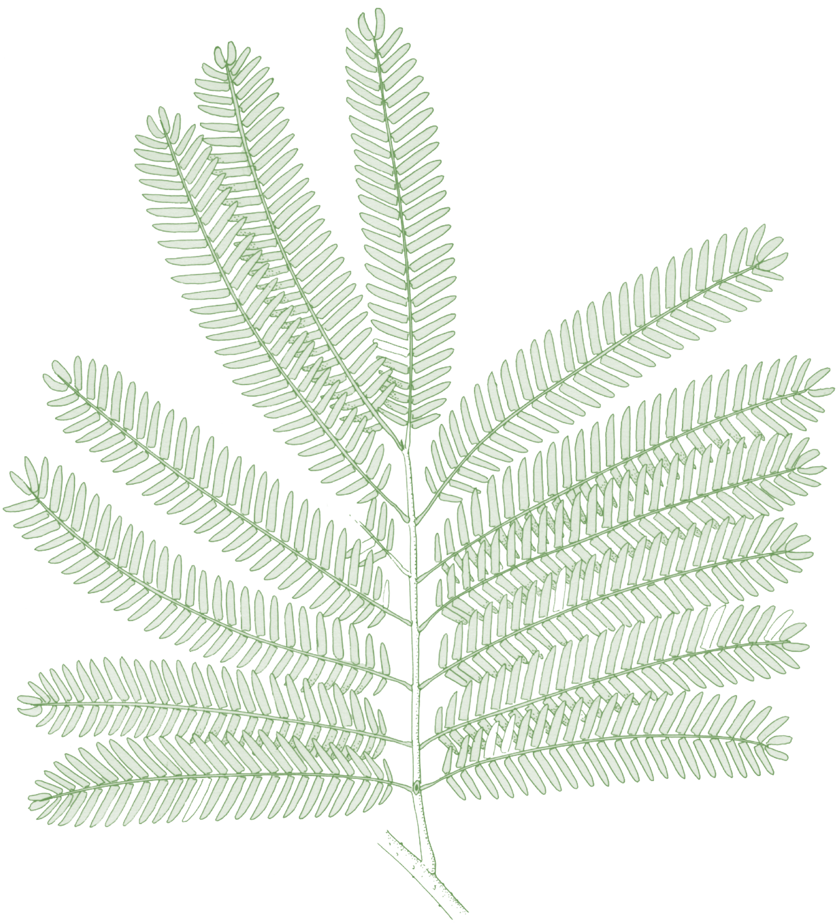
Bioversity International

MODULE 1
Species conservation strategies

Case study 1.1

Leucaena salvadorensis: genetic variation and conservation

David Boshier



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Module 1
Species conservation strategies

Case Study 1.1

Leucaena salvadorensis: genetic variation and conservation

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This case study presents information on *Leucaena salvadorensis* (Standley ex Britton & Rose), a little-known species that has been largely neglected and overlooked by foresters and botanists until recently. Use the information to devise a conservation strategy for the genetic conservation of this threatened species, on a country basis (either El Salvador, Honduras or Nicaragua), or from the global perspective of an international organisation that supports conservation (e.g. FAO). The strategies should take into account both the patterns of genetic variation in the species and the forestry/socio-economic context of the different countries, and may combine *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, as funds for conservation will be limited, indicate the relative priority of actions. The exercise is set in the 1990s, both in terms of the species status and the country profiles. 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 has human disturbance shaped the genetics of *L. salvadorensis*?
- What is the mating system, the seed and pollen dispersal mechanism?
- What are the levels of genetic variation and how are the alleles distributed across populations? List the localised but common alleles (see Table 2).
- Are the provenance regions suggested in the map valid? Which populations are different? e.g. original collectors grouped the Calaire and Charco Verde sites together as one provenance - is this valid? (see Figs 1-2, Table 1).

In your strategy you should detail:

- What are the threats to *L. salvadorensis* (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? see Table 1); ***other types of problems*** (e.g. social, communication, resources – see Conservation status, Country profiles sections)
- Which conservation methods - *in situ*, *ex situ*, on-farms (*circa situm*)?
- What are the limiting social factors to conservation and planting?
- What do end-users need to know and how will you communicate that?
- ***Who*** will do, ***what***, **where** and ***how*** will you pay for it?

Introduction

There are some 22 species of *Leucaena*, all native to Mexico, Central America and northern South America. One of these, *L. leucocephala*, is popular because of its abundant seed availability, ease of management, potential growth, nutritional benefits for livestock and range of products. *L. leucocephala* has been widely used and promoted by a variety of organizations, both internationally and in Central America, for roadside and village plantings, small-scale plantations and more recently for live fences, soil conservation barriers and windbreaks.

However, in recent years, biological limitations associated with the widespread cultivation of *L. leucocephala* have become evident. These include lack of drought tolerance, poor growth on acid soils, low wood durability, heavy pod production and susceptibility to an insect defoliator (*Heteropsylla cubana*). These limitations are partly attributed to the narrowly based genetic material that has been used in most planting programmes, due to three main factors: 1) the species is largely self-pollinating and therefore inbreeding; 2) there is a lack of knowledge of its natural distribution, believed to be in Guatemala and Mexico, and hence where more variation may occur; 3) cultivated material is derived from a few closely related cultivated trees in Mexico and El Salvador.

One of the ways to diversify the genetic material of *Leucaena* is by utilizing other species in the genus. There are five species of *Leucaena* native to the Honduras-Nicaragua-El Salvador area: *L. diversifolia, L. lempirana, L. multicapitulata, L. salvadorensis, L. shannonii* subsp. *shannonii*. A sixth species, *L. leucocephala* subspecies *glabrata*, is introduced and widely cultivated in all three countries. *L. salvadorensis* has been identified as a potentially valuable species for reforestation programmes because of its environmental tolerance, the quality and traditional use of its products. Preliminary results from species trials which include *Leucaena salvadorensis,* show its potential for planting programmes both in Central America and other tropical regions. Severe deforestation is however threatening this valuable species and active conservation measures are now needed.

Species description, uses and conservation status

Taxonomy and botanical features

L. salvadorensis was named by P.C. Standley in 1925 based on a botanical specimen collected in eastern El Salvador in 1924. Since then, the species was neglected by botanists/foresters being rarely, if ever, collected or seen, until the last fifteen years, when its identity, characteristics and potential became more clearly understood.

The lack of detailed botanical exploration and collection in Central America before 1975, meant that botanists and foresters overlooked *L. salvadorensis* and confused it with other species. Initially, *L. salvadorensis* was confused with *L. leucocephala*. This confusion was aggravated by use of the designation “Salvador-type” to describe the giant arboreal variety of *L. leucocephala*, now known as *L. leucocephala* subsp. *glabrata*. Exploration in eastern El Salvador in and near Jocoro in 1967 by Prof. J.L. Brewbaker from the University of Hawaii, revealed the area was heavily deforested. However a few Salvador-type trees were found in the city square and these were wrongly assumed to be the *L. salvadorensis* found by Calderón forty years earlier. In fact these trees were almost certainly cultivated and belonged to *L. leucocephala*. Genuine *L. salvadorensis* was not found by Brewbaker presumably because it is now rare in that area as in other parts of its native range. In this way, Brewbaker came to treat *L. salvadorensis* as a synonym of *L. leucocephala*.

