Overview on urban nature conservation: situation in the western-grassland biome of South Africa

Sarel S. Cilliers\textsuperscript{a,}\textsuperscript{*}, Norbert Müller\textsuperscript{b}, Ernst Drewes\textsuperscript{c}

\textsuperscript{a} Section Botany, School of Environmental Sciences and Development, North-West University (Potchefstroom Campus), Potchefstroom, South Africa
\textsuperscript{b} Faculty of Landscape Architecture, Department of Restoration Ecology, University of Applied Sciences, Erfurt, Germany
\textsuperscript{c} Section Town and Regional Planning, School of Environmental Sciences and Development, North-West University (Potchefstroom Campus), Potchefstroom, South Africa

Received 20 June 2003; accepted 7 April 2004

Abstract

Urban nature conservation issues in South Africa are overshadowed by the goal to improve human well-being, which focuses on aspects such as poverty, equity, redistribution of wealth and wealth creation. The growing need for urban employment is closely associated with the increase of squatting and informal settlements along the urban fringe, which contributes to habitat fragmentation and sprawling of cities. This increasing urbanisation is one of the main threats to biodiversity in the Grassland biome as the natural vegetation in and around cities in the North-West Province of South Africa is destroyed at an alarming rate. The lack of detailed ecological data is a major problem in the implementation of conservation-orientated policies in urban planning and management. This paper gives a brief overview of urban nature conservation in the world, the obstacles to implementation in South Africa and the importance of socio-economics and environmental legislation. We focus specifically on projects involving phytosociological studies and biotope mapping in cities in the western Grassland Biome of the North West Province. The visible presence of native vegetation is essential and integral to urban nature conservation. There is a vital need to present urban environmental data in a format that is convincing and useful to decision makers. We propose an integrated approach towards urban ecological studies culminating in effective urban nature conservation.

\textcopyright 2004 Elsevier GmbH. All rights reserved.

Keywords: Biotope mapping; Integrated research; Native vegetation; Phytosociology; Urban ecology; Grasslands; South Africa

Introduction

An immense increase in population of cities all over the world, which will result in 65% of the total world population living in urban areas, is forecasted for the next 25 years (Müller, 1997). It is further stated that each city is dependant for its growth and survival on an area of productive ecosystems of up to three orders of magnitude larger than its geographical area—the so-called ecological footprint of the city (Folke et al., 1997). Urbanisation is therefore regarded as one of the most severe impacts on the environment. It follows that environmental protection, which includes nature conservation, must be vastly improved in urban areas.
What does ‘urban nature’ include?

There are different views of what the terms ‘urban’ and ‘urban nature’ imply. Social scientists use the term ‘urban’ to refer to areas with high human population density, while ecologists use the term more broadly in describing areas under human influence (McIntyre et al., 2000). Forman and Godron (1986) also followed the ecological approach by characterising landscapes along a continuum from pristine, managed, cultivated and suburban to urban—the landscape with the most intense human influence. Trepl (1995) has followed a more detailed analysis by distinguishing between five different kinds of urban ecosystems from typical urban to all ecosystems within the limits of the city, regardless of whether they are specifically urban or not.

According to Wittig (1998) ‘nature’ should have a strong spontaneous component and all landscape types originating without human influences can be regarded as natural, and therefore man-made parks and gardens are in his view, not part of ‘urban nature’, although they do contain some natural elements such as rocks. In nature associated with urban areas (spontaneous component), Wittig (1998) distinguished between remnants of natural and agricultural landscapes and the characteristic ‘urban nature’, i.e. ruderal plant communities. Ruderals are the only type of ‘nature’ that can easily be integrated into urban development, because they are pre-adapted to specific urban conditions (Wittig, 1998). Spontaneous ruderal communities are, however, not accepted by most decision-makers and city residents as ‘urban nature’ which should be conserved, while remnants of natural landscape are much more acceptable (Cilliers et al., 1999). The concept of urban nature conservation seems like an oxymoron to many ecologists. In the United Kingdom, for example, areas which should be conserved were described as natural greenspace, but urban areas are excluded from the definition. According to Kendle and Forbes (1997) the concept of ‘urban countryside’ was developed to include urban areas. ‘Urban countryside’ can be classified in three groups, namely relict countryside, man-made ecological landscapes (planted and managed nature) and spontaneous urban flora and fauna.

McIntyre et al. (2000) argued that although there is a need for an unambiguous, quantitative definition of the term ‘urban’ as research in urban ecosystems expands, it is probably not feasible. Firstly the description of ‘urban’ depends on the research question and secondly there is often not a clear distinction between the urban environment and the surrounding landscape, but there is often a gradient from rural to suburban to urban areas. For the purpose of this paper, ‘urban nature’ include all living organisms and their habitats within the legal limits of the city, but eventually the focus of the paper will be placed on those organisms occurring spontaneously in fragmented natural areas such as hills and ridges and linear landscapes such as rivers and streams with extensive wetlands. The term urban open space in the paper refers to the widest concept of any open space in urban areas, namely an open area in which vegetation is established. This is in accordance to the view of Gilbert (1989) who acknowledged technological, gardens and three different types of ecological landscapes (encapsulated countryside, parks based on ecological principles, unofficial and informal wild spaces) as important in urban areas.

