Bioversity International

MODULE 1
Species conservation strategies

Case study 1.2

Talbotiella gentii: genetic variation and conservation

David Boshier, Daniel Dompreh and Mike Swaine

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MODULE 1
Species conservation strategies

Case Study 1.2

Talbotiella gentii: genetic variation and conservation

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This case study presents information on *Talbotiella gentii* (Hutch. & Greenway), a critically endangered tree species with a narrow distribution in eastern Ghana. Use the information given here to devise a conservation strategy for the genetic conservation of this threatened species. The strategy should take into account both the patterns of genetic variation found in the species and the forestry and socio-economic context of Ghana, and may combine both *in situ*, *ex situ* or other conservation measures. **Make sure your recommendations are specific and detailed** (e.g. if you recommend seed collections for *ex situ* conservation, specify from which populations, how many trees, how much seed, where you will store it, etc.). Also indicate the relative priority of actions, as funds will not be limitless. The exercise is set in the context prior to the year 2008, both in terms of the species status and country profile. As such, more recent information and changed contexts are not included as they are not relevant to the exercise.

In your group discussions you should, in particular, think about and respond to the following:

- How is human disturbance likely to have shaped levels of genetic diversity in *T. gentii*?
- What are the mating system, seed and pollen dispersal mechanisms? What do these mean for conservation?
- What are the levels of genetic variation and how is it distributed across populations? Which are different? To what extent does sample size limit the conclusions that can be drawn from the genetic marker data?
- What non-genetic marker information in the study can be used to guide genetic conservation?

In your strategy you should detail:

- What are the threats to *T. gentii* (short-term/long-term) and for which populations is action a priority? Of what type should this be? ***List problems*** by type: ***genetic*** (e.g. which populations are too small?); ***other types of problems*** (e.g. social, communication, resources – see Conservation status, Country profile sections).
- What are the limiting social factors to conservation, utilisation, and planting?
- Which conservation methods - *in situ*, *ex situ*?
- What do end-users need to know and how will they find out?
- ***Who*** will do ***what***, ***where*** and ***how*** will you pay for it?

Introduction

Talbotiella gentii is an evergreen leguminous tree. It is one of a few endemic forest trees in Ghana (i.e. found only in Ghana) and classified as Critically Endangered according to IUCN criteria. Despite being given the highest status for conservation in Ghana, it is seriously threatened with extinction from fire, charcoal cutting and

farming. *T. gentii* is unusual since it occurs as monospecific patches in mixed dry forest in the east of the country. Although these forests are low in height and species number, they are of restricted occurrence within Ghana and not reported from other countries. A relatively high degree of floral endemism distinguishes these forests as a rare ecosystem of conservation importance in Ghana and the world. As such, some of these remnant forests have been officially designated as Globally Significant Biodiversity Areas (GSBAs) within Ghana's biodiversity conservation strategy. However, implementation of effective conservation faces an array of issues related to a lack of knowledge of the ecology of *T. gentii,* and more generally, of this forest type, lack of appreciation of their importance, the extent of damage and fragmentation of this habitat, and social constraints of the area.

Species description, uses and conservation status

Taxonomy and botanical features

Talbotiella is a genus in the Fabaceae (legume), Caesalpinioideae family. It contains only three species, all native to West Africa:

Talbotiella batesii Baker f. Endemic to Cameroon

Talbotiella eketensis Baker f. Endemic to Nigeria

Talbotiella gentii Hutch. & Greenway Endemic to Ghana

Talbotiella gentii is a small- to medium-sized thornless, evergreen tree, up to 20 m in height and 20-45 cm dbh, although exceptionally >60 cm. The crown is dense, dark green, often with low epicormic branches. The bole is rough, dark green, generally slanted or twisted and not cylindrical. The bark is hard and when slashed shows reddish or red-brown outer layers and pale yellow, very fibrous inner layers with hard sapwood. Leaves are pinnate with 4-7 pairs of almost rhombic opposite leaflets (ca. 1 cm wide). Fruits are flat pods with 1-3 seeds, dispersed explosively.

Phenology

T. gentii flowers early in the dry season (October–December) in most years with trees visible at a distance due to its crown of pinkish-white inflorescences. Flowers have a mild sweet scent, although no insects or other animals have been recorded on the flowers by day or night. Pollen traps show some wind-borne pollen, with most dispersed <5 m. Further research is needed before drawing a firm conclusion that *T. gentii* is mainly wind-pollinated. Fruiting is generally annual and often profuse, with seeds explosively dispersed over short distances. The species regenerates in its own shade with abundant seedlings in some larger stands, but few in many other stands. A high rate of abortion of immature fruit during development occurs, such that relatively few fruit mature.

Distribution

T. gentii occurs only in a restricted part of the east of Ghana (Afram and Volta Basins), in small, almost monospecific, stands ranging from two to several hundred mature trees in rocky areas of seasonally dry forest. In particular, it is found in three forest reserves: Bandai Hills, Sapawsu and Yongwa Forest Reserves, separated by approximately 100 km (see Fig. 1a). Other species found in association include *Ceiba pentandra, Cynometra megalophylla, Dennetia tripetala, Dialium guineense, Diospyros abyssinica, Drypetes floribimda,* and *D. parvifolia*. The South-east Outlier and Southern Marginal Forests are the driest forest types (annual rainfall 750 - 1275 mm). They are also the least extensive (approximate area 20 km^2), with small scattered patches characterised by low floral diversity and trees with low canopies, few commercial timber species, but several rare tree species such as *T. gentii*. The record for Cameroon seems to

be an error, as no specimen like *T. gentii* has been seen from Cameroon at major herbaria. It would not be surprising to find isolated pockets of this species in dry rocky forest remnants in the Guinea sub-region, however this would be unlikely to alter its threatened status.

