SEPTEMBER 2022 - SCIENCE BRIEF
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INVESTING IN ECOLOGICAL INFRASTRUCTURE IN SOUTH AFRICA'S SIGNIFICANT CATCHMENTS

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South Africa's Strategic Water Source Areas (SWSAs) are significant at a national level as these provide a disproportionately large amount of runoff, have high levels of groundwater recharge, or both. As such, it is critical for sustainable development and socio-economic well-being that these are protected, including the ecosystems and ecosystem features that keep them functioning optimally. Ecological infrastructure (EI) provides valuable ecosystem services such as water storage and filtration, and flood protection. Where EI is degraded, it can exacerbate the impacts of climatic events and greatly reduce climate resilience in such landscapes.

While factors like climate change (through reduced or irregular rainfall), population growth, and limited storage capacity have played a major role in Cape Town's freefall towards Day Zero, an important leverage point to lessen the impact of these factors remains the investment in catchment areas and healthy river systems. The region is now in an enviable position of near-full storage capacity in its reservoirs going into the next rainy season, but similar scenes are playing out in the Nelson Mandela Bay Metropolitan Area. There is ample evidence to suggest that effective catchment management would have significantly reduced the impact of drought on affected residents in terms of water availability and cost, and that it may provide the best long-term option to ensure a water secure future. However, much of this evidence is mainly available in the forms of models and projections and is yet to be supported by a user-appropriate evidence base (and perhaps increased government support) to attract private sector investment. It is likely that development of such an evidence base could help secure private sector funding for long-term implementation of EI interventions. Specifically, there are still several links that need to be drawn between effective catchment management and the benefits to private sector stakeholders.

The wide-ranging impacts of severe drought and other extreme climatic conditions also suggest the need for a more collaborative approach to management of EI, especially stronger partnerships between government and private sector. This science brief addresses some of the social and economic impacts of the recent and ongoing disasters, such as droughts/floods and how these may be exacerbated by failure to invest in water-related EI collaboratively and consistently.

Background

The term Ecological Infrastructure or EI refers to natural or near-natural ecosystems and ecosystem components that, through their functioning, provide valuable ecosystem services to people. Part of the value of the concept is that it focuses on the physical "infrastructure" (the ecosystems themselves) that can be seen and touched, whereas many of the services ecosystems provide are less visible or tangible. In 2012 in South Africa, the South African National Biodiversity Institute and partners adopted the term EI as the "nature-based equivalent of built or hard infrastructure" to mainstream the importance of EI for service delivery and socio-economic development through a compatible discourse that resonated with the government's focus on built infrastructure development. Internationally, the joint 2019 report by the World Bank and the World Resources Institute on Integrating green and grey: creating next generation infrastructure discourse promotes the integration of gray and green infrastructure with green infrastructure including preserved, enhanced, or restored elements of a natural system. The term EI was first proposed at a 1984 meeting of the Man and Biosphere Programme aimed at urban planning (UNESCO, 1984). The idea was to define a concept that could guide the planning for the development and growth of ecologically sustainable cities.

From the early discussions around EI, three distinct schools of thought emerged, conveniently divided along state lines. The American thesis on EI was centered around using it to increase intensified land use by supporting more efficient urban centers. In Canada, authorities incorporated their version of EI into existing infrastructure such as to lessen the impact of intrusive grey infrastructure such as roads, and to enhance the efficiencies of municipal roles such as drainage and waste management. Lastly, the focus on EI interventions in the UK was much more aligned with its current configuration; that is, a focus on climate change adaptation and ecosystem protection.

While these approaches are distinctly dissimilar as a result of divergent definitions or understandings, they all have one important commonality: the management of EI (in which-ever format) is inherently a function of government. As a result, the need for private sector investment may have been under-discussed for as long as there was no explicit economic sense attached to ecological infrastructure that could be directly linked to economic growth. Thus, more than three decades ago, one of the first articles on ecosystem services valuation was published as a way to describe the previously "priceless" externalities of human civilization development in monetary terms (see Westman, 1977). The article by Westman (1977) points to the assumption that socially equitable decisions could be made easier through an expression of ecosystem services in monetary terms because it allows for the decision-maker to identify the associated costs and opt for the alternative that provides the greatest amount of benefits for the amount of damage done to the ecosystem.

