Chapter 33
Reforestation of Abandoned Pastures: Seed Ecology of Native Species and Production of Indigenous Plant Material

B. Stimm(✉), E. Beck, S. Günter, N. Aguirre, E. Cueva, R. Mosandl, and M. Weber

33.1 Introduction

Tropical forests are characterized by a high diversity of tree species together with a low abundance of individual species. This has far-reaching implications on strategies for a sustainable management and conservation of their genetic resources.

Reforestation with native species is considered a preferable option for sustainable development, overcoming some of the ecological drawbacks of the earlier deforestation and concurrently contributing to the conservation of the region's biodiversity. Until the year 2000, 167 000 ha of plantations were successfully established in Ecuador (FAO 2003). Most of the plantations, however, consist of introduced species, i.e. in the coastal region mainly *Eucalyptus* sp. and *Tectona grandis*, and in the Sierra mainly *Eucalyptus* sp., *Cupressus* sp. and *Pinus* sp. Because of ecological problems with these species, more emphasis is nowadays put on plantations with native species (Brandbyge and Holm-Nielsen 1986; Borja and Lasso 1990; Aguirre et al. 2002a, b; Leischner et al. 2004; Predesur 2004).

However, lack of knowledge of the biology of the trees providing seed resources, e.g. their population densities and reproductive phenology, as well as of their germination physiology and the establishment of seedlings poses a severe challenge for any reforestation project.

The permanent availability and supply of high-quality seed and plant material for any kind of planting activity (enrichment planting, reforestation, plantation establishment; see Chapter 34 in this volume) requires the establishment of production standards. To achieve such standards, the monitoring and approval of seed sources of priority species is essential, which is accomplished by seed certification and control of seed procurement.

E. Beck et al. (eds.), *Gradients in a Tropical Mountain Ecosystem of Ecuador. Ecological Studies 198.*

33.2 Conceptual Aspects for Reforestation Programs

Conservation and sustainable use of forest genetic resources is a major issue in national and international policies (Young et al. 2000). The objective is to secure the adaptedness of forest tree species to the respective environment with its dynamics and potential changes of the ecosystem. Moreover, appropriate concepts must build a basis for improving the production of timber and non-timber commodities but also of other services provided by a forest ecosystem (Graudal et al. 1997). Thus, responsible forest management – aside from maximizing the profit from timber and non-wood forest products (NWFPs) – aims at sustaining the respective forest ecosystem as well. The two basic strategies for conservation of the gene pool complement each other, namely in situ conservation (FAO et al. 2001) and ex situ conservation (FAO, IUFRO 2002).

Therefore forest restoration, e.g. by plantations, can also be an important complementary contribution to a future-oriented “dynamic conservation”.

Much emphasis is put on native tree species plantations, however very little attention is still attributed to the provenance of the material from gene-ecological zones and the importance of using autochthonous planting material as well as to the question of how to produce autochthonous plant material at a larger scale. Hansen and Kjaer (1999) stressed the fact that appropriate genetic material may enhance not only the production and quality but also the health and stability as well as the environmental services of plantations.

Variation in forest genetic resources may become apparent between species, populations, individuals and chromosomes. Many tree species are characterized by high levels of intraspecific genetic variation which ensures the plasticity of the gene-pool concomitantly with its ongoing evolution. Ecological conditions in the Andes differ markedly between the eastern and western Cordillera and vary considerably with elevation (see Part III.1 in this volume). Species like *Cedrela montana* or *Tabebuia chrysantha* are widely distributed (Møller Jørgensen and León-Yánez 1999; MBG 2006) and apparently occur in differing populations, depending on the ecology of the habitat. Separated by altitudinal borderlines, gene flow via pollinators and seed-dispersers between these populations is limited.

Hufford and Mazer (2003) pointed out that the geographical distribution of many plant species used in restoration may span a wide range of environmental conditions. Habitat heterogeneity, combined with natural selection, often results in multiple, genetically distinct ecotypes of a single species. Consequently, data are needed to delineate “seed transfer zones”, or regions in which plants can be transferred with little or no impact on the population fitness.

