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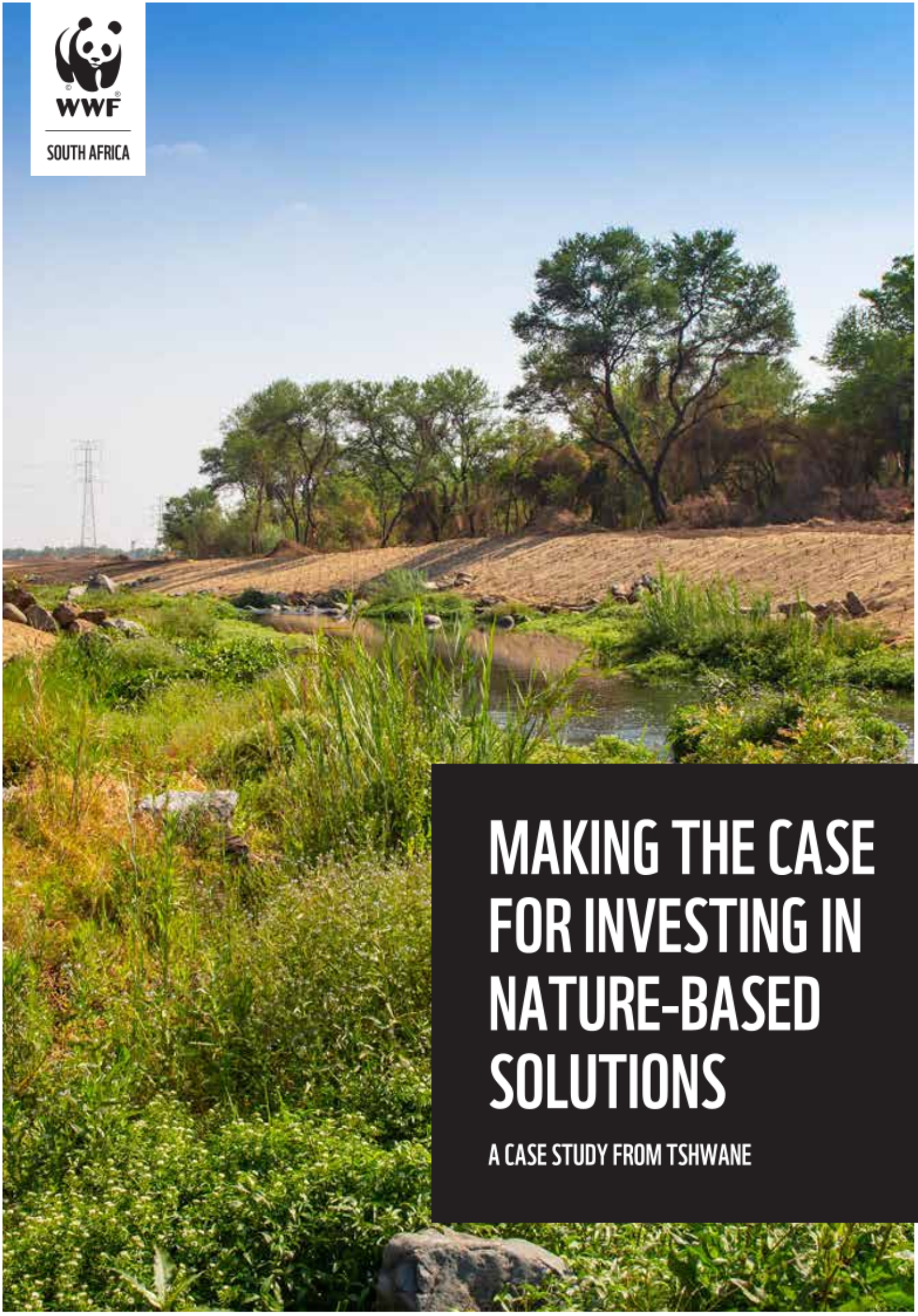

MAKING THE CASE FOR INVESTING IN NATURE-BASED SOLUTIONS

A CASE STUDY FROM TSHWANE

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This publication is a follow-up publication to the WWF report titled *Urban lockdown lessons for South Africa: Nature-based solutions for a green and equitable recovery in municipalities* (Gulati and Scholtz, 2020), which focused on using nature-based solutions to create immediate low-skill jobs in municipalities while at the same time making cities climate resilient, healthy and liveable through improving environmental conditions. Available online at www.wwf.org.za/report/urban_nature_based_solutions.

KEY MESSAGES

This report presents a sustainable asset valuation (SAVi) of nature-based infrastructure to mitigate flooding and heat risks in the City of Tshwane, South Africa.

- The analysis found that nature-based infrastructure can effectively reduce the cost of stormwater treatment and cooling for buildings, while also improving the quality of the area for residents and other city stakeholders.
- The SAVi analysis quantifies the construction and maintenance costs, energy savings, stormwater retention capability and carbon storage benefits of nature-based infrastructure, specifically green roofs and street trees.
- A comparative analysis of these benefits indicates that both green roofs and street trees are economically viable investments in the City of Tshwane. Street trees, especially, could generate significant value and their value will grow as climate change causes warming and more extreme precipitation. More specifically,
  - Green roofs have a benefit-to-cost ratio of 1,21
  - Street trees have a benefit-to-cost ratio of 31,17.
- Given data limitations, it is likely that the benefits of nature-based infrastructure have been underestimated.
- Future work can incorporate more local data, including projections for temperature and precipitation under future climate scenarios.
- Additional analysis could do the following:
  - Demonstrate the value of green roofs and street trees as temperatures and precipitation increase
  - Quantify more positive nature-based infrastructure impacts, such as improved air quality, job creation and increased property values
  - Compare the costs and benefits of nature-based infrastructure and grey infrastructure alternatives by doing a complete assessment of grey infrastructure costs and benefits over the asset lifetime.

Table 1 shows ways in which decision-makers can use the results of this assessment.

TABLE 1: WAYS IN WHICH STAKEHOLDERS CAN USE THE RESULTS OF THE SAVi ASSESSMENT

Stakeholder	Role in the project	How can the stakeholder use the results of the assessment?
National government	Financing nature-based infrastructure, developing building standards	To define standards and regulations for including nature-based infrastructure in new development projects
Local government	Designing and maintaining nature-based infrastructure in public places	▪ To inform climate adaptation plans and strategies that address stormwater run-off and urban heat islands ▪ As evidence that nature-based infrastructure in public spaces can provide benefits at the city-scale
Project developers	Incorporating nature-based infrastructure into development plans	▪ To inform decisions about constructing nature-based infrastructure in new developments ▪ To demonstrate that incorporating nature-based infrastructure in urban developments provides value to city residents and businesses
Donors and investors	Financing nature-based infrastructure	▪ As quantitative evidence that nature-based infrastructure is economically viable ▪ To define funding priorities for infrastructure investments

INTRODUCTION

South African municipalities are facing unprecedented challenges in the face of climate-related shocks and stresses, and will face more in the future. The City of Tshwane has developed extensive climate action plans to both reduce the city's greenhouse gas emissions and make it more resilient to future climate shocks.

While often overlooked, investment in nature-based solutions or nature-based infrastructure can support the reduction in carbon emissions and increase the resilience of municipalities to projected climate and environmental challenges.

Nature-based solutions and nature-based infrastructure

Nature-based solutions include ecosystem-based adaptation, natural climate solutions and eco-disaster risk reduction (Preethan and Gupta, 2020). These measures can include **nature-based infrastructure** that is solely supported by nature-based solutions, or hybrid infrastructure where nature-based solutions are used to increase the efficiency of traditional grey infrastructure.

