Journal of Applied Horticulture, 23(1): 28-36, 2021

DOI: https://doi.org/10.37855/jah.2021.v23i01.06

Journal of Applied Horticulture

ISSN: 0972-1045

Determining a landscape plant database matched to hydrozones for South Africa

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Abstract

About 27 % of available water in South Africa is utilised in the urban environment. Estimates for South Africa place ornamental landscape water use as high as 50 % of urban water use. South Africa's average annual rainfall is approximately 495 mm. Rainfall patterns are erratic with periodic droughts of anticipated increased frequency. Ornamental landscapes require additional watering to minimise impacts of dry periods. These landscapes are often over- rather than under-watered. One method of reducing urban ornamental landscape water use is to group plants according to predefined hydrozones to optimise water use through improved site maintenance, landscape design and irrigation application. Currently no extensive researched database of commonly grown ornamental landscape plants linked to hydrozones exists for South Africa. To produce such a plant database, an analysis determining the hydrozone rating of plants sold in South African nurseries was undertaken. The result of this study is a database of plant species suitable for ornamental landscape hydrozones (high, medium, low and very low water requirements) and linked to a plant factor. This provides South African Green Industries Council members, especially landscapers with a database to assist in selecting the most appropriate plants for each hydrozone for their ornamental landscapes and gardens. The database will support South African ornamental landscape water use models.

Key words: Hydrozone, ornamental landscape, plant database, plant coefficient, plant factor, indigenous plants, exotic plants.

Introduction

The urban landscaped environment is characterised by a range of hard-landscapes surrounded by lawns, ornamental vegetation and scattered trees (Byrne and Grewal, 2008) and is often manipulated by humans for the purpose of enhancing ecological aesthetics (Acar *et al.*, 2007). The functional value of ornamental landscapes is linked to aspects such as aesthetic appearance, utility, and recreation (Kjelgren *et al.*, 2000). The South African Green Industry consists of landscapers, landscape architects, irrigation designers, wholesale nursery growers and nurseries/ garden centres. Each ornamental landscape is unique in its plant selection, design and location resulting in site specific water requirements and should be treated as such.

Supplementary watering of ornamental landscapes minimises the effects of drought (Fereres *et al.*, 2003) which could be aggravated by climate change (UNESCO, 2020). Internationally, ornamental landscape water use figures indicated as a percentage of total domestic water use, ranges between 7-75 % (Barta *et al.*, 2004; Devi, 2009), while for South Africa this ranges from 30 to 50 % (Landscape Irrigation Association of SA, 2009; Wegelin and Jacobs, 2013). The total water requirements for ornamental landscapes varies depending on the location of the landscape, the climate (Devi, 2009) and the maintenance of the site. Turf grass and ornamental landscapes tend to be overwatered (Kjelgren *et al.*, 2000; Barta *et al.*, 2004; St. Hilaire *et al.*, 2008), however they should only be irrigated when rain is inadequate to support expected plant growth (Kjelgren *et al.*, 2000; Stabler and Martin, 2004). Measures to reduce water use in ornamental landscapes include amongst others, improved plant species selection, water efficient landscaping (St. Hilaire *et al.*, 2008; Gössling *et al.*, 2012), hydrozoning (Randolph, 2005; University of California Agriculture and Natural Resources, 2015; Hoy *et al.*, 2017: Team Watersmart - Regional District of Nanaimo, 2018), and the use of indigenous plants and appropriate garden designs (Keane, 1995; Gössling *et al.*, 2012).

A hydrozone can be described as a landscaped area consisting of plants with similar (homogenous) water and climatic needs that are served by one irrigation valve or set of valves with the same watering schedule (UCCECDWR, 2000; Randolph, 2005). Incorrect plant choices and incorrect placement of plants in the hydrozones (*i.e.,* placing high water use plants in the same bed as low water use plants, using the same irrigation system and control valves) of an ornamental landscape act as constraints to water conservation.

South Africa's average annual rainfall is approximately 495 mm, compared to the global average of 1033 mm (Hedden and Cilliers, 2014). South Africa is periodically afflicted by severe and prolonged droughts which are often terminated by severe floods (O'Keeffe *et al.*, 1992). Recently recorded droughts and dry cycles for South Africa include 1982 to 1995 (Backeberg and Viljoen, 2003), 1992 to 1995, 2015 to 2016 (Baudoina *et al.*, 2017) and 2017 (Masante *et al.*, 2018).

Large portions of South Africa are arid and providing sufficient water resources for societal needs is a challenge. If water misuse (uncontrolled leaks and excessive application) continues, many parts of the country will face excessive water shortages within the next few years (National Business Initiative, 2011). South Africans use more water than the country's catchments are able to replenish (National Business Initiative, 2011). The demand for water in the large and rapidly growing areas of Johannesburg-Pretoria (Gauteng), Cape Town (Western Cape) and Durban (Kwazulu-Natal) is compounding the requirement for additional water supply (Binns *et al.*, 2001). In addition, climate change will impose significant challenges on fresh water sources and most of South Africa is likely to become drier and hotter in the future (National Business Initiative, 2011; UNESCO, 2020).

Reliable international data on ornamental plant water use is limited because of the large diversity of plant species (Kjelgren *et al.*, 2000; Pittenger and Shaw, 2004). Water use of plant species linked to specific hydrozones within ornamental landscapes in South Africa has been undertaken by individual publications but has not been extensively assessed or researched. Moreover, there is little scientific data available on plant water use within the South African context. Only one scientific article can be traced for South Africa which covers selected turf grass species (Jansen van Vuuren, 1997).

Indigenous plant species occur in diverse habitats and in areas of varying rainfall. Some plants of the same species have adapted to grow in different localities with different rainfall regimes and climates. Plants require different amounts of water to grow and flourish within habitats due to site-specific environmental factors (*e.g.,* those growing within the riparian habitat, as opposed to those growing slightly further away in a terrestrial habitat) (Van Jaarsveld, 2000). As an example, *Agapanthus praecox* is a plant suitable for a fynbos garden, a thicket garden and a highveld garden (Van Jaarsveld, 2000). Each of these landscapes exhibit different rainfall regimes and climates (Van Jaarsveld, 2000). Taking this into account, the concept of emulating variations in water availability should be repeated within ornamental landscapes in the form of hydrozones relative to the location of the landscape. When deciding on plants for a landscape it is necessary to consider location and to select suitable plants (Kopp *et al.*, 2002). These plants need to be grouped according to their water requirements (Kopp *et al.*, 2002; Randolph, 2005).

