Water Sensitive Urban Planning as Adaptation Strategy

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Synapse
Cities in areas getting hotter and drier have to find alternative approaches to manage the increased demand for water versus the shrinking supply, while also climate proofing their cities. Water sensitive urban design as an adaptation strategy integrates the management of urban water resources with urban planning.

1. Introduction

Water is one of the most vulnerable and threatened resources in the world that should be protected and managed for the survival and well-being of people. Water is also a hazard that people should be protected from, for too much or too little water threatens our survival and well-being (Rosenzweig, et al., 2015; Prüss, et al., 2002).

Urbanisation and its associated opportunities and challenges has resulted in an increase in the demand for water in cities (UN Water, 2017). While the demand for water is growing, the supply of fresh water is being compromised by climate change, amongst others. Water is predicted to be the “primary medium through which early climate change impacts will be felt by people, ecosystems and economies” (Butterworth & Guendel, 2011). It is thus vital to understand the impacts of climate change on urban water supplies, as well as the vulnerability and exposure of people, infrastructure and economic activities to weather-related hazards, to be able to adapt accordingly. A water sensitive approach is aimed at integrating the management of urban water services and resources with urban planning (Celeste, et al., 2013). As the basis for an adaptation strategy it includes various adaptation actions aimed at regenerating water services as well as reducing the impact of hydrological climatic events (Armitage, et al., 2014). This paper argues that water sensitive urban design should be used to frame the strategy for adapting cities projected to become hotter and drier in future. It discusses a framework to select adaptation actions linked to the risk profiles of cities as part of a water sensitive adaptation strategy.

2. The growing demand for water in cities

Urbanisation poses a challenges to water supply. As urban populations worldwide continue to grow, the demand for water in cities grow due to the sheer increase in the number of people and economic activities. Simultaneously, water consumption per capita (and the resultant quantity of waste water) rises as economic development increases due to changing lifestyles, before it levels off or eventually declines per capita (Yang & Jia, 2005; Popkin, 2006; Anisfield, 2010). In many developing countries where urbanisation rates are high, and expected to remain high for decades to come, much of this growth is occurring in places without hard infrastructure (Bahri, et al., 2016). Informal settlements, extensions on the periphery of cities, and rapidly growing small towns all have to be supplied with water (Bahri, et al., 2016). However, limited resources and capacity has meant that municipalities struggle to keep up with the demands, resulting in growing water service backlogs (Fatti & Patel, 2013; Muller, 2007). Furthermore, ageing water delivery infrastructure is not always maintained adequately, or has in many cases reached the end of its design life, leading to significant water losses through leakage (SAICE 2011; Bahri, et al., 2016; Multikanga, et al., 2009). Many cities thus face the huge challenge of managing current water use as well as planning for increasing future water demand against a shrinking supply, yet current water management and infrastructure tend to be fixed (World Bank, 2018).

Urbanisation poses a threat to water sources. Population pressures may lead to groundwater pollution and a deterioration of stormwater quality. Higher building densities mean an increase in impervious areas and therefore increases in the volume and rate of stormwater runoff, leading to greater flow rates and volumes in watercourses, and increases in risks for downstream flooding and erosion (Armitage, et al., 2014; Wong, et al., 2012). Studies also show that 80-90% of all wastewater generated in cities in developing countries is not properly treated before being discharged into surface water bodies. The collection, treatment and disposal of increasing quantities of wastewater is a major challenge for cities in both developed and developing countries (UN Water, 2017).

All of these issues combined, with increased vulnerability and risk to environmental hazards, place water at the nexus of the development challenge (SADC, 2012).

3. The impact of climate change on cities and water systems

Changes in the climate have significant impacts on the water systems of cities, particularly in regions that will become hotter and drier. The demand for water is increasing while the water supply is impacted by rising temperatures through higher rates of evapotranspiration and decreasing run-off, placing severe strain on already stretched water systems (Engelbrecht, 2017). Changes in the frequency, severity, duration and distribution of extreme weather events can affect the quality and supply of water, sanitation services and infrastructure (Armitage, et al., 2014; Carmon & Shamir, 2010).