Subsequently, debate ensued about the premise of such a valuation. Most widely implemented perhaps is the exchange of carbon credits that allows for off-site carbon sequestration through planting of trees or conservation of important ecosystems to offset greenhouse gas production. While this allows for the introduction of more beneficiaries of wealth generated through certain economic activities, it invariably focuses on maintaining the status quo of production rather than to encourage innovation in the production process itself. However, it also appears to submit that the most cost-effective way to manage greenhouse gases and, by extension, the earth's climate, is through maintenance of natural ecosystems or at least their functions.

Since the article by Westman (1977), several articles have been published on the issue. Most notably, a complete estimate of global ecosystem services was presented by Constanza et al. (1997), at approximately US$ 33 trillion per year, of which forests and wetlands accounted for about 38% at US$ 4.7 trillion and US$ 4.9 trillion per year respectively. At the time of its publication, the (formal) global economy had a market value of around US$18 trillion a year. Fourteen years later, Constanza et al. (2011) updated these estimates to US$ 125 trillion per year, which might have been 145 trillion per year but for the estimated loss of ecosystem services between 1997 and 2011. Locally, ecosystem service valuation has differed markedly depending on the methodology used, with Turpie et al. (2017) estimating it at USD 17.68 billion (R257 billion) and Abd El Basit et al. (2021) suggesting a higher valuation at USD 437 billion. While these discussions have been useful and contributed greatly to our understanding of the importance of considering ecological/green infrastructure alongside grey infrastructure, the numbers remain estimates based on projections or models rather than hard data generated from real-world examples. Critically, these numbers did not translate into the more socially equitable decision-making at the scale and impact envisioned by Westman. In the two demonstration catchments under investigation through South Africa's Ecological Infrastructure for Water Security (EI4WS) project, similar conclusions are being drawn to previous work done under the SEBEI (Social-Ecological Benefits of Ecological Infrastructure) project. For instance, Rebelo et al. (2021) pointed out that our understanding of the economic benefits of EI investment is reliant on such projections but confidence in such models may be undermined by the lack of ground-truthing.

In South Africa, water-related EI has been receiving more and more recognition for its importance in improving and maintaining high levels of water security. For context, the South African government through programmes like Working for Water has spent more than R15 billion between 1995 and 2017 on controlling the spread of invasive alien plants (IAP), some of which threaten water security (Van Wilgen et al., 2020). Van Wilgen et al. (1996) compared the approximate costs of building new water supply systems such as dams and distribution networks, management of alien plant invasion, and alternatives such as desalination and building new recycling facilities. Using a theoretical 10,000 ha Western Cape catchment area, they suggest that alternatives to optimally managed catchment areas could cost consumers between 1.8 and 6.7 times more per unit water than sufficient investment in and management of EI. Interestingly, the paper also estimated that its theoretical catchment could yield up to 30% more water if just managed properly (i.e., with regards to alien plant invasion, including a 14% differential in the unit cost of water between well-managed and poorly managed catchment areas as a result of the difference in water availability).