T. gentii only occurs along the southern scarp of the Akwapim-Atewa hills, where the soil is interrupted by rocky outcrops and as such its distribution seems to be naturally fragmented. Within this range, the species' occurrence does not appear to be strictly limited by environmental factors such as soil conditions, which vary with geology (Table 1), yet it is absent from many apparently suitable rocky hills. So soils at some sites are base-rich, while others are more acidic.

Table 1. Environmental conditions at five *Talbotiella gentii* locations in Ghana (Swaine and Hall, 1981)

Location	Geology	Cation Exchange Capacity (mill equivalent 100g-1)	% saturation of cation exchange capacity	pH	Organic carbon %	Approx mean annual rainfall (mm)
Krobo	Basic gneiss	22	96	6.6	2.9	750
Yongwa	Quartzites/shales	12	100	6.6	1.6	1000
Yongwa	Quartzites/shales	2	10	4.0	3.9	1000
Sapawsu	Quartzites/shales	2	20	4.2	2.5	1000
Worobong	Sandstone	5	88	5.6	1.1	1250

Uses and potential value

T. gentii is not a high-value commercial timber species, but its dense wood makes excellent charcoal and it is cut preferentially for charcoal/fuelwood. It is known locally as Takorowanua or 'charcoal tree' in direct reference to traditional use by local communities on the forest fringes. Trees resprout after coppicing/pollarding and can be managed in this way. A small amount of *T. gentii* is exploited by local communities for medicinal use (for stomach ulcers), bridge construction, furniture and building pillars.

The forest reserves to which *T. gentii* is mostly now restricted, have socio-economic value, providing local people with basic needs and supplementary income at the start of the farming season when they need financial resources. Fringe communities have a strong relationship with the reserves due to belief in the presence of gods within the forest which has consequently been protected traditionally through taboos, as well as local by-laws. The forest is a rich source of game (e.g. antelopes, bush bucks, duikers, grasscutters), firewood, pestles, rafters and medicinal plants. Local people are also aware of the forest's environmental services.

Socio-economic development could be enhanced using the reserves' natural and cultural resources to develop eco-tourism. Steep slopes and caves offer opportunities for recreation, while the traditions, rites and cultures of communities surrounding the forest could also attract visitors. Yongwa and Sapawsu reserves are close to the Akosombo Dam, so that tourists on cruises to Dodi Island could also visit and learn about the ecological importance, rarity and conservation of trees such as *T. gentii* and the ecosystem in which they occur. Local participation in ensuring conservation of resources within the reserves could give rise to income from such visits. Yongwa Reserve also offers more general opportunities for education. Roads to the reserve are generally good, allowing general public access.

Pests and diseases

There are few reports of pest and diseases associated with *T. gentii*, although lack of research precludes definitive statements. There are reports of fungi that occur on the flowers, limiting pollination and causing fruit abortion, and also some beetle larvae destroying seed. Vesicular-arbuscular mycorrhizae have been found associated with the tree roots, but no ectomycorrhiza.

Trial results

Although the tree is known to be slow-growing, field trials of *T. gentii* are only at an initial stage, but have shown 89% survival 10 months after *ex situ* planting. The forest reserves represent important field research areas for studying the species' ecology and biology.

Conservation status

T. gentii is classified under IUCN criteria as critically endangered, i.e. faces an extremely high risk of extinction in the wild in the immediate future, as defined by the following criteria (CR. A1c, B1+2c):

A) Population reduction in the form of:

1) An observed, estimated, inferred or suspected reduction of at least 80% over the last 10 years or three generations, whichever is the longer, based on:

c) a decline in area of occupancy, extent of occurrence and/or quality of habitat

B) Extent of occurrence estimated to be less than 100 km^2 or area of occupancy estimated to be less than 10 km^2, and estimates indicating both of the following:

1) Severely fragmented or known to exist at only a single location.

2) Continuing decline, observed, inferred or projected, in:

c) area, extent and/or quality of habitat.

List of Threats:

1.1 Habitat Loss/Degradation - Agriculture (ongoing)

1.3.3.3 Habitat Loss/Degradation - Extraction - Wood – Clear-cutting (ongoing)

1.4.2 Habitat Loss/Degradation - Infrastructure development - Human settlement (ongoing)

Of 28 known populations/locations, the species is now extinct at 15, having been destroyed by fire, farming and charcoal burning (Fig. 1, Table 2). The original area of dry forest has been extensively destroyed by incursions by people and subsequent exploitation of forested areas resulting in reduced populations and increased fragmentation above natural levels. Until effective fire management practices are implemented (currently being established by the Forestry Department), stand erosion will continue annually at increasing rates. The greatest concentration of *T. gentii* stands is in the eastern part of its distribution, on the ridges around Akosombo (Sapawsu and Yongwa reserves; see map). Major threats to efficient management of the reserves include frequent wildfires, exploitation of *T. gentii* and other species for firewood and hunting. There is also occasional illegal encroachment by farmers and charcoal manufacturers. The condition of the three reserves that cover the largest remaining populations varies.

Bandai Hills
Area 161 km^2, 5% with >15º slope. Reserve established 1928. Forest condition - very poor.

Last logging recorded in 1991. Most of the reserve is extremely burnt, although patches exist where *T. gentii* is dominant. Much of the middle of the reserve is savanna with hard exposed rocks, and has probably been like that since before people arrived in the area. The bad condition is therefore not entirely due to human disturbance. Nevertheless, poor external and farm boundary maintenance has no doubt contributed to serious disturbance in previously undamaged forest.

Sapawsu and extension
Area 15 km^2, 90% with >15º slope. Reserve established 1957. Forest condition - very poor.