Additionally, when considering plants for an ornamental landscape the emphasis should be on using indigenous plants. They are seen as being water efficient and suited to local microclimate conditions (Botha and Botha, 1995; Van Jaarsveld, 2000; Johnson *et al.*, 2002; Randolph, 2005), are low maintenance (Johnson *et al.*, 2002) and require less watering (Randolph, 2005; Water Wise, 2016), provided they are planted in a similar climatic situation/landscape to that of their natural habitat (Pienaar, 1985; Van Jaarsveld, 2000; Johnson *et al.*, 2002). Indigenous plants used in an ornamental landscape should be regionally and ecologically appropriate to the broad area that they will be planted in (Keane, 1995; Byrne and Associates, 2013; Cabrera *et al.*, 2013; Van Jaarsveld, 2000).

Ascertaining ornamental plant water use can be achieved by determining either a crop/species coefficient (factor) (Kc) or plant coefficient (factor) (PF). The Kc is the fraction of water lost from the crop relative to reference evapotranspiration (University of California Cooperative Extension California Department of Water Resources, (UCCECDWR), 2000). A Kc for plants is determined and required when it is essential to achieve maximum yield and optimal growth (*e.g.,* crop production and turf landscapes). Determining the specific Kc involves the use of lysimeters or gravimetrical methodology, and is complex and time consuming (Niu *et al.*, 2006; Jansen van Vuuren, 1997). A PF is determined when plants are required to provide acceptable function and appearance, as in ornamental landscapes (University of California Division of Agriculture and Natural Sciences, 2018).

Due to the large variety of ornamental species used in ornamental landscapes, the Kc has not been determined for many ornamental plants and it is impossible to determine annual, monthly or daily minimum water use requirements (Pittenger and Shaw, 2004; Pittenger, 2014). To assist landscapers and to comply with international norms, lists of plant species have been produced with an associated PF coefficient value (Schuch and Burger, 1997; UCCECDWR, 2000; Connellan, 2002; Pittenger and Shaw, 2004; McCabe, 2005; Harivandi *et al.*, 2009; Pittenger, 2014).

Plant databases (linked to PF's) must ideally be used together with ornamental landscape water use models to ensure that site landscape water requirements are correctly determined. For this to apply, each plant/hydrozone must be allocated a PF. The lack of a South African Green Industry wide agreed plant species data base linked to specific hydrozones and PF's requires addressing. This will allow for correctly hydrozoned ornamental landscapes to be more sustainable while using less water.

Currently there is no single common database of plants linked to hydrozones available to the Green Industry in South Africa that links commonly grown/sold plants to specific hydrozones. The important concept of landscaping using hydrozones and linking this to all aspects of an ornamental site is crucial to landscape water use (Randolph, 2005; Hoy *et al.*, 2017).

The aim of this study is to develop a comprehensive South African database of Water Use Classification for Landscape Plant Species, of common commercially available ornamental horticultural plants (indigenous and exotic), each linked to a specifically identified hydrozone and PF.

Materials and methods

Ethical clearance (2015/CAES/096) was obtained from the University of South Africa (Unisa) to undertake a mixed methods study. Signed approval to engage members of the South African Green Industry Council (SAGIC) was obtained from chairpersons of the subsets of SAGIC (such as landscapers, growers, retail nurseries and irrigation designers) that were engaged in this study.

Data for the study was collected from a range of primary (wholesale growers) and secondary (published information) sources to produce a plant database for plant species currently sold in South Africa, with each plant species linked to one of four specific hydrozones. The South African Nursery Association (SANA) subset of SAGIC, which is centered on wholesale plant production and sales, was used for determining the plant database. The SANA members were used because they are specialists in their field and because they grow plants for the nursery and landscaping trade. The use of both primary and secondary data sets assisted in providing a combination of published and current data.

Disproportionate stratification was used for this study since it allows for a smaller focused sample size where the strata has less variability resulting in cost savings. This allowed the researcher to use only selected (volunteer/co-opted) members of the SAGIC subset (SANA growers) in the plant list data gathering process

(Stat Trek, 2018). A disproportionate stratification still allows for the same level of precision as does data selection from larger strata populations with a high degree of variability. This allowed the researcher to maximise precision for a single important survey measure, namely the SANA growers (Israel, 2009).

Plant selection process matched to hydrozones: This study covered ornamental plants sold in South Africa. The following methodology was used to collect plant hydrozone related information. This involved a multistage data gathering process. Data was gathered from a range of sources which included books, research papers, internet sites, published plant lists (secondary sources) and direct feedback from a survey with wholesale growers (primary sources), before determining plant water needs based on what was supplied (Creswell, 2014).

High, medium, low and very low water hydrozones were selected for use in the study. Lists linked to water use (hydrozones) were obtained from the internet (*e.g.,* Salt Lake City Public Utilities, 2013; Green Buildings Council of South Africa, 2014; Kwantlen Polytechnic University, 2015; Arizona Municipal Water Users Association, 2017), literature sources (*e.g.,* Simpson, 1985; Pienaar, 1991; Sheat, 1993; Joffe, 2003; Allaway, 2013) and industry data (from wholesale plant growers in South Africa).

For this study the Water Wise's Standard Operating Procedures (SOP) (Rand Water, n.d; Hoy *et al.*, 2017) definition of hydrozones has been adopted (Table 1). All surveys and data collected were correlated back to the Water Wise definitions and descriptions.

Lists of plants available for sale in South Africa for inclusion in the database: The first stage of the multistage data gathering required that plants used in the proposed database had to be available for sale in South Africa during the data gathering period (2015 to 2017). Only information from available plants for sale were gathered from grower sources. A total of 36 sales/availability lists were obtained at four SANA tradeshows in Gauteng (August 2015, March 2016, August 2016 and March 2017) from wholesale growers. This included growers who responded to a request for plant list information sent out via SANA to members. Both indigenous and exotic plants were included in the list allowing for a complete list of available plants sold in South Africa.