The existing water supply and sanitation infrastructure was heretofore designed for different resource availability and water use. Such historical infrastructure is increasingly under greater pressure owing to changes in the climate and demand for water. Changes in the climate may have the following impacts on cities' water systems:

Climate related events and impacts	**Potential impacts on urban water systems**
Storms, flooding and intense rainfall	• Put pressure on or overwhelm the design capacity of existing drainage infrastructure; • Overwhelm stormwater management systems that lead to backups that cause localised flooding or greater runoff of contaminants such as trash, nutrients, sediment or bacteria into local waterways; • Cause stormwater runoff to wash pollutants, sediment and nutrients into water sources. These can threaten drinking water sources, diminish water quality, and complicate water treatment processes; • Lead to, and increase, erosion and larger sediment loads that can cause a reduction in water storage capacity as a result of the rapid sedimentation of storage reservoirs; • Disrupt water services and cause breakdowns in pipelines that distribute water; • Cause sewage contaminated flooding where stormwater drainage and sewerage systems are combined; • Inundate toilets and/or sewage treatment facilities that increases the risk of contamination of the environment;

	• Lead to the destruction or the deterioration of the structural integrity of basic water infrastructure; • Contaminate water sources, leading to increases in the incidence of water-related and waterborne diseases; • Cause a rise in groundwater that puts sewage treatment plants at risk when they are positioned on low-lying ground due to their reliance on gravity; • Cause a rise in groundwater that decreases the efficiency of natural purification processes, resulting in an increase in the risk of the spread and contamination of infectious diseases and exposure to toxic chemicals;
Decrease in precipitation and drought	• Lead to insufficient water resources being available to meet the demand by households and economic activities for the operation and performance of water systems such as to flush sewage systems adequately; • Concentrate pollutants and limit dilution due to lower streamflow; • Increase the drying up of water sources and, for vulnerable communities, a resultant extension in the distances that must be travelled in order to access water;
Increased temperature	• Affect the quality and availability of water supply; • Result in a reduction of surface water availability from an increase in evaporation from reservoirs and lakes and a decrease in stormwater runoff; • Increase water demands for industrial and domestic water use; • Increase the extent and rate of algal growth in nutrient-enriched surface waters; • Impact on how sewage systems operate.

Table 1 – The impact of climate change on urban water systems (Mottaghi, et al., 2015; Wong, et al., 2012; Daniell, et al., 2015; Climate Change Adaptation Resource Center, 2018; NIWA, 2017)

In summary, the potential impacts of climate change on the supply of water in cities include a reduced flow of water posing possible shortages in water, an increase in the demand for and use of water, increased stress on future water supply, the contamination of water through sewage systems, a decrease in surface water, a decrease in stormwater runoff, increases in water tariffs, as well as water related health problems.

"An understanding of the known risks posed by existing climate variability reinforces the need for responses that are robust to both existing variability and future uncertainty, alongside other pressures on resources, systems and services" (Oates, et al., 2014). Cities need to prepare for the widely anticipated consequences of climate change which will put at risk access to safe drinking water and adequate sanitation. Compromising on these qualities will have many secondary and tertiary effects on development, the environment and human health (Butterworth & Guendel, 2011).

4. Adapting water systems to climate change

The upgrading and expansion of the water system is an urgent developmental concern that is also an opportunity to adapt to climate change. The development of new water resources and the adaptation of existing urban water systems to become more resilient will require a range of different solutions, many of which will take time and/or result in substantial costs (Sikaundi, et al., 2016). These solutions will need to respond to issues such as the availability of water resources, the nature and condition of existing water infrastructure, the availability of resources and capacity to develop and manage systems, and existing urban demand patterns for water. These systems must also achieve defined minimum water standards (CSIR, 2018).

Water systems in urban areas can be divided into two categories. The first category consists of water services that provide water for everyday use, for instance for drinking, cooking and cleaning (Sikaundi, et al., 2016). The second category consists of water resources that manage water in catchment areas, urban rivers and streams as well as runoff and stormwater generated within and around urban (Sikaundi, et al., 2016). When adapting to climate change both the water services and the resources need to be addressed. Increased water self-sufficiency should be an objective. By expanding the water mix a larger variety of water resources are accessed to reduce the current reliance on surface water. These can include groundwater, rain- and stormwater harvesting, water recycling and the reuse of grey water (SA Government, 2015). The importance of maintaining and rehabilitating water systems cannot be overemphasised. Maintenance sustain and improve water systems over time, whereas an increase in the backlog in maintenance result in significant wastage and unreliable water services. Upgrades and expansions to the water system can be used to increase water service revenues and provide a firm foundation for further improvements to water infrastructure in urban areas.