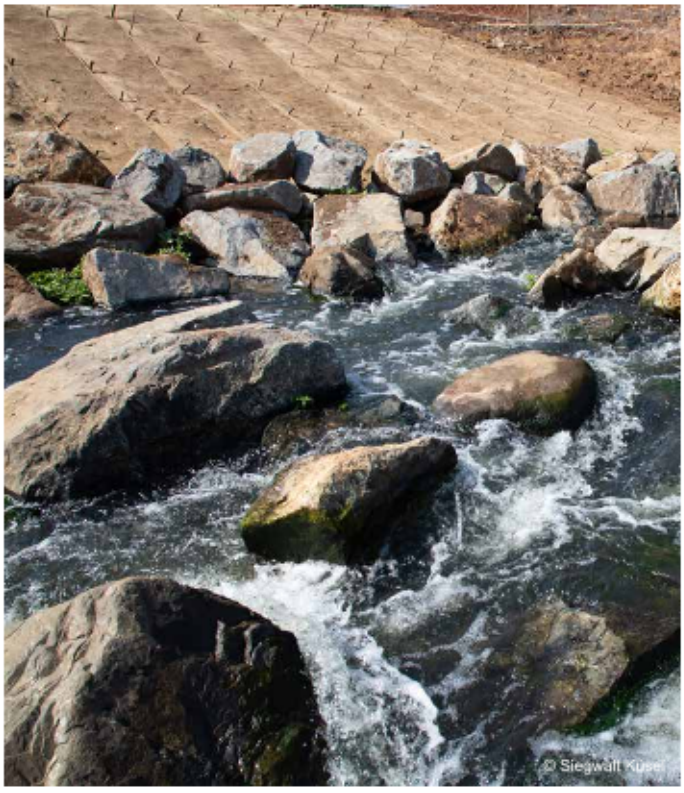
Specific urban examples of nature-based solutions include green rooftops and trees, greening cycling and pedestrian routes and river corridors, encouraging spontaneous flora, and creating sustainable urban drainage, rain gardens, green walls or greened brownfields, green wharfs, community gardens, parks, non-woodland ecosystems (e.g. wetlands), water bodies and new woodland areas and woodland ecosystems.

These interventions offer cities the triple dividend of delivering climate, economic and social benefits through:

- Improving resilience to climate change via improved water management, addressing rising temperatures and heat islands in cities, improving air quality and supporting climate-change mitigation goals through increasing urban carbon sinks and reducing carbon emissions.
- Rapidly generating jobs and providing accessible employment opportunities for lower-skilled workers while creating healthier, greener and more liveable cities.
- Supporting long-term economic growth by increasing food and water security and business productivity, among others.

However, a key barrier to adopting nature-based solutions is the lack of capacity and knowledge of these solutions in cities. Cities face knowledge gaps on:

- The scope and role of nature-based solutions in urban areas
- Technical guidance for the implementation of nature-based solutions
- Which ecological functions to promote in their own context
- Operationalising, maintaining and integrating nature-based solutions with existing conventional infrastructure
- Financing nature-based solutions.



City-wide collaboration

The implementation of nature-based solutions by cities can also provide opportunities for collaboration between the city and its citizens. This is particularly true for property developers of large tracts of land where there are opportunities to integrate nature-based solutions in the planning cycle from the outset. Just like cities, developers are often not aware of the benefits of nature-based solutions or find it difficult to make the financial case for investing in them. Integrating these solutions not only offers the potential to increase the resilience of the particular development to future climate impacts but also contributes to and strengthens the overall resilience of the city.

Sustainable asset valuation (SAVi)

This publication presents the results of a sustainable asset valuation (SAVi) of nature-based infrastructure to mitigate flooding and heat risks in the City of Tshwane, South Africa. The modelling done for this study uses a place-based approach to quantify the benefits of investing in nature-based infrastructure to mitigate flooding and heat risk, using as a starting point a specific local greenfield development in the Tshwane metropolitan area.

ABOUT SUSTAINABLE ASSET VALUATION (SAVi) METHODOLOGY

SAVi is a simulation service that helps governments and investors to value the many risks and externalities that affect the performance of infrastructure projects.

The distinctive features of SAVi are:

- **Valuation:** SAVi values, in financial terms, the material environmental, social and economic risks and externalities of infrastructure projects. These variables are ignored in traditional financial analyses.
- **Simulation:** SAVi combines the results of systems thinking and system dynamics simulation with project finance modelling. Researchers engage with asset owners to identify the risks material to their infrastructure projects and then design appropriate simulation scenarios.
- **Customisation:** SAVi is customised to individual infrastructure projects.

FUTURE CLIMATE CHALLENGES FOR THE CITY OF TSHWANE

Climate change, population growth, a decrease in permeable surfaces, informal urban expansion and inadequate stormwater system maintenance are predicted to increase the risks of flooding and heat stress in Tshwane over the coming decades (City Sustainability Unit, 2021). All new property developments should take these factors into account and must include the appropriate mitigation measures.

The City of Tshwane's City Sustainability Unit in the Office of the Executive Mayor has a mandate to address climate change and the green economy. In seeking an evidence-based approach, it has compiled a greenhouse gas emissions inventory and a climate risk and vulnerability assessment (CRVA).

The CRVA was first developed in 2015 and confirmed a 1,8 °C average change in temperature in Tshwane since 1960. Following the first CRVA, an urban heat island study was commissioned, which confirmed the conformity between urban development and the urban heat island effect. It also demonstrated the contribution of topographical features: the northern and northwestern parts of the metropolitan area are warmer than the southern and southeastern parts. The CRVA was updated between 2019 and 2021 and climate hazards and the production of climate risk zones were revised.

The CRVA 2021 developed climate risk zones for singular and multiple climate hazards for the present day and the future (2050). Figure 1 indicates the projected flood pressure by 2050 and Figure 2 the projected heat stress pressure. In Figure 1, risk combines the flood hazard, exposure and vulnerability. Future flood risk accounts for projected changes in extreme rainfall, growth of informal settlements and population change. In Figure 2, future heat stress is calculated from current heat stress, projected change in very hot days and population growth. In both figures the pin shows the approximate location of Rainbow Junction.