Regional programs must be developed which care for a sustainable provision of forest commodities to meet the region’s requirements for timber, poles, fuel, fodder, food, medicine and shelter. This must go hand in hand with the rehabilitation of degraded areas and the conservation of genetic resources of trees.

This goal needs time and several short-term steps must be envisaged. One of these is the provision of genetically suitable seed and other plant reproductive material from selected indigenous seed sources. “Suitable seed” means the location, use and maintenance of clearly defined and well documented seed sources. To the best of our knowledge, no species-specific conservation or management plans have been implemented in Ecuador with the objective to protect the great variety of forest tree genetic resources for future use.

33.3 Plant Production as a Prerequisite for Reforestation

Most of the recent Ecuadorian reforestation projects deal with exotic species of the genera *Eucalyptus*, *Pinus* or *Cupressus*, while native species due to the reasons discussed below have not been used in the Andean region so far (see also Chapter 34 in this volume). Knowledge of the reproductive biology of indigenous species is very limited, but indispensable for the supply of high quality tree seeds and the production of adequate numbers of high quality seedlings in tree nurseries. An overview of the key requirements in the process of tree seedling production is shown in Fig. 33.1.

33.3.1 Selection and Survey of Priority Species

Besides the endangeredness of species the main criteria for including species in genetic resource conservation programs are their present use and their potential use (Graudal et al. 1997).

In our research area, based inter alia on a timber market survey by Leischner and Bussmann (2002), a first selection of priority species was made. From the over 200 regional tree species potentially suitable species were selected by the following criteria: high local acceptance, economic value (both timber and non-timber products), endangered or species with a high ecological significance. Some 15 native species with promising potential for reforestation were chosen (see also Table 33.1).

33.3.2 Phenology as a Means for the Prediction of Quality, Quantity and Harvest Time of Seed Crops

Whilst comprehensive studies of reproductive phenology have been performed in tropical lowland rain forests (e.g. Frankie et al. 1974; Croat 1975; Opler et al. 1980; Hamann and Curio 1999; Newstrom et al. 1994; Schöngart el al. 2002), only a few studies exist addressing phenological aspects of tropical mountain rain forests. For example, Koptur et al. (1988) investigated the phenology of bushes and treelets in Costa Rica in an altitudinal range between 1300 m and 1650 m a.s.l. More comprehensive long-term studies of the phenology of flowering and fruiting have been performed in Southeast Asia, showing quite different patterns in one and the same forest (Sakai et al. 1999; Hamann 2004).

Bendix et al. (2006c) discussed various hypotheses addressing individual elements of the climate as ultimate factors that trigger seasonality in the equatorial tropics. They examined the hypothesis that in the area of the RBSF cloudiness is the master trigger of periodic phenological events in plant life which are,