Was extensively farmed under the taungya system[1], in some cases illegally. Taungya failed (1 563 ha of teak planted between 1972-1987), leaving the hills virtually bare except for a 100x300 m patch, which has been burnt. The extension is a small hill with forest much destroyed by taungya, and separated from the main block by a road. The extension is remarkable for a gregarious stand of *T. gentii* which, whilst apparently healthy with abundant regeneration, its medium- to long-term survival is under threat from fire, illegal clearance or other chance events.

Yongwa
Area 8 km^2, 80% with >15º slope. Reserve established 1957. Forest condition - partly degraded.

One of Ghana's 34 designated GSBAs, it currently harbours the best remaining stand (134 ha) of *T. gentii*. The reserve is a rocky ridge with vegetation critical to preventing erosion and landslides. Species of this forest type are well adapted to the area and difficult to replace once their habitat is lost. Environmental benefits from the forest are appreciated by fringe communities, e.g. improved air quality, hill protection, enhanced rainfall. Taungya plantings cover 20% of the reserve (160 ha, *Cassia* sp. 1972-87). Annual bushfires over the last decade damaged the forest cover and continue to be a major factor affecting the reserve's potential, but otherwise the condition is fair. The area is enough to provide adequate habitat for effective management of viable populations of fauna and flora that are restricted to this forest type and also to maintain ecological processes.

Management of protected areas
In recent years, conservation and management of protected areas have included participation of all stakeholders (e.g. Forestry Commission, Environmental Protection Agency, District Assemblies, land holders, environment/conservation NGOs, forest fringe communities, charcoal burners, Volta Lake Transport Co., Volta River Authority, Police and Judiciary) through consulting their interests in managing/developing the potential of the Forest Reserves and how their sustainable use could benefit local people and society at large. Communities surrounding reserves were almost unanimous in support for continued existence of the forest, especially the protection of endemic species and activities to maintain the reserves' ecological integrity. They are open to collaborating with Forest Services Division (FSD) staff in management of the reserves in areas such as: rehabilitation of degraded sites, enactment and enforcement of by-laws such as prohibition of cutting of fresh *T. gentii* and plantation establishment. Local community involvement offers great potential for FSD staff to collaborate in ensuring conservation of biological resources. Limited resources, especially in staffing, coupled with steepness of the reserves, make work

[1] The Taungya system combines forestry crops and agricultural crops during the first years of establishment of the forestry plantation. The main objective of taungya is wood production.

and patrolling of boundaries difficult. There is also a problem integrating traditional approaches to reserve management with the needs of local people, given the fact that local people have helped to conserve reserves without incentives. The absence of alternative livelihoods and the capital to develop such livelihoods by local people could continue to pose a threat to the effective management and conservation of the reserves. Fringe communities of Sapwsu and Yongwa Reserves have amenities such as basic schools, borehole water supply, community clinics, and a central market for commercial activities, but few have electricity. There is a good network of mostly un-tarred roads, a number of guest houses and a few good hotels which could facilitate economic development (e.g. through eco-tourism) in the area.

Current conservation initiatives include *ex situ* conservation in plantations and *in situ* conservation in collaboration with local communities. A joint project between the Forest Research Institute of Ghana (FORIG) and the University of Aberdeen (UK) aims to secure *ex situ* conservation for all remaining populations at three protected sites. A network will be established amongst local communities for monitoring tree phenology and collecting seeds/seedlings, with local nurseries encouraged to re-introduce the species. An extensive education programme is also planned, as there is a general lack of knowledge of this endemic species among the Ghanaian public.

Genetic variation in natural populations

Trees were sampled from 17 populations/locations, covering the entire 100 km natural range of *T. gentii* along the forest-savanna boundary (Fig. 1). Numbers of trees sampled varied, with only 2-4 individuals from small populations (Table 3). Genetic diversity within each population/location was surveyed for RAPD polymorphisms using 8 primers (Table 3). Within-population genetic variability was generally low, with larger populations showing a higher percentage of polymorphic loci (e.g. Abiriwapong 16.9%, Yongwa 13.6%, Chalet 8.4%) compared with smaller populations. Although the data are clearly biased by the unequal and low sample sizes, in the case of some of the small populations this represents a 100% sample (e.g. Botriansa, Senkyeso, Hospital) and is therefore a true reflection of low genetic diversity in these remnants. Exploitation of *T. gentii* for charcoal/fuelwood, periodic bush fires and farming activities are likely to have increased the natural disjunct distribution of the species and left populations small and isolated.

Analysis of molecular variance showed that 94.1% of the total genetic variation was due to variability between populations and only 5.9% from within populations. Such high population differentiation and hence, limited gene flow between the remnant populations, coincides with indications of limited pollen and seed dispersal (see Phenology section). Correspondence analysis of the 108 samples also provided evidence of strong inter-population differentiation with groups related in part to geographical origin (Fig. 2). All genotypes from around Abiriwapong (western edge of distribution), except Kuwere, formed one group, clearly separated from the rest. All genotypes near Akosombo (eastern edge of distribution), except Hospital, also formed a group. Yongwa genotypes clearly separated as a group (on axis 2, Fig. 2). Hospital and Kuwere genotypes formed intermediate groups between Akosombo and Abiriwapong, also clustering with some Hotel genotypes. Failure of samples from some locations to group genetically with other geographically close locations is likely to reflect sampling and bottleneck effects from both the small sample and actual sizes of some remnant stands, rather than any true genetic differentiation.

Figure 1a. Distribution of Forest Types, Forest Reserves and *Talbotiella gentii* in southern Ghana (from Dompreh 2008). isopluvial lines mark mean annual rainfall (range 750-2250 mm), and delimit main forest types (WE–wet evergreen, ME–moist evergreen, MSD–moist semi-deciduous, DSD–dry semi-deciduous, SM–southern marginal).