Data gathered from wholesalers, the internet and printed literature plant databases for inclusion in the database: The second stage of data gathering focused on hydrozone data linking plant species available for sale in South Africa to specific hydrozones, which was gathered from 64 different sources (Table 2) of which 47 were secondary sources and 17 primary sources.

Internet sites were sourced using a variety of search engine requests for plant databases specifically indicating water use requirements of each plant listed. Examples of internet sites used include Keith Kirstens, n.d. <http://plantinfo.co.za/plant>; Utah State University Cooperative Extension, 2003 <http://www.waterwiseplants.utah.gov/>; Salt Lake City Public Utilities, 2013; <http://www.slcdocs.com/utilities/PDF %20Files/2013_SLCPlantList_ver2-1.pdf>; and Green Buildings Council of South Africa, 2014 <https://www.gbcsa.org.za/>.

Books and printed media (such as plant catalogues, booklets, reports and published lists) were used for data collection. Each plant species list included information about plants linked to specific hydrozones. Fifteen were internationally produced lists and 17 were South African.

Via SANA (2017) emails were sent to all registered growers requesting them to supply data regarding plants suited to specific hydrozones. A range of reminder emails were sent out, however, responses were very slow. All plant wholesale growers were instructed to list the plant species they grow and sell, against the following criteria: One of four hydrozones as defined by Water Wise (Rand Water, n.d; Hoy *et al.*, 2017) as set out in Table 1. Which one of the four hydrozones they would advise customers to grow the plants in? The plants local growing area requirements. For example a grower in Brits (Northwest Province) would advise on hydrozones based on the local growing conditions in Brits.

Data captured from the various plant databases from a range of sources provided different hydrozone ratings for the same plants

Table 1: Water wise Standard Operating Procedures (SOP) of Rand Water application rates for each hydrozone (Rand Water, n.d.; Hoy *et al.,* 2017)

	High zone	Medium zone	Low zone	Very low zone
Summer	25 mm/week	15 mm/week	12 mm/week	Rely on natural rainfall.
Spring	15 mm/week	12 mm/week	7 mm/week	Rely on natural rainfall.
Winter	12 mm/week	7 mm/week	12 mm every second week (excluding lawns, however if dormant no water)	Rely on natural rainfall.
Autumn	15 mm/week	12 mm/week	7 mm/week	Rely on natural rainfall.
Annualised water use*	750 mm – 1000 mm/ annum	500 mm – 750 mm/ annum	300 mm – 500 mm/annum	< 300 mm/annum

* Note these amounts are to be applied only after the settling in period for plants which will range from 12 to 24 months (SAGIC, 2018).

Table 2. Summary of plant data hydrozone information sources

	Second stage of multistage data gathering			First stage of multistage data gathering
	Internet sites. (Secondary source).	Books and printed media (Secondary source).	South African based wholesale nurseries that responded to RW definition (Primary source).	Wholesale nursery growers whose catalogues were obtained at trade shows (Aug 2015. March 2016 and March 2017) to determine what plants are grown (Primary source).
International and South Africa focus	13	15	N/A	N/A
South African focus	3	16	17	36
Total Sources	16	31	17	36

(*i.e.* not all sources placed the same plant in the same hydrozone). The number of plants per database assessed varied across all sources, ranging from 20 to 671 plants. The use of secondary data allowed for a larger sample field as well as access to published data that otherwise would not have been obtainable for the study. The primary and secondary data was integrated into one data set for final analyses and hydrozone determination.

Cleaning up the database: The total plant list of data gathered from all sources was checked for duplicates, incorrect names, and spelling. Some plant species were listed as the same species name but with different colours, trademark names or variety names. In these instances, the plant varieties were amalgamated, and the plant listed in the database was given the suffix varieties. Plants of the same species sold under two different genus or species names were also merged under the correct name. In some cases, outdated nomenclature was used and in other cases the spelling of names was incorrect resulting in duplication. These were all corrected and the cleaned data was incorporated into the database.

In some examples the spelling of plant names was incorrect for example *Carya illinoinensis* (incorrect) *versus Carya illinoensis* (correct). Spelling was corrected and data was captured against the correct species listing. Plants where descriptions were so generic that plants could not be identified were deleted from the database.

Some sources *e.g., Strelitzia* spp. (Brandies, 1994), *Petunia* hybrids (Keane, 1995), *Pentas* spp. (Elands Nursery), *Dahlia* hybrids (BallStraathof; Perry, 1982) and *Dahlia* spp (Andy Titterton Wholesale Nursery; Keane, 1995), only listed plants down to genus level with the suffix species (spp) or hybrid. These have been included in the final database. Other sources (wholesale growers) provided information for some plants down to subspecies/variety/cultivar level, examples being *Agapanthus orientalis* 'Golden Drop' var. (Malanseuns), *Alstroemeria* Princess Lilies Princess Ariane var. 'Zapriari' (Malanseuns), *Dianella tasmaniaca* 'variegata' (Elands Nursery) and *Penstemon hartweggii* 'tubular bells' (Ballstraathof). These were included in the database as provided.

In instances where various references listed the same variety against different hydrozone requirements, the highest listed hydrozone was awarded to the generic variety in the final list. This is in support of Barta *et al.* (2004) and Randolph (2005) who indicate that ornamental landscapes are rather over- than under-watered by end users.

Alien invasive plants listed as category 1a (All species in this category must be combatted and eradicated. Any form of trade or planting is strictly prohibited.) and 1b (plant species that are not allowed to be grown and sold in certain areas of South Africa according to legislation) were removed from the final database (National Environmental Management: Biodiversity Act (NEMA), 2004).