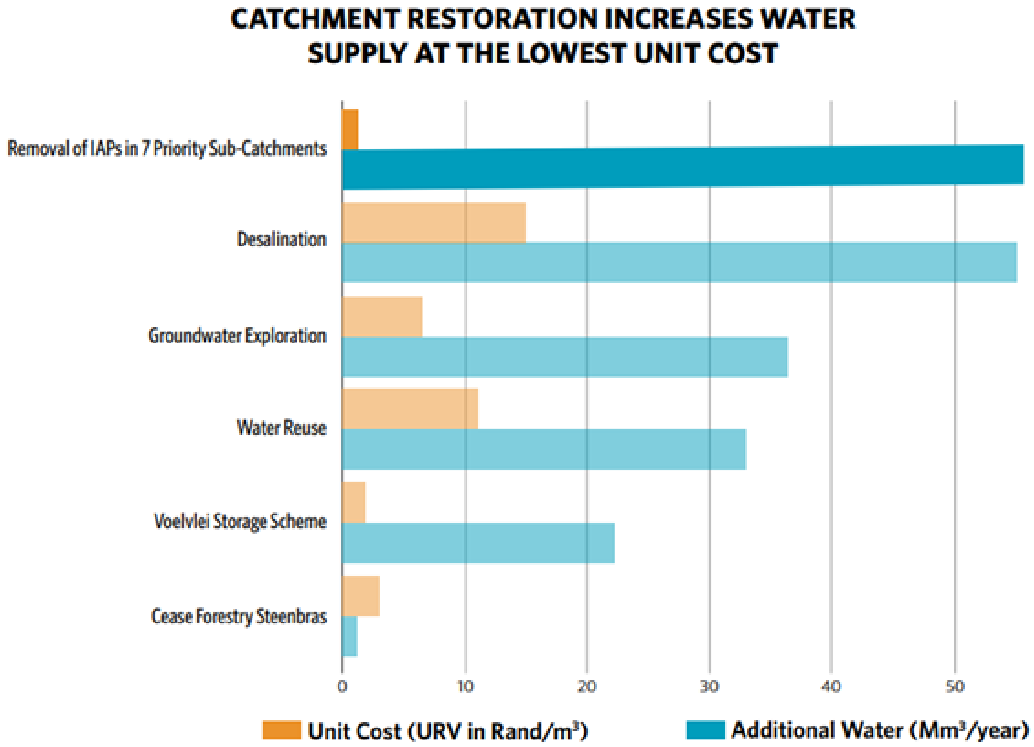

Figure 1: Cost estimates and water availability increases through different interventions (source: Stafford et al., 2019)

This has since been the narrative: not investing in proper EI management could lead to significant economic downturns, and thus should include participation of the private sector. This has been advocated through programmes such as Water Funds, which are rolled out by The Nature Conservancy (TNC) and aim to involve private sector water users in issues of catchment management. A business case has been developed by TNC to address the need for catchment management as a cost-effective tool to greatly improve water security in the greater Cape Town area (Stafford et al., 2019; Figure 1). By their estimates, by far the most efficient means of increasing water availability is through IAP removal when accounting for the cost-per-unit water produced and the additional water made available to the system. The business case suggested that IAP removal in the area could free up to 55.6 Mm^3 of water annually after 6 years of implementation. However, the cost to secure this water could be as low as R1.20 m^{-3} (including sanitation). For comparison, desalinated water was estimated to cost up to R14.90 m^{-3} in this study.

Additionally, Le Maître (2020) estimated that IAPs in South Africa's catchment areas could cause annual runoff reductions of approximately 2.6 billion m^3 $year^{-1}$ in 25 years' time if we assume a spreading rate of 5% per year and a density increase of 1%. An earlier estimate by Le Maître et al. (2016) reported annual runoff reduction of about 1.44 billion m^3 $year^{-1}$. The 2016 value represented 2.9% of the naturalised mean annual runoff, while the 2020 prediction represents 5.2%. In the water supply system to Cape Town, Le Maître et al. (2019) estimated that water lost to IAPs could be around 38 million m^3 $year^{-1}$, which translates to approximately 60 days of water supplied to the city under normal circumstances.

There is thus good available evidence to support the investment into IAP clearing as a mechanism to reduce the water lost to evapotranspiration, as there is enough information available on the water use of key IAP species in South Africa. There is also a good understanding of its disruption of the processes usually associated with natural ecosystems, especially in riparian zones and catchment areas. We are also aware of the need for effective catchment management to minimise upstream erosion and subsequent siltation of dams. The links between siltation and ineffective catchment management is currently being addressed by the Water Research Commission-managed NatSilt programme, which aims to develop a National Siltation Strategy for South Africa's large dams.

However, many ecosystem services are still difficult to quantify (as shown by the divergent valuations of South African ecosystems services alluded to earlier) and to relate to beneficiaries such as farms and downstream water users. The long-term monitoring of EI interventions often only report on easily measured metrics like hectares cleared of IAP, and not readily on the ecosystem services that were improved because of the intervention. Thus, a persistent challenge in garnering support for this work around EI has been the absence of a user-appropriate evidence base for EI rehabilitation and management that confirm that i) effective EI interventions can lead to quantifiable increases in the provision of ecosystem services, and ii) these benefits will be directly relevant to those financing its implementation (if from the private sector). Recent WRC projects that have aimed to address the need for wider involvement include a report on managing risk for the insurance industry (Pringle et al., 2018), communal land and rangelands (Mantel et al., 2021), while another is underway that discusses the rehabilitation options of the Baakens River with a focus on EI.

The Water Research Commission is further exploring the current available evidence base and identifying steps to address potential shortfalls. In the interim, we explore the cases of the recent Cape Town drought and the current Eastern Cape drought to make an argument for the urgent restoration of EI as a critical aspect of water security in South Africa.