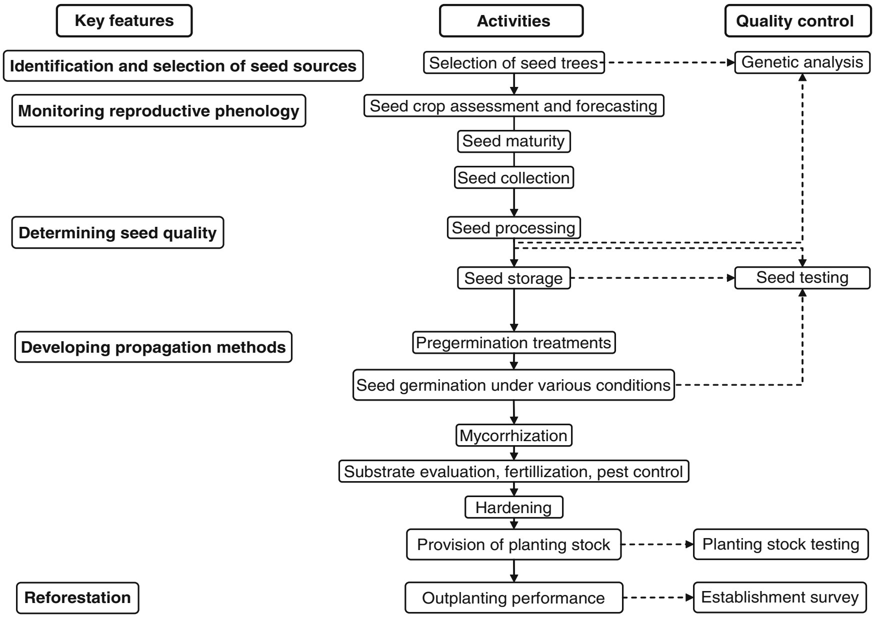


Fig. 33.1 Key features, flow diagram of activities and quality management in forest seedling production

however, modulated by climatic irregularities (see also Chapter 20 in this volume).

In the RBSF phenological studies have been carried out by several working groups (Wolff et al. 2003; Cabrera and Ordoñez 2004; Diaz and Lojan 2004; Bendix et al. 2006c; Cueva et al. 2006). Cueva et al. (2006) examined 400 individuals of more than ten tree species over a period of three to four years with respect to flowering and fruiting (see also Table 33.2). In spite of the perhumid climate the authors observed a high degree of synchronization at the species level, also groups of non-related species showed synchronized flowering and fructification.

33.3.2.1 Seasonality of Flowering

The records of flowering showed two principal patterns. One group of trees, consisting of *Piptocoma discolor*, *Tabebuia chrysantha*, *Myrica pubescens*, *Cedrela montana*, *Purdiaea nutans* and *Inga* sp. flowered during the less humid period of the year, i.e. between August and February, while *Clethra revoluta*, *Heliocarpus americanus*, *Isertia laevis*, *Viburnum* sp. and *Vismia tomentosa* flowered during the wettest season (March to July). Exceptions were male individuals of

Table 33.1 Seed ecology data of selected native South Ecuadorian mountain rainforest tree species. Species nomenclature follows W^3TROPICOS Missouri Botanical Garden's VAST nomenclatural database (ver. 1.5). *Prov* Provenance, *Disp* seed dispersal mode, *M.C.* moisture content of seeds. Data compiled from: Beck (personal communication), Briceño (2005), Cabrera and Ordoñez (2004), Cueva (personal communication), Diaz and Lojan (2004), Homeier (personal communication), Jara and Romero (2005), Leischner (2005), Merkl (2000)

Species	Prov[a]	Disp[b]	Flower[c] (months)	Fruiting (months)	Ave. purity (%)	M.C. (%)	Weight[d] (g)	No. seeds/ kg[e] (×1000)	No. seeds/ fruit	No. fruits/ tree (×1000)	No. seeds/ tree (×1000)	Ave. germination[f] (%)
Alnus acuminata Kunth	EB	w	VIII–III	IX–V	91	–	0.29–0.31	3400	180–210	–	–	35 (*39*)
Alnus acuminata Kunth	A	w	–	–	–	–	0.19	5263	–	–	–	58 (*38*)
Cedrela lilloi C.DC.	SF	w	–	–	–	–	11.9–15.0	83.9–66.0	21–24	0.01–0.5	0.23–11.5	62
Cedrela montana Moritz ex Turcz.	SF	w	X–III	II–VIII	90	12	12.4	81.6	–	–	–	86 (*80*)
Cedrela montana Moritz ex Turcz.	EB	w	VIII–III	XI–V	90	–	42.5	23.5	27	–	–	86 (*69*)
Cinchona officinalis L.	EB	w	ay	ay	77	–	0.67–0.97	1310	39–42	–	–	80 (*90*)
Clethra revoluta Ruiz & Pav.	SF	w	III–VII	IV–X	63	6.5	0.05	19 417	–	–	–	69 (*22*)
Clethra revoluta Ruiz & Pav.	EB	w	X–III	XI–IV	93	–	0.073–0.078	13 260	40–46	–	–	4 (*8*)
Cupania sp.	EB	a/g	I–VIII	VI–XI	93	–	445–580	–	3	–	–	(*40*)
Heliocarpus americanus L.	SF	w	II–VIII	V–X	93	10.4	1.39	732.3	1–3	21.9–125.0	42.5–250.0	27 (*20*)
Inga acreana Harms	SF	a/g	IX	III–V	98	3.6	550.1	1.8	–	0.3	2.2	84
Isertia laevis (Triana) B. M. Boom	SF	a	I–IX	VI–III	62	14.0	0.15–0.23	5530	200–300	1.0–2.4	200–720	–89
Juglans neotropica Diels	L	a/g	VII–II	IX–VI	–	–	18 200–21 400	0.05	1	0.5–1.0	–	(*72*)

