

# Conservation value of the Egoli Granite Grassland, an endemic grassland in Gauteng, South Africa

G.J. BREDEKAMP, L.R. BROWN and M.F. PFAB

Bredenkamp, G.J., L.R. Brown and M.F. Pfab. 2006. Conservation value of the Egoli Granite Grassland, an endemic grassland in Gauteng, South Africa. *Koedoe* 49(2): 59–66. Pretoria. ISSN 0075-6458.

Gauteng is the most densely populated province in South Africa. Its remaining natural areas are constantly under threat from urban development and the associated impacts. Presently, the natural areas of Gauteng support a large diversity of ecosystems. One such ecosystem is the Egoli Granite Grassland, endemic to the province, poorly conserved and therefore highly threatened. This paper describes the original Egoli Granite Grassland and the anthropogenic *Hyparrhenia hirta* dominated grassland that has replaced it in many of the remnant areas. Human impacts on this sensitive ecosystem have resulted in an altered species composition, loss of many species, and a change from a species-rich grassland with high conservation value to a species-poor grassland with low conservation value. The conservation of the last remaining relicts of original Egoli Granite Grassland is essential.

Keywords: Egoli Granite Grassland; conservation value; *Hyparrhenia hirta*, Gauteng.

*G.J. Bredenkamp, African Vegetation and Plant Diversity Research Centre, University of Pretoria; L.R. Brown, Applied Behavioural Ecology and Ecosystem Research Unit, University of South Africa; M.F. Pfab, Bioregional Planning, Gauteng Department of Agriculture, Conservation and Environment, Johannesburg, 2001 South Africa.*

## Introduction

The Egoli Granite Grassland is a type of grassland and a mapping unit (Gm10) classified under the Mesic Highveld Grassland Bioregion according to the new Vegetation Map of South Africa, Lesotho and Swaziland (Mucina *et al.* 2005). This grassland was mapped as Bankenveld (veld type 61) by Acocks (1988), and Rocky Highveld Grassland (Vegetation Type 34) by Bredenkamp & Van Rooyen (1996). Acocks (1988) describes the Bankenveld as a False Grassveld Type. The climax vegetation of this veld type should be, according to Acocks, an open savanna, that is a bushveld vegetation, but it has been changed to, and maintained as grassveld by regular veld fires. However, Bredenkamp & Brown (2003) consider Bankenveld vegetation as a mosaic of grassland and woodland communities controlled by (micro-)climatic conditions that exist in the topographically heterogeneous landscape

in the transition zone between the Grassland and Savanna biomes.

From a conservation planning or urban development viewpoint, the range of structural and floristic variation is considered too large to define Bankenveld as a single unit, even on the reconnaissance level of vegetation investigation. Bredenkamp & Brown (2003) recognised 16 major vegetation types within Bankenveld. The Egoli Granite Grassland is considered as mainly belonging to the *Hyparrhenia hirta* Anthropogenic Grassland (Bredenkamp & Brown 2003).

Egoli Granite Grassland is restricted to the Gauteng Province of South Africa and is located north of the Roodepoort / Krugersdorp ridge complex and stretches over a distance of approximately 35 km to Centurion in the north. This grassland stretches over a distance of approximately 50 km in a westerly direction from the R21 highway in the east. The 28° longitude and 26° latitudi-

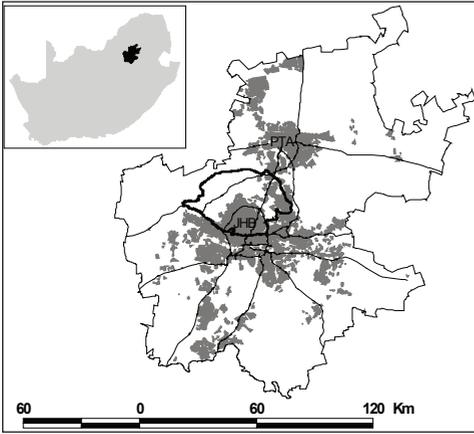


Fig. 1. Locality map of the Egoli Granite Grassland. Grey areas indicate urbanisation

nal lines cross in the centre of this grassland (Fig. 1).