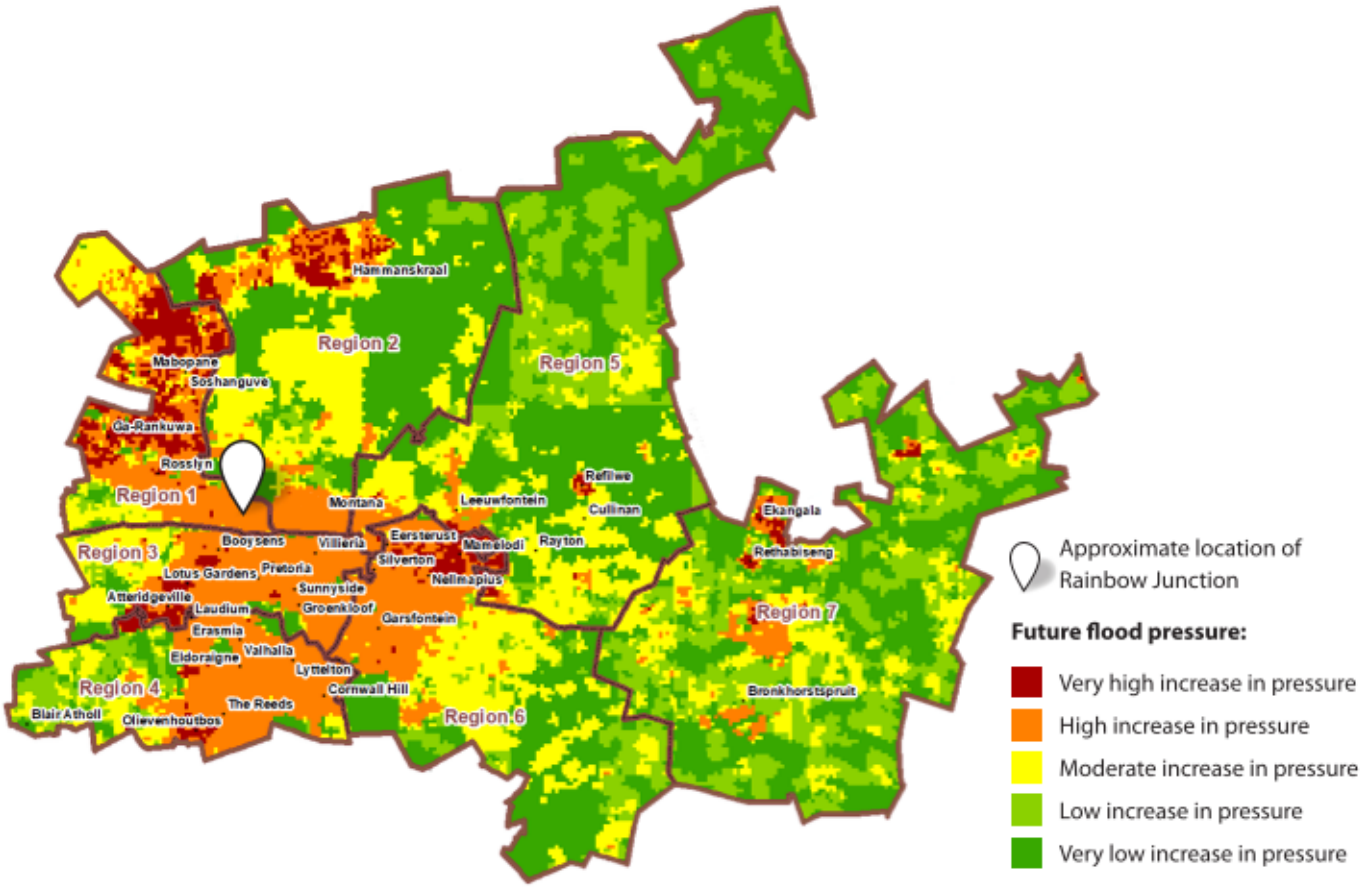
WHAT ARE URBAN HEAT ISLANDS?

Urban heat islands occur in cities or urban areas. These areas are significantly warmer than the surrounding rural areas because heat is created by the concentration of human activities, cars, buses and trains. The temperature difference is usually larger at night than during the day and the heat island effect is more noticeable during summer and winter.

WHAT ARE CLIMATE RISK ZONES?

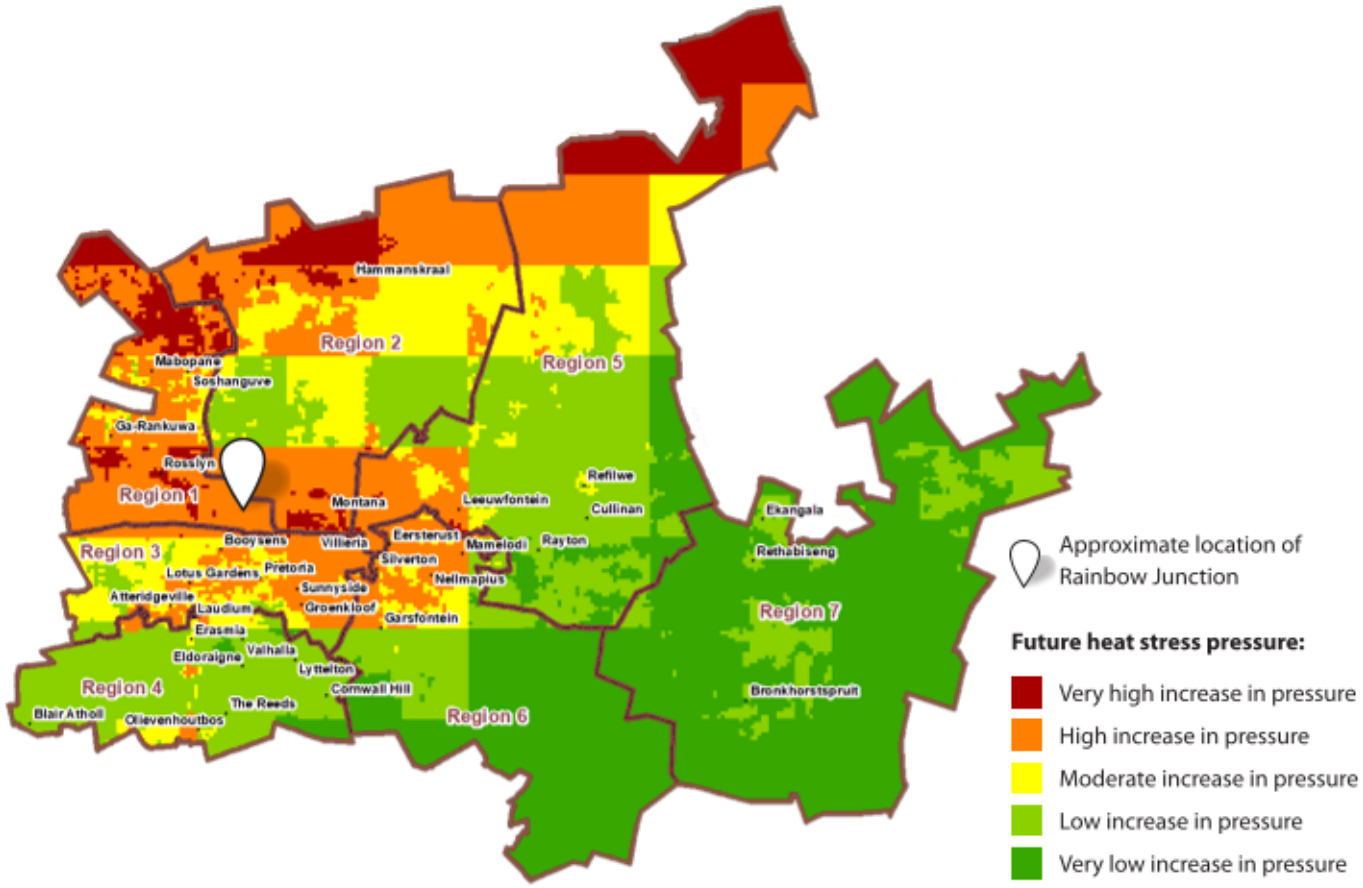
Climate risk zones are defined as spatial areas where there is a risk of loss of life or loss of livelihoods because a vulnerable community, infrastructure or environment is directly exposed to one or more hydrometeorological hazards. Hydrometeorological hazards include thunderstorms, hailstorms, coastal storms, tornados, floods (including flash floods), drought, heatwaves and extreme cold spells.

FIGURE 1: PROJECTED FLOOD RISK FOR THE CITY OF TSHWANE BY 2050



Source: City Sustainability Unit, 2021

FIGURE 2: PROJECTED HEAT STRESS FOR THE CITY OF TSHWANE BY 2050



Source: City Sustainability Unit, 2021

The importance of collaborative action between cities and developers

Given the knowledge that urban development contributes to the urban heat island effect, there is a genuine concern that existing developments need to add as many cooling measures as possible. There is also an understanding that greenfields developments such as Rainbow Junction will worsen the urban heat island effect and increase run-off through the removal of permeable surfaces. Unless rigorous cooling and greening measures are applied, for example by incorporating nature-based infrastructure, these impacts can be significant. Property developers can make a meaningful contribution in this regard. By collaborating with cities, they can include nature-based solutions in their projects in line with the city's climate research and climate action plans to make the urban environment more resilient to climate-change impacts.

