of competencies and funding will be a reasonable way for-ward for Ukrainian water management. For setting up realistic river basin management planning the following prerequisites remain indispensable:

– political will and a clear legal basis at the national *level*,

– an enhanced collaboration of the ministries' branches at oblast *level* and oblast authorities is essential. A first important step concerns the cooperation and coordination of the administrations for water and the environment. Only then should cross-sector cooperation between authorities be started (e.g. integrating the agricultural sector). One recommendation is to renew the formal agreements between the state actors within the Western Bug River Basin. The agreements should also integrate the coordination of monitoring programmes, as well as an agreement on how the data exchange is executed in detail.

– an *enforcement instrument* is essential, so that state actors can be forced to cooperate, for example in terms of data delivery.

[82] This is completely in accordance with the Ukrainian action plan for water management until 2020.

– negotiations on a strategy for (i) data management and structure, (ii) data/information exchange between authorities, (iii) data provision for other actors, and (iv) reporting requirements. A good starting point is to facilitate sharing information and thus reduce information asymmetry, for example by setting up an information platform. In this respect, a web service is being developed by the IWAS research team. The question arises, of whether that information can be combined and integrated with Ukrainian data. A jointly developed platform could support stakeholder processes, at least from the point of knowledge. Such a platform should ideally be placed in the WBRB Department, since they already collect data and information from other authorities.

8.5.2.1 Process for knowledge exchange and capacity development

Strong commitment from the national stakeholders is needed for reducing pressures at the regional level. Therefore, a working group with members of the Ministry of Ecology and Natural Resources of Ukraine, the State Agency for Water Resources and the IWAS project was founded to improve river basin management. One of the goals was to develop and carry out the above mentioned strategies for information management, including the re-establishment of the meetings of the Western Bug River basin council. In 2012, 6 years after the last meeting, the council convened. Such coordination meetings on a regular basis are important for knowledge exchange and for creating a spirit of cooperation and mutual confidence between the members, for example by acting jointly and reaching goals together. Apart from that, the political negotiations revealed that cooperation with foreign authorities is an important success factor. For example, the twinning-instrument, i.e. the cooperation of authorities from EU member countries and neighbouring countries, is a proven institution-building instrument (Bartels and Rach 2009), so that ambitious efforts of the Ministry of Ecology and Natural Resources of Ukraine towards such cooperation are currently underway.

8.5.2.2 Integration of case studies

We used two case studies at different levels of water management in order to demonstrate the interrelation between all levels.

Based on the management strategies, the combined rehabilitation measures and capacity development measures from the two case studies are shown in relation to water management in Ukraine (Figure 29). An important next step could be to combine all efforts, for example to set up a centre of water competence in Ukraine with a tailor-made knowledge platform integrating existing management strategies and including prospective measures.

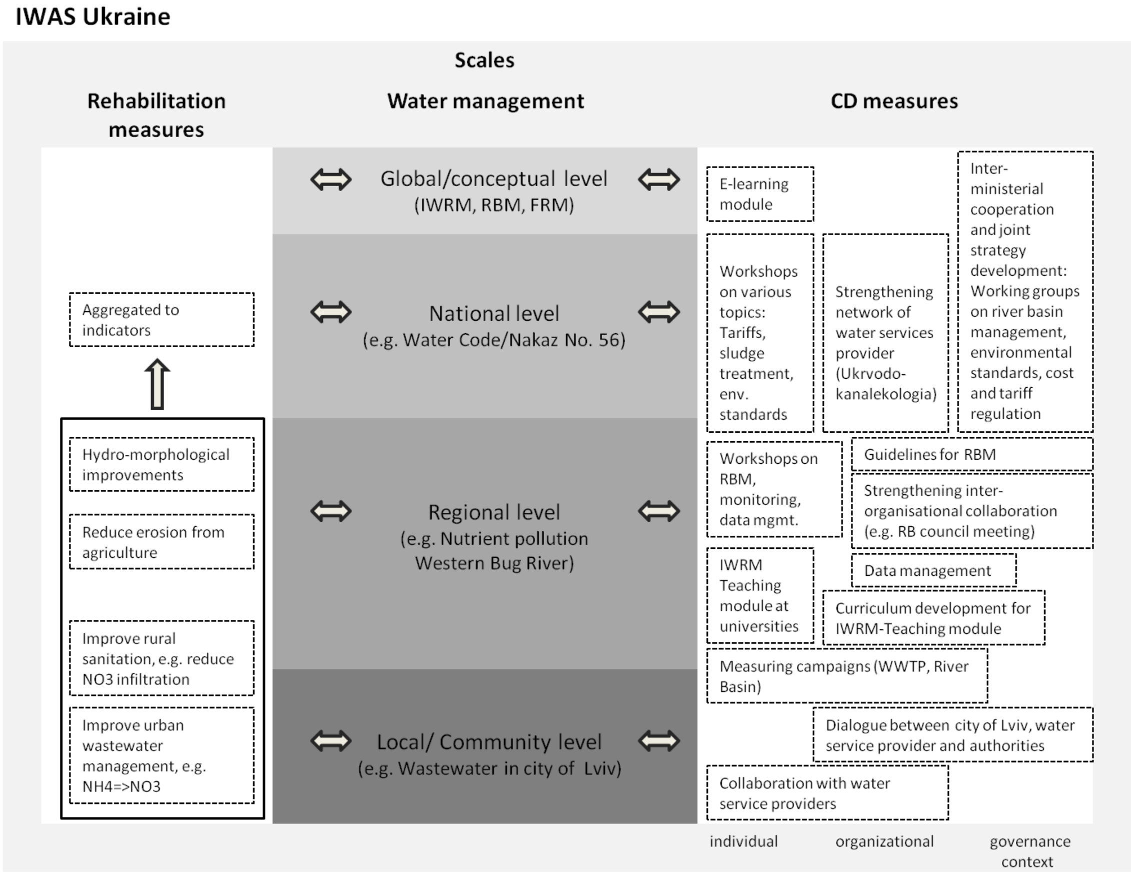


Figure 29: Rehabilitation measures and capacity development measures for IWAS Ukraine

It assures the long term availability of knowledge and its improvement and exchange, facilitating cooperation, and foster social learning. Because actors in Ukraine are exchanged frequently, particularly within ministries and authorities, such a centre could decrease the knowledge that is lost.

8.6 Discussion

Within the model and capacity based IWRM framework, natural, technical and socioeconomic threads and available capacities are assessed and interrelated by means of combining the S/P and the S/C matrix. The resulting management options are derived by a *cross-scale* analysis, i.e. the current situation is reflected from a scientific as well as from an institutional point of view.

Yet, potential divergence of temporal implementation horizons of different management options need to be explicitly addressed to enable an adequate functioning of the overall management strategy, i.e. to avoid institutional fragmentation and a loss of trust. The ranked list of management options forms the basis of informed decisions. Yet, the responsibility for the decision of which strategy is implemented, which reflects common sense, is left to the user.

The already noticeable impact of global changes on hydrological and urban water cycles clearly shows that existing institutions need additional capacities to adapt to emerging tasks. A critical issue in this regard is the willingness and capacity of actors to act *across* their *scale*. One way of increasing this willingness is to apply methods that support *self-assessments* (Pearson 2011). This can be achieved, for instance, by integrating stakeholders in model-based systems analysis at an early stage. The big challenge for stakeholders here is to develop adequate understanding of partially complex issues, such as model concepts, within short periods of time. Translating technically complex interactions into clear and transparent concepts is most essential as it enables relevant actors to generate knowledge and understanding on their own.

The case study research in the Upper Western Bug River catchment must be conceived as an initiating impulse to support the shift from external assistance towards a locally driven initiative enabling actors to achieve development objectives independently. In particular, the improved access to knowledge is a vital prerequisite to gradually develop required capacities, i.e. to make complete self-assessments possible. Further coordination gaps are addressed by our approach only implicitly. Still, the presented approach provides the flexibility to integrate missing gaps in the future to cover other possible deficiencies.

The approach of introducing *boundary objects* is a feasible way of tackling *scale* challenges and can support or substitute the *rescaling* of management activities, for example the transfer of competencies by establishing river basin management authorities. This is particularly relevant as Roggero and Fritsch (2010) show that rescaling can increase governance costs, so that utilizing *boundary objects* instead may turn out to be more efficient. To find a clear and solid conclusion, the issue of quantifying governance costs of boundary objects should be further addressed in future research. Considering the fact that a river basin council and administrations have already been installed in Ukraine, the coordination of activities within the catchment should be accomplished by these institutions. Instead of repeatedly setting up new administrative structures, the proposed *boundary object* should be applied by the river basin administration for supporting collaboration within the WBRB. Implementation is a long-term activity and can be supported by methodological inherent policy advise, a top-down approach establishing the necessary governance structures as well as support from foreign authorities as for instance by twinning activities.

IWAS project work in various model regions across the world, namely Southeast Asia (Vietnam), the Middle East (Oman) and Latin America (Brazil) underline that pressures and capacity gaps are interdependent and similarly exist worldwide. The studies reveal that there is a need for synchronizing systems analysis and capacity assessments (Leidel et al. 2014). A workshop discussion on capacity analysis within the scope of the IWAS project has shown that it is necessary to integrate all relevant *levels* of water management into the assessment. A prerequisite for successfully implementation of our approach is however that an adequate *legal* basis with compliance and enforcement for implementing sustainable water management is available. For any region, the approach needs to be adapted to the prevailing (political) circumstances. Our approach of combining S/P and S/C matrices addresses this requirement within the Ukrainian case study, showing the capability of conducting full-fledged analysis on the one hand and a reduced analysis on the other hand. Yet, further research has to be carried out to see whether this is also evident in other case studies. Moreover, research has to be conducted to see whether our approach can be integrated into the on-going discussions on the nexus of water, energy and food security (e.g. Hoff 2011) by improving the coherence between these sectors.

Above all, our self-conception is *merely* to initiate the transition towards improving water management, since this process actually should be endogenous (cf. Ubels et al. 2010). The presented approach supports the shift to a more endogenous process by knowledge exchange and joint development of management options. Yet, in Ukraine the external actors are at least in the medium-term required to continue initiating and facilitating this development.

8.7 Conclusions

The approach shows the advantages of combining model-based systems analysis and capacity analysis within a *boundary object* for sustainable water management. It could be shown that integrating all three *strategies* is reasonable and supports the development process by delivering management options that are scientifically credible and also accepted by and relevant for the actors. The Ukrainian case study revealed that:

– intervention measures for the urban wastewater system are urgently required also to withstand future challenges (climate and demographic change, emerging pollutants),

– external funding is necessary,

– a holistic and integrated consideration of water management (sewer, WWTP, water quality) is essential.

These technical issues have to be jointly implemented with appropriate capacity development measures and an accompanying political discussion on:

–strengthening the institutional framework including transdisciplinary and inter-ministerial collaboration on all *levels*,

–setting up prerequisites for realistic river basin management planning (Monitoring, information management, legal enforcement),

–a revision of effluent standards and a differentiated levy system,

–cost covering tariffs,

– association work.

This clearly shows that IWRM is a highly political process. Our approach cannot cover all obstacles of political dimension (e.g. hidden agendas, vested interests). Yet, it supports the political process by delineating management options in a transparent way.

Political changes and the exchange of expert staff have severe impacts on the implementation. This can be attenuated by setting up information systems, knowledge exchange platforms or establishing water competence centres.

Encouraging the participating actors is an essential to support the transition process as the Ukrainian case study revealed. Therefore, it is important to verify the feasibility of the measures and to develop a follow-up process at an early stage. It needs to be assured that the proposed method is transferred from research to follow-up activities, for example long-term implementation projects within the development cooperation or projects that focus on administrative collaboration.

There are no panaceas in water resources management (cf. Meinzen-Dick 2007; Pahl-Wostl 2008). Yet, exploring and reducing information and capacity gaps is essential for water sector evolution worldwide, so that the presented approach has the potential to be adapted and applied.

Acknowledgments

This work was supported by funding from the German Federal Ministry for Education and Research (BMBF) in the framework of the project "IWAS—International Water Research Alliance Saxony" (Grant 02WM1027 and 02WM1028).

8.8 References

Alaerts GJ (2009) Knowledge and capacity development (KCD) as tool for institutional strengthening and change. In: Alaerts GJ, Dickinson N (eds) Water for a changing world—developing local knowledge and capacity. Delft

Alaerts GJ, Kaspersma JM (2009) Progress and challenges in knowledge and capacity development. In: Blokland M, Alaerts GJ, Kaspersma JM, Hare M (eds) Capacity development for improved water management. CRC Press, London

Bartels M, Rach Y, Federal Ministry of Economics and Technology (eds) (2009) Twinning projects led by Germany—relevance, effectiveness, impact and sustainability. An evaluation of outcomes by the German National Coordinator for Twinning. Documentation Nr. 578. http://www.bmwi.de/English/Redaktion/Pdf/documentation-578-twinning-projects

Benedetti L, Blumensaat F, Bönisch G, Dirckx G, Jardin N, Krebs P, Vanrolleghem PA (2005) Systems analysis of urban wastewater systems—two systematic approaches to analyse a complex system. Water Sci Technol 52(12):171–179

Biswas AK (2004) Integrated water resources management: a reassessment. A water forum contribution. Water Int 29(2):248–256

Blumensaat F (2010) Model-based optimisation of urban wastewater systems perspectives for the Poltva River from an engineering view point. Perspectives for the Poltva River in L'viv international conference and workshop. Deutsche Gesellschaft fu¨r Technische Zusammenarbeit (GTZ), Lviv, Ukraine

Blumensaat F, Tränckner J, Hoeft S, Jardin N, Krebs P (2009) Quantifying effects of interacting optimisation measures in urban drainage systems. Urban Water Journal 6(2):93–105

Blumensaat F, Wolfram M, Krebs P (2012) Sewer model development under minimum data requirements. Environ Earth Sci 65(5):1427–1437. doi: 10.1007/s12665-011-1146-1

Blumensaat F, Tränckner J, Helm B, Kroll S, Dirckx G, Krebs P (2013) An adaptive framework to differentiate water quality impacts on a multi-scale level. Water Sci Technol 67(2):424–432

Cash DW, Adger W, Berkes F, Garden P, Lebel L, Olsson P, Pritchard L, Young O (2006) Scale and cross-scale dynamics: governance and information in a multilevel world. Ecol Soc 11(2):8

Charbit C (2011) Governance of public policies in decentralized contexts: the multi-level approach. OECD Regional Development Working Papers, 2011/04, OECD Publishing, Paris

Davis LE, North DC (1971) Institutional change and American economic growth. Cambridge University Press, Cambridge

Dietrich O, Steidl J, Pavlik D (2012) The impact of global change on the water balance of large wetlands in the Elbe Lowland. Reg Environ Change 12(4):701–713

Ertel AMA, Lupo A, Scheifhacken N, Bodnarchuk T, Manturova O, Berendonk TU, Petzoldt T (2012) Heavy load and high potential: anthropogenic pressures and their impacts on the water quality along a lowland river (Western Bug, Ukraine). Environ Earth Sci 65(5):1459–1473

Gibson C, Ostrom E, Ahn T-K (2000) The concept of scale and the human dimensions of global change: a survey. Ecol Econ 32:217–239

Global Water Partnership (GWP) (2000) Integrated water resources management. TAC Background Papers, No. 4, Stockholm

Gupta J, Pahl-Wostl C (2013) Global water governance in the context of global and multi-level governance: its need, form, and challenges. Ecol Soc 18(4):53

Guston DH (2001) Boundary organizations in environmental policy and science: an introduction. Sci Technol Hum Values 26(4):399–408

Hagemann N, Leidel M (2014) River basin management in Ukraine. In: Huitema D, Meijerink S, Verduijn S (eds) The politics of river basin organizations. Edward Elgar, Cheltenham, pp 210–233

Hagemann N, Klauer B, Moynihan RM, Leidel M, Scheifhacken N (2014a) The role of institutional and legal constraints on river water quality monitoring in Ukraine. Environ Earth Sci. doi: 10. 1007/s12665-014-3307-5

Hagemann N, Blumensaat F, Tavares Wahren F, Trümper J, Burmeister C, Moynihan R, Scheifhacken N (2014b) The long road to improving the water quality of the Western Bug River (Ukraine)—a multi-scale analysis. J Hydrol. doi: 10.1016/j. jhydrol

Hoff H (2011) Understanding the Nexus. Background paper for the Bonn 2011 conference: the water, energy and food security Nexus. Stockholm Environment Institute, Stockholm

Hooper BP, Mcdonald GT, Mitchell B (1999) Facilitating integrated resource and environmental management: Australian and Canadian perspectives. J Environ Plan Manag 42(5):747–766

Kalbus E, Kalbacher T, Kolditz O, Krüger E, Seegert J, Röstel G, Teutsch G, Borchardt D, Krebs P (2012) Integrated water resources management under different hydrological, climatic and socio-economic conditions. Environ Earth Sci 65(5):1363–1366. doi: 10.1007/s12665-011-1330-3

Krutilla K, Krause R (2011) Transaction costs and environmental policy: an assessment framework and literature review. Int Rev Environ Resour Econ 4(3–4):261–354

Lang DJ, Wiek A, Bergmann M, Stauffacher M, Martens P, Moll P, Swilling M, Thomas MJ (2012) Transdisciplinary research in sustainability science: practice, principles, and challenges. Sust Sci 7:25–43

Leidel M, Niemann S, Hagemann N (2012) Capacity development as key factor for integrated water resources management (IWRM): improving water management in the Western Bug River Basin, Ukraine. Environ Earth Sci. 65(5):1415–1426. doi: 10.1007/s12665-011-1223-5

Leidel M, Seegert J, Niemann S, Stefan C, Mai Phan H, Weigelt C, Grundmann J, Lennartz F, Bernhofer C (2014) Fostering water management through capacity development—lessons from the International Water Research Alliance Saxony (IWAS). In: Hülsmann S, Ardakanian R (eds) Proceedings of the special session "Societal Concerns and Capacity Development" at the symposium of European Freshwater Sciences (SEFS 8). ISBN 978-3-944863-08-5

Lopes C, Theisohn T (2003) Ownership, leadership and transformation. Can we do better for capacity development? Earthscan, London

Medema W, McIntosh BS, Jeffrey BJ (2008) From premise to practice: a critical assessment of integrated water resources management and adaptive management approaches in the water sector. Ecol Soc 13(2):29

Meinzen-Dick R (2007) Beyond panaceas in water institutions. Proc Natl Acad Sci. doi: 10.1073/pnas.0702296104

Mollinga P (2008) The rational organisation of dissent. Boundary concepts, boundary objects and boundary settings in the interdisciplinary study of natural resources management. ZEF Working Paper Series, Center for Development Research, University of Bonn, Bonn

Mollinga P (2010) Boundary work and the complexity of natural resources management. Crop Sci 50:S-1–S-9. doi: 10.2135/ cropsci2009.10.0570

Moss T (2003) Solving problems of 'fit' at the expense of problems of 'interplay'? The spatial reorganisation of water management following the EU Water Framework Directive. In: Breit H, Engels A, Moss T, Troja M (eds) How institutions change. Perspectives on social learning in global and local environmental contexts. Leske Budrich, Opladen, pp 85–121

Moss T, Newig J (2010) Multilevel water governance and problems of scale: setting the stage for a broader debate. Environ Manag 46(1):1–6. doi: 10.1007/s00267-010-9531-1

OECD (2012) Meeting the water reform challenge. In: OECD studies on water. OECD, Washington. doi: 10.1787/9789264170001-en

Pahl-Wostl C (2008) Requirements for adaptive water management. In: Pahl-Wostl C, Kabat P, Möltgen J (eds) Adaptive and integrated water management. Springer, New York, pp 1–22

Pahl-Wostl C, Lebel L, Knieper C, Nikitina E (2012) From applying panaceas to mastering complexity: toward adaptive water governance in river basins. Environ Sci Policy 23:24–34

Pahl-Wostl C, Vörösmarty C, Bhaduri A, Bogardi J, Rockström J, Alcamo J (2013) Towards a sustainable water future: shaping the next decade of global water research. Curr Opin Environ Sust 5:708–714

Pavlik D, Söhl D, Pluntke T, Mykhnovych A, Bernhofer C (2012) Dynamic downscaling of global climate projections for Eastern Europe with a horizontal resolution of 7 km. Environ Earth Sci 65(5):1475–1482. doi: 10.1007/s12665-011-1081-1

Pearson J (2011) LenCD learning package on capacity development. http:// www.lencd.org/learning

Pohl C, Hirsch Hadorn G (2008) Methodological challenges of transdisciplinary research. Nat Sci Soc 16:111–121. doi: 10.1051/nss:2008035

Reed MSA, Evely C, Cundill, G, Fazey I, Glass J, Laing A, Newig J, Parrish B, Prell C, Raymond C, Stringer LC (2010) What is social learning? Ecol Soc 15(4): r1. [online] http://www. ecologyandsociety.org/vol15/iss4/resp1/

Roggero M, Fritsch O (2010) Mind the costs: rescaling and multi-level environmental governance in Venice Lagoon. Environ Manage 46:17–28. doi: 10.1007/s00267-010-9449-7

Roth M, Nobis R, Stetsuik V, Kruhlov I (eds) (2008) Transformation process in the Western Ukraine—concept for sustainable land use. Weissensee Verlag Oekologie, Berlin

Salamé L, van der Zaag P (2010) Enhanced knowledge and education systems for strengthening the capacity of transboundary water management. In: Earle A, Jagerskög A, Ojendaal J (eds) Transboundary water management. London, Washington D.C., pp 171–186

Schanze J, Trümper J, Burmeister C, Pavlik D, Kruhlov I (2012) A methodology for dealing with regional change in integrated water resources management. Environ Earth Sci 65(5): 1405–1414. doi: 10.1007/s12665-011-1311-6

Scheifhacken N, Haase U, Gram-Radu L, Kozovyi R, Berendonk TU (2012) How to assess hydromorphology? A comparison of Ukrainian and German approaches. Environ Earth Sci 65(5): 1483–1499

Sigel K, Hagemann N, Leidel M, Niemann S, Weigelt C (2014) Insights regarding transdisciplinarity and knowledge transfer gained from two case studies on integrated water resources management in Ukraine and Mongolia. Interdiscip Sci Rev 39(4):343–361

Speed R, Li Y, Le Quesne T, Pegram G, Zhiwei Z (2013) Basin water allocation planning. Principles, procedures and approaches for basin allocation planning. UNESCO, Paris

Star SL, Griesemer JR (1989) Institutional ecology, 'Translations' and boundary objects: amateurs and professionals in Berkeley's Museum of Vertebrate Zoology, 1907–39. Soc Stud Sci. 19, Nr. 3. doi: 10.1177/030631289019003001

Helm B, Terekhanova T, Tränckner J (2012) Attributiveness of a mass flow analysis model for integrated water resources assessment under data-scarce conditions. Water Sci Technol. doi: 10.2166/wst.2012.497

Timmerman JG, Beinat E, Termeer CJAM, Cofino WP (2010) A methodology to bridge the water information gap. Water Sci Technol 62(10):2419–2426

Ubels J, Fowler A, Acquaye-Baddoo N-A (eds) (2010) Capacity development in practice. Earthscan, London

UNESCO (2009) IWRM guidelines at river basin level. Part 1 and part 2. 1

van Hofwegen P (2004) Capacity-building for water and irrigation sector management with application in Indonesia. FAO Water Reports 26. FAO, Rome

Vreugdenhil H, Slinger J, Kater E, Thissen W (2010) The influence of scale preferences on the design of a water innovation: a case in Dutch River management. Environ Manag 46(1):29–43. doi: 10. 1007/s00267-010-9524-0

Young OR (2002) The institutional dimensions of environmental change: fit, interplay, and scale (global environmental accords: strategies for sustainability). MIT Press, Cumberland

9 Supporting water resources management through education

Throughout this thesis it has been underscored that capacity development is needed for supporting water resources management. In the following, two examples are demonstrated that show how contemporary capacity development for the individual level, i.e. through education and training activities, can be conducted. First of all, one possibility of e-learning for improving knowhow on IWRM in general is shown, which should complement traditional teaching activities, for example academic education and training activities (Study courses and study programmes at universities, training facilities for water and environmental authorities). E-learning should not substitute classroom teaching activities like lectures and seminars but should in the best case be applied in a blended learning environment, i.e. a combination of e-learning and classroom teaching. Therefore, we developed also a classroom teaching module on IWRM, which was implemented at a Ukrainian university, which is a key university in terms of water resources related academic education.

9.1 IWRM education: e-learning module on Integrated Water Resources Management

The following sub-chapter is a citation of the original published manuscript:

Leidel M, Niemann S, Saliha AH, Cullmann J, Seidel N, Borchardt D, Krebs P, Bernhofer C (2013) IWRM- Education: E-Learning Module on Integrated Water Resources Management. Environ Earth Sci. doi 10.1007/s12665-012-2059-3

9.1.1 Introduction

Integrated Water Resources Management (IWRM) has been generally accepted as the leading concept for a holistic management of water resources that is shaped by balancing the different interests of water users in due consideration of the principle of sustainability. It constitutes the basis for the transition from sectoral water management towards an integrated approach incorporating all necessary issues. Consequently, IWRM can be considered as a societal task that steers the dynamic and diverse interdependencies between the biophysical processes of the water balance and human activities. Among other things, IWRM deals therefore, with various aspects of society like urban and rural planning, vulnerability towards hydrological extremes or the development of technologies for the utilization of water. Hence, natural and engineering scientific factors play the same important role as socioeconomic ones. It has to be acknowledged that IWRM is a conceptual framework that still has to be adapted to the societal and natural requirements of the region concerned (Leidel et al. 2012).