When adapting water systems to climate change, Venema and Temmer (2017) names the following principles to be kept in mind:

- Build robustness: Draw upon multi-barrier water protection principles by integrating procedures, processes and tools that prevent contamination/pollution of drinking water in providing infrastructure and services. Decentralisation, mechanical robustness and non-reliance on centralised power/energy sources are some options.
- Promote redundancy: Focus on diversity of water sources for water supply, such as groundwater, rainwater and stormwater harvesting, to mitigate adverse conditions such as droughts and floods that impair the quality and availability of conventional water sources (dams and rivers).
- Resourcefulness: Creative re-use of and retention of water that minimise reliance on conventional water resources and centralised supply networks that are vulnerable to climate change. Rainwater harvesting from roofs and other catchment areas, green roofs and parks for water retention are some options, as well as neighbourhood level bio-retention, vegetated filter strips, permeable pavements and grassed swales to maximise the retention of run-off, nutrients and suspended solids (silt) to be used as alternative sources of water.

In adapting cities to climate change, water-wise cities, water-sensitive cities or water-smart cities are becoming more popular in the discourse. Water sensitive urban design features can be used to adapt places to, and reduce, the impacts of climate change in urban areas.

5. Water sensitive urban design

Water-sensitive urban design is seen as crucial to the delivery of cities of the future (Ministry of Interior, 2011). Many urban areas in hot and dry climates are more likely to experience extreme heat, decreased precipitation as well as more intense and extreme weather events. Hotter and drier conditions will put stress on water resources, while extreme weather events such as intense rainfall will place huge burdens on urban drainage systems leading to an increase in risk of urban flash floods (Carmon & Shamir, 2010; Brown, et al., 2008). Growing urban populations also put pressure on water services and resources, requiring careful planning (ACT Government, 2014). In the past, water systems were designed in a linear way, i.e. sourcing, treating, transporting, distributing, collecting, treating and disposing water. This highly technological approach is resource intensive and results in the fragmentation of the urban water cycle (Armitage, et al., 2014). Cities thus need to adapt their conventional approach to urban water management at the macro-level by adopting a transdisciplinary approach that considers the environmental, social and economic consequences and opportunities of water management (Ministry of Interior, 2011).

Water sensitive urban design (WSUD) is a development framework aimed at integrating the management of urban water services and resources such as stormwater, groundwater, waste water and water supply with urban planning and design (Celeste, et al., 2013; Brown, et al., 2008). WSUD aims to reconfigure cities in a way to enable regenerative water services while also reducing the impact of hydrological climatic events on urban environments (International Water Association, 2016; Brown, et al., 2008; Armitage, et al., 2014; ADB, 2012). This approach emphasises cities as crucial water supply catchments and as crucial places for the provision of ecosystem services. The notion of using wastewater, greywater, recycled water, and harvesting stormwater for gardens, parks and green areas, as well as for sanitation purposes is gaining importance (Maksimović, et al., 2015). By treating all types of water as a valuable resource, a diversity of water sources can be pursued through centralised and decentralised infrastructure. Such diversity reduces the stress on surface and groundwater resources, and introduces new sources of water to the urban water systems (ADB, 2012; Brown, et al., 2008; Wong & Brown, 2008).

The objectives of WSUD are to design, plan and manage urban landscapes to improve water security, climate proof cities, manage and reverse water pollution, improve and protect the health of ecosystems and receiving water bodies, contribute to human wellbeing and public health, to address resource efficiency and energy transition, reduce the ecological impacts that are associated with water management, support affordable living through the reduction of long term costs that are associated with the management of water, and create more liveable cities by linking water infrastructures to aesthetical and recreational land uses (Hoyer, et al., 2011; Armitage, et al., 2014).