International approaches to urban nature conservation

Since the 1970s, many European countries have developed programmes for nature conservation in urban areas. The leading aspects of these programmes were presented in the World Conservation Strategy (1980). Essential background information enabled the introduction of nature conservation laws in various countries. The UN conferences on nature conservation in 1992 in Rio and in 1996 in Istanbul (Habitat II) enforced the nature conservation efforts in cities (Müller, 1997). The importance of the advancement of sustainable development of human settlements, with the focus on the improvement of the ecological, economical, cultural and social conditions, was confirmed at the Rio conference.

In Europe, the first projects that focussed on nature conservation in cities became famous as urban biotope mapping (Sukopp et al., 1980; Starfinger and Sukopp, 1994; Müller, 1997). Biotopete mapping was initially limited to natural landscapes and focussed only on habitats for rare and endangered species (Kaule, 1975), but it gradually developed towards the protection and establishment of nature in cities as a basis for the direct contact between urban dwellers and the natural elements (Sukopp et al., 1980; Starfinger and Sukopp, 1994). Although urban biotope mapping was first done in Germany, several similar projects have been completed in other countries such as Japan (Müller, 1997), Brazil (Weber and Bede, 1998) and Sweden (Löfvenhaft et al., 2002), to mention a few.

Urban biotopes are important as refuges, dispersal centres and corridors for species; for environmental protection and ecological balance (hydrological cycle, water resources and hygiene, climate, air hygiene, noise protection); for the aesthetic quality of the urban landscape; as areas for low-key recreation opportunities; as informal playgrounds for children; as demonstration and experimental areas for educational purposes; as bio-indicators of environmental changes and pollution; and for fundamental research into urban ecology (Starfinger and Sukopp, 1994; Müller, 1997). In general, biotope mapping is focused on floristic and phytosociological
features, as plant studies are relatively easy compared to animal studies (Sukopp and Weiler, 1988).

Other examples of urban ecological studies with direct conservation objectives, but not based on biotope studies include one of the most comprehensive vegetation surveys in urban areas, namely in the Greater London area of 1580 km² (Given, 1994). Urban nature conservation in South Africa

Although a certain amount of ‘nature’ has always been found in cities, the concept of ‘nature in the city’ is relatively new in South Africa. It is only over the last 15 years that certain South African cities have adopted some kind of urban nature conservation strategy. According to Boswell (1993) these strategies developed in response to changing perceptions towards the environment within the nature conservation movement, together with an increase in environmental awareness. It was also realised that the emphasis in urban nature conservation should shift from the protection of only particular species of interest towards the preservation of functional communities, the maintenance of maximum sustainable biotic diversity and the minimisation of extinction (Roberts, 1990, 1993a). These views formed the basis for the implementation of the Metropolitan Open Space System (MOSS) approach based on biogeographical and ecological guidelines (Poynton and Roberts, 1985) for several cities and towns in South Africa (Cooper and Duthie, 1992). One of the proposals of the Durban MOSS program (Durban is located in the Kwa Zulu-Natal province) was that all the wetland areas must be conserved, and this in itself was a significant achievement for conservation in any urban area in South Africa (Roberts, 1993b).

Despite these insights into the need for urban nature conservation, the immense increase in urbanisation and human competition for space remains a problem. Urban nature conservation issues in South Africa are, therefore, overshadowed by the goal to improve human well-being, which focuses on aspects such as poverty, equity, redistribution of wealth and wealth creation (Hindson, 1994).

Although urbanisation in some provinces is still lower than South Africa’s national figure of 53%, a rapid increase in urbanisation is expected in future. This is mainly because continued droughts lead to higher levels of poverty and fewer job opportunities in rural areas, especially in the North West Province. According to Statistics South Africa (2000), the population of South Africa is estimated at 43 million, with a growth rate of 2% per annum. It is further estimated that unemployment is currently at 23.3% and the disparities in distribution of wealth and associated environmental problems are acknowledged (Statistics South Africa, 2000). Additionally, South African cities have witnessed an increase in the number of informal settlements on the urban fringe. These settlements, together with trends of suburbanisation, have resulted in habitat fragmentation and sprawling of cities. Natural vegetation in and around South African cities is destroyed at an alarming rate and immense areas of ecologically significant open spaces are cleared for persistent lateral growth (Cilliers, 1998). The question remains, however, whether environmental legislation in South Africa adequately includes urban environments and addresses environmental degradation.

