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State-of-knowledge on *Myracrodruon urundeuva* Fr. Allemão (Anacardiaceae) for genetic conservation in Brazil

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Abstract

This study explores the basis for conservation action on *Myracrodruon urundeuva* Fr. Allemão (Anacardiaceae). This is a wide-ranging forest species occurring in Brazil and other South American countries, notably in the Cerrado region. This paper aims to provide a structured review of available knowledge of its biology, ecology, silviculture and management. Widely-scattered published reports have been critically considered and efforts made to highlight and resolve contradictions and inconsistencies. Information about this species is scanty and scattered, particularly in respect to its biology and ecology. Some effort has been applied to its domestication and improvement, but opinion on its silviculture and management is still controversial. The taxon is typical of open and deciduous forest in the Cerrado. Gaps in current knowledge relevant for conservation are identified and steps to fill them proposed. Where in situ conservation proved to be more appropriate, recommendations are made for the location of additional protected areas. Complementary ex situ and enrichment conservation actions are suggested for specific parts of the range where resource losses are already so extensive that in situ measures alone are inadvisable. Opportunities for refining the limited management and conservation knowledge are proposed by highlighting priorities for study of the taxon. Finally, future action is discussed in the context of the infrastructure of the national conservation sector.

Key words: Anacardiaceae, Brazilian savanna, Cerrado, conservation, forest genetic resources

Introduction

It is understandable that in situ conservation efforts usually focus upon ecosystems. There is, however, a need to complement this approach with attention directed at particular target species. This approach is developed here for *Myracrodruon urundeuva* Fr. Allemão, a forest species which is typical of, although not necessarily restricted to the Cerrado, a distinctive but threatened habitat in central Brazil. This taxon is included in the listing of 23 priority species for Brazil drawn up by the Brazilian Agricultural Research Organization through its Genetic Resources and Biotechnology Research National Centre (Embrapa-Cenargen 1988) in connection with the Brazilian government's national conservation strategy. Criteria for selection were those recommended by the FAO Panel of Experts on Forest Gene Resources: restricted ecological distri-

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bution, low population densities, heavy exploitation for wood and other products, unknown or deficient silviculture and threatened habitat (Roche 1987).

Efforts to apply a robust but flexible standard system for acquiring, collating and organizing information on named neotropical tree species have not hitherto been successful. The reasons always reside in problems of standardisation of taxonomic and systematic nomenclature, in the regional variability of taxa (particularly a problem for widely-distributed woody species), as well as the generally scattered nature of the knowledge about these species. Reference to the World Conservation Monitoring Centre (WCMC-Kew 1990) indicates that this situation is no different for other tropical areas. Since species are the targets of gene resource conservation, a structured review of existing knowledge has great appeal when conservation strategies are to be formulated. Accordingly, this paper offers a framework for such action, with *M. urundeuva* serving as a case study. Fortunately, in the last couple of years a full data sheet on the species has been produced for the *Forestry Compendium* of CAB International (2000), as well as the instructive account, with nice figures, of the species provided by Lorenzi (2000).

The form and distribution of knowledge about tropical tree species introduce complications in information retrieval. Unprocessed 'raw data' (for example, those recovered from herbarium holdings, ecological literature and species listings) need to be thoroughly reviewed and critically incorporated into the progressing study. In an uncollated state, published information is often very dispersed, much of it (notably early references) being in obscure or little-circulated documents. Records may be in many different languages, and references may be made under obsolete names which reflect broader or narrower concepts of the species than those accepted today. For many wide-ranging species these problems are acute, making the preparation of a unifying account a taxing, time-consuming and sometimes laborious process. The exercise is nevertheless important as the basis of an authoritative conservation planning.

Few can claim familiarity with all aspects of the existing knowledge of a wide-ranging species. Information about a species covers many fields of enquiry, each with its own specialists and technical language: foresters, ecologists, geographers and botanists. Geographical spread also complicates matters greatly since concern about the status of a certain species is often restricted to the national level rather than considering the full species range. Obviously differences in the circumscription and in the nomenclature of species need to be recognized (and perhaps reconciled) and taken into account as the information is integrated. Whether or not this can be achieved in a single step depends on the species in question, the quantity of published and archival information (including herbarium material), and on the resources and time available to the investigator.

The present study, which is aimed at producing a current state-of-knowledge account for *M. urundeuva* to support genetic conservation programmes in Brazil and other South American countries, has three objectives: (1) to review available information on the biology, ecology, silviculture and management of *M. urundeuva* relevant to its genetic conservation as a sustainable resource; (2) to create a comprehensive and authoritative monographic account of the species by a critical analysis of available information, highlighting in the process unresolved misinterpretations and inconsistencies which need clarification; and (3) to identify the major gaps in current knowledge of the taxon and recommend positive research actions to fill them.

Material and methods

The fragmented and unsatisfactory species information for many species in the Neotropics requires today's monographers to invest more thought, effort and time to taxonomic circumscriptions and their geographical implications than their counterparts in Africa, Asia or Australia. In the present research, a retrospective picture of the taxonomic chronology was a necessary preliminary to an overview of the knowledge base. More specific comments on the importance of knowledge of the different aspects of a species have been given by Hall (1993, 1994). Hall reports the general need for monographic accounts on both multipurpose tree species and traditional forestry trees rather than only lists, brief profiles, data-sheets and bibliographies. Monographs represent the most authoritative and comprehensive documents of the state of knowledge on any species. However, it is important that they are based as a sound framework in the form of a set of headings covering all aspects of the tree's biology and resource potential: taxonomy/morphology, distribution, ecology, genetics and silviculture/management. Critical assessment of the information gathered is important, and nomenclatural contradictions and differences of opinion need to be explained and resolved as far as possible. Hall stresses the prominent role distribution maps should play among these headings. The necessary data for these come from five distinct sources: herbaria, taxonomic literature (basically in the form of floras), inventories, ecological literature and personal observations. Distributions can then be related to complementary data sets such as terrain, climate and soils. Hall (1994) also discusses the potential combined role of such information sets in distinguish-

ing genetically determined variation from ecologically determined variation in a wide-ranging species once mapped. A critical approach to these issues is essential if conservation programmes are to be successful.