Nevertheless, the concept of IWRM is often criticized because of its vagueness and the challenges while implementing it (i.a. Biswas 2004). One of the key challenges is the lack of capacity, meaning that competencies and knowledge are not sufficient to implement such a complex task as IWRM. Therefore, a prerequisite for sustainable development in water resources management is harmonising processes of IWRM and capacity development (Leidel et al. 2012).

Capacity development (CD) can be understood as the "process through which individuals, organizations and societies obtain, strengthen and maintain the capabilities to set and achieve their own development objectives over time" (UN Development Programm Capacity Development Group 2008). Thereby, it is often distinguished between different levels of CD measures, namely between the individual level (education and training), the institutional level (development of institutions) and the enabling environment, i.e., the improvement of the societal and political system (cf. van Hofwegen 2004; Alaerts 2009). Within this triad, we'll examine the individual level, often referred to as the basis for capacity development, and focus on education and training through an electronic learning module on IWRM.

This is well in accordance with the United Nations Decade of Education for Sustainable Development (DESD 2005–2014) that demands an appropriate education in the field of hydro sciences in order to approach IWRM.

9.1.2 Development, concept and content of the e-learning module on IWRM

One way to support the worldwide implementation of IWRM is to improve respective education. This is why IWAS (Kalbus et al. 2012) and the German IHP/HWRP Secretariat have jointly developed an e-learning module on IWRM that is supposed to complement classical learning options at universities as well as at vocational training facilities. This e-learning module on IWRM is one possibility to emphasize the linkages between natural, social, and engineering sciences in water management and to facilitate the implementation of IWRM (http://www.iwrm-education.de).

According to the state of the art in IWRM, most relevant topics have been chosen to fit in a comprehensive representation of current water issues (Table 20). Academics from various universities and research institutions, as well as practitioners have been selected in order to videotape their lecture.

To facilitate access to the e-learning module, a thematic introduction to IWRM and a user guide showing the functionalities of the module are provided. It is possible to access and navigate through the electronically available lectures via keywords, text search function and categories (thematic areas). Furthermore, all lectures within such a thematic area are sorted in a didactical order, beginning with basic lectures and becoming gradually more advanced.

To account for the complexity of IWRM, the current 39 lectures are structured in several thematic areas. Those thematic areas assure a coherent and intuitive access to the field of IWRM (Figure 30).

Table 20: Current topics covered in the IWRM e-learning module

Lecturer	Topic
Adane Abebe	Copula modelling of hydrological drought using proxy data
Juliane Albrecht	Water law
Seleshi B. Awulachew	Soil erosion and sediment transport
Tenalem Ayenew	Occurrence of groundwater, characterization of aquifers; groundwater flow modelling
Klaus-Dieter Balke	Surface water and ground water relations; water balance
Thomas U. Berendonk	Freshwater biology and quality—an introduction and case study
Christian Bernhofer	Impacts of climate change on IWRM
Anik Bhaduri	Political altruism of water sharing; climate change and cooperation in transboundary water sharing
Janos Bogardi	Vulnerability: a new concept in IWRM
Dietrich Borchardt	Introduction to Integrated Water Resources Management; EU Water Framework Directive
Johannes Cullmann	Introduction to hydrological extremes
Andriy Demydenko	Implementation of IWRM in post-soviet countries
Ines Dombrowsky	Economic analysis of transboundary cooperation problems
Olivier Graefe, U. Meyer	Gender issues in Integrated Water Resource Management
Walter Huppert	Water governance
Asie Kemal Jabir	Groundwater contamination
Peter Krebs	Urban water management
Paul Lehmann	The economics of water pricing
Marco Leidel, S. Niemann	Capacity development in Integrated Water Resources Management
Franz Lennartz	Fundamentals of hydrology
Stefan Liehr, J. Röhrig	Modelling and instruments for decision support
Philipp Magiera	Implementing the IWRM principles in development cooperation
Ursula Mayer, O. Graefe	Gender issues in Integrated Water Resource Management
Timothy Moss	Institutionalising river basin management: challenges of space, sector and scale
Roland Müller	Decentralised wastewater treatment systems
Jan-Peter Mund	GIS and hydrology
Jens Newig	Participation
Steffen Niemann, M. Leidel	Capacity development in Integrated Water Resources Management
Manfred Ostrowski	Adaptive sustainable management of reservoir systems
Georg Petersen	Soil and water conservation practices; flood protection measures
Julia Röhrig, S. Liehr	Modelling and instruments for decision support
Alemayehu Habte Saliha	Introduction to sediment management; hydrological modeling concepts and practice

Jochen Schanze	Development of river basins; from complex systems to integrated management
Waltina Scheumann	Cooperation on transboundary aquifers/ground water
Daniel Tsegai	Interaction of economic and hydrologic models for optimal water allocation

The thematic area "water and the physical environment" depicts primarily the natural science aspects of the water-related man-environmental systems, thus the components and processes within the hydrologic cycle and resulting management options. It includes different methods to quantify water balance, soil erosion, sediment and contaminant transport. Issues are covered that are related to groundwater quantity and quality, surface water quality, climate change and hydrological extremes.

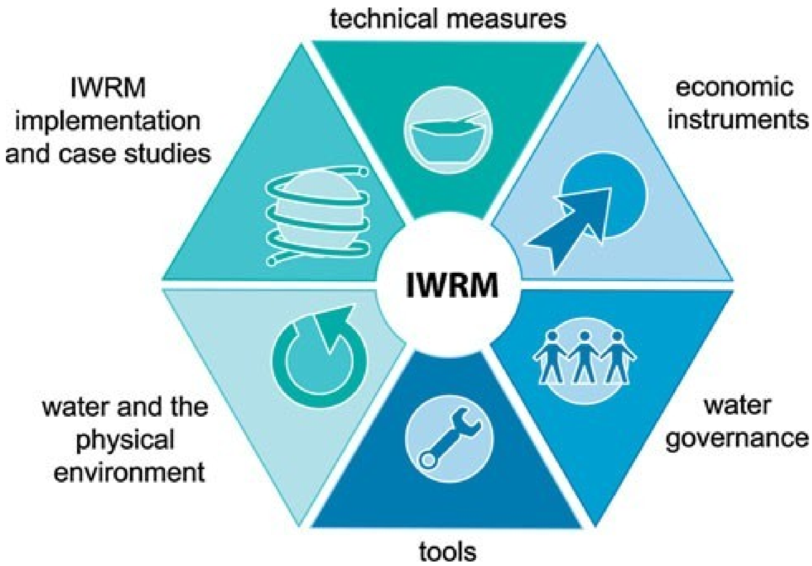


Figure 30: Thematic areas of the e-learning module on IWRM

The next thematic area deals with tools for understanding the natural and societal systems that facilitate decision-making processes. A wide range of tools and methods are shown, e.g. modelling, model coupling, geographic information systems (GIS) and consequently their usage within decision-support-systems (DSS). The cluster further addresses issues related to vulnerability and uncertainty in decision making, e.g. showing tools like scenario planning.

Another subject area comprises the important aspects of water governance. Issues of governance reveal to be of utmost importance for sustainable water resources management. Following an introduction into the topic of water governance, fundamentals in water law, gender issues, options for participation as well as prevailing spatial and sectoral challenges in river basin management get addressed. Particular emphasis is given to capacity development.

Holistic water management needs also economic instruments. Hence, in this section, economic instruments that regulate the water demand and their interaction with hydrologic models are explained and illustrated. Further- more, economic problems in multilateral cooperation on shared watercourses (transboundary water management) as well as the issue of water pricing are successively explained.

The technological aspects that are important for IWRM are shown in the thematic area “technical measures”. It covers issues from urban water management (centralized and decentralized wastewater treatment), as well as the important issues of reservoir management. Furthermore, flood protection measures as an integral part of flood management are shown.

Lastly, one thematic area deals with IWRM implementation and case studies, because the implementation of IWRM is still in its infancy. Case studies from different hydrologically sensitive regions of the world are shown in order to discuss challenges that often occur when one tries to practically implement IWRM. Topics include such important issues like transboundary water management as well as the implementation of IWRM in Europe and in the development cooperation.

9.1.3 Linking topics ensures intuitive access to the integrated information

Since IWRM is complex and as interdisciplinarity is often missing in water management, it is important to facilitate the access to the information in order to make it comprehensible for the users of the e-learning module. Therefore, the module interlinks lectures, i.e. thematic correlations are illustrated (e.g. climate change) and appear as linkages (hyperlinks) between the lectures, allowing the user to switch and navigate from one lecture to another one. The hyperlinks are temporally referenced and thus appear in a semantic manner, meaning that the linkage appears when the lecturer describes this issue. Those so called hypervideos (video stream with embedded hyperlinks) are helpful, since none of the lecturers can cover all issues in IWRM. There will be always interfaces to other topics and those interfaces need to be identified and made available. The additional value of this e-learning concept is that the complexity of IWRM can be better conveyed to persons interested in this topic. Here again, the special hyperlink feature makes clearly visible the linkages between the different sciences (natural sciences, social sciences, engineering sciences) in water management.

There are two interactive hyperlink types within the e-lectures. One type links to definitions or explanations in another lecture and has loop back functions, so that the user can go back to the original content he was watching before. Figure 31 shows as an example the lecture by Dr. Moss dealing with institutionalizing river basin management. Here, a hyperlink pops up that links to another lecture that explicitly deals with the basics of river basin management. In the referred content, the ever visible "return to" hyperlinks cue the user on their location within the lectures and aid navigation. The second type of hyperlinks serves to quickly navigate to the start of a complete lecture or a specific topic. All links are integrated in the timeline and identifiable by mouseover events. Links to related lectures are shown at the end of the hypervideos.

Figure 31: Hyperlink with a loop-back function encircled in red

9.1.4 Software development and dissemination

The technical realization of this module has been facilitated by a player that is set up for interactive videos such as the collection of IWRM hypervideos. The authoring tasks comprise mainly the annotation of spatio-temporal hyper- links and the temporal arrangement of slides and further contents. Both components are designed and developed as web applications to enable system independent usage and maintenance.

Target groups of the e-learning module are graduating students in water-related fields, decision-makers, water experts and administrative staff primarily in developing and transition countries. The module is available in the World Wide Web (http://www.iwrm-education.de) as well as on USB flash drives.

9.1.5 Summary and outlook

The e-learning module on IWRM is an attempt to pursue and follow the full complexity of IWRM by linking interactively different aspects of water management. In this respect, the module is a cutting edge approach in its presented contents as well as in its technical realization.

Similarly to the process of IWRM, the development of this module is an adaptive and iterative process, meaning that the development of this module has not been finished. Further lectures and hyperlinks will be integrated and existing lectures and hyperlinks will be subject to a continuous improvement process. A further planned step in this respect is the evaluation of the utilization of the lectures and hyperlinks within the module and the integration of further authoring components in the video content management system.

In order to be in accordance with the contextuality of IWRM, context specific regional adaptations of this IWRM e-Learning module will be realized.

9.1.6 References

Alaerts GJ (2009) Knowledge and capacity development (KCD) as tool for institutional strengthening and change. In: Alaerts GJ, Dickinson N (eds) Water for a changing world—developing local knowledge and capacity, Delft

Biswas AK (2004) Integrated Water Resources Management: a reassessment. A water forum contribution. Water Int 29(2):248–256

Kalbus E, Kalbacher T, Kolditz O, Krüger E, Seegert J, Teutsch G, Krebs P, Borchardt D (2012) IWAS—Integrated Water Resources Management under different hydrological, climatic and socio-economic conditions, IWAS SI editorial. Environ Earth Sci 65(5):1363–1366. doi:10.1007/s12665-011

Leidel M, Niemann S, Hagemann N (2012) Capacity development as key factor for Integrated Water Resources Management (IWRM): improving water management in the Western Bug River Basin, Ukraine. Environ Earth Sci 65(5):1415–1426. doi: 10.1007/s12665-011-1223-5

UN Development Programm Capacity Development Group (2008) Capacity development practice note

Van Hofwegen P (2004) Capacity-building for water and irrigation sector management with application in Indonesia. FAO water reports 26. FAO, Rome

9.2 Evaluation of IWRM education

The e-learning module on IWRM was used on several occasions, e.g. two times for IWRM summerschools, for supporting learning within an IWRM course in Ukraine (chapter 9.3) as well as for supporting the IWRM module offered for the water related M.Sc. programmes at TU Dresden since 2012. In order to improve the e-learning module, there was always an evaluation conducted with the participants whether the module was a good support for their learning success.

9.2.1 Concept of the evaluation

The most comprehensive evaluation was done during the IWRM module at TU Dresden in the summer term 2015. The concept for the evaluation was that the students should get acquainted with IWRM-education and then they should choose one lecture, which they have to study in-depth. After that, the participants will get an exam for testing their knowledge. The final step was an evaluation of the e-learning module by the students. Therefore, a questionnaire was prepared with 16 overall questions and several subquestions that were grouped into (i) content, (ii) structure layout components, (iii) general issues (Questionnaire in the doctoral thesis database). The idea behind the concept is that it is assumed that the evaluation is more realistic, if the students have *really* studied at least one complete lecture within IWRM-education. And the test also checks whether the students understood the content of the lectures. The whole evaluation, including choosing of lectures and the examinations, were implemented within the learning management system of the TU Dresden named Opal. For assuring that not only one lecture was chosen by the students, it was arranged in Opal that a maximum of two students can choose the same lecture. Since this evaluation was on a voluntary basis, it was highlighted that the participation is a good preparation for the final exam of the whole IWRM course, but as additional incentive, it was offered that the best 10% of the test results will get a voucher (Amazon, 15€). Eventually, all students (28) took part in the evaluation, and 11 did the test (39%). Table 21 shows the chosen lectures and the results of the test. The results show that the majority of the students have understood the contents of the lectures, since only 2 out of 11 are below 50% and 6 are above 75%.

Chosen lectures	Points reached	Points max.	Percentage
Adaptive sustainable management of reservoir systems	10,0	10,0	100,0
Flood protection measures	7,0	8,0	87,5
Freshwater biology	7,0	9,0	77,8
Freshwater biology	7,0	9,0	77,8
Impacts of Climate Change on IWRM	4,5	9,0	50,0
Surface and groundwater relations	8,5	10,0	85,0
Surface and groundwater relations	4,5	10,0	45,0
Urban Water Management	3,0	10,0	30,0
Water governance	5,0	5,0	100,0
Water Pricing	3,5	7,0	50,0

Water Pricing	5,0	7,0	71,4

Table 21: Test results within the evaluation of IWRM-education

9.2.2 Results of the evaluation

The anonymized evaluation (questionnaire) was handed out during one of the lectures of the IWRM module. Table 22 shows that participants originate from several regions of the world, with the majority from Europe. Almost 90% of the students are below thirty years, so they belong to the generation of "digital natives" i.e. that on the one hand side they are capable of using ICT, but on the other hand also require a learning environment that uses more media than traditional teaching methods did.

Region	Percentage	Age	Percentage	Gender	Percentage
Africa	4%	20-25	57%	Female	39%
Asia	14%	26-30	32%	Male	57%
Australia	0%	31-35	7%	No answer	4%
North America	4%	36-40	0%		
South America	11%	>40	0%		
Europe	64%	No answer	4%		
No answer	4%				

Table 22: General facts about participants

In terms of content, it can be concluded that the participants consider the lectures and its structure as appropriate, and that the lecturers are competent enough to clarify complicated facts (Figure 32). 36% consider the statement that integration of practical tutorials/ training sessions e.g. on software like GIS or modeling software would have been helpful as completely correct and 21% as mainly correct. Moreover, a learning management system that transfers knowledge about river basin management in general (basics like in this e-learning module) as well as information and data on a concrete river basin as a case study for future water managers is considered as very important by 25%, and important by 61%.

In terms of structure and layout, the participants appreciated the format and also the design was appealing for many (Figure 33). For 18 %, the navigation through the module is completely intuitive and self explaining and for additional 54% it is mainly intuitive. In overall, the hyperlinks are helpful for understanding was stated by 29 % (completely correct) and 43 % (mainly correct). The hyperlinks with the loop-back function are particularly helpful was stated by 36% (completely), 39% (mainly) and 11% (partly). All hyperlinks should have a loop-back function was mentioned by 21% (completely), 21% (mainly) and 29% (partly). This implies that a potential technical improvement is to equip all hyperlinks with a loop-back function. One part of the questionnaire was related to additional components that improve the performance of the e-learning module and thus the learning (Table 23). Exercises with solutions (93% completely and mainly) and self-assessments (86% completely and mainly) would be highly important. Downloading parts (75% completely and mainly) and the combination with a water information system (71% completely and mainly) are also appreciated. A Discussion forum is less important (61% completely and mainly), as well as establishing a wiki (57% completely and mainly). A version for the mobile phone is considered as unnecessary (28% completely and mainly).

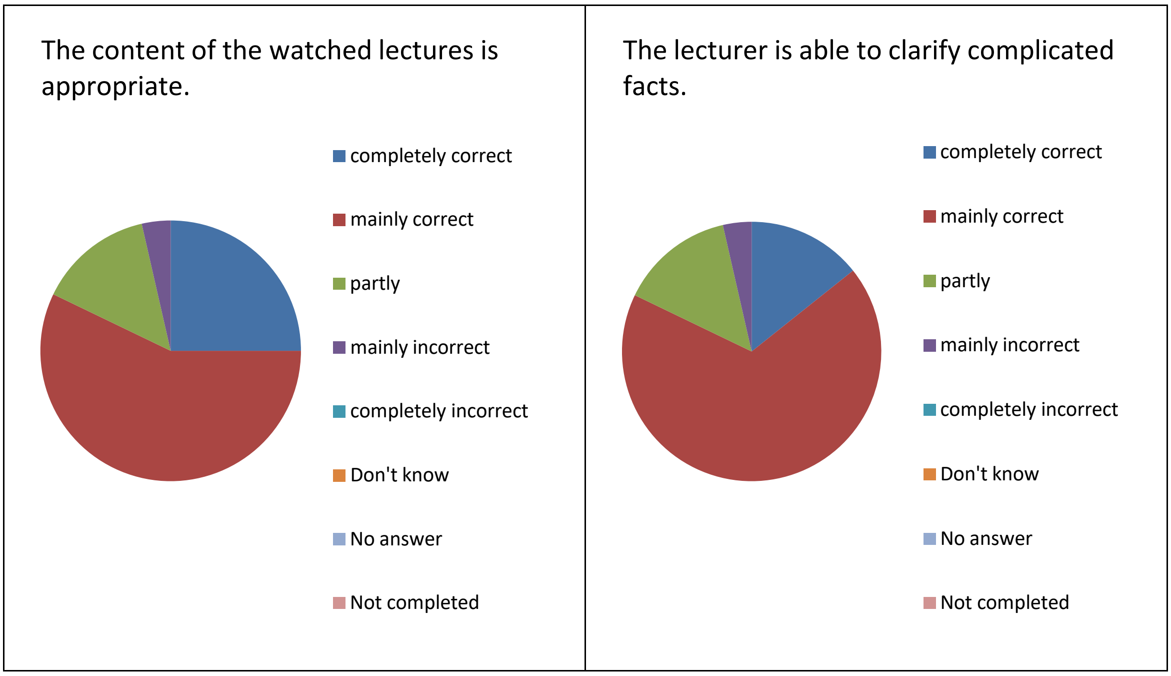


Figure 32: Selected evaluation results for the content

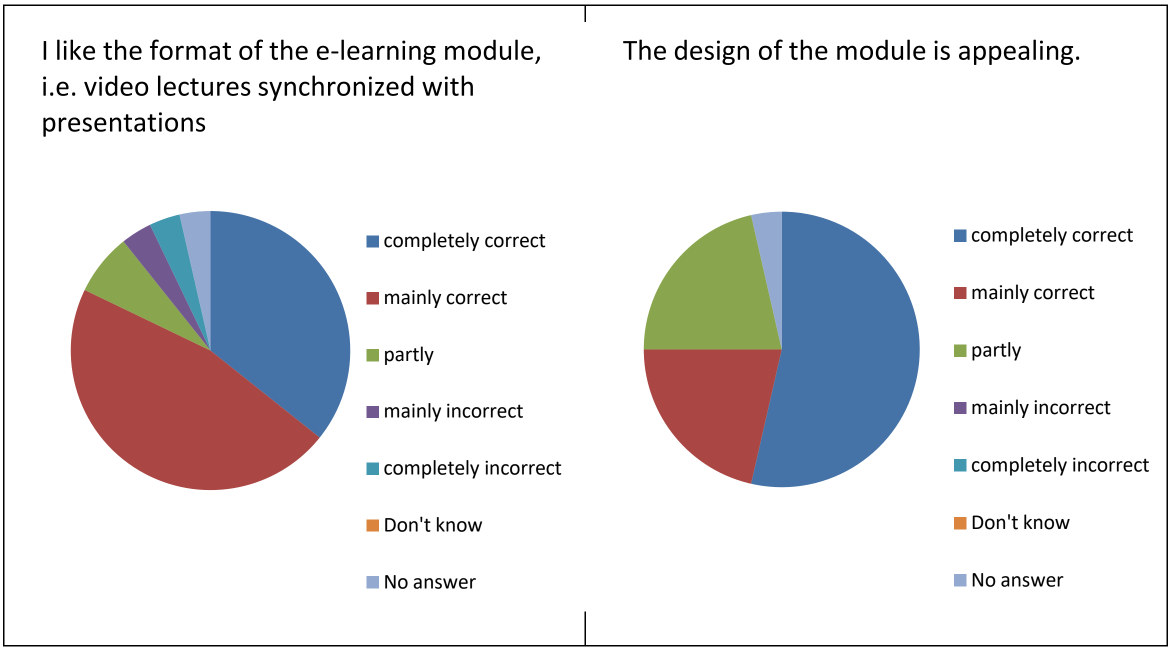


Figure 33: Selected evaluation results for the structure

	Discussion Forum	Download parts of the module	Version for mobile phone	Wiki	Exercises with solutions	Self-assessment	Combining with Water Info. System
completely correct	11%	21%	14%	21%	64%	36%	32%
mainly correct	50%	54%	14%	36%	29%	50%	39%
partly	21%	11%	18%	25%	4%	7%	14%
mainly incorrect	11%	11%	32%	0%	0%	4%	4%
completely incorrect	0%	0%	7%	0%	0%	0%	0%
Don't know	0%	0%	0%	0%	0%	0%	0%
No answer	7%	4%	14%	18%	4%	4%	11%

Table 23: Potential components for improvement

In general, the participants liked this way of learning as additional information on IWRM (completely 25%, mainly 57%). Similarly, they will use this module to support their further academic activities (completely 18%, mainly 46%, partly 29%). In terms of overall grade for the e-learning module, 29% give a *very good* and 54% a *good* (Figure 34).

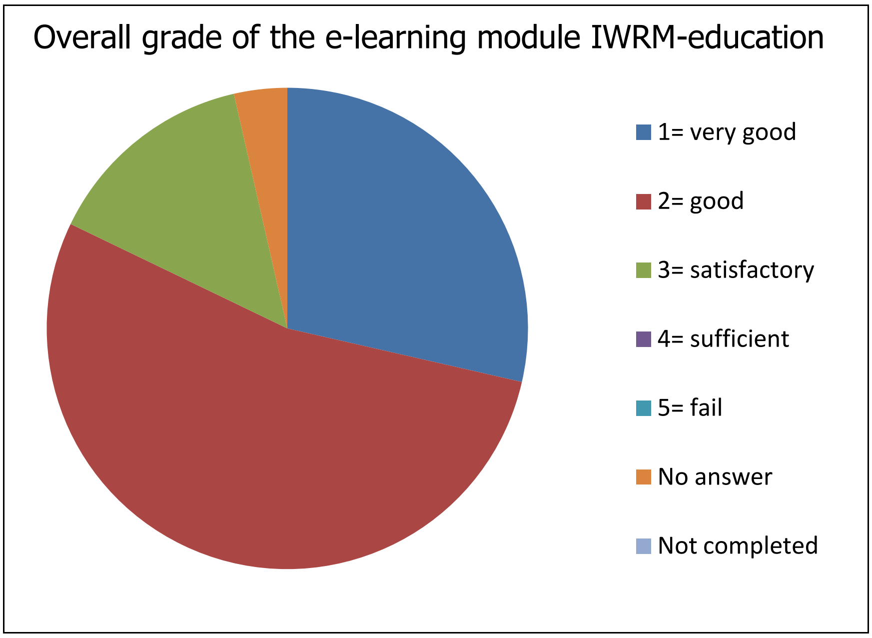


Figure 34: Overall grade of IWRM-education

The population (amount of all potential objects for analysing a certain question) of the e-learning module is difficult to define, since it can be accessed worldwide in the internet without any registration. Accordingly, no random sampling is possible so that the sample was taken from the IWRM course at TU Dresden. Thus, it is questionable whether this evaluation is an average sample and consequently whether it is possible to do an induction, i.e. to reason from the sample to the population. On the other hand, the sample from TU Dresden represents quite well the target group of the e-learning module, namely postgraduate students from water-related programmes and thus (future) water experts from several regions of the world. So, it can be concluded that results from this evaluation can be used and are valuable for improving IWRM-education.

