International Water Security Network

Resilience by Design:
A selection of case studies

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We would sincerely like to thank all the presenters who attended the workshop held on 11th August 2016 at the Institute of Natural Resources (INR), South Africa and engaged so enthusiastically. There are some presenters who attended the workshop who could not contribute to this publication including Richard Meissner and Sabine Stuart-Hill and we sincerely thank them for their contribution to the discourse of resilience by design in this publication. We especially thank all the contributors who made this small publication possible.

A final word of thanks to Charles Breen who willingly coordinated the workshop held at INR and laid the foundations for this resulting publication.

Achieving Resilience by Design

The International Water Security Network project is a joint initiative funded by Lloyds Register Foundation and led by the University of the West of England in partnership with the University of Arizona, Monash South Africa and the Institute of Natural Resources. The project is investigating water security issues through three key work packages:

1. Towards Urban Water Security (UWE, Bristol)
2. Transboundary Water Security (University of Arizona)
3. Improving Water Quality Security (Monash South Africa)

These work packages are grounded in real world concerns and experiences and propose solutions and best practices that can be transferred and shared for the public good.

The initiative reported on here arose from a publication of the Lloyd's Register Foundation Foresight review of resilience engineering that considered how to 'design for the expected and unexpected'. As our interests centre on governance, we posed the question: Can we consciously design social-ecological systems such that they become more resilient? Inherent in this question is the notion that it may also be desirable to weaken resilience in those systems that persist in an undesirable state. To this end we invited researchers who were engaging social-ecological systems in different ways to reflect on the relevance of the concept of resilience for their research. Our intention was to provide a forum for discussion and learning, particularly given that "Resilience has fast become a popular catchphrase used by government, international finance organisations, NGOs, community groups and activists all over the globe. Despite its widespread use, there remains confusion over what resilience is and the purpose it serves." (Cretney, 2014:627).

In this report we provide short summaries of authors' contributions. Further information can be obtained from Professor Bimo Nkhata or the authors.

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Resilience by design participants at workshop held on 11th August 2016

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Reflection on the theme: “Achieving resilience by design”

Brian Chaffin

The theme and concept of “achieving resilience by design” seems like a reasonable goal of environmental governance and development when taken at face value. Resilience, in popular connotation, is often synonymous with longevity, persistence, resistance, and strength in the face of adversity (Zolli and Healy 2012). It is inherent that humans want a resilient earth and resilient societies that persist through disturbances and adversity, and it is understandable that humans want to create and *sustain* this resilience despite the biophysical and social changes we continue to experience on this planet.

But how do you design for resilience? I argue here that a critical element in this discussion revolves around how “resilience” is defined. In both popular and academic literatures there are a multitude of definitions for the term “resilience” (see Brand and Jax 2007). There are three distinct definitions, however, that are critically important to the discussion of resilience in environment and development research: 1) engineering resilience; 2) social resilience; and 3) ecological (or social-ecological) resilience. In all three definitions, resilience can be said to be a property of complex systems. The first definition, engineering resilience, is relatively straightforward: resistance to disturbance and return time to an original (equilibrium) state are the measure of the property of resilience in systems (Gunderson and Holling 2002 citing others, p. 27). In contrast, Adger (2000, p. 347) defines social resilience as “the ability of groups or communities to cope with external stresses and disturbances as a result of social, political and environmental change.” This definition emphasises the adaptability of humans and the property of resilience is measured in terms of human capacity (as opposed to system-wide) to cope with changing social-ecological contexts or to mitigate uncertainty.

In the definitions of both engineering and social resilience, the property of resilience resonates normatively. The capacity of a system to return to an equilibrium state or the capacity of a society to persist through adaptation to disturbance is valued as a desirable quality. The third definition of resilience, ecological resilience, emphasises instead that resilience is a valueless, non-normative property of complex systems. This definition describes the property of resilience as the capacity of a system to withstand disturbance while still maintaining structure and function. Ecological resilience incorporates the idea that there is not a single state of equilibrium for any given system, but instead systems can and do exist in multiple states of being based on a changing configuration of controlling variables that organise the structure and function of the system. Each of these states (also termed “regimes”) has an associated level of “resilience” to shifting into an alternate state. Disturbances, both internal to the system and external in scale, can weaken or exceed the resilience of a system, causing a regime shift across a threshold to a new state. In this case, the property of resilience is not good or bad, but instead the state of a given system may be desirable or undesirable. Through environmental governance we aim to strengthen resilience of systems in desirable states and weaken resilience of systems in undesirable states, potentially causing a regime shift in an effort to direct a system toward a more desirable and sustainable regime.

Resilience and sustainability, however, are different. A sustainable SES, one in which human use and conservation of resources provides adequately for future generations, is inherently a desirable SES at a societal level. A resilient SES, however, is not always desirable. A SES stuck in a degraded state or an unfavourable regime may be very resilient to change—think of the takeover of an invasive pest or plant that inhibits agriculture or the dominance of a powerful and oppressive dictatorship. In these cases, the goal of research on resilience is to better understand a SES’s dynamics, controlling variables, and cross-scale interactions that support the current regime, so that governance actors may be better informed in attempts to build capacity to weaken SES resilience and guide regime shifts.

Accordingly, a major research question might be: *how do we build capacity to either strengthen or weaken resilience of SESs*? Equally important, however, is the question: *how do we know when to strengthen or weaken resilience*, or in other words, *how do we collectively define desirable SES regimes*? These are questions of governance and of the negotiation of human values and are difficult to quantify. They involve issues of fairness, inclusiveness, transparency, and accountability as well as how governance actors should exercise their authorities (Lockwood, 2010). We must not only consider “resilience of what, to what” (Carpenter et al. 2001), but also resilience for whom” (Cretney 2014). The concept of resilience as a property of complex systems, as well as the questions outlined above, are important to consider when attempting to “achieve resilience by design.” Resilience is more than just a state to achieve; resilience thinking encompasses a host of conceptual ideas toward a deeper understanding of the dynamics of complex SESs, and thus is critical for an informed approach to actively designing more desirable and sustainable SESs.

Polycentric governance: Designing resilient solutions for improving water quality security in a complex world

Bimo Nkhata and Machaya Chomba

Water quality is fundamental for good river health. It sustains ecological processes and supports economic productivity and human health. Water quality security refers to the capacity of social actors to safeguard access to desirable quality of water for ecosystems and society. The term 'safeguard' in this context denotes the ability to handle uncertainty and surprises associated with water quality management. Yet, undesirable water quality in Southern African river basins continues to place the safety of life and property at great risk. While there are significant social and economic costs associated with the deteriorating quality of water, it is important to also acknowledge the various important benefits of water quality.

One of the most confounding challenges facing water quality management in Southern African is how to encourage effective problem solving and resilient solutions at larger scales. While encouraging effective problem solving may be easier at micro scales such as laboratories, resilient solutions require working not only at the micro but also at the meso and macro levels. Resilient solutions denote the capacity of interventions to deliver intended benefits, despite changes in their complex context. A vital foundation for resilient solutions is polycentric systems of governance which involve a diversity of decision-making (governance) centres, of which government is just a part. Over the years, our research has highlighted the great magnitude of uncertainties and surprises that underlie the water quality related management programmes in Southern Africa.

Emerging findings and conclusion

Conventional water quality management is often expressed in technical terms such as eutrophication, bioaccumulation and toxicity. It is represented by the significant advances in fields such as water microbiology and chemical engineering that strongly focus on understanding biotic and chemical interactions. For example, there is now better appreciation of the proximate causes of water pollution such as nutrients, heavy metals, organic micro-pollutants and microbial contaminants. This paradigm of water quality management is essentially experimental, analytical and reductionist. It mostly operates at micro scales such as laboratories where it has been predominantly successful.