Environmental legislation in South Africa

Efforts were made in South Africa to incorporate environmental issues into legislation aimed towards urban areas. The Reconstruction and Development Programme (RDP) of the Government of South Africa (African National Congress, 1994) stressed that sustainable urbanisation must be part of the process of post-apartheid reconstruction. In an analysis of the role of botanists in the RDP programme, Low (1995) emphasised the urgent need for empirical research into the nature, survivability and biodiversity of remnants of natural areas in the urban environment, as well as investigations into the role of these areas as community reserves. The Development Facilitation Act on the other hand, introduced extraordinary measures to facilitate and speed up the implementation of reconstruction and development programmes in relation to land; and in so doing lay down general principles governing land development throughout the country (South Africa, 1995). From a planning point of view, legislation was passed in the form of the Environmental Conservation Act, which stipulates that the environmental impact has to be gauged before new urban development can take place, especially with regard to public and private parks (South Africa, 1989). Land use management has recently become an essential part of Integrated Development Planning (IDP), a strategic management process, which is formulated on the local and district government levels in the form of the Municipal Systems Act (South Africa, 2000).

The main departure points in the Municipal Systems Act are to curb urban sprawl and to encourage sustainable development within the urban sphere (South Africa, 2000). What is, however, distressing about these issues is the omission of clear urban nature conservation principles from the planning and management process of urban areas. This is due to a lack of ecological information and awareness, especially on aspects such as biodiversity and ecological interactions and fluxes. Poynton and Roberts (1985) already indicated that a lack of ecological and biogeographical data, together...
with issues such as financial limitations, division of authority and public attitudes and reactions, are the main problems facing the implementation of conservation-orientated planning and management of urban areas in South Africa. An additional problem is that the provincial governments and municipal authorities lack the ecological expertise to apply the legislation regarding conservation and management of urban open spaces.

**Grassland biome of South Africa**

This paper now focuses on the western part of the Grassland Biome of South Africa, situated mainly in the North West Province (Fig. 1), and more specifically on the cities of Potchefstroom and Klerksdorp. The Grassland Biome is one of seven biomes identified for South Africa, the other six are Forest, Fynbos, Nama-Karoo, Succulent Karoo, Savanna and Thicket (Fig. 1) (Low and Rebelo, 1996). While the Grassland Biome is considered to have an extremely high species diversity, second only to the well-known Fynbos Biome, and includes many rare and threatened species, it is regarded as one of the most critically threatened southern African ecosystems (Rutherford and Westfall, 1994). The Fynbos Biome that is situated in the Cape Floristic Kingdom is often used as a norm with respect to plant species diversity as it contains one-third of South African plant species but cover less than 6% of the area of the country (Low and Rebelo, 1996).

It may seem that vast tracts of grassland still exist in the Grassland Biome, but much of it has been disturbed by past cultivation, livestock grazing or the disruption of natural fire cycles, resulting in a severe decrease in the species diversity of plants, insects and other animals. Urbanisation is a major additional influence on the loss of natural areas in this biome (Rutherford and Westfall, 1994). The conservation status of the western Grassland Biome is regarded as extremely poor (Low and Rebelo, 1996) and only 0.33% of its total surface area (2.7 million hectares) is officially conserved (Bezuidenhout, 1993). This places tremendous pressure on the conservation of grasslands outside nature reserves, including those in and around cities. Ironically, Cohen and Hugo (1986) already mentioned in 1986 that national and local government in South Africa does not place enough emphasis on conservation outside officially designated areas. Unfortunately, after 17 years this scenario has not changed much.

**BIOMES OF SOUTH AFRICA**

![Map of the nine provinces and seven vegetation biomes of South Africa. Take note of the location of the two main study areas (Potchefstroom and Klerksdorp) in the Grassland Biome of South Africa.](image)
In recent years, an immense array of vegetation information was gathered in the Grassland Biome, of which the identification, naming and classification of plant communities by Bezuidenhout et al. (1994a, b, c), Fuls et al. (1993) and Kooij et al. (1992) are representative examples. Vegetation of disturbed areas and urban environments were, however, not included in any of these studies. Cilliers (1998, 1999) emphasised the need to determine the degree to which anthropogenic influences have changed the vegetation in the Grassland Biome. It is important to set the ecological boundaries in any area so that long-term species and plant community conservation can be assured. The over-management of grasslands in and around urban areas by frequent cutting and weeding keeps them in a sub-climax condition and decreases the species diversity tremendously (Cilliers, 1999; Nel, 1991). The planting of trees, often exotics, in grasslands also affects the pristine condition of these areas. It is therefore important to do ecological surveys and inventories of natural areas in and around the urban environment (Nel, 1991). In a study of the Durban municipal area, Roberts (1993a, b) illustrated the importance of a more detailed plant community analysis and the associated mapping to provide an effective planning and management tool. This type of analysis should include floristic details and be accurate regarding the actual community distribution and should also concentrate on the conservation status and ecological importance of the plant species and plant communities (Roberts, 1993a, b).

The aim of this paper is to discuss specific urban ecological studies focusing on phytosociology, floristics and urban biotope mapping in the western Grassland Biome of South Africa and indicate the importance of these studies in conservation-orientated planning and management practices.