Selecting the study site

Rainbow Junction, a new 140 ha mixed-use development in the City of Tshwane, was selected to investigate the potential for nature-based infrastructure to mitigate urban heat islands and stormwater run-off using the SAVi tool. As shown in Figure 1 and Figure 2, the development is in an area in which both flooding and heat pressure are expected to increase significantly.

The area that is earmarked for the Rainbow Junction development is a pocket of green space between heavily built-up areas, 6 km north of the City of Tshwane's central business district. It combines residential and commercial land uses with open space (*Rainbow Junction*, 2021). The site was selected with the assistance of the City's Sustainability Unit. Figure 3 shows the location of Rainbow Junction and Figure 4 shows the layout of the development.

FIGURE 3: THE RAINBOW JUNCTION SITE SHOWING LOCATION AND TRANSPORT ACCESS

FIGURE 4: THE RAINBOW JUNCTION SITE'S LANDSCAPE PLAN

Source: Rainbow Junction

MEASURING THE IMPACT OF NATURE-BASED SOLUTIONS

The aim of the SAVi assessment was to quantify the value of nature-based infrastructure, specifically green roofs and street trees, to cost-effectively address climate change at Rainbow Junction. This was done by analysing different scenarios.

Three scenarios

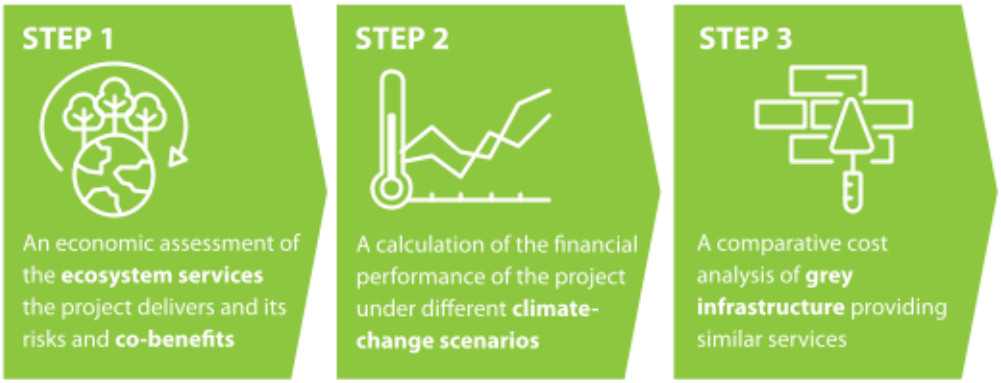
Three scenarios were considered for the SAVi assessment:

1. A 500 m² green roof is installed on a single building. This type of analysis can be used by a property owner or developer to assess the impact of choosing a green roof instead of a conventional roof.
2. Green roofs totalling an area of 67 000 m² are installed. This roof area is 10% of the land in Rainbow Junction designated for buildings. These results can be used to evaluate the impact of green roofs on a larger scale.
3. One thousand additional street trees are planted. These trees would be planted in addition to any trees already planned for Rainbow Junction and would be separate from the 35 ha of open space at the development.

The researchers used multipliers from the international literature to estimate the costs and benefits of using green roofs and street trees at Rainbow Junction. They included construction and maintenance costs, carbon storage, water retention and energy savings benefits.

- **Construction and maintenance costs** are the costs to install and maintain the roofs and trees for 40 years. The avoided cost of installing conventional roofs was also included.
- **Carbon storage** is valued based on the total amount of carbon sequestered by the nature-based infrastructure and the social cost of carbon.
- **Water retention** benefits are quantified using the area of impervious surfaces and the cost to treat stormwater.
- **Energy savings** are calculated relative to a grey infrastructure alternative. For green roofs, the researchers calculated the reduction in energy required for heating and cooling compared to what is needed with a conventional roof. For trees, energy use was considered compared to a situation with no street vegetation.

FIGURE 5: CUSTOMISED VALUATION OF A NATURE-BASED PROJECT



Source: IISD, 2021

The SAVi assessment of nature-based infrastructure for the Rainbow Junction development followed the steps shown in Figure 5. For Step 3, only the avoided cost and energy savings of conventional roof construction were included rather than a complete assessment of costs and benefits over the asset lifetime.

Important assumptions

The following assumptions were made for the analysis:

Social cost of carbon

The global social cost of carbon in 2020 is $37,3 per tonne of carbon dioxide (CO_2) (measured in 2010 US dollar terms) (Nordhaus, 2017). Accounting for inflation, the social cost of carbon in 2020 terms is $44,53 per tonne of CO_2. With an exchange rate of $0,07 to the rand, the social cost of carbon is R636,10 per tonne of CO_2. It was assumed that this value would not change in the future.

Electricity price

The 2020–2021 residential cost of electricity per kilowatt hour (kWh) in South Africa is, on average, R3,14, and the commercial price averages R1,50 per kWh. It was assumed that 15% of buildings in Rainbow Junction would be used for residential and 85% for commercial purposes. From this, a weighted average electricity price of R1,73 per kWh in 2021 was calculated (Luyt, 2021). It was assumed that this price would increase by 8% per year (Luyt, 2021).

Carbon intensity of electricity

Altogether 0,879 kg of CO_2 is emitted for every kWh of electricity generated in South Africa (Climate Transparency, 2020).

Value of stormwater retention

Fisher-Jeffes and Armitage (2013) determined that a fair monthly stormwater fee for the City of Tshwane would be R60–R87 per 160 m^2 of impervious area. Their calculation is based on the avoided cost of treating stormwater (retaining it, thus reducing run-off, and removing pollutants) to an acceptable level using a conventional treatment system. From this, the researchers used a mid-range estimate of R69 per month per 160 m^2 (R5,18 per year per m^2) of impervious area.

Green roofs

A green roof is any roof covered with soil used to grow plants (Van der Meulen, 2019). The vegetation and substrate are typically built on top of filter and drainage layers. Below these layers are a root barrier and waterproofing material (Manso et al., 2021; Vijayaraghavan, 2016).

"Intensive" green roofs have a thick substrate layer (20–200 cm) and can support many types of plants, including small trees and shrubs. They can be rooftop gardens or parks and have high maintenance costs (Manso et al., 2021; Van der Meulen, 2019; Vijayaraghavan, 2016).

"Extensive" green roofs (Figures 6 and 7) have a substrate layer that is 6–20 cm thick. With a thinner substrate, the choice of plants is limited and typically consists of grasses, mosses and sedum (stonecrop species.

Extensive roofs are lighter in weight and require less maintenance than intensive roofs but are often not usable as gardens or parks (Manso et al., 2021; Van der Meulen, 2019; Vijayaraghavan, 2016). For the SAVi assessment, we assumed that the roofs installed would be extensive green roofs.

FIGURE 6: AN EXAMPLE OF AN "EXTENSIVE" GREEN ROOF ON A COMMERCIAL BUILDING

FIGURE 7: AN EXAMPLE OF AN "EXTENSIVE" GREEN ROOF ON A RESIDENTIAL BUILDING

Cost and benefit multipliers and data sources for green roofs are given in Table 2. In cases where there were multiple estimates for a parameter, a mid-range value was used.

Note that the insulation effect of green roofs (building energy-use reduction) was separated from the urban heat island effect (energy savings nearby). As above, the exchange rate of $0,07 = R1 was used to convert all values to rand.

In 2013, it was estimated that installing a green roof in Cape Town, South Africa, would be two to three times more expensive than a conventional roof (Luyt, 2021). Thus, the researchers assumed that the cost of installing a green roof would be 2,5 times the cost of a conventional roof.