From the late 1970s, botanical exploration and collection in Central America led to the discovery of *L. salvadorensis* in Nicaragua and Honduras. At the same time, the morphological differences from *L. shannonii* and *L. leucocephala* suggested that *L. salvadorensis* did in fact represent a true species in its own right. *L. salvadorensis* can be distinguished from other *Leucaena* species based on a range of morphological traits and geography. Further differences in cytology and growth characteristics based on cultivated material in Hawaii have also confirmed the distinction of *L. salvadorensis* as a separate species.

Tree characteristics

L. salvadorensis forms a small- to medium-sized thornless tree, typically 10-15 m in height, with 20-50 cm dbh (diameter at breast height). Occasionally, mature trees can reach 20 m height and 70-100 cm in diameter. Trees are typically branchy when young, but may have a short clear bole to 5 m height when older. The upright angular branches form a narrow, open crown. The bark on young trees is smooth, mid metallic grey or grey-brown, while the inner bark is salmon pink. With age, the bark becomes darker grey-brown; rougher and shallow vertical fissures develop and the inner bark becomes deep red.

Phenology

Trees are wholly or partially deciduous losing some or all of their leaves in the dry season for one to four months. In the mid to late dry season (February–April), as pods are shed, there is a major burst of flowering which often coincides with leaflessness. For a number of weeks, trees are covered in sweetly scented flowers which are visited by large numbers of small bee species. Small bees groom the surface of the flower heads for pollen and are likely to play an active role in pollination. Leaf flushing occurs gradually in April/May, with small unripe seed pods formed during the same period. Pods take approximately 10-12 months to ripen, seeds being dispersed by gravity.

L. salvadorensis produces relatively few seeds in comparison with *L. leucocephala*. Despite flowering and fruiting abundantly after only 2-3 years, there is rarely more than one pod per flower head whereas *L. leucocephala* flowers and fruits prolifically after 1 year, with 5-20 pods per flower head. In natural populations of *L. salvadorensis*, seed production is variable from area to area and year to year. *L. salvadorensis* is a self-incompatible outcrossing species, which can explain why seed production is higher in dense stands of trees and lower in the case of isolated trees. Unripe pods can be damaged by strong early dry season winds which can further limit seed production in natural stands. Cold stored (5°C) seed can retain its viability for many years (>20).

Distribution

L. salvadorensis occurs in El Salvador, Honduras and Nicaragua in the seasonally dry tropical forest on south-facing Pacific slopes between 200-800 m (occasionally as high as 1000 m) above sea level (see Fig. 1). The many drought tolerant species in the flora reflects the very long and severe dry season. This dry forest is rich in species, with up to 300 native tree species. The climate in the natural range of *L. salvadorensis* is strongly seasonal, typically with a 5-7 month dry season. Annual rainfall varies from around 800-2000 mm and the mean annual temperature from 25-30°C. The dry season is always severe and prolonged, with early dry season desiccating winds common in all the distribution.

The species occupies a clearly defined largely contiguous distribution. It has been found almost exclusively on the southern slopes of the Pacific watershed and rarely, if ever, on the flat coastal plains. It is also notable that the distribution rarely overlaps with other *Leucaena* species. The only exception is *L. shannonii*, but even here, the two species are largely separate. The soils where *L. salvadorensis* is found are young and superficial and primarily of volcanic origin. The soils have suffered severe degradation through slash and burn agriculture, desiccation and erosion. They are extremely rocky, shallow, skeletal and generally freely drained. Tentative broad provenance regions have been defined as a basis for seed collection (see Fig. 1). Main watersheds were largely used as a pragmatic basis for defining the provenance regions, except for western and eastern regions, where national boundaries between Honduras/El Salvador and Honduras/Nicaragua were used.

Uses and potential value for tree planting

L. salvadorensis is highly prized by local communities as a source of a range of products. Trees can produce straight poles and these are used in traditional house construction as large diameter corner posts and in roof construction. *L. salvadorensis* is sometimes managed by pruning to produce suitable posts for house construction. The wood is reputed to be resistant to decay and durable when in contact with the ground. According to local residents, corner posts in the ground last between 15 - 20 years. The wood is also an excellent fuel being dense, easily split and dried. The density of *L. salvadorensis* (0.81) is marginally greater than that of *L. leucocephala* (0.5-0.7), with abundant heartwood produced from an early age (e.g. 56% at 5 years). Woody biomass production of *L. salvadorensis* is high at 22 tons dry weight/ha/year at 4 years of age.

The trees resprout after coppicing or pollarding and can be managed in this way. Natural regeneration is browsed by cattle and so the tree may have fodder potential. Initial research on nutritive value indicates high *in vitro* digestibility, but low palatability. The traditional retention of *L. salvadorensis* by farmers in fields in parts of Honduras and Nicaragua indicates the species agroforestry potential. *L. salvadorensis* can also be raised as a plantation crop, as single tree plantings and in a range of other agroforestry/agropastoral systems. In several areas, *L. salvadorensis* has been studied in a series of alley cropping/soil conservation trials and intercropped with corn, sorghum and cowpea.

In Central America, there is no evidence that *L. salvadorensis* poses a threat as a weed, and given the sparse seed production compared with other *Leucaena* species (e.g. *L. leucocephala*), is unlikely to be an aggressive colonizer when planted elsewhere. The most common method of propagating *L. salvadorensis* in its native distribution is to encourage natural regeneration and protect seedlings and coppice shoots from fire and grazing animals.

Pests and diseases

The psyllid, *Heteropsylla cubana,* is a small sap-sucking insect, which is native to Central America and feeds on young shoots and new leaves of *Leucaena* species. *H. cubana* is highly mobile and large numbers may cause defoliation and sometimes death of a tree. Psyllids have been found attacking *L. salvadorensis* in both Honduras and Hawaii but comparative susceptibility studies with other *Leucaena* species have not been done. Seed pods can also show high levels of damage by bruchid beetles.

In 1990, a seed pod disease was discovered in a *L. salvadorensis* seed orchard. Preliminary analysis identified a fungal complex of a *Ravenelia* sp. and a *Fusarium* sp. causing lesions and pod rotting. The *Ravenelia* sp. may be pathogenic and the *Fusarium* sp. probably a secondary infection. There have been some observations of progressive mortality in *L. salvadorensis*, with symptoms of shoot die-back followed by drying of the twigs and eventual death. In a *Leucaena* species elimination trial in Honduras, *L. salvadorensis* had some of the lowest survival (74-84%) compared to other *Leucaena* species. The causes of this die-back are unknown but poor site adaptability is a possibility.