Due to high demand for developable land in Gauteng, and especially the Johannesburg / Pretoria corridor, the Egoli Granite Grassland is under extreme pressure. Large areas are already developed for residential, industrial and commercial purposes. This has led to the destruction of vast tracts of this grassland. At least 61% of Egoli Granite Grassland has been permanently transformed: 27% by urban development (Fig. 2); 17% by smallholdings; 12% by agriculture (cultivated lands); and 5% by other impacts such as exotic plantations, mining and planted pastures. An estimated additional 17% of Egoli Granite Grassland is degraded due to overgrazing and the influence of edge effects associated with a highly fragmented landscape (Fahrig 2003). Other effects, such as trampling, increased pollutants and the infestation of weeds and alien species also contribute to degradation of this grassland. It is therefore highly likely that the national target for conservation of this grassland type, i.e., 25% of the total extent, will never be realised.

Egoli Granite Grassland is extremely poorly conserved, with only 0.02% (26 ha) of the vegetation type currently protected, includ-

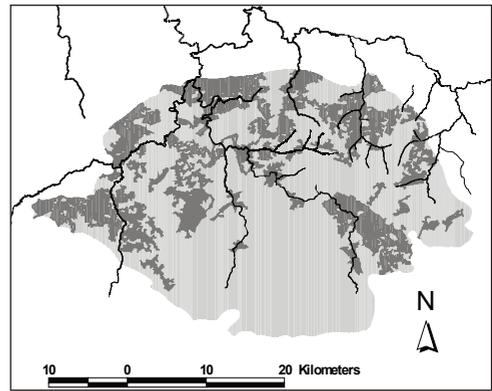


Fig. 2. Dark gray represents remnant areas of potentially original Egoli Granite Grassland; perennial rivers shown.

ing 3 ha in Glen Austin Bird Sanctuary, 3 ha in Melville Koppies Nature Reserve, 9 ha in Ruimsig Nature Reserve, and 11 ha in the Walter Sisulu Botanical Gardens (Fig. 2). The current protection status of Egoli Granite Grassland is therefore completely inadequate, with only 0.1% of the national target actually achieved. In order to meet South Africa's international obligations, it is imperative that the Gauteng provincial government put in place measures to improve the conservation status of Egoli Granite Grassland.

Any viable remnant patch of original Egoli Granite Grassland must therefore be protected from transforming land uses. In order to assess whether a valuable remnant patch will be affected by a proposed development, environmental consultants involved in vegetation impact assessments are required by the Gauteng Department of Agriculture, Conservation and Environment (GDACE) to assess the presence and condition of Egoli Granite Grassland on any site proposed for development.

As this grassland was only recently defined with the development of the new Vegetation Map of South Africa, Lesotho and Swaziland (Mucina *et al.* 2005), very little information on its floristic composition, condition, the

extent of the grassland, and the management thereof exists, causing some confusion among nature conservationists, environmental consultants and local authorities. The aim of this paper is therefore to provide an ecological overview of this grassland.

## Physical Environment

This area is generally characterised by rocky undulating plains representing crests, slopes and valley bottoms with shallow, nutrient-poor soils. Shallow drainage lines and vleilike wetland areas occur in the valley bottoms. Rockiness of the soil surface is a further common characteristic shared by most Bankenveld areas.

Mean monthly temperature in the study area is 16.8 °C with a mean maximum of 22.6 °C and a mean minimum of 10.8 °C. The mean winter temperature is 13.8 °C and mean summer temperature, 25.6 °C (Weather Bureau 2000; Grobler *et al.* 2002). Mean annual rainfall in Gauteng is 670 mm (Gauteng 1997).

Old granitic and gneissic rocks at least 2400 million years old (Kerfoot 1987) are exposed in the Egoli Granite Grassland area. The Halfway House Granites (Fig. 3) of the Johannesburg Dome are intensively weathered with deep drainage lines resulting in a gently rolling topography, with shallow, coarse, nutrient-poor, well-drained soils. The granite areas are mostly covered by grassland vegetation though patches of woodland vegetation are found at sheltered sites on hillslopes and rocky outcrops within this veld type (Grobler 2000; Grobler *et al.* 2002, 2006).

