Governance of groundwater ecosystem service trade-offs in Gauteng, South Africa – An institutional analysis

Charlotte Beckh[1]

Abstract

The governance of groundwater ecosystem services and trade-offs is still poorly understood. The highly urbanized South African province Gauteng currently faces problems of groundwater over-abstraction and pollution. Population growth, economic development and climate change impacts contribute to an increasing risk of crisis. Groundwater trade-offs between diverse user sectors with conflicting resources interests are apparent. The South African National Water Act makes sophisticated provisions for ecosystem services and trade-offs that are not always effective in practice. The paper thus asks the question: How are groundwater ecosystem service trade-offs governed in practice in Gauteng? The paper offers answers to this question through a review of relevant literature and the qualitative analysis of 41 interviews conducted with experts from the government, science, and society. The results confirm that formal institutions are frequently ineffective, and applied and enforced in a biased manner, prioritizing socio-economic development over environmental sustainability. The analysis of informal institutions and their interplay with formal ones unveils deep-seated reasons for the ineffectiveness of current groundwater governance. Four informal institutions in terms of socially shared expectations have been identified that compete with formal institutions. In contrast, networks from the informal realm enhance the effectiveness of formal institutions and governance. While self-regulation and networking need to be fostered, governance through a hierarchical command-and-control approach is preferred and market mechanisms are generally met with suspicion by civil society. The paper argues that a holistic approach and political will is needed for translating existing formal institutions into social practice while unlocking the potential of civil society. Mainstreaming the concept of ecosystem services and related trade-offs into the groundwater governance discourse and practice, as well as the consideration of informal institutions, can lead to improved decision-making and more effective and sustainable groundwater governance.

Keywords*:* governance, groundwater, ecosystem service trade-offs, formal and informal institutions, modes of governance, South Africa

[1]Institute for Advanced Sustainability Studies (IASS) Potsdam
Email: charlotte.beckh@iass-potsdam.de

1 INTRODUCTION

In the face of climate change, economic development, population growth and an associated growing demand for water, the pressure on freshwater resources is constantly increasing (Carpenter and Biggs, 2009; Rodríguez et al., 2006). Given that the semi-arid country of South Africa is water-stressed and its surface water resources have been developed to their capacity, groundwater and its ecosystem services are growing in importance (Braune, 2000; Kelbe and Rawlins, 2004). Yet they are often forgotten, misunderstood, undervalued and mismanaged (Braune, 2000; Burke and Moench, 2000; DWA, 2010; Knüppe, 2011).

In the South African province of Gauteng, high yielding dolomitic aquifers provide groundwater for domestic uses, agriculture, mining, and the environment. These different user sectors have conflicting interests in groundwater ecosystem services regarding quantity and quality, and heavily impact the resource through over-abstraction and pollution (DACE, 2004; DWA, 2010; Kelbe and Rawlins, 2004). Since the diverging claims can often not be satisfied simultaneously and ecosystem services are interdependent, trade-offs occur. Governing these trade-offs is a major challenge. Society tries to balance these trade-offs by devising formal and informal institutions and governance modes which influence societal behavior in such a way that the normative goal of human well-being and sustainability may be achieved. South Africa's National Water Act (NWA) of 1998 is amongst the most modern and progressive water legislations worldwide that addresses ecosystem services and trade-offs (Carpenter and Biggs, 2009; MacKay, 2003; Quibell, 2007). However, the implementation of this innovative formal institution is still being hampered (DWA, 2010; Knüppe, 2011; Quibell, 2007). This raises the question of how the reality gap between de jure and de facto governance can be closed. Informal institutions such as common sense practices and traditions might be well in place for managing the use and trade-offs of groundwater ecosystem services (Colvin and Saayman, 2007; Kapfudzaruwa and Sowman, 2009; Malzbender et al., 2005).

The purpose of this study is thus to explore how groundwater ecosystem service trade-offs are governed in Gauteng, South Africa. The amount of literature on groundwater governance in general (e.g. Burke and Moench, 2000; Foster et al., 2010; Lopez-Gunn et al., 2011; Theesfeld, 2010), groundwater governance in South Africa (e.g. Colvin and Saayman, 2007; Kelbe and Rawlins, 2004; Knüppe, 2011; Pietersen et al., 2011; Seward et al., 2006; Seward, 2010) and groundwater ecosystem services, including related trade-offs (e.g. Avramov et al., 2010; Bergkamp and Cross, 2006; Danielopol et al., 2003; Danielopol et al., 2008) is growing continuously, but explorative studies dealing with the linkages and complexities of groundwater institutions remain weak. This study aims to contribute to this body of literature while taking on an institutional lens and focusing on Gauteng.

This paper is divided into 6 sections. The first section presents the current state of knowledge regarding groundwater ecosystem service trade-offs, the groundwater situation in Gauteng, and South Africa's groundwater governance system. The second section explains the theoretical framework used for the institutional analysis including the interplay of formal and informal institutions, and different modes of governance. The third section describes the methods employed to gain the empirical basis of the study. The results derived from the expert interviews are summarized in the fourth section to provide insights into the role of informal institutions and the influence and potential of markets, bureaucratic hierarchies and networks for South Africa's groundwater governance. The results are discussed in relation to the current state of knowledge and the theory of institutions in the fifth section. Finally,

concluding remarks and suggestions for research and policy are provided in the sixth section.

2 CURRENT STATE OF KNOWLEDGE

2.1 Groundwater ecosystem service trade-offs

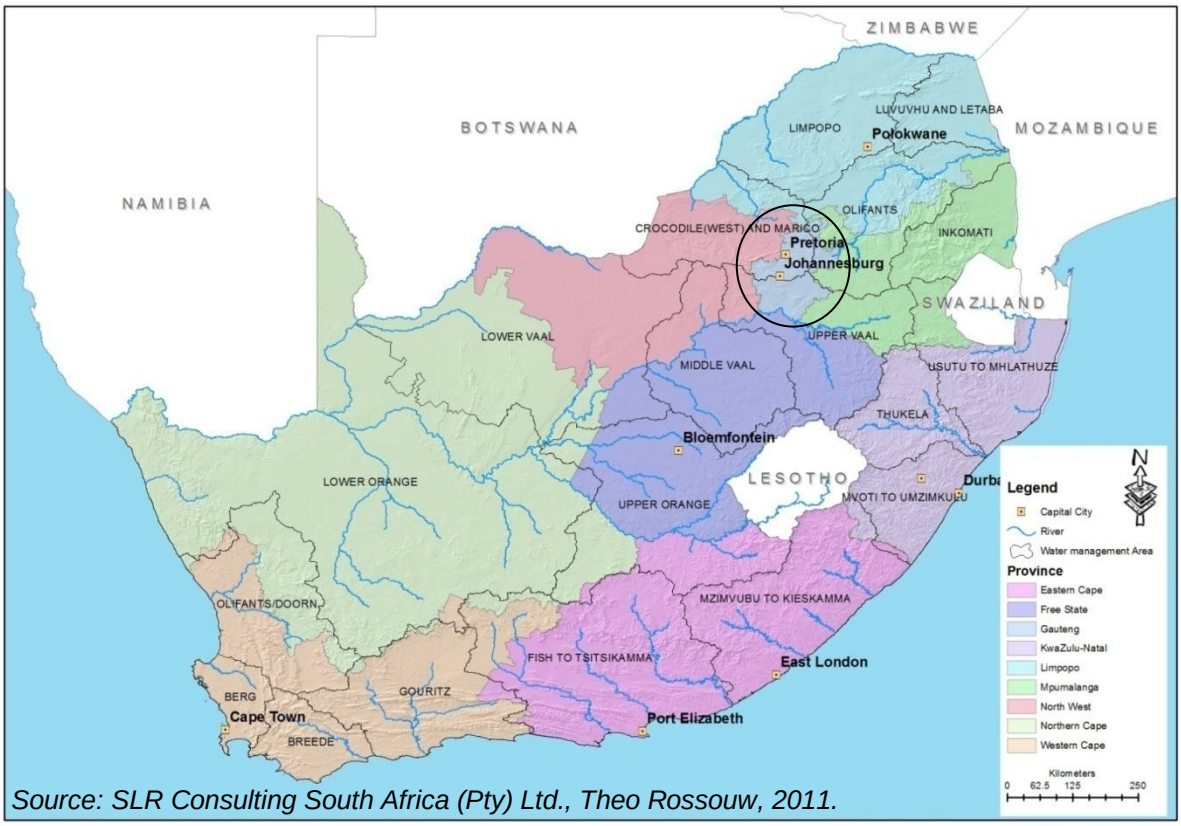
Groundwater offers multiple ecosystem services for human well-being and ecosystem functioning. Ecosystem services, the "benefits people obtain from ecosystems", can be categorized into provisioning, regulating, cultural and supporting services (MA, 2005b: v; Brauman et al., 2007) and defined by attributes of quantity, quality, time and space (Brauman et al., 2007). Since these ecosystem services reveal complex and often non-linear interdependencies which are only poorly understood, trade-offs or synergies emerge (Bennett et al., 2009; Brauman et al., 2007; Costanza, 2008; Le Maitre et al., 2007; MA, 2005a; Raudsepp-Hearne et al., 2010). The effects of groundwater over-abstraction or pollution, for example, may only become apparent after a certain time lag or may even be irreversible (Theesfeld, 2010). Moreover, the diverging claims of different groundwater users can often not be satisfied simultaneously and thus trade-offs occur. A trade-off might hence occur unintentionally or as an explicit choice (Bennett et al., 2009; Carpenter et al., 2009; Rodríguez et al., 2006; WRI, 2000). A simplified example of such an ecosystem service trade-off is when the use of groundwater for agricultural purposes reduces the amount of groundwater available for domestic use. Since different actors have different, often competing value systems and interests, their perceived value of an ecosystem service and definition of an acceptable trade-off may diverge. They may also set competing priorities regarding societal and individual interests as well as the three pillars of social, economic and environmental sustainability (Arrow et al., 2000; Biggs et al., 2004; Brauman et al., 2007; Chapin, 2009; Daily and Dasgupta, 2001; Lankford et al., 2010; MA, 2005c; WRI, 2000). The Millennium Ecosystem Assessment (MA), for example, revealed that there is a tendency in trade-off decisions to prefer provisioning, over regulating, and finally over cultural services. Supporting services are often "taken for granted" (MA, 2005a: 433). A common trade-off is the increase in provisioning services to meet short-term societal needs to the detriment of long-term needs of ecosystems that provide services also in the future, and secure social and economic development (Bohensky et al., 2006; Chapin, 2009; Falkenmark, 2003; MA, 2005a). It is hence crucial to consider the complex interdependencies between ecosystem services themselves and the societal system and thus related trade-offs in groundwater governance in order to make sound decisions that sustain the ecological support systems of society (Hancock, 2010). This has also been shown by empirical studies (e.g. Lankford et al., 2010; MA, 2005a; Raudsepp-Hearne et al., 2010; Wainger et al., 2010).