Conventional water quality management is also principally driven by state agencies. In South Africa, for example, water quality management is an exclusive state competency and is the responsibility of the Minister of Water and Sanitation. This approach centres on activities such as centralised technical decision-making, setting of technical standards for water quality parameters, and monitoring of water pollution impacts. In 2008, based on this approach, the then Department of Water Affairs introduced a national water quality programme aimed at improving the quality of tap water through compliance monitoring. The introduction of this programme led to the initiation of a centralised state-based monitoring scheme called the Blue Drop system. This system aims to test the quality of drinking water provided by the country's municipalities. It involves the granting of 'Blue Drop' status by the state to municipalities that meet 95% of the monitoring criteria.

Management of water quality is complex and difficult at larger scales such as river basins that have multiple, conflicting uses of water. The water quality problems that emerge from this complexity are inherently multi-scale and involve interactions across different variables. While state driven management of water quality seems to be successful at micro scales, it usually generates partial solutions to the broader problem of water quality insecurity. In addition, Polycentric governance denotes multiple centres of authority across institutional scales thereby allowing cross scale interaction in the governance system. It is important to note that actors have different capacities and resources that influence cross scale interaction. The degree to which actors actively participate in polycentric governance arrangements depends on how actors engage across institutional scales and the extent to which they recognise and aware of the problem domain and risks their face collectively as stakeholders.

Resilience entails multiple stable states that are associated with certain institutional outcomes. These institutional outcomes produce varying benefits that may favour some actors and not others. A shift of resilience from one resilience state to another may face resistance by actors whose current resilience state benefits. For example, the current state of water allocation in the Kafue River Basin, particularly in the Kafue Flats is associated with favouring certain institutional actors such as Zambia Electricity Supply Corporation (ZESCO), commercial farmers and the water municipality. A shift in water allocation regime to a more resilience regime is prone to face some resistance from certain actors.

Science -policy dialogues and resilience

Christopher Scott, Robert Varady, and Adriana Zuniga-Teran

The standard approach to water security has been through the human-centred use of technology. While this approach was successful in providing water of good quality to support large populations of humans around the globe it has had many unintended, mostly negative, consequences.

An alternative approach to water security is one that considers from the outset the potential outcomes of the integrated and dynamic social - ecological - hydrological systems (Figure). This approach assumes that altering one system - as a means to provide water security - has the potential to change, through a rippling effect, the other systems sometimes leading to negative, unanticipated outcomes. Resilience in this context means that, even after encountering disturbances, the systems do not pass thresholds that would push them into a different state.

Adaptive management through science-policy dialogues show some promise in enhancing resilience and water security. This is because it is a management approach that "accounts for what is uncertain as well as what is known about the processes that influence natural resources behaviour through time and the influence of management on resource changes (adaptive management) seeks to reduce this uncertainty and thereby improve management through enhanced understanding of management effects." (Williams and Brown 2012: 18).

Science-policy dialogues comprise a series of meetings where a network of people involved in decision-making (e.g., about water resource management) gather with scientists to explore ways to reduce vulnerability and increase adaptation to changing climatic conditions (Scott et al. 2012). To succeed, science-policy dialogues need four conditions:

1. Inclusivity – the presence of wide-ranging viewpoints and interests
2. Involvement – the persistence of individuals to participate
3. Interaction – the usefulness of discussions and exchanges among participants
4. Influence – the ability to affect or inform policy outcomes.

Adaptive management enhances resilience because it uses flexible planning, knowledge-sharing, and capacity-building.

Flexible planning means that the outcomes of a plan are monitored, evaluated, and revised in a short-iterative process that repeats over time. This allows working with uncertainty and as the future unfolds, decision-makers re-evaluate the plan and develop new objectives.

Knowledge-sharing comes from the scientists sharing their findings and assessments and from the community of stakeholders who have the opportunity to formulate scientific inquiry customised to their needs. This is commonly referred to as *use-inspired science.* This, successful knowledge-sharing occurs in two directions, between scientists and stakeholders.

Capacity-building may occur, for example, through workshops and a series of science-policy dialogues where the professionals in charge of managing water resources can learn the state-of-the-art in scientific discoveries in terms of governance and technologies. They would also become familiar with the real needs of the local residents, users, and other stakeholders. This process would help enable them do their job—manage water—more effectively.

Experience has shown that science-policy dialogues can offer more robust solutions than conventional approaches to assist in decision-making under conditions of uncertainty. In the conventional approach, for example, the role that scientists play, tends to be separated from policy outcomes and the findings of scientific inquiry are confined to scientific publications, typically not sources of information for non-scientific decision-makers. By contrast, the policy-dialogue approach—which ideally includes social scientists, physical scientists, engineers, lawyers, and others—ensures inclusivity among the multiple stakeholders, allows the necessary interactions to address uncertainty, and distributes usable information. Through a set of sequential interactions, a series of dialogues and solutions sets can develop over time.

Figure: Water security lies at the centre of the interactions between the social-ecological-hydrological systems. Scott et al., 2013.

Slow variables, critical thresholds and cross-scale interactions in Zambia: Vulnerability of the Kafue Floodplain people

Agness Musutu, Charles Breen, Linda Downsborough, and Bimo Nkhata

The Zambian economy is largely dependent on hydropower generated in the Kafue and Zambezi rivers with the Kafue River catchment accounting for 85% of the total water demand. The Zambia Electricity Supply Corporation (ZESCO) defines its challenge in terms of supply of power to the country. It needs to sustain a sufficient head of water in the Kafue Gorge dam for power generation. Thus, ZESCO seeks to shift the water management focus to ensuring that water reaching the Kafue Gorge dam is always sufficient to meet the national demand for power. It also seeks to control downstream water abstraction for irrigation by controlling releases from Itezhi-Tezhi Dam.

Rainfall in Zambia is seasonally variable with little rain in the dry winter and early summer. Consequently, the challenge for the large sugar estates on the Kafue Flats is a more secure supply in the dry months. They seek to shift the focus of river flow management to lowering floods and raising winter flows. However, there are 1.1 million people whose livelihoods are sustained by summer floods that create conditions for fish breeding and regrowth of floodplain pastures. Their challenge is to achieve a flow pattern that mimics river flow before it was regulated by the Itezhi-Tezhi Dam. But, because of increasing demand for water and lower rainfall over the past 20 years, flows are already very different to the historical flows and they are expected to change further with agricultural expansion in the upper catchment and growth in demand for hydropower. Unless energy can be drawn from other sources it will become less feasible to implement a flow regime that can sustain the floodplain and the livelihoods dependent on its services.

The per capita fish production has declined by about 64% from around 14 kg per person per year in the 1980s to around 5 kg per person per year in 2000s while per capita maize production has declined by about 75% from around 800 kg per person per year in the 1980s to around 200 kg per person per year in 2000s and per capita cattle heads has declined by about 50% from around 1.2 heads per person per year in the 1980s to around 0.6 heads per person per year in the 2000s (Ngoma, 2010:49). Cross scale interactions are shaping the trend in vulnerability. Demands for water and for energy are driven by national priorities that make it difficult to conceive of local scale strategies that can mitigate the factors that are driving the system towards a threshold. And, as vulnerability increases, local smaller scale changes, such as increased fishing activity, while seeming to alleviate the situation, strengthen the trend in the longer term.

These findings suggest that vulnerability of the floodplain social-ecological system is a slowly changing variable that while acutely experienced at local scale is less evident and 'real' for those remote from it. Increasing vulnerability of the floodplain people will drive change at larger scale, as the nation is forced to respond. Thus, it can be argued that reversing the trend requires solutions that are derived through cross scale interactions and that "Addressing challenges in one nexus domain without considering the connections to other actors or nexus dimensions can have the result that problems are not solved but shifted to other actors, sectors, geographic locations or scales." (Stein et al., 2014:1).