Unification of information on a species into a structured and authoritative monograph has been achieved for the African dry zone tree *Balanites aegyptiaca* (L.) Delile (Balanitaceae) by Hall & Walker (1991). This study serves as a useful model for a monograph, though it must be adapted for other species. In the present case, prominence has been given to conservation; this aspect was excluded by Hall & Walker (1991) although separately considered at some length elsewhere (Hall 1992). The present work is based on diverse sources of information. For Brazil these are published and unpublished material at Embrapa and Cenargen, National Parks management plans, and lists and maps of current protected areas at the Brazilian Institute for the Environment and Renewable Natural Resources-Ibama. Paraguayan Conservation Data Centre data sheets on the target taxa were also obtained. In Britain, WCMC's database information on protected areas and assessment of conservation status of the target species were consulted and information assembled through visits to and correspondence with the Royal Botanic Garden, Kew (both herbarium and library). Electronic (Web of Science, CABI TreeCD) and traditional abstracting facilities (Forestry and Biological Abstracts) and a range of periodicals – particularly *Forest Ecology and Management*, *Forest Genetic Resources Information*, *Threatened Plants Newsletter*, *Scientia Forestalis* and *Silvae Genetica* – were also consulted. Further information was collected in discussions and correspondence with experts – both in Britain and abroad (Brazil, Paraguay, Switzerland).

Results

Systematic position and circumscription

Myracrodruon urundeuva was the name given to a previously undescribed species by Francisco Allemão & Cysneiro in 1862. In 1883, however, Adolf Engler reduced the taxonomic rank from genus to that of a section, within *Astronium*. The rank of *Myracrodruon* was changed again (raised to subgenus) by Barkley (1968), and the sections *Eumyracrodruon* and *Macrocalyx* were recognized within it. *Astronium urundeuva* (represented by var. *urundeuva* and var. *candollei*) was re-instated as a genus of two species (*M. urundeuva* and *M. balansae* (Engl.) D.A. Santin) by Santin & Leitão Filho (1991). *Astronium* and *Myracrodruon* are separated from each other primarily on the basis of ovary features. In *Astronium*, the ovaries are fusiform in fruit, while in *Myracrodruon* they are spherical.

The thirteen species in the genus *Astronium* were mentioned elsewhere by Leite (2002) as well as its taxonomic history.

Vernacular names of Myracrodruon urundeuva

Portuguese: aroeira, aroeira-do-sertão, aroeira-preta, aroeira-da-serra, aroeira-do-campo, urundeúva, urindeúva, arindiúva (Rizzini 1978), aderno, arendiúva, aroeira-legítima, aroeira-prata, aroeira-vermelha, oriundeúva, orindiúva, ubatan and ubatami (Nogueira et al. 1982, 1986), chibatan, gibatão, sotocele, ubatão (Barkley 1968), arendeúva, arindeúva and orindeúva (FAO 1986).

Spanish: urundel, urunday, urunday-mí, cuchi (Barkley 1968; Record & Hess 1972; López 1987).

Guarany: urunde'yva, urunde'y mi (López 1987; Muñoz 1990).

Description

Habit, size and form: *Myracrodruon urundeuva* is a deciduous tree, with a flat crown of long ascending branches (López 1987); these are grey and pubescent when young but grey and glabrous on older individuals (Muñoz 1990).

The species is small in the Caatinga and Cerrado, with individuals reaching 5–15 m in height and 15–60 cm in diameter. In the rain forest, the tree can be 30 m high and may have a diameter of 100 cm (FAO 1986). Record & Hess (1972) report individuals occasionally reaching over 30 m at Jujuy and Salta in Argentina, but the height attained does not normally exceed 20 m, with a maximum diameter of 75 cm. The trunk is straight and cylindrical, sometimes rather expanded at the base (López 1987). The bark is dark brown and scaly on older individuals, while younger individuals have a smooth grey bark with rough lenticels (Rizzini 1978). The characteristic outer bark is 10–15 mm thick and hard with a rough surface and longitudinal depressions. The inner bark is fibrous, pinkish and 9–12 mm thick (López 1987).

Foliage: The compound imparipinnate leaves reach 10–30 cm in length. There are 7–15 oblong or ovate subcoriaceous leaflets. These are sparsely pubescent on both abaxial and adaxial surfaces in *M. urundeuva* var. *urundeuva*, which has also pubescent branches, while *M. urundeuva* var. *candollei* has glabrous leaflets and branches. The leaflets are slightly serrate-crenate, 3–6 cm long and 2.0–3.5 cm wide. The apex is rounded or slightly acuminate. The base is orbicular and rather oblique. The venation is inconspicuous, ciliate. The petiole is hispid and 2–4 cm long. The petiolules, also pilose, are 2–4 mm long. As with *A. fraxinifolium*, the leaflets are mango-scented when crushed (Barkley 1968; Rizzini 1978; Nogueira et al. 1982; López 1987; Muñoz 1990).

Flowers and fruits: The inflorescences are racemes which are clustered at the tips of the leafless branchlets. They are c. 10–15 cm long, and sparsely pilose. The flowers, on pedicels 0.5–1.0 mm long, are either male or female. In both infraspecific types the sepals are spherical in shape, 0.4 mm long and 0.5 mm wide and glabrous, except on the margin where they are ciliolate. The petals are 2 mm long, reflexed and ciliate. The anthers are exserted, ovate and tiny, and borne on long (2 mm) filaments. The ovary is superior and glabrous. The staminate flowers have short stamens (Fig. 1). The pistillate flowers bear slightly smaller stamens and an ovoid pistil, 0.3 mm long and 0.2 mm broad. There is a sessile stigma. The fruit is a spherical drupe, 3–4 mm in diameter. The persistent sepals are twice as long as the fruit and surround it (Fig. 1). The exocarp is thin and glabrous and adherent to the thin, resinous mesocarp which, in turn, is adherent to the rough bony endocarp. The seed is 3.2 mm broad, 3 mm long and irregularly lenticular in shape. It is 1 mm thick except in the region of two prominent protuberances where it is 2 mm thick (Barkley 1968; Rizzini 1978; Nogueira et al. 1982; López 1987; Muñoz 1990).