The Bb land type predominates over the entire region (Land Type Survey Staff 1984, 1985, 1987) (Fig. 3). The residual granitic soils are very shallow and poorly drained. The A horizon is often sandy and light in colour with little organic matter and with an increase in clay content with depth. The soils are invariably acid and very rich in silica (Kerfoot 1987).

## Vegetation

### Current vegetation

This tall grassland occurs over vast areas, usually on shallow, leached soils on the Johannesburg Granite Dome. Disturbed grassland or other disturbed areas such as road reserves or old fields, not cultivated for some years, are also usually *Hypparrhenia* species-dominated and low in species richness. Although some of these tall grasslands appear to be quite natural, they are mostly associated with an anthropogenic influence from recent or even iron-age times.

These grasslands are characterised by the tall-growing dominant grass *Hypparrhenia hirta* and the invader dwarf shrub *Seriphium plumosum* (= *Stoebe vulgaris*), indicating its low successional status or degraded condition.

Dense *Hypparrhenia* species-dominated grassland mostly has low species richness, with only a few other species able to establish or survive in the shade of the dense sward of tall grass. Most of these species are relict pioneers or early seral species. The most prominent species include the grasses *Cynodon dactylon*, *Eragrostis chloromelas*, *E. racemosa*, *E. curvula* and *Aristida congesta*. Forbs are rarely encountered, though a few individuals of species such as *Anthospermum hispidulum*, *Pseudognaphalium luteo-album*, *Conyza albida*, *C. podocephala*, *Crabbea angustifolia*, *Helichrysum nudifolium* and *H. rugulosum* are often present. The woody layer, which has a very low cover, consists of small clumps of indigenous trees and shrubs widely scattered within this grassland. The scanty woody species include the trees *Rhus pyroides* and *Ziziphus mucronata*, together with the scandent shrub *Ziziphus zeyheriana*. Declared alien invasive species such as *Melia azedarach*, *Eucalyptus* species, *Pinus* species and planted ornamentals are often present.

Typical species found in anthropogenic *Hypparrhenia hirta*-dominated Egoli Granite Grassland are indicated below:

- Trees and Shrubs

*Acacia caffra* (Thunb.) Willd.  
\**Eucalyptus* species  
*Gymnosporia buxifolia* L. Szysyal  
\**Melia azedarach* L.  
*Olea europaea* L. ssp. *africana* (Mill.) P.S.Green  
\**Pinus* species  
*Rhus lancea* L.f.  
*Rhus leptodictya* Diels  
*Rhus pyroides* Burch.  
*Ziziphus mucronata* Willd.  
*Ziziphus zeyheriana* Sond.

- Grasses

*Aristida bipartita* (Nees) Trin. & Rupr.  
*Aristida canescens* Henrard  
*Aristida congesta* Roem. & Schult. ssp. *barbicollis*  
(Trin. & Rupr.) De Winter  
*Aristida congesta* Roem. & Schult. ssp. *congesta*  
*Cynodon dactylon* (L.) Pers.  
*Diheteropogon amplexans* (Nees) Clayton  
*Elionurus muticus* (Spreng.) Kunth  
*Eragrostis chloromelas* Steud.  
*Eragrostis curvula* (Schrad.) Nees  
*Eragrostis gummiflua* Nees  
*Eragrostis plana* Nees  
*Eragrostis racemosa* (Thunb.) Steud.  
*Eragrostis rigidior* Pilg.  
*Heteropogon contortus* (L.) Roem. & Schult.  
*Hyparrhenia filipendula* (Hochst.) Stapf  
*Hyparrhenia hirta* (L.) Stapf  
*Melinis repens* (Willd.) Zizka  
*Pogonarthria squarrosa* (Roem. & Schult.) Pilg.  
*Sporobolus africanus* (Poir.) Robyns & Tournay  
*Trichoneura grandiglumis* (Nees) Ekman