Manso et al. (2021) calculated the average lifetime of green roofs to be 40 years. This is also true of Kantor (2017) and Van der Walt (2018) for their life-cycle assessments of green roofs. Following this precedent, we assumed a lifetime of 40 years for green roofs. However, some studies indicate that the lifetime may be closer to 50 years or more (Manso et al., 2021; Miller et al., 2011).

Conventional roofs typically have a lifetime of 10–25 years (Kantor, 2017; Manso et al., 2021; Van der Walt, 2018). For this analysis, it was assumed that a conventional roof would last 20 years; therefore, the conventional roof waterproofing must be replaced after 20 years (Van der Walt, 2018), i.e. once in a 40-year cycle.

TABLE 2: MULTIPLIERS USED TO ESTIMATE THE COSTS AND BENEFITS OF GREEN ROOFS

Parameter	Unit	Value	Study location	Source
Construction costs	R/m²	2 668	Johannesburg	Van der Walt, 2018
Maintenance costs in year 1	R/yr/m²	157	Johannesburg	Van der Walt, 2018
Maintenance costs after year 1	R/yr/m²	69	Johannesburg	Van der Walt, 2018
Avoided conventional roof construction cost in year 1	R/m²	1 067	South Africa	Luyt, 2021
Avoided conventional roof waterproofing cost in year 21	R/m²	509	Johannesburg	Van der Walt, 2018
Water retention	m³/m²	0,035	Netherlands	Green Deal Groene Daken, 2018
Building energy-use reduction	kWh/yr/m²	7,9	Toronto, Canada; Wuxi, China	Banting et al., 2005; Cai et al., 2019
Energy savings nearby	kWh/yr/m²	2,37	Toronto, Canada	Banting et al., 2005
Carbon storage	kg/m²	0,375	USA	Getter et al., 2009

HOW GREEN ROOFS AND STREET TREES MITIGATE THE EFFECTS OF CLIMATE CHANGE

Green roofs insulate the buildings below and cool ambient air temperatures (Banting et al., 2005; Rosenzweig et al., 2006; Santamouris, 2014). Insulating a building by means of a green roof reduces energy use for heating and cooling, while the effect on ambient temperatures mitigates urban heat islands (Banting et al., 2005). Green roofs also retain water in the plants and soil, store carbon and have a longer lifetime than conventional roofs (Berghage et al., n.d.; Getter et al., 2009; Green Deal Groene Daken, 2018; Kantor, 2017; Van der Walt, 2018).

Similarly, street trees provide shade that cools the local environment, retain water and sequester carbon (Mullaney, 2015; Rosenzweig et al., 2006; Song et al., 2018; US EPA, 2015; Xiao and McPherson, 2002).

Street trees

It was assumed that the additional trees planted will be a mix of endemic species and others native to the region. These trees include:

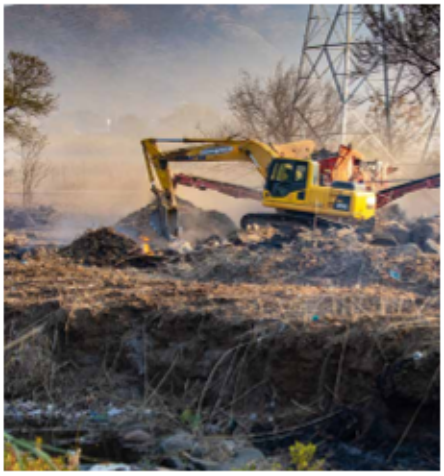
- *Berchemia zeyheri* (red ivorywood, purple ivory, pink ivory)
- *Buddleja saligna* (false olive)
- *Grewia occidentalis* (cross-berry, four corners)
- *Gymnosporia polycantha* (hedge spike-thorn)
- *Schotia brachypetala* (weeping boer-bean, tree fuchsia, African walnut)
- *Senegalia caffra* (common hook-thorn, cat thorn).

Multipliers used to quantify the costs and benefits of street trees are given in Table 3. As with green roofs, mid-range estimates were used when necessary, assuming an exchange rate of $0,07 = R1. Costs and benefits were calculated over 40 years.

The carbon storage per tree is the average value for a tree that is allowed to grow for 10 years (US EPA, 2015). It was assumed that no carbon would be sequestered after this point.

TABLE 3: MULTIPLIERS USED TO ESTIMATE COSTS AND BENEFITS OF URBAN TREES

Parameter	Unit	Value	Study location	Source
Purchase cost	R/tree	500	Rainbow Junction	Newton, 2021
Maintenance costs	R/yr/tree	50	Rainbow Junction	Newton, 2021
Water retention	m^3/yr/tree	6,6	California	Xiao and McPherson, 2002
Building energy-use reduction	kWh/yr/tree	156	International	Song et al., 2018
Carbon sequestration	kg/tree	68,3	USA	US EPA, 2015
Required soil area	m^2/tree	15,6	Virginia, USA	Marritz and Hunter, 2020



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CLIMATE AND WATER MANAGEMENT BENEFITS OF NATURE-BASED INTERVENTIONS

The results for the three scenarios in the SAVi assessment focused on the costs and benefits of green roofs and street trees.

Green roofs: Benefits are underestimated

For green roofs, the energy cost reduction includes the effect of both insulating the building below and cooling ambient air temperatures, as shown in Table 4.

A single 500 m^2 green roof would cost R1 333 788 to install, which is R800 273 more than a conventional roof. Green roof annual maintenance costs are R78 500 in the first year and R34 500 in each following year. This amounts to R1 389 500 in maintenance costs over 40 years, compared to R254 389 to replace the waterproofing of a conventional roof after 20 years.

A green roof would store 187,5 kg of carbon (0,69 tonnes of CO_2), valued at R437 based on the social cost of carbon. Annual energy requirements would be lowered by 5 138 kWh, avoiding 4,5 tonnes of CO_2 emissions per year for electricity generation.

Expanding the analysis to 67 000 m^2 of green roofs, installation costs are R107 236 581 more than installing conventional roofs.

Annual maintenance costs are R10 519 000 in the first year and R4 623 000 from year 2 onwards. Thus, total maintenance costs over 40 years would be R186 193 000, whereas replacing the waterproofing for a conventional roof of this size once during 40 years would cost R34 088 084.

Carbon storage for the 67 000 m^2 of green roofs is 25 125 kg (92,1 tonnes of CO_2). Total annual building energy savings would be 688 425 kWh, avoiding 605 tonnes of CO_2 emissions per year.

Installing 67 000 m^2 of green roofs can reduce stormwater run-off by up to 91 455 m^3. The value of this water retention is R346 725 per year based on the reduction in impervious area and the cost of stormwater treatment.

According to this analysis, the benefit-to-cost ratio for green roofs is 1,21. However, it is highly likely that the benefits of green roofs have been underestimated. A 40-year lifetime for green roofs is conservative. If green roofs last longer than 40 years, then the net benefits of green roofs would increase because it would be necessary to continue replacing the conventional roof waterproofing every 20 years. Similarly, if conventional roofs must be replaced more than once during the 40-year timeframe, green roofs would be more economical.

In addition, as temperatures increase due to global warming, there would be a greater need for cooling. If we assume that cooling is needed for twice as many days in the future, then the energy savings from green roofs also double. In this scenario, the avoided annual energy cost in 2060 would be R357 565 for a single 500 m^2 green roof and R47 913 643 for 67 000 m^2 of green roofs. It is important to note that this is a speculative scenario that considers both climate trends and assumptions about cooling days. However, any increase in energy savings over the full 40-year lifetime of green roofs would lead to larger net benefits of these roofs.

Furthermore, the value used for the cost of stormwater accounts for the cost of constructing and maintaining stormwater treatment facilities. There could be additional savings if the capacity of stormwater infrastructure can be reduced. More extreme precipitation in the future would also increase the value of diverting water from the stormwater system by increasing water retention on green roofs.