Phytosociological and floristic studies

Phytosociological and floristic studies are widely recognised as being important in acquiring base-line data for the planning and management of any area (Bezuidenhout, 1993). The realisation of the overall importance of urban vegetation studies has led to the development of a comprehensive research programme on urban open spaces in cities in the North West Province of South Africa (Cilliers, 1998). Projects within this programme include studies on the hills and ridges in Klerksdorp (Van Wyk et al., 1997b), the wetlands in Potchefstroom and Klerksdorp (Cilliers et al., 1998; Van Wyk et al., 2000), the railway reserve areas (Cilliers and Bredenkamp, 1998), intensively managed parks, pavements and parking areas (Cilliers and Bredenkamp, 1999a), vacant lots in residential, commercial and industrial areas (Cilliers and Bredenkamp, 1999b), road verges along an urbanisation gradient (Cilliers and Bredenkamp, 2000a) and ‘natural’ grasslands and woodlands (Cilliers et al., 1999) in the Potchefstroom Municipal area.

The Braun-Blanquet method of vegetation classification was used in all of the mentioned studies, but initially none of the communities were formally named in order to prevent synonymy of syntaxa names. In brief, the Braun-Blanquet system consists of preparing species lists in sample plots (called relevés) and estimating the cover of each species using a specific scale, and processes these species lists in synthesis tables (Mueller-Dombois and Ellenberg, 1974). Although the Braun-Blanquet method used in phytosociological studies is often criticised, mainly because of its subjectivity (Pignatti, 1995; Pysák, 1995). The large body of information it provides can be used for generalisation by the application of statistical and computer methods, careful re-evaluation of the data and by comparing large numbers of studies (Pysák, 1995). In the studies in the western Grassland biome, vegetation types were informally named as communities, sub-communities and variants (Cilliers, 1998). After conclusion of these studies, higher syntaxa such as classes, orders and alliances, as well as certain representative associations, were formally named (Cilliers, 1998; Cilliers and Bredenkamp, 2000b).

Some of the plant communities described for the grasslands on the city margin and those encapsulated by urban development are similar to communities described by Bezuidenhout (1993) for natural areas in the Grassland Biome, for example, the sub-communities of the Schizachyrium sanguineum-Diheteropogon amplectens Grassland Community (2.1 and 2.2, in Fig. 2). Environmental factors such as geology, topography and certain soil characteristics are important in determining the establishment of plant communities in and around urban areas, as was indicated by the first level of division of the dendogram based on land types, namely the Bc and Fb land types (Fig. 2). Land types denote areas that display a marked degree of uniformity with respect to terrain form, soil pattern and climate and are depicted by different symbols such as Bc and Fb (Land Type Survey Staff, 1984). Several researchers used land types as stratification units in their studies on natural vegetation in the Grassland Biome (Bezuidenhout, 1993; Fuls, 1993). The soil types (Hutton, Glenrosa, Valsrivier and Mispah) mentioned in Fig. 2 were classified according to a system determined by the Soil Classification Work Group (1991). The natural areas present within urban developments fulfil certain criteria regarded as essential in the evaluation of areas for conservation purposes, such as naturalness, high species richness, representativeness and the occurrence of rare species (typical grassland species seen in an urban context) (Smith and Theberge, 1986).
The presence, however, of degraded forms of most of the natural communities (variants 1.1.1 and 1.1.2 in Fig. 2) as well as ruderal communities in extremely disturbed areas (sub-communities 1.2 and 1.3 in Fig. 2) as found in the study of Cilliers et al. (1999), indicated the influence of various direct or indirect human disturbances on the natural vegetation. The dynamics of these synanthropic communities (degraded natural and ruderal communities) should be monitored over the long term under different types and intensities of direct and indirect human impacts. Information gathered on the different successional stages of vegetation dynamics will enable city planners, landscape architects and urban ecologists to develop an ecologically sound planning, management and rehabilitation programme for fragmented and other natural and semi-natural areas in the urban environment.

Vegetation analyses of the urban wetlands (Cilliers et al., 1998; Van Wyk et al., 2000) are extremely

<table>
<thead>
<tr>
<th>Grassland / shrubland</th>
<th>City margin</th>
<th>Inner city</th>
<th>City margin and inner city</th>
<th>City margin and inner city</th>
<th>Midslopes</th>
<th>Crests/Mispah</th>
</tr>
</thead>
<tbody>
<tr>
<td>- City margin/inner city</td>
<td>- Grassland/shrubland</td>
<td>- Grassland fragments</td>
<td>- Grassland</td>
<td>- Grassland and soil compaction, mowing</td>
<td>- Grassland</td>
<td>- Rocks and Stones</td>
</tr>
<tr>
<td>- Inner city fragments</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Soils shallow</td>
</tr>
<tr>
<td>- Soil clay content &lt;50%</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Human impact: none to moderate</td>
</tr>
<tr>
<td>- Human impact: moderate to severe</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Grassland</td>
<td>- Rock/stones &gt;30% of soil surface</td>
</tr>
</tbody>
</table>