- Forbs

*Acalypha angustata* Sond.  
*Anthospermum hispidulum* E.Mey. ex Sond.  
*Asparagus larinicus* Burch.  
*Asparagus suaveolens* Burch.  
*Bidens formosa* (Bonato) Sch.Bip.  
*Bidens pilosa* L.  
*Chamaecrista mimosoides* (L.) Greene  
*Cirsium vulgare* (Savi) Ten.  
*Commelina africana* L.  
*Conyza albida* Spreng.  
*Cucumis zeyheri* Sond.  
*Cyperus* species  
*Elephantorrhiza elephantina* (Burch.) Skeels  
*Felicia muricata* (Thunb.) Nees  
*Gazania krebsiana* Less.  
*Geigeria burkei* Harv.  
*Gomphocarpus fruticosus* (L.) Aiton f.  
*Helichrysum nudifolium* (L.) Less.  
*Helichrysum rugulosum* Less.  
*Hermannia depressa* N.E.Br.  
*Hibiscus aethiopicus*  
*Hypoxis rigidula*  
*Lactuca* species  
*Ledebouria marginata* (Baker) Jessop

*Nidorella hottentotica* DC.  
*Pseudognaphalium luteo-album* (L.) Hilliard &  
B.L.Burt  
*Schkuhria pinnata* (Lam.) Cabrera  
*Seriphium plumosum* L.  
*Tagetes minuta* L.  
*Verbena bonariensis* L.  
*Verbena brasiliensis* Vell.  
*Vernonia oligocephala* (DC.) Sch.Bip. ex Walp.  
*Walafrida densiflora* (Rolfe) Rolfe  
*Zinnia peruviana* (L.) L.

*Original vegetation*

The original vegetation is thought to be typical Bankenveld (Acocks 1988) or Rocky Highveld Grassland (Bredenkamp & Van Rooyen 1996). Bredenkamp & Brown (1998) found a few relict sites which indicate that the original vegetation on the shallow granitic soils of the Johannesburg Granite Dome could have been a variant of the *Monocymbium ceressiforme-Loudezia simplex* Grassland (Bredenkamp & Brown 2003). This vegetation is found in areas where little or no disturbance is evident.

The herbaceous layer covers approximately 80% and is dominated by the grasses *Loudezia simplex*, *Trachypogon spicatus*, *Schizachyrium sanguineum*, *Monocymbium ceresiiforme*, *Digitaria monodactyla*, *Eragrostis racemosa*, *Andropogon shirensis*, *Brachiaria serrata*, *Alloteropsis semialata*, *Bewsia biflora* and *Themeda triandra*.

The woody layer consists mainly of a few scattered individuals of the trees *Rhus pyroides*, *R. leptodictya*, *Ziziphus mucronata*, the dwarf shrubs *Protea welwitschii*, *Lopholaenia coriifolia*, and the geoxylphyte *Parinari capensis* that are locally prominent. The grasses *Panicum natalense*, *Urelytrum agropyroides*, *Tristachya leucothrix*, *Cymbopogon excavatus* and *Elionurus muticus* are also abundant together with the forbs *Cyanotis speciosa*, *Bulbostylis burchellii*, *Crabbea acaulis*, *Anthospermum hispidulum* and *Senecio venosus*. The grass *Hyparrhenia hirta* is often present and may become more prominent at disturbed sites.

This grassland is characterised by a high species richness with a patchy dominance of