Water sensitive urban design include the following practices at various scales:

- Incorporating green infrastructure aimed at capturing and treating stormwater for a range of uses (McCormick & Dorworth, undated);
- Protecting the supply of water against increasing variability of annual and seasonal precipitation and runoff by building additional infrastructure for the storage of water such as storage tanks or reservoirs (ACT Government, 2014; SADC, 2012);
- Developing new groundwater sources, increasing the groundwater recharge potential and decreasing the discharged wastewater to public sewers (Angiello, et al., 2017; McCormick & Dorworth, undated; SADC, 2012);
- Diversifying and improving water supply sources, including the reuse and recycling of water (ACT Government, 2014; SADC, 2012);
- Treating stormwater to be discharged to surface waters or reused and treating wastewater or minimising the generation of wastewater (Celeste, et al., 2013; Harisyanti & Ryanti, 2017);
- Reducing flood risks through the integration of the design of urban drainage solutions with urban infrastructure design (Angiello, et al., 2017);
- Incorporating flood protection infrastructure in the design of developments in order to prevent the contamination of sources of water supply and treatment works (ACT Government, 2014);
- Using inclusive public spaces, multipurpose space and infrastructure and roadside green infrastructure to enhance the liveability of urban areas with visible water (Angiello, et al., 2017);
- Encouraging riparian buffers along streams, rivers, and waterways and maintain floodplains (McCormick & Dorworth, undated);

- Adapting and modifying urban materials of roads, roofs, etc., to minimise their impact on the pollution of water (Angiello, et al., 2017);
- Making use of street trees, rain gardens, green roofs, infiltration trenches, cisterns, rain barrels, vegetated swales, wetlands and porous paving to reduce the runoff from storms and to decrease the pressure on treatment facilities (ACT Government, 2014; McCormick & Dorworth, undated);
- Clearing alien invasive vegetation from infested catchments, and landscaping with indigenous vegetation to further reduce runoff and the need for irrigation (McCormick & Dorworth, undated);
- Using ground and surface water conjunctively, together with water sources at household level such as roof water harvesting in order to mitigate the impacts of disruptions related to weather on any given component of the system (ACT Government, 2014);
- Employing conservation technologies that reduces demand such as leakage management, detection and repair, water efficient fixtures and appliances, water metering and pricing, and pressure management (Fisher-Jeffes, et al., 2012; Elliot, et al., 2011; GreenCape, 2016).

Stormwater management deserves special mention here because it constitutes a big part of WSUD, called sustainable drainage systems (SuDS). Conventional urban stormwater management focuses largely on managing the quantity (flow) of stormwater by collecting runoff and channelling it away from the city as soon as possible to prevent flooding. This has led to the erosion of natural channels and pollution, resulting in environmental degradation (GreenCape, 2016). WSUD approaches stormwater as a resource and asset rather than a nuisance (Mottaghi, et al., 2015). Stormwater design calculations will be affected by climate change in numerous ways such as through the increase in the frequency and intensity of heavy rainfall events, and through changes in the antecedent moisture loading of soils and the average water supply in storage ponds (Shaw, et al., 2005). Stormwater can be transformed from a possible hazard into a resource by capturing stormwater close to its source with infiltration galleries, detention basins, green roofs, porous asphalt and cisterns (Elliott, et al., 2011).

The performance of WSUD can be measured against its efficiency in conserving water in various urban land uses and in irrigated open spaces; against runoff quantity and quality in urban developments and roads, streets and thoroughfares (for example by assessing whether there have been resultant reductions in total pollutant loads as compared to untreated runoff from storms, or whether the capacity of drainage systems has not been exceeded); and lastly against whether WSUD are designed in an integrated way, i.e. whether it supports the relevant development objectives through the engagement of relevant stakeholders at the appropriate stages of planning, designing, constructing and managing WSUD (Government of South Australia, 2013).

6. Framework for water sensitive adaptation planning

Spatial planning, land use and urban design decisions have long lasting consequences for the supply and demand for water services and resources (Rozenzweig, et al., 2015). Both the impacts of the availability of water on land use as well as the impacts of land use on the availability of water have to be considered when dealing with water resources and their management. Water sensitive adaptation measures should thus be identified and integrated with urban planning as early in the planning process as possible (Grau, undated).