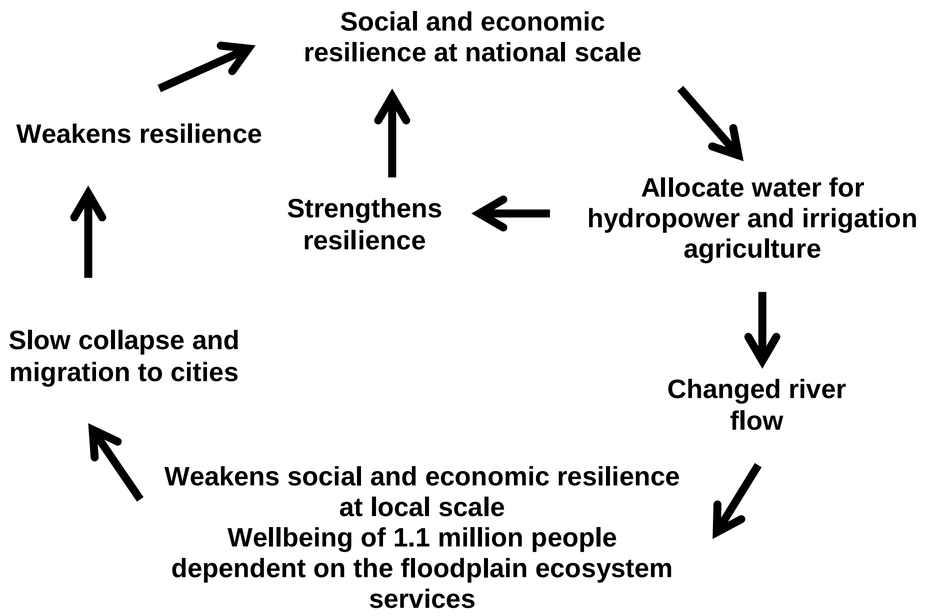

Figure: Climate change, water use and migration into the area are forcing the floodplain social-ecological system toward a threshold that can be largely defined by increasing human vulnerability. Musutu, 2016.

Small-scale sugar cane out-growers: context, capacity and system resilience

Nkosinomusa Ncube, Charles Breen, and Linda Downsborough

How we cope with change, whether intended or unintended, depends on our ability to engage and to influence the trajectory (direction and pace) of change; it requires the ongoing development and application of collective capacity at all levels from individual to institutional. By mobilising collective capacity, we are enabled to bring about appropriate regime shifts and progress toward more desirable system states. In this sense capacity to effect change and to strengthen or weaken resilience is context dependent. It is now well established that system conditions (the context within which a community exists) strongly affect capacity to respond to disasters and change endeavours. This understanding directs attention to the need to find ways of building enabling social contexts that are more supportive of effecting change through improved self-organisation.

This study focused on smallholders in two out-grower schemes in the sugar industry of Zambia that have different origins and operating contexts. Our intention was to elucidate how context was enabling or disabling development of the capacity required for success. Smallholders in such schemes depend on each other, especially when they share a water distribution system. This interdependence requires willingness and the necessary capabilities to work collectively in order to achieve their individual and corporate objectives. At Manyonyo smallholder out-grower scheme 164 farmers jointly own the land, have a water user right to abstract water from the Kafue River and have established the Manyonyo Water User Association which operates the Manyonyo Irrigation Company (MIC). By contrast, the Kaleya Smallholders Company (KASCOL) operates the Kaleya Estate that provides the core sugar cane production system, infrastructure and support for 160 smallholders who farm on part of the estate that is land leased from KASCOL. The other part of the estate is also used for sugar cane production but is not leased to smallholders. The farmers working on this part of the estate are not smallholders but are employees of the company.

Access to resources, such as land and water, should be empowering forces in smallholder agriculture. While participants in both smallholder out-grower schemes have access to water and land, ownership and the ability to control these resources are shown to be distinguishing contextual factors shaping attitudes, motivation and performance and hence influence over system resilience. While the resource ownership at Manyonyo might be expected to position them well for building resilience, the results suggest that they are not able to realise its full potential because other factors including financial resources and infrastructure, constrain their performance. The opposite prevails in Kaleya where infrastructure and finances are provided but the lack of ownership constrains performance. Context is shown to be dynamic, multifaceted with complex interactions in both schemes. We suggest that while a resilience approach to sustainability rightly focuses on how to build capacity to deal with unexpected change, it should also give explicit attention to establishing contextual conditions that would be more supportive of the seven actions suggested by Simonsen et al. (2015): Maintain diversity and redundancy; Manage connectivity; Manage slow variables and feedbacks; Foster complex adaptive systems thinking; Encourage learning; Broaden participation and Promote polycentric governance systems.

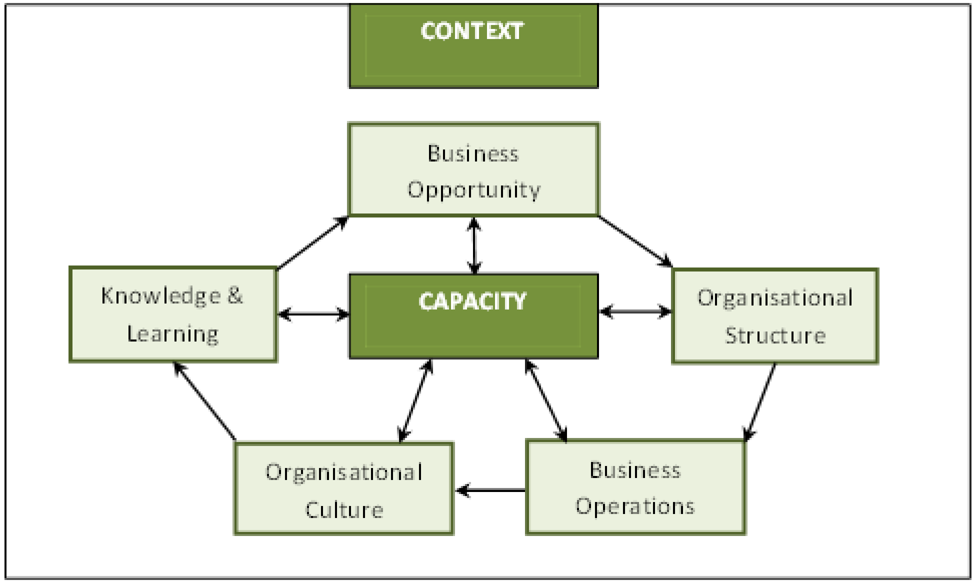

Figure: Illustration of capacity and system resilience. Ncube, 2016.

Resilience and the Mooi River dairy farmers

Nyaradzo Nazare, Charles Breen and Linda Downsborough

The dairy farmers in this study perceive themselves as vulnerable to water insecurity, increasing energy cost and declining profit margins. Because resource scarcity (risk) motivates self-regulation (Baumeister et al., 2006) developing the capacity to self-regulate is a way in which individuals and organisations manage vulnerability and enhance resilience (Engle, 2011).

Photo: D. Hay

Because the above mentioned three risks are common to all the farmers, they establish direct connections among individual and collective decision-making processes that are directed toward designing and implementing cost-effective ways of reducing risks to tolerable levels. And, the ability to do so is continually reinforced through anticipating, responding, monitoring and learning from the feedbacks associated with the changes in risk-related behaviour and re-allocation of the resource. The commonality of risks and the need to manage them collectively, results in an inclusive organisational unit (a social-ecological system bounded in space and time) within which the social decision-making and learning processes lead to explicit strategies that promote development of the social capital and trust required to sustain social cohesion.

Growing demands from other sectors and users of water and their own critical reliance on a sustained water supply motivates the farmers to use water and energy efficiently. In an attempt to regulate their own water use and achieve 'best practices' the Moor river dairy farmers have formed close knit 'study groups'. The learning from these groups is put into practice by individual farmers. However, because of the scarcity of water and the requirement that water should not be wasted, farmers are subject to sanction by the Mooi River Irrigation Board (MRIB) if they do not implement 'best farming practice'. In this way, the farmers collectively configure their capabilities to mitigate risk. While the strategies for allocation and learning do contribute to the sustainable use of water, the underlying intent is to enable the farmers to enhance system resilience in the face of water insecurity and increasing costs of production.