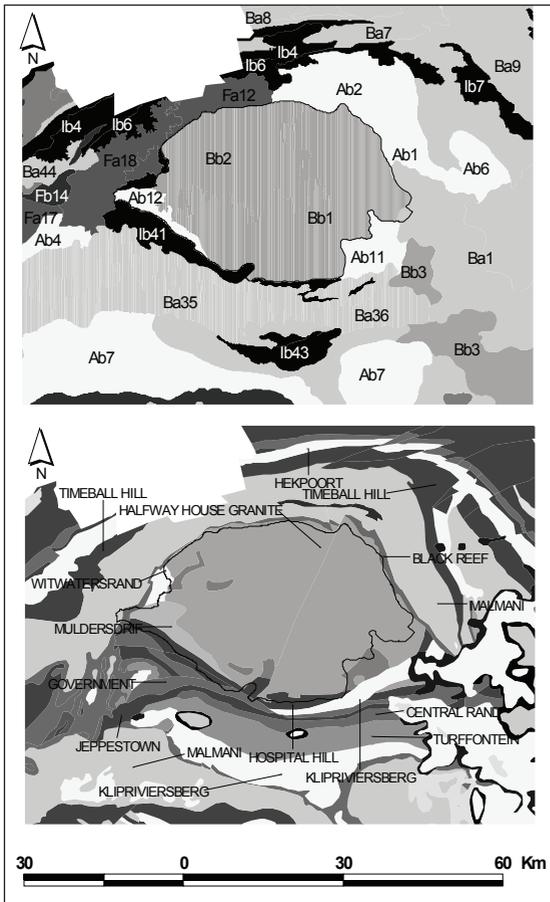


Fig. 3. Land Types (above) and Geology (bottom) within the Egoli Granite Grassland

various grass species and a large variety of forbs (Louw 1970), representing a climax or close to climax condition. Grazing by cattle is often found in this vegetation type, but the dominance of sour grass species often results in a low nutrient status of the grass during winter (Kerfoot 1987; Bredenkamp & Van Rooyen 1996).

Typical species found in the original Egoli Granite Grassland are indicated below:

- Trees and shrubs

- Acacia caffra* (Thunb.) Willd.
- Celtis africana* Burm.f.
- Elephantorrhiza elephantina* (Burch.) Skeels
- Gymnosporia buxifolia* L. Szysyal

- Olea europaea* L. ssp. *africana* (Mill.) P.S.Green
- Rhus lancea* L.f.
- Rhus leptodictya* Diels
- Rhus pyroides* Burch.
- Ziziphus mucronata* Willd.
- Ziziphus zeyheriana* Sond.

- Grasses

- Andropogon schirensis* A.Rich.
- Aristida adscensionis* L.
- Aristida canescens* Henrard
- Aristida congesta* Roem. & Schult. ssp. *congesta*
- Brachiaria serrata* (Thunb.) Stapf
- Cymbopogon excavatus* (Hochst.) Stapf ex Burt Davy
- Cymbopogon pospischilli* (K.Schum.) C.E. Hubb
- Cynodon dactylon* (L.) Pers.
- Digitaria brazzae* (Franch.) Stapf
- Diheteropogon amplexens* (Nees) Clayton
- Elionurus muticus* (Spreng.) Kunth
- Eragrostis chloromelas* Steud.
- Eragrostis curvula* (Schrad.) Nees
- Eragrostis racemosa* (Thunb.) Steud.
- Harpochloa falx* (L.f.) Kuntze
- Heteropogon contortus* (L.) Roem. & Schult.
- Hyparrhenia hirta* (L.) Stapf
- Melinis repens* (Willd.) Zizka
- Monocymbium cereisiiforme* (Nees) Stapf
- Panicum natalense* Hochst.
- Schizachyrium sanguineum* (Retz.) Alston
- Sporobolus pectinatus* Hack.
- Themeda triandra* Forssk.
- Trachypogon spicatus* (L.f.) Kuntze
- Trichoneura grandiglumis* (Nees) Ekman
- Tristachya leucothrix* Nees
- Tristachya rehmannii* Hack

- Forbs

- Acalypha angustata* Sond.
- Aloe transvaalensis* Kuntze
- Aloe greatheadii* Schönland
- Anthericum* species
- Anthospermum hispidulum* E.Mey. ex Sond.
- Asparagus suaveolens* Burch.
- Aster bakeranus* Burt Davy ex C.A.Sm.
- Babiana hypogaea* Burch.
- Becium obovatum* (E.Mey. ex Benth.) N.E.Br.
- Blepharis subvolubilis* C.B.Clarke
- Boophane disticha* (L.f.) Herb.
- Bulbostylis hispidula* (Vahl) R.W.Haines
- Chascanum hederaceum* (Sond.) Moldenke var. *hederaceum*
- Chaetacanthus burchellii* Nees
- Chlorophytum fasciculatum* (Baker) Kativu
- Crabbea acaulis* N.E.Br.
- Crabbea angustifolia* Nees
- Crassula capitella* Thunb. ssp. *capitella*
- Crinum bulbispermum* (Burm.f.) Milne-Redh. & Schweick.