Trial results

L. salvadorensis has, in terms of early height growth, outperformed a wide range of other *Leucaena* species in trials on a variety of sites in Honduras. The trials also contained some well known native species, including; *Albizia saman*, *Cordia alliodora, Enterolobium cyclocarpum*, *Hymenea courbaril* and *Swietenia humilis*, as well as other exotic species. Further research is, however, needed to elucidate the specific soil and climatic factors involved. Limited trials have not revealed much about provenance differences, although provisional provenance zones were proposed based on distribution, topography and elevation (see Fig. 1 and section on distribution).

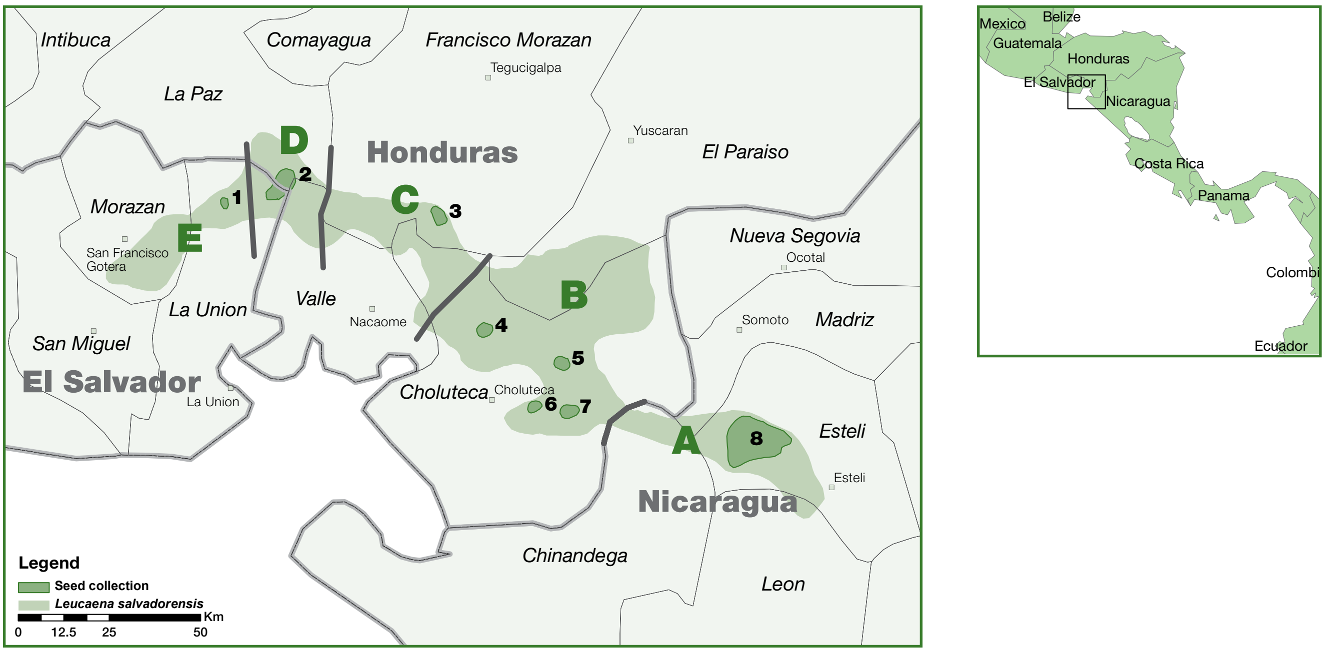
Conservation status

The dry forest is the most degraded and endangered forest type in Central America. Historically it was readily converted to other land uses such as cropping and grazing in addition to extensive cutting of valuable timber trees and fuelwood. There remains less than 2% of undisturbed dry tropical forest in Central America, with only 0.08% within national parks or other conserved areas. Degradation of the last remnants of intact forest is exacerbated by fire which is a common occurrence during the dry season as further land is cleared for cropping.

Degradation of the natural dry forest has been particularly severe in most parts of *L. salvadorensis*' distribution, and only a few small forest remnants, on steep inaccessible slopes and gullies, are now known. The genetic resource of *L. salvadorensis* is probably severely degraded as a result of this clearance of the natural forest cover. *L. salvadorensis* trees are often found in such remnant forest patches in Honduras, while on the hills around San Juan de Limay (northern Nicaragua) there is a lower human population density and not only has the tree cover survived better, but *L. salvadorensis* is more abundant than elsewhere.

Degradation has been mitigated by traditional agroforestry practices which include retention of *L. salvadorensis* in fields by farmers within its native range and means that the species is more common than the depleted state of the natural forest cover would suggest. *L. salvadorensis* is deliberately retained and protected by farmers around houses and in fields and fencelines, although there is little tradition of planting the species. Without this retention and protection *L. salvadorensis* would now be extremely rare and threatened with extinction. The possible depletion of the genetic base of *L. salvadorensis* caused by the high rates of deforestation has been compounded recently by the indiscriminate planting of *L. leucocephala* in those areas where *L. salvadorensis* occurs naturally. The continued traditional use of *L. salvadorensis* is under threat by the introduction of *L. leucocephala* and its promotion for tree planting by development agencies. By concentrating on *L. leucocephala* in tree planting programmes, there is a danger that the traditional retention of *L. salvadorensis* in agroforestry systems will be neglected. This could rapidly hasten the demise of *L. salvadorensis*.

Figure 1. Natural distribution of *Leucaena salvadorensis* (shaded area). Numbers (1-8) refer to the corresponding population numbers in Table 1. Letters (A-E) refer to provenance regions delimited by bold lines (see explanation in Distribution section)



Genetic variation in natural populations

Genetic variation and population differentiation in *Leucaena salvadorensis* were studied within and among eight populations across the species' range in Central America. Measures of genetic variation were determined using isozyme electrophoresis of seed tissue.

Seed collection

Eight populations, representing the entire natural range of *L. salvadorensis* (Fig. 1 & Table 1), were sampled. These consist of highly degraded and fragmented populations such as scattered forest remnants, secondary scrub and scattered trees in fields, fencelines and on farms around houses. In each population, 60 open-pollinated seeds from a minimum of 6, normally 20, mother trees (e.g. 3 seeds from each of 20 mother trees; 6 seeds from 10) were analysed. Sample sizes varied, depending on seed availability.

Distances between sampled trees varied substantially due to population size and significant human disturbance of the populations. Population sizes (Table 1) varied considerably, from large - which included more than 1,000 individuals (San Juan de Limay), medium size - more than 100 individuals (e.g. San Antonio del Norte), to only 16 trees in the only population in El Salvador (Nueva Esparta) of which only three were old trees, suggesting very low effective population size.

Table 1. Site data for *Leucaena salvadorensis* populations.