Systematic anatomy: Little has been reported on this. Barkley (1968) reported in *Astronium* schizolysigenous canals in the phloem which extend to the leaves and flowers.

Reproductive biology

It has been established by Allem (1991) that the species presents some individuals with male flowers only, whereas others bear male flowers with rudimentary non-functional ovaries. He has also found individuals with female flowers only.

Phenology: A distinctive phenological feature is that flowering usually takes place after the leaves have been shed (Barkley 1968). Rizzini (1978) reports the flowering period in Brazil as November to January and fruiting to occur in September and/or October. According to FAO (1986), however, fruiting in Amazonia occurs in January and February after flowering in July and August. This corroborates the information given by Nogueira et al. (1986). Carpanezzi et al. (1976), noted the period of leaf fall to be July and August in central Brazil locations.

López (1987) reported flowering in Paraguay to be in August and September on leafless individuals and fruiting in November and December. Muñoz (1990) noted flowering from July to as late as November, and fruiting as early as August but continuing until December.

Pollination and dispersal: Barkley (1968) draws attention to the fact that the pistillate flowers have large obovate sepals, which enlarge rapidly after pollination and become the 'wings' of the seed. Allem (1991) reported bee (*Trigona spinips*) pollination for the species.

The seeds are wind dispersed. Large losses of seed due to strong winds and thunderstorms are reported (Nogueira et al. 1982).

Seed biology in natural conditions: Germination is rapid: 4–7 days (Rizzini 1978; López 1987). This makes the existence of dormancy mechanisms improbable.

Genetics: Grattapaglia et al. (1996) and Ciampi et al. (1997) using AFLP and RAPD molecular markers, respectively, reported that anecdotal evidences indicate an important apomict component in the reproduction and dispersion of this, primarily known as a dioecious species. Such assumptions have been corroborated when they found very limited amount of DNA polymorphism for what would be a strictly allogamous plant.

However, studies of Lacerda et al. (1999), using isozyme electrophoresis, in two distinct Caatinga populations with different levels of anthropogenic disturbance, have confirmed the primarily allogamous character of the species. Moraes (1992) assessed genetic variability in two southern natural populations of the species through quantitative traits and isozyme electrophoresis. He found that the traits showed no significant differences between populations, characterizing, therefore, variation within populations. The electrophoresis analysis showed also that variation is predominantly within populations and that there is predominance of outcrossing between related individuals in both populations.

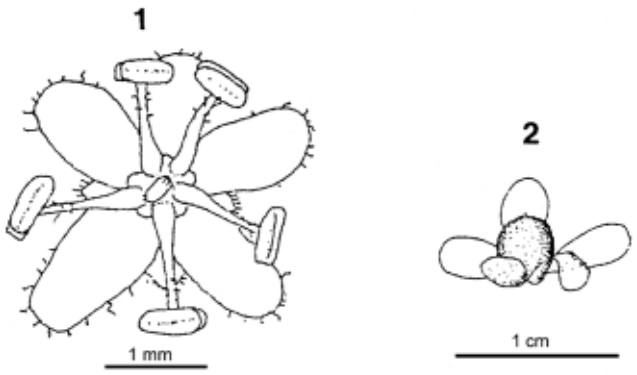

Fig. 1. Schematic drawing (1) of a staminate flower, and (2) of a fruit of *Myracrodruon urundeuva* (after Barkley 1968).

Distribution and ecology

Distribution

Present distribution: The distribution of *M. urundeuva* (Fig. 2) involves Brazil, Argentina, Bolivia and Paraguay (Barkley 1968; Record & Hess 1972; Garrido & Poggiani 1979; WCMC, pers. comm. 1992).

Range: The range (Garrido & Poggiani 1979) covers vast areas in Brazil, from the State of Pará in the north, throughout neighbouring Maranhão, to Bahia and other northeastern states (1). *Myracrodruon urundeuva* is also found in Minas Gerais, Rio de Janeiro and São Paulo (2,3,4) (Barkley 1968), with the main concentration in the west of the latter state (Carpanezzi et al. 1976). In addition, it occurs in the central states of Mato Grosso, Mato Grosso do Sul, Tocantins and Goiás (3,5). The northernmost occurrences are in the transition between the Amazonian forests and the Cerrado and Caatinga. It is absent from the Amazonian rain forests. Record & Hess (1972) noted that the distribution of section *Myracrodruon* was limited to areas south of Amazonia. Outside Brazil, *M. urundeuva* occurs sporadically in eastern and western Paraguay, concentrated along the Paraguay River watershed (5) (López 1987; Muñoz 1990). There are dense disjunct populations in southern Bolivia and northern Argentina (5) (Barkley 1968; Prado 1991). Absence of collecting in central Bolivia could explain the existent gap in distribution between the supposedly disjunct populations in Paraguay and Brazil.

Paraguayan and Argentinian occurrences of the typical variety and *M. urundeuva* var. *candollei* overlap each other.

Ecology

Elevation: According to Garrido & Poggiani (1979) the species occurs at a range of altitudes from the lowlands up to 900 m. However, this upper limit is at variance with the occurrences in, for example, Brasília at 1100 m and up to 1200 m (Salomão & Leite 1991). Barkley (1968) noted occurrences up to 1500 m in Bolivia.

Climate: The distribution of the species can be related to mean annual rainfall using a climatic map for South America (WMO et al. 1975) and represented in Fig. 2. The association with rainfall shows a distribution varying widely, particularly in Brazilian territory, from 600 mm in drier areas in the northeast to up to twice as much rainfall (1200 mm) in the centre and southeastern parts of the country.