2.2 Groundwater in Gauteng

Gauteng (see Figure 1), the smallest province of South Africa, is densely populated, largely urbanized and industrialized. It is the economic powerhouse of South Africa and especially famous for its gold mining industry (DACE, 2004). Since the supply of Gauteng's huge water demand by surface water transfer schemes is limited, groundwater is growing in importance (DWAF, 2004c; Gauteng Companies, 2011; Pietersen et al., 2011). Gauteng is characterized by strategic groundwater resources from high yielding dolomitic aquifers (Pietersen et al., 2011). The physical characteristics of the host rock make groundwater resources in these dolomitic areas very vulnerable to unsustainable practices such as over-exploitation and pollution

(Pietersen et al., 2011). The Gauteng dolomites provide water for large- and small-scale agriculture, mining processes and industry, domestic use and the environment (DACE, 2004; DWA, 2010; Kelbe and Rawlins, 2004; Pietersen et al., 2011). They significantly contribute to sustaining three major water catchment areas converging in the province including wetlands, springs and rivers (DACE, 2004; DWA, 2010; Pietersen et al., 2011). They contribute to water purification, flood control and subsidence prevention by supporting the geological structure (NRC, 1997). Moreover, nature reserves and cultural heritage sites such as the Cradle of Humankind depend on the integrity of these aquifers.

However, mining activities, agriculture and urban infrastructure heavily impact these dolomitic aquifer systems through groundwater over-abstraction and pollution (DWA, 2010). The main issue currently receiving considerable media coverage is acid mine drainage (AMD). Contaminated water decanting from abandoned mines and running off from slimes dams affects aquatic and terrestrial ecosystems as well as many farming communities and informal settlements depending on boreholes (McCarthy, 2011; van Eeden et al., 2009). It is important to mention that the Gauteng dolomites are underlain by the gold bearing Witwatersrand formation (Pietersen et al., 2011). The problem of AMD is partly due to the reluctance of mining companies to take responsibility and of the government to take punitive steps or to force the mines to rehabilitate polluted areas. Additionally, many mines cannot be legally compelled to remediate their environmental and socio-economic impacts, as they were abandoned or insolvent long before their full impacts became evident (van Eeden et al., 2009). The dewatering of active mines and groundwater over-abstraction for agriculture also has detrimental impacts such declining groundwater tables resulting in soil instability and subsidence, as well as dried up springs and boreholes. Moreover, agricultural run-off, effluent discharge from industries and municipal wastewater treatment works, and storm water run-off from urban areas and informal settlements negatively impact groundwater quality (DACE, 2004; DWA, 2010; DWAF, 2003; DWAF, 2004b,c; Kelbe and Rawlins, 2004; Pietersen et al., 2011; van Eeden et al., 2009). Gauteng thus reveals a wide range of different sectors that have conflicting interests in groundwater ecosystem services regarding quantity and quality.



Source: SLR Consulting South Africa (Pty) Ltd., Theo Rossouw, 2011.

Figure 1: Map of South Africa showing the location of the province of Gauteng with the two cities of Pretoria and Johannesburg as well as the three water management areas converging in Gauteng.

2.3 The governance of groundwater ecosystem service trade-offs in South Africa

Governance has been conceptualized following different approaches and there is no single agreed upon definition of governance (Biermann, 2008; Pahl-Wostl, 2009; Rogers and Hall, 2003). What can be observed is that the discourse has evolved from the notion of government as the single decision-making authority that steers and controls society in a hierarchical way to the much broader concept of multi-level, polycentric governance including civil society and the private sector (Benz, 2004; Lebel et al., 2006; Mayntz, 2006; Pahl-Wostl, 2009; Tropp, 2007). Turton et al. (2006, 2007) propose a “trialogue” model of governance, which distinguishes the three interfacing actor-clusters of government, science, and society including the private sector. The holistic and inclusive understanding of governance implies a broader range of governance modes, reaching beyond bureaucratic hierarchies to market and network forms of coordinating social life (Benz, 2004; Kooiman, 2000; Mayntz, 2006; Plummer and Armitage, 2010).

Governance thus refers to the processes of making choices, decisions and trade-offs, and involves the balancing of various interests (Mayntz, 2006; Rogers and Hall, 2003; Tropp, 2007; Turton et al. 2006). It embraces the relationships between different social actors as well as formal and informal institutions that guide such relationships and influence the actors’ behavior in order to create societal opportunities and solve common problems (Kooiman, 2000; Lopez-Gunn et al., 2011; Tropp, 2007).

The past and present groundwater governance paradigm

Under the apartheid regime, a technocratic and engineering approach to water use, together with a centralized command-and-control management run by a bureaucracy, made up a technical control paradigm. Based on the Riparian principle, the old Water Act of 1956 recognized water as a privately owned resource tied to land property rights. This led to great inequities in access to water as ownership of land was greatly skewed towards a minority of the population, namely White people (Bohensky and Lynam, 2005; Bohensky, 2008; Braune, 2000; Kelbe and Rawlins, 2004; MacKay, 2003; Muller, 2009; Stuart-Hill and Schulze, 2010). However, the negative ecological consequences of this paradigm and the limits of the supply augmentation approach became gradually apparent and called for a new water management approach (Bohensky and Lynam, 2005; Bohensky, 2008; MacKay, 2003).

With the end of the apartheid regime and the transition to democracy in 1994, South Africa's water sector has been subject to a paradigm shift towards the goal of better reconciling its water resources with the needs of society and ecosystems, and a participatory instead of a technocratic arena for decision-making (Bohensky and Lynam, 2005). The 'new' NWA of 1998 has abolished the private ownership of water and instead defines water as a public resource with the Department of Water Affairs (DWA) acting as a public trustee (Braune, 2000; Muller, 2009; RSA, 1998).

Laws, regulations and policies

The NWA is amongst the most modern and progressive water legislations worldwide. It recognizes the value of ecosystem services, addresses trade-offs and provides for participatory decision-making (Carpenter and Biggs, 2009; DWA, 2010; Le Maitre et al., 2007; MacKay, 2003; Quibell, 2007).

The most innovative regulatory provision of the NWA is the Reserve, which provides rights to water for basic human and ecological needs. The Ecological Reserve specifies the quantity and quality of groundwater necessary to protect aquatic ecosystems in order to sustain the provision of ecosystem services for human well-being and sustainable development. After having met the requirements of the Reserve, water can be allocated to other uses (Braune, 2000; Carpenter and Biggs, 2009; DWAF, undated; Liphadzi, 2007; MacKay, 2003; Quibell, 2007; van Wyk et al., 2006). Moreover, licenses and water use authorizations are most relevant with regard to trade-offs, as they are designed to allocate water equitably and in the public interest, aiming for the optimum balance of social, economic and environmental needs (DWAF, undated; DWAF, 2000; RSA, 1998). Water use refers to any activity that may impact the quantity, quality or reliability of groundwater, including pollution and abstraction (DWAF, undated; Kelbe and Rawlins, 2004). The provisions related to licensing are part of the Water Allocation Reform (WAR), which aims to redress inequities (DWA, 2011). It hence might need curtailments to existing lawful water users in order to meet all demands (Backeberg, 2006; DWAF, undated; RSA, 1998).

Economic policy instruments include a pricing strategy for raw water use charges and fiscal instruments such as a waste discharge charge system, adopting the Polluter Pays Principle (MacKay, 2003; Nahman et al., 2009). Water use charges can be used as incentives for protecting and sustaining ecosystem services (DWAF, 2007; Quibell, 2007; RSA, 1998). Moreover, various payments for ecosystem services (PES) schemes have been trialled (Nahman et al., 2009; van Jaarsveld et al., 2005).