No*	Population	Country	Lat.	Long.	Altitude masl	Mean annual rainfall/ mm	No trees in population	No trees sampled
1	Nueva Esparta	El Salvador	13°48'N	87°50'W	320	2200	16	6
2	San Antonio del Norte	Honduras	13°52'N	87°41'W	200-400	2200	224	20
3	Rio Nacaome	Honduras	13°45'N	87°18'W	650-780	1200	120	10
4	La Garita	Honduras	13°26'N	87°11'W	480-600	1120	500	20
5	La Galera	Honduras	13°22'N	87°01'W	500	2037	181	14
6	Calaire	Honduras	13°15'N	87°06'W	350-500	2037	700	20
7	Charco Verde	Honduras	13°16'N	87°00'W	540	2037	79	6
8	San Juan de Limay	Nicaragua	13°12'N	86°29'W	500-900	850	>1000	20

Note: * refers to the corresponding numbers in Fig. 1

Data analysis

Standard measures of genetic diversity including the percentage of polymorphic loci (*P*), the mean number of alleles per locus (*A*), and both genetic diversity or expected heterozygosity (H_e) and observed heterozygosity (H_o) were calculated for each population. Population differentiation was investigated using Wright's *F* statistics and Nei's genetic diversity statistics. Nei's genetic distances were calculated among pairs of populations and used in a hierarchical cluster analysis of populations (Fig. 2). The relationship between genetic differentiation and geographic distribution was investigated by regressing gene flow (Nm) values computed for all pairs of populations on the distance between pairs of populations (Table 4 & Fig. 3).

Table 2. Allelic frequencies at seven polymorphic loci in “natural” populations of *Leucaena salvadorensis*

Locus	Allele	Population								Mean
		1) NES	2) SAN	3) RIO	4) GAR	5) GAL	6) CAL	7) CV	8) SJL	
Pgm-1	a	-	-	0.085	-	-	-	-	-	0.008
	b	1.000	0.925	0.415	0.092	0.508	0.817	0.450	0.608	0.595
	c	-	0.075	0.500	0.908	0.492	0.183	0.512	0.392	0.397
					*				*	*
Pgm-2	a	0.750	0.983	-	0.050	0.412	0.142	0.483	0.483	0.431
	b	-	-	-	0.050	0.017	0.342	-	0.067	0.062
	c	0.250	0.017	1.000	0.900	0.567	0.517	0.517	0.450	0.508
		*			*					*
Pgi-2	a	0.667	0.417	0.427	0.292	-	0.475	0.492	0.608	0.422
	b	0.117	0.300	0.256	0.425	-	0.283	-	0.212	0.197
	c	0.217	0.283	0.317	0.283	1.000	0.242	0.508	0.175	0.381
		*			*		*			*
Pgi-3	a	0.367	-	-	-	0.292	0.083	-	0.692	0.187
	b	-	-	-	-	0.342	-	-	-	0.045
	c	0.633	1.000	-	0.150	-	0.808	-	-	0.337
	d	-	-	1.000	0.850	0.367	0.083	1.000	0.308	0.428
	e	-	-	-	-	-	0.025	-	-	0.003
		*				*	*			*
Pgd-1	a	-	0.475	0.512	0.450	0.467	0.508	0.500	-	0.358
	b	-	-	-	0.150	-	-	0.025	0.950	0.147
	c	1.000	0.525	0.488	0.400	0.533	0.492	0.475	0.050	0.496
					*			*		*
Idh-1	a	0.150	0.117	0.281	0.175	-	0.392	-	-	0.133
	b	0.467	0.267	0.342	0.208	1.000	0.267	0.092	0.100	0.343
	c	0.375	0.592	0.342	0.617	-	0.333	0.908	0.900	0.515
	d	0.008	0.025	0.037	-	-	0.008	-	-	0.009
		*								*
Idh-2	a	0.492	0.492	0.390	0.458	0.458	0.708	0.467	0.200	0.461
	b	0.212	0.217	0.402	0.483	0.300	-	0.025	0.292	0.235
	c	0.292	0.292	0.195	0.058	0.242	0.292	0.508	0.508	0.303
	d	-	-	0.012	-	-	-	-	-	0.001
		*			*			*		*

Notes: * significant deviation from Hardy-Weinberg expectations at $P<0.05$. Populations: NES - Nueva Esparta; SAN - San Antonio del Norte; RIO - Rio Nacaome; GAR - La Garita; GAL - La Galera; CAL - Calaire; CV - Charco Verde; SJL - San Juan de Limay. Locus: Pgm-Phosphoglucomutase; Pgi–Phosphoglucose isomerase; Pgd–Phosphogluconate dehydrogenase; Idh–Isocitrate dehydrogenase

Results

Seven polymorphic loci were identified in four enzyme systems (Table 2). Mean number of alleles per locus (*A*), % of polymorphic loci (*P*), mean observed (H_o) and Hardy-Weinberg expected heterozygosities (H_e) are summarised in Table 3. The mean number of alleles per locus in the populations ranged from 2.14 (Charco Verde) to 2.86 (Calaire). The percentage of polymorphic loci ranged from 71% in La Garita to 100% in the San Juan de Limay and Calaire populations. Mean *Ho* ranged from 0.300 (Nueva Esparta) to 0.495 (Calaire). The most variable population under all criteria was Calaire and the least variable in terms of *A* were La Galera and Charco Verde, and Nueva Esparta for H_o.

L. salvadorensis showed relatively large levels of genetic differentiation between populations (mean of 0.316; values may range from 0 – populations not different, to 1 – populations differ highly in alleles and frequencies). Similarities between populations (Fig. 2) and a weak (non-significant) negative correlation between genetic and geographic distances (r = -0.17, Table 4) showed a general lack of geographical relationships. Some geographically close populations (e.g. La Galera, Calaire) failed to group together, whilst others (e.g. San Antonio del Norte, Nueva Esparta) did. The species' current distribution is very patchy, and likely to be due to recent extensive deforestation of the dry forest. The data suggest this has already led to some population differentiation and fixation of some alleles, possibly due to founder effects from reductions in population size. Population sizes have, however, probably remained sufficiently high to maintain high levels of genetic diversity within individual populations.

Table 3. Genetic variability for *L. salvadorensis* populations at seven isozyme loci.

Population	Mean no. of alleles per locus (A)	% polymorphic loci* (P)	Mean heterozygosity	
			Observed (H_o)	Expected (H_e)
1) Nueva Esparta	2.29	71.4	0.300	0.372
2) San Antonio del Norte	2.43	85.7	0.350	0.363
3) Rio Nacaome	2.57	71.4	0.460	0.442
4) La Garita	2.71	71.4	0.374	0.423
5) La Galera	2.14	71.4	0.445	0.405
6) Calaire	2.86	100.0	0.495	0.496
7) Charco Verde	2.14	85.7	0.393	0.380
8) San Juan de Limay	2.43	100.0	0.355	0.419
Mean	2.51	79.2	0.394	0.599

Note: * a locus is considered polymorphic if the frequency of the most common allele does not exceed 0.95.