It is not usually necessary or possible to apply every WSUD technique there is, but it is also highly unlikely that any single action on its own will suffice to deal with climate impacts. A basket of actions should be selected with the possible impacts of climate change in mind that incrementally reduces the frequencies and volumes of runoff, flow rates and pollution and takes local conditions into consideration (Van Niekerk, 2018; Vermont Department of Environmental Conservation, 2010; Grau, undated). It would be more effective to implement a basket of measures that will combined the mitigation of long term effects with short term adaptation impact. A framework for selecting such a basket of actions is proposed in Figure 1. This framework was developed for South African cities in an ongoing research project called the Green Book (CSIR, 2018), but can be applied elsewhere. The steps below were followed to develop this framework:

1. Potential climate hazards were identified from climate change projections (South Africa in the case of the project). These hazards included coastal flooding, inland flooding, heat stress, drought, and wildfire.
2. The extent of the local urban planning function was defined, and utilised as criteria for selecting adaptation actions from a literature survey. The local urban planning function was extensively defined to include spatial planning, land use management, environmental planning, engineering services, and landscape and urban design.
3. Based on this criteria, a survey was undertaken of existing local and international adaptation plans, strategies and academic literature to compile a wide-ranging menu of adaptation actions. Much of what is proposed as adaptation actions, is simply good planning practice but essential to mitigate the impacts of climate change.
4. Each adaptation action was linked to one or more climate hazards, and also given a property as being a win-win adaptation action, a no-regrets action, or a low regrets action[i]. This property can be linked to the adaptive capacity or vulnerabilities of a place, i.e. if the economic base as well as the population growth trends of a place are in decline, then it is possible to only select those actions that do not involve a huge capital investment, i.e. soft adaptation actions.
5. Relevant adaptation actions were then selected and organised in a framework according to the planning function they fulfil. These were tested with a focus group for their relevance to the local planning function and then refined.
6. The next step was to structure the framework in a hierarchy and to connect adaptation actions to each other in the hierarchy (see Figure 1 below). Thus if you select one action, the linked actions will also be recommended. This is to ensure that a single proposed action is supported within a hierarchy of urban planning instruments. For example, if heat stress is projected to become more extreme in future, one of the adaptation actions proposed under the urban landscape and design category is to design shaded public spaces. The associated actions in the hierarchy are to identify such spaces in the spatial plan, and to protect them through land use management.

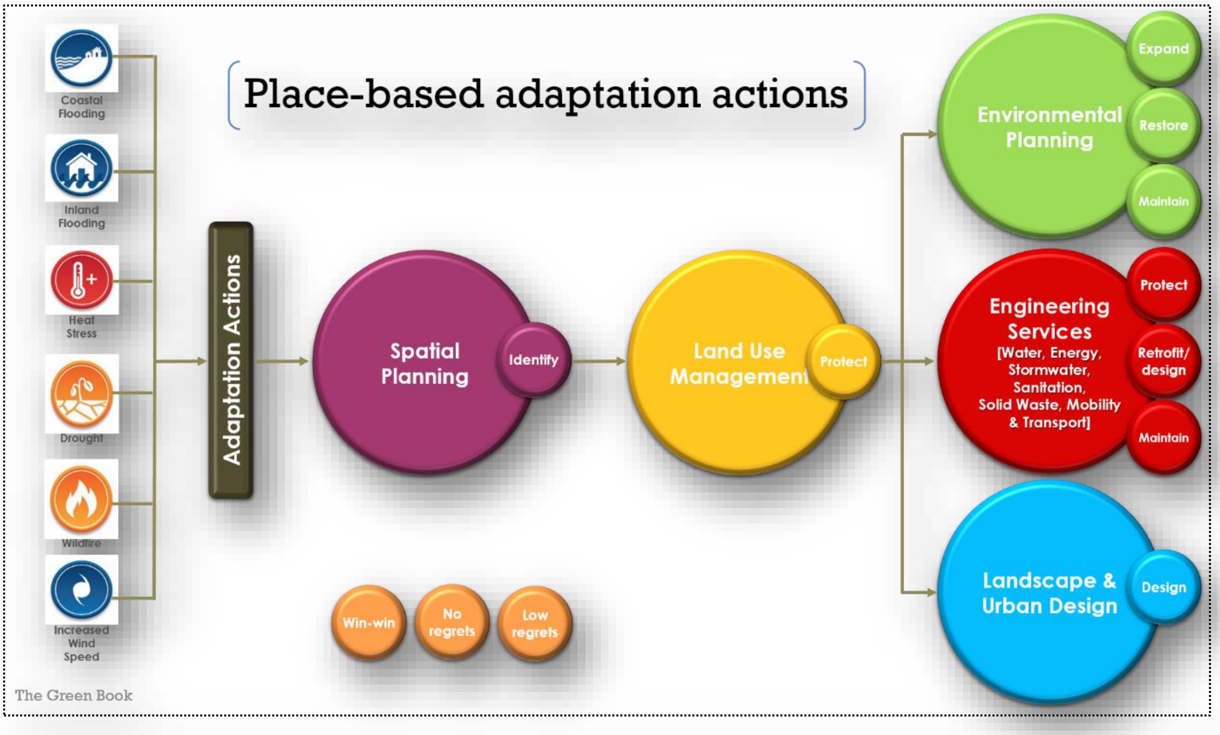

Figure 1: A framework for selecting place-based adaptation actions (Van Niekerk, et al., 2018)

