Spatial planning and land-use management tools in aid of securing water sustainability: The case study of Mogalakwena Local Municipality in South Africa

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Abstract

The concept of Water-Sensitive Settlements is gaining importance within broader sustainability thinking. There is limited research in urban planning literature, in particular, on the quantitative impact of land-use decisions on water resources.

This article proposes a spatial modelling approach that combines land-use and water-consumption data in order to identify areas of intervention, which could feed into future development plans and strategies. The research considers the Mogalakwena Local Municipality as a case study, because of its socio-economic characteristics as well as the spatial and billing data that were generated from an ongoing research project funded by the Water Research Commission. It was evident that spatial modelling of land use and water consumption can be utilised as a tool to determine the impact of land-use decision on water resources.

Having generated spatial information on ‘where’ and by ‘which’ land use the demand for water is highest, municipal planners are able to make informed future land-use decisions, which will ultimately affect water resources. In addition, the information can be used to enforce new thinking within the municipal spatial planning domain on, among others, implementing water-sensitive mitigation measures such as revisiting water tariff structures; re-evaluating the promised level of services; implementing water-efficiency building regulations, and rethinking the business-as-usual approach to settlement planning.

Keywords: Spatial modelling, spatial planning, WSUD, Water-Sensitive Settlements

RUIMTELIKE BEPLANNING EN GRONDGEBRUIKBESTUURSINSTRUMENTE TEN EINDE WATERVOLHOUBAARHEID TE VERSEKER: DIE GEVALLESTUDIE VAN MOGALAKWENA PLAASLIKE MUNISIPALITEIT IN SUID-AFRIKA

Die belangrikheid van die konsep Water Sensitiewe Nedersettings neem toe binne die raamwerk van breër volhoubaarheidsdenke. Daar is beperkte navorsing, veral in stedelike beplanningsliteratuur, oor die kwantitatiewe impak van grondgebruiksbesluite op water as ŉ hulpbron.

Die navorsing in hierdie artikel stel ŉ ruimtelike modelleringsbenadering voor wat grondgebruik- en waterverbruikdata kombineer ten einde areas van ingryping te identifiseer en wat ingesluit kan word in toekomstige ontwikkelingsplanne en -strategieë. Die navorsing gebruik die Mogalakwena Plaaslike Munisipaliteit as gevallestudie weens sy sosio-ekonomiese eienskappe, asook die ruimtelike en faktuurdata wat uit ŉ deurlopende navorsingsprojek gegenereer is, befonds deur die Waternavorsingskommissie. Daar is oortuigend bewys dat ruimtelike modellering gebruik kan word as hulpmiddel om die impak van grondgebruikbesluite te rig, asook om groei patrone te stimuleer.

Met ruimtelike inligting oor ‘waar’ en deur ‘watter’ grondgebruik die vraag na water die hoogste is, kan munisipale beplanners ingeligte toekomstige grondgebruikbesluite neem wat uiteindelik weer sal impakteer op waterhulpbronne. Daarbenewens kan die inligting gebruik word om nuwe denke in die munisipale ruimtelike beplanningsdomein op te stel. Dit sluit ondermeer in die implementering van maatreëls soos die hersiening van waterbetalingstrukture, die herbeoordeling van die beloofde vlak van dienste, die implementering van waterdoeltreffendheidsbouregulasies, en die heroorweging van die tradisionele benadering tot nedersettingsbeplanning.

Sleutelwoorde: Ruimtelike beplanning, ruimtelike modellering, WSUD, Water Sensitiewe Nedersettings

TLHOPHISO YA SEPAKAPAKA LE TSHEBEDISO YA DISEBEDISWA TSA TAOLO YA LEFATSHE BAKENG SA THUSO YA HO FUMANA POLOKO YA METSI: THUTO YA MOHLALA YA MMASEPALA WA SELEHAE WA MOGALAKWENA, AFRIKA BORWA

Taba ya bodulo bo nang le tlhokomelo ya metsi (WSS) bo ntse bo fumanwa bo le bohlokwa monahanong wa ho boloka. Diphuputso tse teng di nyenyane bakeng sa kgahlamelo ya dipalopalo hodima diqeto tsa tshebediso ya lefatshe ho disebediswa tsa metsi, haholoholo dingolweng tsa tlhophiso ya ditoropo.

Atikele ena e hlahisa mokgwa wa popo ya sepakapaka e kopanyang tshebediso ya lefatshe le pokello ya dintlha tsa tshebediso ya metsi ho bontsha dibaka tsa bonamodi, tse ka fepang merero ya ntlafatso le maano a nako e tlang. Diphuputso di sheba Mmasepala wa selehae wa Mogalakwena jwalo ka thuto ya mehlala, ka lebaka la matshwao a moruo wa setjhaba Mmasepaleng; ha mmoho le pokello ya dintlha tsa sepakapaka le ditefello; tse ileng tsa fumanwa ho tswa projekeng ya diphuputso e tswellang pele, e lefellet-sweng ke Water Research Committee.

Ho totobetse hore popo ya sepakapaka tshebedisong ya lefatshe le metsi, di ka sebediswa jwalo ka disebediswa bakeng sa ho hlahisa tshusumetso qetong ya tshebediso ya lefatshe hodima disebediswa tsa metsi.

Ka ho hlahisa tlhahisoleseding ya sepakapaka ka hore ke ‘kae’ le hore ‘ke se feng’ sebaka seo tlhoko ya sona ya metsi e leng hodimo ka ho fetisisa, bahlophisi ba Mmasepala ba kgona ho etsa diqeto tse tsebisahalang tsa bokamoso tse amang mehlodi ya lefatshe, tseo qetellong di tla ba le kgahlamelo ho disebediswa tsa metsi. Ho tlatselletsa, tlhahisoleseding e ka sebediswa ho tiisa monahano o motjha tlhophisong ya sepakapaka sebakeng sa Mmasepala; e kenyelletsang ho fokotsa mekgwa ya tshenyo ya metsi, jwalo ka ho matlafatsa dibopeho tsa ditefiso tsa metsi, tekolobotjha ya boemo boo ho tshepisanweng ka bona ba ho fana ka ditshebeletso, ho phethahatsa melao ya metsi e ahang bokgoni le ho nahana

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botjha mokgwa wa kgwebo-ka-tlwaelo ha ho tluwa tlhophisong ya bodulo.

Mantswe a sehlooho: Popo ya Sepakapaka, Tlhophiso ya Sepakapaka, WSUD, Bodulo bo nang le Tlhokomelo ya Metsi

1. INTRODUCTION

Since the 18th century, towns and cities have become dependent on engineered infrastructure designed to supply safer and larger quantities of water to growing urban communities (Goodland, Orlando & Anhang, 2001: 24; Winiwarter, Haidvogl, Hohensinner, Hauer & Burkner, 2016: 211), leading to the development of a modern water- and waste water-treatment system, consisting of dams, pipes, treatment plans and storm-water infrastructure (DWS, 2015: 14).

According to Marsalek, Jiménez-Cisneros, Malmquist, Karamouz, Goldenfum & Chocat (2006: 3), this artificial hydrological cycle has altered the natural rate and functionality of the cycle of replenishment and the hydrological responses of watersheds, making the renewability of water resources increasingly questionable. Urban population growth projections indicate that, between 2000 and 2050, the amount of urban space will need to double in developed countries and expanded by 326% in developing countries to accommodate the expected growth (Angel, Parent, Civco & Blei, 2010: 49). According to Grimm, Faeth, Golubiewski, Redman & Wu (2008: 756-760), urbanisation not only results in changes in land cover, but also in hydrological systems, biogeochemistry, climate, and biodiversity. Seto, Fragkias, Güneralp & Reilly (2011: 1) have also proven that rapid and unplanned land-cover change driven by urbanisation patterns has a direct qualitative impact on local hydrological and ecological systems. In addition, urbanisation and land-use change also express a quantitative need for water resources, which, in most cases, will result in increased water resource consumption patterns, due to the higher level of services and access to services provided in urban areas (UN Habitat, 2013: 70). The IWMI (2006: 8) reports that rising income levels, sanctioned by urbanization, will also change food habits towards richer and more varied diets "not only to increasing consumption of staples cereals, but also a shift in consumption patterns away from cereal crop towards livestock and fish products and high-value crops" which, in order to produce, require far more water resources.