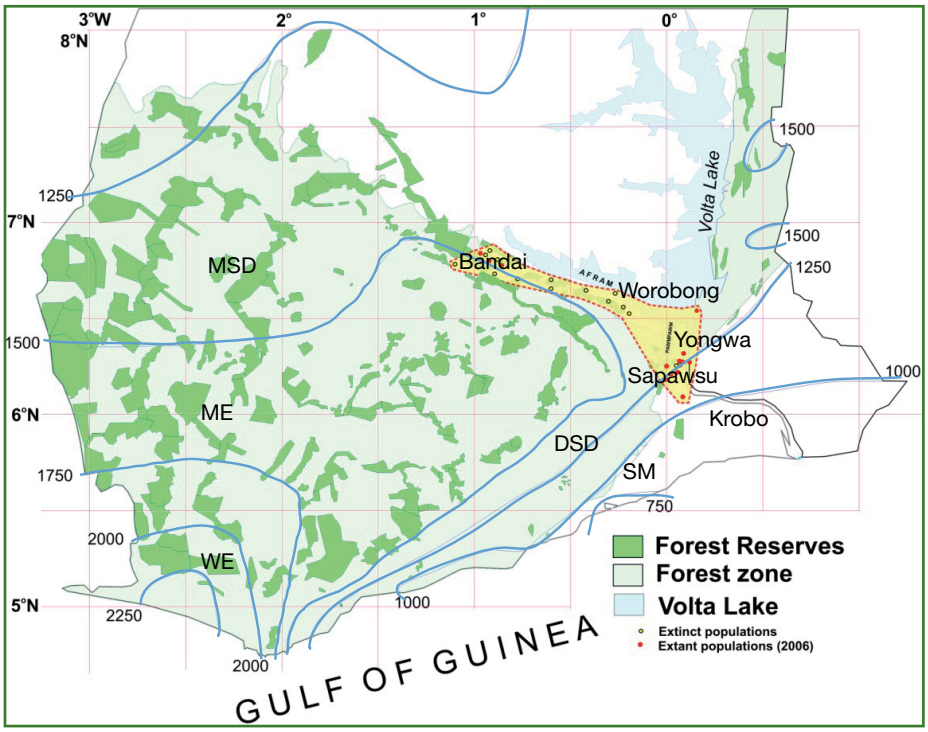


Figure 1b. Close-up of *Talbotiella gentii* distribution in Ghana. Red/closed circles = extant populations, Yellow/open circles = extinct populations.