(continued)

Table 33.1 (continued)

Species	Prov[a]	Disp[b]	Flower[c] (months)	Fruiting (months)	Ave. purity (%)	M.C. (%)	Weight[d] (g)	No. seeds/ kg[e] (×1000)	No. seeds/ fruit	No. fruits/ tree (×1000)	No. seeds/ tree (×1000)	Ave. germination[f] (%)
Myrica pubescens Humb. & Bonpl. ex Willd.	SF	a	V–VI ♂ ay ♀	II–III ♂ ay ♀	98	11.9	12.3	85.7	1	30.8	30.8	76 (*11*)
Myrica pubescens Humb. & Bonpl. ex Willd.	EB	a	ay ♀	ay ♀	96	–	3.45	290	1	–	–	(*15*)
Piptocoma discolor (Kunth) Pruski	SF	w/(a)	VII–X	VIII–II	93	8.6	0.29	3434.4	–	254.7	509	23 (*13*)
Prumnopitys montana (Humb. & Bonpl. ex Willd.) de Laub.	SF	a/g	XI–II	II–V	–	–	–	–	–	–	–	–
Prumnopitys montana (Humb. & Bonpl. ex Willd.) de Laub.	EB	a/g	IX–IV	XII–VI	–	–	74.0	13.5	1	–	–	–
Tabebuia chrysantha (Jacq.) G. Nicholson	SF	w	VIII–XI	X–I	–	–	9.0	111	–	–	–	86 (*59*)
Vismia tomentosa Ruiz & Pav.	SF	a	IX–V	I–VIII	85	11.0	0.59	1724	60	9	540	15

[a] Provenance: A = Alisal, EB = El Bosque, L = Loja, SF = San Francisco.

[b] Seed dispersal mode: a = animal, g = gravity, w = wind.

[c] Flowering period (in calendar months): ay = all year.

[d] Weight of 1000 seeds.

[e] Number of seeds per kilogram of seeds.

[f] Average germination on wet filter paper or wet sand under laboratory conditions; in *italics*: max. germination (%) in greenhouse tests.

Table 33.2 Fruiting periods and percentage of fruiting trees of ten tree species indigenous to the mountain rain forest of South Ecuador

Species	Fruiting period (calendar months)	Trees fruiting per year (%)			
		2000	2001	2002	2003
Piptocoma discolor	XI–I	100	9	90	–
Tabebuia chrysantha	XI–I	53	28	35	–
Myrica pubescens (female)	II–III	–	40	27	36
Inga cf. *acreana*	III–V	–	50	75	0
Cedrela montana	VI–VII	–	50	83	0
Heliocarpus americanus	VI–IX	–	40	80	66
Clethra revoluta	VI–IX	20	10	50	–
Vismia tomentosa	VI–IX	71	0	75	–
Isertia laevis	V–XI	92	78	56	–
Ficus sp. 1	II–VI	–	33	–	–
Ficus sp. 2	I–III	–	–	11	–
Ficus sp. 3	XI–III	–	–	–	11

Myrica pubescens, of which flowers were seen for ten months per year (but also with a maximum during the less humid period, while female individuals usually flowered for less than one month), and *Graffenrieda emarginata* of which pronounced periodicity of flowering could not be observed. However, this species extends over a wide altitudinal range and therefore the collected data may not be sufficient to reveal intraspecific synchronization. Interestingly flowering of the majority of the wet season species (*Clethra revoluta*, etc.) commenced in December or even earlier, when the monthly rainfall was still low. This observation suggests a climatic factor other than precipitation may trigger flowering of that group of plants.