The United Nations (UN) states that current water use (direct and indirect) is growing at twice the rate of the population (UN Habitat, 2013: 18) and will continue to increase with rising demands from municipal, industrial and agricultural uses (IWMI, 2006: 8). As such, many countries now face economic water scarcity, as illustrated in Figure 1, which depicts the IWMI analysis done for the comprehensive assessment for water management in agriculture using the Watersim model on a global scale (IWMI, 2006: 8).

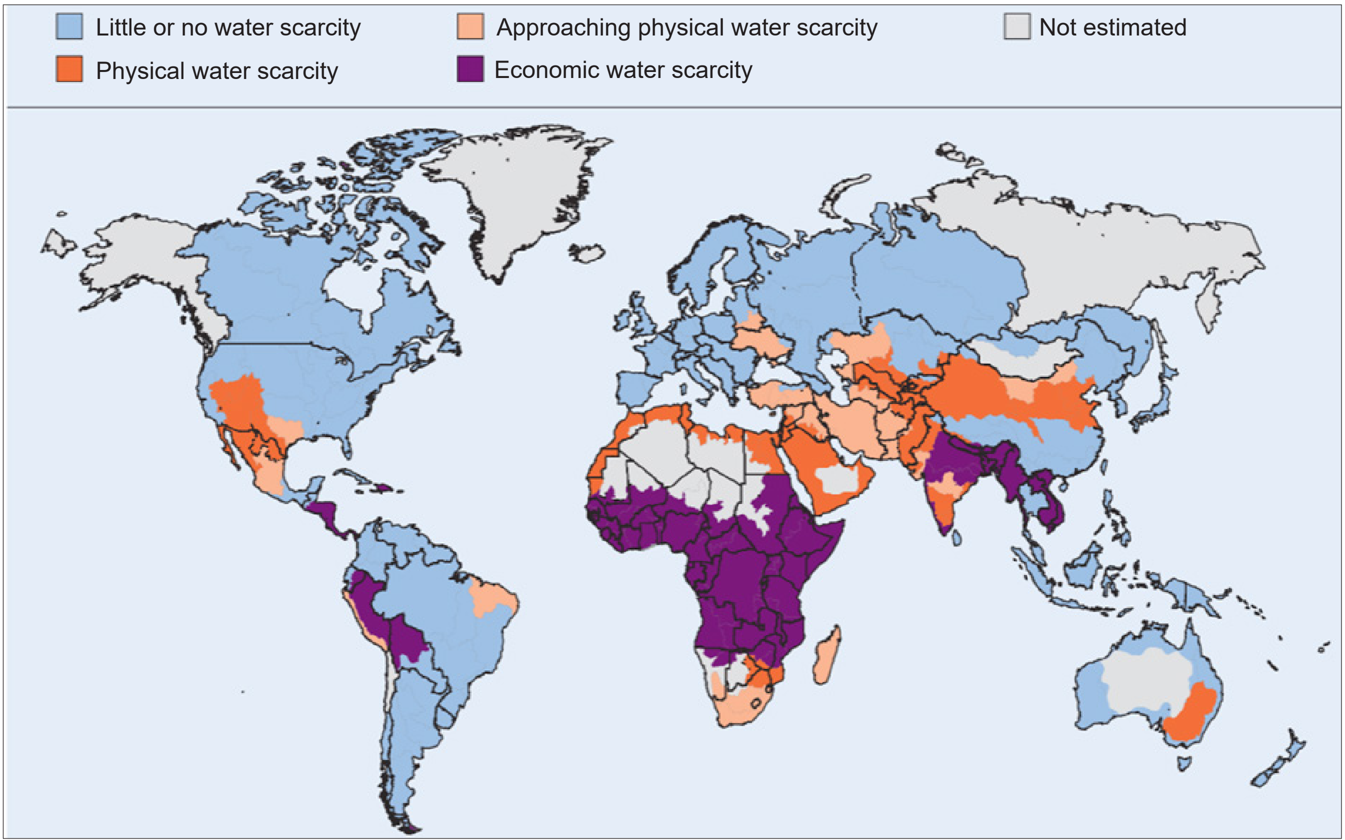

Figure 1: IWMI status of water scarcity on a global scale

Source: UN-Water (2006: 8)

Figure 1 shows that South Africa has limited water resources and the lack of understanding in terms of the impact of land-use decisions taken by spatial planners has had a detrimental impact on South Africa's already scarce water resources. The enactment of the Spatial Planning and Land-Use Management Act of 2013 now presents opportunities for integrated planning approaches[1] (RSA, 2013).

One of these approaches is to utilise spatial modelling tools (refer to Table 2) used by spatial planners to determine the impact of land-use decisions and, ultimately, to analyse growth patterns. Both of these have a qualitative and quantitative impact on water resources. The hydrological impacts of land-cover change are well-documented, placing the focus primarily on streamflow, stormflow, surface runoff generated, and groundwater impact. However, limited research can be found on the quantitative impact of land-use decisions on water resources, especially in urban planning literature.

The research emphasises the importance of translating water sensitivity into spatial planning practices. It also provides recommendations for a typical category B municipality, constrained by limited spatial data, on how to identify planning opportunities to facilitate the transition towards creating Water-Sensitive Settlements(WSSs).

2. STRATEGIC ISSUES AND REALITIES IN SOUTH AFRICA

2.1 Lasting impact of spatial decisions

The early 1990s marked the end of the apartheid era in South Africa and with this, Government introduced the Reconstruction and Development Plan (RDP) which was, and still is, committed to establishing viable communities for housing beneficiaries in areas close to economic opportunities and to health, educational, and social amenities as well as transport infrastructure (O'Malley, 2016). According to Oosthuizen (2000: 103), this could only be achieved by either "filling up" open space in large cities, or by expanding the cities' borders into adjacent rural areas. The latter resulted in large-scale, low-income housing developments with low-density patterns (Boshoff, 2014: 13), consuming significant amounts of land per capita and generating even larger per capita infrastructure costs (UN Habitat, 2013: 29). Although the RDP strategy echoed the integrated planning and sustainable development principles of Agenda 21 (Rowlston & Schreiner, 2011: 50), the ambitious programme to eradicate the housing backlog hardly considered the fact that it accelerated rapid urban expansion and urban sprawl. According to the latest State of South African Cities Report (SACN, 2016: 165), the "typical South African city is characterised as being resource intensive and suffers from inefficiencies across sectors (energy, food, water, waste, and transport)", of which the water sector lies centrally.

2.2 Depleting natural ecosystems

The loss of ecological formations in South Africa is a direct result of the overall population growth, rapid urbanisation and increasing urban sprawl (SACN, 2016: 5). As such, over half of South African rivers are classed as threatened, of which 25% critically endangered, 19% endangered, and 13% vulnerable (Driver, Sink, Nel, Holness, Van Niekerk, Daniels, Jonas, Majiedt, Harris & Maze, 2012: 6). Wetlands only make up 2.4% of South Africa's land surface area; yet the 2011 National Biodiversity Assessment revealed that 48% of the country's wetlands types are critically endangered, followed by 39% of estuaries types (Driver *et al.,* 2012: 7). While South Africa has a plethora of environmental legislation and instruments promoting ecologically sustainable development through systematic biodiversity planning (Nel, Driver, Strydom, Maherry, Petersen, Hill, Roux, Nienaber, Van Deventer, Swartz & Smith-Adao, 2011: 7), the above figures reveal a different reality. Furthermore, the country is expected to face a water demand-supply gap of nearly 17% by 2030 (2030 Water Resource Group, 2009: 63). The DWS (2014: 7) warns that increases in the water supply cannot match the expected increase in demand without additional and far-reaching interventions. According to the Minister of the Department of Water and Sanitation (DWS), the water crisis cannot be solved through engineering alone; demand management regarding both efficiency and allocation will have to play a large part in the efforts to close the water demand-supply gap in South Africa (DWS, 2014: 11).