Thus, although green roofs are more expensive to install and maintain than conventional roofs, the services they provide far outweigh the costs. These benefits will increase as the climate warms and electricity prices rise.

TABLE 4: COSTS AND BENEFITS OF GREEN ROOFS AND STREET TREES (IN RAND, UNDISCOUNTED AND CUMULATIVE OVER 40 YEARS)

	500 m^2 green roof	67 000 m^2 green roofs	1 000 trees
Costs (R)			
Construction costs	1 333 788	178 727 635	500 000
Maintenance costs	1 39 500	186 193 000	1 950 000
Total costs	2 723 288	364 920 635	2 450 000
Benefits (R)			
Avoided conventional roof costs	787 904	105 579 138	N/A
Energy cost reduction	2 293 574	307 338 927	69 644 293
Carbon storage	437	58 604	159 412
Avoided carbon emissions	112 037	15 012 906	3 401 988
Stormwater retention	100 912	13 522 275	3 150 029
Total benefits (R)	3 294 865	441 511 851	76 355 722
Net benefits (R)	**571 576**	**76 591 216**	**73 905 722**
Benefit-to-cost ratio	**1,21**	**1,21**	**31,17**

Street trees: A high benefit-to-cost ratio

Planting 1 000 trees costs R500 000 and requires R50 000 in annual maintenance costs. These trees could sequester a total of 68 343 kg of carbon (250,6 tonnes of CO_2). Reducing the need for air conditioning would lower energy requirements by 156 000 kWh every year, compared to a scenario with no street vegetation. These energy savings avoid 137 tonnes of CO_2 emissions per year.

As with green roofs, the volume of water retained can also be estimated. Using data from Southern California, it was calculated that 1 000 trees can retain up to 6 600 m^3 of run-off every year. However, this is probably underestimated. Monthly average precipitation is 3–118 mm in the City of Tshwane and 0–89 mm in Southern California (Climate-Data.org, n.d.). Although precipitation data for Tshwane is available, there is no local estimate for water retention from trees.

It stands to reason that with more precipitation, trees would intercept more water, but there is not a simple relationship between precipitation and water retention. Because, on average, Tshwane has a higher rainfall than California, it is likely that street trees in Tshwane would retain more water than those in California.

It is estimated that the benefit-to-cost ratio of tree planting would be 30,17. This may also be underestimated. Again, a value was not assigned to the benefit of reducing the required stormwater capacity. Instead, only the value of a smaller stormwater volume was considered.

A review of urban tree benefits by Song et al. (2018) found that estimates for cooling savings per tree were between 23 kWh and 288 kWh. In this assessment, the researchers used a value of 157 kWh/tree, which is in the middle of this range. However, the total energy savings, including heating and cooling, were 12–919 kWh/tree in the Song et al. (2018) review.

Because this SAVi assessment is concerned with mitigating urban heat islands, the researchers did not use this larger range to estimate energy savings, but it is possible that the energy reductions from street trees could be much larger than what has been estimated.

Finally, climate change and urban development patterns will increase the need for cooling and stormwater retention. This will lead to higher value of energy savings and water retention from trees.

THE WAY FORWARD

Further and more extensive modelling will strengthen the case for the investment in nature-based infrastructure by cities and property developers alike.

Local data will improve the analysis

Ideally, an analysis such as this one would use local data. Except for construction and maintenance costs, stormwater fees and electricity prices, such data was not available for the SAVi analysis, so the researchers used data from other countries. The energy savings from green roofs, for example, are calculated as the average of two studies, one conducted in Toronto, Canada, and the other in Wuxi, China. Toronto is, on average, cooler than the City of Tshwane, whereas Wuxi is typically warmer (Climate-Data.org, n.d.). The researchers therefore expect that the green roof energy savings in Tshwane would be between those in Toronto and Wuxi, but they do not know the precise value. To improve the results, the numbers in Table 2 should reflect the local context.

In this SAVi assessment, the assumption was that the green roofs installed would be extensive green roofs, with a relatively thin substrate (see "Green roofs" on page 11). An intensive green roof costs, on average, three to four times more than an extensive green roof to install, and annual maintenance costs are about 25% higher (Manso et al., 2021). However, intensive roofs have greater benefits, such as retaining 0,03–0,09 m^3 of water per m^2 compared to 0,02–0,05 m^3/m^2 for extensive roofs (Green Deal Groene Daken, 2018). If the design parameters of green roofs at Rainbow Junction are different from what we have assumed, the costs and benefits would change.

Furthermore, the effect of trees on energy use depends on the distance between and the orientation of trees and buildings (McPherson et al., 1994). The estimate used in this analysis is based on a review of 34 studies, which probably included trees of varying distances from and orientations to buildings (Song et al., 2018). For carbon sequestration, tree species and environmental conditions are important (US EPA, 2015). Thus, knowing the type and location of trees is needed for a more accurate assessment of benefits.

Climate projections will be useful

Other data that could be incorporated into the assessment include climate projections. Precipitation and temperature projections for multiple climate scenarios are available from the Copernicus Climate Data Store (Copernicus Climate Change Service, 2020). Including these data products in the valuation was outside the scope of this assessment, but they could improve estimates of stormwater retention and reduced energy requirements.

Figure 8 shows temperature projections for the City of Tshwane under low and high climate-change scenarios. There is a clear warming trend, particularly under the high climate-change scenario. With warmer temperatures, one would expect higher energy demand and, therefore, greater energy savings from green roofs and street trees.

Stormwater run-off is expected to worsen in the City of Tshwane due to the loss of permeable surfaces and inadequate drainage system maintenance (City Sustainability Unit, 2021). As shown in Figure 9, under a high climate-change scenario there may also be more extreme rainfall than under a low climate-change scenario. Nature-based infrastructure can reverse the loss of impervious surfaces and increase the capacity for stormwater retention. Thus, as the climate changes, we would expect larger avoided stormwater costs from nature-based infrastructure.

Additional indicators will complete the story

Green roofs and urban trees provide many benefits not included in this analysis, such as:

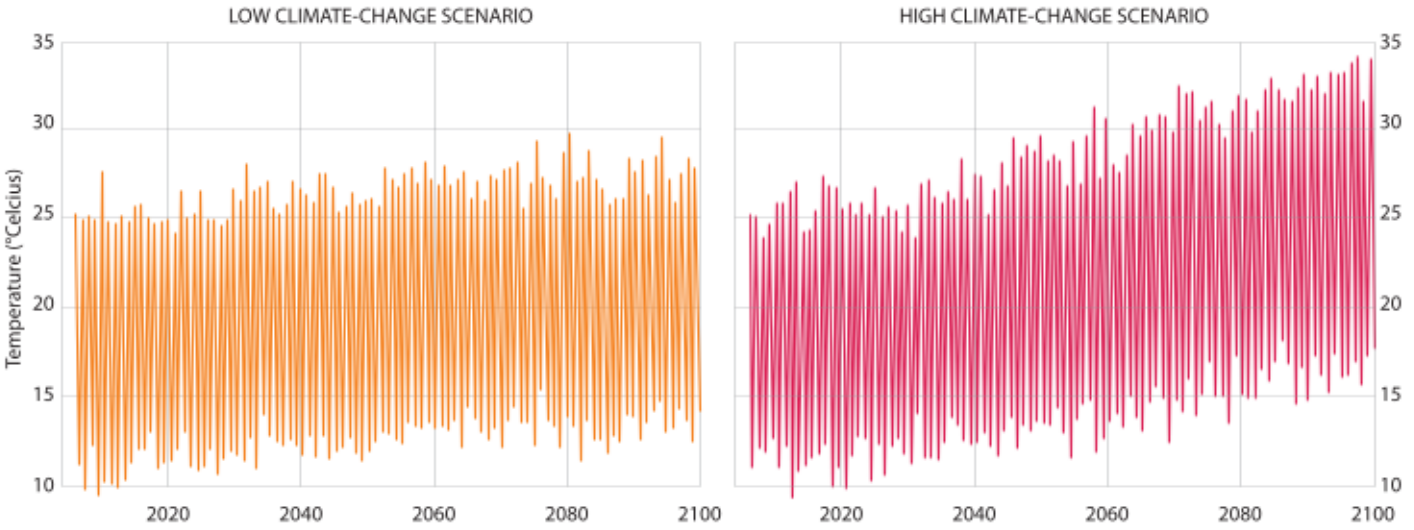
- **Improved air quality** (Banting et al., 2005; Demuzere et al., 2014; Peck et al., 1999; Song et al., 2018)
- **Increased property values** (Manso et al., 2021; McCord et al., 2014)
- **Job creation** (Del Pino et al., 2020; Euro Cities, 2015; Kopsiker et al., 2021).