The approach followed by these farmers illustrates the importance of having a nested organisational structure in which the individual farmers, study groups, collective of farmers, the Mooi River Irrigation Board and others are sufficiently independent to enable each to make decisions within their own competency, while contextualising their decisions with reference to the system as a whole.

Evidence suggests that resilience of the Mooi River Dairy farmer social-ecological system is being strengthened by sustaining their capacity to engage the seven activities suggested by Simonsen et al. (2015):

- Maintain diversity and redundancy – farmers are interdependent and support each other to prevent failure. There is redundancy in the system in the sense that failure of one farmer would not necessarily lead to system collapse
- Manage connectivity- Individual farmers within the system are embedded within a web of connections
- Manage slow variables and feedback -farmers take a long-term view of their business, and so they are vulnerable to change that emerges slowly over time
- Foster complex adaptive systems thinking - The dairy farmers in this study are specialists
- Encourage learning; Risk motivates learning and the development of 'best farming practices'
- Broaden participation - farmers awareness of the larger systems is reflected in the strength of their connectedness with other organisations that operate at larger scale.
- Promote polycentric governance systems - individual farmers, study groups, collective of farmers, the MRIB, and others are sufficiently independent to enable each to make decisions within their own competency, while contextualising their decisions with reference to the system as a whole.

These findings suggest that the farmers are consciously developing capabilities to monitor, respond, anticipate and learn. The commonality of risks and the need to manage them collectively results in an inclusive organisational unit (a social-ecological system bounded in space and time) within which the social decision-making and learning processes lead to explicit strategies that promote resilience.

Adaptive capacity and water security in complex irrigation systems: A case of small-scale farmers in South Africa

Binganidzo Muchara, Brigid Letty and Maxwell Mudhara

It can be argued that the complex nature of communal irrigation systems, which stems mostly from the inherent complex designs, exposes the systems to high failure rates. Reducing the complexity of the system as well as adaptive capacity can be regarded as key to building resilient systems (Walker et al., 2002). It is based on this thinking that the study applied the basic principles of adaptive capacity to understand the state of water insecurity and governance in the Mooi River Irrigation Scheme (MRIS). The importance of adaptive management and understanding the complexity of an agricultural setup is borne by the fact that water security in such environments is not always guaranteed. To promulgate this notion, Allan (2013) argued that where irrigation is taking place, there is a possibility of running out of water, thereby exposing the farmers to high risk of losing their crops and livelihoods. The power of adaptive capacity is important among South African smallholder irrigators in order to reduce vulnerability and improve coping strategies in response to drought as well as seasonal variation in irrigation water supply.

Photo: B, Muchara

The study was conducted in the Mooi River Irrigation Scheme (MRIS) located in the KwaZulu-Natal Province of South Africa. The MRIS consists of 15 blocks (604ha) that run along the Mooi River and is managed by 824 scheme members and unknown number of irrigators with plots outside the scheme boundaries. Water for irrigation is diverted from a weir constructed across the Mooi River and flows by gravity along the main canal, which is about 20.8km in length. The size of the scheme in terms of number of water users and the water sharing arrangements makes the scheme inherently complex. The open access nature of the canal water made the enforcement of the principle of resource bounding of a socio-ecological system a challenge and led to water shortages among water users, with severe consequences among the tail end irrigators.

There was a general perception that infield water distribution among block/scheme members was unfair. Unequal water distribution had existed for a long time and negatively impacted on farmers' relations and trust, hence affected irrigators' commitment to performing group activities in the scheme. Lack of trust also limited the level and intensity of networks that could have been used to improve benefit sharing by confining the interactions to relatives, close family friends and church members. Although farmers in MRIS believed that water measurement devices could "to a lesser extend" help to improve the current unequal water allocation patterns, there is a strong view that farmers' willingness to comply with water allocation regulations had a potential to offer much more sustainable solutions to the water shortages being experienced.

Farmers' willingness to participate in water management processes is critical at the local level. The study revealed that although farmers were dissatisfied with the level of water supply in the scheme, about 35% of these farmers were not participating in water management structures and were not willing to do so, while a further 21% were willing to participate but were not doing so. This exposed another form of complexity where decentralisation of water management systems was impeded by the unwillingness of the irrigators to take part in the process of management. Increased willingness to participate in activities such as cleaning the canal would be likely to improve water security. More effective management of the irrigation scheme would require a more effective polycentric and adaptive governance system, which has a capability to reduce complexity of the system and not just adding another layer of governance. The challenge that the water governing authorities and other stakeholders grapple with, is how to instil the sense of responsibility and willingness of the smallholder farmers to actively and responsibly participate in water related activities to enhance water security.

Can ecological restoration enhance social-ecological resilience of small scale farmers in rural KwaZulu-Natal, South Africa?

Ernita van Wyk, Michael Jennings, Mpfunzeni Tshindane, Mandy Barnett and Japie Buckle

It can be argued that ecological restoration is an intervention that purposefully alters the flow and levels of ecosystem services (i.e. benefits) and that the intention is to improve and enhance benefits to society (van Wyk et al., 2016; Egan et al., 2012). Because the purposeful altering of benefits and benefit streams affect different stakeholders differently, plans for restoration sometimes creates opportunities for conflict. But it also creates opportunities for deliberation and the development of social and institutional capital (van Wyk et al., 2014; Adams et al., 2003). As stakeholders discuss and try to reconcile individual and shared gains and losses, they may generate appreciation for the common good and make behavioural adjustments that align more closely with shared goals of the group, despite individual interests. Therefore, perceptions of risks and opportunities in relation to benefits shape stakeholder response. Implied in this is the notion that planned ecological restoration is a vehicle for anticipating change, for stimulating self-organisation and for cultivating the social adaptation skills and habits needed to successfully engage change. When viewed in this way, ecological restoration provides opportunities for enhancing social-ecological resilience. But how can plans for ecological restoration and the associated altered provision of ecosystem services purposefully incorporate the intention to enhance resilience?

The uMgungundlovu District (9 513 km^2) in KwaZulu-Natal comprises mainly local communities who are primarily small-scale farmers. A major issue for small-scale farmers is their vulnerability to more erratic and extreme climatic patterns and events. In addition, the area has an under-resourced municipality, further increasing overall vulnerability. As a result, this area has been selected for a landscape scale ecological restoration initiative. This intervention will include 12 km of riparian and 200 ha of grassland restoration (SANBI, undated). Reduced farmer vulnerability, social transformation and resilience are stated as intended outcomes of the restoration interventions. The early stage of this project (currently - 2016 - in the planning phase) presents an opportunity to consider how restoration interventions can be planned to purposefully enhance social-ecological resilience.

Whilst restoration interventions may lead to ecological resilience of grasslands and riparian habitats, it cannot be assumed that these changes will necessarily lead to enhanced benefits or that the community will be able to adapt and take advantage of the potential change in the provision of benefits. Simonsen et al., 2015 and Biggs et al., 2015, propose seven principles of resilience. These are useful as they represent the attributes of resilient systems. But how can communities develop such that their social-ecological system is characterised by resilience? Initially resilience work focused on the capacity to absorb shocks and still maintain original function. But more recently, emphasis has moved to include aspects around the capacity for renewal, re-organisation and development (Folke, 2006). Recognising the need for and creating capacity for managing resilience in social-ecological systems are important themes in the contemporary global sustainability agenda (Biggs et al., 2015; Walker et al., 2004; Gallopín, 2002). Within this context, social and institutional anticipation of risks and opportunities, learning and adaptive capacity are important dimensions of resilience when considering how societies prepare for change whilst facing an uncertain future (Gallopín, 2002; Lebel et al., 2006). In the case of the KwaZulu-Natal rural farmers, it will also be important to understand these factors in an historical context in order to appreciate why the system has moved into an undesirable state and how this might influence their capacity to benefit from the planned restoration.