2.3 Water-resource infrastructure: Water losses and non-revenue water

Water-resource planning, dealing with balancing the water demand and supply, relies on water-reconciliation studies and water-metering information to determine how much water is being used and wasted (DWA, 2013b: 18-20; DEA, 2013: 55-58). The International Water Association water balance has been modified for South Africa's situation to include (DWS, 2015: 45-46):

- Revenue water regarding (i) billed metered consumption and (ii) billed un-metered consumption (e.g., flat rate tariff and free basic water used though unbilled unmetered standpipe or yard connections), and
- Non-revenue water in terms of (i) unbilled metered (e.g., government buildings or parks); (ii) unbilled unmetered (e.g., estimated water used for legitimate purposes such as firefighting and also usage above the free basic water limit for unmetered, unbilled standpipe and yard connections usage); (iii) apparent losses (e.g., water used through illegal connections, water used but not billed for because of inaccurate meters, data transfer errors, low-estimate readings or any administrative errors, and (iv) real losses which refer to water

1 Act 16 of 2013, Section 4(c).

that leaks from the system through pipes and connections, or overflows from reservoirs.

According to the DWS (2015: 45), 39% of all municipal water is considered non-revenue water, and 36% is classified as water losses, as reflected in South Africa's Infrastructure Leakage Index of 5.3. The highest percentage of water losses and usage of non-revenue water occurs in the smaller, more rural municipalities, which only demand approximately 17% of the total municipal system input, compared to metropolitan municipalities demanding over 50% of the total national volume (DWS, 2015: 45). However, concluding remarks from ten water-reconciliation strategies and the "905 all town studies" (DWA, 2013b: 23) indicate that water-services authorities have limited information to substantiate these figures, due to a lack of billing information (DWA, 2013b: 24).

3. ADAPTING PLANNING APPROACHES

For many South Africans, water scarcity is an abstract concept, as they believe that water simply runs from a tap. For others, it is a stark reality when rivers, streams and perhaps the one communal tap runs dry, causing major food shortages, with many going hungry for days at a time. Although access to basic services such as water is a constitutional right, the provision of sustainable water supply to 55.6 million citizens (Statistics South Africa, 2016: 19) in a semi-arid country is an overwhelming task, as the current and expected future demand exceeds the available supply.

3.1 Strategic water-resource planning goals

Like many other countries, South Africa is committed to sustainable development, as evident in the Rio Declaration on Environment and Development, the World Summit on Sustainable Development, the World Summit for Social Development, the Programme of Action of the International Conference on Population and Development, the Beijing Platform for Action, the United Nations Conference on Sustainable Development, and the most recent 2030 Agenda for Sustainable Development. The latter, which came into effect on 1 January 2016, stipulates 17 Sustainable Development Goals (SDG) with 169 targets to address specific issues (UN, 2015: 10).

The 2030 SDG calls attention to sustainable development, which recognises that eradicating poverty in all its forms and dimensions, combating inequality within and among countries, preserving the planet, creating sustained, inclusive and sustainable economic growth and fostering social inclusion are linked to each other and are interdependent (UN, 2015: 5).

Two goals are directly related to strategic water-resource planning and management, and human settlements (see Table 1).

Table 1: Water planning-related goals derived from the SDG

SDG goals	Goal 6 "Clean water and sanitation"	Goal 11 "Sustainable cities and communities"
Aim	Availability and sustainable management of water and sanitation. Refers to: 6.1: safe and affordable drinking water 6.2: adequate and equitable sanitation 6.3: safe water reuse 6.4: water scarcity and water use efficiency 6.5 integrated water-resource management	Make cities and human settlements inclusive, safe, resilient and sustainable. Refers to 11.1: basic services 11.3: integrated and sustainable human settlement planning 11.5: water-related disasters 11.6: per capita environmental impact of cities 11.7: green public spaces
Focus	• By 2030, expand international cooperation and capacity to developing countries in water-related activities and programmes • Support and strengthen the participation of local communities in improving water and sanitation management	• Support positive economic, social, and environmental links • By 2020, substantially increase inclusion, resource efficiency, mitigation and adaptation to climate change, resilience to disasters • Support least developed countries in building sustainable and resilient buildings

Source: UN (2015: 22-26)

3.2 From goals to practice through Water-Sensitive Urban Design

Within these SDGs, the notion of WSUD is accentuated as a tool for advancing the principles of sustainable development through a multi-disciplined approach to urban water management, which aims to holistically consider the environmental, social and economic consequences of water management and infrastructure (Wong, 2006). WSUD has evolved from its early association with storm-water management that focused primarily on sustainable urban water drainage systems (SuDS), into an approach that integrates the urban water cycle (including potable water, waste water and storm-water) and the built and natural urban landscape to provide multiple benefits to society. The concept of WSUD was introduced in the conceptual framework of the "Water-Sensitive City" (Wong & Brown, 2008; Brown, Keath & Wong, 2008). Such a city serves as a potential water supply catchment, providing a range of different water sources at a range of different scales, and for a range of different uses; provides ecosystem services and a healthy natural environment, thereby offering a range of social, ecological, and economic benefits; and consist[s] of water sensitive communities where citizens have the knowledge and desire to make wise choices about water, is actively engaged in decision-making and demonstrate[s] positive behaviours such as conserving water at home (Wong, Allen, Brown, Deletić, Gangadharan, Gernjak, Jakob, Johnstone, Reeder, Tapper & Vietz 2013: 7).

WSUD was proposed as a tool, within a broader urban and rural landscape, to realise the objectives of a WSC.

Currently, the concept of the WSC is progressively being refined to adapt to local situations and realities. South Africa's framework for WSUD suggests that a WSS is one where the management of the water cycle

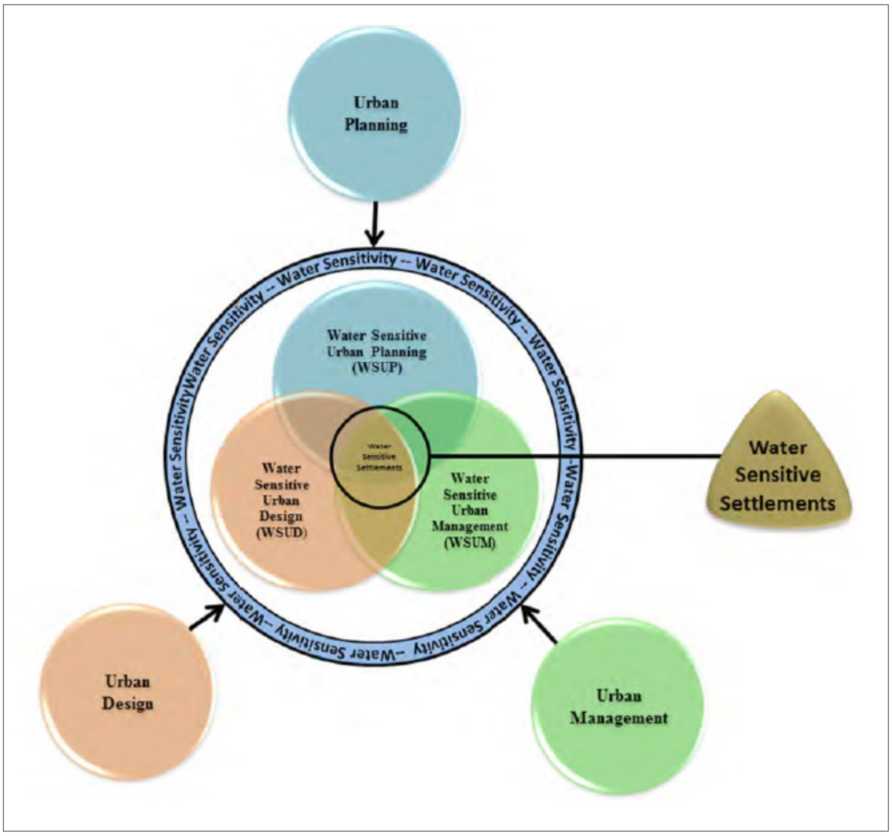

Figure 2: The integration of WSUD, WSUP, and WSUM towards WSS
Source: Armitage *et al*. (2014: 19)