To illustrate how this applies to water sensitive urban planning, say for example a city is projected to become hotter and drier, and at risk of recurring drought in the future. The city's economy is strong and diversified, and the population is growing. Water-sensitive urban design will be crucial to address the future demand for water in the city. Using the proposed framework of adaptation actions, a basket of adaptation actions linked to drought as a hazard will be suggested, each action linked to a hierarchy of planning functions. It is up to the planner then to select all supportive adaptation measures to be integrated into the various related planning instruments. An example would be that 1) the spatial planning instrument(s) is used to identify all the potential water sources in the city as part of a decentralised water provision system; 2) the land use management instrument(s) is used to protect all the potential water sources from development or pollution; and 3) the engineering services function design a diversified water supply system that includes using alternative water sources, recycled water and grey water for non-potable purposes.

The proposed framework assists in selecting the most appropriate adaptation actions as part of a WSUD adaptation strategy, and ensures a single action is supported in a hierarchy of planning instruments, if appropriate.

7. Conclusion

Climate change not only contributes to existing urban challenges, but will also create more problems that will have to be dealt with in the future. It therefore becomes important for planners to be familiar with and thoroughly comprehend the current and potential impacts, to limit and prevent these challenges, particularly in the water sector. Cities are facing the challenge of transforming already fully or over-extended water services infrastructure into systems that can deal with the current and future combined pressures from continued rapid urbanisation and climate change. However, due to the enormity of the urban challenges, the costs of upgrading or replacing old infrastructure to provide immediate services often outweigh any considerations and decisions regarding future climate change. Often cities have limited technical capacity and resources to manage existing water infrastructure, let alone plan and develop new infrastructure that is more sustainable and resilient to climate change. Addressing climate change in urban water systems could therefore be complex, but is an opportunity to address a number of development challenges simultaneously. As water infrastructure may last over 100 years it is important that new infrastructure take into account climatic change that may occur during its lifetime. The development of new water systems and the upgrading of existing systems offer the opportunity to develop systems that are more resilient to future impacts of climate change. It also offers an opportunity to leapfrog conventional wasteful approaches with more effective and resilient systems (Muller, 2007; Bahri, et al., 2016).

Water sensitive urban design should be considered as the basis of city-wide planning instruments in places that are becoming hotter, drier and more at risk of severe climate events. There are numerous potential benefits to water sensitive design for cities:

- Economic benefits include savings on capital costs and costs for water quality improvement, as well as increases in market value from the improved aesthetics that come with some WSUD measures.
- Social benefits include opportunities for the linkages of community nodes through the use of open space, amendable residential and urban landscapes and improved visual amenity. Adapting to climate change is also an opportunity to aim for higher levels of services in unserved areas by leapfrogging the intermediate step of communal services (WHO & DFID, 2009).
- Environmental benefits include the protection it offers for sensitive areas from urban development, contributing to the maintenance of the hydrological balance in cities by encouraging the use of natural processes of evaporation, infiltration and storage, enhancing natural habitats, and supporting the restoration of urban waterways (Van Hattum et al., 2016). Adapting to climate change is also an opportunity to integrate water source sustainability from the outset into new programmes and not as an afterthought (WHO & DFID, 2009).

Given these benefits, this paper proposed a framework for selecting appropriate adaptation actions to be included in a WSUD adaptation strategy that would ensure adaptation actions are not loose standing, but integrated into a hierarchy of planning instruments.

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i ***Win-win actions*** contribute to adaptation whilst also having other social, economic and environmental policy benefits, including those relating to mitigation. ***No regrets actions*** yield benefits even in absence of climate change and where the costs of the adaptation are relatively low vis-à-vis the benefits of acting***. Low regrets actions*** are relatively low cost and provide relatively large benefits under predicted future climates (CSIR, 2018).