Assigning plant categories to all plant species: All plants in the database were categorised as either being indigenous or exotic. All plants were also grouped into plant type categories such as annuals, bulbs, shrubs and sub-shrubs, fruit and herbs. These listings were confirmed by Coetzer (2018) "pers. Comm". Determining the broad categories for plants meant that a wide range of different plants were grouped together. For example, the category 'bulb like' consists of all bulb type plants such as bulbs, corms, rhizomes, tubers and plants with any form of underground storage mechanism. This rationale is consistent with other authors for example Botha and Botha (1995) and Eslick (1999). The 'grass like' category consists of grasses and all plants that have a visible grass like growth structure or appearance.

Determining hydrozones for each plant species: To determine the actual hydrozone to which a particular plant specie belongs, data from all sources for each species were summarized per hydrozone. The data for each species and each hydrozone was summed and weighted using an Excel COUNTIF formula with variations (this identified the maximum data entries present with a specific hydrozone rating). This formula selected the hydrozone for each species based on the highest number of data sources that allocated the specific hydrozone (Table 3).

Determining plant water requirements linked to hydrozones and allocation of plant factors: To allow for a final plant database of plants linked to a specific hydrozone that can be used in an Ornamental Landscape Water Use Model to facilitate water use calculations, a PF is required. To allow for this, the PF (coefficient) as used by UCCECDWR, (2000), Pittenger and Shaw, (2004) and Costello and Jones (2014) was used for three of the four chosen hydrozones. Costello and Jones (2014) and UCCECDWR (2000) provided insufficient information for the very low water hydrozone (they provided only one range, <0.1). A three step coefficient for the very low water hydrozone using the same stepped coefficients as the existing coefficients of UCCECDWR (2000) was developed (Table 7).

Table 3. Examples of hydrozones determined for each species

Scientific name	Plant category	Very low Water hydrozone	Low water hydrozone	Med water hydrozone	High water hydrozone	Final category awarded
Abelia grandiflora (Rovelli ex André)	Shrub and Sub-shrub	0	4	4	0	Medium
Acanthus mollis (L.)	Perennial	0	4	4	7	High
Asparagus falcatus (L.)	Vine/ Climber	1	1	1	2	High
Bauhinia natalensis (Oliv)	Shrub and Sub-shrub	0	3	2	2	Low
Bougainvillea glabra varieties	Vine/ Climber	1	0	0	0	Very low
Cassinopsis ilicifolia (Hochst.)	Shrub and Sub-shrub	0	4	3	3	Low
Echeveria varieties	Succulent	2	2	0	0	Low

Results

Plant database generation and refinement: A total of 17 grower responses were received from a total of 79 wholesale registered nurseries (Growers Association) with SANA, representing a 22 % industry response rate. The number of plants from the suppliers that corresponded with the plants in the research plant database ranged from 20 to 471 plants per supplier. The number of plants from each of the internet sites (16) that matched plants on the research plant list ranged from 20 to 672.

The total number of plants identified from all sources was 5,000. The list was split into genus, species, subspecies and cultivars/hybrid. From the initial database, a total of 24 plants defined as alien invasive plant species were removed (NEMA, 2004) (Table 4). After cleaning up the database, the final database of 2,529 plants was divided into high/medium/low/very low water use. Plants were categorised into 18 different plant type categories (Table 5) consisting of both indigenous and exotic plants.

Of the plants sold in South Africa and that were included into the database, a total of 37 % (947) were categorised as indigenous and 63 % (1582) exotic. For the database there were a number of corresponding hydrozone listings (where there is full agreement into which hydrozone a specific plant should be placed) that exists between the overseas data sources and South African data sources. This matching hydrozone data of overseas data compared to South African data is least in the very low water hydrozone, with the most matching data in the medium water hydrozone (Fig. 1). Similarities between hydrozone data from the SA literature, internet sources and South Africa wholesale growers, ranges from four plants in the very low water hydrozone to 134 in the low water hydrozone, 489 in the medium hydrozone and 44 in the high hydrozone (Fig. 2).

Table 5. Breakdown of plant categories

Category	Total plants in this category	Exotic	Indigenous
Annuals	270	243	27
Bulb like	160	60	100
Conifer trees and shrubs	33	33	0
Cycads	12	3	9
Ferns	19	6	13
Fruit	65	64	1
Grass like	119	66	53
Ground cover	115	49	66
Herbs	36	35	1
Orchids	8	6	2
Palms	33	31	2
Perennials	424	319	105
Shrub and sub-shrub	669	376	293
Succulents	126	46	80
Trees	289	121	168
Vegetables	35	35	0
Vines/climbers	101	81	20
Water plants	15	8	7
Total	2,529	1,582	947

Table 4. Exotic invader plants removed from the list

	Scientific name	Plant category	Common name	Indigenous/ Exotic	Invader category
1	*Albizia lebbeck* (L.) Benth.	Tree	Lebbeck Tree/Siris	Exotic	Invader Cat 1b
2	*Antigonon leptopus* (Hook. and Arn,)	Vine/Climber	Coral (Honolulu) Creeper	Exotic	Invader Cat 1b
3	*Coreopsis lanceolata* (Sch. Bip.)	Perennial	Tickseed	Exotic	Invader Cat 1b
4	*Cotoneaster franchetii* (Bois)	Shrub and Sub-shrub	Orange cotoneaster	Exotic	Invader Cat 1b
5	*Cotoneaster salicifolius* (Franch.)	Shrub and Sub-shrub	Willow-leaf cotoneaster	Exotic	Invader Cat 1b
6	*Duchesnea indica* (Andrews)	Ground Cover	Mock strawberry	Exotic	Invader Cat 1b
7	*Euphorbia leucocephala* (Lotsy)	Shrub and Sub-shrub	White Poinsettia/Snow of Kilimanjaro	Exotic	Invader Cat 1b
8	*Hedychium gardnerianum* (Sheph. ex Ker Gawl.)	Bulb like	Ginger lily	Exotic	Invader Cat 1b
9	*Iris pseudacorus* (L.)	Bulb like	Yellow Flag Iris	Exotic	Invader Cat 1b
10	*Leptospermum laevigatum* (Geartn.)	Shrub and Sub-shrub	Australian Tea Tree	Exotic	Invader Cat 1b
11	*Melaleuca quinquenervia* (Cav.)	Tree	Cajeput / Paper bark Tree	Exotic	Invader Cat 1b
12	*Mirabilis jalapa* (L.)	Perennial	Four O'Clock Flower	Exotic	Invader Cat 1b
13	*Stipa tenuissima* (Trin.)	Grass like	Mexican Feather Grass	Exotic	(=*Nasella tenuissima*) Cat 1b
14	*Parkinsonia aculeate* (L.)	Tree	Jerusalem thorn	Exotic	Invader Cat 1b
15	*Paulownia tomentosa* (Steud.)	Tree	Empress tree	Exotic	Invader Cat 1a
16	*Pennisetum villosum* (Frensen)	Grass like	Feathertop	Exotic	(=*P. longistylum*) Invader Cat 1b
17	*Pinus roxburghii* (Sarg.)	Tree	Himalayan long-leaf pine	Exotic	Invader Cat 2
18	*Pontederia cordata* (L.)	Water plants	Pickerel weed/wampee	Exotic	Invader Cat 1b
19	*Psidium cattleianum* (Afzel. ex Sabine)	Fruit	Cherry/strawberry/ guava	Exotic	Invader Cat 1b
20	*Robinia pseudoacacia* (L.)	Shrub and Sub-shrub	Black locust	Exotic	Invader Cat 1b
21	*Sambucus nigra* (L.)	Herb	Elderberry	Exotic	Invader Cat 1b
22	*Solanum pseudocapsicum* (L.)	Shrub and Sub-shrub	Jerusalem cherry	Exotic	Invader Cat 1b
23	*Polygonum capitatum* (Buch.-Ham. ex D.Don)	Ground Cover	Knot weed	Exotic	Invader Cat 1b
24	*Zebrina pendula* (Schinzl.)	Ground Cover	Wandering Jew	Exotic	(= *Tradescantia zebrina*) Cat1b