is undertaken in a water-sensitive manner with the overall objective of ecologically sustainable development (Armitage, Fisher-Jeffes, Carden, Winter, Naidoo, Spiegel, Mauck & Coulsen, 2014: 8). The framework highlights that WSS consists of three components, but that it should be considered in an integrated manner, which includes (Armitage *et al*., 2014: 19): (i) Water-Sensitive Urban Design (WSUD); (ii) Water-Sensitive Urban Planning (WSUP) which brings together two components 'water sensitivity' and 'urban planning', ensuring that 'urban planning' is undertaken in a manner that considers and treats water sensitively, and (iii) Water-Sensitive Urban Management (WSUM), as illustrated in Figure 2.

While WSUD is considered to be a well-researched and well-practised concept regarding technical illustrations and approaches to the urban water infrastructure component, information is limited as to exactly how design and planning should engage with the concept of WSS, specifically in the South African context. Concluding remarks from the framework state that municipal authorities need to go beyond the delivery of basic services to ensure urban resilience by reconfiguring cities through strategic planning and investment in order to address future uncertainties such as resource shortages (Armitage *et al*., 2014: 35). Municipalities with limited funding and capacity must "do what you can with what you have", beginning with strengthening local legislation and regulations to encourage this transition (Armitage *et al*., 2014: 28).

4. THE ROLE OF SPATIAL PLANNING TO GUIDE WSUD

The dependency and close relationship between human and natural systems imply that cities and settlements cannot be sustainable or resilient until their reliance on ecosystem services is recognised (Cilliers & Cilliers, 2016: 15) and the value of ecologically sustainable development acknowledged (Armitage *et al*., 2014: 46). Despite this close association, a silo-planning approach is currently impeding the successful integration of spatial planning and environmental resource management, enforced by institutional arrangements, often to the detriment of sustainable development.

The recently enacted Spatial Planning and Land-Use Management Act 16 of 2013 (SPLUMA) firmly mandates municipal planning as primarily the task of local governments and declares that "sustainable development of land requires the integration of social, economic and environmental considerations in both forward-planning and ongoing land use management to ensure that development of land serves present and future generations" (RSA, 2013: 4). SPLUMA (Act 16 of 2013) also states that the RSA's spatial planning system consists of, among others, (i) a land-use scheme that seeks to manage the legality of **existing land uses** and buildings, and (ii) a spatial development framework intended to plan for **future development** of a municipality. Within the scope of SPLUMA, new opportunities arise where spatial planning could guide future WSUD approaches, as explained accordingly.

4.1 Planning for existing land uses

SPLUMA (Act 16 of 2013) stipulates that municipalities should now develop a wall-to-wall Land-Use Scheme, implying the inclusion of all areas (including traditional villages and rural areas). Section 26(1)(a) of the Act states that "an approved land use scheme has the force of law, and all landowners and users of land, including a municipality, a state-owned enterprise, and organs of state within the municipal boundary, are bound by the provision of such land use scheme" (RSA, 2013:x36). Section 26(2)(a) further states that "land may only be used for the purposes permitted by a land use scheme" (RSA, 2013: 36). As such, spatial planners have the opportunity to develop and enforce water-conscious land-use planning, which can facilitate WSS. However, the compilation of a wall-to-wall land-use scheme is a challenging task, in particular with the vast majority of rural land uses being un-surveyed. In this regard, spatial planning should thus seek integration between different planning sectors in an attempt to build a data basis for land-use planning. In this sense, a land-use scheme should consider the protection and management of ecological formations, to inform the development of WSS. The Atlas of Freshwater Ecosystems Priority Areas (FEPA) in South Africa (Nel *et al*., 2011: 7) might offer insights, as it enforces systematic biodiversity planning by identifying areas important for biodiversity conservation (Nel *et al*., 2011: 7).

Figure 3(A-C) illustrates how different spatial data sets from two sectors can be overlapped and integrated to guide land-use and water-resource planning and management.

Figure 3(A) illustrates the FEPA identified within the Limpopo Water Management Area. It also shows a zoomed in image of a wetland cluster that allows for important ecological processes, as identified by Nel *et al*. (2011:14). Figure 3(B) illustrates the overlap when incorporating land-use data, originally not included in the National Freshwater Ecosystem Priority Areas, thus now generating a wall-to-wall land audit, where human impact on water resources becomes evident. Figure 3(C) illustrates the 5-year spatial growth pattern of the rural settlement footprint, in relation to the water resources.

4.2 Planning for future growth

Translating existing land-uses into future demand requires the inputs of spatial modelling systems. According to Abebe (2011: 32) and Armitage *et al*. (2014: 113-127), some models and techniques are designed to simulate future urban growth. Table 2 enumerates a selection of local land-use change models currently utilised by various departments and cities in South Africa.

The bulk of land-use models employed in South Africa is GIS-based or linked to spreadsheets that contain demographic or housing projections (Wray *et al*., 2013: 23). The most advanced modelling system currently used in some of South Africa's metropolitan areas such as eThekwini, Nelson Mandela Bay and Johannesburg is the CSIR UrbanSim model (CSIR, 2011: 18).

However, the UrbanSim model is considered to be highly technical, data-intensive and very expensive (Wray *et al.,* 2013: 55), hence the reason why it is only used by metropolitan municipalities. The inclusion of urban water as part of these modelling systems was not evident, and such possibilities should be explored.