*Cucumis zeyheri* Sond.  
*Dicoma anomala* Sond.  
*Eriosema cordatum* E.Mey.  
*Eulophia* species  
*Felicia muricata* (Thunb.) Nees  
*Gladiolus crassifolius* Baker  
*Gnidia capitata* L.f.  
*Haplocarpha scaposa* Harv.  
*Helichrysum aureonitens* Sch.Bip.  
*Helichrysum miconiifolia* Hilliard  
*Helichrysum nudifolium* (L.) Less.  
*Hermannia depressa* N.E.Br.  
*Hypericum aethiopicum* (Bret.) N.K.B.  
*Hypericum lalandii* Choisy  
*Hypoxis hemerocallidea* Fisch. & Mey.  
*Hypoxis multiceps* Buchinger ex Baker  
*Hypoxis rigidula* Baker  
*Ipomoea obscura* (L.) Ker Gawl.  
*Ipomoea ommaneyi* Rendle  
*Justicia anagalloides* (Nees) T.Anderson  
*Kohautia amatymbica* Eckl. & Zeyh.  
*Ledebouria ovatifolia* (Baker) Jessop  
*Ledebouria marginata* (Baker) Jessop  
*Lotononis foliosa* Bolus  
*Mariscus congestus* (Vahl) C.B.Clarke  
*Neorautanenia ficifolius* (Benth.) C.A.Sm.  
*Pentanisia angustifolia* (Hochst.) Hochst.  
*Pentanisia prunelloides* Klotzsch ex Eckl. & Zeyh.) Walp.  
*Raphionacme hirsuta* (E.Mey.) R.A.Dyer ex E.Phillips  
*Scabiosa columbaria* L.  
*Schistostephium crataegifolium* (DC.) Fenzl ex Harv.  
*Senecio venosus* Harv.  
*Tephrosia capensis* (Jacq.) Pers.  
*Triumfetta sonderi* Ficalho & Hiern  
*Tulbaghia acutiloba* Harv.  
*Turbina oblongata* (E.Mey. ex Choisy) A.Meeuse  
*Ursinia nana* DC.  
*Vernonia natalensis* Sch.Bip. ex Walp.  
*Vernonia oligocephala* (DC.) Sch.Bip. ex Walp.

### *Origin of the current vegetation*

The shallow, nutrient-poor soils provide a habitat suited to the climax vegetation as discussed previously. Some nutrients are available in the topsoil, supplemented from fallen leaf litter and decomposition, and also from ashes of burned herbaceous layer (if there was a fire). Nutrients are quickly utilised by plants and are furthermore also quickly leached from the very coarse sandy soils. Nutrient cycling is therefore very rapid.

The system is quite stable and fairly predictable without much change caused by normal droughts or grazing. However, if overgrazed

or disturbed to such an extent that degradation proceeds beyond a threshold, then recovery is very slow, due to reduced nutrient cycling and decreased nutrient availability and the vegetation may change to another domain of attraction (Bosch 1989), different from the original climax vegetation, representing a plagioclimax (Fig. 4). A change back to the original domain of attraction is unlikely if not impossible in the short and medium term. Due to the granitically derived shallow nutrient poor soils these systems are sensitive and intolerant to frequent impacts such as heavy grazing, ploughing, trampling and general domestic activities. Thus degradation occurs easily resulting in a change from the climax (high species richness) vegetation to an anthropogenic *Hyparrhenia hirta* (low species richness) dominated vegetation type.

Very often *Hyparrhenia* species-dominated grasslands occur on ancient lands in the Central Variation of the Bankenveld (Acocks 1988) and in the surroundings of archaeological sites (Bredenkamp & Brown 2003), where the inhabitants had a mosaic of cultivated lands and grazing of domestic stock. The more recent European settlers also had a profound effect on the natural vegetation as they developed the cities of Johannesburg and Pretoria following the discovery of gold more than a century ago. It seems that the degraded sites developed into *Hyparrhenia* species-dominated grasslands, which tend to be stable for a very long time. Moll (1965) and Smits *et al.* (1999) also indicated that *Hyparrhenia* species-dominated tall grasslands are anthropogenic in origin.