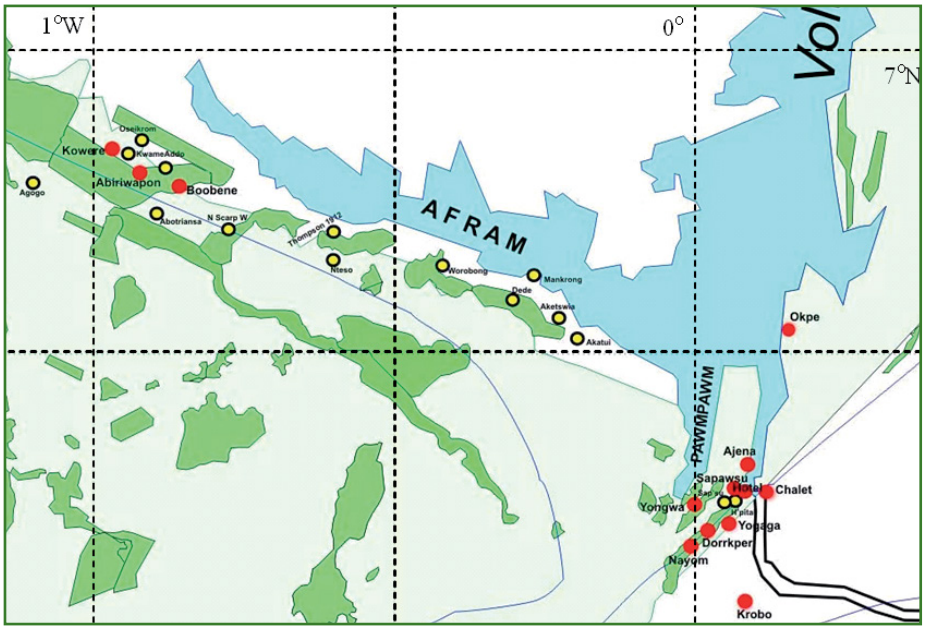


Table 2. Status of known populations of *Talbotiella gentii*

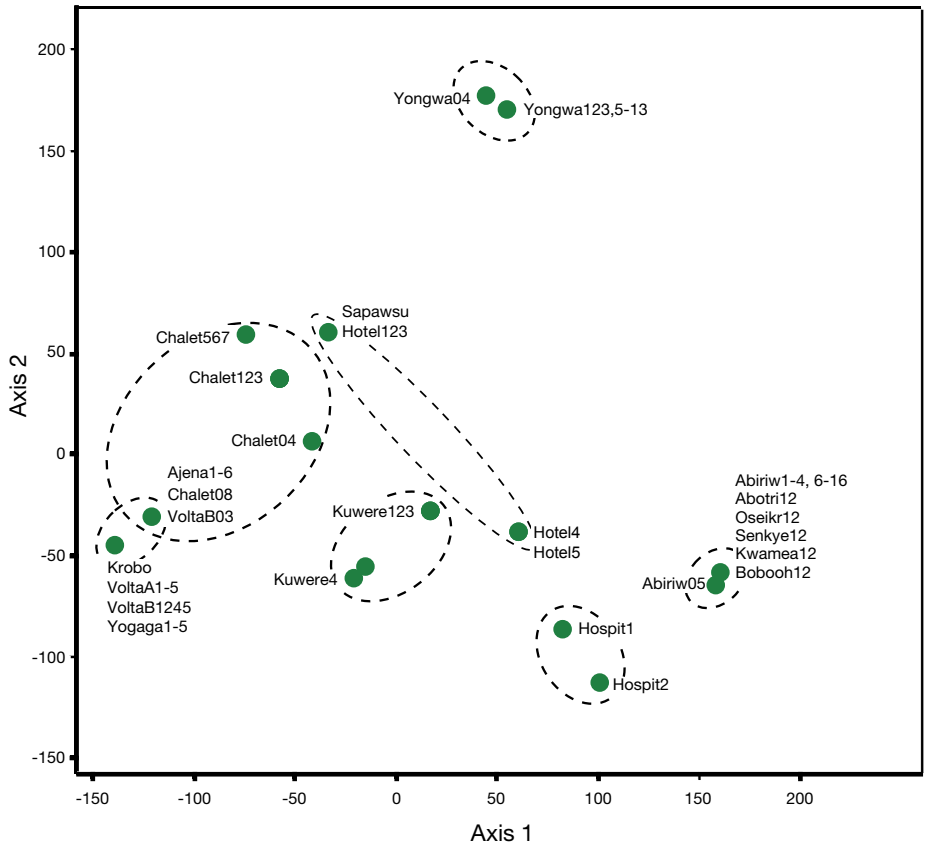
Name	No. of stands	Size/ no. trees	Status	Threats	Reason for Protection	Protection by	Official Reserve
Yongwa Forest Reserve (FR)	4	>100	**Extant**	Fire, exploitation for charcoal/fuelwood	GSBA1, Yongwa community river god.	Forestry Comm., Yongwa community	Yes
Abiriwapong (Bandai Hills FR)	3	>100	**Extant**	Fire, exploitation for charcoal/fuelwood	Threatened species conservation, taungya.	Forestry Comm., Abiriwapong comm	Yes
Kuwere	1	16	**Extant**	Fire, land clearance for farming	Watershed protection.	Nyamebekyere community	No
Boboohene	2	20	**Extant**	Fire, exploitation for charcoal/fuelwood	Taungya.	Boboohene community	No
Nayom, Volta B FR	1	39	**Extant**	Fire, exploitation for charcoal/fuelwood	Threatened species, watershed protection.	Forestry Commission	Yes
Doorkper, Volta B FR	1	21	**Extant**	Fire, exploitation for charcoal/fuelwood	Threatened species, watershed protection.	Forestry Commission	Yes
Yogoga FR	1	11	**Extant**	Fire, exploitation for charcoal/fuelwood	Sacred - Yogoga Mt. god.	Krobo Odumasi stool	Yes
Hotel (Volta Hotel)	3	27	**Extant**	Fire, exploitation for charcoal/fuelwood		Minimal by VRA[2]/ Forestry Comm.	No
Chalet	7	>50	**Extant**	Fire, highly exploited for charcoal/fuelwood	Protect Volta Lake watershed vegetation.	VRA	No
Sapawsu FR (Extension)	2	>50	**Extant**	Fire, exploitation for charcoal/fuelwood	GSBA, taungya.	Forestry Commission/ VRA	Yes
Okpe (Anum Boso)	1	197	**Extant**	Exploitation for fuelwood	Watershed protection.	VRA and Anum Stool	No
Krobo Mtn.	2	>20	Largely destroyed	Fire, exploitation for fuelwood	Sacred - Krobo Mt. gods – ancestors.	Somanya stool Forestry Comm.	No
Ajena (Oninwi)	4	>50	**Extant**	Fire, highly exploited for charcoal/fuelwood	Protect Volta Lake watershed vegetation.	Minimal Protection by VRA	No
Oseikrom	1	6	Recently extinct				No
Botriansa	1	2	Recently extinct				No
Sapawsu FR	1	-	Extinct				No
Northern scarp WFR	-	-	Extinct				Yes
Boumfum FR	-	-	Probably extinct				Yes
Hunhunya	-	-	Probably extinct				No
Akatui	-	-	Probably extinct				No
Kwahu Nteso	-	-	Extinct				No
Hospital (Akosombo)	1	2	Recently extinct				No
Aketswia	-	-	Probably extinct				No
Worobong	-	1 ha (1972)	Extinct				No
Afram Mankrong FR	-	-	Probably extinct				Yes
Senkyeso	1	2	Recently extinct				No
Kwame Addo	1	3	Recently extinct				No
Agogo	-	-	Extinct				No

[1] GSBA - Globally Significant Biodiversity Area; [2] VRA – Volta River Authority

Table 3. Within population genetic variability in *Talbotiella gentii*, estimated by percentage of polymorphic loci for 83 RAPDs polymorphic bands (8 primers).