9.3 IWRM teaching module for Ukrainian Universities

Even if IWRM is considered to be the basis for improving water resources management, the worldwide implementation and its scientific operationalization is still not very advanced. This holds also true for Ukraine as discussed in chapter 6.2.2 on the capacity assessment for the academic education in the Ukrainian water sector. The education in the field of water sciences is largely focusing on natural sciences and engineering sciences, i.e. no interdisciplinary courses on IWRM are available at Ukrainian universities (Demydenko and Leidel 2010).

Thus, IWRM and RBM need to be integrated in curricula of universities in Ukraine, so that future decision makers in the field of water resources management can be reached. Accordingly, the IWAS project developed together with the NUWMNRU Rivne, PNU Lviv and IFNU L'viv a postgraduate module on IWRM. The first one was integrated because of the important role within the Ukrainian academic water education, and the latter two because of their local knowledge and their important role within the catchment of the Western Bug River. However, the course is developed in such a way that it can be adapted to other Ukrainian universities based on an assessment showing the existing IWRM capacities.

9.3.1 Objectives and basic concept

The IWRM module is addressing study courses in the field of hydro sciences and related academic fields like physical geography. The objective is to transfer the concept of IWRM and the correlations between the single subtasks of water management. The module follows an "Umbrella-concept", i.e. it shows the full range of IWRM related topics and focuses on the horizontal relations of IWRM (Figure 35). Consequently single subjects can be taught in depth only to a certain extent. And the expertise within those single subjects is often already available at the participating universities. Besides the scientific aspects, also the practical implications for water management in the Ukraine are demonstrated.

The basis for this module is the long-lasting experience of the Department of hydrosciences of the TU Dresden (TUD), as well as the e-learning module IWRM-education, which was jointly developed by IWAS and the German secretariat of UNESCO-IHP and

WMO-HWRP (chapter 9.1). The adaptation to the Ukrainian context was done in close collaboration with Ukrainian experts.

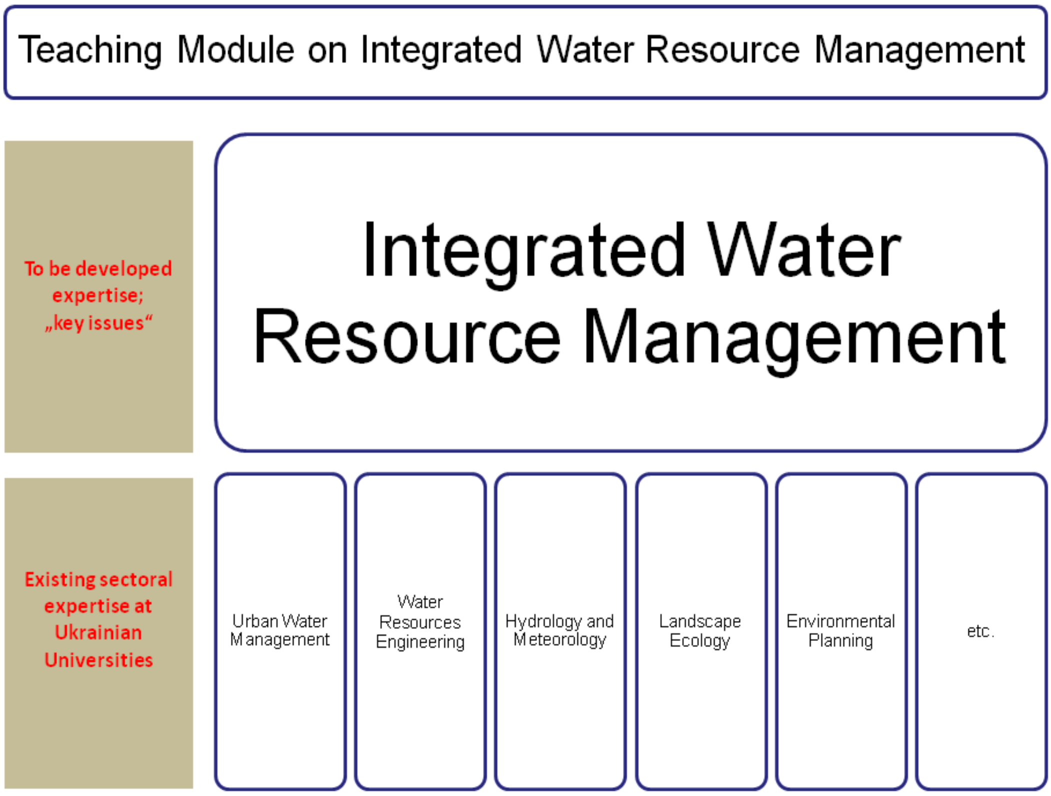


Figure 35: Structure of the IWRM teaching module

Requirements for the participation were a sufficient natural scientific and engineering background for understanding the advanced contents of the module. Additionally, sufficient English skills for the communication with the instructors and for reading international literature are essential.

9.3.2 Structure and content

At the beginning, an introduction to IWRM is given and subsequently the individual lectures to the chosen topics are presented. The content of the lectures was selected and presented in such a way that the connections to the overarching IWRM topic can be conveyed to the participants, thus displaying an interdisciplinary teaching module. To complement the lectures, also tutorials were given for consolidation of knowledge and for learning of practical methods.

Central contents of the module are the emergent overall tasks of IWRM, as well as essential subtasks. Emergent topics are especially (i) the legislative and institutional frame of management and other governance issues, (ii) holistic, intersectoral and cross-territorial management tasks as for instance within man-environment systems on the level of river basins, (iii) cooperation and collaboration in such systems and the integration of relevant actors, (iv) multi criteria analyis of the sustainability of initial conditions and developed measures (e.g. Analytical Hierachy Process), and (v) estimating future development by scenario development for global and regional change.

The individual lectures deal with the water balance and its relation to societal needs and water uses. The lectures range from climate change and climate variability to water and matter fluxes as well as specific water demands, e.g. within urban water management. In addition, also hydrological extremes (floods and droughts) and its socio-economic and environmental vulnerabilities are explained. As far as possible, all lectures integrate current scientifc and practical challenges of water management, e.g. climate or societal change, and the consequences for their particular subject, for the overall IWRM and for the implementation of IWRM tasks. This incorporates also potential conflicts as well as problem solving strategies for integrated river basin management, as for instance transboundary water management. The modular structure with IWRM as the *leitmotif* (common thread) and the detailled description of the individual lectures can be found in Annex A.2. This structure cannot be overestimated, since IWRM is a complex topic so that it is essential for the understanding of the participants to have a common thread. Without, it would be merely a incoherent series of lectures.

9.3.3 Development of the IWRM teaching module

The development and adaptation to the Ukrainian context and towards the previous knowledge of the participants was coordinated with professors from PNU Lviv, IFNU Lviv, and NUWMNRU Rivne, especially with Prof. Hirol. The complete process form the first ideas to the first implementation took circa 1.5 years (Table 24). Concurrently, also an IWRM module was developed at TU Dresden for the M.Sc. study courses in the department of hydrosciences, which started in summer term 2012 and is offered since then each summer term. Furthermore, an e-learning module was jointly developed with German secretariat of UNESCO-IHE (chapter 9.1). The experiences from the development of both modules were used for the development of the module in Ukraine and vice versa.

Especially important was to start an accompanying continuous process for generating trust and for the affirmation of good cooperation. Hereby, one essential aspect is to respect important items from the partner universities. For instance, the NUWMNRU is organizing a biannual conference for young scientist and doctoral candidates, which is a very important event for the NUWMNRU. We were co-convener of the conference and were present on the conferences in the year 2010[83] with five students and PhD candidates from TU Dresden, and 2012[84] with three students and PhD candidates. However, we also raised issues that are important for us, e.g. it was a long way until it was accepted that English is accepted as third conference language (2010), respectively that English will become the only conference language (2012). We could convince the organizers that a broader participation of universities from EU is only possible, if the conference is in English- and it is also important for Ukrainian and Belarusian students to train their English language skills for getting closer to the European research area. Prof. Hirol could enforce this, however with a considerable amount of resistance, meaning that he and his department had to organize the conference on their own with little support from other departments.

Being co-convener and showing presence on the conferences as well as joint measuring campaigns at the Western Bug River and joint additional research projects was important for trust building between the scientists and thus between the universities, and it was especially important as a support for our partners at the NUWMNRU to convince the rectorial board of the NUWMNRU that the collaboration with the German partners is worthwhile. Because there have been professors that opposed a collaboration with Western European universities.

Within the development of the teaching module, one essential point was raised by Prof. Hirol, who mentioned that it is important that not only legal aspects of water management are taught. But since Rivne is a university with focus on technical issues he mentioned that the combination between technical aspects and legal and institutional aspects are important. He had experiences with a Dutch project, where only legal aspects were considered and thus the students could not follow the content completely and also the faculty was reluctant because of this partial representation, so that the course was not adopted at the university. Moreover, it was the objective to develop a course that is relevant for future water managers in Ukraine, therefore, the deliberations about the contents were executed by German and Ukrainian scientists and water experts as well as a person (Dr. O. Kovalchuk) who is working part-time as a lecturer at Lviv Polytechnic National University (PNU Lviv) as well as being the head of monitoring department of the Department of Environment and Natural Resources of Lviv Regional State Administration.

---

[83] International scientific conference of young scientists and post-graduate students "Water management - state and prospect of development". April, 14-17, 2010.
[84] International Scientific Conference of Young Scientists and Students: "Innovative Technologies in Water Management Complex". April, 23-25, 2012.

This mixture of actors assured that state-of-the-art knowledge on water resources management is adapted to the Ukrainian context and towards the previous knowledge of the participants, which reflects the spirit of transdisciplinarity. In order to integrate as many actors as necessary, the documents about the module objectives, description of contents, scope, schedule and realization were translated into Ukrainian, respectively Russian language.

Accordingly, the final agreement was to cover natural scientific, engineering and technical aspects as well as socio-economic and institutional aspects within an “umbrella course”, highlighting the interaction between the single disciplines and sectors of water management (Figure 35).

9.3.4 First realization of the IWRM teaching module

The first realization took place in September 2011 (26/09-30/09/2011). Participants were students from third and fourth year of studies, doctoral candidates and post-docs ((NUWMNRU, Faculty of Water Resources), as well as students from the Lviv Polytechnic National University, study course Ecology and Environmental Protection (25 participants in total).

Figure 36: Implementation of IWRM teaching module at NUWMNRU Rivne

Ten instructors were doing the lecturing, whereas most of them came from TU Dresden and Leibniz Institute of Ecological Urban and Regional Development. One e-lecture on governance held by a German senior water management and development cooperation consultant (Dr. Huppert) was also shown. This lecture was taken from the e-learning module IWRM-education (qv. Chapter 9.1). In fact, the e-learning module was provided on USB flash drives for the library of the NUWMNRU so that the participants can use it as additional learning resources. The implementation of IWRM in post-soviet countries was elaborated by a senior water resources specialist from GWP Ukraine. Apart from lectures, also practical field work on hydromorphology, as well as a water balance modeling exercise (with the WEAP software) was integrated in the module. Moreover, the participants could take part in a session of an external workshop that was organized by the IWAS project, the German Water Partnership and Ukrvodokanalekologia, which was mainly dealing with problems of urban water management.

The detailed description of lectures, responsible lecturers and the workflow can be seen in the doctoral thesis database. The course was launched as an optional 3 ECTS course, and certificates as well as a documentation of all lectures and additional materials were provided.

9.3.5 Results of the first realization

9.3.5.1 Feedback of students

A round table discussion at the end of the realization of the module was used for getting feedback from the participants, separated in a feedback on the overall course and subsequently on the single lectures and tutorials. The feedback on the single lectures within the IWRM module can be found in the doctoral thesis database.

The overall evaluation was very positive. The participants mentioned that the combination of theoretical issues with tutorials and excursions was supportive for the learning success. Moreover, getting in contact with new information and new ways of studying (e.g. good presentation skills; discussions within lectures) was brought up positively. And to become acquainted with the "German" way of thinking and approaching issues was also appreciated. Additionally, they put forward that the block course format is reasonable, since the participants can focus on the IWRM issue with no further lectures.

The participants' main critique was that too much information was delivered in too less time, and that the content has to be adapted even stronger to the target group. This could maximize the learning success. On the other hand, they mentioned that some important parts were missing, e.g. groundwater, hydropower, efficient water use, or quite specific the heating up of rivers from nuclear power plants.

Despite the relatively good English language skills, some terms and meanings were not understood, especially new technical and law terms.

And the participants also suggested focusing in future module implementations more on the comparison between German/ European and Ukrainian approaches of water resources management.

9.3.5.2 Feedback of lecturers

All lectures took part in the feedback and in general, the lectures had a good impression of the realization of the module and their individual lecture. Yet, several lecturers mentioned that it would have been desirable, if the existing knowledge from the participants would have been available beforehand, so that the particular lectures could have been better adapted to the participants. But it has to be emphasized that many lecturers have a priori assessed the existing knowledge correctly. This can be seen by the positive feedback from the students as well as intensive discussions and questions related to the presented topics. Furthermore, the connection between the individual lectures could be even more interrelated to each other. And the scope of the tutorials should be reduced, respectively more time and/ or more supervisors should be allocated. The supervisor of the hydromorphological tutorial proposed to separate the tutorial in a theoretical part and a practical part, so that the practical part can be fully used for the evaluation of the status of the water bodies and the floodplains. Additionally, it was stated that it would be an added value for the participants to compare international research results with current research conditions in Ukraine. Last but not least, one lecturer mentioned the need to incorporate more legal and institutional aspects, since respective teaching is not enough at the Ukrainian universities.

9.3.5.3 Feedback of NUWMNRU Rivne

The feedback from the NUWMNRU Rivne was generally positive. Especially the rectorial board with Prof. Sapsay (Vice-rector for research, education and inter-national relations Prof. Hirol (Vice-rector for research) and Prof. Turchenyuk, Dean of Faculty of Water Resources was convinced that a partnership between NUWMNRU Rivne and TUD, respectively IWAS is worthwhile.

Of vital importance for the NUWMNRU Rivne is a cooperation agreement between both universities as a basis of collaboration. It was agreed that the IWRM module should be integrated into curricula of master courses of the faculty, namely (I) water management and natural building, (ii) hydrotechnics, and (iii) rational use and protection of water resources. Moreover, it was agreed that a gradual transfer of the module to NUWMNRU, under auspices of Faculty of Water Resources and a twinning between chairs of NUWMNRU and TUD is essential for the assuring a long-term perspective of the IWRM module. In order to facilitate the access of NUWMNRU's staff to the module, learning materials will be provided in Ukrainian language. And Prof. Turchenyuk proposed to offer a technical English class as prerequisite for IWRM module in the 4th study year.

The meeting of the faculty board of the faculty of water resources together with IWAS members was fruitful in terms of further development of IWRM module, and the discussion on thematic partnerships (twinning of chairs). It was decided that a 2nd realization of the IWRM module should be executed in the next year (2012). However some members of the board were not fully convinced that an IWRM module is needed respectively did not see the added value of collaboration with German universities. The impression was that this is due to the language barriers and due to a perceived danger of losing control over their subjects by external encroachment. This impression was corroborated by discussions with (younger) PhDs and PhD candidates.

9.3.6 Overall assessment and further development

The feedback from participants, the students as well as from the Faculty of Water Resources from NUWMNRU was positive, so that the first realization of the IWRM teaching module can be considered as success. Yet, the feedback brought up new insights, which need to be integrated in future realizations. E.g. to tackle language difficulties, it is proposed to provide keywords before the lecture starts, or to provide technical English classes before the module proceeds. Based on the feedback, minor optimization of the lectures can be implemented, i.e. fitting the classes better to the perceptions and needs of the participants and to the perceptions of the faculty of water resources from NUWMNRU.

The "umbrella-concept", i.e. that IWRM and the correlations between the single subtasks of water management is shown, can be considered as a feasible way of strengthening the sectoral academic education at Ukrainian universities. It should be aspired to integrate such IWRM teaching modules at more Ukrainian universities in the field of hydro sciences. It has to be assured that the individual classes are following IWRM as the common thread, so that the risk of reducing the module to a mere series of lectures is mitigated. The module has also potential to be adapted to the education at other universities, also in Germany. Experiences from the first realization have been used for the development of the IWRM module at the Department of Hydrosciences at TUD and vice versa.

Date	Place	Main topics	Participants
22/04/2009	Rivne	• Meeting with members of the rectorial board and with the Dean of Faculty of Water Resources for discussing the potential of having a cooperation between TUD and NUWMNRU - academic relations to NUWMNRU - Student exchange and acceptance of course achievements - Clarifying potential to jointly develop teaching module in the realm of IWRM - Clarifying interest for joint measuring campaigns	- Prof. Hirol, vice-rector for research of NUWMNRU; at that time also Dean of Faculty of Water Resources - Prof. Sapsay, vice-rector for research, education a. international relations of NUWMNRU - Mr. Leidel (TUD) - Ms. Weigelt (DREBERIS)
15/4/2010	Rivne	• Basic issues about a joint IWRM module: - English as language difficult, but the only feasible option; documentation in English and Ukrainian language - combination of technical and legal aspects of water management - Optional course with implementation expected in 02/2011, then assessing how to integrate it in the curriculum of water management study courses - 1st proposal based on the outcomes of this meeting - According to proposal it is evaluated, which Ukrainian scientist fit to the single topics - Contract between TUD and NUWMNRU for module development necessary, especially as support for Prof. Hirol and his faculty - Advertising campaign for IWRM course 8 weeks before implementation	- Prof. Hirol - Mr. Leidel
16/11-19/11/2010	Kiev	• International Conference GLOBAL AND REGIONAL CLIMATE CHANGES - Presentation on Education as a key for IWRM and adaptation to climate change	- Dr. Demydenko (GWP Ukraine; water expert) - Mr. Leidel
17/12/2010	Dresden	• Discussion on current state of education: - PNU Lviv - NUWMNRU Rivne - IFNU Lviv - TU Dresden • Needed IWRM topics based on 1st proposal and new insights • Target groups • Agreeing on umbrella course	- Prof. Hirol - Prof. Kruglov (IFNU Lviv) - Prof. Schanze (TUD) - Dr. O. Kovalchuk (PNU Lviv) - Dr. Petzoldt (TUD) - Dr. Baskyr (UFZ) - M.Sc. Leidel
02/2011	Kiev	• Interviews with educational actors and water experts concerning the state of the academic water education in Ukraine - Evaluating possibilities for further IWRM related courses in Ukraine, especially an introductory course on IWRM at the National University of "Kyiv-Mohyla Academy" • Evaluating possibilities for adaptation of e-learning module IWRM-education to Ukrainian context	- Ms. Maslyukivska, Senior Lecturer, Department of Environmental Studies, National University of "Kyiv-Mohyla Academy" - Dr. Demydenko - Mr. Leidel

02/05- 05/05/2011	Dres- den	• Shooting of the lecture "Implementation of IWRM in post-soviet countries" for the e-learning module IWRM-education • Discussion on integrating this lecture in the IWRM teaching module at NUWMNRU	- Dr. Demydenko - Mr. Leidel
29/06/2011	Dres- den	• Drafting of an IWRM module at TU Dresden - Discussion on different definitions of IWRM - Elaboration of relevant contents - Integration of natural scientific, engineering, socio-economic and institutional aspects - Importance of showing interdependencies - Delineation of new module to already existing modules - Development of a concept with the single lectures and trainings for the module	- Prof. Krebs (TUD) - Prof. Bernhofer (TUD) - Prof. Liedl (TUD) - Dr. Lennartz (TUD) - Jörg Seegert (TUD) - Andy Philipp (TUD) - Marco Leidel (TUD) - External experts: - Dr. Klauer (Expert for economics of water resources; UFZ) - Dr. Huppert (retired expert for water governance, formerly working with FAO, World Bank, IWMI, GTZ)
26/09- 30/09/2011	Rivne	• 1st implementation of the IWRM teaching module	- See Annex A.2
30/09/2011	Rivne	• Meeting with members of the rectorial board of NUWMNRU and Faculty of Water Resources for further collaboration between TUD and NUWMNRU - Basic points of collaboration (student, scientist exchange, etc.) - Discussion on cooperation agreement - Further development of IWRM module - Integration of IWRM module into curricula of master courses of the faculty: *water management and natural building, hydrotechnics* and *rational use and protection of water resources* - Technical English class as prerequisite for IWRM module in the 4th study year - Gradual transfer of the module to NUWMNRU, under auspices of Faculty of Water Resources; twinning between chairs of NUWMNRU and TUD - Learning materials in Ukrainian language for facilitating access of NUWMNRU's staff	- Prof. Sapsay - Prof. Hirol, vice-rector for research of NUWMNRU - Prof. Turchenyuk, Dean of Faculty of Water Resources - Prof. Schanze - Mr. Leidel - Translators: Ms. Wolf, Ms. Hirol
30/09/2011	Rivne	• Meeting of the faculty board of the faculty of water resources - Discussion on further development of IWRM module - Discussion on thematic partnerships (twinning of chairs) - Decision that 2nd realization of IWRM module should be executed in the next year	- Members of the faculty board - Prof. Turchenyuk (Dean) - Prof. Schanze - Mr. Leidel

Table 24: Milestones for the development of an IWRM teaching module in UA

10 Discussion and conclusion

10.1 Conceptual framework towards sustainable water management

This thesis is based on the concept of IWRM as overarching paradigm for contemporary water resources management, even if many critics are present that doubt the appropriateness of the concept. In the following, it is advocated to rethink IWRM, respectively going back to the beginnings of IWRM and thus proposing a pragmatic view on IWRM.

First of all, it clearly has to be defined and promoted, what exactly IWRM is and what it is not on (I) a conceptual level, but also (ii) within the development and implementation of IWRM projects. Recognizing IWRM only as a general and (contemporary) fashionable slogan as described by Dukhorny (2004) clearly has to be countered. In fact, it is decisive to overcome or to substantiate vague and universal approaches, which is not only true for IWRM, but also for other concepts that were fashionable once, or will become contemporary like the water energy food security nexus. General concepts like IWRM on a global and abstract level are reasonable and necessary, only if they gradually become more context specific by concretizing them at the national, regional and local level (Leidel et al. 2014). Additionally, it is questionable whether paradigms developed by one sector (e.g. IWRM within the water sector) can be easily accepted by other sectors, respectively can be applied by the other sectors.

IWRM is a paradigm that has to be adapted to the context together with relevant actors (Leidel et al. 2012). Thus, IWRM should not be dogmatic (e.g. "holistic participatory approaches are always needed for IWRM"), but it should be substantiated why specific IWRM principles, reorganization or measures are needed, or as Muller (2010) mentioned "where there is clear demand". And van der Zaag (2005) mentioned that IWRM is a relevant, yet fuzzy concept that inspires to think outside the water box. Thus, it is essential is to follow an integrated approach that respects the context, is pragmatic and problem focused. And it has to be acknowledged that IWRM deals with transdisciplinary management problems.

It has to be clarified, on which kind of management is focused within the implementation process, the normative management (Governance) or functional management like water quality monitoring within water authorities. Furthermore, it has to be clarified what the pitfalls of implementation and integration are, i.e. what should be integrated or which coordination mechanism are needed. Institutional integration/ reorganization as the only answer to sectoral fragmentation is at least disputable, if not unrealistic as mentioned in previous chapters. In terms of cross-sectoral integration pragmatic and reasonable solutions are necessary. That means that rescaling of management activities and thus setting up of new water management authorities like RBOs is not always the best solution. Van der Zaag (2005), for instance, argues in favor of pragmatic approaches for developing water management institutions that do not ignore existing institutional structures. In fact, he states that executive functions are not a requisite for new water management authorities, but instead they should be consultative bodies which guarantee that the development is coordinated between the different sectors (Ibid.). This means that also other coordination mechanisms are needed, next to "integration". The focus has to be on close collaboration, cooperation, and coordination between the manifold involved sectors and institutions. And empowering stakeholders is necessary for a sustainable implementation of IWRM. Yet, cooperation and coordination between actors are challenges of integration that frequently occur in transdisciplinary approaches because of boundaries between the different actors (e.g. different world views). Important for overcoming boundaries is to develop and apply boundary objects, which deliver the "knowledge for doing" (Mollinga 2010), e.g. reports, frameworks or decision support systems. For improving IWRM, the boundary object needs to combine scientific analyses, frameworks for understanding as well as participatory processes for knowledge exchange and capacity development (Leidel et al. 2014). In fact, for strengthening water resources management, it is important to emphasize the importance of capacity development (Alaerts et al. 1991; Alaerts 2009). Similarly, it is frequently mentioned that the implementation of IWRM is not a technical or physical issue, but a water governance challenge, which implies focusing on improving water governance. Even though it is a valid argument, it might lead to neglecting physical aspects of the water crisis. Instead of playing off water governance against physical and technical aspects of water management, this thesis focused on a joint approach, i.e. integrating all relevant aspects of water management and treating them according to their importance for the particular problem.