It is interesting to note that *M. urundeuva* var. *candollei*, the glabrous infraspecific variety, is particularly found in drier locations in northern Argentina and Paraguay, between 600 mm and 800 mm.

Soils: There is not sufficient evidence that this species requires rich soils and reports suggest (e.g. Nogueira et al. 1986) that its presence on deep 'terra roxa' in Brazil is unusual. Nevertheless, it is found on fairly rich soils in the northeast (luvisols) and, particularly, the rather richer soils of the southwestern part of the range (fluvisols and planosols). The most peculiar characteristic of the species is, however, its association with calcareous outcrops, mainly in gentle landscapes of central Brazil. In this region it appears to be a calcicole species, and there appears to be a consistent association between the species and presence of significant amounts of calcium in the soil.

Soil seems to be the key factor for the successful establishment of the species, which thrives in soils with a high pH level, as on calcareous outcrops where it reaches maximum size. In the Cerrado, it is generally associated with calcareous soils and represents a calciphilous species. In a comparison of several species Carpanezzi et al. (1976) measured the nutrient contents in leaves of various ages. In *M. urundeuva* they found low concentrations of Ca and Mg, but relatively high concentrations of P. In Paraguay the species is associated with well-drained sandy soils (López 1987).

Myracrodruon urundeuva survives long periods without moisture as in the semiarid northeastern region of Brazil (Garrido & Poggiani 1979). However, Muñoz (1990) points out that the size of the tree is directly proportional to water availability – the largest individuals occurring in rain forests.

Community context of **Myracrodruon urundeuva**

Associated species: In closed forests the species is associated with *Piptadenia* sp. Benth., *Chorisia speciosa* A. St.-Hil., *Tabebuia impetiginosa* (Mart. ex DC.) Standl. and *Hymenaea courbaril* var. *stilbocarpa* (Hayne) Lee & Lang. (Garrido & Poggiani 1979). In the Caatinga it occurs with, among others, *Amburana cearensis* (Fr. Allem.) A.C. Smith, *Commiphora leptophloeos* (Mart.) J.B. Gillett, *Anadenanthera macrocarpa* (Benth.) Brenan and *T. impetiginosa* (Mart. ex DC.) Standl. (Salomão & Leite 1991).

Relations with the natural fauna: There are reports of locust (*Stiphra robusta*) attacks on seedlings and termite damage to roots in trial stands (Lima et al. 1982).

Relations with forest disturbance: There seems to be a correlation between the presence of the species in secondary forests and the formation of almost pure stands by means of vegetative propagation (FAO 1986; Nogueira et al. 1986). A likely factor responsible for this might be the induction of development of suckers by fire.