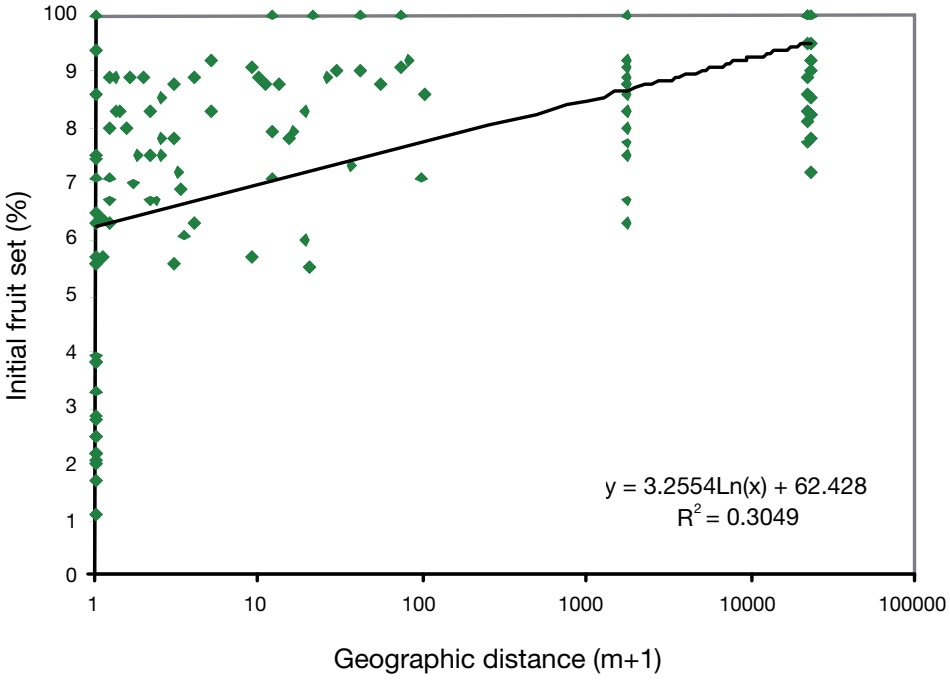
Population	Population size	No. of samples	% polymorphic loci
Abiriwapong	>100	16	16.3
Yongwa	>100	13	13.6
Sapawsu	>50	8	8.1
Chalet	>50	8	8.4
Krobo	>20	8	7.7
Ajena	>50	6	4.8
Nayom	39	5	5.2
Hotel	27	5	4.4
Doorkper	21	5	3.9
Yogoga	11	5	7.9
Kuwere	16	4	3.1
Boobohene	20	2	2.1
Oseikrom	6	2	2.1
Kwame Addo	3	2	2.1
Botriansa	2	2	2.1
Hospital	2	2	0.8
Senkyeso	2	2	2.1

Figure 2. Correspondence analysis for 108 genotypes of *Talbotiella gentii*. Broken lines enclose samples from the same population using 83 polymorphic bands from RAPDs. NB: axes are unitless, numbers after site names correspond to sampled trees at each site.



Studies of the reproductive biology also provide information on factors that limit regeneration and survival of remnant populations. The observed high fruit abortion (see Phenology section) and associated reproductive failure may be a major factor preventing recovery in areas where *T. gentii* is nearly extinct. Self-pollination showed that *T. gentii* is self-compatible, with 44.3% of self-pollinated flowers setting fruits. Fruit set from open pollination (51.8%) was between the values from selfing and cross-pollination (80%), suggesting that under current conditions, *T. gentii* shows mixed mating (pollination by a mixture of selfed and out-crossed pollen). Though capable of selfing, there is evidence of this leading to inbreeding depression in *T. gentii*. Fruit and seed abortion may regulate the genetic quality of the offspring, but limit overall reproduction. Compared to both self- and open-pollination, cross-pollination produced not only higher initial and ripe fruit set, but also a higher number of mature seeds per pod, and better quality seed in terms of seed mass, germination and seedling survival. There were highly significant differences ($P<0.001$) in germination between seed from self-pollination (56%), open- (80%) and cross-pollination (92.5%). Though seedling survival after germination was very low, outcrosses (6.9%) showed significantly higher survival than self- (1.2%) and open-pollination (2.4%).

Figure 3. Effect of geographic distance of pollen source on initial fruit set in *Talbotiella gentii*.



Controlled pollinations between trees from different populations (Yongwa, Sapawsu, Hotel) show increased fitness with increased geographic and genetic distance between parents. Initial fruit set increased significantly with geographic distance ($P=0.00$, Fig. 3), as did the number of ripe fruits ($P=0.00$), seeds per pod ($P=0.001$) and seed mass ($P=0.002$). Similarly, initial fruit set ($P=0.001$), number of ripe fruits ($P=0.001$) and seed mass ($P=0.002$) increased significantly with genetic distance. Improved seed/seedling performance with increasing genetic and geographical distance supports the idea that *T. gentii* populations have been affected by increased fragmentation and reductions in size, leading to increased selfing and inbreeding depression. Inbreeding depression may negatively affect demography and thus threaten the conservation of an endangered species. Inter-population crosses can enable species to recover from such inbreeding depression. However, such out-crossing does not currently occur, as the short-distance wind dispersal

of *T. gentii* pollen and an apparent absence of insect pollination suggest limited pollen exchange between trees within and between populations.

The main threats to *T. gentii* are anthropogenic, however its restriction to small remnant stands with low genetic diversity and inbreeding depression at various stages of reproduction, pose real genetic threats and limitations to natural regeneration. Limited pollen and seed dispersal suggest very restricted gene flow between these remnant stands, limiting their capacity to produce more viable seed. Research suggests that conservation actions that promote out-crossing in *T. gentii* will increase genetic viability and reduce the negative impacts of inbreeding.