Resources management frequently has to deal with collective-action problems (motivation and information problems), which lead to incentives of actors of not (satisfactorily) solving a situation (Ostrom et al. 2001). Therefore, it is as important to develop appropriate incentives within IWRM projects, as well as addressing incentive problems like corruption or rent-seeking. We implicitly were addressing incentives; however a stronger focus on incentives could have potentially delivered more insights, whether governance systems support IWRM implementation or rather on the contrary, e.g. through using the Incentive Compatibility Analysis (Fischer et al. 2004; Huppert 2007), which analyses whether the governance system provides incentives for implementing IWRM through carrots and sticks.

Obviously, but often ignored, IWRM is a long term process, i.e. that progress needs time. But the rapid changing conditions within many river basin of the world call for immediate and continuous action. This should follow recursive and adaptive approaches like transdisciplinary or adaptive management. As Pahl-Wostl (2004) mentioned that it is essential to have iterative management cycles and thus learning instead of mere control. This will gradually improve the water resources management system, since new insights lead to the adaptation of the goals and strategies of the management. And consequently, the adaptive capacity of integrated water systems is increased.

Therefore, we link IWRM and capacity development within a transdisciplinary framework with iterative cycles, so that continuous learning and improvement and thus adaptation are assured.

10.2 Theoretical framework

The theoretical framework of the study is predominately based on transdisciplinarity and the concepts of boundary issues and objects. However, also other theoretical frameworks for analysing complex case studies are available, inter alia the institutional analysis and development framework established by Ostrom (2005) for understanding institutional diversity. It would have been worthwhile to elaborate a theoretical triangulation, i.e. applying Ostrom's framework and evaluating, whether similar results or contradicting outcomes would have been produced. Yet, it would have been difficult to explain the stakeholders in Ukraine that we want to apply rival theories. Such comparisons, which are scientifically reasonable, would have been considered as a sign of inaptitude of our approach and would imply some sort of incompetency of our research. The Ukrainian considered the IWAS team as experts, so at least the administrative actors would question why we want to apply rival theories.

Transdisciplinarity is an adaptive and recursive process for both, the overall process as well as within the particular phases, which is a pragmatic approach to analyse whether the proposed course of action and the preliminary results are reasonable, and if not, to adjust it (Pohl and Hirsch Hadorn 2006). This is similar to adaptive management, which attempts to reduce uncertainties continually by monitoring and assessing the system, which will gradually lead to an advanced and thus more adapted (management) system with adapted goals and strategies. Pahl-Wostl (2004) mentions that adaptive management is needed, because uncertainties and risks in the management of ecological systems exist, so that it is difficult to predict the behaviour and responses of the system in the future. And managing the water system includes even more complexities, so that the control of all relevant processes and to precisely predict the outcome of management decisions is difficult (Pahl-Wostl 2008). Pahl-Wostl and colleagues emphasize the importance of adaptive management and social learning for improving water resources management; however we focus more on cooperation as one part of boundary management within a transdisciplinary concept. It would be interesting, whether our approach and our results would be significantly different by applying the theoretical framework of Pahl-Wostl. Comparative studies that explore similarities and differences between work that is based on the concepts of social learning on the one hand, and projects based on transdisciplinarity and boundary management on the other hand, need to be conducted for getting more insights and for potentially merging both concepts.

However, applying transdisciplinary concepts for IWRM studies is reasonable, because (i) resolving integration problems is central to transdisciplinarity (Jahn 2008), and (ii) transdisciplinarity includes boundary management (Mollinga 2010) - both points are essential for improving IWRM. And transdisciplinarity is inherently related to capacity development, which is another important success factor for IWRM. It facilitates collaboration, combines learning and research, provides mutual learning of actors and knowledge on complex interrelationships, and it can improve environmental awareness so that Scholz (2011) mentioned that capacity development is the key function of transdisciplinarity. This correlates with the evidence that capacity development can be seen as a key factor for natural resources management, and especially for water resources management as reasoned by Alaerts et al. (1991), Alaerts (2009) and others authors.

Transdisciplinarity is characterized by having a complex problem and a problem solving strategy with (i) problem identification and understanding, (ii) separation of the overall problem into several parts with subdivided questions, (iii) elaboration of the sections by taking the other parts into consideration and finally (iv) integration of the different parts for solving the overall problem and having transdisciplinary result options for solving the complex problem (Pohl and Hirsch Hadorn 2006). Our approach is following this procedure of "integration and separation", i.e. using the full range of scientific approaches, from transdisciplinarity to interdisciplinarity, multidisciplinarity and disciplinarity. As described by Pohl and Hirsch Hadorn (2006), there are phases were the focus is more on transdisciplinary or interdisciplinary collaboration that change with phases that focus more on individual disciplinary work. That holds true for our work, yet, we assumed that the amplitude between transdisciplinary collaboration and disciplinary work should be minimized so that we integrated a knowledge exchange and capacity development process for securing a continuous transdisciplinarity within our study.

Another essential point within transdisciplinary research is to combine forms of collaboration with means of integration (Pohl and Hirsch Hadorn 2008). We show that the integration of the diversity of knowledge is enhanced by using *several* means of integration and forms of collaboration. Accordingly, we used as forms of collaboration *common group learning* (integration via learning processes), *deliberation among experts* (integration via exchange between experts) and *integration by a subgroup or individual* as proposed by Pohl and Hirsch Hadorn (2008). The applied means of integration are based on Pohl and Hirsch Hadorn (2008) and are m*utual understanding*, i.e. we defined and adapted terms to the users, t*heoretical concepts*, i.e. especially new bridge concepts are developed that merge different scientific perspectives and different actors' perspectives, m*odels*, i.e. for developing a joint understanding or for mutual learning, and *products*, e.g. frameworks, or databases. Thus, we developed an integration approach that is a bridge concept with a *boundary object* supporting mutual understanding and altogether the knowledge integration, because the function of boundary management is to reduce the integration problems of transdisciplinarity within man-environment systems. Yet, the essential question is, how such a boundary crossing can be realized, because crossing boundaries is not happening automatically as mentioned by Mollinga (2008; 2010). Boundary objects facilitate the collaboration between two parties; however Guston (2001) argues that additional opportunities and incentives for the development and use of boundary objects are important, so that he proposes to develop boundary organisations that have rules and procedures for carrying out their tasks at the interface between social actors. Mollinga (2008) similarly argue that boundary objects, boundary settings and boundary concepts are needed, which is essential for dealing with the complexities of natural resources management. Turnhout (2009) argues that boundary objects can only connect social worlds that are similar, i.e. share common values and preferences. Likewise, boundary objects rely on voluntary collaboration between the different actors, so that boundary objects appear to be essential but not sufficient for a comprehensive boundary management that improves the integration between different stakeholders. In summary, the main challenge of boundary objects is still to address simultaneously salience, credibility, and legitimacy as described by Cash et al. (2003). Mollinga (2008; 2010) described three strategies for developing a boundary object (i) analytical route with models as boundary objects, (ii) assessment route with frameworks as boundary objects, and (iii) participatory route with processes and people as boundary object. All three strategies have their disadvantages if used as stand-alone strategy. However, they could benefit from each other, so that converging the three routes seems plausible according to Mollinga (2008). The convergence of the three strategies is a reasonable way of merging credibility, salience and legitimacy of the exchanged and developed knowledge. Yet, the three strategies are associated with different policies, disciplines and attitudes, which makes the convergence difficult according to Mollinga (2008). However, overcoming such obstacles is the task of transdisciplinary management. Our approach combines the three different strategies into one boundary object, so that credibility, salience and legitimacy are assured and eventually the water resources management is strengthened.

In addition, the IWAS project took boundary management seriously, i.e. communication, mutual understanding and mediation have been done continuously and frequently and the boundary manager was accountable to the actors on both sides of the boundary. And we applied a boundary object for developing jointly knowledge based on insights from both sides of the boundary, i.e. scientists and practitioners.

Applying this approach in Ukraine showed that knowledge and capacities of various stakeholder groups can be improved even in contested political environments. Yet, progress of political changes was comparatively slow, which can be attributed to missing incentives, as well as hidden and opposing interests of some actors. For instance, there is no incentive for improving the environmental legislation as it was in the former EU-candidate countries in Eastern Europe. The ratified association agreement between EU and UA might increase incentives, since it states to improve the cooperation in environmental protection and that a "gradual approximation of Ukrainian legislation to EU law and policy on environment shall proceed..." This seems promising, however the current political instability of Ukraine makes it difficult to estimate future progress related to transforming environmental legislation or the adequate adaptation of EU directives.

10.3 Methodological framework

In terms of methodology, I applied mixed methods research, which is a comparably new methodology. It emerged from a long-lasting dispute whether qualitative and quantitative research can be mixed or not. The legitimisation of mixed methods research has been presented in chapter 5.3. I have applied mixed methods research within a case study approach, which is legitimate (e.g. Yin 2009; Creswell and Plano Clark 2011). The case study method, and especially the embedded design, is particularly apt for structuring transdisciplinary processes (Scholz 2011) so that I have chosen this design for my research.

The challenge is, however, that researcher within such a complex action research environment needs various skills for conducting adequately such studies. A profound knowledge of qualitative as well as quantitative analyses methods are needed with at least an overview of limitations, differences and philosophical paradigms underlying these strategies (e.g.

deduction versus induction). For this dissertation, additionally a profound knowledge about natural scientific, engineering as well as social scientific processes and its complex interdependencies is of utmost importance. As Yin (2009) states that case study researchers need to understand the issues being studied, i.e. the researcher must be able to interpret the data. Yet, it is impossible to be an expert in the manifold fields addressed in my study. Who can be an expert in the entire field of IWRM? - Certainly nobody. However, for my study it is necessary to have a broad understanding of the various disciplines needed and to admit where further experts are needed for solving the issue. This is actually the executed way in the IWAS model region Ukraine, where an interdisciplinary team of scientists worked together with me as a "knowledge broker", i.e. a transmitter between scientists and the stakeholders in the model region as well as between the scientific communities. As Lewin (1946) already mentioned that it is most important for the management of intergroup relations to have scientists that can handle scientific issues, but also can work in teams with practitioners. Based on profound natural scientific experiences from my studies on environmental resources management, I have the required understanding for discussing issues with the executives in the water authorities in Ukraine, who are mainly engineers or natural scientists and equally important, I can talk therefore in a similar technical language. They focused within the first interviews and discussions always on aspects related to infrastructure, rehabilitation measures or monitoring programmes, and other aspects or challenges related to the institutional set up were discounted. So it was my task to discuss with them technical details of our research programme, but then also directing the conversation to more governance and capacity related points. But it was only after the technical discussions that the executives were willing to talk about institutional challenges, so that my know-how facilitated trust generation and thus the access to the more complex institutional topic. Accordingly, it is obvious that the study deals intensively also with societal problems and social methodologies, so that social scientific expertise is necessary. I am not a graduated social scientist, so that it could be argued that potential inaccuracies may occur during this study. However, my interdisciplinary study programmes provided my already a first insight into governance and capacity issues. Additionally, I reduced the likelihood of inaccuracies by (i) collaborating within an interdisciplinary research team including also social scientists, (ii) triangulating my results with the results from social scientific colleagues working in our IWAS research team, and (iii) discussing methodologies with social scientists from academic fields, that are not related to water management.

I have conducted a single case study research. One challenge of single case study design is the potential misrepresentation of the chosen case study, so that a thorough analysis of the potential case has to be done (Yin 2009). Furthermore, it has to be assured that the data needed for the evidence can be collected (Ibid.) Multiple case study research would provide a bigger potential for generalization of conclusions (Miles and Huberman 1994). Multiple case studies could improve triangulation and thus validity through different data sources. Furthermore the developed framework could be tested and verified in another case study and thus potentially enhancing the framework's rigor. So, the analytical benefits of multiple-case study research may be significant (Yin 2009). Yet, one out of five rationales for using a single case study is according to Yin (2009), when it represents a *critical case*, i.e. testing a developed theory. Thus, a theory, with a precise set of propositions and the context within which these hypotheses should be true, is confirmed, contested or expanded by a single case (Yin 2009). Therefore, it is justified that I have chosen a single case design for my thesis for analysing whether my proposed framework is reasonable within the context of post-soviet societies. Another problem of *single-case study with one main unit of analysis* is according to Yin (2009) that it is potentially carried out at an abstract level, which is inappropriate for my proposed inquiry in Ukraine. And such a holistic design has a further problem of potentially slipping into a situation, where gained evidence leads to different research questions than the original ones (Ibid.). In fact, one of the major critics on the case study method is that some researchers change the research questions so that they fit to the research design with the evidence not pointing on the previous research questions but to the "new" ones (COSMOS Cooperation 1983, in Yin 2009). To encounter these problems, Yin (2009) propose to apply a *single case design with embedded units of analysis*, in order to improve the opportunities for in-depth analyses and to avoid the pitfall of having a research design not fitting to the research questions. Therefore, I have chosen a single case design with embedded units of analysis. Yet, an embedded design has the potential danger to focus too much on the embedded subunits and neglecting the main unit of analysis (Yin 2009). That means that the intended research focus would become the context of the study (Yin 2009). Being aware of this fact, I always have addressed water resources management within the Western Bug River Basin and not only focused on the subunits. Acknowledging the complexity of water resources management in general, and especially in Ukraine and due to our fundamental intent of combining research and implementation (action research) in a transdisciplinary sense, our conviction was to establish and execute a single-case study thoroughly, instead of having several cases studied inaccurately. This goes hand in hand with practical restrictions for applying a single case study instead of a multiple-case study. First of all, it has to be mentioned that the amount of time and funds available for the research was adequate for a single case study, but not for multiple cases. And the research set up in the other IWAS model regions was different and not as holistic as within the Ukrainian case study. Still, comparisons have been made between the model regions in terms of the relation between water resources management, capacity issues and governance aspects.

A further measure for enhancing the validity of the results is that our research is based on mixed methods, which improves triangulation through different data sources. Above that, my research design was slightly altered during the course of the study, due to new insights. The major research questions, however, were not changed, which is in accordance with Yin (2009) who states that careful alterations of the design are possible as long as the research objectives are not changed and thus the precision with which case study research should be conducted is not reduced. As a matter of fact, reconsidering theoretical propositions and modifying the design due to new discoveries is a main characteristic of mixed methods research (MMR), as described in chapter 5.3 that MMR has a cyclic nature with deductive and inductive phases (cf. Tashakkori and Teddlie 2010). And, in a more pragmatic view, modifications due to new findings are necessary because otherwise the researcher can be suspected to be selective in data reporting, meaning that s/he only uses data that fits to initial theories and hypotheses (Yin 2009).

Rival propositions are essential for the quality of case studies (Yin 2009); therefore I have considered some that challenge my assumptions. Applying a different theoretical framework might have delivered different results, but as mentioned above, this scientific exercise was impossible to conduct within the case study. Other rival propositions like only using quantitative analyses or only natural science analyses can be empirically rejected, since the added value of a combined analysis was proven. Moreover, other rival propositions exist that are not implementable. For instance propositions that a variation among stakeholders would have delivered other interpretations are not realistic, because we have integrated the essential and most knowledgeable stakeholders that have been identified according to various methods so that the key role of the stakeholders can be assured.

Reviewing the study by peers and informants significantly improves the overall quality of the study by increasing the construct validity (Yin 2009). Therefore, one Ukrainian key informant was a co-author of one journal article that I have published and which is one of the cornerstones of this thesis. Moreover, for each of the two journal articles related to the Ukrainian case one of the two reviewers was very probably a Ukrainian peer, because the questions within the review process where very profoundly related to Ukrainian specific issues and legislation.

Boundaries of a case study, i.e. the difference between the case and the context, are difficult to draw. However, I found information with only minor relevance for my study so that the boundaries can be approached. E.g. financial limitations and the overall socio-economic development were often specified as a major obstacle for water management, yet further data and triangulation revealed that, even if it is an essential limitation, other obstacles are more decisive in an immediate sense, e.g. the inconsistent monitoring system.

Since we conducted a transdisciplinary study, one explicit aim of the study was to exchange research results with various stakeholders varying from specialists to laypersons. Therefore we used case study research, because the strength of this methodology is to transfer results to various stakeholders (Yin 2009). This was done in different formats namely meetings, workshops, narratives (study reports, policy briefs with recommendations), but also lectures at Ukrainian universities as well as e-lectures within an e-learning module.

This also shows that it is of public interest and that the raised issues are important for the Ukraine, as well as for the worldwide debate on sustainable water resources management so that the case study is significant.

In terms of generalisation of the results it has to be stated that the results of my mixed methods study cannot be generalised as within a pure quantitative study. Transdisciplinary studies as within this thesis cannot be generalised based on standard conditions, but the developed theoretical model is validated within concrete real world conditions as proposed by Pohl and Hirsch Hadorn (2008).

Therefore, one may be more pragmatic and use the term transferability of results instead of generalisation as suggested by several authors (e.g. Morgan 2007). That means that my developed approach might be transferred to other cases, but it is not comparable to the generalization of a quantitative study, where the complete results of the study can be universalized. Thus, extrapolating qualitative studies is not as accurate as quantitative studies; yet, we used a mixed methods approach, which combines qualitative and quantitative items, which enhances the accuracy. Additionally, validation of our approach was improved by iteration within adaptive cycles and thus enhancing the potential transferability of the developed model. This clearly shows that our study, as TR in general, is more than consulting.

Related to that are cross-level problems, i.e. generalising from one level to another and to find the appropriate scale(s) and level(s) for analysis and action. We addressed that partially by using a multi-level approach and multiple scales, i.e. not to generalise but to attempt to conduct the analysis on all relevant levels and scales

10.4 Methodology for improving IWRM implementation

Within natural resources management, rational planning approaches are not always leading to the desired results (cf. Forester 1989) especially in developing countries, but rather incremental approaches that combine strategic intent with flexibility (cf. ECDPM 2009) or a combination of both approaches, if appropriate. Our incremental approach (I) has strategic intent, but is flexible and adaptive in the implementation accepting constantly changing conditions, (ii) focuses on the multiple levels of capacity development for institutional strengthening and structural changes, especially by empowering stakeholders, and (iii) prescribes no universal solutions "ex-factory" or predefined outcomes, rather acknowledging that institutions and management options work differently (or not at all) in different contexts.

That means we refer to a cycling spiral with planning, action, and reflection in terms of results and action. Thereby, we can generate improved results based on the interactions between theories and practice (application in the Ukrainian case study) and we can pursue a continuous learning within the process. Accordingly, my thesis consists of two research cycles (Figure 17) where the first cycle is basically about the interaction between IWRM and CD (Leidel et al. 2012), and the second one more specifically on a management framework for aligning model-based systems analysis and capacity assessments for overcoming environmental pressures and capacity gaps (Leidel et al. 2014).

Implementing IWRM means that institutions are changed. Therefore institutional analysis and actors analysis is essential. Yet, additionally applying the concept of storylines (Hajer 2003; 2006) seems to have advantages, especially for transdisciplinary projects, because it analyses how the actors grasp their problems themselves. Thus it is evaluated, which importance the problems have for the local scale. We implicitly used this concept for our case study. And it has to be acknowledged that water management is not only about formal institutions, but rather about water politics (Mollinga 2008), so that an accompanying political process for exploring water politics and related issues like hidden agendas is essential.

10.4.1 Combining IWRM and CD processes

An initial framework was developed as described in chapter 7 (Leidel et al. 2012), which is based on the question how the implementation of sustainable water management can be supported. Many scholars (e.g. Alaerts et al. 1991) have stated that capacity development is the "missing link" for sustainable water management. This is analogue to the fact that the introduction of new technologies within industrial processes is often conducted without having appropriate competencies for realisation of the innovation (cf. Staudt et al. 2002).

Accordingly, CD is frequently done only after the innovation process and often in a rush and thus immature way. Several studies recognized CD as the bottleneck for innovation, yet simultaneous engineering, e.g. the parallelisation of research and development or production and marketing, is still excluding capacity development (Staudt et al. 2002). In the wider sense of simultaneous engineering, we therefore propose the parallelisation of processes of IWRM with processes of Capacity Development, i.e. to align and interrelate them from the very beginning. This assures that CD becomes an integral part of IWRM and thus measures proposed for improving water resources management fit to the available capacities and the overall context, respectively to develop CD measures needed for supporting the water resources specific measures. We applied the well accepted multi-level approach (e.g. Lopes and Theisohn 2003; van Hofwegen 2004; Alaerts 2009) for CD, highlighting that society is a nested, interdependent system comprising the three levels (individual, organisational, system) and that the levels are relevant for all societal groups like authorities or the science community. For instance, a profound CD approach for the environmental authorities would integrate new or improved training and education for the focused subject like water quality monitoring (individual level), improve the authorities as an organisation, e.g. defining a strategy and responsibilities for water monitoring and allocate budget (organisational level) as well as addressing the regulatory frame like the environmental legislation or changing funding priorities (system level). The whole process has to be targeted to the needs and thus it has to be harmonized with the existing water resources management and incorporated into existing strategies for the CD as well as the development of the sector in general.

Therefore, the combined and harmonized IWRM and CD processes start with a situation analysis that includes natural and technical aspects as well as socio-economic, governance and capacity related issues. The application of the methodology in the Ukrainian case study showed that a combined approach of IWRM and CD is reasonable, especially because it supports actors in recognizing the state and the full scope of the problem (Leidel et al. 2012). Yet, the application in the case study also showed that the interaction between capacity analyses and model-based systems analyses needs to be sharpened. And in consequence, it has to be clarified more, how the *concrete* interlinkage between environmental pressures and capacity issues can be improved. In addition, it is necessary to develop a more transparent and practice-relevant method for combining model-based system planning and capacity assessments as a basis for management options.

Thus, the transdisciplinary collaboration, and especially the Science-Policy-Interface (SPI) needs to be improved and the whole process needs to be more applicable for actors.

10.4.2 Integrated analysis of environmental pressures and capacity gaps

The results from the first research cycle were gradually adapted and amended by further theories and insights from the case study mirroring the action research cycle, as well as the iterative and cycling nature of mixed methods research. The hypothesis is that the implementation of IWRM needs a coordination mechanism between different actors, which addresses scientific work, capacity issues as well as the political process. Such a framework can support the cohesion between different actors as for instance within a river basin. It improves the transparency and applicability and eventually constitutes the basis for closing information and capacity gaps.

Eventually this led to an emerging methodology for an integrated analysis of environmental pressures and capacity gaps. In chapter 8 (Leidel et al. 2014) this cross-scale management framework with a conjoint systems and capacity analysis and thus with quantitative and qualitative analyses (MMR) is described. For balancing water management with available and developable capacities, a *boundary object* is developed consisting of a management framework with model-based systems analysis and capacity analysis as well as a political process for CD and knowledge exchange (Leidel et al. 2014). This assures that credibility, salience and legitimacy are addressed simultaneously. Our approach mirrors therefore the proposition of Cash et al. (2003) that *effective* boundary management facilitate what the multiple actors involved in sustainable resources management perceive under credibility, salience and legitimacy. We subsume that under the term t*ransdisciplinary management* as an adaptive process that facilitates sustainable natural resources management on several levels of management and the integration of all relevant actors. This assures that the developed options are scientifically robust, context-specific and can support decision making and capacity development.

For structuring and making the results of the analysis more transparent, we developed the Subsystem-Pressure-Coordination-matrix as information units based on an approach by Blumensaat et al. (2013). Resulting management options support water management actors in reducing environmental pressures as well as capacity and information gaps (Leidel et al. 2014). The S/P/C matrix can qualitatively describe the status of the water management technically and capacity-wise for the particular level of water management, e.g. the local level. Further points on the framework are discussed in chapter 8.6.

The methodology showed that a coordination mechanism as the developed boundary object is essential for improving water resources management.

10.5 Case study Ukraine and Western Bug River Basin

The Case study clearly showed the challenges that are inherent in transdisciplinary projects as described by Pohl and Hirsch Haddorn (2008). The problem identification and the definition of the common good required many resources (time, humans) and was a lengthy process. Reasons are manifold, i.a. different perceptions to the problem and its solutions due to differences in backgrounds, cultures or political opinions.

In the best case, all actors are interested in the change process, have sufficient incentives to participate and the process is not overly driven by science. It could be observed that the interest and the ownership towards the problem and its solution increased during the course of the IWAS project. Yet, a constant need for facilitation of the process was needed, which was done by the IWAS project. This implies to a certain extent that the Ukrainian actors have no full ownership of the problem. Yet, facilitation of such processes is always needed. In order to avoid that science is the main driver, we were integrating CD into our IWRM approach and thus the perceptions of relevant actors from the beginning, e.g. through interviews and workshops. And the developed approach in Leidel et al. (2014) emphasized the importance of all relevant actors for the development process for assuring credibility, salience and legitimacy by focusing on boundary management with analytical, assessment and participatory strategies. Yet, it has to be acknowledged that transdisciplinary research needs long term and continuous cooperation, so that e.g. Roux et al. (2006) suggests having project cycles of five to ten years for effective transdisciplinary work. Yet, in reality projects are often only three years and rarely up to five years, at least in the realm of scientific funding. In this context, the question might arise how to distinguish TR projects from development cooperation, especially if project cycles of TR projects would be extended. In my opinion, (transdisciplinary) research projects and development cooperation have to converge, i.e. that development cooperation has to become more transdisciplinary in future and thus the borders between applied research and development cooperation will vanish.