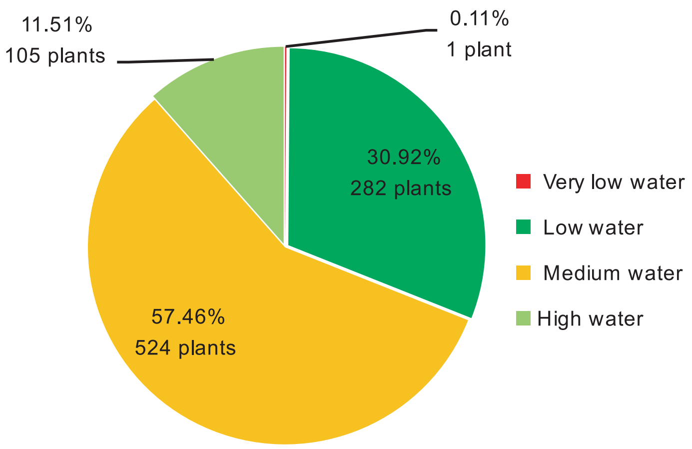

Fig. 1. Totals of matching hydrozone data for overseas and South Africa data bases.

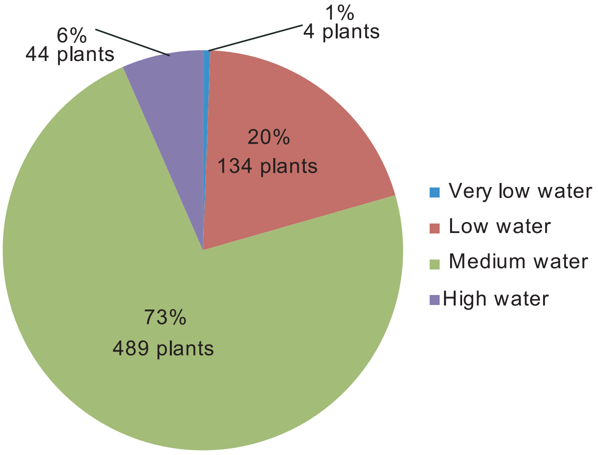

Fig. 2. Totals of matching hydrozone data, South Africa primary and secondary sources.

Table 6. Example of a portion of the plant database linked to hydrozones

Genus	Species	Variety/ cultivar/ subspecies	Common name	Plant category	Indigenous/ Exotic	Synonyms or changed botanical names or/& Invader status	Hydro-zone
Abelia	*chinensis* (R.Br.)		Chinese Abelia	Shrub and Sub-shrub	Exotic		Medium
Abelia	*grandiflora* (Rovelli ex André)	varieties	Prostrata Abelia	Shrub and Sub-shrub	Exotic		Medium
Abelia	*spp*		Abelia	Shrub and Sub-shrub	Exotic		Low
Acacia	*baileyana* (F.Muell.)		Bailey Acacia	Tree	Exotic	Invader Cat 3	Low
Acalypha	*hispida africana*		Chenille Plant	Shrub and Sub-shrub	Exotic		Medium
Acanthus	*mollis* (L.)		Wild Rhubarb	Perennial	Exotic		High
Acanthus	spp.			Perennial	Exotic		Medium
Acer	*buergerianum* (Miq.)		Chinese Maple	Tree	Exotic	(=*A. trifidium*) Invader Cat3	Medium
Acer	*negundo* (L.)		Box Elder	Tree	Exotic	Invader Cat 3	Low
Callistemon	*viminalis* (Sol. ex Gaertn.)		Weeping Bottlebrush	Tree	Exotic	Invader Cat 1b and Cat 3	Low
Celosia	spp			Annual	Exotic		High
Celtis	*africana* (Burm.f.)		White Stinkwood, Witstinkhout	Tree	Indigenous		Medium
Celtis	*australis*(L.)		Hackberry	Tree	Exotic	Invader Cat 3	Medium
Felicia	*heterophylla* (Cass.)		Felicia	Perennial	Indigenous		Low
Felicia	spp		Felecia	Perennial	Indigenous		Medium
Ilex	*cornuta* (Lindl. and Paxton)	spp	Chinese Holly	Shrub and Sub-shrub	Exotic		Low
Ilex	x *meserveae* (S.Y.Hu)		Cape Holly	Tree	Indigenous	*Ilex mitis*	High
Impatiens	*balsamina* (L.)		Balsam	Annual	Exotic		Medium
Kalanchoe	*tomentosa* (Baker)		Panda plant	Succulent	Exotic		Low
Karomia	*speciosa* (Hutch. and Corbishley) R.Fern.)		Parasol flower/ chinese-hat plant	Shrub and Sub-shrub	Indigenous	(=*Holmskioldia tettensis*)	Medium
Khaya	*nyasica* (ex (Baker f.)		Red mahogany	Tree	Exotic		Medium
Nymphoides	*indica* (L.) Kuntze		small yellow water lily/ Water snowflake	water plants	Indigenous		High
Zinnia	*spp*		Zinnia	Annual	Exotic		Low
Ziziphus	*mucronata* (Willd.)		Buffalo Thorn	Tree	Indigenous		Medium
Ziziphus	*rivularis* (Codd)		False Buffalo Thorn	Tree	Indigenous		High