Regarding cooperative instruments, the catchment management areas (CMAs) and water user associations (WUAs) are helpful provisions of the NWA that allow deciding upon different trade-offs in a participatory way and facilitate interest-based

negotiations among different water users (Carpenter and Biggs, 2009; DWAF, undated; DWAF, 2004a; Stuart-Hill and Schulze, 2010).
Laws and policies beyond the water sector impact groundwater indirectly, such as the South African Constitution (RSA, 1996), the National Environmental Management Act (NEMA) or the Mineral and Petroleum Resources Development Act (MPRDA) (Pietersen et al., 2011).
Customary rules and laws, associated with traditional governance systems that already existed prior to colonization and apartheid, mostly prevail in rural areas where they tend to supplement inefficient government structures (Kapfudzaruwa and Sowman, 2009; Lopez-Gunn et al., 2011; Malzbender et al., 2005). For example, water is often treated as a God-given common pool resource, implying use entitlements for all people and no individual ownership. This contradicts statutory law, which treats water as an economic good that users have to pay for (Kapfudzaruwa and Sowman, 2009). However, these customary laws seem to be increasingly abandoned due to globalization processes and especially in highly urbanized areas such as Gauteng (Kapfudzaruwa and Sowman, 2009; Malzbender et al., 2005).

Challenges of current groundwater governance
While the laws and policies can be considered groundbreaking and excellent on paper, their implementation into practice poses a serious problem and is often uneven, inconsistent and inadequate (DWA, 2010; Knüppe, 2011; Pegram et al., 2006; Quibell, 2007). The current lack of implementation, enforcement and compliance monitoring is due to different shortcomings (DWA, 2010; Knüppe, 2011; Stuart-Hill and Schulze, 2010):

- A lack of public awareness and understanding of the potential and value of groundwater (Burke and Moench, 2000; DWA, 2010; Knüppe, 2011);
- A lack of incorporating traditional by-laws and local, informal norms into the formal legal framework (Kapfudzaruwa and Sowman, 2009; Malzbender et al., 2005; Theesfeld, 2010);
- A lack of hydrogeological and socio-economic data and thus scientific uncertainty in information and knowledge (DWA, 2010; Knüppe, 2011; Pegram et al., 2006; Pietersen et al., 2011);
- A lack of human resources at all management levels (DWA, 2010; Knüppe, 2011; Pegram et al., 2006; Pietersen et al., 2011; Stuart-Hill and Schulze, 2010);
- The fragmentation of government departments and administrative levels (Knüppe, 2011);
- Poor institutional linkages between water resource managers and scientists (Pegram et al., 2006);
- Weak and barely realized participatory processes (Knüppe, 2011; MacKay, 2003; Stuart-Hill and Schulze, 2010);
- The mismatch of the administrative and the water management area (WMA) boundaries (DWA, 2010; Herrfahrdt-Pähle, 2010).

3 THEORETICAL RESEARCH FRAMEWORK

3.1 The interplay of formal and informal institutions

Institutions have been defined in various ways (see e.g. Vatn, 2005 for an overview; Scott, 2008; Young, 2002). They are often referred to as “the rules of the game” (North, 1996: 3) or as rules that govern human behavior by constraining or incentivizing it (Esser, 2000; Pahl-Wostl, 2009; Scott, 2008; de Soysa and Jütting,

2007). Institutions are decision-making procedures or programs that define social practices, assign roles to individuals and organizations, direct the allocation of resources, protect interests and adjust conflicting stakeholder claims for scarce resources. They might also be historical artifacts of human experience (Challen, 2000; Kofinas, 2009; Ostrom 1990; Vatn, 2005; Young, 2002). Institutions are rules that are expected from actors of a collective and that claim validity in case of rule-breaking. The claim for validity can be based on the threat of sanctions or the fact that compliance is already deemed reasonable in one's own interest (Esser, 2000). The creation and design as well as change of institutions depends on the actors' interests, values and mindsets, as well as their power and resources (Casson et al., 2010; Helmke and Levitsky, 2004; Pahl-Wostl, 2009). This paper understands institutions as distinct from organizations.

The literature mostly distinguishes between formal and informal institutions. Formal institutions are created, communicated and enforced by governmental bureaucracies, and are typically written and codified in regulatory frameworks or legally binding documents. They include rules such as constitutions, laws, by-laws, and regulations. Informal institutions are created, communicated and enforced outside of legally sanctioned and public channels, and are mostly unwritten and non-codified. They refer to socially shared rules such as social or cultural norms, shared expectations about others' behavior, and customary rules (Helmke and Levitsky, 2004; Kofinas, 2009; North, 1996; Pahl-Wostl et al., 2007; Pahl-Wostl, 2009). Informal institutions can be created from the top down, emerge out of a participatory process, or as an unintended product of a historically contingent process. They may be communicated and institutionalized through social learning, trial and error, social networks or political organizations (Helmke and Levitsky, 2004).

One has to keep in mind that formal and informal institutions are not two separate worlds; rather they are mutually dependent, interplay and affect governance systems (Rottenburg, 1995; Kofinas, 2009; Scott, 2008). Helmke and Levitsky (2004) provide a fourfold typology for the interplay of formal and informal institutions based on two dimensions: the goal compatibility of formal and informal institutions and the effectiveness of formal institutions in terms of enforcement and compliance in practice (see Table 1).

Table 1: Interplay of formal and informal institutions (adapted from Helmke and Levitsky, 2004).

Goals	Effective formal institutions	Ineffective formal institutions
Compatible	a) complementary	c) substitutive
Conflicting	b) accommodating	d) competing

For this paper, the case of ineffective formal institutions is of interest. If the goals are compatible, then the two types of rule systems are substitutive (c). As formal institutions are not routinely enforced, informal institutions that aim for the same goals can substitute or even subvert formal ones. They can help to achieve the goals that formal institutions were supposed to achieve but failed. This case often emerges when states have weak structures or lack authority (Helmke and Levitsky, 2004). If the goals are conflicting, then the two types of rule systems compete with each other (d). This is a problematic case since the actors have to violate one rule in order to be able to follow another rule. Ignoring or violating formal institutions is, however, easy since even strong formal institutions existing on paper are not systematically enforced and implemented in practice. Governance regimes with such competing institutions are likely to reveal high degrees of corruption, non-transparent decision-

making processes and dominant established power structures (Helmke and Levitsky, 2004; Pahl-Wostl, 2009).

3.2 Modes of governance

The literature on governance distinguishes three ideal types of governance modes, which refer to different forms of coordinating social life: markets, bureaucratic hierarchies and networks (Benz, 2004; Kooiman, 2000; Mayntz, 2006; Powell, 1991; Thompson et al., 1991). These three modes of governance reveal different key features (Powell, 1991) and can additionally be described with regard to the degree of formality of institutions and the role of state versus non-state actors (see Figure 2) (Pahl-Wostl, 2009).

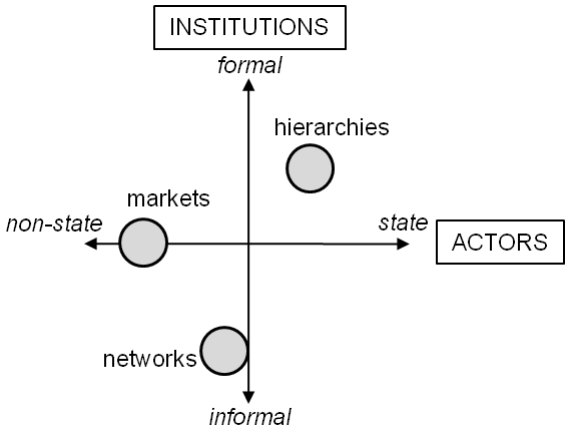


Figure 2: Modes of governance classified according to the degree of formality of institutions and the role of state and non-state actors (adapted from Pahl-Wostl, 2009).

The market mode of governance refers to the central coordination mechanism of price competition through which independent, rational actors interact (Powell, 1991; Thompson et al., 1991). The basis of markets is a combination of formal and informal institutions in which non-state actors prevail (Pahl-Wostl, 2009).
The mode of bureaucratic hierarchy refers to the coordination by an authoritarian system of command-and-control with a fixed set of administrative procedures (Thompson et al., 1991). The regulatory processes are mostly based on formal institutions and dominated by governmental actors (Kooiman, 2000; Pahl-Wostl, 2009).
Due to the perceived limitations of the market and bureaucratic hierarchy mode of governance in practice, there has been a growing interest in the network mode (Keast et al., 2006). The network mode refers to the informal mechanisms of self-organization with negotiated and agreed upon rules that are based on trust, cooperation and reciprocity (Rhodes, 2000; Thompson et al., 1991). It enhances learning because it provides access to new knowledge and skills, fosters their transmission and allows for multiple ways of interpretation (Pahl-Wostl, 2009; Powell, 1991). Networks, which mainly refer to informal institutions, include both state and non-state actors (Pahl-Wostl, 2009; Rhodes, 2000). While self-organizing networks can negatively impact on the capacity of governments to steer and can block the implementation of formal institutions, they can also increase efficiency by cooperating in their implementation (Kjær, 2004). The involvement of a broader range of actors with their different types of knowledge and experiences may help improve the understanding of resource governance problems, find innovative solutions and reduce the likelihood of unexpected resistance to implementation (Pahl-Wostl, 2009).

Involving non-state actors in the design of formal institutions that are actually supposed to govern their behavior might increase compliance and effectiveness. One has to take into consideration that actors might comply with formal institutions not only because of formal sanctions, but also because they are embedded in their values and norms (Pahl-Wostl, 2009). With regard to changing informal institutions, states might have a limited role. Civil society including activists, NGOs and pressure groups as well as key personalities can however play an important role in changing social norms and traditions (de Soysa and Jütting, 2007). When state and non-state actors as well as different types of governance modes become intertwined, the distinction between formal and informal institutions might become blurred (Pahl-Wostl, 2009).
With regard to the goal of sustainable resource governance, it is suggested that a combination of the different modes of governance is preferable to the dominance of one mode (Pahl-Wostl, 2009). The three modes can emerge as remixes or hybrid arrangements retaining some of the virtues of every mode, such as the accountability and transparency of bureaucratic hierarchies, the efficiency aspects of markets and the networks of trust, reciprocity and shared responsibilities (Keast et al., 2006).