Figure 2. Genetic similarities (Nei unbiased genetic distance) between *L. salvadorensis* populations

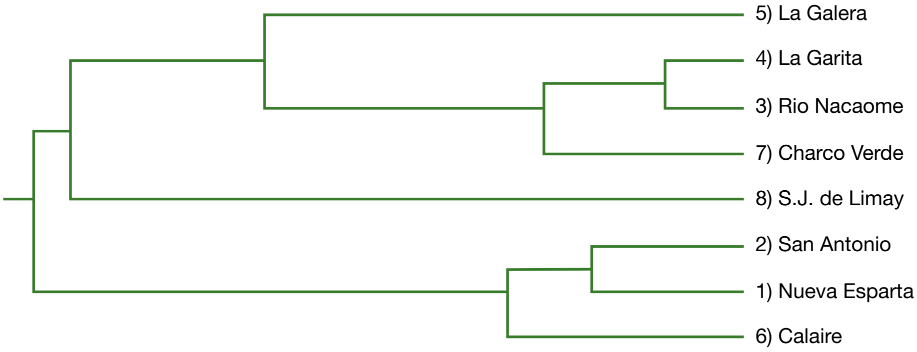
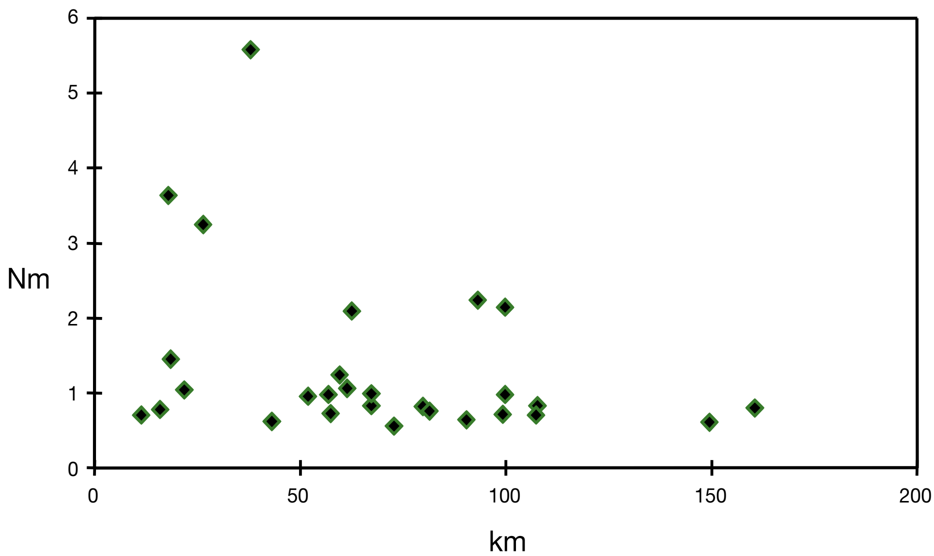


Table 4. Gene flow (Nm - number of migrants per generation) below shaded diagonal and geographic distance (in km) above shaded diagonal between *L. salvadorensis* populations (details in Table 1). Correlation between gene flow and geographic distance: *r* = - 0.17

Population	1) NES	2) SAN	3) RIO	4) GAR	5) GAL	6) CAL	7) CV	8) SJL
1) NES	-	18.0	57.5	81.4	99.8	99.8	107.4	160.5
2) SAN	3.64	-	43.1	72.9	90.4	93.2	99.3	149.6
3) RIO	0.72	0.62	-	37.9	52.0	59.7	62.5	107.7
4) GAR	0.76	0.56	5.58	-	18.5	21.8	26.4	79.9
5) GAL	0.78	0.64	1.45	1.06	-	15.9	11.3	61.4
6) CAL	2.14	2.24	1.24	1.04	0.96	-	11.0	67.3
7) CV	0.70	0.71	2.09	3.25	0.98	0.99	-	56.8
8) SJL	0.80	0.70	0.83	0.82	0.61	0.83	0.98	-

Figure 3. Relationship between gene flow between populations (Nm – number of migrants per generation) and geographic distance (km); based on data from Table 4



Country and organization profiles

(Source: extracts from country submissions to IPGRI, 1998 and as such reflect their emphases)

El Salvador

- Area: 21 040 km^2 Administrative regions: municipalities within 14 Departments
- Population: 6 000 000
- Seasons: Dry (Nov-April), Rainy (May-Oct)
- Rainfall: 1500-2500 mm per year
- 3 climatic zones: Hot: 0-800 masl (metres above sea level)
  Temperate: 800-1200 masl
  Cold: 1200-2700 masl
- The flora of El Salvador has few endemic species
- Agriculture is the principal economic activity. For management of the agricultural/forestry resource base, several zones have been classified: intensive cultivation, permanent cultivation, forestry, and marginal agricultural use. The main crops important to the economy are: coffee, cotton, sugar cane, cereals, henequen (sisal hemp), oil seeds (palm oil), tobacco, fruit and vegetables.

Native phytogenetic resources

- Due to the alarming deterioration of plant genetic resources, in 1985 the Centro Nacional de Tecnologia Agropecuaria y Forestal (CENTA) created the Programme of Phytogenetic Resources, focussing on 3 areas (botanical gardens and collections, seed banks, tissue culture), giving priority to species with potential for food/nutrition and medicine.
- Deforestation in El Salvador has been steadily increasing, due to a high population density (261/km^2), in combination with economic factors, which place high pressure on forested areas. The annual deforestation rate is 4500 ha, which supplies the demand for forest products, primarily fuelwood (estimated annual demand, 4.5 million m^3). This supplies mainly rural households and small industries such as brick-making, salt and lime production.
- Institutional reforestation efforts have been minimal in comparison to deforestation. Reforestation programmes which are operating in El Salvador are orientated to satisfy demand for fuel and timber for rural construction, using mainly exotic species, but also native *Gliricidia* and *Leucaena* species. The latter two genera dominate current reforestation programmes, although figures of areas planted are unavailable. Many reforestation programmes have also focused on the creation of protected areas.
- Species in danger of extinction are listed below:

Species	**Family**	**Common name**
Abies guatemalensis	Pinaceae	Pinabete
Acacia centralis	Mimosaceae	Quebracho
Aeroponax lanchonocephalus	Araliaceae	Mano de León
Agronanda racemosa	Apiliaceae	Ciprés silvestre
Amyris elemifera	Rutaceae	Roldán
Aspidosperma megalocarpon	Apocynaceae	Jabillo, cordel
Astianthus viminalis	Bignoniaceae	Chilca
Beilschmiedia mexicana	Lauraceae	Aguacate macho
Bocconia glaucifolia	Papaveraceae	Brasil