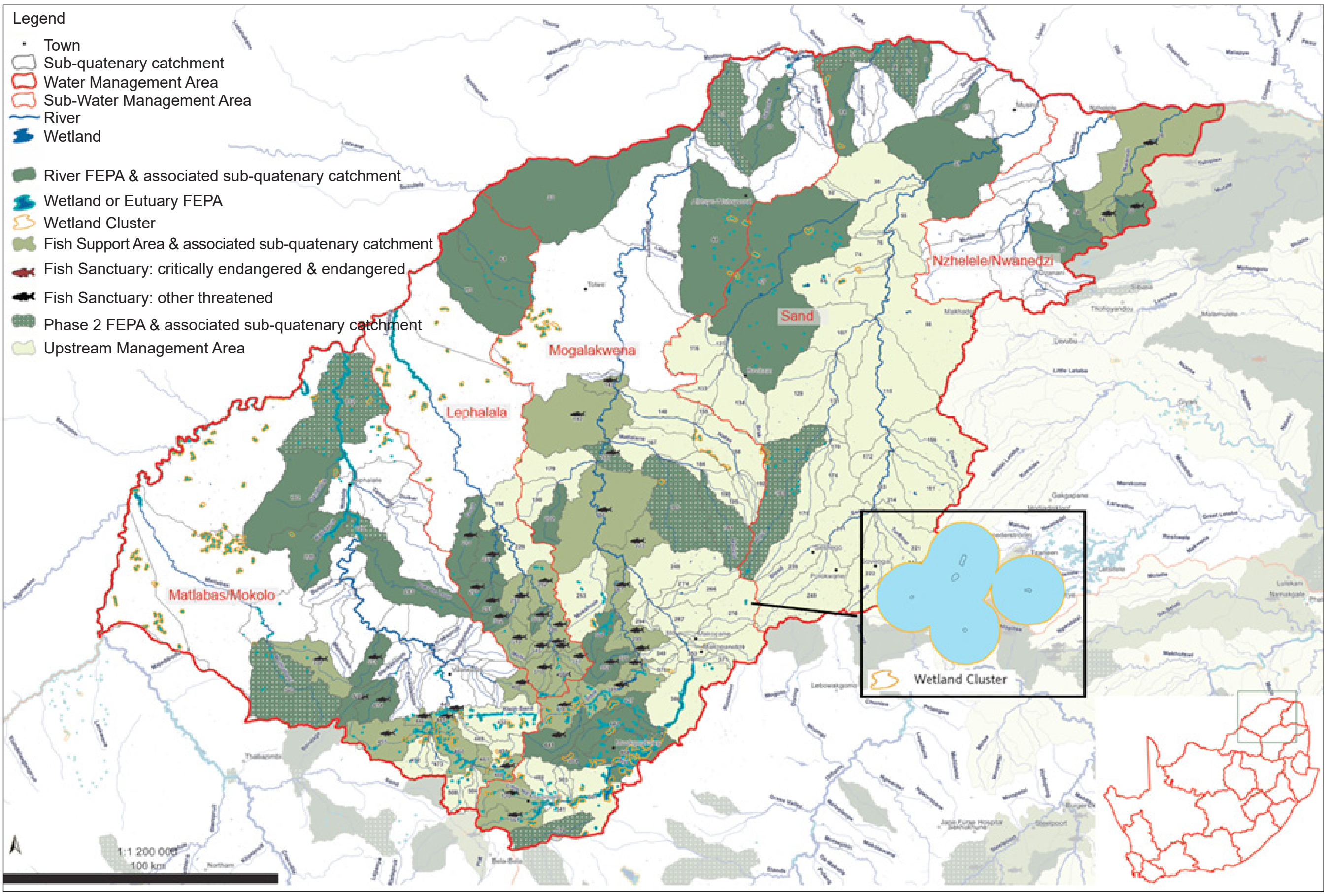

Figure 3(A):Freshwater ecosystems priority areas within the Limpopo Water Management area

Source: Nel *et al*. (2011: 15)

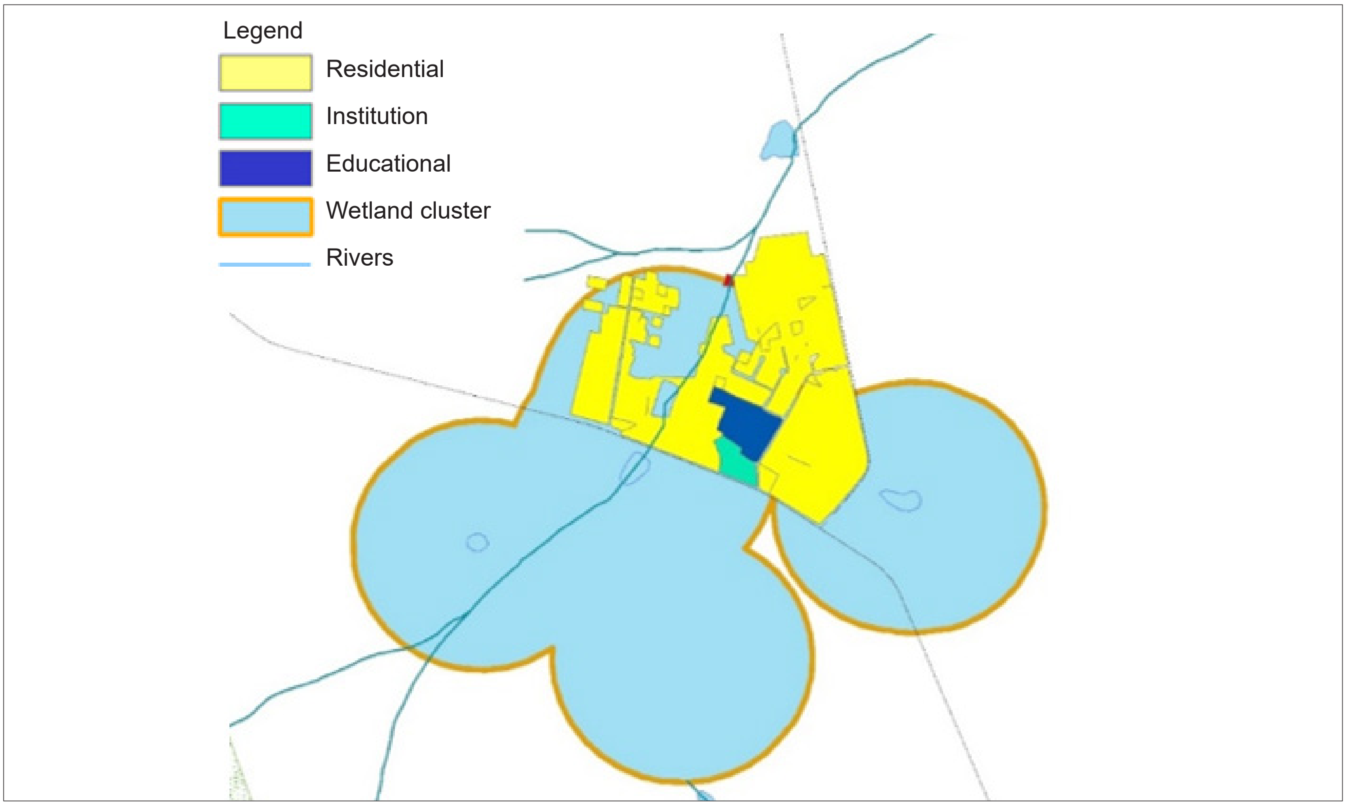

Figure 3(B): Rural land-use survey data in 2010. Spatial representation of the wetlands cluster and land-audit data to guide a wall-to-wall land-use scheme, as required by Section 26 of SPLUMA