### *Importance*

The substrate of the Johannesburg Granite Dome (Halfway House Granites, Fig.3) is suitable for development. The area is well situated between Johannesburg, the economic powerhouse of South Africa, and Pretoria the administrative capital of the country. There is an enormous demand for developable land in this area, which has resulted in the loss of large tracts of the original Egoli Granite Grassland. Due to general disturbance, ploughing and degradation, an esti-

mated 60% of the remaining original Egoli Granite Grassland has been transformed to *Hyparrhenia hirta* dominated grassland. Only relatively small scattered pockets of the original grassland are still intact and these are considered rare and highly threatened. Due to its high species richness and restricted occurrence, this endemic grassland has a high conservation value.

Furthermore, the bottomland areas and wetlands within the Egoli Granite Grassland provide suitable habitat for various sensitive fauna species such as the Grass Owl *Tyto capensis* (Red Listed), Marsh Sylph *Metisella meninx* (Vulnerable), and the Giant Bullfrog *Pyxicephalus adspersus* (Near Threatened).

## Conclusion

Egoli Granite Grassland is a poorly conserved, severely transformed, highly fragmented and degraded vegetation type. It is estimated that only 22% of the original extent of Egoli Granite Grassland remains in its original state. Many of these remnant areas are likely to be destroyed in the near future due to previously authorised developments (e.g. Cosmo City to the north-west of Johannesburg) or illegal activities. It is therefore essential that any viable remnant patch of original Egoli Granite Grassland is conserved.

Areas associated with transformed grassland, where *Hyparrhenia hirta* is dominant and species richness is low, have a low value with respect to achieving the national conservation target for Egoli Granite Grassland. It should be noted however, that *Hyparrhenia hirta* dominated grassland may be valuable for the conservation of sensitive fauna, e.g. Grass Owl (*Tyto capensis*) and Giant Bullfrog (*Pyxicephalus adspersus*).

A mixture of various grasses and high forb diversity renders the original Egoli Granite Grassland with a high conservation value and conservation of remnant areas is especially

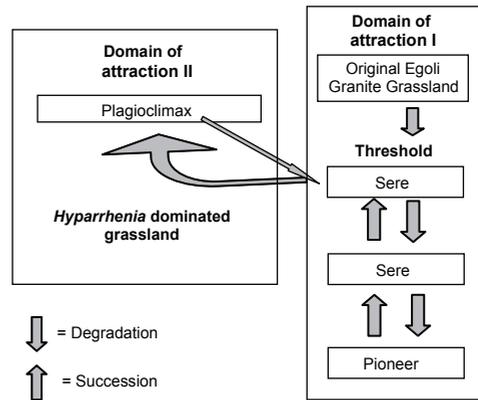


Fig. 4. A model indicating degradation of original Egoli Granite Grassland climax and succession towards a *Hyparrhenia hirta* dominated vegetation type.

important since it is unlikely that the transformed anthropogenic grassland will return to the original climax vegetation.

Since Egoli Granite Grassland is endemic to Gauteng, its protection is both a provincial and national priority. It also forms part of a global ecoregion in crisis, an area where biodiversity and ecosystem services are at greatest risk and focused on-the-ground conservation action are required (Hoekstra *et al.* 2005).

## References

- ACOCKS, J.P.H. 1988. Veld types of South Africa. 3rd ed. *Memoirs of the botanical Survey of South Africa* 57: 1–146.
- BARNES, K.N. (ed.) 2000. *The Escom Red Data Book of Birds of South Africa, Lesotho and Swaziland*. Johannesburg: BirdLife South Africa.
- BOSCH, O.J.H. 1989. Degradation of the semi-arid grasslands of southern Africa. *Journal of Arid Environments* 16: 165–175.
- BREDENKAMP, G.J & L.R. BROWN. 1998. A vegetation assessment of the northern areas of the Northern Metropolitan local Council. Pretoria: Ekotrust cc. Unpublished report.
- BREDENKAMP, G.J & L.R. BROWN. 2003. A reappraisal of Acocks' Bankenveld: origin and diversity of vegetation types. *South African Journal of Botany* 69(1): 7–26.