Table 7. Hydrozones allocated to the plant database and associated coefficient

Hydrozone	High	High	High	Medium	Medium	Medium	Low	Low	Low	Very low water	Very low water	Very low water
Coefficient	0.9	0.8	0.7	0.6	0.5	0.4	0.3	0.2	0.1	0.05	0.03	0.01

An example of a portion of the layout of the final plant database produced that includes full plant names, plant categories, genus, species, variety (where supplied), common names (where available), synonyms, indigenous/exotic and finally plant rating (hydrozone) is listed in Table 6. Due to the extent of the full plant database, it cannot be included in this report and is available on request from the corresponding author.

The hydrozones coefficient (PF) chart required the development of a three-step coefficient range. The coefficient for the very low water hydrozone ranges was developed (Table 7), namely 0.05 to 0.01.

The total number of plants in the database linked to each hydrozone were very low (20), low (549), medium (1433), and high (526) water use plants.

Discussion

A total number of 5000 plant species were analysed of which 2529 were successfully categorised into four different hydrozones. The plants assessed and allocated to hydrozones reflected a variety of exotic (63 %) and indigenous (37 %) plants sold by wholesale nurseries in South Africa. Almost two thirds of the plants sold and categorised were exotic. This supports findings by Middelton (2015) indicating that often consumers have specific preferences for popular exotic plants. The information contained in the resultant database is based on expert opinion and databases from both South Africa as well as international sources. This study is the most comprehensive study to date in South Africa involving as wide a field as it has and resulting in an inclusive list of plant species linked to the four defined hydrozones and their associated PFs (coefficients). The database can be used to guide growers, retailers, landscape architects and landscapers on the most appropriate hydrozone in which to place plants. This database will in turn positively influence ornamental landscape water use.

The notion that certain plants require more water than others to grow in selected ornamental landscape environments is undisputed (Ash, 1998; Pittenger, 2014). The exact amount of water required by plants for survival, to look aesthetically pleasing, or to grow optimally is debateable, subjective and influenced by a wide range of aspects (Pittenger, 2014). The determination of plant water use is not an exact science and depending on the specialist's sources, their understanding (possibly even their localised knowledge context) and their reference point, could influence the specific rating of a hydrozone (Table 6) and linked to that a PF (Table 7) they recommend for a particular plant. Considering the large number of plants included in the database, the methodology as used in this study for determining plant water use is currently the most efficient, economical and reliable available at present in South Africa.

To address the current inconsistency with regard to hydrozone definitions as well as water applications for each hydrozone, it would be pertinent for the South African ornamental horticultural and landscaping professionals and community to adopt the definitions used in this study as a standardised approach. Doing this allows for correct hydrozone allocation in design, plant choice, optimal irrigation design and watering, as well as efficient site maintenance.

It will also assist wholesale plant growers, Nurseries and Garden centres for use as a control to ensure that plants are sold using the correct hydrozone and watering information on plant labels, plant lists and sales lists. Landscapers and landscape architects can use this as a tool to ensure correct plant placement in the correct hydrozone when designing new landscapes or revamping existing ones. Irrigation designers will also benefit since they contribute towards designing landscapes to specific hydrozones.

The use of the plant database and associated hydrozones cannot be viewed in isolation and should be used concurrently. When using the database, landscapers must also consider and correctly select as well as place plants in the landscape to suite the environmental and climatic factors for the specific hydrozone. The choice of using indigenous versus exotic plants within ornamental landscapes is ongoing; however correct placement of plants in the appropriate hydrozone within the ornamental landscape should be the essence of correct design. Using this database correctly will contribute positively towards reducing water use within ornamental landscapes and the urban environment. A recommendation for a future version of this database would be to include aspects such as frost sensitivity, sun/shade tolerance, soil pH, climatic factors, edaphic factors, etcetera.

The research undertaken in this study resulted in the production of a plant database that will provide SAGIC members with plant hydrozone information applicable for plant selection in ornamental landscapes, propagation, sales, design and maintenance of existing landscapes. This will improve water use efficiency and allow for more sustainable ornamental landscape sites. The urgent need to reduce water use within the industry as well as within ornamental landscapes will be achieved with correct implementation of the hydrozone plant database information.

Acknowledgements

The authors would like to thank Rand Water who provided financial support for the project, and the SAGIC Associations and members for their plant list feedback and support of the project.

References

Acar, C., H. Acar and E. Eroğlu, 2007. Evaluation of ornamental plant resources to urban biodiversity and cultural changing: A case study of residential landscapes in Trabzon city (Turkey). *Building and Environment,* 42(1): 218-229. <https://doi.org/10.1016/j.buildenv.2005.08.030>

Allaway, Z. (ed) 2013. *The Royal Horticultural Society What Plant Where Encyclopedia.* Dorling Kindersley Limited, London.

Arizona Municipal Water Users Association, 2017. Landscape Plants for the Arizona Desert. <http://www.amwua.org/plants/>

Ash, T. 1998. *Landscape water management: How to profit from a water efficient future*. Municipal Water District of Orange County: California.

Backeberg, G.R. and M.F. Viljoen, 2003. *Drought Management in South Africa*. Paper presented at Workshop of the ICID working Group on Irrigation under Drought and Water Scarcity, (2003:Tehran, I.R. of Iran).