10.5.1 Government and authorities

In general, it can be mentioned that political and administrative instability constrained water resources management throughout the project time. Moreover, water resources management is not a top priority of the government and thus the commitment and the political will towards change is low. Various executive institutions on all government levels exist that are involved in the water sector with frequent changes in responsibilities and tasks due to frequently changing policies and the unavailability of a holistic sector strategy with effective inter-agency coordination mechanisms. Also personnel are frequently exchanged due to several reasons, often related to power play. Another important point is that the regulatory system is complex and legislation is not fully enforced. Funding is a major issue, which is lacking for adequate operation and maintenance as well as modernisation of infrastructure or programmes of measures for RBM.

Another result is that a "bottom up approach" for RBM, i.e. predominately including local and regional actors, is not successful. Even if regional decision makers and authorities claim to have full authority on the RBM process, a stronger involvement and commitment of the national level is needed to ensure that the process is not interrupted by unclear responsibilities and/ or informal structures (as it was the case with the meeting of the WBRB council in 2010). Tangible decisions and concrete proposals are often impeded by these unclear responsibilities and informal structures as well as by a lack of political will and intransparent political and economic relations. This goes along with a lack of accountability and oral agreements are frequently not adhered to. Therefore, we adapted the project strategy. We continued with the "bottom-up approach", but additionally we established a top-down approach, meaning to incorporate and strengthen the national level, so that decisions are transparent and cannot be overruled in an inexplicable way by regional decision makers. For that reason, a political process for RBM on the national level was initiated and a working group on integrated water resources management was established by the Ukrainian government. The strategy was to discuss RBM with the national level, and only after getting the commitment of the major national actors to collaborate, we proceeded with the process in the WBRB. In addition, a national and a regional coordinator were installed for improving the cooperation between actors and we encouraged the use of written agreements and minutes for better transparency.

This strategy of combining a top-down approach with a bottom up approach was successful: The RBM in the WBRB was strengthened and the meeting of the WBRB council was realized in 2012. The council adopted also a work plan for the WBRBD for 2012-2103. The national process towards improving RBM was supported by a policy paper on *Strengthening Implementation of Integrated Water Resources Management (IWRM) in Ukraine*, and by initiating a follow up on the IWAS activities, with an emphasis on twinning activities. We facilitated the discussion between German/ EU representatives and the Ministry of Ecology and Natural Resources of Ukraine on possibilities of cooperation and eventually a project proposal was developed named *Capacity Development for strengthening water monitoring as a contribution to river basin management*. The project purpose is to contribute to the improvement of the water administration in Ukraine by advancement and harmonization of water monitoring according to EU water related aquis communautaire. Due to the escalating violence of the Euromaidan movement in February 2014, however, no responsible person within the Ministry of Ecology and Natural Resources of Ukraine was able to hand in the finalized proposal before the deadline of the EU. Several other options for financing an EU-UA partnership in the water sector were investigated; arguing for a *window of opportunity* for collaboration after the new Ukrainian government was established. Yet, the situation until mid of 2014 was that German/ European decision makers opted for not financing any major activities due to the instable and unpredictable political situation.

The current river basin approach in the WBRB is not working effectively. The major reason is that the WBRBD is not a fully effective boundary organisation. The WBRBD is not fully integrated into the existing legal framework towards water resources management and environmental protection. There are legal documents describing the relationship between the existing environmental and water authorities and the WBRBD. Yet, detailed working procedures are missing and most importantly a spirit of cooperation between the longer existing authorities (especially of oblast L'viv) and the "new" WBRBD is missing. It seems that they perceive the WBRBD as dangerous to their roles in the institutional context of RBM with potentially losing power or even their jobs so that there is only low willingness to contribute to a successful WBRBD and thus RBM.

In addition, the WBRBD has not set up an effective coordination mechanism between different actors, which addresses scientific work, capacity issues as well as the political process. That means that effective collaboration with appropriate communication and mediation is not conducted sufficiently by the WBRBD thus having lower levels of credibility, salience and legitimacy. E.g. the credibility of the water quality parameters is question able. The WBRBD has a GIS-based information system with a limited online repository which could be considered as part of a boundary object. The information provided from the WBRBD is salient, however, not all salient information are available. The WBRBD respectively the State Agency of Water Resources has not developed adequate rules, procedures and norms for clearly assigning responsibilities, monitoring tasks to the different authorities as well as for data exchange. The national level has not put many efforts into a political process lobbying for RBM. Officially, the WBRB Council can be considered legitimate, since all relevant actors are represented in the council. However, the enforcement of decisions is low, interactions with activities from other line ministries are elusive and opinions from NGOs are often discarded.

A well-functioning boundary organisation would need to integrate the above mentioned points and a *boundary object* is needed consisting of a management framework with model-based systems analysis and capacity analysis as well as a political process for CD and knowledge exchange as described in Leidel et al. 2014. This assures that credibility, salience and legitimacy are addressed simultaneously and consistently. It was shown in Leidel et al. (2014) that it is possible to apply this framework for our case study in the WBRB. However, it would be essential to institutionalize this methodology, i.e. that the WBRBD would need to adapt it for *effective* boundary management so that credibility, salience and legitimacy can be fully addressed. This t*ransdisciplinary management* will improve the sustainable water resources management within the WBRB by assuring that developed management options are scientifically robust, context-specific and that RBM fits into the existing legal framework.

10.5.2 IWRM teaching module for Ukrainian Universities

During the first realization in September 2011, most of the content was taught by instructors from TU Dresden. It was intended that the content and the responsibilities of the lectures will be gradually transferred to instructors and institutes from NUWMNRU. First of all, this is important for the ownership of the potential Ukrainian lecturers towards the module, and that the Ukrainian scientists get acquainted with the tasks. Secondly, this will assure that the module is executed on a long term basis, because foreign experts are normally only able to teach within financed projects, thus without financing, classroom teaching becomes unrealistic. And the efforts to gather ten lecturers from Germany including three professors within one week were enormous, needless to say that travel preparations to a provincial medium sized city in Ukraine were also immense. Furthermore, it should be focused on integrating also younger post-docs and PhD candidates, since they have on the one hand enough English skills, and on the other hand they showed great interest in the taught topics and in a strong partnership. The second realization was intended to be used for the training of future Ukrainian lecturers.

One additional way of alleviating this issue next to shifting responsibilities to the Ukrainian counterparts is to develop e-learning contents, which can be used as preparation or as support for classroom teaching. Yet, this transfer of responsibilities and the content was problematic, because of language barriers between German and Ukrainian professors, making the (scientific) collaboration difficult. Professors in Ukraine hardly speak English, yet some (younger) post-docs were able to talk in English. Next to that, scientific barriers between German and Ukrainian institutes exist, i.e. that German scientists raised the issue that research on a par with many Ukrainian colleagues is difficult, so that there are little incentives for German researchers to collaborate, if it is not worthwhile for them. As a matter of fact, researchers within projects (as our IWAS-project) have to publish scientific papers, since this is necessary for their career as well as for the positive evaluation of the project. And even if there are no massive scientific barriers, there are different research specializations, making it also difficult to cooperate without having a joint research project. And there might be a perceived danger of external encroachment by foreign scientists and lecturers leading to negative incentives.

It could be seen that joint additional research projects, even small ones like the WTZ Ukraine project[85], increase material and nonmaterial incentives for both sides and thus facilitate the collaboration, because there is a joint research topic, interesting for all involved parties. And it potentially reduces the impression of being impaired by foreign scientists.

The long term target was to fully integrate this teaching module into the curricula of existing study courses at the NUWMNRU. The idea was that curricula development instead of merely teaching lectures occasionally and the gradual transfer of the module assure a long-term and sustainable enhancement of the tertiary education in the field of water science. The NUWMNRU mentioned that a cooperation agreement between the two universities is essential for deepening the collaboration. And that this agreement needs to be signed on the level of the universities' rectors. This agreement would have increased the incentives of the NUWMNRU enormously; however, the TUD's strategy at that time was to sign only cooperation agreements with international renowned top-ranking universities. A strategy highly controversial, if projects in the realm of development cooperation and capacity development or transdisciplinary projects at the intersection between science and practice like IWAS are conducted.

Nevertheless, there were already deliberations for the gradual transfer and the planning for the second realization with more Ukrainian lecturers participating. It was scheduled for autumn 2012; however, due to the upcoming Ukrainian elections and thus due to the not known budget, the rectorial board of the NUWMNRU informed us that it will postpone the final decision on the realization of the module. In the beginning of 2013, there were then additionally major reorganizations within the NUWMNRU and especially within the faculty of water management, so that the second round of implementation with more Ukrainian lecturers and the integration into the curriculum was paused. The reorganization was not finished until fall 2013, so that it became difficult to arrange a second realization within the IWAS project, since it terminated in July 2013.

[85] Wiisenschaftlich-Technische Zusammenarbeit (Scientific-technical cooperation) funded by the German government.

The success factor for the good collaboration and the implementation of the module was to develop an accompanying process of continuous communication and *real* cooperation with the partner universities. This created a spirit of collaboration and mutual recognition and generated mutual trust, so that incentives of the Ukrainian colleagues to cooperate increased. These nonmaterial incentives are related to the willingness to improve the academic education, and on more personal incentives like scientific validation, and on career advancement within their university.

Yet, to sustain this process man power, creativity for developing new forms of collaboration and financial means are decisive in order not to stall the process. And also incentives for cooperation of the German counterparts are needed, i.e. that not only cutting edge research should be valued, but also capacity development activities. Yet, this is easier said than done, because science is organized in such a way that research counts significantly more than educational activities. And some scientists were reluctant in joining capacity development measures and stated that their job description within the employment contract is not mentioning any capacity development activities.

It could be also seen that starting with intermediate steps is a reasonable way of cooperation- we started with joint measuring campaigns, coming to joint conferences and eventually joint module development. But it has to be acknowledged that these processes take time. As an example, from the first joint measuring campaign in autumn 2009 it took additional two years to the implementation of the IWRM module in autumn 2011.

11 Recommendations

11.1 Methodology for integrated analysis of environmental pressures and capacity gaps

The combined IWRM and CD framework with the S/P/C matrix can describe the status of the water management technically and capacity-wise. For increasing the usability and to make it more practice relevant for policy makers, a normalized indicator system, which can be used for ranking or comparing different river basins or management levels, could be developed in future. In this respect, a further improvement could be to weight the different factors, e.g. through stakeholders (expert-based approach) so that a more differentiated picture of the situation can be drawn. The weighted indicators could then be integrated into a composite water management unit (Multi Criteria Analysis), and it could be thought of applying a regionalization approach.

Another step for increasing the usability of the approach would be to develop a water knowledge management system as an extension of the described boundary object. Improving the methodology and setting up such a system needs to be done in a transdisciplinary sense, i.e. a joint development with participation of all relevant actors. This would support the credibility, salience and legitimacy.

11.2 The way forward: Water knowledge management system

Capacity and information gaps have to be closed simultaneously, i.e. that information on the status of the water resources is only 'one side of the medal'. It is as important to provide the necessary capacity and knowledge to apply the available information. That means in practice that people from water authorities as well as other interested stakeholders need training and education in order to grasp the information, i.e. providing possibilities for delivering necessary knowledge. However, not only understanding the information is necessary, but also the capacity to use it, e.g. for river basin management planning.

Therefore, it would be necessary to develop a water knowledge management system, which combines learning management systems (LMS) and water information systems (WIS), i.e. learning modules and water information are integrated. For that, learning theory and didactical issues that are relevant for capacity development need to be reviewed, as well as e-learning approaches and especially those within the water sciences. The advantages and disadvantages of applying e-learning approaches and LMS must be evaluated and also the didactics of water information systems. Eventually, a generic framework for a water knowledge management system (WKMS) needs to be developed following and extending the developed boundary object. It needs (i) a structure for providing and analysing necessary data/ information for doing RBM, (ii) as well as the necessary capacity and knowledge how to do river basin management, and (iii) tools for supporting social learning and participatory processes. This would reflect the analytical, assessment and participatory strategy for boundary objects as proposed by Mollinga (2010) and developed within Leidel et al. (2014).

Another step for the mentioned point (i) is to evaluate the possibilities of integrating GIS functionalities or modelling approaches depending on the need of the particular river basin. In the Ukrainian case study, for instance, integrating a water balance model would be beneficial. WEAP (Water Evaluation And Planning System, developed by the Stockholm Environment Institute) would be a useful water balance model, since it is user friendly (can be applied with varying complexity) and has an integrated approach to water resources planning. Integrating such models would be good for getting a more complete understanding of the interrelationships within water management and thus would increase credibility. And this would be well in accordance with learning theories that state that collaborative and hands-on working is better than merely providing information.

The second point (ii) can be forwarded to the user by means of lectures, whereas the relevant topics (lectures) are hyperlinked in order to convey the complexity of RBM to the user. This could follow the approach used in the UNESCO-IWAS IWRM E-Learning module (Leidel et al. 2013). Correspondingly, linkages or ontologies between lectures and WIS need to be developed. The third point (iii) can be supported by setting up a LMS, respectively by integrating media and Web 2.0 technologies for facilitating interactions between actors.

This generic approach can then be applied within context and regional specific case studies, i.e. in a specific river basin. It would be worthwhile to transfer the boundary object developed within the IWAS model region Western Bug River Basin into a water knowledge management system and extending it by the above mentioned points.

11.3 Case study Western Bug River Basin

11.3.1 Recommendations for administration

In general, it can be recommended that actors from one level should participate in decision making at another level. As for instance in Ukraine, the participation of regional actors at the national level and vice versa was initiated within the IWAS project. This facilitates that actors from one level understand the challenges of the other levels, e.g. in devising rules and ordinances. Regional actors are thus involved in the design of rules and norms, and potentially can influence this process. And the knowledge from regional or local actors is transferred to higher levels and thus potentially influencing higher level decisions. This would eventually lead to a common definition of IWRM, respectively RBM, shared by all actors about what RBM is and what the requirements should be as well as an assessment of knowledge for enhancing RBM in Ukraine (Hagemann and Leidel 2014).

11.3.2 Recommendations for national level

The (political) process of river basin management has to be strengthened in Ukraine. It would be necessary to proceed with the analysis how parts of other international RBM approaches (e.g. EU-WFD) can be used for strengthening the Ukrainian approach. Testing proposals in concrete pilot studies, preferably in a twinning arrangement is recommended, as described below. A strong commitment of the national stakeholders is needed for improving river basin management, so that it is recommended to continue with the working group with members of the Ministry of Environment, the State Agency of Water Management that was founded on initiative of the IWAS-project. The national authorities and the legislative bodies need to examine the current legal basis and the assignment of competencies. Due to overlapping responsibilities, but also because of the judicial system, enforcement mechanisms are not fully efficient. Therefore, the authorities have to screen for overlapping guidelines and responsibilities and subsequently they need to reform the legal and policy framework.

As a further step, the started process of strengthening RBM in Ukraine should be intensified. Capacity development can enormously be enhanced by cooperation with foreign authorities, since there is mutual understanding of structures, objectives and behaviour (ethos) within authorities. One example for such cooperation is the twinning instrument, which is a proven institution-building instrument (Bartels and Rach 2009). Hall et al. (2009) describes further advantages of so-called public-public partnerships (PUPs) like low transaction costs, non-commercial relationship, long-term gain in CD, and that partners which have benefitted from a twinning can become the supporting partner to other authorities in need of assistance. Boag and McDonald (2010) raise the point that there is a tendency that such PUPs are uncritically celebrated. Thus, twinning approaches have to be carefully planned, assessing the practical and theoretical advantages and disadvantages of the twinning instrument. In order to exchange experiences between each other, we recommend a methodological sound twinning arrangement between Ukrainian environmental authorities and e.g. authorities from the EU in the field of water monitoring, data management and collaboration. It could be viable, for instance, to arrange trainings/courses in terms of water monitoring (e.g. biological monitoring and hydromorphology) together with representatives from administration of EU member countries. The process has been established and an application for an EU-twinning project was already drafted, ready to be handed in by the Ukrainian Ministry of Environment to the EU commission. Unfortunately the process stalled because of the political turmoil in Ukraine.

Another viable option for strengthening water management in Ukraine, which is similar to the PUP of authorities, is the water operator partnership (WOP). For instance in Germany, the so called neighbourhood system, which was developed in 1968 and run by the DWA (German Association for Water, Wastewater and Waste), is a success story for water operators. Neighbourhoods exist for sewage treatment, plants, sewerage networks, water bodies and flood waters and are basically a platform that combines regularly decentralised training on various relevant issues, mutual exchange of experience and best practices among members, emergency assistance, enhancing self-monitoring, detecting problems and comparing work results and eventually developing measures. For adopting such a system of WOPs in Ukraine, it would be reasonable to further strengthen one of the national association, (e.g. Ukrovodokanalekologia), so that members can be supported and encouraged to set up such partnerships and that eventually networks between the member water operator can be established, similar to the German experiences.

It is recommended that all these activities are streamlined within a hub for capacity development, e.g. a centre of water competence in Ukraine (chapter 11.3.6).

11.3.3 Recommendations for regional level

An important step towards river basin management planning is an enhanced communication and collaboration of the ministries' branches at oblast level, i.e. relational capacities need to be developed to enhance cooperation and build trust. A streamlined coordination approach based on the existing administrative structures and capacities as well as the assignment of competencies will be a reasonable way for Ukrainian water management. Since river basin council and administrations have been installed in Ukraine, the coordination of activities in the catchment should be their task. New administrative structures are not a feasible way for river basin management. At the beginning, only the administrations of the water and the environmental sector need to cooperate and coordinate. The cross-sector cooperation between authorities (e.g. integrating the agricultural sector) should be done gradually. Accordingly, it is recommended to renew the formal agreements between the state actors within in the Western Bug River Basin. The agreements should also integrate the coordination of monitoring programmes, as well as an agreement about how the data/ information exchange is executed in detail. Furthermore, an enforcement instrument is essential, so that state actors can be forced to cooperate, e.g. in terms of data delivery.

One first step is to have coordination meetings (Western Bug River Basin council meetings) on a regular basis. They are important for solving problems and most importantly to create a spirit of cooperation between the members of the council and to provide mutual confidence, e.g. by acting jointly and reaching (sub-) goals together. One of the goals of the above mentioned working group was to re-establish the meetings of the Western Bug River basin council, since the last meeting was in the year 2006. In 2012, a meeting with an accompanying workshop on collaboration in river basin was executed.

Moreover, we recommend executing more workshops on RBM and how it functions in EU, on how to cooperate in a river basin, how to coordinate, presumably in the realm of the above mentioned twinning arrangement for the national level. This goes hand in hand with improving and harmonising the data and information basis, i.e. by measuring campaigns and intercalibration of different measuring methods. For sharing of data and information the development and enhancement of data base systems, respectively setting up or improving water information system is necessary in order to reduce information asymmetry. A basic web service for the data and information was developed by IWAS. The question arises, whether that information can be combined and integrated with Ukrainian data, e.g. the information system of the Western Bug River Basin Department. Here, it could be discussed what kind of technical solutions are possible (development of data bases, harmonization of data, water information systems, water knowledge platform). Such an information system needs also trained government employees that understand the importance of knowledge exchange. Therefore, CD measures should be streamlined and integrated into technical solutions like information systems. However, it is also recommended to strengthen the overall knowledge about RBM within all levels of employees in the administration.

Knowledge and capacity development is a continuous process, meaning that it has no end and thus knowledge and capacity gaps have to be narrowed constantly. A facilitating mechanism for continuous adaptation and learning, integrating all relevant actors, is therefore necessary. Therefore, we recommend a knowledge management platform with free access to all actors, since knowledge exchange facilitates communication, cooperation and learning of actors; eventually this contributes to narrowing the science-policy-interface.

Within this platform, data, information and knowledge can be stored. It could be e.g. used to inform all levels of society, from the laypersons to the authorities and the scientists with tailor-made access points for the target groups integrating in the best case even social collaborative media like forums or wikis. E.g. the decision makers within this basin could be informed about the advantages of modelling for integrated RBM (Support informed and coordinated decision). Such a platform should ideally be placed at the Western Bug River Basin Department, since they already collect data and information.

11.3.4 Recommendations for data management and water monitoring

It would be reasonable to provide data and information on a platform with access at least to all authorities. Therefore, the willingness of authorities to cooperate is essential. A strategy is necessary for data management, data management structure, data/information exchange between authorities and data provision for other actors (general public), and reporting requirements. The data structure should be established in such a way that it could be applied by models (data-model-approach). A good possibility is to have a combined platform for all regional data and information (river basin information system or water information system). Yet, it is important to identify content-related, financial and political obstacles of such a system. The following content-related steps are suggested for data management:

- Comparison of differences and similarities of methods for the management of collected data (What kind of practices are applied in data management, what kind of data base management systems are used, analogue data/electronic data, how are historical data dealt with)
- Data harmonization (format, meta data)
- Platform, systems selection; web-based system useful to allow access for all relevant institutions (and were appropriate other actors)
- What kind of technical solutions are possible (development of data bases, harmonization of data, water information systems, knowledge platforms)

In terms of water monitoring, there are still some contradictions, whether there is a mutual adapted methodology for water monitoring or not and whether there is a strategy how to handle different methodologies. Thus, it is recommended that this is clarified within a scientific analysis of the monitoring system. Another recommendation for future work is about improving the scientific basis of monitoring for the introduction of a river basin management planning. Therefore, the monitoring systems need to be improved as well, especially setting up river and rain gauges where needed. This is important since the data basis has to be precise and consistent in order to calibrate models and thus support decision makers. In addition, research in this field (e.g. on biological monitoring) is an important means for the preparation of management plans. This is well in accordance with the

Ukrainian action plan for water management until 2020. We suggest the following content-related steps for monitoring of water bodies:

- Comparison of differences and similarities of methods for the analysis (sampling [date, interval, place], stabilization, transport, documentation)
- Comparison of differences and similarities of methods for analytics (preparation of samplings, facilities/methods of analysis, documentation); comparison of advantages/disadvantages of different methods (i.e. precision, costs)
- Intercalibration of applied methods
- Comparison of differences and similarities of methods for quality control
- Capacity assessment for the involved monitoring authorities

11.3.5 Recommendations for education and research

For reaching a vast amount of future decision makers in the field of water resources management in Ukraine, we recommend to set IWRM and RBM on the agenda of the Ministry of Education, so that IWRM can be integrated in curricula of universities in Ukraine. In order to educate the large amount of students needed, lecturers have to be trained as well, at best within train-the-trainer courses, so that a swift uptake and spreading of know how is possible. The curricula development and the trainer courses could be based on the experiences from the postgraduate course at the university in Rivne. Based on the umbrella concept of the IWRM course, various needed specializations within water resources management should be developed, respectively existing study courses should be adapted so that they fit into the concept of sustainable water resources management. It is recommended to utilize the developed network of water sector organizations (mainly within Ukrovodokanalekologia) for discussions on additional relevant content, respectively specializations. Essential is that new or refurbished study courses contain scientific explicit and tacit knowledge and the overview on the various interrelated topics and subjects within IWRM (umbrella). Additionally, also know-how on capacity development in general and further soft skills is needed. Accordingly, it is reasonable to delineate (water related) study courses in a "T-shaped" profile, which has been described by Uhlenbrook and De Jong (2012) as well as in similar form done at TU Dresden within the M.Sc. course *Hydro Science and Engineering*. The vertical part of the "T" describes the major part of the study course, e.g. hydrology, and the horizontal bar integrates adjacent fields like water management and its interrelations. The latter is what we described above as umbrella, i.e. the IWRM module, and should also include an overview on capacity development, organizational development, didactics, governance, etc. The horizontal bar additionally should include functional competencies (e.g. report writing), as well as interpersonal competencies (e.g. moral integrity, communication or adequate behavior; Uhlenbrook and De Jong 2012). The key to change are leadership skills, consisting of interpersonal skills, tacit knowledge and buildup of experiences to develop a visionary mind (Wehn de Montalvo and Alaerts 2013). Thus, study courses should, as far as possible, teach insights from leadership.

Moreover, a regional adaptation of our developed e-learning module on IWRM (Leidel et al. 2013) could be elaborated to be used for training and information of authorities as well as support for universities. We recommend developing context-specific (e-) learning materials on IWRM for various target groups from the academic education to layperson. It could be used for support trainings, e.g. on biological monitoring. A first regional adaptation was already implemented by our partners from GWP Ukraine/MAMA-86. Based on the e-learning module IWRM-education, they developed additional lectures for covering Ukrainian specific materials[86]. Yet, it has to be emphasized that blended learning concepts, i.e. the combination of classroom teaching *and* self-paced/e-learning is most promising for best learning results, and especially if it is organized within a learning management system.

Furthermore, research in the field of water sciences and especially on modelling should be strengthened, e.g. through networking between Ukrainian universities and universities from EU to come closer to the European Research Area (ERA). It is also necessary to promote inter- and transdisciplinary approaches, so that a close cooperation between scientists and practitioners can evolve.