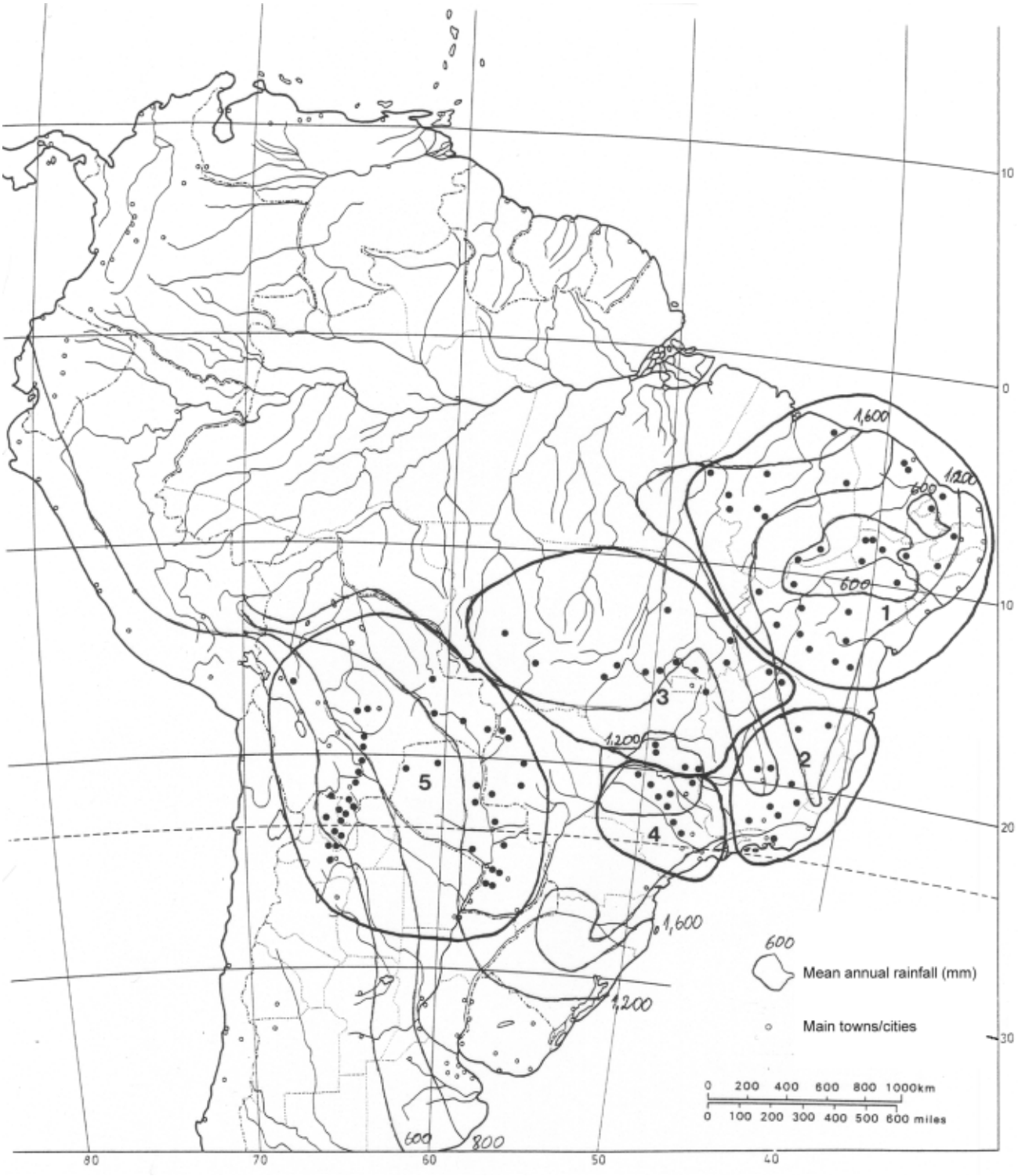

Fig. 2. Distribution of *Myracrodruon urundeuva* in South America. Numbers denote sub-regions and countries as follows: 1, northeastern Brazil; 2, southeastern Brazil; 3, central Brazil; 4, southern Brazil; and 5, western Brazil, southern Bolivia, northern Argentina and western Paraguay.

In the Cerrado surrounding Brasília, it is rather difficult to find populations of the species and those present are composed mostly of scattered individuals on farmland, the largest individuals having already been felled. There are a few areas where it occurs on calcareous outcrops and is protected, allowing dense populations to develop (E.J. Leite, pers. observ.)

Silviculture and management

Experience with artificial regeneration

Propagation: The species has potential for vegetative propagation, in addition to sexual reproduction. While details of the breeding system are not known, Nogueira et al. (1986) suggested, based on statistics from silvicultural trials, that the species is cross-fertilized but apomixis also occurs.

Collection of seed in a very dry state risks losses by wind blowing the seed away (Nogueira et al. 1982; FAO 1986). One kilogram contains from 14,000 (FAO 1986) to c. 47,500 seeds (Rizzini 1978). However, extrapolation from other data (Souza & Lima 1982) suggests a much higher number, i.e. c. 61,000 seeds kg^{-1} due to the existence of intraspecific variation. FAO (1986) reported that seed could be stored under ambient conditions or refrigerated without seriously reducing its capacity to germinate (up to 70% success under laboratory conditions after 13 months of storage). Souza & Lima (1982) found 85% germination under laboratory conditions within a test period of 2–5 days on apparently fresh-collected seed. The normal period of germination in the nursery is up to two weeks (FAO 1986). In laboratory research, however, Reis et al. (1980) found seeds that had not germinated after 112 days, had not deteriorated and concluded that a dormancy mechanism was involved. These conflicting results on germination and the presence of dormancy might well be related to differences between the two existing varieties.

Outplanting and establishment: Salomão & Leite (1991) rate the seedlings as photosensitive and recommend shading when planting out. Nogueira et al. (1982) experienced problems using fairly small bags for seedling production. The rapid growth of the seedlings resulted in intermingling of roots and consequent damage to the seedlings when planted out. Lima et al. (1982) reported locust (*Stiphra robusta*) damage to leaves and termite attacks on the roots of recently planted out seedlings.

Performance of planted individuals: There are planted stands of the species in a number of places, mostly as experimental trials. In the State of São Paulo, there is an experiment in Assis planted in 1970 and another in Pederneiras planted in 1981. In northeastern Brazil there have been plantings in experiments in Petrolina, Sobral, Açu, Floriano, Bodocó-Ouricuri, Santa Maria da Boa Vista, Arcoverde, Caruaru and Serra Talhada. FAO (1986) reviewed (see below) studies on forest performance of the species in both homogeneous and mixed stands, particularly in the northeast, for an afforestation programme for the local Caatinga.

There are conflicting reports on the potential of *M. urundeuva* for plantations. While Carpanezzi et al. (1976), reported slow growth in a spacing trial, Garrido & Poggiani (1979) recommended commercial planting even in the Cerrado, subject to correction of soil acidity. Garrido & Poggiani (1979) calculated, for a 10-years period, a mean annual increment of 0.9 cm (diameter) and 0.8 m (height). The species tends to bifurcate heavily during the first years in the field (Garrido & Poggiani 1979; Salomão & Leite 1991) making pruning necessary to favour a straight stem. Salomão & Leite (1991) and Garrido & Poggiani (1979) suggest that planting the species by enriching previously established plantations to create multispecific stands could solve this problem and enhance the bole length.

Garrido & Poggiani (1979) carried out a 40% thinning at the eighth year. The felled logs were used for fencing stakes and firewood. Survival rates in plantations are good: 75% in trials at sites in the Brazilian southeast and northeast (Drumond 1982; Nogueira et al. 1982). Growth seems to be slower in the northeast than in the southern regions (Drumond 1982; Lima et al. 1982). At three years, plants in a trial carried out in the northeast (Petrolina) achieved an average height of 1.7 m whereas in a southern location (São José do Rio Preto), an average height of 5.1 m was attained at four years of age (FAO 1986). In another southern location (Assis) at nine years, average height was 9.6 m and average dbh was 9.7 cm.

Kageyama (1990) draws attention to large variation in height growth both among and within open pollinated progenies of *M. urundeuva* assessed at four years of age in the State of São Paulo. He adds that this seems to represent real genetic differences in the material tested.

Management attention in forest stands: Due to the fact that management of a stand to produce logs demands periodic thinning, Garrido & Poggiani (1979) recommend a thinning schedule for mixed stands that include the species. After the first thinning 60% of the trees first planted remain.

Utilization

Wood properties

Macro- and microscopic features: The sapwood is white to yellowish-pink, comparatively thin and sharply

demarcated from the heartwood. The heartwood is fairly uniformly cherry-red coloured but deepens to dark brownish-red on exposure. *Myracrodruon urundeuva* wood lacks the bold, blackish striping of *Astronium* woods.