Strengthening resilience to environmental disruptions through risk management: A case of the South African sugar industry

Busani Masiri

Environmental disruptions (risks) such as droughts can have ecological and economic consequences and will pose an increasing challenge to water users as the global climate changes. This is especially so in southern Africa where the frequency of extreme weather events is expected to increase (Tschirley et al., 2004). Response to these changes entails reducing vulnerability and enhancing the capacity to adapt, thus by extension the resilience of social ecological systems (SES) (Nelson et al., 2007).

Managing risk is central to organisational sustainability; the better actors are at sensing and constructively responding to emerging risk the better they are able to cope with change. Polycentric systems (if applied consciously) provide a foundation for resilient solutions to environmental disruptions like droughts because they comprise multiple decision-making centres. Not only does this provide opportunities for strengthening resilience at localised levels but it also acts as a platform for diverse solutions to environmental disruptions and risks that they pose.

The manner in which actors, individually and collectively, organise and conduct their affairs determines their capacity to anticipate and cope with change – it influences their resilience and that of the systems of which they are a part. In this regard the South African sugar industry provided a case study through which I could explore one of the seven principles of building resilience in SES as expressed by Simonsen et al. (2015): 'promote polycentric governance systems'. This is so because the nested structure which characterises the sugar industry in South Africa builds redundancy within governance institutions thus when there's a failure in one jurisdiction restoration can be achieved by leveraging the redundancy in adjacent systems or a higher level jurisdiction thus allowing the SES to retain its function and structure whilst maintaining options to develop. The figure below shows how risk transcends the value chain in the sugar industry.

Actors within the sugar industry experience risk differently. Yet, how each actor (or interest group) responds can have profound influences for all stakeholders. The interdependence among actors in SES, the collective exposure to risk, and the need for purposeful management of risk are the drivers for the need to strengthen resilience within agro-ecosystems, the sugar industry in particular.

This helps us appreciate the need for a collective approach to risk management within and across scales with recognition of self-organisation among interest groups. Because of the interconnection within and among SES in a polycentric system there's an advancement of collective learning through coordination and integrated decision-making. This then becomes a way of strengthening resilience into the social-ecological system. The Millers, Cane Growers and the South African Sugar Association (SASA) provide the capacity for resilience by building 'shadow' networks and social capital through organisational nesting.

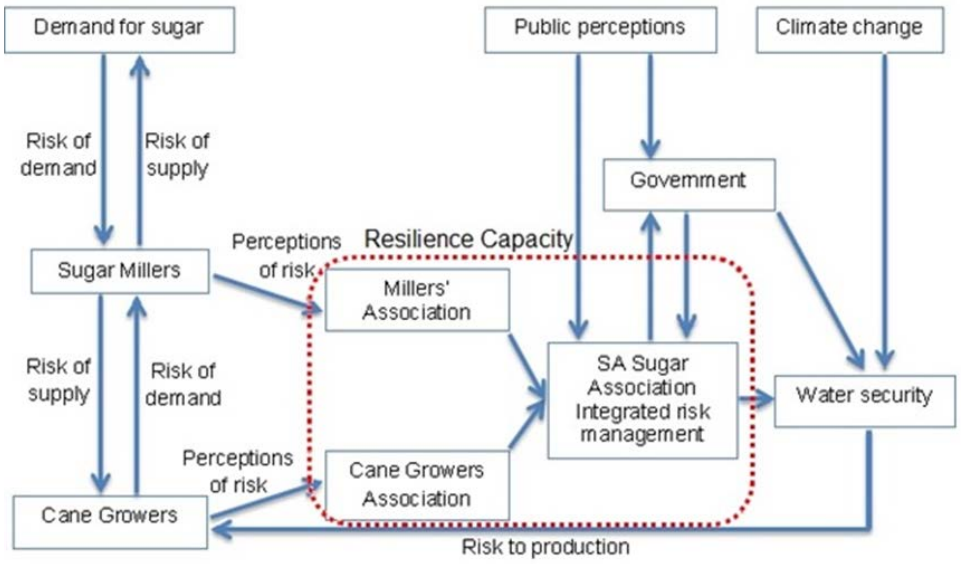

Figure: How risk transcends the supply chain in the sugar industry. Masiri, 2016.

Diversity as a key element of urban resilience
Adriana Zuniga-Teran and Tamee Albrecht

Cities and towns are home to half the world's population and this is expected to increase to more than sixty per cent by 2050. Not surprisingly the 100 resilient cities initiative suggests that 'Cities are our biggest hope but also our greatest risk." While we cannot escape risk, there are things we can do to ensure we are better able to cope, survive and adapt. One way is to promote diversity and redundancy. Diversity allows risk to be distributed; it provides for multiple options while redundancy provides for failure without compromising the larger system.

Some risks emerge slowly over time. The city of Detroit, for example, hosted the rise of the motor industry in the United States. These businesses attracted many people and the city grew six fold, becoming the fifth largest city in the United States. People depended on the car industry; when it suffered, most people also suffered. There were few options and the city was not resilient to its emergent social and economic conditions which were aggravated by social and economic segregation and weak social cohesion.

Social cohesion - or sense of community - is an essential element for resilience. People who possess a mixture of social connections are more likely to survive the disturbance and adapt more quickly to the new circumstances. During the 1995 heat wave in Chicago victims were mostly poor people who did not have air conditioning systems and who would not open the windows for fear of crime. The survivors were more socially engaged because they were able to draw on each other for support. Including a range of types of small businesses in city design can also promote social cohesion. When shops and restaurants are close to homes, people establish personal contacts and with more people on the streets they provide security from crime and customers for businesses.

As climate change and population growth threaten the functioning of cities across the globe, increasing diversity in all the subsystems of a city (economic, industrial, transportation, housing, society, water, energy, and land use) adds redundancy to the connections between subsystems. And, with more options when one connection fails others maintain the functioning of the whole system. For example, resilience can be enhanced by diversifying modes of transportation. A city that has infrastructure in place for rapid transit systems (e.g. trains or subway), buses, walking and biking paths, and automobiles is more resilient than a city that becomes too reliant on one mode (e.g., automobiles). During 2015 Boston despite multiple modes of transportation, was seriously disrupted after several blizzards. The Governor of Massachusetts subsequently announced a "winter resiliency" plan that included: an electrified third rail; snow ploughs attached to the front of some trains; snow fighter machines to clear railways; new communications; new heating equipment to the two train lines that were most affected; and a partnership with the Department of Corrections to have inmates help clear railways during storms. As trains are the most reliable mode of transportation during snowstorms, the winter resiliency plan focuses on recovering train functioning as quickly as possible. Getting people back to work helps support normal functioning of Boston's economic sectors. Thereafter the focus shifts to clearing roads for buses and automobiles.

"Uniformity is death; diversity is life" – Street sign at Andres Bello University in Santiago, Chile (Photo: R. Varady)

Cities are complex systems with multiple interacting components and processes. The importance of the water-energy nexus is particularly evident during emergency situations. When an unanticipated catastrophic event causes infrastructure to stop functioning, it is necessary to have alternative water and energy sources while the damaged infrastructure is repaired. In 2005 the U.S. Gulf Coast, particularly the City of New Orleans, was deeply affected during hurricane Katrina. The protective levees failed and New Orleans was almost completely flooded. A serious challenge communities faced was a lack of drinking water and sanitation. Failure of the electricity supply led to failure of wastewater-treatment plants which added burden to health services.
There are no simple solutions in complex systems such as cities. But, focusing on promoting diversity and redundancy in the context of fostering resilience can help us understand how to develop the capacity we require for cities to survive, adapt and grow while providing a desirable place to live.