Barta, R., R. Ward, R. Waskom and D. Smith, 2004. *Stretching Urban Water Supplies in Colorado: Strategies for Landscape Water Conservation*. Colorado: Colorado Water Resources Research Institute. *<http://www.cwi.colostate.edu/media/publications/sr/13.pdf>*

Baudoina, M.A., C. Vogel, K. Nortje and M. Naik, 2017. Living with drought in South Africa: lessons learnt from the recent El Niño drought period. *International Journal of Disaster Risk Reduction*, <http://dx.doi.org/10.1016/j.ijdrr.2017.05.005>: 128-137.

Binns, J.A., P.M. Illgner and E.L. Nel, 2001. Water Shortage, Deforestation and Development: South Africa's Working for Water Programme. *Land Degradation and Development*, 12: 341-355.

Botha, C. and J. Botha, 1995. *Bring Nature Back To Your Garden*. Natal Region of the Wildlife and Environment Society, Durban.

Brandies, M.M. 1994. *Xeriscaping for Florida Homes*. Great Outdoors Publishing Company, St. Petersburg (Florida).

Byrne, J. and Associates. 2013. *A guide to water efficient Landscape and Irrigation*. Fremantle: Water Corporation of Western Australia. <https://joshbyrne.com.au/project/guide-water-efficient-landscape-irrigation/>

Byrne, L.B. and P. Grewal, 2008. Introduction to Ecological Landscaping: A Holistic Description and Framework to Guide the Study and Management of Urban Landscape Parcels. Cities and the Environment, 1(2); article 3.

Cabrera, R.I., K.L. Wagner, B. Wherley and L. Lee, 2013. *Urban Landscape Water Use In Texas*. s.l.: Texas Water Resource Institute. <http://twri.tamu.edu/publications/educational-materials/2013/em-116/>

Connellan, G. 2002. *Efficient irrigation: A reference manual for turf and landscape*. Melbourne: University of Melbourne. <http://southeastwater.com.au/SiteCollectionDocuments/Business/Local-government/Attachment6EfficientIrrigationForTurfAndLandscape.pdf>

Costello, L.R. and K.S. Jones, 2014. *Water Use Classification of Landscape Species: WUCOLS IV 2014*. s.l.: University of California. <ucanr.edu/sites/WUCOLS/Download_WUCOLS_IV_List/?sharebar=share>

Creswell, J.W. 2014. *Research Design Qualitative, Quantitative and Mixed Methods Approaches. California*: Sage Publications Inc.

Devi, B.L. 2009. *A Framework for Development and Evaluation of Policies and Programs for Urban Irrigation Demand Management*. s.l.: s.n. <https://researchdirect.westernsydney.edu.au/islandora/object/uws %3A7097>

Eslick, C. 1999. *Growers guide to Bulbs*. North Sydney, Murdock Books.

Fereres, E., D.A. Goldhamer and L.R. Parsons, 2003. Irrigation water management of horticultural crops. *HortScience*, (35)5 August: 1036-1042.

Gössling, S., P. Peeters, C. Michael Hall, J. Ceron, G. Dubois, L.V. Lehmann and D. Scott, 2012. Toursim and water use:Supply, demand, and security. An international review. *Tourism Management,* (33): 1-15. <www.elsevier.com/locate/tourman>

Green Building Council of South Africa. 2014. *Green Star SA – Existing Building Performance PILOT, Potable Water Calculator Guide Revision 1*. <https://www.gbcsa.org.za/>

Harivandi, M.A., J. Baird, J. Hartin, M. Henry and D. Shaw, 2009. *Managing Turfgrasses during Drought*. Oakland (California), University of California Division of Agricultural and Natural Resources, 1-9. <https://anrcatalog.ucanr.edu/pdf/8395.pdf.>

Hedden, S. and J. Cilliers, 2014. *Parched Prospects: The emerging water crisis in South Africa*. African Futures Paper 11. s.l., Institute of Security Studies.

Hoy, L., M. Donnelly, D. Whitehead, K. Montgomery and S. Solwandle, (Eds) 2017. *South African Landscapers' Institute & Rand Water's Guide to Water Wise Landscaping*. s.l., Rand Water and South African Landscapers Association.

Israel, D.G. 2009. *Sampling the Evidence of Extension Program Impact*. University of Florida: Florida. <http://edis.ifas.ufl.edu.>

Jansen Van Vuuren, J.D. 1997. *Optimal Water Use of Turf Grass*. Potchefstroom: Department of Plant and Soil Sciences Potchefstroom University.

Joffe, P. 2003. *Easy Guide to Indigenous Shrubs*. Briza Publications, Pretoria.

Johnson, D., S. Johnson and G. Nichols, 2002. *Gardening with Indigenous Shrubs*. Struik, Cape Town.

Keane, T. 1995. *Water-wise Landscaping Guide for Water Management Planning*. Utah State University Cooperative: Utah. pp. 37-70. <https://digitalcommons.usu.edu/cgi/viewcontent.cgi?article=1974&context=extension_histall>

Keith Kirstens, n.d.. Plantinfo. <http://plantinfo.co.za/plant>

Kjelgren, R., L. Rupp and D. Kilgren, 2000. Water conservation in urban landscapes. *HortScience,* 35(6): 1037-1040.

Kopp, K.L., T. Cerny and R. Hefelbower, 2002. *Water Wise Landscaping* (*CWEL Extension Fact Sheets. Paper 3*). Utah: Utah State University.

Kwantlen Polytecchnic University, 2015. *Plant Database*. s.l., s.n. <https://plantdatabase.kpu.ca/plant/resourcePlantMasterList>

Landscape Irrigation Association of South Africa. 2009. *LIA Code of Standards Design/Installation/Maintenance.* s.l.: Landscape Irrigation Association of South Africa.