There is similarity to *Schinopsis* ('quebracho'), but the grain is generally not so irregular – although it can be interlocked, the consistency is not so flinty and the appearance is more oily. The demarcation between heartwood and sapwood is sharper. The texture is fine. There is no distinct odour or taste (Record & Hess 1972; FAO 1986). The vessels are excessively obstructed by tyloses of oil resin and the lumen fibres are extremely reduced (FAO 1986).

Physical and mechanical features: The timber of the species is very strong and heavy, and has a high mechanical resistance. Weight is 849–1281 kg m^{-3} (Record & Hess 1972).

Use as timber

Seasoning and preservation: FAO (1986) reported that permeability to preservative solutions is extremely low in treatments under pressure.

Durability and workability: FAO (1986) consider the wood highly resistant to decay, even in the ground (López 1987). In a study of traditional farming in the northeast of Brazil, Emperaire & Pinton (1986) found out that the species is one of those traditionally chosen for durability when used in fencing and for poles.

Ease of working is variable – from easy to rather difficult, but the wood turns readily, finishes very smoothly and takes a high natural polish (Record & Hess 1972).

Uses: The wood is mostly used externally for fence stakes, poles, sleepers, bridges, piling and posts (Record & Hess 1972; Rizzini 1978; FAO 1986; López 1987). Salomão & Leite (1991) draw attention to an extended range of uses such as civil, hydraulic and naval constructions, carpentry and cattle pens. It is also amenable to lathe working and carving (FAO 1986).

Other uses

Fuel: Ribaski (1986), López (1987) and Record & Hess (1972) report use as firewood and in charcoal making.

Tannin: The bark contains c. 15–17% of tannin and is used in the leather industry (Drumond 1982; López 1987).

Medicinal: The bark is used in folk medicine for the treatment of respiratory and urinary diseases. Menezes et al. (1986) and Rao et al. (1987), studying alcoholic and aqueous extracts of the bark, concluded that the well known anti-ulcerogenic activity of this species is primarily due to anti-cholinergic and anti-histaminic properties. Aqueous extracts significantly inhibited aspirin induced gastric lesions. The anti-cholinergic property would explain action against diarrheal conditions (Menezes & Rao 1988). Rao et al. (1986) found a potent anti-inflammatory effect and concluded potential in the treatment of human inflammatory bowel disease. The possible mechanism involved in this anti-inflammatory activity would be, according to Menezes et al. (1985), direct antagonism to anti-inflammatory mediators such as acetylcholine, histamine and bradikinin, as well as a stabilizing effect on lysosomal and mast cell membranes.

Forage: Fallen leaves are used as dry season forage (Drumond 1982).

Conservation status

Present conservation status

The species merits priority for conservation action (Roche 1987). It is considered one of the most threatened woody species of the Neotropics due to overexploitation – mostly for heavy duty use such as in fence stakes and posts (FAO 1986; Salomão & Leite 1991). The reported collection not only of wood, but also of bark stripped for medicine and use in tanning, threaten the species (FAO 1986).

Many areas from which the species has been reported now support reduced and impoverished populations or lack them completely. The explanation is that the land is privately owned and felling has not been controlled. Heavy exploitation in areas previously untouched is also cause for concern.

Myracrodruon urundeuva is assigned to the 'endangered' category of the IUCN Red Data Book in all four WCMC areas of occurrence within the range of its distribution (WCMC, pers. comm. 1992).

Present conservation priorities

A number of ex situ plantations have been proposed for northeastern Brazil. Most of the places where the species is reported should be considered as sources for material to use in ex situ stands (Salomão & Leite 1991) to compensate for low impact from in situ conservation since extant populations tend to be on private farmland. Some occurrences in national parks (e.g. National Park of Ubajara, Serra da Capivara National Park) and other conservation units, offer prospects for in situ conservation.

The São Paulo State Forest Institute, through its genetic improvement programme, is conserving ex situ stands of this species in one location with genetic ma-

terial from five provenances in the state. Ninety-one progenies have been assessed for variability. Height evaluation at three years of age has revealed significant differences among provenances (Nogueira et al. 1982, 1986; FAO 1986). There are no reports of conservation measures in other countries within the range.

Discussion

Efforts have been made to link needed key genetic conservation research areas presented by Roche (1975) and National Research Council (1991) with current knowledge on the reviewed taxon. Gaps in such knowledge, which were revealed in this study, were given particular attention. What has been established about each target taxon has nevertheless been used as a foundation for offering practical suggestions on potentially rewarding conservation approaches, following Hall's (1992) model for *Balanites aegyptiaca*.

A good deal is known about the wood properties of *M. urundeuva*, and about its taxonomy and morphology. However, the taxonomic circumscription of the species remains disputed and clarification is needed, particularly outside Brazil, where occurrences of *M. urundeuva* invite further study to verify the consistency of the data. The distribution information available could be used as a basis for locating potential in situ conservation areas or for planning germplasm collections for provenance trials. However, to pinpoint precise locations to conserve the genetic variability of this taxon, further refinement of the maps is needed based on visits to previous collection points as well as to new areas, in order to assess more fully the level of infraspecific variation. It is possible that taxonomic revision of the species will lead to changes in these maps.

Despite the relatively high number of sources, our ecological knowledge about the species is inconsistent and incomplete. Our present information on the reproductive biology of the taxon is also unsatisfactory. Comparison of the distribution of the species with major soil units was made using the FAO-UNESCO (1971) soil map. *Myracrodruon urundeuva* was prominent in moderately hilly areas of deep, well-drained rich luvisols in the Brazilian northeast and in gentler northern Argentinian landscapes. It was also prominent on sandy-clayey – and richer – planosols in Paraguay. Although the species has received a good deal of consideration in terms of silviculture and management, clarification of its potential for commercial plantations is needed, due to contradictions in published comments. Carpanezzi et al. (1976) stressed the slow growth achieved by the species in a spacing trial. Conversely, Garrido & Poggiani (1979) recommended commercial planting even in the Cerrado subject to correction of soil acidity.