Source: Authors' own compilation, adapted from Nel *et al*., 2011: 15

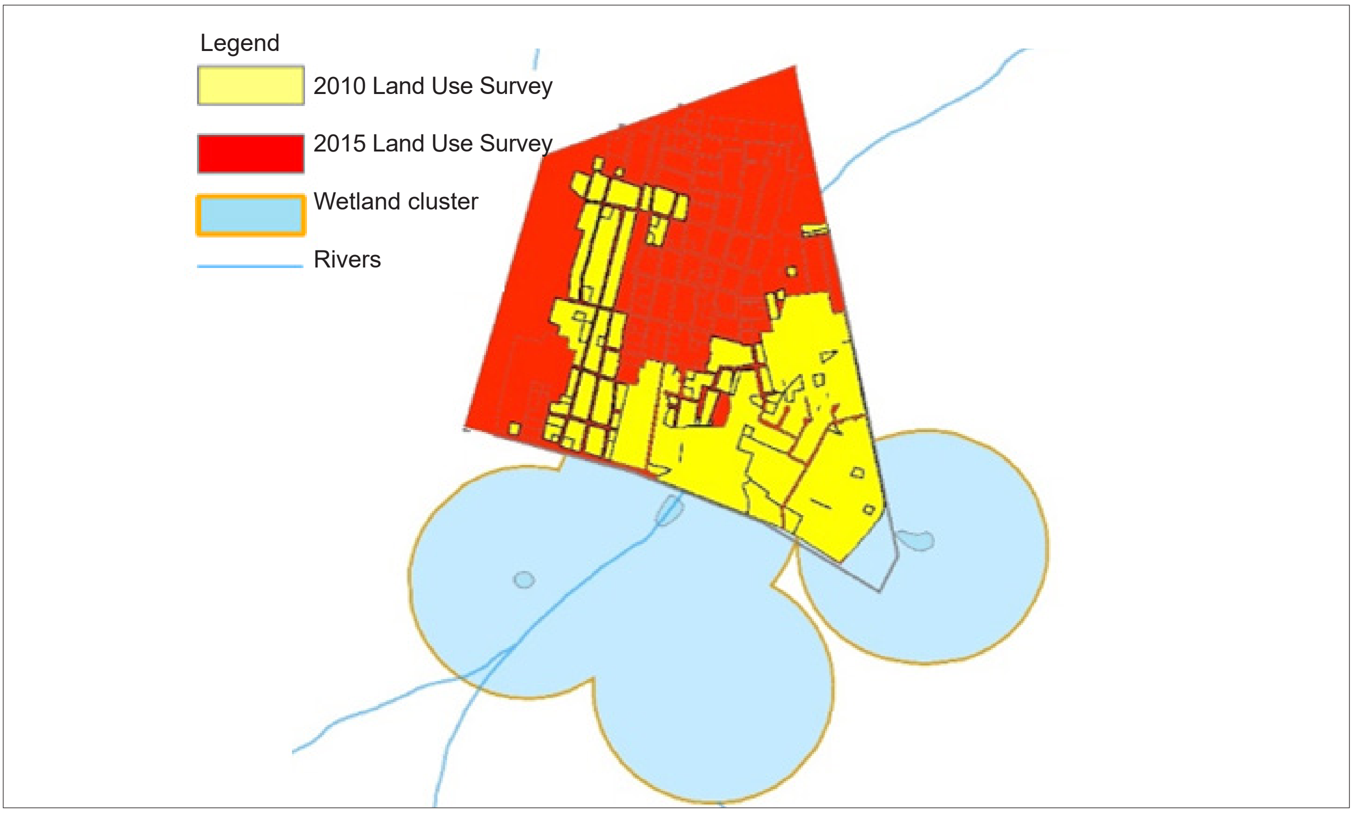

Figure 3(C): Rural land-use survey data of 2016. Spatial representation of expanding rural footprint within five years and the growing impact on the wetlands cluster

Source: Authors' own compilation, adapted from Nel *et al*., 2011: 15

Table 2: Selected South African land-use change modelling initiatives

Model	Model type	Main purpose and key model components
Gauteng Integrated Transport Modelling	Econometric/ microsimulation/ ABM	GITMC builds on the data and modelling created in the CSIR UrbanSim and MATSim simulation project to produce urban growth scenarios based on different infrastructure initiatives.
Gauteng Infrastructure Planning Tool	GIS-based model	Developed to assist with the short- and medium-term integrated planning of education and health facilities within the province. Using the current location of schools, hospitals and clinics, the future demand and location of new facilities are modelled, providing planners with a tool to test different development scenarios for determining optimal locations of public social facilities.
Gauteng Department of Economic Development	GIS-based models	The model analyses the existing urban patterns for Gauteng and serves as a basis for future spatial strategies that feed into supporting policy and planning decisions. The models include an urban profile, urban morphology, connectivity, bid rent, and virtual model room.
Cost surface model	GIS-based	Models the costs of providing bulk infrastructure in various locations based on the geotechnical analysis.
e-Thekwini Accessibility model	GIS-based	The Accessibility model analyses the distances and time required to access certain destinations spatially. This model typically relates to accessibility analysis of social services and feeds into future infrastructure investment if the need for such investment is required.
City of Cape Town: Urban Growth Modelling	GIS-based	Models future growth directions by estimating residential, industrial and mixed-use land requirements, spatially and over time. It also estimates the city services' investment needs.
CSIR UrbanSim	Econometric/ microsimulation/ ABM	CSIR UrbanSim simulates urban growth 30 years into the future based on current spatial policy and investment decisions. UrbanSim creates a scenario based on households and businesses about property and services, developers as suppliers of services, and government provision of infrastructure and services.
UCT School of Architecture, Planning and Geomatics	ABM	Patterns and trends in land occupation change over time in a Cape Town informal settlement.

Source: Authors' own compilation, adapted from Gauteng Department of Economic Development, 2011: 74-123; CSIR, 2011: 18-19; Shoko & Smit, 2013: 60-66; Wray, Musango & Damon, 2013: 74-78

This is especially important regarding section 21(h) of SPLUMA, requiring the Spatial Development Framework to further identify, quantify and provide location requirements of engineering infrastructure and services provision for existing and future development needs (RSA, 2013: 33).

The growth and resource demand modelling simulations and projections should feed into Spatial Development Frameworks to guide future developments in a municipality. The following case study provides an example of how spatial data and municipal water-billing data can be modelled to estimate the future demand for resources. In this specific case study, the authors argue that water-demand management and conservation should be the first priority in becoming a WCS. In other cities or settlements, the hierarchy of priorities could possibly differ, depending on local context. For example, many cities could be affected by flooding or lack of storage of water resources. As such, these cities' or settlements' first priority would be to use WSUD for flood mitigation or use rainwater-harvesting methods to store excess water.

5. CASE STUDY: COMBINING SPATIAL AND WATER DATA

In an attempt to illustrate how spatial modelling could translate to municipalities' 5-year, 10-year and 20-year spatial vision (as required by SPLUMA), the case study of Mogalakwena Local Municipality is presented accordingly. The findings raised in this case study emanated from an ongoing research project funded by the South African Water Research Commission (WRC) titled "Securing Water Sustainability through Innovative Spatial Planning and Land Use Management Tools".

5.1 Study area

Mogalakwena Local Municipality is considered to be a typical Category B Local Municipality, located within the iconic Waterberg District Municipality. Mogalakwena functions largely as the interface between the Waterberg District Municipality and the Capricorn District, and is surrounded by mainly deep rural areas of Lephalale Local Municipality to the north and west (Mogalakwena Local Municipality, 2016: 7).

Mogalakwena Local Municipality has a well-defined urban and rural development footprint which consists of 3 proclaimed townships and 178 villages (Mogalakwena Local Municipality, 2016: 8). However, this footprint has already caused severe damage to environmentally sensitive areas (Mogalakwena Local Municipality, 2016: 17). The Municipality's economy is, to a large extent, dependent on agricultural and mining activities; these land-use activities have been criticised for being culprits in surface- and groundwater contamination (Mogalakwena Local Municipality, 2016: 12).

The Mogalakwena Local Municipality 2016/2017 Integrated Development Plan (IDP) identified this as a strategic issue as over 19% of the municipal area is supplied with underground water resources (Mogalakwena Local Municipality, 2016: 15). According to the water reconciliation strategy conducted for the Olifants River water management area, demand for water is mainly driven by increased mining and associated urban growth (DWA, 2013a: 22). The additional water demand required by 2035 is estimated at 156 million m^3/a. Therefore, far-reaching interventions, in this case through spatial planning and land-use management, must be introduced to meet such demand.

5.2 Making a case for land use-related water consumption

Different land uses consume water at different rates. Table 3 illustrates an extract from the billing