11.3.6 Recommendations for enhancing collaboration and transdisciplinarity

It is recommended to set up a centre of water competence in Ukraine for all levels of capacity development as mentioned above. Assessments have shown that several capacity development measures (training, education) exist, however, a holistic strategy between all actors is absent. Thus, there is a need for a structure that combines these efforts. Therefore, setting up a center of water competence in Ukraine for all levels of capacity development would strengthen the overall capacity development. As a first step, an assessment of existing measures for capacity development and knowledge transfer from universities, education and vocational training centers (e.g. from the Ministry of Environmental Protection, water associations, etc.), regional and national information systems should be conducted. It should be continuously assessed, which further CD-measures are necessary for improving

[86] (http://www.gwp.org/es/GWP-CEE/gwp-cee-in-action/news-and-activities/GWP-Ukraine-developed-IWRM-climate-change-course/ accessed on 01/07/2015)

water management in Ukraine. Based on that, the centre should develop a tailor-made modular knowledge management platform for connecting actors and for connecting existing intervention options, measures and knowledge including the development of additional knowledge transfer measures.

The aim of such a water competence centre is to support the continuous adaptation of strategies, intervention options and measures in the realm of water management as well as the development of partnerships between authorities, water operators and academic institutions. And the centre of water competence could support the joint development and implementation of a Ukrainian-EU strategy for capacity development in the water sector. However, the setup of such a hub needs the strong political support from the national Ukrainian government. Financing the establishment of a water competence centre could be done by donor countries.

11.4 Recommendations for future research projects in the realm of IWRM

In order to approach sustainable water resources management, the real and most relevant problems have to be tackled, or as Schön (1983) paraphrased to go fr*om the solid grounds to the swamps*. It was demonstrated that a transdisciplinary approach is necessary, since it integrate context specific and scientific knowledge, i.e. that technical rigor is embedded into a reflective and social process and thus the scientific analysis is combined with an intervention in the real world. Thus, it is recommended to apply transdisciplinarity within future applied research projects and there is a clear call for the development cooperation to integrate science and vice versa, so that theoretic state-of-the-art know-how meets case specific know how. The complexity of most water resources problems and the manifold perceptions makes it necessary to iterate between theory and action.

It would be worthwhile to explore institutional context patterns for IWRM and eventually generalizing and grouping them, e.g. into institutional context for industrialized countries, post-soviet countries, transition countries, least developed countries, etc. This could facilitate and advance the work within such regions, giving advice on to be expected institutional behavior and possible challenges.

Donor concepts like IWRM and the IWRM implementation in receiving countries should be scrutinized in terms of their willingness to integrate profound institutional analyses in the receiving countries, before the hard path is introduced.

The evaluation of research projects that aim at transdisciplinary research should not focus only on published scientific papers, but also on other aspects like capacity development activities within the case study region. This would enhance the incentives of researchers to collaborate and cooperate with local actors and local scientists. It was shown within IWAS that setting incentives for doing CD is a viable way, e.g. a joint measuring campaign, which is used for collecting scientific data *and* knowledge exchange with and CD for the practitioners. Such a measuring campaign can be also considered as a boundary object, having a meaning to different actor groups, the scientists, the practitioners and the facilitators. And convincing scientists about the importance of CD measures and about their (voluntary) participation as experts is usually also working. Sometimes, however, the participation within CD work has to be enforced. One possibility for enforcement could be to reserve a certain amount of working time for capacity development measures, which is written in the employment contracts of the scientists. This would also mirror the transdisciplinary project structure and would underscore the importance of both, research and capacity development.

The IWAS Ukraine project showed that there is a clear need for knowledge brokers who facilitate the work between scientific disciplines and especially between scientists and stakeholders. The success of transdisciplinary research depends largely on trust generation with local actors, so that a work package focusing on those collaborative processes is essential.

It would be interesting to analyse CD concepts within developed countries like Germany and compare them with the herein developed concept or with other existing approaches in development cooperation, as well as potentially delivering insights for countries attempting to improve the CD. It would be interesting to analyse how actors work together for CD in developed countries, or which policy instruments and coordination mechanisms are used.

Research has to be done on the above mentioned recommendations for extending the methodology for an integrated analysis of environmental pressures and capacity gaps. In addition, the developed boundary object needs to be extended and transferred into a practical application like a water knowledge management system for securing the long term cooperation of actors, especially between different authorities.

11.5 Recommendations for future teaching activities at TU Dresden

The profile of the Faculty of Environmental Sciences of TU Dresden (TUD) states that inter alia integrated management of water resources, sustainable development, and value added in rural regions belongs to the profile lines of the faculty. The faculty's interest in development topics can be also seen by the fact that an environmental management course program is realized at TU Dresden in collaboration inter alia with UNEP and UNESCO through the Centre for International Postgraduate Studies of Environmental Management (CIPSEM) since 1977. And currently established cooperation, e.g. with the United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES) or the Centre for Advanced Water Research (CAWR) between TUD and the Helmholtz Centre for Environmental Research-UFZ shows that there is a high interest in doing research and educational activities in the realm of sustainable development.

In terms of extending teaching activities, it is recommended to build upon the experiences from the e-learning module IWRM-education, as well as from the realization of the IWRM teaching module in Ukraine. We assume that the implementation and transfer of the IWRM teaching module to other international partner universities will have several positive effects for TUD. First of all, experiences from the realization at foreign universities have been already used for teaching at TUD and can be used in future. In fact, there was a mutual influence of this activities and the development of a module on IWRM for water related master programmes at TUD.

Moreover, also new research directions, especially in relation to transdisciplinary research, can potentially be drawn from it. However, for conducting these realizations, cooperation agreements with partner universities are the rule rather than the exception. Therefore, it is recommended that TUD revises its cooperation agreement policy, so that it is also possible to cooperate with universities that are not belonging to the list of top-ranking universities. This is especially important, because within the discourse on IWRM, the role of development countries, emerging nations as well as transition countries is essential. By encouraging training activities for actors of such countries like the IWRM teaching module, the e-learning module or blended learning concepts, the TUD can position itself as an excellent educational institution in the realm of hydrosciences and enhance its profile. An excellent inspiring example could be UNESCO-IHE in cooperation with TU Delft, Netherlands, which is the largest international graduate water education facility in the world.

11.6 Best practice

General approaches like IWRM, but also the NEXUS discussion, needs to be downscaled to practitioners. The analogy of a map fits well in this respect: The scale of the map has to be defined according to what we want to use the map for. Sometimes we need a global map and sometimes a local map depending on the problem we want to solve with the map. Additionally, we need different kinds of maps depending on the intended use; e.g. for hiking a different map is needed than for climate analysis. That means that the problem definition is essential.

Effective resources management depends on credible, salient and legitimate knowledge, i.e. iterative and frequent communication is necessary (Cash et al. 2003). There has to be a *real* exchange of information between scientists and decision makers, so that it is avoided that scientist assume what is salient for the decision makers, as well as to avoid that decision makers think that the credible know how is the (only) relevant information. A frequent communication instead of only meeting at the beginning also assures that the *current* problems are included and thus credible and salient know-how can be developed. Within the Ukrainian case study, a continuous communication assured an intensive exchange between scientist and stakeholders. This was done by regular meetings, joint measuring campaigns and continuous information updates by email and telephone. The frequency varied yet, depending also on the part of the assessment and the actors involved. It was important to ascertain the continuous communication, i.e. to recall all actors to communicate regularly, by having a person at the interface between all actors.

Mutual understanding gradually improved, however it was a long term process. Also mediation was necessary to narrow the boundaries between various actors. Yet, mediation is a difficult process as Cash et al. (2003) mentioned, meaning that the boundaries should be like a "semi-permeable membrane", letting through e.g. actors needs towards the research, but having a reduced permeability for political influences. The range is between a rigid boundary that secures credibility, but reduces saliency and a weak boundary leading to a reduced credibility by having integrated too much influence from decision makers (Ibid.).

It is vital to do a stakeholder analysis, update it regularly and assess which stakeholders are needed for the different phases and different measures within IWRM projects. In order to reduce complexity, it is reasonable to analyze the degree of stakeholders' participation needed for different measures ranging from full participation to information.

For enhancing transdisciplinary projects, it is essential to strengthen the incentives of the counterparts in the target region (Universities, Administration, Water Service Provider, NGOs, etc.) to collaborate. This can be done by assigning individual subtasks or work packages to the actors, for which they are responsible in terms of content as well as finances. These work packages need to be integrated in the overall workflow of the project, e.g. into the model-based and capacity based IWRM framework (Leidel et al. 2014). Such work packages should be defined together with the local actors, so that their perceptions are integrated. However, this is often easier said than done, because frequently, not all actors are known at the beginning, respectively it is not clear who is willing or able to participate. In addition, financing foreign actors is sometimes also difficult. For improving incentives it is also essential to develop a political and participative process that integrates relevant actors from the very beginning. To keep this process continually running throughout the project and beyond is even more important, but also more challenging. Training and education are also effective means for creating incentive structures. Taking these points into account will advance the ownership and the accountability of the local actors towards the problem and the solution within the project.

The example in the Western Bug River Basin has shown that only working with the regional and local decision making authorities is not a viable option. The national level has to be integrated. Therefore, combining bottom up *and* top-down approaches for the flow of authority is reasonable for water resources management. An emphasis should be also on network analyses, since networks exist across scales and levels. Understanding formal, but especially informal networks is one key of understanding the (non-) functioning of water resources management.

The Ukrainian case study showed that universities and research institutions have their strengths in systems analyses, impact assessments, and development of alternative management options. And they can also play a decisive role as knowledge broker and facilitator for the development process, since they are considered as impartial. Yet, if it comes to the implementation of management options they do have limitations. Time, personnel, incentives and capacities for implementation are frequently limiting factors. Therefore it is recommended to strengthen the collaboration between science and organizations of the development cooperation (DC), since the latter often have long term experiences with the country system, but can benefit from the scrutiny of scientific analyses for the further development process. Thus, a pilot project would be worthwhile, in which research institutions and organization of development cooperation work together from the very beginning, of course with local actors as described in the transdisciplinary approach of this thesis. The workloads would vary for the science and the DC during the course of the project mirroring a sinusoidal amplitude. The focus at the beginning would be on (transdisciplinary) research components, gradually shifting towards more DC work. In compliance with transdisciplinarity and adaptive management, this process has to be cycling.

11.7 Contributions to the international discussion towards sustainable water management

IWRM is a general concept, which needs to be downscaled and adapted to the national, regional and local level, so that there is an added value for water resources management practitioners. For increasing the practical value of such concepts, it is essential to align them with capacity development on all necessary administrative and capacity levels, as e.g. the harmonization of IWRM and CD processes (Leidel et al. 2012, 2014).

IWRM should be implemented within the existing organizational and institutional framework, but with enhanced cooperation and coordination between the various actors, i.e. that institutions have to be changed in such a way that they can extent cooperation. For this, clear and binding institutional settings are needed, as well as mechanisms/ instruments to govern IWRM, e.g. platforms for intra and inter-sector coordination. Such platforms are e.g. inter-ministerial commissions, RBOs, or consultation procedures like round tables. River Basin Councils and RBOs are a reasonable option for enhancing cooperation between existing authorities and resolve disputes between different water uses, yet it should be carefully assessed, which further aspects of RBM should be handed over. Experts and know-how are available in the line ministries and subordinated regional authorities, and there is in general reluctance to give away power.

Boundary objects that address credibility, salience and legitimacy are means for supporting the functioning of cooperation and coordination between actors. Based on that, it seems reasonable to establish knowledge management systems, since (I) they facilitate the collaboration of different actor groups, (ii) increase capacities and knowledge of actors, (iii) increase the transparency and salience of decisions, (iv) potentially improves credibility, and (v) information remains available, even if responsibilities within authorities and companies change frequently. Such mechanisms are also important for addressing rebound effects, e.g. improving the irrigation efficiency upstream could decrease the water availability downstream. A coordination platform could attempt to balance upstream downstream issues. And it is important to have scientists within such platforms, since they can identify critical linkages relevant for rebound effects and the overall systems behavior. For a prioritization of measures and policies for addressing adverse effects, a science policy interface is reasonable. That means that coordination mechanisms are more important in IWRM or the NEXUS discussion *than* integrating more and more issues that makes the process unmanageable. Similarly, the systems should not be as big as possible, but as big as necessary. It has to be asked, which system is the appropriate system under which conditions.

Even if coordination and cooperation is essential, it has to be acknowledged that water resources management is an inherently political process, as already ascertained by several scholars (e.g. Mollinga 2010). Thus, evidence-based decision making is not always the rule, but instead most frequently interest-based decision-making. Notwithstanding, it is important to convince decision makers that expenses for careful planning are a good investment, because sound integrated planning is essential and always cheaper than poorly designed intervention options.

Transboundary water resources management is complex and already the cooperation within one country is difficult e.g. between several provinces within a river basin or various involved actors. Thus, cooperation processes should start in the country and then be extended to adjacent countries within the river basin. Yet, if the incentives for management can be increased by integrating riparian states, then transboundary cooperation can be viable from the very beginning. An example could be the willingness of the neighboring country to improve water resources management because of water quality issues downstream, thus willing to spend efforts and finances for improving the environmental situation by stronger cooperation, coordination and institutional change in the whole basin. However, the question remains, whether the upstream country wants to cooperate, respectively on the economic perspective of how to internalize externalities. E.g. negative externalities may be internalized through side-payments in bilateral negotiations (Coase theorem). Yet, this is difficult for transboundary issues, since property rights are often not clear, information asymmetries and high transaction costs exist and often no enforcing authority is available.

The Ukrainian case study showed that research and academic education is frequently not aligned to the (new) needs of administrations, water service providers and other relevant organizations. Therefore, strengthening the relationship between universities and research institutes, authorities, as well as sector associations is vital for improving the relevancy of study courses, as well as for focusing the research on providing assistance or solutions for urgent practical problems of the other water sector organizations. The curriculum development with actors from various fields, for instance, could contribute to assure the timeliness and adequacy of the content. Within the Ukrainian case study, joint workshops between the sector association and universities, and having a working group related to improving river basin management where water administration and scientists are participating, improved the relationship and can be considered as important steps for developing knowledge networks. Based on the strengthened relationship, the curriculum for the IWRM module in Ukraine was developed by the implicit and explicit integration of knowhow from water sector actors. Yet, there is a clear need for institutionalized long-term, more donor independent networking and knowledge management, since this is more resilient than the demonstrated activities that were initiated by IWAS, which have the danger of becoming gradually inactive without having a coordination body that continuously facilitates and supports networking activities. One possibility could be, as mentioned above, the establishment of a water competence centre with a knowledge management platform for connecting actors and for continuous adaptation of strategies and thus needed knowledge and resulting research and education activities.

In summary, it can be concluded that institutional minimum standards for sustainable river basin management are (I) the establishment of competent river basin authorities for coordination and supervising tasks or assigning it to one existing authority and clearly defining responsibilities of all involved authorities, (ii) administrative arrangements for cooperation and coordination of river basin management between the involved authorities and with other relevant actors including enforcement options, and (iii) a coordination mechanism like a boundary object for supporting cooperation that comprises analytical, assessment and participatory strategies, (iv) a comprehensive river basin management plan within an iterative planning cycle based on an integrated analysis of environmental pressures and capacity gaps. Other institutional settings and solutions can be discussed and are also dependent on the context and the existing challenges. The Ukrainian case study showed that technical cooperation can be a facilitator for political processes and that it is important to start with simple objectives, then gradually extent them. This also demonstrates that a pragmatic approach to IWRM is necessary. However, a pragmatic approach should not mean to "muddle through" the problems, but to combine analytical frameworks with an operative methodology that integrates all important actors. That is what can be considered as transdisciplinary management:

Start with a preliminary situation analysis instead of hypotheses. The analysis needs to integrate scientific issues as well as local context specific issues, thus the integration of all relevant stakeholders is needed. It has to be assessed how the context *really* works, i.e. existing institutions and practices need to be understood. The Ukrainian case study showed that we have to look beyond the formal institutions "on paper" to the institutions that work in practice. Hence, trust is needed for governance and capacity analyses, and thus time is a major limiting factor. It was observed that scientists are accepted as facilitators for the political process (honest broker). The analysis leads to the identification of the dimensions/ scales and levels of the problem (spatial, temporal, jurisdictional, etc.) and the identification of the relevant systems (compartments and its interactions, borders, etc.), which usually constitutes also the frame for the solutions. The systems analysis leads to the description of impacts and the interdependencies of the impacts, e.g. between environmental pressures and capacity deficits. This has to be made transparent and has to be processed for the understanding of all actors. Management options have to be developed and discussed and its feasibility has to be assessed, in terms of political, institutional, economic, environmental, social and cultural feasibility. Yet, it clearly has to be mentioned that this is not a rational planning approach, i.e. first designing the process and the outcomes than implementing it, but instead, it is a combination of rational planning and incrementalism.

No matter how the concept is named, it is essential to get things done: diagnosis and planning, then remedy and overall evaluation. IWRM is a reasonable paradigm that is already fairly wide distributed around the world and therefore should remain as overarching concept for the transdisciplinary management of integrated water systems.

Literature

Adelman C (1993) Kurt Lewin and the Origins of Action Research, Educational Action Research, 1:1, 7-24, DOI: 10.1080/0965079930010102

Agence Française de Développement (AFD 2012): AFD, water and sanitation: A service for all, a resource for tomorrow.

Alaerts GJ, Blair TL, Hartvelt FJA (eds) (1991) A strategy for the water sector capacity building. International Institute for Hydraulic and Environmental Engineering IHE/UNDP, Delft/ New York

Alaerts GJ (1999) Institutions for River Basin Management. The Role of External Support Agencies (International Donors) in Developing Cooperative Arrangements. The World Bank, Washington, DC.

Alaerts GJ (2009) Knowledge and capacity development (KCD) as tool for institutional strengthening and change. In: Alaerts GJ, Dickinson N (eds) Water for a changing world—developing local knowledge and capacity. Delft

Alaerts GJ, Kaspersma JM (2009) Progress and challenges in knowledge and capacity development. In: Blokland M, Alaerts GJ, Kaspersma JM, Hare M (eds) Capacity development for improved water management. CRC Press, London

Ardakanian R, Hülsmann S, Johmann J (2011) Proceedings –1st International Scoping Workshop on the establishment of the United Nations University Institute for Integrated Management of Material Fluxes and of Resources (UNU-FLORES) and its Twin in Mozambique. UNU-ViE, Bonn.

Arnold JG, Srinivasin R, Muttiah RS, Williams JR (1998) Large Area Hydrologic Modeling and Assessment: Part I. Model Development. JAWRA 34(1):73-89

Barnola, JM, Raynaud D, Lorius C, and Barkov NI (2003) Historical CO2 record from the Vostok ice core. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A.

Baser H, Morgan P (2008) 'Capacity, change and performance: Study report', Discussion Paper 59B, European Centre for Development Policy Management (ECDPM), Maastricht

Baum I, Renger J, Werchota R (2009) Good governance in the water sector. In: Ernstorfer A, Stockmayer A (eds) Capacity development for good governance. Nomos, Baden–Baden, pp 30–44

Bea FX, Haas J (2005) Strategisches management. UTB, Stuttgart

Beetham D (1996) Bureaucracy . 2nd edition. Buckingham: Open University Press

Behrendt H, Huber P, Kornmilch M, Opitz D, Schmoll O, Scholz G, Uebe R (2000) Nutrient balances of German river basins. UBA-Texte, 23/2000, 261 pp

Behrendt H, Kornmilch M, Opitz D, Schmoll O, Scholz G (2002) Estimation of the nutrient inputs into river systems – experiences from German rivers. Regional Environmental Change, Volume 3, Issue 1-3, pp 107-117

Bergmann M, Jahn T, Knobloch T, Krohn W, Pohl C, Schramm E (2012) Methods for Transdisciplinary Research. A Primer for Practice. Campus Verlag, Frankfurt/Main, Germany.

Bernard HR (2011) Research Methods in Anthropology: Qualitative and Quantitative Approaches. Alta Mira Press. elSBN: 9780759112438

Berne A, Delrieu G, Creutin J, Obed C (2004) Temporal and spatial resolution of rainfall measurements required for urban hydrology. Journal of Hydrology, 299, 166-179.

Bernhofer C, Matschullat J, Bobeth A (Hrsg.) (2011) Klimaprojektionen für die REGKLAM-Modellregion Dresden. Publikationsreihe des BMBF-geförderten Projektes REGKLAM – Regionales Klimaanpassungsprogramm für die Modellregion Dresden. Heft 2. Rhombos-Verlag, Berlin. ISBN: 978-3-941216-71-6

Bernhofer C (2013) The Climate System. Lecture notes for the module Climate Change within the M.Sc. study programme Hydro Science and Engineering. Institute of Hydrology and Meteorology, Technische Universität Dresden, Germany

Bernhofer C & Leidel M (2014) Capacity Development for Research and Education: Teaching and training programmes addressing the nexus. In S. Hülsmann, & R. Ardakanian (Eds.), White Book on Advancing a Nexus Approach to the Sustainable Management of Water, Soil and Waste (pp. 41-55). Dresden: UNU-FLORES.

Bickman L and Rog DJ (1998) Introduction: Why a Handbook of Applied Social Reseach Methods? In: **Bickman L and Rog DJ (Eds.)** Handbook of Applied Social Research Methods. Sage Publications. ISBN 0-7619-0672-X.

Biswas, AK (Ed., 1978) United Nations Water Conference: Summary and Main Documents", Pergamon Press, Oxford, 217 p.

Biswas AK (2004) Integrated water resources management: a reassessment. A water forum contribution. Water Int 29(2):248–256

Biswas, AK (2009) Impacts of Megaconferences on Global Water Development and Management. In: Biswas, AK and Tortajada, C (Eds.) Impacts of Megaconferences on the Water Sector. DOI 10.1007/978-3-540-37224-0

Blokland M, Alaerts GJ, Kaspersma J, Hare (eds) (2009) Capacity development for improved water management. CRC Press, London

Blumensaat F (2010) Model-based optimisation of urban wastewater systems perspectives for the Poltva River from an engineering view point. Perspectives for the Poltva River in L'viv international conference and workshop. Deutsche Gesellschaft für Technische Zusammenarbeit (GTZ), Lviv, Ukraine

Blumensaat F, Wolfram M, Krebs P (2012) Sewer model development under minimum data requirements. Environ Earth Sci 65(5):1427–1437. doi:10.1007/s12665-011-1146-1

Blumensaat F, Tränckner J, Helm B, Kroll S, Dirckx G, Krebs P (2013) An adaptive framework to differentiate water quality impacts on a multi-scale level. Water Sci Technol 67(2):424–432

BMZ- German Federal Ministry for Economic Cooperation and Development (2006) Water Sector Strategy. Strategies 152. Bonn

Boag G, McDonald DA (2010) A critical review of public-public partnerships in water services. Water Alternatives 3: 1-25

Bormann BT, Cunningham PG, Brookes MH, Manning VW, Collopy MW (1994) Adaptive ecosystem management in the Pacific Northwest. Gen. Literature ii Tech. Rep. PNW-GTR-341. Portland, OR: U.S. Department of Agriculture, Forest Service, Pacific Northwest Research Station.

Bradbury H, Mirvis P, Neilsen E, Pasmore W (2008) Action research at work: Creating the future following the path from Lewin. In: **Reason P and Bradbury H (Eds)** The SAGE Handbook of Action Research- Participative Inquiry and Practice. SAGE Publications. London.

Buchanan JM (1975) The Samaritan's Dilemma. In: **E. S. Phelps (ed.)** Altruism, Morality and Economic Theory. Russell Sage Foundation. New York

Burgoyne JG (1994) Stakeholder analysis. In: Catherine Cassell & Gillian Symon (Eds.) Qualitative Methods in Organizational Research: A Practical Guide. Sage Publications. ISBN 978-0803987708.

Cassell C and Symon G (1994) Qualitative research in work contexts. In: Catherine Cassell & Gillian Symon (Eds.) Qualitative Methods in Organizational Research: A Practical Guide. Sage Publications. ISBN 978-0803987708.

Cassell C and Symon G (Eds.) (2004) Essential guide to qualitative methods in organizational research. Sage Publications ISBN 0 7619 4887 2.

Chech, Thomas V (2010) Principles of Water Resources: History, Development, Management, and Policy. Wiley, New York.

Chasek P, Dafoe J, Lebada AM, Leone F (2014) SUMMARY OF THE THIRTEENTH SESSION OF THE UN GENERAL ASSEMBLY OPEN WORKING GROUP ON SUSTAINABLE DEVELOPMENT GOALS: 14-19 JULY 2014. Earth Negotiations Bulletin. Vol. 32 No. 13. International Institute for Sustainable Development (IIS D). http://www.iisd.ca/download/pdf/enb3213e.pdf (accessed on 12/12/2014).

Clark TW (2002) The Policy Process: A Practical Guide for Natural Resource Professionals. New Haven, CT: Yale University Press, 2002.

Molle F, Wester P and Hirsch P (2007) River basin development and management. In: Comprehensive Assessment of Water Management in Agriculture (2007) Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. Chapter 16.London: Earthscan, and Colombo: International Water Management Institute.

Conradt T, Kaltofen M, Hentschel M, Hattermann FF, Wechsung F (2007) Impacts of global change on water-related sectors and society in a trans-boundary central European river basin—part 2: from eco-hydrology to water demand management. Adv Geosci 11:93–99. doi:10.5194/adgeo-11-93-2007

Creswell JW (2008) Research design: Qualitative, quantitative, and mixed methods approaches. SAGE Pulications. ISBN 978-1-4129-6557-6

Creswell JW (2010) Mapping the developing landscape of mixed methods research. In: **Tashakkori A and Teddlie C (Eds.)** Mixed Methods in Social and Behavioral Research. Thousand Oaks: Sage Publications.