Enviro-Champs: Community mobilisation, education and relationship building
Jim and Liz Taylor

The Challenge
For over twenty years sewerage has flowed from Mpophomeni Township into Midmar dam. This is a serious problem for KwaZulu Natal (KZN) since Midmar dam supplies virtually all the water for Durban and Pietermaritzburg, South Africa's second largest economic hub. One can even see the green swathes from the surcharging sewers on satellite images. Four years ago, in 2012, Sbu Khuzwayo, Mdu Mchunu and Liz Taylor established the Enviro-Champs[1], through DUCT, as an effort to provide a bottom-up and top-down mechanism to change the situation for the better. This was potentially a powerful form of resilience by design!

In sharing this story we foreground the evaluation processes that we are using to try to understand social change processes better. A series of ten principles of human capacity development were also used, as a lens, with which to shape our learning programmes (Lotz-Sisitka, 2005).

After three and a half years of consistent effort, raising awareness and productive cooperation, it seemed as though nothing measureable was being achieved. The sewerage and solid waste continued to flow and accumulate. The Enviro-Champs had done careful monitoring and had all the statistics at their fingertips (recorded on a pivot-table in EXCEL). This monitoring record included when or where the spillages were, who was notified, how long the call-out time took, who fixed the leak, how long before it spilt again etc. All the data recorded in the monitoring table is linked to geographical coordinates and social media is used to enable all to share and contribute to solving the issues.

A turning point ….
Towards the end of 2015 the situation reached a tipping point and a directive was sent from the national Department of Water and Sanitation (DWS) office to send in a team to fix the problem areas. By the 21st of December 2015 the sewers stopped continuous spilling! This is a success story but it was not only due to the Enviro-Champs and their activities. Everyone started to pull their weight.

uMgungundlovu District Municipality (UMDM), Local Municipalities, DWS, Umgeni Water, GroundTruth and WESSA (who provided human capacity development and career pathing for the Enviro-Champs) all helped.

Seeking to understand change
Using a "realistic evaluation" methodology (Pawson and Tilley, 1997) Mike Ward carefully scoped the factors that make this work effective (Ward, 2016). His evaluation research revealed how important relationship building, education and engaged citizen science (Dambuza and Taylor, 2015) really is in achieving more sustainable living. Accredited training courses, offered by WESSA, also supported the processes. The courses require participants to undertake a "Change Project" through which they change their work or home-based practices as a result of the insights received in the training courses. The Change Projects then provide evidence which is assessed towards the accreditation.

What worked – in a nutshell ….
Clearly the combination of citizen science tools, 'close and local' activities, as well as relationship building with key stakeholders all supported the productive changes in Mpophomeni. Well designed and engaging Education for Sustainable Development (Taylor, 2014) processes enabled a groundswell of possibility, which, when coupled with knowledge, understanding and engagement really made a remarkably positive difference in a challenging township context.

Figure: Hot-spot monitoring using Google Earth. This monitoring system is maintained by the Enviro-Champs and provides a pictorial representation of the more problematic hotspots. (Photo: Jim and Liz Taylor)

[1] An Enviro-Champ is any person who seeks to enhance the conditions of her or his immediate neighbourhood by addressing environmental problems or by linking the problems to those who may be able to solve them. The emphasis is "close and local action" for a more sustainable future.

Designing resilience into urban water security in the Msunduzi River Catchment

Catherine Pringle and Duncan Hay

Photo: C. Pringle and D. Hay

The Msunduzi River, which flows through Pietermaritzburg, has become increasingly degraded through poor management and overexploitation. Sewer infrastructure and maintenance is inadequate, sewer lines carry legal and illegal industrial effluent discharges, and storm-water enters sewer reticulation systems causing them to overflow and spew raw sewage into adjacent streams. Many urban residents also receive no or erratic water supply; a function of aging and poorly maintained infrastructure and reduced supply during the drought. So how do we address these issues? Resilience thinking provides a way of investigating how systems can be better managed to ensure a sustainable supply of ecosystem services. Simonsen et al., (2015) have distilled seven principles considered crucial for designing resilience into social-ecological systems.

The first principle suggests that the presence of multiple components, or functional redundancy, enables some components to compensate for loss or failure of others. Currently water, sewage and storm-water systems in the Msunduzi catchment are each managed as a single system by a single agency. If the agency fails or one of the physical systems fails, it is catastrophic. Diversifying the physical system is critical, which in turn will diversify the governance system as responsibilities become apportioned across a range of citizens, small groups, large organisations and government. From a water supply perspective this may include rainwater harvesting, recycling and re-use, and innovative storage systems while on the sewage and storm-water front, this may entail smaller waste water treatment works servicing single suburbs; alternate sewage management; and designing rivers to better manage storm-water flows.

The second principle requires that the nature and strength of interactions between components, or connectivity, is managed. From a physical perspective, this requires connecting storm-water to water supply to harness the resource; linking treated sewage back into the water supply system and severing physical links between storm-water and sewage systems. On the social front it is imperative that connectivity between and within government structures and civil society is restored, that relationships are developed and that co-operative governance happens.

The third principle identifies the presence of feedbacks between variables which either re-inforce or dampen change. Within the context of the Msunduzi, four important slow variables exert both negative and positive pressure on the social-ecological system; c*limate change* is accelerating the destruction of *physical infrastructure*, which in turn further compromises *government capacity* to fix what is broken leading to increased *societal action* as water quality and supply issues persist.

The fourth principle suggests that building resilience necessitates complex adaptive systems thinking. This approach is appropriate in the Msunduzi – learning together, acting on what has been learnt, reviewing and reflecting on the outcome, and refining the action. Currently adaptive systems thinking is undermined by criticism of those tasked with fixing the problem.

The fifth principle advocates a “learning by doing” or adaptive management approach, which emphasises knowledge sharing between actors, in order to develop social norms and cooperation. Learning about both the biophysical and social elements of the Msunduzi social-ecological system by all constituents is critical. Particularly important is that decision-makers learn and understand so that municipal resources can be directed at the right priorities.

The sixth principle requires active engagement of a broad range of stakeholders. While overall accountability and responsibility for water and sanitation services rests with municipal authorities it is clear that civil society must assume greater responsibility. Collective participation from an empowered citizenry is required.

The last principle promotes a polycentric governance system with multiple centres of decision-making. Polycentric governance is largely embedded in Principles 1 to 6. The growing network of actors and relationships in the Msunduzi catchment provides a solid foundation for polycentricity. The challenge before us is actioning the other resilience principles to build and enhance polycentric governance.

Design for a resilient garden route landscape

Myles Mander and James Blignaut

The Garden Route is one of the national priorities in terms of alien plant management given the high levels of infestations, the limited water supply capabilities, and a high demand for water. Consequently, there has been a large scale investment by Working for Water in the region. However, the success in reducing alien plant infestations across the landscape has been limited. A three step process was implemented to develop a strategy to address the perceived limitations.

Step 1 - Review of current practices

- The biophysical elements of alien plant management were well understood and addressed adequately.
- The solutions to a more lasting impact or a more resilient landscape lie in the human domain. There is too little shared responsibility, the range of incentives is too narrow, the perception of risk to livelihoods or wellbeing is too remote and long term, there are too few partnerships, too little regular communication and too little learning from experiences.
- The existing approach has not developed the institutional and social capital required to lead and sustain a lasting alien plant reduction at the landscape level.
- There is a need for greater learning from experiences and adaptation of approaches.
- There was a need to consider setting the objective of the management process in a broader context, such as – to develop a resilient Garden Route landscape – one where alien plants are not only removed, but where the landscape processes are effectively established to prevent re-infestation.