The researchers have also not included costs related to removal of the nature-based infrastructure at the end of its lifetime. Quantifying additional costs and benefits would allow for a more complete assessment of green roofs and urban trees.

Comparisons with grey infrastructure will provide insight

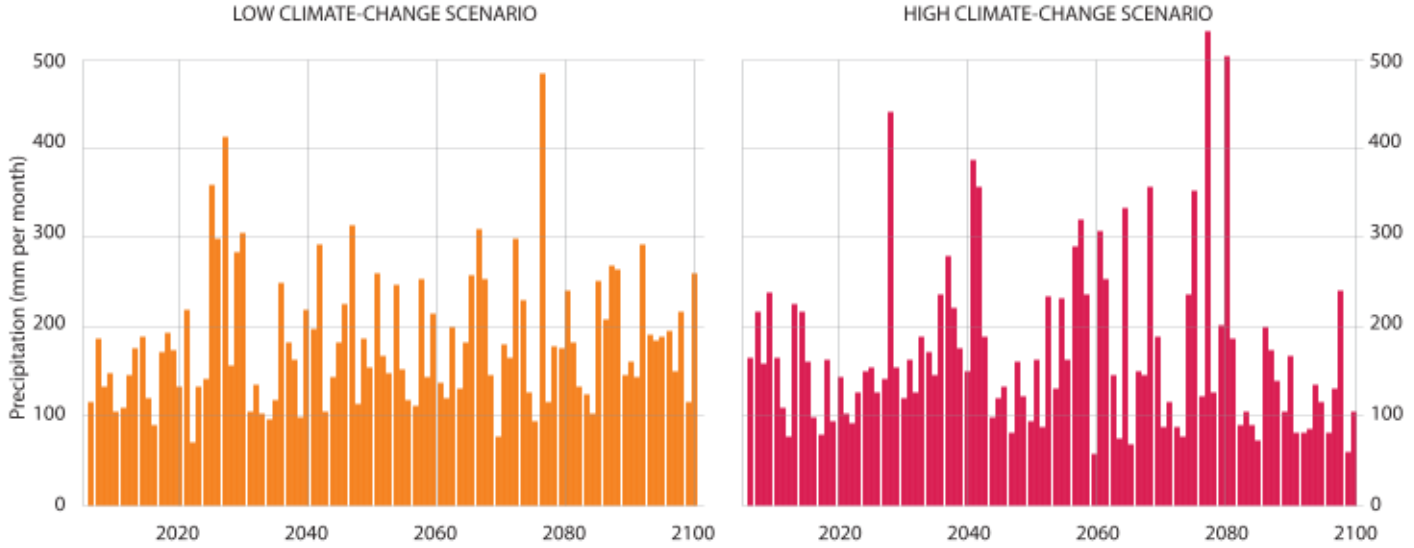
This SAVi assessment did not consider the relative costs and benefits of nature-based infrastructure compared to grey infrastructure. Although the avoided cost of conventional roof construction was included and the energy savings are relative to a scenario without nature-based infrastructure, a complete assessment of grey infrastructure costs and benefits over the asset lifetime was not done. Kantor (2017), for example, shows that the life-cycle costs of green roofs are 16–37% lower than those of conventional roofs. Similarly, the cost of trees could be compared to the cost of installing pavements, the cost of increasing stormwater treatment capacity and/or the cost of renewable energy to reduce emissions. These types of comparisons would show whether nature-based infrastructure is a cheaper alternative.

FIGURE 8: TEMPERATURE PROJECTION IN THE CITY OF TSHWANE FOR A LOW AND HIGH CLIMATE-CHANGE SCENARIO



Source: Copernicus Climate Data Store, n.d.

FIGURE 9: PRECIPITATION PROJECTION IN THE CITY OF TSHWANE FOR A LOW AND HIGH CLIMATE-CHANGE SCENARIO



Source: Copernicus Climate Data Store, n.d.

HOW DECISION-MAKERS CAN IMPLEMENT THE SAVi ASSESSMENT RESULTS

Stakeholders such as the national government, local government, project developers and donors and investors could use the results of this SAVI assessment to their benefit when making decisions about infrastructure (see Table 1 for this information in table format).

The **national government**, which provides the finance for building infrastructure, can use these results to develop building standards and regulations that include nature-based infrastructure in new developments.

Local governments, which design and maintain infrastructure in public places, can use these results to inform climate adaptation plans and strategies that address stormwater run-off and urban heat islands, and as evidence that nature-based infrastructure in public spaces provides benefits at the city scale.

Project developers, who plan new developments, can use these results to inform decisions about constructing nature-based infrastructure, and to demonstrate that nature-based infrastructure in urban developments can provide value to city residents and businesses.

Donors and investors, who finance infrastructure, can use these results as quantitative evidence that nature-based infrastructure is economically viable, and to define funding priorities for new infrastructure investments.

REFERENCES

Banting, D., Doshi, H., Li, J., Missios, P., Au, A., Currie, B.A. and Verrati, M. 2005. *Report on the environmental benefits and costs of green roof technology for the City of Toronto*. Ryerson University, Toronto, Canada. boardofreps.org/Data/Sites/43/userfiles/committees/operations/items/2019/030063/030063_toronto_report.pdf.

Berghage, R.D., Beattie, D., Jarrett, A.R., Thuring, C., Razaei, F. and O'Connor, T.P. n.d. *Green roofs for stormwater run-off control*. National Risk Management Research Laboratory Office of Research and Development, US Environmental Protection Agency, Washington, D.C., USA. nps.gov/tps/sustainability/greendocs/epa%20stormwater-sm.pdf, p. 81.

Cai, L., Feng, X.-P., Yu, J.-Y., Xiang, Q.-C. and Chen, R. 2019. Reduction in carbon dioxide emission and energy savings obtained by using a green roof. *Aerosol and Air Quality Research*, 19(11): 2432–2445. doi.org/10.4209/aaqr.2019.09.0455.

City Sustainability Unit. 2021. *Key findings from updated Climate Risk and Vulnerability Assessment*. Office of the Executive Mayor, City of Tshwane, South Africa.

Climate Transparency. 2020. *The Climate Transparency Report 2020: Comparing G20 climate action and responses to the COVID-19 crisis*. climate-transparency.org/g20-climate-performance/the-climate-transparency-report-2020#1531904804037-423d5c88-a7a7.

Climate-Data.org. n.d. *Climate data for cities worldwide*. en.climate-data.org.

Copernicus Climate Change Service. 2020. *Climate Data Store*. cds.climate.copernicus.eu/cdsapp#!/home.

Copernicus Climate Data Store. n.d. IPSL-CM5A-MR. *Coupled Model Intercomparison Project Phase 5*. cds.climate.copernicus.eu/apps/12778/iisd-demo-new-1-no-bold-no-figure-title.