Species	Family	Common name
Bumelia celastrina	Sapotaceae	Hormigo
Capparis calciphila	Capparaceae	Repollo
Capparis tuerckhemi	Capparaceae	Palo de pólvora
Cedrela tonduzii	Meliaceae	Cedro peludo
Colubrina gloverata	Rhamnaceae	
Conostegia icosandra	Melastomataceae	Ciren de árbol
Cordia collococca	Boraginaceae	Manune rojo
Cordia salvadorensis	Boraginaceae	
Cosmibuena matudae	Rubiaceae	Hoja de cohete
Dalbergia funera	Papilionaceae	Funera
Diospyros nicaraguensis	Ebenaceae	Ébano
Erythea salvadorensis	Palmaceae	Palma de sombrero
Esenbeckia litoralis	Rutaceae	Matazanillo
Eugenia pachychiamis	Myrtaceae	
Eupatorium ruae	Asteraceae	
Exostema caribaeum	Rubiaceae	Quina
Exostema mexicanum	Rubiaceae	Quina
Exothea paniculata	Sapindaceae	Cuiliote
Ficus morazaniana	Moraceae	Amate
Ficus rensoniana	Moraceae	
Gliricidia guatemalensis	Papilionaceae	
Guaiacum sanctum	Zygophyllaceae	Guayacán
Guapira witsbergeri	Nyctaginaceae	Siete camisas
Guatteria anomala	Annonaceae	
Haematoxylon brassiletto	Mimosaceae	Brasil
Hampea reynae	Malvaceae	Majagua
Hampea stipitata	Malvaceae	
Hauya ruacophillia	Onagraceae	Guayabillo
Leucaena shannonii	Mimosaceae	Hormiguillo rojo
Lonchocarpus michelianus	Papilionaceae	Chaperno
Lysiloma multifoliolatum	Mimosaceae	
Matudae trinervia	Hamamelidaceae	Ujushte
Maytenus chiapensis	Celastraceae	Escobo blanco
Miconia prasina	Melastomataceae	
Mimosa platycarpa	Mimosaceae	
Ormosia macrocalyx	Papilionaceae	Pito
Parathesis acuminata	Myrsinaceae	
Parathesis congesta	Myrsinaceae	Amaranto silvestre
Phyllanthus acuminatus	Phyllanthaceae	Jocotillo
Pisonia donnell-smithii	Nyctaginaceae	

Species	Family	Common name
Platymiscium pleiostachyum	Papilionaceae	Palo de marimba
Quercus esesmilensis	Fagaceae	
Quetzalia reynae	Celastraceae	Pato de palomo
Robinsonella speciosa	Malvaceae	Mozoton
Simira calderoniana	Rubiaceae	Limpiadientes
Synardisia venosa	Myrsinaceae	Cerezo
Taxus globosa	Taxaceae	
Thouina acuminata	Sapindaceae	
Ulmus mexicana	Ulmaceae	Mezcal
Viburnum mortonianun	Caprifoliaceae	
Weinmannia balbisiana	Cunoniaceae	Malacate
Wimmeria cyclocarpa	Celastraceae	Lupita
Zanthoxylum aguilarii	Rutaceae	Pochote de tierra

In situ *conservation activities*

- Population growth and urban expansion have resulted in less than 3% of the country's territory remaining under cover of original or primary forest.

Forestry and phytogenetic resources

- Every year, with the Forestry Service, the Department of Natural Resources formulates a plan for seed collection of both exotic and native forest tree species. The Forestry Service's seed bank collects germplasm mainly from species which are in demand for reforestation projects. Amongst the most used are: *Tectona grandis* (Teak), *Eucalyptus camaldulensis, E. citriodora, E. deglupta, E. tereticornis, Leucaena leucocephala, Gliricidia sepium, Cassia siamea, Tabebuia donnell-smithii* and *T. rosea.*
- The Forest Service's seedbank is the only official institution which collects seeds, though there has been an increase in private seed collectors. Along with nursery production of seedlings, seeds are used for reforestation and commercialisation. The increase in promotion of forest resources has resulted in good prices for seeds.

Programme for genetic improvement in forestry implementation

Collections used to be carried out for the seed bank within a defined area, using few technical criteria, only collecting from trees with the desired form. During 1983-1991 a CATIE project (Proyecto Leña y Fuentes Alternas de Energia and its successor Madeleña) introduced seeds of some forest species from the CATIE seedbank to El Salvador to compare adaptability to local conditions. This material was evaluated through field trials, managed as seed orchards, to produce seeds of those species that were proven as best adapted e.g. *Tectona grandis* (Teak), *Eucalyptus camaldulensis, E. citriodora, E. tereticornis, Leucaena leucocephala, Acacia mangium, Colubrina ferruginosa,* amongst others. Seed is distributed by the Forest Service by sale or donation. Through a CATIE-DGRNR agreement, the seed bank also collects and distributes seeds through a network of institutions. Distribution must meet the objectives of promoting and increasing forest cover.

Aims, policies, programmes and national legislation

In 1989, the El Salvador government set up the Programme of Economic and Social Development which detected the need to implement an ecological policy, which protected the environment permanently and developed alternatives to reduce current environmental problems. On this basis, the Executive Secretary of the Environment (SEMA) was created within the Ministry of Agriculture and Ranching. Within SEMA's agenda are the Environmental Agency and Development Planning, and the Forestry Action Plan for El Salvador. Both were formulated to include the participation of national institutions (public and private) and NGOs, to promote forestry plantations establishment for energy (biomass), increasing the production and supply of fuelwood, while conserving the few native reserves. To preserve natural areas, instruments such as the Law of Conservation of Wildlife, were created, and agreements with CITES signed to avoid commercialisation of forestry species in danger of extinction.

Honduras

- Area: 112 492 km^2. Administrative regions: municipalities within 18 Departments
- Altitudes: from sea level to 2872 masl
- Population: 5 200 000, 64% of households below the poverty line, 71% of which are in rural areas (1993).
- GDP: $116 per capita the lowest in Central America. Income distributions are below global average, the situation being worse in rural areas, where income of >80% of thepopulation does not meet basic needs.

Forest resources

- Area defined as forest: 77 886 km^2. Only about 50% of that actually has forest cover.
- During the 25 year period from 1965 to 1990 forest cover decreased by 14 283 km^2 (20.1%). The decrease has been more noticeable in broadleaved forests, with a loss of 12 250 km^2 (30.1%).
- The principal causes of deforestation are: migratory agriculture, extensive cattle grazing/ranching and pasture, over-exploitation of fuelwood, and forest fires, all of which affect 20 000 ha annually.
- The agricultural sector in Honduras is divided. Most farms are small, managed by campesinos who use mainly local seed/stock and traditional, subsistence practices, including slash and burn, hand-sowing, often on slopes steeper than 30%. At the other extreme, are large industrial plantations and ranching, occupying large areas of the best agricultural land, especially in interior valleys, plains and Atlantic coastal valleys.