The Cape Town drought

The years 2015 to 2017 were associated with a rainfall deficit in South Africa, with 2015 being the lowest on record (403 mm avg.) for the country (SAWS, 2016). Subsequently, the 2017 Western Cape drought was the worst after the 1904 drought and was accompanied by an unprecedented water shortage in the region (Botai et al., 2017; Wolski 2018). The drought that hit Cape town as a result of this rainfall deficit presents a great case study and opportunity to discuss the impact of ecological infrastructure failure when compounded with changing climate scenarios and increasing population sizes. It is generally accepted that the reduction in rainfall over those three years led to the deficit in water supply (Pascale et al., 2020). In their review of the climatic conditions leading to the now well-known "Day Zero" scenario, Pascale et al. (2020) also reference the droughts experienced in the region in the 1920s, 1970s, and early 2000s. Drought cycles in the area are thus not new but may have sped up along with the changing climate. In another analysis of this drought, Otto et al. (2018) estimated a median increase of 3.3x greater likelihood of this 1/100-year event taking place during the current climate scenarios when compared to pre-industrial times. With the dams making up the Western Cape Water Supply System (WCWSS) predominantly depending on consistent seasonal rainfall, the areas supplied by these dams may become more vulnerable to changes in surface water availability.

While the drought is most often discussed for its economic impact, ordinary citizens were also harshly affected. During 2018, the City of Cape Town (CoCT) instituted a pipe charge (fixed water charge) to its water pricing strategy while increasing per unit water tariffs, in addition to imposing water restrictions on ordinary citizens. The pipe charge was added as a fixed water charge that ensures cash flow even when water usage is low. This is mainly because the cost of maintaining water-related infrastructure does not fluctuate appreciably with changes in water usage. This base tariff allows for the continuation of funds for maintenance even when sales revenue from water is low. The tariff structure has been implemented as a response to the droughts in the area, which led to dramatically reduced water availability and drastically increased per-unit prices which together led to the under-recovery of funds for maintenance and other operational costs.

But as with most things, the Cape Town drought had a disproportionate impact on poorer communities who had to wait for government intervention while individuals from richer suburbs had the option of sheltering themselves from its effects. Nowhere was this more evident than in areas where citizens had boreholes drilled in their own front yards (see this article in the Washington Post: https://www.washingtonpost.com/news/world/wp/2018/02/23/feature/as-cape-towns-water-runs-out-the-rich-drill-wells-the-poor-worry-about-eating/). All of this while the agricultural sector had job losses totaling about 30,000 casualties, most of which was accounted for by unskilled labourers.

Although little can be done to increase the rainfall in drought-stricken areas, measures can be taken to preserve the surface run-off from the low precipitation. It is estimated that IAPs utilise approximately 6.7 % of the estimated mean annual runoff of water over the entire area of South Africa, and as high as 15.8 % in the Western Cape Province (Enright, 2000). The impacts are significantly greater, on percentage basis, during drought periods as the riparian invaders still have free access to water. The rural and urban communities with limited water storage capacities for water supply, and thus dependent on direct abstraction of water from rivers, are particularly affected by this reduced flow. As summarised by the OECD (2021), the management of the surrounding complex natural environments that are associated with the City's water supply system is crucial for improving water security in the region.

Moreover, the need for more effective climate resilience planning is becoming more apparent, especially as it relates to the impact of IAPs and surface water supply and storage. One of the challenges identified that exacerbate the water supply vulnerability appears to be a lack of coordination between various stakeholders mandated with either water resources management or biodiversity conservation policy implementation. This has partly been addressed through the establishment of the Greater Cape Town Water Fund. The Fund focuses mainly on IAP clearing and ecosystem rehabilitation, both as a means to increase the immediate supply of water by reducing evapotranspiration, and to improve ecosystem functions such as water infiltration and slow release, which prolongs availability of water. Of importance in this respect is that storage does not only happen in dams – the soils and recharged aquifers in intact, functioning catchments provide less visible, but hugely significant storage capacity. It is the slow release of this water throughout the year that keeps rivers flowing during the dry season. Besides slowing the drawdown of dams during the dry season, these flows are vital for users who draw their water directly from rivers. These users include many irrigation farmers and communities that lack access to water via built infrastructure. There tends to be an under-accounting of the water that is lost through mismanagement of catchment areas and would otherwise also be available for use. So, while the rainfall deficit and climate change in general can be blamed for the recent Cape Town droughts, there is now general agreement that social, ecological, and economic resilience in this region are strongly linked to natural ecosystems and their associated processes which need to be protected.