Masante, D., N. Mccormick, J. Vogt, C. Carmona-Moreno, E. Cordano and I. Ameztoy, 2018. *Drought and Water Crisis in Southern Africa*, European Commission, Ispra ISBN 978-92-79-85851-2, <http://publications.jrc.ec.europa.eu/repository/bitstream/JRC111596/drought_water_crisis_in_southern_africa2018_doi_isbn.pdf>

Mccabe, J. 2005. *Landscape Irrigation Scheduling and Water Management*. s.l., The Irrigation Association. <http://www.irrometer.com/pdf/research/IA_BMP_APRIL_2005.pdf>

National Business Initiative. 2011. *CDP Water Disclosure South Africa Report 2011*. London: Carbon Disclosure Project. <https://www.cdp.net/CDPResults/CDP-Water-Disclosure-South-Africa-Report-2011.pdf>

National Environmental Management: Biodiversity Act, 2004 (Act No.10 of 2004) (NEMA). *Alien and Invasive Species Lists, 2016*. Government Gazette (29 July 2016).

Niu, G., D.S. Rodriguez, R. Cabrera, C. Mckenney and W. Mackay, 2006. Determining Water Use and Crop Coefficients of Five Woody Landscape Plants. *Journal of Environmental Horticulture.* <http://www.academia.edu/22075765/Determining_Water_Use_and_Crop_Coefficients_of_Five_Woody_Landscape_Plants1>

O'Keeffe, J., M. Uys and M.N. Bruton, 1992. Freshwater Systems. In: *Environmental Management in South Africa*. Fuggle, R.F., Rabie, M.A. (Eds.). Juta & Co, Johannesburg.

Perry, F. ed., 1982. *The Macdonald Encyclopaedia of Plants & Flowers*. Macdonald & Co, London.

Pienaar, K. 1985. *Grow South African Plants*. Struik Publishers, Cape Town.

Pienaar, K. 1991. *Gardening with Indigenous Plants.* Cape Town: Struik Timmins Publishers.

Pittenger, D. 2014. *A Report to the Barton Springs/Edwards aquifer conservation trust: Methodology for estimating landscape irrigation demand, Review and recommendations.* s.l., s.n.. <bseacd.org/uploads/BSEACD_Irr_Demand_Meth_Rprt_2014_Final_140424.pdf>

Pittenger, D. and D. Shaw, 2004. What We Know About Landscape Water Requirements. *Co-Hort.*, 6.1(Spring): 1-3.

Rand Water Environmental Management Services Department. n.d. *Water Wise Watering*. <http://www.waterwise.co.za/export/sites/water-wise/gardening/water-your-garden/downloads/Water_Wise_Watering.pdf>

Randolph, D.R. 2005. *Hydrozone Design: Resources in Support of Water-Conserving Landscape Ordinance Design Requirements in Pasco County, Florida*. Masters Landscape Architecture: University of Florida.

SAGIC (South African Green Industries Council, - Strydom, I. M.). 2018. *Minutes For The Cape Resilient Landscaping Forum Meeting*. [Meeting] (28 March 2018).

Salt Lake City Public Utilities. 2013. *Salt Lake City Plant List and Hydrozone Schedule 2013*. Salt Lake City. <http://www.slcdocs.com/utilities/PDF %20Files/2013_SLCPlantList_ver2-1.pdf>

Schuch, U.K. and D.W. Burger, 1997. Water use and crop coefficients of woody ornamentals in containers. *Journal of the American Society for Horticultural Science.* 122(5): 727-734. <https://arizona.pure.elsevier.com/en/publications/water-use-and-crop-coefficients-of-woody-ornamentals-in-container>

Sheat, W.G. 1993. *The A-Z of Gardening in South Africa.* Struik Publishers, Cape Town.

Simpson, M. 1985. *Annuals for the South African Garden.* Centaur: Cape Town.

South African Nursery Association (SANA). 2017. *SANA 70th Annual General Meeting*. Knoppieslaagte: SANA.

St. Hilaire, R., M.A. Arnold, D.C. Wilkerson, D.A. Devitt, B.H. Hurd, B.J. Lesikar, V.I. Lohr, C.A. Martin, G.V. Mcdonald, R.L. Morris and co-authors. 2008. Efficient water use in residential urban landscapes. *HortScience*, 43(7): 2081-2092.

Stabler, L.B. and C.A. Martin, 2004. Irrigation and pruning affect growth water use efficiency of two desert-adapted shrubs. *International Society for Horticultural Science.* <http://www.actahort.org/members/showpdf?booknrarnr=638_33>

Stat Trek. 2018. Stratified Random Sampling. <http://stattrek.com/survey-research/stratified-sampling.aspx>

Team Watersmart - Regional District Of Nanaimo, 2018. Landscape Guide to Water Efficiency. Canada: Regional District of Nanaimo. <www.rdn.bc.ca/cms/wpattachments/wpID2155atID3697.pdf>

UNESCO, UN-Water, 2020: *United Nations World Water Development Report 2020: Water and Climate Change*, Paris, UNESCO.

University Of California Cooperative Extension California Department Of Water Resources (UCCECDWR). 2000, *A Guide to Estimating Irrigation Water Needs of Landscape Plantings in California*. *<ucanr.org/sites/OC/files/132534.pdf>*

University Of California Agriculture And Natural Resources. 2015. *Keeping Plants Alive under Drought or Water Restrictions*. Richmond CA: University of California. <https://ucanr.edu/sites/sbmg/files/224849.pdf>

University Of California Division of Agriculture And Natural Sciences. 2018. *Plant Factor or Crop Coefficient: What is the difference?* University of California. <https://ucanr.edu/sites/UrbanHort/Water_Use_of_Turfgrass_and_Landscape_Plant_Materials/Plant_Factor_or_Crop_Coefficient__What %E2 %80 %99s_the_difference/>

Utah State University Cooperative Extension. 2003. Water Wise Plants for Utah Landscapes. s.l., Utah State University Cooperative extension. <http://www.waterwiseplants.utah.gov/>

Van Jaarsveld, E. 2000. *Wonderful Waterwise Gardening: A regional guide to indigenous gardening in South Africa*. Tafelberg Publishers, Cape Town.

Water Wise. 2016. *Choose Water Wise Plants*. <http://www.waterwise.co.za/>

Wegelin, W.A. and H.E. Jacobs, 2013. *The development of a municipal water conservation and demand management strategy and business plan as required by the Water Services Act, South Africa*. <http://www.wrc.org.za>

Received: July, 2020; Revised: August, 2020; Accepted: August, 2020