3.3 Visual summary

The following mind map (Figure 3) represents the underlying rationale of this study. It visualizes the interplay of the social and ecological system by highlighting the different elements of the theoretical framework and how they in turn relate to the concept of ecosystem services and trade-offs. The rationale is the following: Society depends on and influences the ecological system. Trade-offs (and synergies) arise from interacting ecosystem services and societal choices and management decisions. Society governs these trade-offs (and synergies) by means of institutions and through different modes while aiming for the overarching normative goal of human well-being and sustainability.

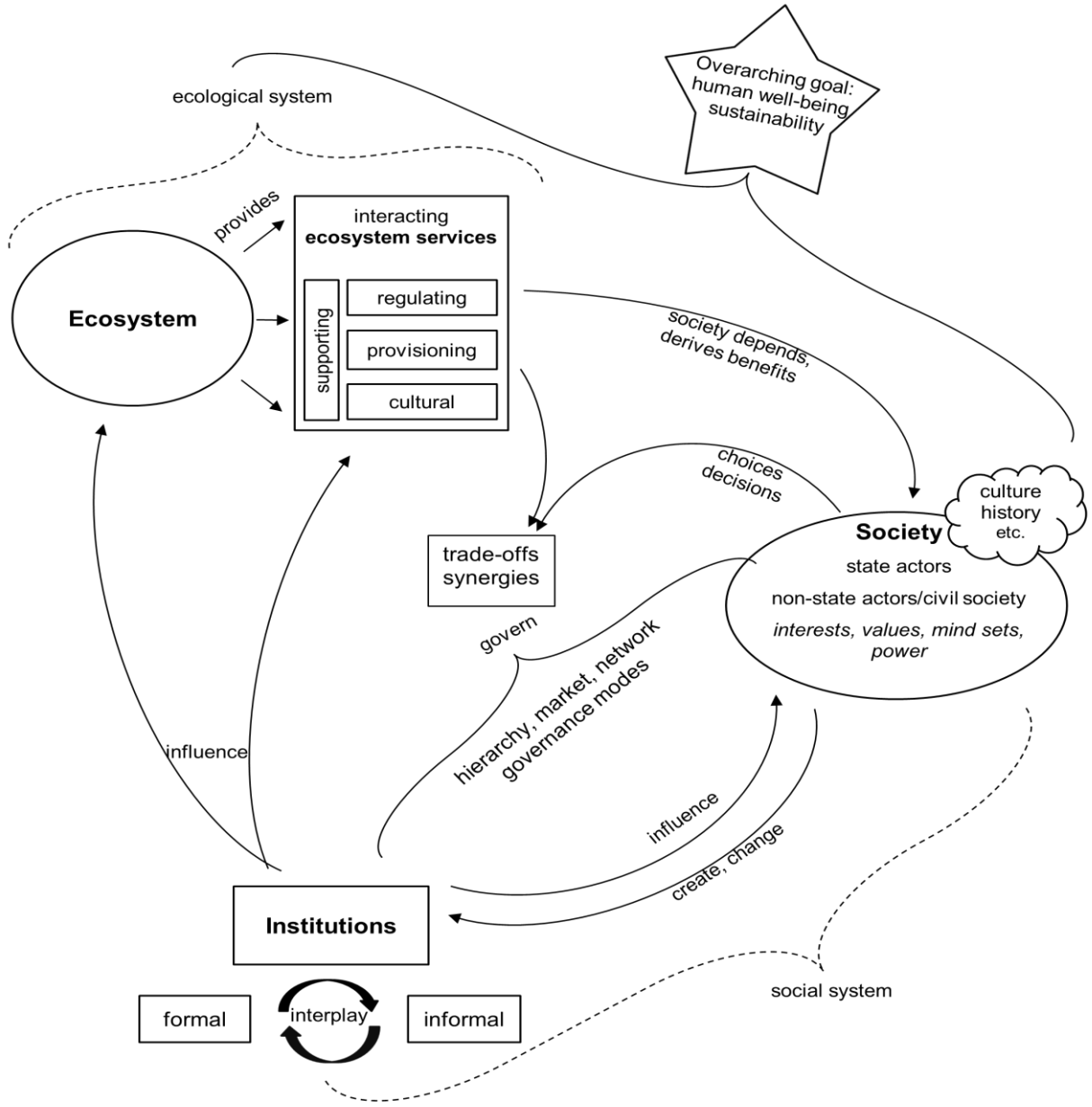


Figure 3: Mind map of the theoretical framework on the governance of ecosystem service trade-offs.

4 METHODOLOGICAL APPROACH

The following qualitative assessment of the governance of groundwater ecosystem service trade-offs is based on the results of a recent qualitative research study in the South African province Gauteng (Beckh, 2011). The provincial level was deemed more appropriate for the analysis than the level of WMAs, since CMAs have not yet been established in Gauteng and thus the national and provincial level remain by default in charge of water resources management (DACE, 2004; DWA, 2010).
For this study, semi-structured, individual face-to-face interviews were conducted with 41 South African experts involved in groundwater governance in July 2011. The experts that participated in the study were selected by combining the snowball and the maximal variation sampling strategy. The snowball strategy helped to identify suitable individuals by asking independent experts and sampled participants for recommendations. The maximal variation strategy helped in grasping the complexity

by including perspectives of many different individuals and steering the selection of participants by defining criteria according to two different dimensions. The first dimension consists of the three actor-clusters of government, science and society (according to Turton et al.'s (2006) trialogue model of governance). The second dimension refers to the area of expertise of the participants, including agriculture, mining and industry, domestic use, environment, groundwater, and water governance. To ensure the diversity of perspectives, experts were chosen from different types of organizations, located on different levels ranging from the local to the international level, as well as from different hierarchical levels within organizations (see Table 2).

A non-standardized interview guideline with open-ended and probing questions as well as checklist items was designed as the instrument of inquiry for the expert interviews. The openness and flexibility of this method allows the participants to respond according to their perceptions and to focus on the issues they deem to be most relevant (Gläser and Laudel, 2004). At the same time, the researcher can react to emerging ideas, gain a deeper understanding of the individual's knowledge, and may also adapt the questions to the language and area of expertise of the participants. Moreover, open-ended questions help to reduce the researcher's bias with his/her attitudes and previous assumptions (Creswell, 2011).

With regard to the approach of inquiry, the researcher aimed at engaging the participants as active co-creators of knowledge in order to explore the issues at stake together.

The transcription of the expert interviews was guided by a combination of predefined categories derived from the guiding questions, the research questions and theoretical considerations as well as by categories emerging from the data (Gläser and Laudel, 2004; Meuser and Nagel, 1991). The preliminary structured transcripts were fed into the software tool MAXQDA, which facilitated sorting all 41 transcripts by category and setting up a refined code system in several iterations. The codes were both inductively developed from the data material and derived from predefined theoretical considerations. Finally, the meanings of the data were interpreted and discussed with reference to and in comparison with the literature and theoretical framework (Creswell, 2011; Gläser and Laudel, 2004).

It is important to keep in mind that the researcher's perspectives, experiences and background, as well as the applied methods influence the whole research process including the results.

Table 2: Overview of the 41 expert interviews described by type of organization and classified regarding the area of expertise and actor-cluster.

The preceding numbers represent the chronological numeration of the expert interviews. Superscript numbers indicate which experts work in the same organization. Abbreviations are used to support a clear arrangement: dept. (department), org. (organization), univ. (university).

The slash-sign ("/") indicates that no experts from this field were interviewed. Reasons included practical difficulties in finding and contacting suitable experts, a possible lack of interest and/or time from experts who were contacted, as well as overlap with interviews which had already been arranged.

	Actor-cluster		
Area of expertise	**Government**	**Science**	**Society**
Agriculture	36 provincial dept.	16 water research org.[2]	02 consultancy[5] 22 farm 23 trade association 34 water user association
Mining and industry	09 national water board	35 mineral research org.	06 consultancy 18 consultancy
Domestic use		/	/
Environment	/	17 water research org.[2] 21 biodiversity research org. 39 univ. research institute[3]	08 environmental NGO 10 law firm 41 consultancy
Groundwater	04 national dept.[1] 29 national dept.[1] 30 national dept.[1] 32 national dept.[1] 33 national dept.[1] 37 national dept.[1]	12 water research org.[2] 15 water research org.[2] 20 univ. research institute 25 research org.[4] 26 research org.[4] 40 univ. research institute[3]	01 consultancy[5] 03 consultancy[5] 05 consultancy 07 consultancy 13 consultancy[5]
Water governance	24 inter-governmental water org.	14 water research org.[2] 19 research org.[4] 27 research org.[4] 28 research org.[4] 31 water research org.[2] 38 univ. research institute[3]	11 consultancy
Number of interviews	9	17	15

5 RESULTS

5.1 Informal institutions competing with formal institutions

The formal laws and regulations of the NWA theoretically address and govern the different groundwater ecosystem service trade-offs between the groundwater user sectors of agriculture, mining and industry, domestic use, environment and urban infrastructure. However, as the literature and the interviews show, these formal institutions are to a great extent not implemented, nor enforced, nor complied with and considered as ineffective. Regarding law enforcement, the participants complain about the inconsistent, selective and biased manner, which prioritizes socio-economic development over environmental sustainability in practice. Hence there seems to be a gap between the "de jure" and "de facto" governance of groundwater

ecosystem service trade-offs. The expert interviews were conducted to explore how groundwater ecosystem services are governed “de facto”. Over a third of the participants state that in the absence of the formal institutions, groundwater resources are not managed sustainably and trade-offs are not dealt with. The informal institutions revealed through the interviews compete with the formal institutions of the NWA and exacerbate the situation. Despite the extreme views of several participants of either the non-existence or the existence of an endless number of informal institutions, four different competing informal institutions in terms of socially shared expectations can be identified.