Nelson Mandela Bay Drought

In the neighbouring Eastern Cape, similar challenges are currently experienced, where the catchment areas supplying water to the Nelson Mandela Bay Municipality (NMBM) and its surrounding towns are currently undergoing an extended drought period. The NMBM has a water usage of approximately 280 Ml day^{-1}, of which 167 Ml day^{-1} is sourced from the Western Supply System containing the Churchill, Impofu, and Kouga dams (the Loerie dam is also part of this system as a holding dam). The rest of this daily demand is supplied by the Eastern System consisting of transfer schemes connected to the Orange-Fish and Lower Sundays River transfer schemes, directly linked to the Gariep Dam. Of the total licensed abstraction for the NMBM (354.73 Ml day^{-1}) the Western Supply System currently accounts for 47.2% of its total allowable allocation. However, this area has also been going through a severe drought brought on by multiple years of below-average rainfall in its catchment areas of the Langkloof and Baviaanskloof.

The Krom, Kouga and Baviaanskloof rivers are also heavily invaded by pines, wattles, and gums, while the important Palmiet wetlands of the Krom have been significantly reduced in size and function over the last century. Adding to this, inappropriate fire management of privately owned catchment areas to improve grazing has also led to decreased fynbos diversity, increased soil erosion, and further spread of IAPs. It should also be noted that the municipality has been plagued by widespread failing grey infrastructure leading to leakages of up to 29% of the total water supplied to the city (40% water losses in total if we consider the additional water lost to illegal use and inaccurate metering; NMBM 2020/2021 annual report). This needs to be addressed urgently to complement other long-term catchment-based interventions aimed at increasing the sustainability of water supply.

Similar to the Cape Town case, Mander et al. (2017) proposed that effective catchment management could be significantly more cost-effective in producing water than any other augmentation method available to the region. They estimated that maintaining ecological infrastructure could release 1m^3 of water at R1.17 vs other methods like boreholes (R5.40 m^{-3}), water transfer schemes (R5.51 m^{-3}), and desalination (R9.01 m^{-3}; in 2014 Rand terms). Catchment management activities like IAP clearing could also be associated with opportunities for employment creation, value adding and creating of secondary industries around IAP biomass.

A feature of the Baviaanskloof, the catchment area for the Baviaanskloof River which along with the Kouga River drain into the Kouga dam, is its exposed topsoil and low vegetation cover. The reduction in plant cover in the Baviaanskloof can largely be attributed to decades of unsustainable farming practices in an already arid environment (Figure 2).

Figure 2: (top) Dry slopes with little to no plant cover in the Baviaanskloof (Source: Luyanda Luthuli) and (bottom) the Kouga dam at 14% full on 26 November 2021 (source: https://www.facebook.com/gamtoosirrigationboard)

Increased indigenous plant cover in this area can significantly delay runoff after rainfall events, leading to reduced erosion and sediment transport, replenished groundwater, and longer-term availability of surface water. This can also slow the potential for decreased water holding capacity of the dams as a result of siltation.

Discussion and Synthesis

This science brief sheds light on the recent and on-going droughts in two of South Africa's catchments and the importance of effective protection of its ecological infrastructure. Building resilience against climate change depends on various modes of implementing nature-based solutions in the management of our natural sources. This can be applied to various instances of sustainable development, as discussed by the United Nations Convention to Combat Desertification's (UNCCD) reports on restoration and rehabilitation in production landscapes (Crossman, 2016), rural restoration's linkages to urban development (Forster et al., 2021), the positive feedback loop between climate change and land degradation, and the need for realigning of finances to reflect these realities (Van der Esch et al., 2022).

Over the last few years, the discussion around the Cape Town drought has rightly been focused on increasing the reliability of water supply to the metro and has led to focus being placed on diversification of supply. This included large investment into temporary desalination plants, with current plans to erect a more permanent facility. Similarly, the slow rate of investment into other types of grey infrastructure was questioned. An example of this is an article published by Mike Muller, titled "Cape Town's drought: don't blame climate change" (https://www.nature.com/articles/d41586-018-05649-1). Muller reported that the South African government experienced losses of at least R2.5 billion through job losses, revenue reduction from water sales, reduced agricultural production, and even declines in tourism. Muller attributes the disaster to a lack of planning and foresight on the side of government, particularly in risk reduction through early allocation of resources towards increasing storage capacity.