Information on the species conservation status is limited to the IUCN Red Data Book (WCMC, pers. comm. 1992). More noteworthy, however, is the consistent presence of several other target taxa on the FAO Panel of Experts on Forest Gene Resources list (Roche 1987). This was the basic document used by Cenargen to choose target species for the national programme of genetic conservation in Brazil. The main priorities of this programme are to promote in situ conservation by the establishment of genetic reserves wherever possible and particularly in existing protected areas. Additionally, ex situ conservation is sought through setting up germplasm banks and provenance and progeny trials (especially using the species). In situ genetic reserves should, however, be as large as possible to minimize problems of genetic drift and consequent depression of genetic variability that can be expected in the existing small reserves. Both in situ and ex situ methods require management.

An illustration of the types of information needed to develop a conservation strategy is presented in Box 1, together with the appropriate information for *M. urundeuva*.

In spite of the rudimentary level of knowledge of the characteristics of this species, which are relevant to conservation, it appears to be typical of thinly dispersed outcrossing forest trees which are at risk as forest disturbance levels increase and individuals, unisexual in this case, become increasingly isolated. *Myracrodruon urundeuva* and *Amburana cearensis* – another target species – are well known as associates, inviting conservation management under a common scheme and indicating a high degree of similarity in habitat requirements.

A listing of potentially viable protected areas is used according with Ibama's definition (J.C. Gonchorosky, pers. comm.) of conservation units of indirect use (national parks, biological reserves, ecological stations) and direct use (national forests and extractive reserves).

It is important to establish as far as possible to what extent the species is distributed within protected areas. Figure 3 shows a map where the species may occur within protected areas. Three regions correspond to the core of its distribution: the central Cerrado, the northeastern Caatinga and the centre-south. The National Parks of Ubajara (12), Serra da Capivara (10), and Chapada Diamantina (5) represent samples of the thorny scrub vegetation of the Caatinga and fall within the distribution of the species. The National Parks of Araguaia (2), Emas (6) and Pantanal (9) are potentially important conservation areas in the Cerrado region. In the centre-south region, however, due to unrelenting pressure sustained since the turn of the century on the original tropical/subtropical seasonal forest for

Box 1. Type of information required for conservation	**Current knowledge relevant to the conservation of *Myracrodruon urundeuva***
1. Population status and structure Reflect mainly levels of stocking (individuals ha^{-1}), and prominence represents distinctiveness of the species among constituents of the habitat.	Stocking levels unknown; prominent mostly in core areas of Brazilian northeast and centre-south.
2. Resilience (a) Physical The importance of resilience to physical disturbance agents, normally natural (fire, browsing, drought) or 'management' activities (selective logging, clear-felling, girdling) is in the definition of methods of protection and intervention to favour the species.	Endures drought but growth impaired.
(b) Herbivores and/or pathogens The role of herbivores and/or pathogens is important to consider when commercial species are involved.	Seedlings attacked by locust and termites.
3. Level of exploitation Exploitation of the resource relates to the degree to which the species is seen as economically important and under pressure in the current context.	Overexploited species mainly for external uses of the wood. Logging a marginal operation in clearing of land for cultivation. Other (non-wood) uses wide-ranging.
4. Level of rehabilitation Level of rehabilitation and resource creation cover capability in securing regeneration as desired and in controlling agents antagonistic to establishment.	Afforestation programme proposed for northeastern Brazil.
5. Quantification and characterization of genetic variability Quantification and characterization of genetic variability are achieved through careful examination of collected material within the range of the species looking for variation at an infraspecific level, mainly by observation of phenotypic traits such as shape and size of leaves, fruits, seeds and bark.	Infraspecific variation existent: var. *typical* and *candollei*, but overlapping in Argentina and Paraguay. Formal provenance trials established in the Cerrado region.
6. Site Site represents the small-scale environmental variation (e.g. soil texture and composition and topographic features).	Calcareous outcrops particularly in Cerrado – possibly compensating for the generally poor soils of the region.
7. Breeding system and reproductive biology (a) Sexual system Breeding systems and reproductive biology are important to ascertain by which type of reproductive system species populations are perpetuated.	No consistent information available on this aspect for this dioecious species.
(b) Pollination and dispersal Important is insight into agents responsible for pollination and seed dispersal.	Little information on pollination. Winged fruit and anemochoric seed dispersal.
8. Seed biology Seed biology knowledge, involving phases subsequent to fertilization (seed crop, pre-dispersal predation and dormancy patterns) is important for prediction of how much is produced and the proportion likely to germinate successfully. (a) Seed crop; (b) seed pre-dispersal predation; and (c) seed dormancy.	No information on seed crop; varies widely in seed weight: 14,000–61,000 seeds kg^{-1}. No reported predation of seed. Quick germination suggests no dormancy.
9. Nursery technology Nursery technology, involving raising planting stock both as selected seedlings and as cuttings, is important for enrichment planting and intervention in a management scheme. (a) Seedling production; and (b) clonal production.	Good germination levels even of seed stored under ambient conditions. Seedling predation protection required. Possibilities of planting cuttings good judged by prolific sprouting in secondary growth.
10. Forest policy to curb threats The forest policy aspect relates to the extent of involvement of the legal authority and how actively it promotes law enforcement regarding conservation matters for the species and how threats to it are curbed.	Recognition of threatened status widely accepted. Practical action to conserve extant populations and rehabilitate degraded areas, particularly in central and northeastern Brazil for the typical variety, and in Argentina and Paraguay for the glabrous variety, still lacking.