The first informal institution refers to socially shared expectations of the role of the government. Many participants mention that people expect the government and thus the DWA to act in order to enforce and control the adherence to laws and regulations. An expert from the agricultural trade association compares this human behavior with speeding on a highway: “If I am travelling on the highway exceeding speed limit and nobody is stopping me, I will continue that, even speed up some more.” (23)

The second informal institution refers to economic self-interest. Over a third of the participants state that people exploit groundwater for their own quick economic profit in a short-sighted and greedy manner which blanks out environmental protection. A water governance scientist explains that “most informal rules in use are ‘grab it while you can’. It’s pretty much the tragedy of the commons. That seems to be the norm” (38). Moreover, a groundwater government official explains that

> *“something that is maybe peculiar to our society, the Afrikaaner farmer society, you know, it’s every man for himself. You don’t feel anything for your neighbor, if you impact on him. […] [There is] even less care about the environment. Maybe I am not so nice now; maybe there are farmers that care about the environment.” (4)*

Half of the participants further state that people even deliberately take advantage of the weak formal governance. A groundwater government official elaborates that they

> *“[…] try their luck, they push it. In that sense, there are a lot of people that know that they are doing wrong, but they are still doing it. Or they know that there are not a lot of knowledgeable people in the department [DWA] or in government or whatever. Because I think the people that you are talking to are the few that know something. […] And sometimes it feels to me that the guy, that is doing the pollution, is doing it deliberately because he knows that the department is not implementing the Water Act because of lack of experience etc..” (30)*

Destructive and unsustainable farming practices such as depleting the value of the land and abstracting the maximum amount of groundwater also arise due to the restitution and redistribution policy, under which certain formerly privileged farmers face land claims and thus lose their right to the land. Furthermore, a few participants mention the problem of corruption where people comply with a bribe due to the complexity of formal institutions and related high transaction costs, as well as low bureaucratic capacity.

The third informal institution, which also explains why people exploit groundwater as they want, refers to a historical rule regarding property rights. Over a third of the participants explain that many people, especially farmers, still act according to the old Water Act of 1956 and continue to claim their right to water based on private ownership. The farmer was hence the most powerful groundwater manager at that time. Against this background, the NWA of 1998 requires a huge change in behavior and mindset. Many groundwater users object licenses and especially the Ecological Reserve for fear of losing their share of water. This makes the equitable redistribution of water and the reduction of existing lawful uses especially challenging. A groundwater scientist describes the situation as follows:

> *“So just think what happened when the law [the NWA of 1998] came and now the Minister suddenly wanted to say to a farmer ‘You need a license’. What do you think the farmer said to the Minister? ‘You can jump in the lake, this is my water!’ And so this is re-education and getting*

discipline into the country from what the government had previously completely disregarded to now wanting to control. I think that this battle is still very tough."(20)

The fourth informal institution that should be distinguished is only described very shortly by two participants, referring to a spiritual rule that prevails nowadays. They explain that water is often seen as a God-given gift, which is for free. This, however, leads to the situation that especially poor communities do not understand why water should be regulated and priced.

5.2 The influence and potential of markets, bureaucratic hierarchies and networks

Referring to the market mode of governance, several participants mention that economic mechanisms are important in tackling groundwater quantity and quality, and in allowing for good ecosystem service governance. An increased water price could incentivize water use efficiency, recycling, reuse and protection. Yet, the government is reluctant to take any action since an increased water price for industry may negatively impact economic growth, and an increased water price for domestic users is an unpopular decision. In an indirect way, the price of electricity which is needed for pumping can also control groundwater use. Moreover, the economic valuation of groundwater ecosystem services and environmental accounting should be integrated into the pricing strategy. Incentive-based approaches such as payments for ecosystem service schemes for managing resources and addressing trade-offs should be promoted as well.

In relation to the governance mode of bureaucratic hierarchies, an environmental consultant explains that government, which likes to have full control, dislikes market mechanisms driven by the private sector and civil society, as they represent responses to government failure. Yet since the existing sticks for controlling are not used, economic incentives are needed. Since there is also a significant market failure, the government must still play a role and create an enabling environment for governance. The mining scientist is convinced that a stick, a carrot or a combination is needed to incentivize behavior, as people do not tend to behave altruistically. An environmental scientist has the impression that in South Africa

"self-regulation is generally met with a lot of suspicion by civil society and the public. I think we still live in a society that holds that command-and-control approach very close to its side. But people want to feel like government is watching, government is regulating rather than handing it over to industry, where, you know, there is a little more suspicion about the motives, and why they are doing it like that. […] So you know, I think on one hand, you've got a society like the United States where there is a strong push to minimize government interference and regulation, and regulatory burdens. And then you've got your more highly regulated societies, maybe like Scandinavian countries, your social democracies, where there is a very strong level of government involvement in all areas of life. I think we are not at either of those extremes. I think we are somewhere in the middle." (21)

Referring to the network mode of governance, a third of the participants state that self-regulation and networking can be observed. Independently of the existence of any laws, resource users, especially farmers, form bottom-up driven associations and networks in order to jointly manage the groundwater resources in their compartment on which their livelihoods depend on. The interviewed farmer explains that their local farmer association functions in line with the NWA by aiming for sustainable resource management, allows for mutual assistance, informal controlling regarding over-abstraction and ensuring that everyone behaves in the same way. Due to internal pressure, some farmers have even changed their "this is my water"-standpoint (34). Other members of the public and NGOs also raise awareness, informally discourage groundwater polluting activities, name and shame, build up pressure through the media, support less represented groups such as impacted traditional communities,

voice concern at higher levels of the government, and even fight against the government.
Highly motivated and influential individuals, whose decisions and advices are respected by the people, are an important part of the informal realm for groundwater management to happen. A water governance scientist gives the example of an environmental activist who is whistle-blowing against polluting mining companies who are responsible to warn affected communities about health impacts. There is an interesting interaction between the formal law that protects the activist to speak out against the mines, and the informal processes of mines keeping their reputation safe by paying the activist.
There are also transdisciplinary networks between science and practice, including scientists, resource users, and government officials, that contribute to effective groundwater governance. Scientists engage in informal relationships with activists, especially in the AMD case, or bring in their views in contrast to the rather sensationalist perspective of the media and activists. Due to a lack of knowledge, the government often calls for input from scientists and consultants who are not caught up in daily bureaucracy. An environmental scientist observes the advantage, but also the risk of such transdisciplinary networks:

> *"Ground-level bureaucrats form networks with colleagues, with people in other organizations, with counterparts in other government departments, with civil society, in order to help them to fill that vacuum [of guidance]. So their understanding of policy implementation is then informed more by these networks that they form than by let's say internal guidance provided from their department, because that guidance is not there. And we have seen a lot of these networks emerge. Some of them function very well. But of course, I think, the risk of these networks is that they are very susceptible to being hijacked by vested interests. So this is where for example, the users, perhaps some of these bureaucrats come to rely very heavily on the people that they are supposed to be regulating. So the industries that are supposed to be regulated are very involved in advising the regulators. And I think there are big risks." (21)*

Only a few participants do not see any, or only limited self-regulation and networking. They state, for example, that at grassroots level, communities often neither take ownership of boreholes, nor of the equipment, nor do they appoint anyone to take care of the resource.
As a few experts mention, self-regulation and networking depend on the habits and character of the people. Moreover, forming networks seems to be easier in rural areas since there are more homogenous groups of people than in urban areas such as Gauteng with a diversity of cultures having different approaches.
In general, it is deemed important to encourage self-regulation and not to leave the management of groundwater to the government. The only few existing environmental non-governmental organizations (NGOs) should cooperate more in order to increase their influence. A groundwater government official explains that

> *"it also depends on the maturity of society and institutions, which in South Africa is probably a bit premature for us to think along those lines. But it's that direction that we are heading towards, because I've said earlier that no government department will ever be able to police water management, it must come from within." (33)*

6 DISCUSSION

6.1 The role of informal institutions in governance

Informal institutions can be decisive in governance. Unveiling informal institutions with their origin and context can widen the perspectives and bring in deep-rooted reasons for the ineffectiveness of formal institutions and governance, especially regarding compliance. At the same time, the informal institutions seem to be fostered through ineffective governance. Informal institutions can indicate weaknesses, which can be dealt with in order to improve governance. However, making informal

institutions explicit and consciously talking about them is challenging since they are often implicit and deeply enshrined in one's behaviour and mindset. In most of the cases, one has to weigh up thoroughly if an observed behavior is a pattern that endures through time and a socially shared expectation, or if it is just a behavioral pattern that is not rule-bound or rooted in shared expectations (Helmke and Levitsky, 2004).
The participants mention four informal institutions in terms of socially shared expectations that compete with formal institutions and thus contribute to the ineffectiveness of the NWA. Informal institutions that complement, substitute or accommodate formal institutions might either just not exist or they might not be perceived or known by the experts interviewed.

Groundwater management as government's obligation
The first identified informal institution refers to the people's expectations of the government's role to act using a command-and-control approach for sustainable groundwater governance. The past apartheid regime has certainly contributed to this attitude. This institution competes with the goal of the NWA to enhance participation and responsibility on the part of civil society. Given the people expect the government to act, yet at the same time the government is not able to implement and enforce any regulation effectively, the then occurring problem is that nothing happens and environmental sustainability is likely to be traded off.