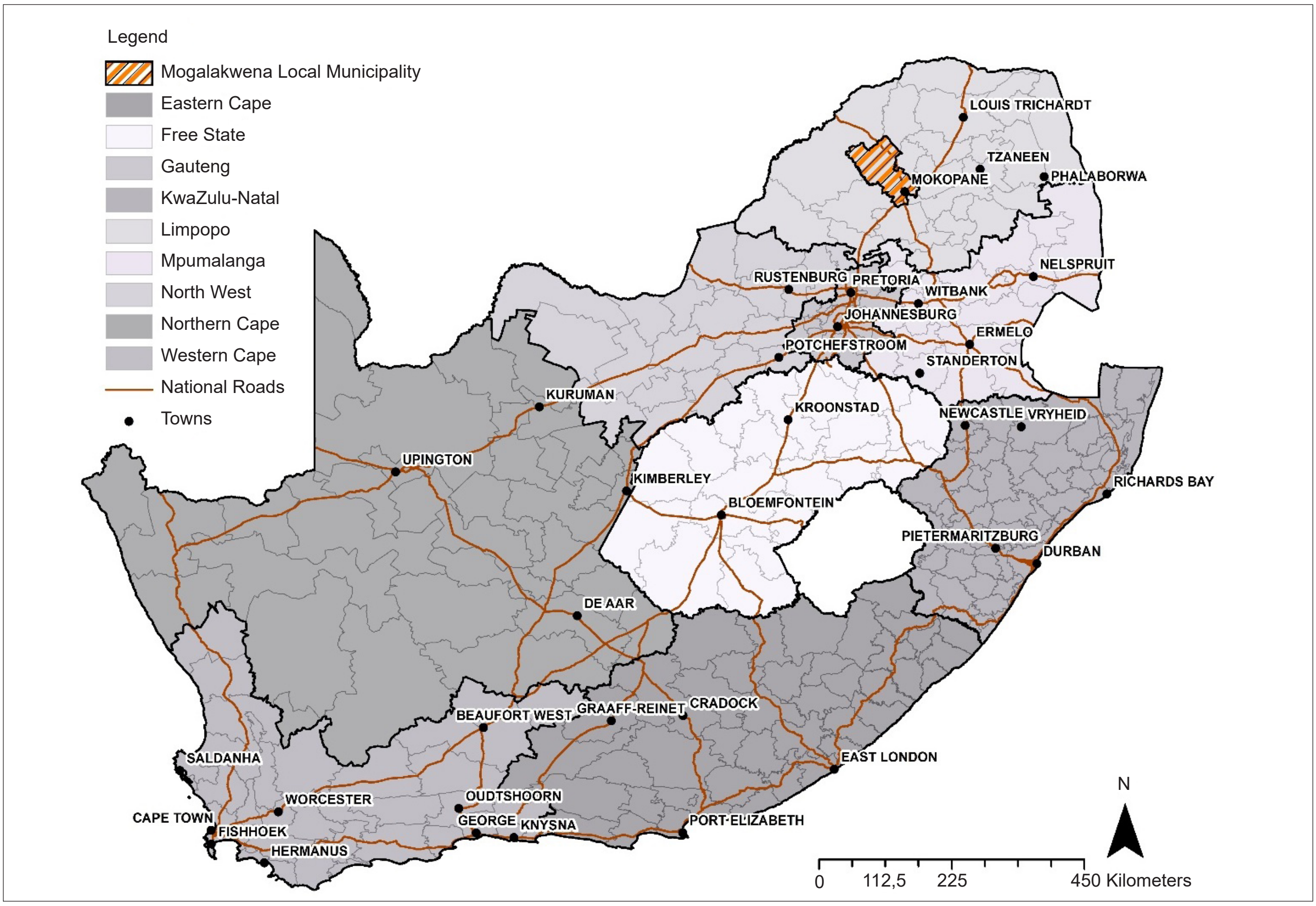

Figure 4: Locational map of Mogalakwena Local Municipality

Source: Authors' own compilation

system of Mogalakwena Local Municipality, obtained from the Field MeterReading, which among other, provides valuable information regarding water consumption in the municipality.

The "Unit" field contains codes of locational information (town, extension, stand number, and subdivision), which can be used to locate the information spatially. The field "YYMM" provides information on the year and month of the reading and "Meter type" indicates that the meter is a water meter (MW08). As all municipalities are required to have a land-use scheme that assigns a land-use right to a specific property, it is possible to overlap different data sets, using the specific property as the common denominator. The land-use and water-consumption data were modelled accordingly to illustrate the results of such spatially. The different land uses were coded in terms of different colours and the average monthly water consumption

Table 3: Extract of the billing system of the Mogalakwena Local Municipality

Unit	Account	YYMM	Read date	Meter reading	Read type	Meter ref.	Meter type
1000000000000010000000000000	1031054	200801	20080107	1840.000	3	380147	MW08
1000000000000010000000000000	1031054	200712	20071203	1839.000	3	380147	MW08
1000000000000010000000000000	1031054	200711	20071101	1839.000	3	380147	MW08
1000000000000010000000000000	1031054	200710	20071008	1837.000	3	380147	MW08
1000000000000010000000000000	1031054	200709	20070903	1833.000	3	380147	MW08
1000000000000010000000000000	1031054	200708	20070801	1826.000	3	380147	MW08
1000000000000010000000000000	1031054	200707	20070702	1814.000	3	380147	MW08
1000000000000010000000000000	1031054	200706	20070601	1805.000	3	380147	MW08
1000000000000010000000000000	1031054	200705	20070502	1800.000	3	380147	MW08
1000000000000010000000000000	1031054	200704	20070402	1798.000	3	380147	MW08
1000000000000010000000000000	1031054	200703	20070301	1798.000	3	380147	MW08
1000000000000010000000000000	1031054	200702	20070205	1797.000	3	380147	MW08
1000000000000010000000000000	1031054	200701	20070103	1796.000	3	380147	MW08
1000000000000010000000000000	1031054	200612	20061204	1795.000	3	380147	MW08
1000000000000010000000000000	1031054	200611	20061101	1793.000	3	380147	MW08
1000000000000010000000000000	1031054	200610	20061003	1791.000	3	380147	MW08

of the specific property (relating to specific land-use) is illustrated in terms of height in Figure 4.

Figure 5 indicates that the bulk of water consumption of the Mogalakwena Local Municipality is consumed in the central business district (CBD), followed by the industrial node. Figure 5 further indicates that residential properties in close proximity to the CBD consumed more water than those in outlying areas, which also related to different income levels in these areas.

The spatial modelling of monthly water-consumption data also enables the comparison of land-use and water-consumption data. Table 4 is a summary of the water-billing systems and land-use scheme and illustrates metered consumption (not the total consumption of the Municipality).

Table 4 indicates that land-uses utilised for business in Mogalakwena Local Municipality (of which there are only 315) use nearly twice the total amount of water than residential land uses (of which there are over 30 608).

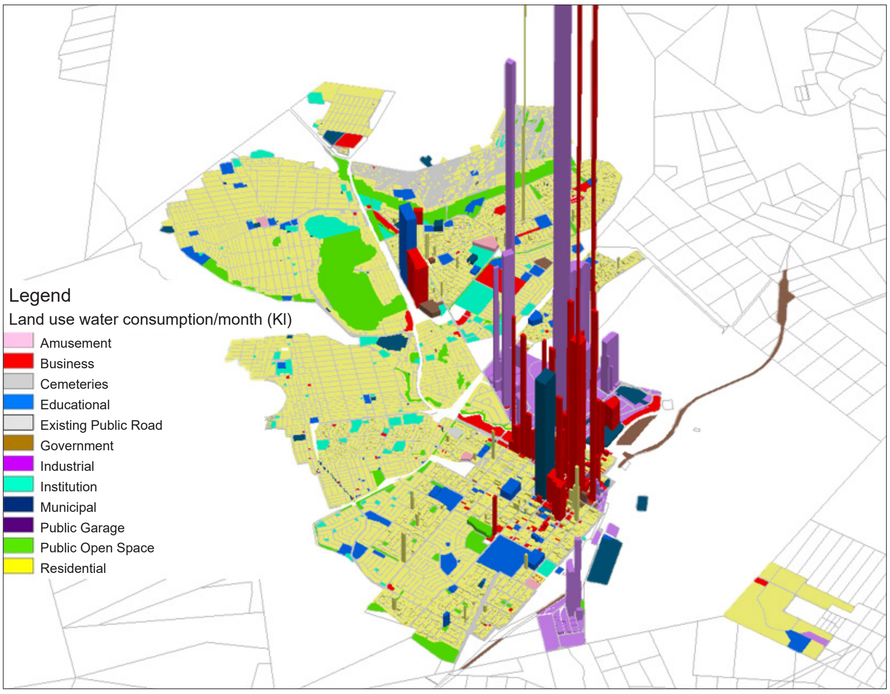

Figure 5: Spatial depiction of water consumption by different land uses in the urban areas of Mokopane town in Mogalakwena Local Municipality