Dry zone forest

- The dry zone forest includes a large diversity of broadleaved tree species, and is found in areas of low rainfall and high temperatures in interior valleys and coastal Pacific plains in the southern areas.
- Principle timber species in these forests include: *Swietenia humilis, Albizia longepedata, Bombacopsis quinata;* in danger of extinction through over exploitation, land-use change and lack of management.
- CONSEFORH (Proyecto Conservación y Mejoramiento de los Recursos Forestales de Honduras) started in 1985 to conserve the genetic base of these species, as well as to produce improved seed for reforestation.
- Other threatened species in this zone include: *Crescentia alata, Simarouba glauca* (the seeds are used for making soap), *Bursera simaruba* (used as teeth cleaning sticks), and *Guayacan guatemalensis.*

Forest legislation

- Measures aimed at sustainable management of these forests are outlined in the Law for Modernisation and Development of the Agricultural Sector, as part of the Decreto Legislativo No.31-92 of 5th January 1992.
- Article 71 stipulates that the exploitation, commercialisation and industrialisation (internal and external) of timber and other forest products may be carried out only subject to current legislation.
- Article 73 and regulation 54, decree that management plans that include environmental impact assessments should be obligatory and become standard procedure.

National* in situ *conservation activities

- *In situ* conservation of agricultural species or traditional local varieties is carried out by farmers. They have preserved species through repeated sowing of local material grown for their own consumption, leaving enough each year for the next planting cycle.
- The *in situ* conservation of annual agricultural species is extremely difficult in developing countries because no controls exist on the introduction of improved seed through modern agricultural practices either in reserves or in areas of subsistence agriculture. Consequently, there is an increasing threat of erosion of the genetic base through substitution of improved varieties for local ones.
- *In situ* conservation has been implemented mostly by protecting ecosystems where there are many native species, some of which are closely related to cultivated ones. This has been done through the SINAPH (Sistema National de Areas Protegidas) programme, in accordance with the General Environment Law.

Existing* ex situ *collections

- The composition of national collections is varied. ESNACIFOR (Escuela National de Ciencias Forestales) maintains native material of both broadleaved and coniferous species in its seedbank and seed orchards.

Management of phytogenetic resources

- Existing legislation should dictate policy for exercising the greatest control over the forest and its management (as in protected areas). Lack of trained staff and equipment do not currently permit this.
- *Ex situ* conservation in Honduras and in other Central American countries appears to be the best way to achieve conservation of phytogenetic resources in the face of the increasing threats and extinctions of forest species. For this reason, COHDEFOR (Corporación Hondureña de Desarrollo Forestal) started a programme of genetic improvement of trees in 1977. Subsequently, the CONSEFORH project was established at ESNACIFOR in 1987, with specific aims of conservation and genetic improvement of forest resources. It is a bilateral project between the governments of Honduras and the UK.
- From 1987-1994 seeds of various threatened species were collected by CONSEFORH in dry, humid and coniferous forests. Species included: *Pinus tecunumanii, P. caribaea* (var *hondurensis), Cordia alliodora, Bombacopsis quinata, Albizia niopoides, Albizia guachapele, Swietenia humilis,* and L*eucaena salvadorensis.*
- CONSEFORH established: 1) provenance trials to identify the best origins, 2) progeny trials to investigate within-species variation, 3) seed orchards for production of improved and selected seed, utilising modern designs and with the aim of genetic conservation, 4) silvicultural trials and demonstrations.
- ESNACIFOR provides a seed bank which enables the collection of seeds from selected trees.

Objectives, policies, programmes and national legislation

- The objectives and aims fixed by the government for the development of phytogenetic resources of Honduras are related to the application of the Convention on Biological Diversity.
- Laws and regulations for the conservation and management of the natural resources have been established according to the following: the sustainability principle, the law of modernisation of agriculture, decree 31-92 and its regulation 6 (Forestry Aspects) through agreement 1039-93, and the decrees which protect all wilderness areas (which thus support *in situ* conservation) e.g. Decree 87-87 which protects all cloud forests.

Nicaragua

- Area: approx 130 244 km^2 Administrative regions: municipalities within 15 Departments and 2 self-governing regions (autonomous communities)

- Altitudes: from sea level to 2438 masl
- Population: 5 700 000, 48% of households below the poverty line (1998), 42% of population are rural.

The country comprises 35% forested area. The deforestation rate is the highest in Central America - about 100 000–150 000 ha/year, mainly due to conversion to agriculture. The conservation of forest genetic resources is difficult in a country where adequate forest conservation policies are missing, and this poses special challenges when using local species in long-term genetic improvement programmes. In 1991, the Centro de Mejoramiento Genético y Banco de Semillas Forestales (CMG&BSF), of the Ministry of Environment and Natural Resources (MARENA), with cooperation of the Danish International Development Administration (DANIDA), started a strategy for seed supply, tree improvement and gene resource conservation *in situ* and *ex situ*. This includes native species and provenances of high commercial and/or socio-economic value, which in addition are in danger of genetic depletion or extinction. Exotic species of importance for forestry development in Nicaragua are also included. Within the strategy, seed and conservation stands have been established, mainly in the project area, 79 km northwest of the capital, Managua.

Objectives of the strategy

The strategy for seed supply, tree improvement and genetic conservation has the following objectives:

- Procure and provide forestry germplasm of high quality and sufficient quantities to satisfy national and international demand.
- Genetic improvement of forestry species of high commercial and/or socio-economic importance.
- Conservation of important forestry species and provenances which are in danger of extinction and/or in the process of rapid genetic erosion.
- Promotion of use of forestry germplasm of high genetic quality and dissemination of results and information on forest tree improvement and gene resource conservation to users at both local and regional levels.

Table 5. Priority species for the main ecological zones in Nicaragua

	Dry zone	Montane/pre-montane zone	Humid zone
Species of high priority	*Eucalyptus camaldulensis*	None	*Pinus caribaea*
Species of intermediate priority	*Azadirachta indica* *Bombacopsis quinata* *Gliricidia sepium*	*Pinus tecunumanii*	*Tectona grandis*
Species included in special research programmes	*Cedrela odorata* *Swietenia humilis*	*Cedrela odorata*	*Cedrela odorata* *Swietenia humilis*
Species of low priority	*Albizia guachapele* *Albizia saman* *Caesalpinia velutina* *Callycophyllum candidissimum* *Cassia siamea* *Cordia alliodora* *Dalbergia retusa* *Enterolobium cyclocarpum* *Guazuma ulmifolia* *Leucaena leucocephala* *Leucaena salvadorensis* *Simarouba glauca* *Tabebuia rosea*	*Calliandra calothyrsus* *Cordia alliodora* *Juglans olanchana* *Liquidambar styraciflua* *Pinus maximinoi*	*Acacia mangium* *Calliandra calothyrsus* *Carapa guianensis* *Cordia alliodora* *Dalbergia tucurensis* *Gmelina arborea* *Terminalia ivorensis* *Vochysia guatemalensis*

In 1991, a technical group of CMG&BSF elaborated the first strategy for tree improvement and genetic conservation in Nicaragua. The strategy concentrated on the dry zones of the country, and originally included 19 native and 8 introduced forest tree species recommended for use by the Nicaragua forestry sector, and for which the establishment of conservation stands and seed orchards was considered a priority. Conservation of the diversity of forestry species and provenances was considered important. The selection of species was based on proven economic importance, high present and likely future demand for seed, multiple uses, danger of extinction and/or genetic erosion.