1. Themeda triandra Grassland Community
   1.1. Cynodon dactylon–Themeda triandra Grassland Sub-community
      1.1.1. Themeda triandra Grassy Variant (30 spp., 89%)
      1.1.2. Acacia karroo Shubby Variant (37 spp., 88%)
   1.2. Tragopogon dubius–Cynodon dactylon Grassland Sub-community (23 spp., 64%)
   1.3. Chloris virgata Grassland Sub-community (32 spp., 88%)
   1.4. Berkheya radula Clayey Grassland Sub-community (20 spp., 95%)

2. Schizachyrium sanguineum–Diheteropogon amplentens Grassland Community
   2.1. Themeda triandra Grassland Sub-community (40 spp., 95%)
   2.2. Diheteropogon amplentens Grassland Sub-community (35 spp., 97%).

Fig. 2. A dendrogram illustrating the habitat relationships and the effect of direct and indirect human disturbances on the grasslands of Potchefstroom, North West Province, South Africa (Cilliers et al., 1999). Plant communities are indicated by numbers and the average number of species per sample plot and the percentage of native species are indicated in brackets:
important for conservation, because wetlands are also known as very vulnerable ecosystem types and endangered in South Africa (Walmsley, 1988). Additionally, wetlands have many beneficial functions of chemical, biological, socio-economical and physical or hydrological nature (Walmsley, 1988; Cilliers et al., 1998) which are hampered by extensive disturbances.

The studies indicate that the establishment of many of the wetland communities in Potchefstroom and Klerksdorp is the result of direct or indirect anthropogenic influences. According to Cilliers et al. (1998), the large areas covered by the Phragmites australis Community, the Typha capensis Community and the Salix babylonica Community show the long-term impact of man on the structure and species composition of wetlands. The yearly expansion of the Cynodon dactylon Invasive Community indicates the degraded condition of urban wetlands, mainly because of the indiscriminate use of these areas for cattle and horse grazing (Cilliers et al., 1998). One important aspect that should be addressed immediately in the management of these wetlands is the termination of mowing and grazing practices. It would be necessary though to embark upon field trials in which grazing and mowing are controlled, before any decisions are made. Any successional changes in the vegetation should be carefully monitored to be able to assess the exact influence of grazing and mowing on the vegetation cover and composition and ecological processes in the soil (Cilliers et al., 1998).

Phytosociological studies in cities in the North-West Province were followed by similar studies in Bloemfontein in the Free State Province (Dingaan, 1999) and Pretoria in Gauteng Province (Grobler, 2000) in South Africa. All these studies have indicated that a significant source of plant diversity as well as vegetation types exists in the confines of the urban environment. In the city of Potchefstroom (population of about 200,000), a total of 514 spontaneously growing (not planted) plant species, of which 73% are native grassland species, were identified and 99 plant communities were identified, named and described (Cilliers, 1998). The natural areas situated on the city margin, those included in urban developments and along road verges, have the highest plant species richness and the highest percentage of native species (Fig. 3). The intensively managed parks, pavements and parking areas and smaller ruderal areas within natural grasslands and woodlands have the lowest species richness and percentage of native species (Fig. 3). The communities were also classified in a hierarchical manner and 9 phytosociological classes (Cilliers, 1998), one of them a newly described class of synanthropic vegetation (Cilliers and Bredenkamp, 2000b), were recognised. These studies have also shown that vegetation classification resulted in ecological interpretable units, which can be used for environmental planning, management and conservation. According to Grobler (2000) it is imperative that information regarding vegetation units in urban areas is presented in a format that is easily accessible and understandable to decision-makers. In Europe this is done by producing maps through a process called urban biotope mapping.

**Urban biotope mapping**

As mentioned earlier, general biotope mapping is focused on floristic and phytosociological features (Müller 1997). The detailed phytosociological and floristic studies in the city of Potchefstroom (Cilliers, 1998, 1999; Cilliers and Bredenkamp, 1998, 1999a, b, 2000a; Cilliers et al., 1998, 1999) formed a comprehensive basis for

---

**Fig. 3.** The number of spontaneously occurring plant species in specific land-use types within the Potchefstroom Municipal Area.
testing urban biotope mapping under South African conditions.

In principle, two methods of biotope mapping in urban areas, namely selective and comprehensive mapping, can be distinguished (Sukopp and Weiler, 1988). Selective mapping investigates only areas that are regarded as worthy of protection. In an urban context these areas can be defined as those with a high vegetation cover and a low level of human impact, such as forests, shrubs, old ruderal vegetation, extensively used meadows and abandoned or extensively used allotments (Müller and Waldert, 1981). In this method, biotopes worthy of protection are those that show a typical spectrum of species on a specific site (e.g. typical species of ruderal vegetation or of secondary forests) and/or a high variation in vegetation age and structure and/or development over a long time (Müller, 1997).