Ghana country profile

(based on 2001 submission to IPGRI)

Introduction

- Area: 238 539 km^2. Most below 600 masl; <10% above 300 masl; very few areas >1000 masl.
- Population: 22 113 000, 60% of which is rural where poverty is concentrated (comprising 84% of the country's total poverty), particularly among small farmers in savanna zones.
- Economic growth has been led by agriculture, notably consecutive bumper cocoa crops aided by favourable weather and improved policies. Forty percent of national income is derived from agriculture and fisheries. Forestry, including logging and timber processing, constitutes 6% of GDP. About 120 000 people are employed in the forestry sector, timber industry and public institutions. Many more are employed in the informal forestry sector. Real GDP growth reached 5.9% in 2005, up from an average annual growth rate of 5.5% between 2000-2004. Growth was projected to increase to about 6.1% in 2007. For management of the development of the national estate, several zones are classified: intensive cultivation, permanent cultivation, forestry and marginal agricultural use. Main economic crops are: cocoa, timber, cotton, sugarcane, palm oil, tobacco, fruits, and vegetables.
- Seasons: dry (Nov-Apr), rainy (May-Oct). Rain: 600-2100mm/year, varies by agroecological zone
- 6 agroecological zones: Coastal savanna, Guinea savanna, Sudan savanna, Forest (Deciduous, Moist evergreen, Wet evergreen), Semi-deciduous forest zone, Forest-savanna transition.

Forestry and phytogenetic resources: key Ghanaian facilities

Council for Scientific and Industrial Research Centres (CSIR). The following are affiliated with CSIR and important for genetic biodiversity conservation:

- Plant Genetic Resources Centre (PGRC), Bunso, Eastern region. Established 1964, main institution mandated for plant genetic resources activities. PGRC collects plant genetic resources throughout Ghana and in neighbouring countries; characterizes, evaluates, conserves, distributes and documents.
- Crop Research Institute, Horticulture Division, Kumasi: research on fruit, cashew, vegetables, cereals, and legumes, development of new varieties and promoting appropriate technologies to farmers.
- Savanna Agricultural Research Institute (SARI), Tamale: conducts research on cereals, legumes, vegetables, etc. with a focus on the northern region of Ghana.

Also: Cocoa Research Institute of Ghana, New Tafo (research on cocoa productivity); Forestry Research Institute of Ghana, (FORIG), Kumasi (research on forest species, timber production, tree entomology, etc.); International Institute of Tropical Agriculture, Kumasi (a CGIAR organization); Palm Research Institute, Kade, Ghana Ministry of Agriculture (oil palm, coconuts).

Seed collection and storage and *ex situ* collections

Reliable seed storage facilities are fundamental to any genetic resource conservation strategy. Current facilities within Ghana are inadequate for requirements. Current demand for forest tree seed is about 10 000 kg per year, with projected demand higher due to increases in afforestation, reforestation, agroforestry and community forestry. Currently, some organisations such as the Forestry Service Division and the Agroforestry Unit collect seed in forest reserves and plantations. Others depend on FORIG for their seed supply, but FORIG cannot meet demand as it lacks the facilities to collect and store seeds on a large scale. Its refrigerated container is subject to breakdown, but a new US$0.5 million seed centre/bank should be operational by 2007. Limited facilities at the PGRC for seed storage, with a focus on crop species, include voltage-stabilized deep freezers, small capacity standby generator and a drying room with dehumidifier/air conditioner. Other institutions (SARI, Crop Science Department (CSD), University of Ghana, Legon) have 5ºC cold storage facilities for crop seed. The Forestry Commission (FC) Resource Management Support Centre also has a cold storage room, although this is currently not operational.

There are botanical gardens at Aburi and the Botany Department of the University of Ghana. FORIG maintains an arboretum at Bobiri Forest Reserve. The PGRC maintains an arboretum in which some medicinal, ornamental, fruit and timber tree species are conserved. Similarly, the Centre for Scientific Research into Plant Medicine maintains three arboreta of medicinal plants at Mampong, Mamfe and Ayikuma. Both FORIG (work on resistant varieties of *Milicia* spp., diversity within mahogany species for shoot borer resistance) and PGRC have tissue culture facilities.

Facilities for molecular genetics studies

FORIG has a new molecular laboratory with capacity for PCR (RAPD, microsatellites) and isozyme studies. Most research is targeted at plantations and seed orchards, although there is also discussion of the development of projects related to forest management. There are limited facilities (RAPD, isoenzymes) at the CSD, University of Ghana, used in characterisation of crop germplasm collections.

Forest resources

Of Ghana's forested land, 6.4%, roughly 353 000 ha, is classified as primary forest. The closed forest zone occupies the southwestern third of the country. The forest classification system of Hall and Swaine (1981) is the most widely used in Ghana with seven major formation types based mainly on mean annual rainfall data and degree of species diversity.

Wet Evergreen (WE): wet evergreen forest is restricted to the highest rainfall (1500-2100 mm) areas and contains the highest concentration of rare and endemic species in the country. It is the least disturbed forest type in Ghana, probably because there are fewer commercial timber species than in the other forest types. WE is reasonably well represented within Protected Areas (Nini-Suhien National Park, Ankasa Resource Reserve). The latter is considered to have the highest 'Genetic Heat Index' (based on endemism/global rarity of species found in a reserve) of all reserves in the forest zone and the home of *Psychotria ankasensis*, an endemic species now cultivated as an ornamental.

Moist Evergreen (ME): located in areas with 1500-1750 mm rainfall and usually found between the WE to the south and the MSD forest to the north. Floristically, ME is slightly less diverse than WE but contains more species of commercial timber trees and has, therefore, been more heavily impacted by logging. Commercial timber trees include *Khaya ivorensis* (African mahogany), *Triplochiton scleroxylon* (African white wood), *Terminalia ivorensis* (Ivory Coast almond).

Moist Semi-Deciduous (MSD): in areas with 1250-1700 mm rainfall, representing 40% of the closed forest zone. Although the most productive forest type, species diversity is lower than ME. Two subtypes exist: the drier northwest subtype, which harbours forest elephant populations, and the southeast subtype.

Upland Evergreen (UE): in the MSD forest zone are two patches of UE forest covering 0.12% of Ghana (e.g. Tano Ofin, Atewa Forest Reserves). UE forests have floristic similarity to the ME forest type but also contain several rare species (e.g. *Hymenocoleus multinervis* - a herb, *Cyathea manniana* - a tree fern).