Step 2 - Develop a set of responses to address the identified constraints

- Adopt resilience principles (Biggs et al., 2012)
- Prioritise actions to become more efficient in clearing and sustaining gains.
- Promote collaboration to pool resources, generate continuous management and elevate impacts.
- Increase communication to generate greater synergy between agencies.
- Ensure that appropriate incentives are in place to promote increased investment in management.
- Develop the capacity of all agencies and individual actors who participate in promoting resilient landscapes.
- Promote adaptive management with elevated monitoring, reflection and re-directing of management actions.
- Improve data management and data integrity to ensure decisions are properly informed.

Step 3 - Identify implementation priorities

Implementation actions were ranked in terms of the degree of uncertainty of the outcome and relative magnitude of the impact. Divergent perspectives emerged amongst the management agents, with different end objectives being apparent. To progress towards a more resilient system, a single set of priorities generated by both management clusters are necessary to establish an integrated strategy.

Reflections on the process

To date the process has broadened the perspectives of the different agents managing alien plants in the Garden Route, and has identified a broader range of necessary actions to establish a resilient Garden Route landscape. However, the development of a unified vision with integrated objectives regarding the programme of action has not occurred and the next integrating step is required.

Key observations

- Key constraints to developing a resilient Garden Route landscape lie in the domain of institutional cooperation, and in the lack of systemic objectives.
- Designing for resilience requires a landscape level functionality focus that combines human action in sync with ecological processes.
- Generating shared understandings and inclusive strategies, are likely to be critical in establishing a unified approach to landscape level resilience.

Key actions to promote resilience include joint prioritisation, greater collaboration, effective communication and adaptive management (monitoring, reflecting and re-directing management).

Planning for resilience - The case of water as a critical resource in the non-perennial Seekoei catchment, South Africa

Maitland Seaman

Critical to the ecology of non-perennial rivers are connectivity when there is surface flow, and refugia when there is no flow. But variability of flow is high. When Seaman et al. (2010) started their study in the Seekoei sub-catchment of the Upper Orange River, it had not flowed for more than a year, and it then flowed continuously for exactly a full calendar year, followed by no flow for an extended period.

Non-perennial rivers are social-ecological systems (SESs) in the sense that, while ecological connectivity is mainly linear (upstream-downstream, between a sub-catchment with its connection to another similar-level sub-catchment via a downstream higher-level "main" river course), social connectivity would be in all directions, so also horizontal (between parallel catchments).

Scale is particularly relevant because people living in these very dry areas historically were mobile, either as hunter-gatherers or as nomadic herders, so meta-catchments were more important than single linear catchments. Nevertheless, the range of movement was fixed at probably much less than 10000 Km^2 (equivalent to a circle with a radius of less than 60 Km). The size of the social-ecological system presently relates to the sustainability of water supply to the established farming enterprises, which use a single body of water that is mainly underground, manifesting itself sometimes as subsurface and surface flows.

As the present social needs are continuous, as required by fixed communities, these communities would have a suite of abstraction sources geographically and temporarily, e.g. using different boreholes, river pools and flowing rivers according to changing circumstances. Soft boundaries are important. Scale could be tied historically to the distance a hunter-gatherer family can viably move between active springs or pools. A similar scale could apply to a nomadic group with livestock. Presently, where settlement is fixed, except for small numbers of people, the relevant scale is probably very similar, while relative access to water has increased greatly.

The extent to which this suite of sources can supply water (resources) continuously defines the complexity of the system. Redundancy is necessarily high because of the high coefficient of variation of flows in individual catchments. The larger the mega-catchment (suite of sub-catchments), the greater the expected buffering (accommodation or reciprocal cancellation of extremes) of flow in adjoining sub-catchments. Absolute redundancy would be reduced by increasing the size of the mega-catchment, yet relative redundancy would be decreased by the inability of users to bridge the distances between point sources of water. Just what sustainable levels of abstraction should be is extremely difficult to establish, given the large coefficients of variation in rainfall, both spatially and temporarily.

Adaptive governance would seem to be the route to take in order to establish the appropriate size of a suite of sub-catchments which would allow an appropriate body to plan for resilience.

Economic level	**Subsistence economy**		**Market economy**		
	Hunter-gatherer	**Transhumance**	**Farming, permanent settlement**	**Mining and manufacture**	**Service**
Population density	**Extremely low**	**Very low**	**Medium**	**High**	**Very high**
Resource abundance	**Absolute abundance ----------------------------------Absolute shortage**				
	Relative shortage -------Relative abundance-------Relative shortage				
Waste disposal/treatment/ recovery	**Irrelevant--Critical**				

Table: Economic level, population density, resource abundance and the handling of waste

A framework for promoting the resilience of small towns in a rapidly urbanizing South Africa

Robert Fincham

In their paper, Adriana Zuniga-Teran and Tamee Albrecht state that 'Cities are our biggest hope but also our greatest risk'. In the South African context, an integrated urban and rural development policy framework is poorly developed. In rural areas, small town development is serendipitous, some towns flourish while others are backwaters characterised by increasing poverty, social ills and ecological disasters. They populate an oftentimes romanticised rural landscape and the reality is that they are becoming part of our future's 'greatest risk.'
A small but growing 'community of practice' at the universities of KwaZulu-Natal and Nelson Mandela is focusing on the resilience alliance principles as a framework for research and practice. This paper reflects a framework in which resilience forms a significant part. Initial work on the ground suggests an urgent need for *transformative and transgressive (or transdisciplinary)* development, rather than *ad hoc,* piecemeal, single discipline-type research for change.

Initial focus on towns in the Eastern and Northern Cape, and the Karoo highlight vulnerabilities and potentials for transformative change.

Rhodes, an adventure tourism destination in the highlands of the Eastern Cape is likely to be impacted by climate change. It creates risk for, example, one of its key economic drawcards, trout fishing. Changing demographics have also resulted in the growth of cattle on the town commonage, with significant removal of topsoil through overgrazing. No solution or consensus to addressing these challenges has been reached. Richmond, in the Northern Cape and on the main arterial N1 route between Cape Town and Johannesburg has created the first Book Town in South Africa. There has been growth in bed and breakfast facilities and visitors attracted to the book outlets and annual book festival. However, the Integrated Development Plan (IDP) for the town bears no mention of 'Book Town' as an economic driver. Prince Albert, situated at the base of the Swartberg Mountains in the Karoo is a key tourism destination. Like Richmond, house prices have increased over time and a range of tourism activities flourish, including arts, archeological and venture tourism. Fracking is a concern as is the water supply under conditions of climate change, and population growth.

Small towns can be conceptualised as social-ecological systems (SES). The resilience principles are important and issues of diversity and redundancy, connectivity, learning etc. provide a basis for undertaken resilient assessments. Where to intervene most cogently in systems – leverage points– is critical and those that offer deep leverage such as those attached to values, goals and world views of actors provide the key for emerging directions of the system (Figure). They also signal interventions that can result in transformative and transgressive development rather than piecemeal projects and change.