Fig. 3. Distribution of existent protected areas with *Myracrodruon urundeuva*: the National Parks of Ubajara (12), Serra da Capivara (10), and Chapada Diamantina (5) in the Caatinga; the National Parks of Araguaia (2), Emas (6) and Pantanal (9) in the Cerrado; and in the centre-south region, the National Park of Itatiaia (7) and the State Park of Rio Doce (17). Recommended potential protected areas in Brazil regarding *M. urundeuva* conservation: the Amazonia/Caatinga transition (C); the centre-south on the border between Brazil and Paraguay (D); and the interior of the State of São Paulo (E). Current protected areas based on IBGE´s (1993) map.

agricultural land there are few extensive protected areas. There are, however, a couple of smaller ones. The taxon is presumably found in the National Park of Itatiaia (7) and the State Park of Rio Doce (17). There is need for enhanced protection in a number of areas throughout the ranges of the species (cf. Fig. 3). It is at risk in many parts of its distribution: in the Amazonia/Caatinga transition (on the border between the States of Maranhão and Tocantins) (C); in the centre-south on the border between Brazil and Paraguay (D); and in the interior of the State of São Paulo (E). Protection of outlying populations is important due to the likely genetic variability existent in them when compared to the core of the range populations.

Basically, there are three practical options for tackling the conservation problem: (a) traditional in situ reserves, normally in existing protected areas or specifically designated genetic conservation reserves; (b) traditional ex situ stands, mostly provenance and progeny – sometimes silvicultural – trials; and (c) a compromise approach which is based on enrichment action to favour the targeted species.

Considering the current situation of protected areas in Brazil, the geographical distribution patterns of the taxon, and the little that is known of its population structure, some recommendations can be put forward for genetic conservation programmes. *Myracrodruon urundeuva*, which rarely forms dense populations in forest formation, but mostly is found scattered-dispersed over farmlands, is not amenable to wide use of in situ conservation. This leads to reliance on compromise or traditional ex situ approaches particularly for the parts of its range which are under more pressure for land clearing for agriculture: in all localities in the centre-south of Brazil and in transition areas between Amazonia and Caatinga. Local seed sources should be used to raise germplasm for enrichment plantings and formal planted stands of the species, which also invites use in enrichment in secondary vegetation, due to its prolific suckering capability. The present state-of-knowledge of the species emerges as far from satisfactory.

With so many gaps in the silvicultural/management/conservation picture it is important that new initiatives should be on a planned and focussed basis centred on identified priorities and not merely opportunistic. Detailed studies of the reproductive biology and demography of natural stands of *M. urundeuva* are urgently needed.

As indicated in this paper, additional protected areas are necessary to secure a viable gene pool, and suitable areas are pinpointed in Fig. 3. Other important activities to be promoted are seed collection expeditions – these have already been successful for this and one other species, *Amburana cearensis*, of conservation interest and studies of seed storage and germination, as well as nursery establishment. In the longer-term, more involvement in provenance and progeny trials – as has already started with *Amburana cearensis* and *M. urundeuva* – should continue. Teams dealing with reconnaissance surveys or inventories to identify areas (protected or with potential) containing the taxon should also pay special attention to assessing population structure aiming at future rehabilitation (compromise) action. A major role is played by the 'Instituto Florestal' (Forestry Institute) of the State of São Paulo in forest genetic conservation in Brazil. Because most of the actions utilizing ex situ and the compromise (enrichment) approaches are concentrated in a region around that State, it is wise to have their collaboration in these programmes. It is clear, after what has been discussed in this study, that despite the dearth of current knowledge, technical solutions for the conservation of forest genetic resources followed by action are possible. Hopefully, scientific advice will be followed by political will to fulfil expectations.

Conclusions

The effective conservation of *M. urundeuva* in Brazil is thwarted by problems related both to our knowledge of the conservation biology of the species and to the institutions responsible for conservation. The background level of effectiveness and versatility of the system of protected areas in Brazil is still poor as far as conservation of forest genetic resources is concerned. Few examples of the main categories of protected areas which focus on conservation and management (national forest and extractive reserve) of the resource, through intervention, contain the species (cf. Fig. 3). Indeed, the majority of existing areas containing it are 'indirect use' categories (national park, biological reserve, ecological station), as shown in Fig. 3. This means that no management actions will be taken to promote the species studied here due to the non-intervention policy followed by Ibama. Such management actions are better directed to the conservation problem in genetic reserves (in situ conservation) and formal planted stands (ex situ conservation) established by the scientific authority, as can be seen in Fig. 3.

There is no initiative concentrating on alternative conservation approaches, such as enrichment planting, to complement traditional ones. There has also been little implementation in the country of conservation options developed over the last few years from the increasing ecological understanding of tropical forest ecosystems. Much current activity takes insufficient account of the high diversity and low population den-

sities of neotropical forest tree species. The vulnerability of the Cerrado formations to conversion for other land use makes application of effective conservation an urgent need.

Myracrodruon urundeuva is, as a major economic species, heavily utilized but at present measures taken to ensure its sustainability are very limited, do not cover much of the range and are not increasing fast enough to balance exploitation.

Vital aspects important for traditional in situ and ex situ conservation are lacking and, additionally, there is poor legal protection in established areas. Compromise measures, basically through enrichment (e.g. mixture) with local seed source, are therefore urged to compensate for this.

Recommendations

The following recommendations are made, with respect to the conclusions above, to assist the national conservation programme. The patchy characteristics of forest formations in central Brazil Cerrado and the increasing fragmentation of more populated areas in the northeast and the centre-south, require that tackling the conservation problem should take into account the isolated situation of the habitats. This is because such habitats favour high rates of inbreeding, progressive loss of genetic diversity and, in the long run, extinction of species.

To curb this, the establishment of a network of local or, ideally, regional protected areas is recommended containing preferably 'direct use' categories, but not disregarding the possibility of creating 'indirect use' categories when the opportunity arises. A significant increase in the number of even small protected areas contributing to a larger network would increase chances of survival of species. This network has to be supported by complementary approaches to favour thinly dispersed forest species by including sites which serve as links between more widely separated areas. This could involve the use of enrichment techniques with germplasm from nearby sources.

Myracrodruon urundeuva needs more study focused on the reproductive biology. Concurrently, provision should be made for enlargement of the limited existing provenance trials network, to ensure identification of priority provenances for first, conservation, then commercial plantations, with minimal delay.

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