Dry Semi-Deciduous (DSD): occurs as a narrow strip to the north and east of the MSD subtypes separating the closed forest from the northern savanna. Rainfall varies between 1250-1500 mm. Species diversity is low and there are fewer economic timber trees. Like the MSD, the DSD also has two subtypes based mainly on rainfall and occurrence of fire: the wetter Inner Zone and drier Fire Zone characterized by periodic fires. In the Fire Zone, opening of the forest canopy for farming, subsequent invasion of grass, and the effect of fire has destroyed the original high forest and allowed the invasion of savanna trees resulting in a mosaic of forest and savanna vegetation often referred to as derived savanna. This zone, along with the northern savanna, supplies much of Ghana's fuel wood and charcoal.

South-east Outlier (SO): a distinctive forest type, in the southeast of Ghana, characterized by low species diversity but a relatively high proportion of endemic and disjunct species. With a limited distribution and species-unique assemblage, it is of high conservation value.

Southern Marginal (SM): restricted to a narrow strip from Cape Coast to Akosombo, within the coastal savanna vegetation zone. The area is densely populated and human disturbance has reduced SM forests to fragments, mainly on rocky hills. Tree species are characteristically of short stature and include the endangered endemic species *T. gentii*, *Dalbergia setifera*, and *Turraea ghanensis*. Forest management in Ghana is becoming more financially sensitive and revenue generation more critical. In terms of more immediate returns, the teak plantations in this forest type are possible resources. Most were poorly thinned in the past but still contain valuable wood for poles/lumber. Recent studies show good coppicing from thinned stands which, if well managed, will provide a cheap crop.

Wild species and wild relatives of crop plants

Some of Ghana's wild forest species are of great economic importance, e.g. fruits of *Thaumatococcus daniellii* and *Dioscoreophyllum cumminsii*, have sweetening characteristics several times greater than sucrose. The active ingredient in *T. daniellii* fruit is a protein suitable for diabetics. *T. daniellii* leaves are used as wrappers for market foods and the plant to make mats. *T. daniellii* and *D. cumminsii* thrive in the high forest zone but, with rampant deforestation, both are at risk. Several other indigenous forest species are harvested from the wild for use as spices, herbal medicine, etc*.,* e.g. *Piper guineense Tetrapleura tetraptera*, *Xylopia aethiopica, Monodora myristica*, *Parkia clappertoniana*.

Current issues of main concern

Current issues of main concern are: loss of endemic species such as *T. gentii* and biodiversity generally, lack of control of protected areas, lack of collaboration and coordination among stakeholders. Other issues include conflict between conservation and use, conflict in mandates of different institutions (e.g. Minerals Commission and Forestry Commission - FC) and lack of capacity to effectively use project funds to achieve desired impacts. Decline in biodiversity, especially of endemic species has resulted from a lack of FC commitment to institute strategies to remove mainly human-induced threats. In most protected areas, illegal activities continue due to inadequate staffing and lack of alternative

livelihoods for communities living around protected areas. Lack of coordination and collaboration has resulted in duplication and ineffective use of resources. For example, there are many ongoing conservation projects in Ghana but there is no effective system for information sharing to enhance efficiency, avoid duplication of effort and achieve required impacts.

Deforestation, estimated at 1.7%, largely stems from inadequate implementation of the legal framework. The FC has, to a large extent, been unsuccessful in addressing over-exploitation and other threats to forest resources. Degradation and loss of forest resources take place on- and off-reserve. Off-reserve, loss is mainly due to farming expansion (especially cocoa) and demand for timber. On-reserve, degradation has increased dramatically in the last decade, due to over-logging by timber companies, encroachment for alternative uses, illegal logging, and bushfires. Fire is presently the greatest threat to long-term productivity, genetic diversity and general health of Ghana's forests. Forest resources at risk of fire damage and total destruction are huge in both total forest coverage and value. FAO'S 1982/83 assessment indicated that 50% of Ghana's vegetation cover had been destroyed by fire, with 30% of semi-deciduous forest altered in composition and structure. Most of the benefits for which forests are managed (e.g. timber, socio-cultural values) are found in the fire-prone forest belt and even in extremely degraded forests the resources still available are valuable enough to warrant reasonable protection.

The protection and management of Globally Significant Biodiversity Areas (GSBAs) is regarded as the most important single issue, with a need for research to identify and quantify goods and services of these areas. In addition, needs assessment should be conducted in communities surrounding these areas as well as education that focuses on soliciting support from the community instead of blaming them. Various components of biodiversity, their relationship and how they respond to stress or threats should also be explained to the communities around the GSBAs. A major issue that could impede progress towards biodiversity conservation is the FC's self-financing objective through a heavy dependence on income from timber exploitation. Options of forest use other than timber exploitation should be identified.

While Ghana's legal framework for biodiversity conservation and natural resources management embraces community participation and decision-making at local levels, policies/regulations are not translated into action on the ground. The legal/policy framework for biodiversity highlights the importance of using resources wisely to generate income and to alleviate rural poverty, especially for those living near important biodiversity resources. However, those who rely on natural resources for income generation and for cultural/medicinal purposes, and those most impacted by protected areas, are not benefiting from conserving resources and have little input into management decisions. Ownership of Forest Reserves is vested in the President of Ghana in trust for land holders. However, local communities are granted the following rights: a) communal rights e.g. shooting, hunting, collecting snails/firewood, cane, raffia, rattan cutting; b) farming land rights - demarcated areas for individuals or groups.

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Other modules to be published among the following:
Plantation forestry, Tree domestication, Forest restoration, Genetic modification