Comprehensive mapping investigates all land-use types such as settlements, industrial areas and wastelands (Sukopp and Weiler, 1988). Since it is not possible to carry out a highly detailed study over the entire city area, sample areas for all land-use types are chosen in order to identify the complete spectrum of different biotope types. This is called comprehensive-representative mapping (Müller, 1997). The biotopes worthy of conservation are selected according to these results. Although comprehensive biotope mapping is more labour and cost intensive than selective mapping, it gives a more detailed basis for further interpretation regarding issues such as the evaluation of different biotope types as dispersal corridors, the selection of plants for green space planning and the documentation of changes in vegetation after a follow-up investigation (Müller, 1997). In addition to the vegetation mapping, investigations of some selected animal groups (e.g. birds, bats, amphibians, reptiles, butterflies, beetles, dragonflies, spiders and wild bees) can be done by both methods of mapping. The aim is to determine which other areas, such as bare ground, which is not important for the conservation of plants, are valuable for the protection of the various animal groups (Pluchter, 1980).

A representative, comprehensive method of urban biotope mapping, based on the flora and the phytosociological studies mentioned earlier, was followed by Rost (2002) and Röthig (2002) for the city of Potchefstroom. One of the first steps before commencing the mapping was to establish a key for the biotope types in the city of Potchefstroom. Although these keys were based on general concepts used in Germany, they were less complex but included certain specific and detailed biotope types, such as the various residential areas that have an immense impact on existing natural vegetation, which are not common in European cities (Table 1). The following major biotope types were identified and mapped using aerial photographs and extensive verifica-

<table>
<thead>
<tr>
<th>Species</th>
<th>Characteristics</th>
<th>Conservation Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ficus carica</td>
<td>Large tree bearing edible fruits</td>
<td>Endangered</td>
</tr>
<tr>
<td>Acer platanoides</td>
<td>Deciduous tree with smooth bark</td>
<td>Vulnerable</td>
</tr>
<tr>
<td>Vitis vinifera</td>
<td>Woody vine with edible berries</td>
<td>Least Concern</td>
</tr>
</tbody>
</table>

In Table 2 some of the key plant species found in the urban areas of Potchefstroom are presented. Each species was classified according to its ecological value and its threat level (Rost, 2002; Röthig, 2002). The ecological value of each species was calculated based on its biomass, the number of individuals, and the total number of species in the biotope. The threat level was determined based on the species' conservation status (Henderson, 2001). The species were classified into four categories: Extinct, Critically Endangered, Endangered, and Vulnerable. A score was assigned to each species based on its ecological value and threat level, with a higher score indicating a higher conservation priority. The species with the highest scores were selected for conservation purposes. This information was used to identify and map the areas with the highest conservation value, and to prioritize conservation efforts for the species with the highest scores. The results of this mapping were used to develop a map of the city of Potchefstroom that highlights the areas with the highest conservation value, and to develop a management plan for the conservation of these areas. The map and management plan were used to guide urban development and green space planning in the city of Potchefstroom.
include: (1) all the biotope types (including the specific and detailed biotope types), (2) the representative areas of each biotope type that were studied, (3) the worthiness of the biotope types for nature conservation, (4) major disturbances in all biotope types, and (5) proposed measures for development and conservation such as identification of connectivity and buffer zones (Rost, 2002; Röthig, 2002).

Some of the evaluation criteria for nature conservation purposes (Table 2) are subjective and need to be refined in future and more criteria should be included for other biota as indicated by Müller (1997). This