Creswell JW and Plano Clark VL (2011) Designing and Conducting Mixed Methods Research. SAGE Publications. ISBN: 9781412975179

Creutin JD and Borga M (2003) Radar hydrology modifies the monitoring of flash flood hazard. Hydrological Processes, 17(7), 1453–1456.

Davenport TH and Prusak L (1998) Working knowledge: how organizations manage what they know. Harvard Business School Press. ISBN 1-57851-301-4.

De Silva TA (2011) Mixed methods: a reflection of its adoption in environmental reporting. Qualitative Research in Accounting & Management, Vol. 8 Iss 1 pp. 91 – 104 http://dx.doi.org/10.1108/11766091111124720 (accessed on 19/05/2015).

de Rooa Ad PJ, Ben Gouweleeuwa, Jutta Thielena, Jens Bartholmesb, Paolina Bongioannini-Cerlinib, Ezio Todinib, Paul D. Batesc, Matt Horrittd, Neil Hunterd, Keith Bevene, Florian Pappenbergere, Erdmann Heisef, Gdaly Rivinf, Michael Hilsg, Anthony Hollingsworthh, Bo Holsti, Jaap Kwadijkj, Paolo Reggianij, Marc Van Dijkj, Kai Sattlerk & Eric Sprokkereefl (2003) Development of a European flood forecasting system. International Journal of River Basin Management. Volume 1, Issue 1. DOI: 10.1080/15715124.2003.9635192

Denzin NK and Lincoln YS (2000) Introduction: The discipline and practice of qualitative research. In: N.K. Denzin & Y.S. Lincoln (eds.) Handbook of qualitative research, 1-29. Sage Publications, Thousand Oaks.

DFID (2010) Capacity Building in Research. DFID practice paper. Department for international development, UK.

Diez E, McIntosh BS (2009) A review of the factors which influence the use and usefulness of information systems. ENVIRONMENTAL MODELLING & SOFTWARE Volume: 24 Issue: 5. Pages: 588-602. DOI: 10.1016/j.envsoft.2008.10.009

Dombrowsky I (2005) Integriertes Wasserressourcen-Management als Koordinationsproblem. In: Neubert, S., Scheumann, W., Edig, A.v., Huppert, W. (Eds.), Integriertes Wasserressourcen-Management (IWRM). Ein Konzept in die Praxis überführen. Nomos, Baden-Baden, pp. 61–82.

Dombrowsky I (2010): The Role of Intra-water Sector Issue Linkage in the Resolution of Transboundary Water Conflicts, Water International 35(2): 132-149

Dombrowsky I, Hagemann N, and Houdret A 2(014) The river basin as a new scale for water governance in transition countries? A comparative study of Mongolia and Ukraine. Environmental Earth Sciences 72(12): 4705-4726.

Dukhovny V (2004) "Integrated Water Resources Management: A Reassessment" by Asit K. Biswas, Water International, 29:4, 530-531, DOI: 10.1080/02508060408691817

Earl S, Carden F, Smutylo T (2001) Outcome mapping: building learning and reflection into development programs. International Development Research Centre, Ottawa

Ertel A-M, Lupo A, Scheifhacken N, Bodnarchuk T, Manturova O, Berendonk TU, Petzoldt T (2012) Heavy load and high potential. Anthropogenic pressures and their impacts on the water quality along a lowland river (Western Bug, Ukraine). Environ Earth Sci. doi:10.1007/s12665-011-1289-0

Etheridge DM, Steele LP, Langenfelds RL, Francey RJ, Barnola J-M and Morgan VI (1998) Historical CO2 records from the Law Dome DE08, DE08-2, and DSS ice cores. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tenn., U.S.A.

European Centre for Development Policy Management (ECDPM) (2009) Capacity change and performance. Capacity development: between planned interventions and emergent processes- Implications for development cooperation. (Policy Management Brief No.22). Maastricht. ECDPM

European Commission (2007) Tools and methods Series: Reference Document No 1. Institutional Assessment and Capacity Development: Why, what and how? Luxembourg: Office for Official Publications of the European Communities. ISBN 978-92-79-04597-4

European Commission (EC) (2011) Reference Document N°6: Toolkit for Capacity Development. Luxemburg: Publications Office of the European Union. 76 p. ISBN 978–92–79–18759–9

European Environmental Agency (EEA) (1997): Air Pollution in Europe 1997. Executive summary. http://www.eea.europa.eu/publications/92-9167-059-6-sum (accessed on 26/07/2015).

European Environmental Agency (EEA) (2003): Environmental Indicators: Typology and Use in Reporting. Copenhagen. http://didattica.ambra.unibo.it/didattica/att/456d.file.pdf (accessed on 18/07/2015).

European Environmental Agency (2007): Halting the loss of biodiversity by 2010: proposal for a first set of indicators to monitor progress in Europe. EEA Technical Report, No 11/2007. Copenhagen.

Falkenmark M (1997): MAR DEL PLATA ANNIVERSARY SEMINAR- Analytical Summary. In: PROCEEDINGS Mar del Plata 20 YEAR ANNIVERSARY SEMINAR, Stockholm International Water Institute in collaboration with Stockholm Environment Institute. ISBN 91-971929-5-3.

Falkenmark M and Rockström J (2006) The New Blue and Green Water Paradigm: Breaking New Ground for Water Resources Planning and Management. JOURNAL OF WATER RESOURCES PLANNING AND MANAGEMENT.

FAME (Alternative World Water Forum) (2012) DECLARATION OF THE PARTICIPANTS AT THE ALTERNATIVE WORLD WATER FORUM IN MARSEILLE, 14 – 17 march 2012. http://www.fame2012.org/files/declaration-finale-en.pdf (accessed on 28/01/2014).

FAO (1995) Planning for sustainable use of land resources. Towards a new approach. FAO LAND AND WATER BULLETIN 2 Rome, Italy.

FAO (2003) Review of world water resources by country. Water Reports 23. Rome, Italy.

FAO (2005 Fertilizer use by crop in Ukraine. FAO, Rome, Italy.

FAO (2012) Coping with water scarcity- an action framework for agriculture and food security. FAO water reports 38. ISBN 978-92-5-107304-9. Rome, Italy.

Fielding N and Cisneros-Puebla CA (2009) CAQDAS-GIS Convergence: Toward a New Integrated Mixed Method Research Practice? Journal of Mixed Methods Research 2009; 3; 349. DOI: 10.1177/1558689809344973

Fischer A, Petersen L, Huppert W (2004) Natural Resources and Governance: Incentives for Sustainable Resource Use. A Manual. GTZ, Eschborn.

Fischer S, Pluntke T, Pavlik D et al. (2014) Hydrologic effects of climate change in a sub-basin of the Western Bug River. Environ Earth Sci, Western Ukraine. doi:10.1007/s12665-014-3256-z

Floods RL (2006) The relationship of 'Systems Thinking' to Action Research. In: Reason P and Bradbury H (Eds) (2006) Handbook of Action Research. SAGE Publications. London

Forester J (1989) Planning in the Face of Power.

Franz M (2008) Phosphate fertilizer from sewage sludge ash (SSA). Waste Management. Volume 28, Issue 10, Pages 1809–1818

Gibson CC, Andersson K, Ostrom E, Shivakumar S (2005) The Samaritan's Dilemma. The Political Economy of Development Aid. ISBN-13: 978-0-19-927885-5

Giri AK (2002) The calling of a creative transdisciplinarity. Futures 34 (2002) 103–115

Glaser B and Strauss A (1967) The Discovery of Grounded Theory. Aldine Publishing Company, Hawthorne, NY.

Gleick PH (2003) Viewpoint: Global Freshwater Resources: Soft-Path Solutions for the 21st Century. Science Vol. 302 no. 5650 pp. 1524-1528. DOI: 10.1126/ science.1089967

Global Water Partnership (2004) Catalyzing Change: A handbook for developing integrated water resources management (IWRM) and water efficiency strategies. Prepared by the GWP Technical Committee (TEC). ISBN: 91-974559-9-7.

Grambow M (2008) Wassermanagement. Integriertes Wasserressourcenmanagement von der Theorie zur Umsetzung. Vieweg & Sohn Verlag, Wiesbaden.

Grambow M (2012) Management als praktische Konkretisierung des IWRM. In: Grambow M (Hrsg.) Nachhaltige Wasserbewirtschaftung: Konzept und Umsetzung eines vernünftigen Umgangs mit dem Gemeingut Wasser. Vieweg+Teubner Verlag, Wiesbaden.

Graefe O (2011) River basins as new environmental regions? The depolitization of water management. Procedia Social and Behavioral Sciences 14 (2011) 2 –27.

Greene JC, Caracelli VJ, Graham WF (1989) Toward a Conceptual Framework for Mixed-method Evaluation Designs. Educational Evaluation and Policy Analysis, Vol 11, No. 3, pp 255-274.

Grünewald U (2008) Voraussetzungen für eine erfolgreiche Flussgebietsbewirtschaftung: Klare einzugsgebietsbezogene Ursache-Wirkungs-Analysen und klares einzugsgebietsbezogenes Handeln. KW Korrespondenz Wasserwirtschaft, 1/8, 423–426.

Giupponi C, Mysiak J, Depietri Y, Tamaro M (2007) Decision support systems for water resources management: current state and guidelines for tool development. London: IWA Publishing.

Gupta J, Termeer C, Klostermann J, Meijerink S, van den Brink M, Jong P, Nooteboom S, Bergsma E (2010) The adaptive capacity wheel: a method to assess the inherent characteristics of institutions to enable the adaptive capacity of society. Environmental Science and Policy 13: 459-471

Gupta J, Pahl-Wostl C (2013) Global water governance in the context of global and multilevel governance: its need, form, and challenges. Ecol Soc 18(4):53

Gustavsen B, Hansson A, Qvale TU (2008) Action research and the challenge of scope. In : **Reason P and Bradbury H (Eds)** The SAGE Handbook of Action Research- Participative Inquiry and Practice. SAGE Publications. London.

Guston DH (2001) Boundary organizations in environmental policy and science: an introduction. Sci Technol Hum Values 26(4):399–408

Häberli R, Bill A, Grossenbacher-Mansuy W, Thompson Klein J, Scholz RW, Welti M (2001) Synthesis. In: Thompson Klein J, Grossenbacher-Mansuy W, Häberli R, Bill A, Scholz RW, Welti M (Eds.): Transdisciplinarity - Joint Problem Solving among Science, Technology, and Society. Birkhäuser.

Hall D and Popov V (2005) Privatisation and restructuring of water supply in Russia and Ukraine. Public Services International Research Unit (PSIRU).

Hall D, Lobina E, Corral V, Hoedeman O, Terhorst P, Pigeon M, and Kishimoto S (2009) Public-public partnerships (PUPs) in water. PSI-TNI-PSIRU.

http://www.right2water.eu/sites/water/files/2009-03-W-PUPS.pdf (accessed 20 December 2015)

Hajer M and Wagenaar H (2003) Deliberative Policy Analysis: Understanding Governance in the Network Society. Cambridge University Press: Boston, MA

Hardin G (1968) Tragedy of the commons. Science Vol. 162 no. 3859 pp. 1243-1248. DOI: 10.1126/science.162.3859.1243

Hartley J (2004) Case Study Research. In: **Cassell C and Symon G (Eds.) (2004)** Essential guide to qualitative methods in organizational research. Sage Publications ISBN 0 7619 4887 2.

Ul Hassan M, Hornidge A-K, van Veldhuizen L, Akramkhanov A, Rudenko I, Djanibekov, N (2011) Follow the innovation: participatory testing and adaptation of agricultural innovations in Uzbekistan: guidelines for researchers and practitioners. ZEF, Bonn, in Collaboration with ETC Agriculture, the Netherlands.

Hedrick T, Bickman L, Rog DJ (1993) Applied research design. A practical guide. Sage Publications. ISBN 0-8039-3233-2.

Helm B, Terekhanova T, Tränckner J (2012) Attributiveness of a mass flow analysis model for integrated water resources assessment under data-scarce conditions. Water Sci Technol. doi:10.2166/wst.2012.497

Henry GT (1998) Practical Sampling. In: **Bickman L and Rog DJ (Eds.)** Handbook of Applied Social Research Methods. Sage Publications. ISBN 0-7619-0672-X.

Hense A, Panitz HJ, Schädler G, Schölzel C (2010) Teilprojekte „Dynamische regionale Simulation mit CCLM“ und „Anwendung Bayesischer Statistik auf regionale Klimaänderungen“ innerhalb des Forschungsprogramms Herausforderung Klimawandel Baden-Württemberg.

Henze M, Grady CPL, Gujer W, Marais GvR, Matsuo T (1987) Activated Sludge Model No. 1, IAWQ, London, ISSN 1010-707X.

Hoff H (2011) Understanding the Nexus. Background paper for the Bonn 2011 conference: the water, energy and food security Nexus. Stockholm Environment Institute, Stockholm

Holling CS (ed.) (1978) Adaptive Environmental Assessment and Management. John Wiley and Sons. New York.

Hornidge A-K, Mehmood U, Mollinga PP (2009) Follow the innovation - a joint experimentation and learning approach to transdisciplinary innovation research. ZEF working paper series 39, Bonn, Zentrum für Entwicklungsforschung

Hornidge A-K, Ul Hassan M (2010) From ‘plausible promises’ to transdisciplinary innovation research in Uzbekistan - process outline and lessons learnt. Rural Development News 2:53-63

Hornidge A-K, Ul Hassan M, Mollinga P (2011) Transdisciplinary innovation research in Uzbekistan - one year of ‘following the innovation’. Development in Practice 21:825-838

Howell KE (2013) An Introduction to the Philosophy of Methodology. Sage Publications. ISBN: 9781446202999

Huelsmann, S and Ardakanian R, (ed. 2014) Advancing a Nexus Approach to the Sustainable Management of Water, Soil and Waste (White Book). Dresden: UNU-FLORES.

Huitema D and Meijerink S (2014) The Politics of River Basin Organisations. Institutional design, choices, coalitions and consequences **In: Huitema D, and Meijerink S (eds.)** The Politics of River Basin Organisations. Coalitions, Institutional Design Choices and Consequences. Cheltenham, Edward Elgar.

Hüesker F, Moss T (2014) The politics of multi-scalar action in river basin management: Implementing the EU Water Framework Directive (WFD). Land Use Policy 42 (2015) 38–47.

Hunter PR (2003) Climate change and waterborne and vector-borne disease. Journal of Applied Microbiology 2003, 94, 37S–46S

Huppert W (2007) IWRM and Water Governance - Striving for ’Incentive Compatibility’ in the Water Sector. FWU Water Resources Publications. Volume No: 06 / 2007. ISSN No. 1613-1045. LARS 2007 "Catchment and Lake Research". Universitaet Siegen.

Huppert W (2012) Water Governance. Lecture within the e-learning module IWRM-education. www.iwrm-education.de

ICWE (1992) International Conference on Water and the Environment- The Dublin Statement and the Report of the Conference

IPCC (2013) Summary for Policymakers. In: Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

Ison R (2008) Systems Thinking and Practice for Action Research. In: Reason P and Bradbury H (Eds) (2008) The SAGE Handbook of Action Research- Participative Inquiry and Practice. SAGE Publications. London.

Jahn T (2008) Transdisciplinarity in the practice of research. In: Bergmann M, Schramm E (eds) Transdisziplinäre Forschung. Integrative Forschungsprozesse verstehen und bewerten. Campus Verlag, Frankfurt/Main, Germany, pp 21–37. http://www.isoe.de/uploads/media/jahn-transdisciplinarity-2008.pdf (accessed on 08/06/2015).

Janesick VJ (1998) The Dance of Qualitative Research Design: Metaphor, Methodolatry, and Meaning. In: **Norman K. Denzin, Yvonna S. Lincoln (Eds.)** Handbook of Qualitative Research. Sage Publications. ISBN: 0-7619-1435-8

Jaspers F and Gupta J (2014) Global water governance and river basin organisations. In: Huitema D, and Meijerink S (eds.) (2014) The Politics of River Basin Organisations. Coalitions, Institutional Design Choices and Consequences. Cheltenham, Edward Elgar.

Johnson RB and Onwuegbuzie AJ (2004): Mixed Methods Research: A Research Paradigm Whose Time Has Come. Educational Researcher, Vol. 33, No. 7, pp. 14–26. doi: 10.3102/0013189X033007014

Johnson RB, Onwuegbuzie AJ, Turner LA (2007) Towards a definition of mixed methods research. Journal of mixed methods research, 1(2).

Jonker, L. (2007) Integrated water resources management: The theory-praxis-nexus, a South African perspective. Physics and Chemistry of the Earth 32, Issues 15-18. pp 1257 - 1263.

Kabisch S (2014) Inter- and Transdisciplinarity in Urban-Environmental Research: A Subjective Inventory over Twenty Years. Interdisciplinary Science Reviews. Dec2014, Vol. 39 Issue 4, p392-398. 7p

Kaplan A (1999a) Organisational capacity: a different perspective, development Dossier No. 10, Non-Governmental Liaison Service. United Nations, Geneva.

Kaplan A (1999b) The developing of capacity, Community Development Resource Association Cape Town. www.cdra.org.za

Kaspersma J (2013) Competences in Context. Knowledge and Capacity Development in Public Water Management in Indonesia and the Netherlands. Dissertation. ISBN: 978-1-138-00097-1.

Keeling, CD and Whorf TP (2004) Atmospheric CO2 concentrations derived from flask air samples at sites in the SIO network. In Trends: A Compendium of Data on Global Change. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, U.S. Department of Energy, Oak Ridge, Tennessee, U.S.A.

Kemmis S (2008) Critical Theory and Participatory Action Research. In : **Reason P and Bradbury H (Eds)** The SAGE Handbook of Action Research- Participative Inquiry and Practice. SAGE Publications. London.

Kolditz O, Rink K, Shao HB et al. (2012) International viewpoint and news: data and modelling platforms in environmental Earth sciences. Environ Earth Sci 66:1279–1284. doi:10.1007/s12665- 012-1661-8

Krebs P (2012) Introduction to global water aspects. Lecture notes for the module Integrated Water Resources Management within the M.Sc. study programme Hydro Science and Engineering. Institute of Hydrology and Meteorology, Technische Universität Dresden, Germany

Länder-Arbeitsgemeinschaft Wasser (LAWA) (1996) Nationale Gewässerschutzkonzeption - Aktuelle Schwerpunkte. Beschluß der 107. LAWA-Vollversammlung am 20. 9. 1996

Leggett J, Pepper WJ, Swart RJ, Edmonds J, Meira Filho LG, Mintzer I, Wang MX, and Watson J (1992) "Emissions Scenarios for the IPCC: an Update", Climate Change 1992: The Supplementary Report to The IPCC Scientific Assessment, Cambridge University Press, UK, pp. 68-95

Leidel M, Kienberger S, Lang S, Zeil P (2009): Modelling the environmental dimension of vulnerability. Conference Volume of IALE 2009 (International Association for Landscape Ecology, Regional Chapter Germany)

Leidel M, Niemann S, Hagemann N (2012) Capacity development as key factor for integrated water resources management (IWRM): improving water management in the Western Bug River Basin, Ukraine. Environ Earth Sci., 65(5): 1415-1426, doi: 10.1007/s12665-011-1223-5

Leidel M, Niemann S, Saliha AH, Cullmann J, Seidel N, Borchardt D, Krebs P, Bernhofer C (2013) IWRM- Education: E-Learning Module on Integrated Water Resources Management. International viewpoint and news. Environ Earth Sci. Volume 68 (2): 609-613, doi: 10.1007/s12665-012-2059-3

Lewin K (1946) Action Research and Minority Problems, Journal of Social Issues, 2: 34–46. doi: 10.1111/j.1540-4560.1946.tb02295.x

Lipinskyy VM, Dyachuk VA, Babichenko VM (2003) Climate of Ukraine. Rayevskyy Publishing, Kyiv

Luijendijk J and Lincklaen Arriëns WT (2009) Bridging the knowledge gap: The value of knowledge networks. In: Blokland M, Alaerts GJ, Kaspersma JM, Hare M (eds) Capacity development for improved water management. CRC Press, London.

Lusthaus C, Adrien MH, Anderson G, Carden F and Plinio Montalvan G (2002) Organizational assessment: a framework for improving performance. International Development Research Centre/Inter-American Development Bank.

Lupo A, Coyne S, Berendonk TU (2012) Origin and Evolution of Antibiotic Resistance: The Common Mechanisms of Emergence and Spread in Water Bodies. Front Microbiol. 2012; 3: 18. doi: 10.3389/fmicb.2012.00018

Maraun D, Wetterhall F, Ireson AM, Chandler RE, Kendon EJ, Widmann M, Brienen S, Rust HW S, Sauter T, Theme M, Venema VKC, Chun KP, Goodess CM, Jones RG, Onof C, Vrac M, Thiele-Eich I (2010) Precipitation downscaling under climate change: recent developments to bridge the gap between dynamical models and the end user. Rev Geophys, RG 3003(48):1–34. doi:10.1029/2009RG000314

Marty, F. (2001): Managing international rivers: problems, politics and institutions. Berne.

Maxwell JA (1998) Designing a Qualitative Study. In: **Bickman L and Rog DJ (Eds.)** Handbook of Applied Social Research Methods. Sage Publications. ISBN 0-7619-0672-X.

Maxwell JA and Loomis, DM (2003) Mixed Methods Design: An alternative approach. In: **Tashakkori A and Teddlie C (Eds)** Handbook of mixed methods in social and b havioral research. Thousand Oaks: Sage Publications.

McMahon J (2010) Ownership, Authority and Conflict. In: Ubels J, Fowler A, Acquaye-Baddoo N-A (eds) Capacity development in practice. Earthscan, London. ISBN 978-1-84407-741-0.

Meadows DH, Meadows DL, Randers J, Behrens WW, III (1972) The Limits to Growth: A report for the Club of Rome's project on the predicament of mankind**.** Potomac Associates Book. ISBN 0–87663–165–0.

Mertens DM (2007) Transformative Paradigm: Mixed Methods and Social Justice. Journal of Mixed Methods Research; 1; 212. DOI 10.1177/1558689807302811

Messerli B and Messerli P (1979) Wirtschaftliche Entwicklung und ökologische Belastbarkeit im Berggebiet. In: Fachbeiträge zur schweizer. MAB-Information, Nr. 1.

Miles M, & Huberman M (1994) Qualitative data analysis: An expanded sourcebook (2nd ed.). Thousand Oaks, CA: Sage.

Mitchell B (2005) Integrated water resource management, institutional arrangements, and land-use planning. Environment and Planning A37:1335–1352. DOI:10.1068/a37224. http://www.envplan.com/fulltext_temp/0/a37224.pdf. (Accessed on 16/06/2015.)

Molle F (2006) Planning and Managing Water Resources at the River-basin Level: Emergence and evolution of a concept. Colombo, Sri Lanka. International Water Management Institute. 38p. (IWMI Comprehensive Assessment Research Report 16)

Mollinga PP (2006) IWRM in South Asia: A concept looking for a constituency. In: Mollinga PP, Dixit A, Athukorala K (Eds.) Integrated Water Resources Management. Global Theory, Emerging Practice and Local Needs. SAGE Publications. ISBN: 9780761935490

Mollinga PP (2008) The rational organisation of dissent. Boundary concepts, boundary objects and boundary settings in the interdisciplinary study of natural resources management. ZEFWorking Paper Series, Center for Development Research, University of Bonn, Bonn

Mollinga PP (2010) Boundary work and the complexity of natural resources management. Crop Sci 50:S-1–S-9. doi:10.2135/ cropsci2009.10.0570

Morgan P and Taschereau S (1996) CAPACITY AND INSTITUTIONAL ASSESSMENT: Frameworks, Methods and Tools for Analysis. Prepared for CIDA Policy Branch. Canadian International Development Agency.

Morgan DL (2007) Paradigms lost and pragmatism regained. Methodological Implications of Combining Qualitative and Quantitative Methods. Journal of Mixed Methods Research, 1 (1). doi: 10.1177/2345678906292462

Morse GK, Brett SW, Guy JA, Lester JN (1998) Review: Phosphorus removal and recovery technologies. Science of The Total Environment. Volume 212, Issue 1, Pages 69–81

Moss RH, Jae A. Edmonds, Kathy A. Hibbard, Martin R. Manning, Steven K. Rose, Detlef P. van Vuuren, Timothy R. Carter, Seita Emori, Mikiko Kainuma, Tom Kram (2010) The next generation of scenarios for climate change research and assessment. Nature 463, p. 747-756. doi:10.1038/nature08823

Moss T (2003) Solving Problems of "Fit" at the Expense of Problems of "Interplay"? The Spatial Reorganisation of Water Management Following the EU Water Framework Directive. In: Breit, H., Engels, A., Moss, T., & Troja, M. (eds.), How Institutions Change. Perspectives of Social Learning in Global and Local Environmental Contexts. Opladen, Leske & Budrich: 85-122.

Moss T (2006) Solving Problems of "Fit" at the Expense of Problems of "Interplay"? The Spatial Reorganisation of Water Management following the EU Water Framework Directive. In: Mollinga P, Dixit A, Athukorala K (Eds.) Integrated Water Resources Management. Global Theory. Emerging Practice and Local Needs. Sage Publications.