"Grab it while you can"
As the second informal institution shows, the people follow the norm of "grab it while you can" and act in their own economic benefit fostering the bias to the detriment of environmental protection. This competes especially with the formal institution of licenses and the NWA's goal of environmental sustainability. The fact that commercial farmers may have little incentive for long-term management is intensified by regulatory uncertainty, including perceptions of insecure land tenure or of the WAR. In addition, groundwater has a long time lag which means that negative consequences of unsustainable practices may only become visible after years. Moreover, the paradigm of "every man for himself" without any concern for neighbors or the environment prevails, for example, in the culture of the White Afrikaaner farmer society. Culture, history, power relations or environmental settings can all influence social practices. Taking history and the times of change into consideration, it is not surprising that to most people economic issues are more important than the environment. It could thus be that informal rules shaping sustainable behavior might not emerge yet since practices esteemed to be unsustainable are still accepted.

Groundwater as private resource
The third informal institution reflects a historical relic from the old Water Act. Especially farmers continue to treat groundwater as a private resource. The government has hence not yet been able to persuade the water users that the public resource principle of the NWA including licensing provisions is in the long-term interest of all.

Groundwater as God-given gift
The fourth informal institution of considering water as a free, God-given gift competes with the concept of water as a social and economic good with a price. This institution shows that varying beliefs, norms and socially shared expectations regarding (ground)water exist in South Africa and often contradict each other.

The fact that these informal institutions impact groundwater ecosystem services negatively and intensify trade-offs indicates that the linkages between groundwater, ecosystem services and human well-being have not yet been anchored in societal consciousness and practice. Looking at the informal institutions through the lens of the ecosystem service concept reveals that provisioning groundwater services seem to be more important in terms of quantity than quality. Deepening the understanding and raising awareness in such a way might facilitate the designing of measures and actions to improve the governance of groundwater ecosystem service trade-offs.

6.2 The role of governance modes

Taking into consideration the three governance modes of bureaucratic hierarchy, market and network and their role in society further helps to illuminate where the potential for improving the governance of groundwater ecosystem service trade-offs lies.

Expected hierarchy mode unsuccessful

The first informal institution shows that the hierarchy mode referring to a command-and-control approach is expected by society. Yet, even though the government has set the larger rules of the game and can use different policy instruments in order to influence behavior, it is not successful in doing so and seems to be rather restricted in changing informal institutions such as the historical relic.

Market mode treated with suspicion

Carefully designed market-based mechanisms such as an increased water price, economic valuation and PES can help to regulate the rational, profit seeking practices and improve the governance of groundwater ecosystem service trade-offs. However, the government is said to be resistant to market-based mechanisms since it shows its failure. Moreover, the market mode and self-regulation by the private sector are rather met with suspicion by civil society.

Network mode of great potential

The network mode seems to have a positive influence on groundwater governance. Many farmers engage in networks to cooperatively manage their groundwater resources instead of leaving it for the government. Internal pressure among them triggers a change in mindset and behavior towards accepting the public resource provision of the NWA. Networks and non-state actors sometimes have more power to influence social practices and traditions by using social obligation than state actors by employing their external enforcement mechanisms. Moreover, transdisciplinary networks including science, government and society enhance mutual learning by providing access to different types of knowledge, such as scientific facts, sensational media stories or practical approaches. They can help integrate scientific input into policy-making and provide guidance for civil servants. However, networks can also be used to push through individual interests such as economic interests from industry trading off environmental sustainability. Whereas including non-state actors in the design and enforcement of formal institutions can increase compliance and effectiveness, it can also bear the risk that those who are supposed to be regulated influence or even determine themselves how they should be regulated.
Non-state actors might thus have the potential to contribute to the embedment and anchoring of formal institutions thereby enhancing sustainability and succeeding in changing competing informal institutions. Increasing the awareness of society about

its impact by taking on responsibility might help to unlock this potential. At the same time, the government's awareness should be increased about the fact that civil society is able to take action and should thus be considered as a partner in governance to whom power should be eventually devolved, just as prescribed by the NWA. Networks that generally refer to informal institutions can hence interplay with bureaucratic hierarchies that are mainly based on formal institutions in conducive ways.

It is important to find a balance between the three modes of governance while retaining their virtues and considering the societal context. According to the interviews, the government should focus on creating an enabling environment while integrating the advantages of market mechanisms into governance and stimulating self-regulation and networks. A balanced combination can help resolving groundwater ecosystem service trade-offs, achieving the goal of sustainable resource governance and making formal institutions more effective.

7 CONCLUSIONS

Governing groundwater ecosystem service trade-offs is a complex task. In the highly urbanized and populated South African province of Gauteng, groundwater occurring from high yielding dolomitic aquifers offers multiple ecosystem services on which human well-being and ecosystem functioning depend. However, Gauteng currently faces problems of over-abstraction and pollution. Diverse user sectors have conflicting interests in groundwater in terms of quantity and quality. Since the different claims cannot be satisfied simultaneously and the ecosystem services are highly interdependent, trade-offs occur. South Africa seems to have the potential to balance trade-offs through the provisions of the NWA including the Ecological Reserve and participatory measures in particular. However, these formal institutions are largely ineffective as they have not been implemented, enforced, nor complied with. Hence this study explored how groundwater ecosystem service trade-offs are actually governed in Gauteng. The expert interviews reveal that in the absence of the formal institutions, groundwater ecosystem service trade-offs are not dealt with. Overall, environmental sustainability is currently being traded off for socio-economic development. The four identified informal institutions compete with the formal institutions and hence worsen the situation. While they reveal deep-rooted reasons for the ineffectiveness of formal institutions, they in turn also trigger points to improve governance. Yet establishing an understanding for 'new' institutions and changing social norms and practices is challenging and usually takes time, as deep-rooted cultural, historical and societal structures are involved. Translating formal institutions into lived social practice requires not only political will and improved enforcement by bureaucratic hierarchies using a command-and-control approach which is expected by society. Market-based mechanisms might also be needed to regulate rational, economic profit seeking behavior, even though the market mode of governance is met with suspicion by civil society. The network mode seems to have great potential to improve governance that needs to be unlocked. Networks and non-state actors can play a crucial role in changing social practices through social obligation and cooperation. A balanced interplay of these governance modes can help improving the governance of groundwater ecosystem service trade-offs in Gauteng.

Further research could include studying the ecological side of groundwater trade-offs and their translation into the socio-economic realm in order to catch the attention of decision-makers; informal institutions focusing on one groundwater user sector and/or actor-cluster in Gauteng or elsewhere; and the role of laws and regulations beyond the water sector. Of equal interest are processes of how to induce change

regarding competing informal institutions with the goal of better embedding formal institutions into social practice.

8 REFERENCES

Arrow, K.; Daily, G.; Dasgupta, P.; Levin, S.; Maler, K.-G.; Maskin, E.; Starrett, D.; Sterner, T.; Tietenberg, T. (2000). Managing ecosystem resources. *Environmental Science & Technology*, 34 (8), 1401-1406.

Avramov, M.; Schmidt, S. I.; Griebler, C.; Hahn, H. J.; Berkhoff, S. (2010). Dienstleistungen der Grundwasserökosysteme. *Korrespondenz Wasserwirtschaft*, 3 (2), 74-81.

Backeberg, G. (2006). Reform of user charges, market pricing and management of water: Problem or opportunity for irrigated agriculture? *Irrigation and Drainage*, 55, 1-12.

Beckh, C. (2011): Governance of ecosystem services: Groundwater trade-offs in Gauteng, South Africa – An institutional analysis. Master Thesis submitted in partial fulfillment of the requirements for the degree of M.Sc. Environmental Governance, University Freiburg.

Bennett, E. M.; Peterson, G. D.; Gordon, L. J. (2009). Understanding relationships among multiple ecosystem services. *Ecology Letters*, 12, 1-11.

Benz, A. (2004). Einleitung: Governance - Modebegriff oder nützliches sozialwissenschaftliches Konzept? In A. Benz (Ed.), *Governance – Regieren in komplexen Regelsystemen: Eine Einführung*. Wiesbaden: VS Verlag für Sozialwissenschaften, 11-28.

Bergkamp, G.; Cross, K. (2006). Groundwater and ecosystem services: Towards their sustainable use. *Proceedings of the International Symposium on Groundwater Sustainability (ISGWAS)*, Alicante, Spain, 24-27 January 2006, 177-193. Online URL: <http://aguas.igme.es/igme/isgwas/Ponencias%20ISGWAS/13-Bergkamp.pdf> (8.03.2011).

Biermann, F. (2008). Earth System Governance: A research agenda. In O. R. Young; L. A. King; H. Schroeder (Eds.), *Institutions and environmental change. Principal findings, applications, and research frontiers*. Cambridge, Massachusetts: MIT Press, 277-302.

Biggs, R.; Bohensky, E.; Desanker, P. V.; Fabricius, C.; Lynam, T.; Misselhorn, A. A.; Musvoto, C.; Mutale, M.; Reyers, B.; Scholes, R. J.; Shikongo, S.; van Jaarsveld, A. S. (2004). *Nature supporting people. The Southern African Millennium Ecosystem Assessment. Integrated report*. Pretoria: Council for Scientific and Industrial Research (CSIR).

Bohensky, E.; Lynam, T. (2005). Evaluating responses in complex adaptive systems: Insights on water management from the Southern African Millennium Ecosystem Assessment (SAfMA). *Ecology and Society*, 10 (1), pp. 11. Online URL: <http://www.ecologyandsociety.org/vol10/iss1/art11/> (28.03.2011).

Bohensky, E. L.; Reyers, B.; van Jaarsveld, A. S. (2006). Future ecosystem services in a Southern African river basin: A scenario planning approach to uncertainty. *Conservation Biology*, 20 (4), 1051-1061.