Del Pino, D.P., Opperman, J., Stevens, A., Weber, C., Fabricus, C., Escobar, N., Aceituno, E. et al. 2020. *Nature hires: How nature-based solutions can power a green jobs recovery*. World Wildlife Fund and International Labor Organization, Gland, Switzerland. ilo.org/wcmsp5/groups/public/---ed_emp/documents/publication/wcms_757823.pdf.

Demuzere, M., Orru, K., Heidrich, O., Olazabal, E., Geneletti, D., Orru, H., Bhave, A.G., Mittal, N., Feliu, E. and Faehnle, M. 2014. Mitigating and adapting to climate change: Multi-functional and multi-scale assessment of green urban infrastructure. *Journal of Environmental Management*, 146: 107–115. doi.org/10.1016/j.jenvman.2014.07.025.

Euro Cities. 2015. *Green jobs for social inclusion*. Euro Cities, European Commission, Brussels, Belgium. nws.eurocities.eu/MediaShell/media/353-green-web_final.pdf.

Fisher-Jeffes, L. and Armitage, N.P. 2013. Charging for stormwater in South Africa. *Water SA*, 39(3): 429–436. doi.org/10.4314/wsa.v39i3.13.

Getter, K.L., Rowe, D.B., Robertson, G.P., Cregg, B.M. and Andresen, J.A. 2009. Carbon sequestration potential of extensive green roofs. *Environmental Science and Technology*, 43(19): 7564–7570. doi.org/10.1021/es901539x.

Google. n.d. google.com/maps/@-25.6700755,28.1886403,7897m/data=!3m1!1e3.

Green Deal Groene Daken. 2018. *Facts and values green-blue roofs*. greendealgroenedaken.nl/en-facts-values.

Gulati, M. and Scholtz, L. 2020. *Urban lockdown lessons for South Africa: Nature-based solutions for a green and equitable recovery in municipalities*. WWF South Africa, Cape Town, South Africa.

IISD. 2021. *Scaling up investment in nature-based infrastructure*. Webinar held on 21 September. The PowerPoint presentations of findings are available on request from lscholtz@wwf.org.za.

Kantor, D. 2017. Life cycle cost analysis of extensive green roofs in Switzerland and the Netherlands. *Journal of Living Architecture*, 4(1): 14–25. doi.org/10.46534/jliv.2017.04.01.014.

Kopsiker, L., Gerritsen, E., Stainforth, T., Lucic, A., Domingo, G.C., Naumann, S., Roschel, L. and Davis, M. 2021. *Nature-based solutions and their socio-economic benefits for Europe's recovery*. Institute for European Environmental Policy, London, UK. ieep.eu/publications/nature-based-solutions-and-their-socio-economic-benefits-for-europe-s-recovery, p. 23.

Luyt, C. 2021. Ecolution Consulting. Personal communication, 28 July.

Manso, M., Teotónio, I., Silva, C.M. and Cruz, C.O. 2021. Green roof and green wall benefits and costs: A review of the quantitative evidence. *Renewable and Sustainable Energy Reviews*, 135. doi.org/10.1016/j.rser.2020.110111.

Marritz, L. and Hunter, K. 2020. *Soil volume minimums for street trees organized by state/province*. Deeproot. deeproot.com/blog/blog-entries/soil-volume-minimums-organized-by-stateprovince-2.

McCord, J., McCord, M., McCluskey, W., Davis, P.T., McIlhatton, D. and Haran, M. 2014. Effect of public green space on residential property values in Belfast Metropolitan Area. *Journal of Financial Management of Property and Construction*, 19(2): 117–137. doi.org/10.1108/JFMPC-04-2013-0008.

McPherson, G.E., Nowak, D.J. and Rowntree, R.A. 1994. *Chicago's urban forest ecosystem: Results of the Chicago Urban Forest Climate Project* (NE-GTR-186). US Department of Agriculture Forest Service, Northeastern Research Station, Madison, WI, USA. doi.org/10.2737/NE-GTR-186.

Miller, C., Berg, S., Berghage, R.D., Bass, B., Leal, T.M., Husain, S., Richie, J. and Gaffin, S. 2011. *The benefits and challenges of green roofs on public and commercial buildings*. US General Services Administration, Washington, D.C., USA. gsa.gov/cdnstatic/The_Benefits_and_Challenges_of_Green_Roofs_on_Public_and_Commercial_Buildings.pdf.

Mullaney, J. 2015. *Using permeable pavements to promote street tree growth*. University of the Sunshine Coast, Queensland, Australia.

Newton, L. 2021. City of Tshwane. Personal communication, 2 August.

Nordhaus, W.D. 2017. Revisiting the social cost of carbon. *Proceedings of the National Academy of Sciences*, 114(7): 1518–1523. doi.org/10.1073/pnas.1609244114.

Peck, S.W., Callaghan, C., Kuhn, M.E. and Bass, B. 1999. *Greenbacks from green roofs: Forging a new industry in Canada*. Status Report on Benefits, Barriers and Opportunities for Green Roof and Vertical Garden Technology Diffusion. Canada Mortgage and Housing Corporation, Ottawa, Canada. citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.196.7020&rep=rep1&type=pdf, p. 78.

Preethan, P. and Gupta, S. 2020. Nature-based solutions for reimagining the pathway to a sustainable future. *WRI India*, 5 October. wri-india.org/blog/nature-based-solutions-reimagining-pathway-sustainable-future.

Rainbow Junction. 2021. Rainbow Junction, Pretoria, South Africa. rainbowjunction.co.za.

Rosenzweig, C., Solecki, W.D. and Slosberg, R.B. 2006. *Mitigating New York City's heat island with urban forestry, living roofs, and light surfaces*. New York City Regional Heat Island Initiative. New York State Energy Research and Development Authority, New York, USA. researchgate.net/publication/242139673_Mitigating_New_York_City's_heat_island_with_urban_forestry_living_roofs_and_light_surfaces, p. 173.

Santamouris, M. 2014. Cooling the cities: A review of reflective and green roof mitigation technologies to fight heat island and improve comfort in urban environments. *Solar Energy,* 103: 682–703. doi.org/10.1016/j.solener.2012.07.003.

Song, X. P., Tan, P.Y., Edwards, P. and Richards, D. 2018. The economic benefits and costs of trees in urban forest stewardship: A systematic review. *Urban Forestry and Urban Greening*, 29: 162–170. doi.org/10.1016/j.ufug.2017.11.017.

US EPA. 2015. *Greenhouse Gases Equivalencies Calculator – Calculations and References*. US Environmental Protection Agency, Washington, D.C., USA. epa.gov/energy/greenhouse-gases-equivalencies-calculator-calculations-and-references.

Van der Meulen, S.H. 2019. Costs and benefits of green roof types for cities and building owners. *Journal of Sustainable Development of Energy, Water and Environment Systems*, 7(1): 57–71. doi.org/10.13044/j.sdewes.d6.0225.

Van der Walt, P. 2018. *Retrofitting South Africa's cities with green roofs: Cost benefit analyses for large scale green roof implementation*. Unpublished Master's of Engineering, Stellenbosch University, Stellenbosch, South Africa. core.ac.uk/download/pdf/188224474.pdf.

Vijayaraghavan, K. 2016. Green roofs: A critical review on the role of components, benefits, limitations and trends. *Renewable and Sustainable Energy Reviews*, 57: 740–752. doi.org/10.1016/j.rser.2015.12.119.

Xiao, Q. and McPherson, E.G. 2002. Rainfall interception by Santa Monica's municipal urban forest. *Urban Ecosystems*, 6(4): 291–302. doi.org/10.1023/B:UECO.0000004828.05143.67.

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