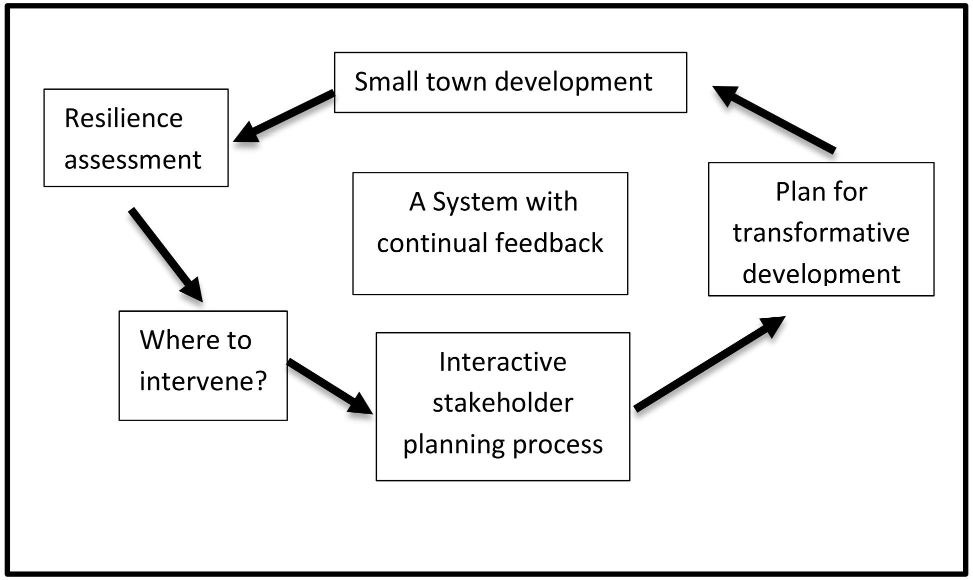

Figure: Small towns as Social-Ecological Systems (SES): understanding present realities and transformative, transgressive futures. Robert Fincham

Achieving resilience by design: Governance innovation at the city and local scale in Durban

Catherine Sutherland

Photo: C. Sutherland

This study reflects on innovative governance processes for resilience that are emerging at both the city and local scale. The research reflects on how the main themes that emerged out of Durban's 100 Resilient Cities Programme (100 RC) relate to the Palmiet Rehabilitation Project (PRP), which is a local resilience project in the city. Durban was selected as one of Rockefeller Foundation's 100 Resilient Cities. It has adopted an innovative and context specific approach in developing its resilience strategy, engaging with a broad range of stakeholders to identify six critical resilience themes namely: bold and participatory governance; a knowledge centred city; innovative place making; a sustainable and ecological city; catalytic and transformative economy; and equitable and inclusive society (eThekwini Municipality, 2015). Resilience is best developed through decentralised, multi-actor governance regimes, which recognise local system characteristics (Moench, 2014). This research therefore explores how well these themes, identified at the city scale, travel down to local spaces within the city.

The Palmiet River was identified as a case study for the uMngeni Ecological Infrastructure Partnership (UEIP), of which the University of KwaZulu-Natal (UKZN) and eThekwini Municipality are key partners. The PRP provides research opportunities for assessing the value of ecological infrastructure in improving water quantity and quality in the uMngeni Catchment. Quarry Road West informal settlement is located on the flood plain of the Palmiet River. The settlement has been in existence for over 32 years and residents are not willing to relocate to distant low cost housing projects despite staying in a high risk area (fires, floods, unhealthy living conditions, and lack of basic services etc). Through a partnership with UKZN researchers, the Quarry Road West committee began to participate in the PRP.

The PRP, through its municipal, university and civil society partners, established a network of actors who have an interest in the Palmiet Catchment. There have been a number of outcomes of the stakeholder engagement process. An actor network has been established, critical issues in the catchment have been identified, knowledge sharing and social learning has taken place among the different actors and an action plan has been developed.

Governance, which includes leadership, champions, actor engagement in networks, the development of a governance system, and innovation has shown to be fundamental to the little (and maybe bigger than we realise) victories in the PRP. The participation of the Quarry Road West community in the PRP has extended its influence and support. The university researchers have built relationships with the community which has connected community members to opportunities of learning. It has also led to engagement between the community and the municipality, which did not occur in the past due to conflictual relations. The community has willingly shared their knowledge with researchers, thereby playing a critical role in building baseline data. An early warning flood system has been established where "River Watch", a civic science community group that is active along the Palmiet River, alerts the PRP group on whatsapp of both weather reports predicting flooding and heavy rainfall, and of high rainfall levels in Westville (a suburb half way up the course of the river) which are measured by River Watch. This information is then communicated to the Quarry Road community so that they can prepare for flooding and heavy rainfall events.

Inequality is the reason why Quarry Road West residents find themselves living in a space of risk in the first place, having to build resilience from such a fragile and vulnerable base. Gender and culture also features strongly in resilience building here. It can be tentatively suggested that resilience in the settlement is largely as a result of the uncompromising leadership and commitment of strong women. Woman have actively engaged themselves in the PRP actor network and have remained committed to it, while men have tended to play a role but on a more individual basis. Culture has been significant as understanding risk from the perspective of African culture has been essential. This supports the argument that all kinds of knowledge need to be understood, drawn in to, and be respected in the governance process if resilience is to be built. It is evident from the PRP that the six resilience themes identified in Durban's 100 RC programme are relevant at the local scale, revealing a common approach to resilience at both the city and local scale in Durban.

Transboundary water governance and its significance for water security
Robert Varady

Transboundary regions are areas that share the same physiography but are separated from each other politically. In spite of such divisions, human-constructed political borders do not divide landscapes, physical processes such as climate or natural disasters, resources, vegetation, or wildlife. Nor do political borders entirely divide human systems. Many border regions share languages, cultural and administrative practices, and social traditions. However, when resources or environmental processes cross borders, they face socio-political and economic obstacles to effective management practices. As a result, border regions often face major management challenges with regard to shared watersheds and airsheds, ecosystems, contamination, and other environmental issues. These challenges impact the ability of neighbouring governments to design and implement policies and procedures that are resilient and durable.

Water management in transboundary watersheds is made more complex because of the involvement of neighbouring and sometimes competing jurisdictions. The transboundary condition is more common than generally acknowledged: among the 35 largest river basins in the world, only 6 are not transboundary. Water management issues that arise in transboundary watersheds include:

1. control of quantity upstream vs. downstream
2. pollution and degraded quality
3. insufficient information and data
4. definition of contours and volume of aquifers
5. inadequacy of transnational institutions
6. asymmetry across border
7. lack of priority

The US-Mexico border, because of its pronounced asymmetries, provides an especially interesting case study of a transboundary region that faces water-security challenges. The similarities and differences between countries play a major role in water management. Similarities between the two countries include climate, particularly extremes; landscape; environment and resource base (water availability, habitat, wildlife); and traditional economic mainstays (mining, farming, ranching). Differences between the two countries include culture, language, and political systems; economy, infrastructure and demographic trends; legal traditions; education system and research establishments; governmental organisations; autonomy of local and regional governments; indigenous societies; relative vigour of civil society; and vulnerability and ability to cope with environmental stress.

Probably the most important difference that affects water security in the U.S.-Mexico border is the institutional context. In the United States, institutions that deal with water management are highly decentralised. Also, the way water is regulated and compartmentalised affects water management and there are multiple agencies at different levels. In addition, climate extremes are treated on an event-by-event basis, with significant regional variation. There is a strong civil society in the US that is interested in water and how it relates to habitat and land. Among the most important elements of water management in the US is the relatively good access to funds for research and management.

In contrast, the institutional context of water management in Mexico is highly centralised, and even though there is great regional variation in conditions, uniform administration and management are more or less uniform. And in Mexico, as in many developing societies, there is uneven access to information and there remains a sizable gap between the existence of laws and their enforcement. Mexico's centralised administration features a few, selected powerful water agencies. Civil society is strengthening, but is still weak, and a shortage of domestic expertise constrains science and management, although this is changing. Finally, in terms of funding, there is a lack of funds that constrain all levels of resource management.

The institutional challenges facing transboundary water management are complex, not only in the US-Mexico border, but everywhere. For example, there is insufficient understanding of the role and significance of conditions and institutions. Also, obtaining compatible information across borders is highly challenging, and frequently there is a pronounced disconnect between hydrological and political world views. In addition, research priorities and decision-making are often poorly matched, and this is coupled with difficulty in overcoming bureaucratic inertia. Partnerships between countries tend to be weak. And although researchers may share interests, they face significant barriers to sharing resources and credit. Finally, poor binational relations can arouse suspicions of motives among neighbouring water management agencies, limiting nations' ability to forge close working relations with agencies, communities, and colleagues across their international borders.

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