Bohensky, E. L. (2008). Discovering resilient pathways for South African water management: Two frameworks for a vision. *Ecology and Society*, 13 (1), pp. 19. Online URL: <http://www.ecologyandsociety.org/vol13/iss1/art19/> (28.03.2011).

Brauman, K. A.; Daily, G. C.; Ka'eo Duarte, T.; Mooney, H. A. (2007). The nature and value of ecosystem services: An overview highlighting hydrologic services. *The Annual Review of Environment and Resources*, 32, 67-98.

Braune, E. (2000). Towards comprehensive groundwater resource management in South Africa. In O. Sililo et al. (Eds.), *Groundwater: Past achievements and future challenges. Proceedings of the XXX IAH Congress on groundwater: Past achievements and future challenges, Cape Town, South Africa, 26 November - 1 December 2000*. Rotterdam: A. A. Balkema, 7-15.

Burke, J. J.; Moench, M. H. (2000). *Groundwater and society: Resources, tensions and opportunities. Themes in groundwater management for the twenty-first century*. New York: United Nations Department of Economic and Social Affairs.

Carpenter, S. R.; Biggs, R. (2009). Freshwaters: Managing across scales in space and time. In F. S. Chapin, III; G. P. Kofinas; C. Folke (Eds.), *Principles of ecosystem stewardship. Resilience-based natural resource management in a changing world*. New York: Springer, 197-220.

Carpenter, S. R.; Mooney, H. A.; Agard, J.; Capistrano, D.; DeFries, R. S.; Díaz, S.; Dietz, T.; Duraiappah, A. K.; Oteng-Yeboah, A.; Miguel Pereira, H.; Perrings, C.; Reid, W. V.; Sarukhan, J.; Scholes, R. J.; Whyte, A. (2009). Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. *Proceedings of the National Academy of Sciences*, 106 (5), 1305-1312.

Casson, M. C.; Della Giusta, M.; Kambhampati, U. S. (2010). Formal and informal institutions and development. *World Development*, 38 (2), 137-141.

Challen, R. (2000). *Institutions, transaction costs and environmental policy. Institutional reform for water resources*. Cheltenham: Edward Elgar Publishing.

Chapin, III, F. S. (2009). Managing ecosystems sustainably: The key role of resilience. In F. S. Chapin, III; G. P. Kofinas; C. Folke (Eds.), *Principles of ecosystem stewardship. Resilience-based natural resource management in a changing world*. New York: Springer, 29-53.

Colvin, C.; Saayman, I. (2007). Challenges to groundwater governance: A case study of groundwater governance in Cape Town, South Africa. *Water Policy*, 9 (2), 127-148.

Costanza, R. (2008). Ecosystem services: Multiple classification systems are needed. *Biological Conservation*, 141, 350-352.

Creswell, J. W. (2011). *Educational research. Planning, conducting and evaluating quantitative and qualitative research*. Fourth edition. Boston: Pearson Education.

Daily, G. C.; Dasgupta, S. (2001). Ecosystem services, concept of. *Encyclopedia of Biodiversity*, 2, 353-362.

Danielopol, D. L.; Griebler, C.; Gunatilaka, A.; Notenboom, J. (2003). Present state and future prospects for groundwater ecosystems. *Environmental Conservation*, 30 (2), 104-130.

Danielopol, D. L.; Griebler, C.; Gunatilaka, A.; Hahn, H. J.; Gibert, J.; Mermillod-Blondin, F.; Messana, G.; Notenboom, J.; Sket, B. (2008). Incorporation of groundwater ecology in environmental policy. In P. Quevauviller, *Groundwater science and policy. An international overview*. Cambridge: The Royal Society of Chemistry, 671-689.

Department of Agriculture, Conservation and Environment (DACE), South Africa (2004). *Gauteng State of Environment Report*. Johannesburg: Gauteng Provincial Government.

Department of Water Affairs (DWA), South Africa (2010). *Groundwater Strategy 2010*. Online URL: <http://www.dwa.gov.za/groundwater/Documents/GSDocument%20FINAL%202010_MedRes.pdf> (15.03.2011).
Department of Water Affairs (DWA), South Africa (2011). *What is Water Allocation Reform (WAR)?* Online URL: <http://www.dwa.gov.za/WAR/> (28.10.2011).
Department of Water Affairs and Forestry (DWAF), South Africa (undated). *Guide to the National Water Act*. Pretoria: Department of Water Affairs and Forestry. Online URL: <http://www.dwa.gov.za/documents/publications/NWAguide.pdf> (28.03.2011).
Department of Water Affairs and Forestry (DWAF), South Africa (2000). *Policy and strategy for groundwater quality management in South Africa.* First edition. Pretoria: Department of Water Affairs and Forestry.
Department of Water Affairs and Forestry (DWAF), South Africa (2003).*Upper Vaal Water Management Area: Overview of water resources availability and utilization*. Pretoria: Department of Water Affairs and Forestry.
Department of Water Affairs and Forestry (DWAF), South Africa (2004a). *National Water Resource Strategy.* First edition. Pretoria: Department of Water Affairs and Forestry.
Department of Water Affairs and Forestry (DWAF), South Africa (2004b). *Crocodile (West) and Marico Water Management Area: Internal strategic perspective of the Crocodile River (West) catchment*. Pretoria: Department of Water Affairs and Forestry.
Department of Water Affairs and Forestry (DWAF), South Africa (2004c). *Upper Vaal Water Management Area: Internal strategic perspective*. Pretoria: Department of Water Affairs and Forestry.
Department of Water Affairs and Forestry (DWAF), South Africa (2007). *Establishment of a pricing strategy for water use charges in terms of section 56(1) of the National Water Act, 1998. A pricing strategy for raw water use charges.* Pretoria: Department of Water Affairs and Forestry.
De Soysa, I.; Jütting, J. (2007). Informal institutions and development: How they matter and what makes them change. In J. Jütting; D. Drechsler; S. Bartsch; I. de Soysa, *Informal institutions: How social norms help or hinder development*. Development Centre Studies. Paris: OECD, 29-43.
Esser, H. (2000). *Soziologie - Spezielle Grundlagen. Band 5: Institutionen.* Frankfurt a. M.: Campus Verlag.
Falkenmark, M. (2003). Freshwater as shared between society and ecosystems: From divided approaches to integrated challenges. *Philosophical Transactions of the Royal Society B, Biological Sciences*, 358, 2037-2049.
Foster, S.; Garduño, H.; Tuinhof, A.; Tovey, C. (2010). *Groundwater governance. Conceptual framework for assessment of provisions and needs*. GW-MATE Strategic Overview Series, Number 1. Washington, DC: World Bank.
Gauteng Companies (2011). *Gauteng Companies: The guide to business and investment in Gauteng province*. Cape Town: Global Africa Network (Pty) Ltd. Online URL: < http://issuu.com/globalafricanetwork/docs/gautengcomapnies?mode=embed&layout=http%3A%2F%2Fskin.issuu.com%2Fv%2Flight%2Flayout.xml&showFlipBtn=true> (3.05.2011).
Gläser, J.; Laudel, G. (2004). *Experteninterviews und qualitative Inhaltsanalyse als Instrumente rekonstruierender Untersuchungen*. Wiesbaden: VS Verlag für Sozialwissenschaften.

Hancock, J. (2010). The case for an ecosystem service approach to decision-making: An overview. *Bioscience Horizons*, 3 (2), 188-196.
Helmke, G.; Levitsky, S. (2004). Informal institutions and comparative politics: A research agenda. *Perspectives on Politics*, 2 (4), 725-740.
Herrfahrdt-Pähle, E. (2010). South African water governance between administrative and hydrological boundaries. *Climate and Development*, 2, 111-127.
Kapfudzaruwa, F.; Sowman, M. (2009). Is there a role for traditional governance systems in South Africa's new water management regime? *Water SA*, 35 (5), 683-692.
Keast, R.; Mandell, M.; Brown, K. (2006). Mixing state, market and network governance modes: The role of government in "crowded" policy domains. *International Journal of Organization Theory and Behavior*, 9 (1), 27-50.
Kelbe, B.; Rawlins, B. (2004). Groundwater management in South Africa. In M. Brentwood; S. F. Robar (Eds.), *Managing common pool groundwater resources: An international perspective*. Westport: Praeger Publishers, 289-310.
Kjær, A. M. (2004). *Governance*. Cambridge: Polity Press.
Knüppe, K. (2011). The challenges facing sustainable and adaptive groundwater management in South Africa. *Water SA*, 37 (1), 67-80.
Kofinas, G. P. (2009). Adaptive co-management in social-ecological governance. In F. S. Chapin, III; G. P. Kofinas; C. Folke (Eds.), *Principles of ecosystem stewardship. Resilience-based natural resource management in a changing world*. New York: Springer, 77-101.
Kooiman, J. (2000). Societal Governance: Levels, modes, and orders of social-political interaction. In J. Pierre (Ed.), *Debating governance: Authority, steering, and democracy*. Oxford: Oxford University Press, 138-164.
Lankford, B.; Pringle, C.; Dickens, C.; Lewis, F.; Chhotray, V.; Mander, M.; Goulden, M.; Nxele, Z.; Quayle, L. (2010). *The impacts of ecosystem services and environmental governance on human well-being in the Pongola region, South Africa*. Report to the Natural Environment Research Council. University of East Anglia and Institute of Natural Resources, London, Norwich, UK and Pietermaritzburg, South Africa. Online URL: <http://www.uea.ac.uk/dev/prespa/FINAL+UEA+Prepsa+NERC+Report+-+April+2010> (18.05.2011).
Lebel, L.; Anderies, J. M.; Campbell, B.; Folke, C.; Hatfield-Dodds, S.; Hughes, T. P.; Wilson, J. (2006). Governance and the capacity to manage resilience in regional social-ecological systems. *Ecology and Society*, 11 (1), pp. 19. Online URL: <http://www.ecologyandsociety.org/vol11/iss1/art19/> (1.09.2011).
Le Maitre, D. C.; O'Farrell, P. J.; Reyers, B. (2007). Ecosystems services in South Africa: A research theme that can engage environmental, economic and social scientists in the development of sustainability science? *South African Journal of Science*, 103, 367-376.
Liphadzi, S. (2007). *Watermark: The lasting impression of the Ecological Reserve*. WRC Report No. TT 307/07. Pretoria: Water Research Commission (WRC).
Lopez-Gunn, E.; Llamas, M. R.; Garrido, A.; Sanz, D. (2011). Groundwater management. In P. Wilderer (Ed.), *Treatise on water science. Management of water resources*. Volume 1. Amsterdam: Elsevier, 97-127.
MacKay, H. (2003). Water policies and practices. In D. Reed; M. de Wit (Eds.), *Towards a just South Africa. The political economy of natural resource wealth*. Washington, DC: World Wide Fund For Nature (WWF); Pretoria: Council for Scientific and Industrial Research (CSIR), 49-83.