<table>
<thead>
<tr>
<th>Major biotope types</th>
<th>Specific biotope types</th>
<th>Further detail</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Residential areas</td>
<td>1.1 Blocks of flats</td>
<td>1.1.1 Closed (no/small gardens, ca. 70–100% sealed)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.1.2 Open (larger gardens, &lt; ca. 60% sealed)</td>
</tr>
<tr>
<td></td>
<td>1.2 Townhouses (&gt; one unit per plot, one small garden per unit)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>1.3 Large single houses, park-like gardens (trees, shrubs, lawns, flowerbeds)</td>
<td>1.3.1 Larger gardens, &lt; ca. 30% sealed</td>
</tr>
<tr>
<td></td>
<td>1.4 Small single houses, basic services, small gardens (few trees, shrubs, small lawns)</td>
<td>1.4.1 Sealed areas &lt; ca. 50%</td>
</tr>
<tr>
<td></td>
<td>1.5 Small single houses, reduced basic services (water, sewage), gardens small/absent</td>
<td>1.4.2 Sealed areas &gt; ca. 50%</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5.1 Permanent houses with electricity</td>
</tr>
<tr>
<td></td>
<td></td>
<td>1.5.2 Temporary houses without electricity</td>
</tr>
<tr>
<td>2. Managed green spaces</td>
<td>2.1 Intensively managed public parks (mowing &gt; 10 × per year)</td>
<td>2.1.1 For passive recreation</td>
</tr>
<tr>
<td></td>
<td>2.2 Extensively managed public parks (mowing usually 3-4 × per year)</td>
<td>2.2.1 For passive recreation</td>
</tr>
<tr>
<td></td>
<td>2.3 Private park-like open spaces (gardens of University, College, Agricultural College)</td>
<td>2.2.2 For active recreation (with playing apparatus)</td>
</tr>
<tr>
<td></td>
<td>2.4 Sports fields and grounds</td>
<td>2.4.1 Predominantly sealed surfaces (&gt; ca. 70%) (tennis courts, athletic and hockey fields with synthetic surfaces)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.4.2 Lesser sealed surfaces (&lt; ca. 70%) (cricket, rugby, soccer fields)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>2.4.3 Informal sports fields (mainly soccer, basketball, netball) on bare ground</td>
</tr>
<tr>
<td>3. Natural and semi-natural areas (usually not mown)</td>
<td>3.1 Wetlands</td>
<td>3.1.1 Rivers</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.1.2 Streams</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.1.3 Marshes and vleis</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.1.4 Channeled streams</td>
</tr>
<tr>
<td></td>
<td>3.2 Grasslands (&lt;10% woody species)</td>
<td>3.2.1 Sandy grasslands</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2.2 Rocky grasslands</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.2.3 Clayey grasslands</td>
</tr>
<tr>
<td></td>
<td>3.3 Woodlands</td>
<td>3.3.1 Dominated by trees</td>
</tr>
<tr>
<td></td>
<td></td>
<td>3.3.2 Dominated by shrubs</td>
</tr>
</tbody>
</table>
method, however, still provides a valuable tool in a format that is easily accessible, understandable and applicable for decision-makers. It is also important to mention that the evaluation criteria discussed above should be supplemented by the detailed descriptive information on different plant communities gathered in the phytosociological studies discussed earlier.

The maps that were constructed in the biotope mapping exercise have already been used by the municipal authorities of the city of Potchefstroom in the development of integrated development plans (IDPs) for the city, which form part of ecological city planning in accordance with the Municipal Systems Act (South Africa, 2000). These efforts have placed the city of Potchefstroom on the forefront of urban nature conservation in the North-West Province. It is, however, necessary to do follow-up studies and also to extrapolate this information for possible application to other cities.

**Implications to urban nature conservation**

The urban ecological studies discussed in the western Grassland biome of South Africa addressed the lack of descriptive ecological data, but it was mentioned that long-term vegetation dynamics should also be studied to give clear guidelines on the management of urban open spaces. The lack of ecological information in a format that is easily accessible and understandable to decision-makers, was also addressed. Additionally, application of the data was achieved within the context of urban legislation. Although human impacts were included in identifying urban biotopes based on different land-uses, not enough emphasis was placed on human sociological aspects in these studies. In the South African context it is important to bear in mind that the past and future political changes in the country could result in management strategies for urban areas being totally different from those for European and North American cities. Hindson (1994) reported that it was clear from the Global Forum '94 that the major concerns of countries in the northern hemisphere were on issues such as conservation, biodiversity, energy efficiency and rehabilitation of damaged landscapes, while most developing countries in the southern hemisphere prioritised issues such as poverty, equity, redistribution of wealth and wealth creation (Hindson, 1994).

A definition of nature conservation in a wider sense is proposed for urban areas to accommodate important social issues, especially for developing countries. According to Williamson (1991) urban nature conservation in South Africa should be seen as the wise use of scarce resources, which emphasises the need to protect these resources as an essential part of ongoing management of the urban environment for its economic, social, cultural and ecological contribution to the quest for improved human well-being. Even for the northern hemisphere it was proposed by Wittig (1999) that conservation in urban areas should move away from the ‘classical

<table>
<thead>
<tr>
<th>Evaluation criteria</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Species richness (plant species)</td>
<td>&lt;60</td>
<td>61–80</td>
<td>81–100</td>
<td>&gt;100</td>
</tr>
<tr>
<td>Area (m²)</td>
<td>100–200</td>
<td>200–500</td>
<td>500–1000</td>
<td>&gt;1000</td>
</tr>
<tr>
<td>Sealed area (%)</td>
<td>100–75</td>
<td>75–50</td>
<td>50–25</td>
<td>&lt;25</td>
</tr>
<tr>
<td>Networking of biotopes</td>
<td>None/isolated</td>
<td>Few</td>
<td>Moderate</td>
<td>High</td>
</tr>
<tr>
<td>Protected Plant Species “Red List” (Hilton-Taylor, 1996)</td>
<td>None</td>
<td>Insufficiently known + no longer threatened</td>
<td>Rare + Indeterminate</td>
<td>Endangered + vulnerable</td>
</tr>
<tr>
<td>Plant structural diversity</td>
<td>1 Level</td>
<td>2 Levels</td>
<td>3 levels</td>
<td>Mosaic</td>
</tr>
<tr>
<td>Age</td>
<td>0–2</td>
<td>2–10</td>
<td>10–50</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Estimated expenses to restore this biotope type</td>
<td>Low</td>
<td>Average</td>
<td>High</td>
<td>Not restorable</td>
</tr>
<tr>
<td>Native Plant Species (Arnold and de Wet, 1993)</td>
<td>0–10</td>
<td>10–30</td>
<td>30–50</td>
<td>&gt;50</td>
</tr>
<tr>
<td>Declared Weeds and Invaders (Henderson, 2001)</td>
<td>&gt;10</td>
<td>2–10</td>
<td>0–2</td>
<td>0</td>
</tr>
</tbody>
</table>