While these may be true, the issue of investing in water-related ecological infrastructure, including removal of thirsty IAPs, is still not enjoying the attention it demands. While Muller takes the viewpoint of an engineer of grey infrastructure, these viewpoints align with the simple fact that freshwater supply is finite; we thus need to become more effective at storage, while exploring the harvesting of previously non-usable water.

The information is thus available to support the notion that investment in EI in South Africa's catchments is of critical importance, both because it is a highly cost-effective and sustainable solution, and because the country is running out of good sites for future storage reservoirs. Unfortunately, this information presents itself in the form of failed management and not much is reported on successful interventions. Changing the way targeted public and private sector stakeholders and decision-makers engage with, think about and integrate ecological infrastructure into water sector development planning and finance is crucial.

However, an important question now needs to be addressed: if there already is evidence to support the need for EI interventions as a critical aspect in improving water security (even where this is just anecdotal), why is its uptake still lagging? In other words, what other factors may impede this work? For example, is there path dependence and vested interests in maintaining the status quo, along the lines of what were identified as obstacles impeding other reforms in water resource management in South Africa (Munnik, 2020)? These are echoed at a global scale in the 2018 United Nations World Water Development Report (WWAP, 2018), which focused on nature-based solutions for water and identified several challenges inhibiting EI approaches from reaching their full and significant potential. There remains an overwhelming dominance of grey infrastructure thinking in civil engineering, economic instruments, and the expertise of service providers (WWAP, 2018). Partly as a result, EI solutions are still often perceived as less efficient, more uncertain, and riskier than built solutions. The required cooperation and synchronization across disciplines, communities of practice and institutions that have traditionally worked in silos can be difficult to achieve. Professionalising and systematising EI, in the same way as has been done for built infrastructure, is critical to overcoming these obstacles and bringing about the required integration between grey and green (Browder et al, 2019).

As mentioned earlier, management of natural resources as a common good is inherently a function of government. However, public finance available for EI management in South Africa falls well short of what is needed for its effective management. Enter private sector. The Water Fund example of a blended finance model may provide a platform for collaboration between government, private sector, and community groups to pool resources and manage water-related EI effectively. Specifically, Water Funds attempt to link downstream water users with upstream catchment management activities, provide a transparent funding and implementation structure, and ensure objectives of stakeholders are aligned and expectations are managed. Could it be that such partnerships first need to show the potential to yield a quantifiable positive return for stakeholders (like risk mitigation) through the delivery of ecosystem services before they will become commonplace? In that case, what are those quantifiable returns directly relevant to private sector investors? It is becoming critical that these questions are answered timeously to properly guide future research and ensure that the uptake of EI in areas like development finance is well supported by the most relevant information. In so doing, user-appropriate evidence bases with metrics and monitoring programmes that consider the needs and concerns of potential investors can be developed. Public and private sector stakeholders will need to develop a shared understanding of the concept of investing in EI, through inclusive and participatory democratic decision-making processes. Articulation of investing in EI must include considerations of service delivery at catchment, local government, and district levels as well as citizen engagement and participation.

Conclusion

For now, there are important lessons to be learnt from the Cape Town and Nelson Mandela Bay droughts. With more irregular climate patterns, proactive approaches to EI management will be key in ensuring water security. Intact EI can support economic and social well-being through scenarios such as drought mitigation, flood protection, and maintenance of water quality. There are many case studies such as these that detail what happens when ecological processes and features are not protected. Perhaps these cases will serve as a timely reminder of what happens when natural ecosystems do not function as they should. Through the activity of the EI4WS project, now is a great opportunity to explore other cases where EI interventions are successful in improving hydrological functioning of catchments and water security for those who depend on it. What these stories do highlight is that management of and investment in natural ecosystems is not just a concern for government but of the general public as well. And while this brief draws on case studies centered around recent and on-going droughts, several other aspects of climate resilience can be addressed through proper investment and management of EI. From recent memory these may include: i) the 2021 Eastern Cape Floods, ii) the 2022 KwaZulu-Natal floods, iii) the 2017 Garden Route fires, and iv) the widespread and increasing siltation of large dams. The impact of these may have been significantly reduced had effective EI been in place and the social, economic, and ecological cost may have been avoided. However, once again this is an informed perception; these disasters offer the opportunity to collect and report on that data/information. The WRC will be looking into this in its current strategic plan as part of its focus on Nature Based Solutions.

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