- BREDENKAMP, G.J. & N. VAN ROOYEN. 1996. Rocky Highveld Grassland. P. 39. In: LOW, A.B. & A.G. REBELO (eds.). *Vegetation of South Africa, Lesotho and Swaziland*. Pretoria: Department of Environmental Affairs & Tourism.
- FAHRIG, L. 2003. Effects of habitat fragmentation on biodiversity. *Annua. Review of Ecology Evolution and Systematics* 34: 487–515.
- GAUTENG, 1997. State of the Environment in Gauteng: A preliminary report. Gauteng Department of Agriculture, Conservation and Environment. Unpublished report, CSIR Environmentek.
- KERFOOT, O. 1987. The geology, physiography and vegetation of the Witwatersrand floral region. Pp. 1-7. In: LOWREY, T.K. & S. WRIGHT (eds.). *The flora of the Witwatersrand* Volume 1: The Monocotyledonae. Johannesburg: Witwatersrand University Press.
- GROBLER, C.H. 2000. The vegetation ecology of urban open spaces in Gauteng. MSc thesis, University of Pretoria, Pretoria.
- GROBLER, C.H., G.J. BREDENKAMP, L.R. BROWN. 2002. Natural woodland vegetation and plant species richness of the urban open spaces in Gauteng, South Africa. *Koedoe* 45: 19–34
- GROBLER, C.H., G.J. BREDENKAMP, L.R. BROWN. 2006. Primary grassland communities of urban open spaces in Gauteng, South Africa. *South African Journal of Botany* 72: 367–377.
- HOEKSTRA J.M., T.M. BOUCHER, T.H. RICKETTS & C. ROBERTS. 2005. Confronting a biome crisis: global disparities of habitat loss and protection. *Ecology Letters* 8: 23–29.
- LAND TYPE SURVEY STAFF. 1984. Land types of the maps 2626 Wes-Rand, 2726 Kroonstad. *Memoirs on the Agricultural Natural Resources of South Africa* 4: 1–342.
- LAND TYPE SURVEY STAFF. 1985. Land types of the maps 2628 East Rand, 2630 Mbabane. *Memoirs on the Agricultural Natural Resources of South Africa* 4: 1–261.
- LAND TYPE SURVEY STAFF. 1987. Land types of the maps 2526 Rustenburg, 2528 Pretoria. *Memoirs on the Agricultural Natural Resources of South Africa* 8: 1–391.
- LOUW, W.J. 1970. Klipveld studies 1: Checklist of vegetation. *Journal of South African Botany* 36: 199–206
- MINTER, L.R., M. BURGER, J.A. HARRISON, H.H. BRAACK, P.J. BISHOP & D. KOEPFER (eds.). 2004. *Atlas and Red Data Book of the Frogs of South Africa, Lesotho and Swaziland*. Washington, DC: Smithsonian Institution.
- MOLL, E.J. 1965. *An account of the plant ecology of the upper Umgeni Catchment*. MSc thesis, University of Natal, Pietermaritzburg
- MUCINA, L., RUTHERFORD, M.C. & L.W. POWRIE (eds.). 2005. *Vegetation map of South Africa, Lesotho & Swaziland, 1:1 000 000 scale sheet maps*. Pretoria: South African National Biodiversity Institute.
- SMITS, N.A.C., G.J. BREDENKAMP, L. MUCINA & J.E. GRANGER. 1999. The vegetation of old fields in Transkei. *South African Journal of Botany* 65: 414–420
- WEATHER BUREAU. 2000. *Prints of the climate statistics of the Johannesburg Leeukop, Pretoria Forum WB, Johannesburg Joubert Park and Krugersdorp Kroningspark weather stations*. Pretoria: Department of Environment Affairs and Tourism.