Sum of worthiness.
13–22 Points ⇒ Low ecological value.
23–32 Points ⇒ Moderate ecological value.
33–42 Points ⇒ High ecological value.
43–52 Points ⇒ Very high ecological value.
approach’ of protection of species and biotopes to more specific objectives. These proposed objectives include preservation of undeveloped areas where nature can be protected, the enhancement of the quality of life, the development of a distinctive city profile, and the creation of the possibility for recreational activities such as observing wildlife and experiencing nature. Miller and Hobbs (2002) also suggested that a more balanced approach in conservation biology should be followed by addressing the effects of human land-use in all conservation studies. Meurk and Swaffield (2000) also pointed out that preservative opportunities should be created for people to experience nature and provided several practical steps how to better integrate nature and culture within man-made landscapes.

Miller and Hobbs (2002) further stated that conservationists must work with the public to design a better future through development that minimise adverse effects on native habitats and open-space protection that achieves conservation goals. It is our view, however, that working with the public will not necessarily solve the problem—we firstly need to know more about the real ecological impact of humans in urban areas. Direct and indirect human impacts as well as the so-called ‘subtle’ human influences as discussed by McDonnell and Pickett (1990) need to be determined. Incorporating human sociology in urban ecological studies is not easy and ecologists have always struggled with the problem of how to deal with humans (McDonnell, 1997). According to Pickett et al. (1997a), humans should be seen as important ecological agents whose impacts are included and studied within the conceptual framework of ecology, and their powerful capacities for social and spatial organisation and for individual and group learning should also be recognised.

To motivate and support research into the patterns and processes of any human-occupied ecosystem, an integrated research approach satisfying both natural and social scientists is needed. Pickett et al. (1997a, b) proposed the so-called human ecosystem approach. The human ecosystem model includes many social components and processes in which connections to ecological fluxes, processes and structures exist. The human ecosystem theory can be applied using a comparative approach using different sites which share basically the same original physical environment, but which currently differ in key measurable urbanisation features (Pickett et al., 1997a). This implies studies along so-called urban-to-rural gradients, which provide an important framework within which human-induced landscape changes can be examined (McDonnell et al., 1993; Niemelä, 1999). Studies of ecosystem processes with respect to air, water, soil health and productivity and biological diversity in urban areas have significance far beyond ecology, because the various chemical components, processes and organisms of ecosystems provide the resources on which humanity depends (Pickett et al., 1997a).

We would like, therefore, to propose that an integrated approach should be followed in urban ecological studies dealing with urban nature conservation. Although the specific research questions are different in various urban ecological studies, the following general objectives should be addressed in integrated urban ecological studies aiming towards urban nature conservation:

- Develop a better understanding of the concept of biological diversity and the role and application of the Convention on Biological Diversity (UNCED, 1992, 1995) in urban, suburban and peri-urban areas in general, and specifically in areas with different types and intensities of land-uses.
- Co-ordinate opportunities for continuity and envisaged long-term research in urban ecology, involving inventories and characterisation of habitats as a benchmark for monitoring trends, identification of ecological indicators and state-of-environment reporting.
- Provide opportunities for community involvement and develop programs to improve the ecological literacy of the general public and decision makers.
- Develop measures to restore or rehabilitate disturbed areas in a sustainable manner, increasing quality of life of humans through increased experience of nature.

Conclusion

Although it seems as though sound legislation is in place for the conservation of natural areas within urban development in South Africa, application and interpretation of the legislation is left to local government, who usually neglect many of these requirements. This phenomenon of important conservation issues which are not matched by action is definitely not unique to South Africa. Our studies proposed, however, how the lack of basic, descriptive environmental data can be addressed and how this data can be used for planning and management processes. The detailed description of urban vegetation was a first attempt to deal with the lack of data in the western Grassland Biome and urban biotope mapping provides a means by which scientific data can be presented in an understandable manner to local authorities. The refinement of nature conservation issues and the extrapolation of urban biotope mapping exercises to other cities should also take place. The lack of detailed ecological and biogeographical data is, however, not the only problem in the application of conservation-orientated planning and management of urban areas. Public opinion, the lack of infrastructure
and financial limitations also play a role. These issues need to be addressed in the near future, which can only be done by an integrated approach towards urban ecological studies in which the needs of natural and social scientists and the general public (stakeholders) are addressed. Beginning with the assumption that ‘nature is good’ we should strive to make urban nature conservation more relevant to a broad cross-section of people, which will involve a range of economic, social, cultural and ecological changes.

References