Moss T (2012) Spatial Fit, from Panacea to Practice: Implementing the EU Water Framework Directive. Ecology and Society 17(3): 2.http://dx.doi.org/10.5751/ES-04821-170302

Moss T, Newig J (2010) Multilevel water governance and problems of scale: setting the stage for a broader debate. Environ Manag 46(1):1–6. doi:10.1007/s00267-010-9531-1

Muller M (2010) Fit for purpose: taking integrated water resource management back to basics. Irrig Drainage Syst (2010) 24:161–175. DOI 10.1007/s10795-010-9105-7

National Oceanic and Atmospheric Administration (NOAA) (2015) Annual mean CO2 concentrations from 1959-2014. NOAA ESRL DATA.

ftp://aftp.cmdl.noaa.gov/products/trends/co2/co2_annmean_mlo.txt (accessed on 21/04/2015)

Najlis P and Kuylenstierna JL (1997) TWENTY YEARS AFTER MAR DEL PLATA - WHERE DO WE STAND AND WHERE DO WE GO? In: PROCEEDINGS Mar del Plata 20 YEAR ANNIVERSARY SEMINAR, Stockholm International Water Institute in collaboration with Stockholm Environment Institute. ISBN 91-971929-5-3.

Network of Heads of European Environment Protection Agencies on the Thematic Strategy on the Sustainable Use of Natural Resources (2006) Delivering the sustainable use of natural resources. http://www.umweltbundesamt.de/energie/archiv/EPA_resourcespaper_2006.pdf (accessed on 01/08/2015).

Neuman WL (2000) Social Research Methods: Qualitative and Quantitative Approaches. Allyn and Bacon Pub (4th ed). ISBN 0205297714

Nightingale A (2003) A feminist in the forest: situated knowledge and mixing methods in natural resources management. ACME: An International E-Journal for critical Geographies, 2 (1).

Niemann S (2005) IWRM und interbasinaler Wassertransfer - ein potenzieller Konflikt? In: S. Neubert, W. Scheumann, A. van Edig & W. Huppert (Eds), Integriertes Wasserressourcen-Management (IWRM). Ein Konzept in die Praxis ueberfuehren. Deutsches Institut für Entwicklungspolitik DIE (pp. 83-95). Baden-Baden: Nomos.

Nonaka I and Takeuchi H (1995) The knowledge creating company: how Japanese companies create the dynamics of innovation. New York: Oxford University Press ISBN 978-0-19-509269-1.

North DC (1990) Institutions, Institutional Change and Economic Performance, Cambridge: Cambridge University Press

North DC (1991) Institutions. The Journal of Economic Perspectives Vol. 5, No. 1 (Winter, 1991), pp. 97-112 Published by: American Economic Association. Stable URL: http://www.jstor.org/stable/1942704 (accessed on 13/05/2015)

Novak JD, and Gowin DB (1984) Learning How to Learn. New York, NY: Cambridge University Press.

Novak J, and Canas A (2007) Theoretical origins of concept maps, how to construct them and uses in education, Reflecting Education, 3(1), 29-42.

Organization for economic cooperation and development (OECD) (2006) The challenge of capacity development: working towards good practice, OECD, Paris

OECD (2012) Meeting the Water Reform Challenge, OECD Studies on Water, OECD Publishing. http://dx.doi.org/10.1787/9789264170001-en

Ostrom E (1990) Governing the Commons: The Evolution of Institutions for Collective Action. Cambridge University Press.

Ostrom E, Gibson C, Shivakumar S, and Andersson K (2001). Aid, Incentives and Sustainability. An Institutional Analysis of Development Cooperation. Indiana University. Workshop in Political Theory and Policy Analysis

Ostrom E (2005) Understanding Institutional Diversity. Princeton University Press, Princeton.

Otoo, S., Agapitova, N., Behrens, J. (2009) The Capacity Development Results Framework. A strategic and results-oriented approach to learning for capacity development. **World Bank Institute (WBI**).

Pahl-Wostl C (2004) The Implications of Complexity for Integrated Resources Management. In: **Pahl-Wostl C, Schmidt S, and Jakeman T (Eds.)** Complexity and Integrated Resources Management. International Environmental Modelling and Software Society, Osnabrück, Germany.

Pahl-Wostl C (2008) Requirements for Adaptive Water Management. In: Pahl-Wostl C, Kabat P, Möltgen J (Eds.) Adaptive and Integrated Water Management, pp 1-22. Springer.

Pahl-Wostl C, Sendzimir J, Jeffrey P, Aerts J, Berkamp, G and Cross K (2007) Managing change toward adaptive water management through social learning. Ecology and Society 12(2):30

Pahl-Wostl C (2009) A conceptual framework for analysing adaptive capacity and multi-level learning processes in resource governance regimes. Global Environmental Change 19 (2009) 354–365.

Pahl-Wostl C, Lebel L, Knieper C, Nikitina E (2012) From applying panaceas to mastering complexity: Toward adaptive water governance in river basins. Environmental Science & Policy 23: 24–34

Palinkas LA, Aarons GA, Horwitz SM, Chamberlain P, Hurlburt M, Landsverk J (2011) Mixed method designs in implementation research. Administration and Policy in Mental Health and Mental Health Services Research, 38, 44–53.

Palinkas LA, Horwitz SM, Green CA, Wisdom JP, Duan N, Hoagwood K (2013) Purposeful Sampling for Qualitative Data Collection and Analysis in Mixed Method Implementation Research. Adm Policy Ment Health. DOI 10.1007/s10488-013-0528-y

Parcell G (2010) Knowledge networking. Learning together: Knowledge networks in Capacity Development Initiatives. In: Ubels J, Fowler A, Acquaye- Baddoo N-A (eds) Capacity development in practice. Earthscan, London. ISBN 978-1-84407-741-0.

Patton MQ (2002) Qualitative research and evaluation methods (3rd ed.). Thousand Oaks, CA: Sage.

Pavlik D, Sohl D, Pluntke T, Mykhnovych A, Bernhofer C (2012) Dynamic downscaling of global climate projections for Eastern Europe with a horizontal resolution of 7 km. Environ Earth Sci 65(5):1475–1482. doi:10.1007/s12665-011-1081-1

Pavlik D, Soehl D, Pluntke T, Bernhofer C (2014) Climate change in the Western Bug river basin and the impact on future hydro-climatic conditions. Environ Earth Sci. doi:10.1007/s12665-014-3068-1

Pearson J (2011) Learning Package on Capacity Development. Learning Network on Capacity Development (LenCD). http://www.lencd.org/learning. Accessed on 20/05/2105.

Peirce CS (1974) Collected papers of Charles Sander Peirce (Vol I-VI). Belknap Press of Harvard University Press.

Peterson, G., G.A. De Leo, J.J. Hellmann, M.A. Janssen, A. Kinzig, J.R. Malcolm, K.L. O'Brien, S.E. Pope, D.S. Rothman, E. Shevliakova, and R.R.T. Tinch (1997) Uncertainty, Climate Change, and Adaptive Management. Conservation Ecology [online] 1(2): 4. http://www.consecol.org/vol1/iss2/art4/ (accessed on 12/06/2015).

Plano Clark VL, and Badiee M (2010) Research questions in mixed methods research. In: **Tashakkori A and Teddlie C (Eds.) (2010)** Mixed Methods un Social and Behavioral Research Thousand Oaks: Sage Publications.

Pluntke T, Pavlik D, Bernhofer C (2014) Reducing uncertainty in hydrological modelling in a data sparse region. Environ Earth Sci. doi:10.1007/s12665-014-3252-3

Pohl C, Hirsch Hadorn G (2007) Principles for designing transdisciplinary research. Proposed by the Swiss Academies of Arts and Sciences. München: oekom verlag, Germany.

Pohl C, Hirsch Hadorn G (2008) Methodological challenges of transdisciplinary research. Nat Sci Soc 16:111–121. doi:10.1051/nss:2008035

Pohl C, von Kerkhoff L, Hirsch Hadorn G, Bammer G (2008) "Core Terms in Transdisciplinary Research". In Handbook of Transdisciplinary Research, edited by G. Hirsch Hadorn, H. Hoffmann-

Riem, S. Biber-Klemm, W. Grossenbacher-Mansuy, D. Joye, C. Pohl, U. Wiesmann, and E. Zemp, chapter 28, p. 427-432. Dordrecht: Springer.

Polany M (1966) The Tacit Dimension. Routledge and Kegan. London.

Popper KR (1974) Objektive Erkenntnis. Ein evolutionärer Entwurf. ISBN 3-455-09088-5.

Probst G, Romhardt, K, Raub S (2003) Wissen managen- wie Unternehmen ihre wertvollste Ressource optimal nutzen. Gabler Verlag. Wiesbaden.

Reason P and Bradbury H (Eds) (2006) Handbook of Action Research. SAGE Publications. London

Reason P and Bradbury H (Eds) (2008) The SAGE Handbook of Action Research- Participative Inquiry and Practice. SAGE Publications. London.

Renn O (2005) 'Partizipation – ein schillernder Begriff.' GAIA - Ecological Perspectives for Science and Society 14 (3): 227-28

Rittel HWJ and Webber MM (1973) Dilemmas in a general theory of planning. Policy Sciences. Volume 4, Issue 2, pp 155-169. DOI: 10.1007/BF01405730.

Rockel B, Will A, Hense A (2008) The Regional Climate Model COSMO-CLM (CCLM). Meteorol Z 17:347–348

Rockström, J (2003) Water for food and nature in drought-prone tropics: vapour shift in rain-fed agriculture. Phil. Trans. R. Soc. Lond. B (2003) 358, 1997–2009. DOI 10.1098/rstb.2003.1400

Roe M (2013) Maritime Governance and Policy-Making. DOI: 10.1007/978-1-4471-4153-2_2, Springer-Verlag London 2013

Rog DJ (1994) Expanding the boundaries of evaluation: Strategies for refining and evaluating ill-defined interventions. In: **Friedman SL, and Haywood HC (Eds.)** Developmental Follow-Up : Concepts, Domains, and Methods. ISBN: 9780122678554.

Rogers, P, and Hall, J-P (2003) Effective water governance. TEC Background Papers No. 7. Global Water Partnership, Stockholm.

Rosenau J (1992). Governance, Order, and Changes in World Politics. in Rosenau J and Czempiel E (Eds.) Governance without Government: Order and Change in World Politics. Cambridge University Press. pp. 1-29.

Roux DJ, Rogers KH, Biggs HC, Ashton PJ, and Sergeant A (2006) Bridging the Science-Management Divide: Moving from Unidirectional Knowledge Transfer to Knowledge Interfacing and Sharing. Ecology and Society 11(1): 4.

Rowley J (2007) The wisdom hierarchy: representations of the DIKW hierarchy. Journal of Information Science April 2007 33: 163-180, first published on February 15, 2007 doi:10.1177/0165551506070706

Ruhrverband (2003): Water management on the Ruhr- the historical collection.

Rüegg-Stürm J (2002) Das neue St. Galler Management-Modell / Grundkategorien einer modernen Managementlehre - der HSG-Ansatz. Bern. ISBN 3258065349

Sangati M and Borga M (2009) Influence of rainfall spatial resolution on flash flood modeling. Nat. Hazards Earth Syst. Sci., 9, 575-584, 2009. doi:10.5194/nhess-9-575-2009

Schanze J, Daschkeit A (2013) Risiken und Chancen des Klimawandels. In: Birkmann, J.; Vollmer, M.; Schanze, J. (Eds.) : Raumentwicklung im Klimawandel - Herausforderungen für die räumliche Planung. Hannover : ARL, 2013, (Forschungsberichte der ARL; 2), S.69-89.

Schanze J, Trümper J, Burmeister C, Pavlik D, Kruhlov I (2012) A methodology for dealing with regional change in integrated water resources management. Environ Earth Sci 65(5): 1405–1414. doi:10.1007/s12665-011-1311-6

Scheifhacken N, Haase U, Gram-Radu L, Kozovyi R, Berendonk TU (2012) How to assess hydromorphology? A comparison of Ukrainian and German approaches. Environ Earth Sci. doi:10.1007/s12665-011-1218-2

Scholz RW (2011) Environmental Literacy in Science and Society: From Knowledge to Decisions. Cambridge University Press. ISBN-13: 978-0521183338

Schön DA (1983) The reflective practitioner - how professionals think in action. Basic Books. ISBN 0465068782

Schubert S and Gupta J (2013) Comparing global coordination mechanisms on energy, environment, and water. Ecology and Society 18(2): 22. http://dx.doi.org/10.5751/ES-05440-180222

Shanahan P, Borchardt D, Henze M, Rauch W, Reichert P, Somlyódy L, Vanrolleghem PA (2001) River Water Quality Model no. 1 (RWQM1): I. Modelling approach. Wat. Sci. Tech., 43 (5), 1–9

Sigel K, Hagemann N, Leidel M, Niemann S, and Weigelt C (2014) Insights regarding transdisciplinarity and knowledge transfer gained from two case studies on integrated water resources management in Ukraine and Mongolia. Interdisciplinary Science Review 39(4), 343-361.

Snider SB & Brimlow JN (2013) An Introduction to Population Growth. Nature Education Knowledge 4(4):3

Solanes M and Gonzalez-Villarreal F (1999) The Dublin Principles for Water as Reflected in a Comparative Assessment of Institutional and Legal Arrangements for Integrated Water Resources Management. GWP-TAC Background papers No.3. Global Water Partnership. ISBN: 91-586-7668-6

Staudt E, Kailer N, Kottmann M, Kriegesmann B, Meier AJ, Muschik C, Stephan H, Ziegler A (2002) Kompetenzentwicklung und Innovation. Die Rolle der Kompetenz bei Organisations-, Unternehmens- und Regionalentwicklung. Edition QUEM. Waxmann Verlag GmbH.

Steffen W, Sanderson A, Tyson PD, Jäger J, Matson PA, Moore III B, Oldfield F, Richardson K, Schellnhuber HJ, Turner II BL, Wasson RJ (2004) Global Change and the Earth System. A Planet Under Pressure. Springer.

Stephens W and Middleton T (2002) Why has the uptake of decision support systems been so poor? In: Matthews R and Stephens W (Eds.) Crop-soil simulation models: applications in developing countries. Wallingford: CAB International; p. 129–147.

Stewart A, Edwards D, Lawrence A (2014) Improving the science–policy–practice interface: decision support system uptake and use in the forestry sector in Great Britain Scandinavian Journal of Forest Research Volume 29. DOI:10.1080/02827581.2013.849358

Surowiecki J (2004) The wisdom of crowds. Why the Many Are Smarter Than the Few. Anchor books, London. ISBN 0-385-72170-6.

Swyngedouw E (1999) Modernity and hybridity: Nature, regeneracionismo, and the production of the Spanish waterscape, 1890-1930. Annals of the Association of American Geographers, 89(3), 443-465.

TACIS (2001) Transboundary Water Quality Monitoring and Assessment: Bug and Latorica/Uzh, Kyiv. Summary report and recommendations of the project.

Tashakkori A and Teddlie C (1998) Mixed methodology: Combining qualitative and quantitative approaches. Thousand Oaks: Sage Publications.

Tashakkori A and Teddlie C (Eds.) (2010) Mixed Methods in Social and Behavioral Research Thousand Oaks: Sage Publications.

Teddlie C and Yu F (2007) Mixed Methods Sampling: A Typology With Examples. Journal of Mixed Methods Research January 2007 1: 77-100, doi:10.1177/2345678906292430

Teddlie C and Tashakkori A (2009) The foundations of mixed methods research: Integrating quantitative and qualitative techniques in the social and behavioural sciences. Thousand Oaks. Sage.

Teutsch G and Krueger E (Eds. 2010) Water Science Alliance- White Paper, Priority Research Fields.

Turnhout E (2009) The effectiveness of boundary objects: the case of ecological indicators. SCIENCE AND PUBLIC POLICY. DOI: 10.3152/030234209X442007

Ubels J, Fowler A, Acquaye-Baddoo N-A (eds) (2010a) Capacity development in practice. Earthscan, London. ISBN 978-1-84407-741-0.

Ubels J, Fowler A, Acquaye-Baddoo N-A (2010b) Learning about the field of capacity development: characteristics, practitioner challenges and future perspectives. In: Ubels J, Fowler A, Acquaye- Baddoo N-A (eds) Capacity development in practice. Earthscan, London. ISBN 978-1-84407-741-0.

Uhlenbrook S, De Jong E (2012) T-shaped competency profile for water professionals of the future. Hydrology and Earth System Sciences, 16 (10), 3475-3483

United Nations (UN) (1997) Programme for the Further Implementation of Agenda 21. Adopted by the General Assembly at its nineteenth special session (23-28 June 1997)

United Nations (UN) (2013): The Millennium Development Goals Report 2013. New York.

United Nations Division for Economic and Social Information (UN DESI) (1983) Mar del Plata action plan : United Nations Water Conference, Mar del Plata, Argentina, 14-25 March 1977. New York, NY, USA.

UNCED (1992) REPORT OF THE UNITED NATIONS CONFERENCE ON ENVIRONMENT AND DEVELOPMENT. Annex I: RIO DECLARATION ON ENVIRONMENT AND DEVELOPMENT (Rio de Janeiro, 3-14 June 1992). Posted online by the United Nations Department of Economic and Social Affairs (DESA) http://www.un.org/documents/ga/conf151/aconf15126-1annex1.htm (accessed on 15/01/2015)

United Nations Department of Economic and Social Affairs (UN-DESA) (1999) Resolution 1996/50 of the UN Economic and Social Council on Integrated water resources development and management.

http://www.un.org/documents/ecosoc/res/1996/eres1996-50.htm (Accessed on 22/01/15)

United Nations, Department of Economic and Social Affairs, Population Division (UN-DESA) (2014). World Urbanization Prospects: The 2014 Revision, Highlights (ST/ESA/SER.A/352).

UNICEF/WHO (2015) Progress on sanitation and drinking water – 2015 update and MDG assessment. ISBN 978 92 4 150914 5.

UN/ ISDR (2005): Hyogo Framework for Action 2005-2015: I S D R International Strategy for Disaster Reduction. Building the Resilience of Nations and Communities to Disasters.

UN-Water (2008) Status report on IWRM and water efficiency plans for CSD16

van der Zaag P (2005) Integrated Water Resources Management: Relevant concept or irrelevant buzzword? A capacity building and research agenda for Southern Africa. Physics and Chemistry of the Earth, Vol. 30, Issues 11–16, 2005, Pages 867–871 Doi:10.1016/j.pce.2005.08.032

Vannote, R. R., G. W. Minshall, K. W. Cummins, J. R. Sedell, and C. E. Cushing. (1980) The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37: 130-137

von Keitz S and Kessler P (2008) Grenzen des Flussgebietsmanagements. Folgt die Wasserwirtschaft dem falschen Ansatz? Korrespondenz Wasserwirtschaft 7, 354-360.

Vörösmarty CJ, Green P, Salisbury J, Lammers RB (2000): Global Water Resources: Vulnerability from Climate Change and Population Growth. Science 289 (5477), 284-288. DOI:10.1126/science.289.5477.284.

C. J. Vörösmarty, P. B. McIntyre, M. O. Gessner, D. Dudgeon, A. Prusevich, P. Green, S. Glidden, S. E. Bunn, C. A. Sullivan, C. Reidy Liermann & P. M. Davies (2010) Global threats to human water security and river biodiversity. Nature 467, 555–561, doi:10.1038/nature09440

Wahren FT, Tarasiuk M, Mykhnovych A, Kit M, Feger KH, Schwärzel K (2012) Estimation of spatially distributed soil information: dealing with data shortages in the Western Bug basin Ukraine. Environ Earth Sci 65(5):1501–1510

Walters C (1997) Challenges in adaptive management of riparian and coastal ecosystems. Conservation Ecology. http://www.consecol.org/vol1/iss2/art1/ (accessed on 12/05/15).

Ward, JV (1989) The four-dimensional nature of lotic ecosystems. J. N. Am. Benthol. Soc., 8(1):2-8

Wetterhall F, He Y, Cloke H, Pappenberger F (2011) Effects of temporal resolution of input precipitation on the performance of hydrological forecasting. Adv. Geosci., 29, 21–25. doi:10.5194/adgeo-29-21-2011

Wolff G and Gleick PH (2002) The soft path for water. In: Gleick PH, Burns WCG, Chalecki EL et al. (eds) The World's Water 2002–2003 The Biennial Report on Freshwater Resources, pp. 1–32. Washington DC. Island Press

Woodhill J (2010) Multiple actors. Capacity lives between multiple stakeholders. In: Ubels J, Fowler A, Acquaye-Baddoo N-A (eds) Capacity development in practice. Earthscan, London

World Bank (1998) World Development Report 1998/1999: Knowledge for Development. New York: Oxford University Press. © World Bank.. www.wdronline.worldbank.org/handle/10986/5981 (accessed on 29/05/2015).

World Water Council (WWC) (2014) List of members, classified by college. http://www.worldwatercouncil.org/fileadmin/world_water_council/documents/wwc-membership/List_of_Members_per_college_April_2014.pdf (accessed on 23/01/2015)

WWAP (World Water Assessment Programme) (2006) The United Nations World Water Development Report 2: Water, a Shared Responsibility. Paris. UNESCO.

WWAP (World Water Assessment Programme) (2012) The United Nations World Water Development Report 4: Managing Water under Uncertainty and Risk. Paris. UNESCO.

Yin RK (2009) Case Study Research: Design and Methods. 4th ed. Sage Publications. ISBN 978-1-4129-6099-1

Zeeuw A, de (2000) Resource Management: Do we need public policy? http://ec.europa.eu/environment/enveco/waste/pdf/zeeuw.pdf (accessed on 08/08/2015).

List of Figures

List of Tables

Important Abbreviations

CD	Capacity Development
DSS	Decision Support System
EEA	European Environment Agency
ENSO	El Niño/Southern Oscillation
EUROSTAT	Statistical Office of the European Communities
FAO	Food and Agriculture Organization of the United Nations
GEF	Global Environment Facility
GHG	Greenhouse gases
GWP	Global Water Partnership
HDI	Human Development Index
IPPC	Intergovernmental Panel on Climate Change
IWRM	Integrated Water Resources Management
LAWA	German Working Group on water issues of the Federal States and the Federal Government represented by the Federal Environment Ministry (Bund/Länder-Arbeitsgemeinschaft Wasser)
MDGs	Millennium Development Goals
NGO	Non-governmental organization
RBM	River Basin Management
RS	Remote Sensing
SPI	Science-Policy-Interface
TR	Transdisciplinary Research
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environmental Programme

UNESCO-IHP	UNESCO International Hydrological Programme
UNU-FLORES	United Nations University Institute for Integrated Management of Material Fluxes and of Resources
WBRB	Western Bug River Basin
WISE	Water Information System for Europe
WFD	Water Framework Directive
WWDR	World Water Development Report
WWTP	Wastewater Treatment Plant

Acknowledgement

I would like to express my gratitude to Prof. Dr. Christian Bernhofer for providing me the opportunity to work in the Institute of Hydrology and Meteorology, for interesting personal and scientific discussions, for the freedom of doing this research and for the supervision of the dissertation. Furthermore I would like to thank Prof. Dr. Peter Krebs for being my second supervisor and being an advocate for strengthening capacity development within water management in his role as the coordinator of the IWAS-project. Special thanks to Prof. Dr. Guy Alaerts who accepted to review my dissertation even though he is very busy in working on water resources management worldwide.

This work was partially supported by funding from the German Federal Ministry for Education and Research (BMBF) in the framework of the project "IWAS—International Water Research Alliance Saxony". I am thankful to the whole IWAS team for inspiring discussions and good cooperation, in particular Jörg Seegert, Dr. Steffen Niemann, Corinna Weigelt, Björn Helm, Dr. Frank Blumensaat and Dr. Nina Hagemann. It was a pleasure working with you! In the context of the IWAS project, I got to know many interesting persons with whom I had great discussions and experiences, in particular: Dr. Johannes Cullmann, Dr. Stephan von Keitz, and Dr. Walter Huppert.

Further I would like to extend my thanks to the co-authors of my publications, who have contributed to the quality of this research.

I must send thanks to the whole team of the Chair of Meteorology for the great working atmosphere. I am especially thankful to Dr. Klemens Barfus, who gave me valuable remarks about my thesis and I always appreciate the discussions with him. And thanks for introducing me to the world of climbing…it's never too late for claiming a place in the squad! Further I would like to extend my thanks to Dr. Johannes Franke for exciting discussions on all relevant aspects of life and for some great mountaineering activities.

For proofreading, I am also grateful to Kristina Brust, Jörg Seegert, Klemens Barfus and Steffen Niemann.

Most importantly, special thanks to my partner in life, Kerstin and her patience with me!

Last but not least, I am indebted to my friends and to my parents, who have always supported and encouraged me to do my best in all matters of life.

Erklärung

Ich versichere, dass ich meine Dissertation ohne Hilfe Dritter und ohne Benutzung anderer als der angegebenen Quellen und Hilfsmittel angefertigt und die den benutzten Quellen wörtlich oder inhaltlich entnommenen Stellen als solche kenntlich gemacht habe. Diese Arbeit hat in gleicher oder ähnlicher Form noch keiner Prüfungsbehörde vorgelegen.

Nachname: Leidel Vorname: Marco

Unterschrift: ____________________