In 1994, the strategy was revised and extended to cover the whole country. For implementation, the country was divided into three main ecological zones: i) dry zone (25 000 km^2); ii) pre-montane zone (20 000 km^2); iii) humid zone (75 000 km^2). By 1992, *Pinus caribaea* (humid zone) and *Eucalyptus camaldulensis* (dry zone) accounted for most industrial plantations. However, in recent years a considerable increase in use of broadleaved native species for high quality wood production or in agroforestry systems was evident.

Tree improvement

Improvement programmes will be at three levels of intensity, depending on the importance of the species; extensive level, intermediate level, intensive level.

Extensive level - for species of minor importance. Seed orchards or seed stands will be established with broadly based genetic material from 50–100 non-related, phenotypically superior trees of the same provenance. These seed orchards/ seed stands will serve both as breeding populations and as seed production stands.

Intermediate level - for species of intermediate priority. The intermediate level was developed for the following two reasons: 1) to ensure improvement of species of some importance though they were not included in the intensive programme; 2) to prepare a flexible genetic improvement programme in case of change of priorities. At all levels, a multiple population approach is considered, and conservation will be closely linked to improvement. Seed orchards will be established using open-pollinated progenies of 30–60 (in some cases more) selected, non-related plus trees. For each species, several seedling seed orchards may be established. Initially, these seed orchards will also be used as progeny trials, to provide information on the genetic value of the mother trees.

Intensive level - includes two high priority species: *Eucalyptus camaldulensis, Pinus caribaea*. More elaborate improvement plans will be developed to maximize yields and other economic characteristics, to enhance the benefits for the forestry sector in different ecological zones. In drawing up such improvement plans, economic and manpower resources available at the CMG&BSF will be realistically considered.

Conservation of forest gene resources

Genetic conservation efforts will form the basis for all tree improvement work and will be carried out: i) *in situ*, for species and provenances of high priority and of proven genetic value and ii) *ex situ*, as a complement to *in situ* strategies for these same species and in some cases also for species of lower priority. *In situ* conservation will only be possible in areas where pressure on forestry resources allows sustainable management. Complementary *ex situ* conservation will be needed in most cases. The strategy recognises the need to identify priority species and provenances for conservation and for management of the resources to fulfil conservation needs. Urgent action is needed to conserve *in situ* some of the natural provenances of *P. caribaea*, including the internationally important Alamicamba provenance. Other species of high economic value included in the strategy are *Bombacopsis quinata*, *Swietenia humilis*, *S. macrophylla*. Until now, the Yucul provenance of *P. tecunumanii*, which proved to be the best provenance in international trials, is the only species effectively conserved *in situ* by CMG&BSF.

The Food and Agriculture Organisation of the United Nations

The Food and Agriculture Organization of the United Nations (FAO) leads international efforts to tackle hunger. Serving developed and developing countries, FAO acts as a neutral forum where nations meet as equals to negotiate agreements and debate policy. FAO is also a source of knowledge and information, helping countries to modernize and improve agriculture, forestry and fisheries practices and ensure good nutrition for all.

FAO's work falls into two categories. The *Regular Programme* is financed through contributions by FAO's 191 members and covers the functions of FAO as: i) an international secretariat for forestry, fisheries and agriculture, ii) a discussion forum among nations, iii) a source of technical, legal and policy level expertise in these fields. Through its *Field Programme*, FAO assists governments and helps development and implementation of national and regional strategies aimed at sustainable rural development. The principle of FAO's technical development assistance is to support national institutions and help build national and local capacities in the areas covered by projects. The five main objectives for the FAO Forestry Department, according to the Medium-Term Plan of 1992-1997, are as follows and apply equally to FAO's *Regular* and forestry *Field Programmes*:

- to assist countries to enhance the productivity and sustained use of forest and tree resources, with a view to maximize their contribution to rural and socio-economic development
- to promote the conservation of forest ecosystems and the integration of forests and trees into land-use systems
- to assist in increasing the value of forest production - both wood and non-wood
- to support full participation in and equitable sharing of benefits among all people dependent on forestry activities, particularly the most vulnerable groups
- to provide policy and planning advice to national forestry administrations.

As part of the Regular Programme, the FAO Panel of Experts on Forest Gene Resources was established in accordance with directives of the 14th Session of the FAO Conference (1967, paragraphs 244, 245): '*244. Forest Tree Genetic Resources…. It recognized that, as development proceeds in the less as well as in the more advanced areas of the world, the reserves of genetic variation stored in the natural forests have been or are being displaced on an increasing scale. Moreover, efforts to explore and collect forest genetic resources were, on a world scale, inadequate and inadequately concerted. 245. The Conference requested the Director-General to establish a Panel of Experts on Forest Gene Resources to help plan and coordinate FAO's efforts to explore, utilize and conserve the gene resources of forest trees and, in particular, help prepare a detailed short-term programme and draft a long-term programme for FAO's action in this field and to provide information to Member Governments.*' The FAO Regular Programme is more limited in scope than the Field Programme, but through the Panel of Experts it assigns funds for specific actions to aid the conservation and use of Forest Genetic Resources (FGR), often on specific species. In the year 1994/95, it assigned US$82 000 across 23 countries (mean $3 600 per grant, max $11 000, min $2 000) in collaboration with national institutes, for exploration, seed collection, distribution, *in situ* and *ex situ* conservation, and establishment and evaluation of field trials.

The larger FAO Field Programme included some 61 projects (total external funding $US120 million) with main activities in one or more of the following areas related to FGR: i) tree seed procurement; ii) tree improvement and conservation of FGR; iii) nature conservation and nature protection; iv) forest management. However, most projects were for Africa and the Asia/Pacific region (both number of projects and total funds), with only 8 in the Latin America/Caribbean region and none in the dry tropics of this region. Projects stressed *in situ*/ecosystem conservation and sustainable use of forests.

Information sources

This study is derived principally from the following sources:

Hellin JJ, Hughes CE. 1993. *Leucaena salvadorensis*: conservation and utilisation in Central America, Serie Miscelánea de CONSEFORH 39-21/93. CONSEFORH, Siguatepeque, Honduras.

Lopes A. 1996. The effects of forest fragmentation on genetic variation in *Leucaena salvadorensis* populations. Unpublished MSc dissertation. Univ. of Oxford.

Forest Genetic Resources Training Guide

Other modules to be published among the following:

Plantation forestry, Tree domestication, Forest restoration, Genetic modification