Source: Authors' own compilation

Table 4: Comparison of land-use and water-consumption data in Mogalakwena Local Municipality

Land use	Total monthly consumption (kl)	Number of properties	Average monthly consumption (kl)
Amusement	611	7	87
Business	678 276	351	1 932
Cemeteries	0	2	0
Educational	13 704	111	123
Government	2 365	34	70
Existing public road	0	115	0
Industrial	373 749	487	767
Institution	164	120	1
Municipal	15 572	77	202
Public garage	111	3	37
Public open space	469	120	4
Residential	373 510	30 608	12
Grand total	1 458 597	33 262	44

Industrial land uses also consume high amounts of water, as evident in the case study. This information can be used by the Municipality to identify and target land uses with high water consumption. Land uses or even buildings with high water consumption offer greater opportunity to reuse water (the rule of thumb is that up to 90% of consumed water can be reused) for non-potable purposes such as irrigation or toilet flushing. In this specific case study, businesses, in general, should be targeted to reuse water, as they use nearly twice the amount of residential land uses. Water-sensitive practices such as water reuse, rain and storm-water harvesting can be implemented through building regulations (e.g., SANS 204: Energy Efficiency in buildings regulations requires that 50% of all hot water in new houses needs to be produced by methods other than electrical element heating – similar regulations could be implemented for water reuse) and land-use controls (e.g., all building should consider either rainwater and storm water harvesting to substitute non-potable water resource demand), both of which can be legally enforced through municipal by-laws.

The spatial modelling for the Mogalakwena Local Municipality also provides valuable information to guide future planning and WSSs. It spatially identifies where, and by which land-use, most of the water is consumed and can be used to predict future growth and demand. The household growth projection was calculated using an Excel-based regression analysis. Households in the Mogalakwena Local Municipality are expected to grow by 4 500 additional households in 5 years and 9 299 households in 10 years. Based on the spatial modelling data, this translates into an additional monthly demand for water as captured in Table 5.

Table 5 quantifies that, by 2026, an estimated additional 111 593kl of water resources will be required by future households if no mitigation measures are implemented. Section 21(h) of Act 16 no. 2013 (RSA, 2013: 26) mandates that a Spatial Development Framework

Table 5: Household growth and water-demand prediction for the Mogalakwena Local Municipality

Year	Households	Additional households	Additional water required (Kl)
2017	84 490	886	10 637
2018	85 386	1 782	21 387
2019	86 292	2 688	32 251
2020	87 206	3 602	43 230
2021	88 131	4 527	54 325
2022	89 066	5 462	65 539
2023	90 010	6 406	76 871
2024	90 964	7 360	88 323
2025	91 929	8 325	99 896
2026	92 903	9 299	111 593

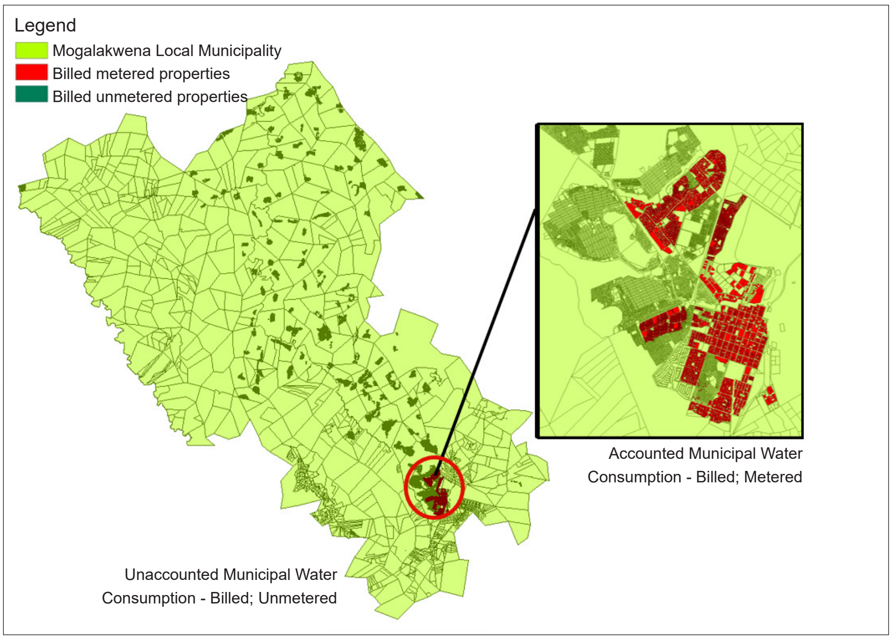

Figure 6: Extent of billed metered and unmetered water-consumption data availability in Mogalakwena Local Municipality

Source: Authors' own compilation

"identify, quantify and provide location requirements of engineering infrastructure and services provision for existing and future development needs for the next five years". Once again, referring back to Wong *et al.*'s (2013: 7) definition of a WSC where a "city can serve as a potential water supply catchment, providing a range of different water sources at a range of different scales, and for a range of different uses", spatial planners should rethink the design and use of buildings, infrastructure and spaces to include water-sensitive design practices such as decentralised waste-water treatment, rainwater, and storm-water harvesting techniques. These techniques are well documented (Rohilla, Matto, Jainer & Sharda, 2017: 33-52; Armitage *et al.*, 2014: 49-75). As such, this article will not go into detail in explaining the techniques. Water-sensitive Spatial Development Frameworks could significantly reduce future water demand, and water quality can also be improved over time. In doing so, the overall sustainability of both the natural and the built environments will most likely improve, making the Municipality more resilient to climate change.

However, the above modelling exercises are limited to the availability of metered billing data. As such, two major land uses known for high water consumption, namely agriculture (responsible for nearly 60% of all water consumption nationally) and mining (responsible for nearly 3% of all water consumption nationally) is not included, due to the fact that these land uses acquire water directly from the Water Boards or from groundwater extracts, and therefore do not form part of the municipal billing system (DWA, 2013a: 9). Furthermore, the 178 villages (see section 6.1) located outside the urban fabric fall within the billed **unmetered consumption** (free basic services) (see section 3.2) category. Figure 5 illustrates the full extent of billed metered and unmetered water consumption. The full extent of water consumption by land use should be investigated when considering water-sensitive spatial modelling.

Spatial modelling of growth and water demand thus provides opportunities to identify targeted areas and land uses to be developed, or conserved, either through water-demand reduction or implementations of green infrastructure and WSUD on a precinct level. By combining the future demand analysis with the spatial targeting intervention, a municipality will be able to determine where and how to best utilise resources.

The future demand for water as a resource, regarding quantity and quality, should form part of broader spatial planning and land-use management by translating water sensitivity into spatial planning practices. A point of departure is to identify the spatial impact of various land uses within a demarcated area, and use such data to make future growth and demand predictions, as illustrated in the Mogalakwena Local Municipality case study. This research argues that spatially targeted interventions, combined with WSUD approaches, can facilitate future sustainable development, but would require a shift in thinking from current silo-management to one where land, water, environment, and infrastructure are planned holistically. A transdisciplinary approach to spatial planning and water management is needed for the development and implementation of successful WSSs.

6. CONCLUSION: THE NEED FOR CHANGE AND INTERVENTION

The “model” or figure presented in this article illustrates a means to identify which land uses demand higher quantities of water. This study has proven that, by combining various data sets within a modelling system (in this case Geographic Information System), spatial planners operating within the municipal environment can now quantify the water-resource impact of land-use decisions. Ultimately, the information can be used to inform spatial growth and resource-demand scenarios. As a Municipality, the information generated from this modelling exercise can be used to develop a business case for increasing water tariffs, re-evaluate the promised level of services, implement water-efficiency building regulations, and rethink the business-as-usual approach to settlement planning and design. Within the holistic context of a WSS, the starting point for many South African municipalities should be to understand and reduce the demand for water, before major interventions and infrastructure retrofitting are considered.

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