Malzbender, D.; Goldin, J.; Turton, A.; Earle, A. (2005). Traditional water governance and South Africa's "National Water Act" – Tension or cooperation? *International workshop on 'African Water Laws: Plural Legislative Frameworks for Rural Water Management in Africa'*, Gauteng, South Africa, 26-28 January 2005. Online URL: <http://www.nri.org/projects/waterlaw/AWLworkshop/MALZBENDER-DB.pdf> (11.03.2011).

Mayntz, R. (2006). Governance Theory als fortentwickelte Steuerungstheorie? In G. F. Schuppert (Ed.), *Governance-Forschung: Vergewisserung über Stand und Entwicklungslinien*. Baden-Baden: Nomos, 11-20.

McCarthy, T. S. (2011). The impact of acid mine drainage in South Africa. *South African Journal of Science*, 107 (5/6), 1-7.

Meuser, M.; Nagel, U. (1991). ExpertInneninterviews – vielfach erprobt, wenig bedacht. Ein Beitrag zur qualitativen Methodendiskussion. In D. Garz; K. Kraimer (Eds.), *Qualitativ-empirische Sozialforschung. Konzepte, Methoden, Analysen*. Opladen: Westdeutscher Verlag, 441-471.

Millennium Ecosystem Assessment (MA) (2005a). *Ecosystems and human well-being: Scenarios*. Volume 2. Chapter 12, Interactions among ecosystem services. Findings of the Scenarios Working Group of the Millennium Ecosystem Assessment. Washington, DC: Island Press.

Millennium Ecosystem Assessment (MA) (2005b). *Ecosystems and human well-being: Synthesis*. Washington, DC: Island Press.

Millennium Ecosystem Assessment (MA) (2005c). *Ecosystems and human well-being: Policy responses.* Volume 3. Chapter 7, Freshwater ecosystem services. Findings of the Responses Working Group of the Millennium Ecosystem Assessment. Washington, DC: Island Press.

Muller, M. (2009). Attempting to do it all: How a new South Africa has harnessed water to address its development challenges. In R. Lenton; M. Muller, *Integrated water resources management in practice. Better water management for development*. London: Earthscan.

Nahman, A.; Wise, R.; de Lange, W. (2009). Environmental and resource economics in South Africa: Status quo and lessons for developing countries. *South African Journal of Science*, 105, 350-355.

National Research Council (NRC) (1997). *Valuing ground water: economic concepts and approaches*. Washington, DC: National Academy Press.

North, D. C. (1996). *Institutions, institutional change and economic performance*. Cambridge: Cambridge University Press.

Ostrom, E. (1990). *Governing the commons: The evolution of institutions for collective action*. Cambridge: Cambridge University Press.

Pahl-Wostl, C.; Craps, M.; Dewulf, A.; Mostert, E.; Tabara, D.; Taillieu, T. (2007). Social learning and water resources management. *Ecology and Society*, 12 (2), pp. 5. Online URL: <http://www.ecologyandsociety.org/vol12/iss2/art5/> (5.04.2011).

Pahl-Wostl, C. (2009). A conceptual framework for analyzing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, 19, 354-365.

Pegram, G.; Mazibuko, G.; Hollingworth, B.; Anderson, E. (2006). *Strategic review of current and emerging governance systems related to water in the environment in South Africa*. WRC Report No. 1514/1/06. Pretoria: Water Research Commission (WRC).

Pietersen, K.; Beekman, H. E., Holland, M. (2011). *South African Groundwater Governance Case Study.* WRC Report No. KV 273/11. Pretoria: Water Research Commission (WRC).
Plummer, R.; Armitage, D. (2010). Integrating perspectives on adaptive capacity and environmental governance. In D. Armitage; R. Plummer (Eds.), *Adaptive capacity and environmental governance*. Berlin: Springer, 1-19.
Powell, W. W. (1991). Neither market nor hierarchy: Network forms of organization. In G. Thompson; J. Frances; R. Levačić; J. Mitchell (Eds.), *Markets, hierarchies and networks. The coordination of social life*. London: Sage Publications, 265-276.
Quibell, G. (2007). *Assessing policy influences on people's relationship to water ecosystem services: The South African experience*. International Institute for Environment and Development. Online URL: <http://pubs.iied.org/GO2515.html> (27.03.2011).
Raudsepp-Hearne, C.; Peterson, G. D.; Bennett, E. M. (2010). Ecosystem service bundles for analyzing tradeoffs in diverse landscapes. *Proceedings of the National Academy of Sciences*, 107 (11), 5242-5247.
Republic of South Africa (RSA) (1996). *Constitution of the Republic of South Africa*. Act 108 of 1996. Pretoria: Government Printer.
Republic of South Africa (RSA) (1998).*National Water Act*. Act No. 36 of 1998. Pretoria: Government Printer.
Rhodes, R. A. W. (2000). Governance and public administration. In J. Pierre (Ed.), *Debating governance: Authority, steering, and democracy*. Oxford: Oxford University Press, 54-90.
Rodríguez, J. P.; Beard, Jr., T. D.; Bennett, E. M.; Cumming, G. S.; Cork, S. J.; Agard, J.; Dobson, A. P.; Peterson, G. D. (2006). Trade-offs across space, time, and ecosystem services. *Ecology and Society*, 11 (1), pp. 28. Online URL: <http://www.ecologyandsociety.org/vol11/iss1/art28/> (16.03.2011).
Rogers, P.; Hall, A. W. (2003). *Effective water governance*. TEC Background Papers No. 7. Stockholm: Global Water Partnership (GWP).
Rottenburg, R. (1995). Formale und informelle Beziehungen in Organisationen. In A. von Oppen; R. Rottenburg, *Organisationswandel in Afrika: Kollektive Praxis und kulturelle Aneignung*. Berlin: Das arabische Buch, 19-34.
Scott, W. R. (2008). *Institutions and organizations: Ideas and interests*. Third edition. Los Angeles: Sage Publications.
Seward, P.; Xu, Y.; Brendonck, L. (2006). Sustainable groundwater use, the capture principle, and adaptive management. *Water SA*, 32 (4), 473-482.
Seward, P. (2010). Challenges facing environmentally sustainable ground water use in South Africa. *Ground Water*, 48 (2), 239-245.
Stuart-Hill, S.; Schulze, R. E. (2010). Does South Africa's water law and policy allow for climate change adaptation? *Climate and Development*, 2, 128-144.
Theesfeld, I. (2010). Institutional challenges for national groundwater governance: Policies and issues. *Ground Water*, 48 (1), 131-142.
Thompson, G.; Frances, J.; Levačić, R.; Mitchell, J. (Eds.) (1991). *Markets, hierarchies and networks. The coordination of social life*. London: Sage Publications.
Tropp, H. (2007). Water governance: Trends and needs for new capacity development. *Water Policy*, 9 (2), 19-30.
Turton, A.; Godfrey, L.; Julien, F.; Hattingh, H. (2006). Unpacking groundwater governance through the lens of a trialogue: A Southern African Case Study. *Proceedings of the International Symposium on Groundwater Sustainability*

(ISGWAS), Alicante, Spain, 24-27 January 2006, 369-386. Online URL:<http://www.ehrn.co.za/publications/download/113.pdf> (11.03.2011).
Turton, A.; Hattingh, H.; Claassen, M.; Roux, D.; Ashton, P. (2007). Towards a model for ecosystem governance: An integrated water resource management example. In A. Turton; H. Hattingh; G. Maree; D. Roux; M. Claassen; W. Strydom (Eds.), *Governance as a trialogue: Government – society – science in transition*. Berlin: Springer, 1-28.
Vatn, A. (2005). *Institutions and the environment*. Cheltenham: Edward Elgar Publishing.
Wainger, L. A.; King, D. M.; Mack, R. N.; Price, E. W.; Maslin, T. (2010). Can the concept of ecosystem services be practically applied to improve natural resource management decisions? *Ecological Economics*, 69, 978-987.
World Resources Institute (WRI) (2000). *A guide to world resources 2000-2001: People and ecosystems: The fraying web of life*. Washington, DC: World Resources Institute.
Young, O. R. (2002). *The institutional dimensions of environmental change: Fit, interplay, and scale*. Cambridge, Massachusetts: MIT Press.