The proportion of flowering individuals of the examined species differed considerably: Of *Heliocarpus* nearly 90% of the individuals flowered at the same time, and of *Piptocoma* the peak of simultaneously flowering trees even exceeded 90% (except in 2001). *Vismia*, *Myrica*, *Clethra*, *Isertia* and *Inga* were further species with reasonably high rates of flowering. In contrast, relatively low percentages of flowering individuals were recorded for *Cedrela* and *Tabebuia*, two of the deciduous species in the forest.

33.3.2.2 Seasonality of Fructification

Due to the differing species-specific time-spans required for seed-set and fruit ripening, the annual phases of fruiting were wider and in most cases not as clearly delimited as for flowering. Nevertheless, again two groups of trees can be differentiated with respect to fructification. *Piptocoma*, *Tabebuia* and *Myrica* were found fruiting still during the less humid season, i.e. in November, December and January. The second group of trees consists of *Cedrela*, *Clethra*, *Heliocarpus*, *Inga* and *Vismia* which exhibited maximum fruiting predominantly during the wet season. Fruiting trees of *Isertia* were present all year round, however, with a pronounced minimum in February/March. While *Vismia* showed a long fruiting period of eight months (in 2002), other species like *Heliocarpus*, *Tabebuia* or *Piptocoma* had comparatively narrow time-windows of three to four months for fructification.

On average, fructification of the ten species examined was higher in 2002 than in 2001. This holds in particular for *Clethra revoluta* which flowered as usual in 2001 but then barely produced fruits. In contrast, *Piptocoma discolor* and *Vismia tomentosa* produced almost no flowers in that year and consequently fruits were not developed. No mature fruits could be found with *Inga* sp. and *Cedrela montana* in 2003. The latter species had already aborted unripe fruits. Table 33.2 shows the records of fruiting for the selected species over the years 2000–2003.

Concomitantly with the phenological recordings, climate was monitored in detail at both the regional and the local scale. Some correlation of flowering and fruiting with precipitation, cloudiness and irradiance could be found (Bendix et al. 2006c).

33.3.2.3 Comparing the Phenological Behavior of the Same Species at Different Sites

Comparative phenological observations were initiated in 2001 at two locations, at the RBSF and at the Reserva Protector 'El Bosque', approximately 10 km southwest from San Pedro de Vilcabamba (Province of Loja). The two sites are about 30 km apart, at an altitude of 2100 m a.s.l. in the evergreen montane rainforest zone. They differ mainly in the precipitation pattern (see Chapter 1 in this volume) and related ecological parameters which may also have a strong impact on the activity of the biota (e.g. pollinators or seed dispersers).

Phenological data of flowering and fruiting were registered at two-week intervals. Details of methodology and first results have been published in Günter et al. (2004). At both study sites the phenology of four species was compared: *Cedrela montana*, *Clethra revoluta*, *Myrica pubescens* and *Prumnopitys montana*.

Flowering of *Cedrela montana* starts more than two months earlier at 'El Bosque' than at RBSF but finishes only one month earlier, i.e. the period of flowering is longer at 'El Bosque'. Also the fruiting season is about two months postponed at RBSF as compared with 'El Bosque', but its time-span is equal at both sites. For *Clethra revoluta* timing of flowering and fruiting differs by about six months in the two study areas (Fig. 33.2). In general the intraspecific variability of the species is lower at 'El Bosque' than at RBSF, but the interspecific synchronization is higher.

Interestingly, not only the rhythms but also the intensities of flowering and fruiting differed at both sites. While the percentage of flowering and fruiting trees decreased in the second year at RBSF, an increase was registered at 'El Bosque'.

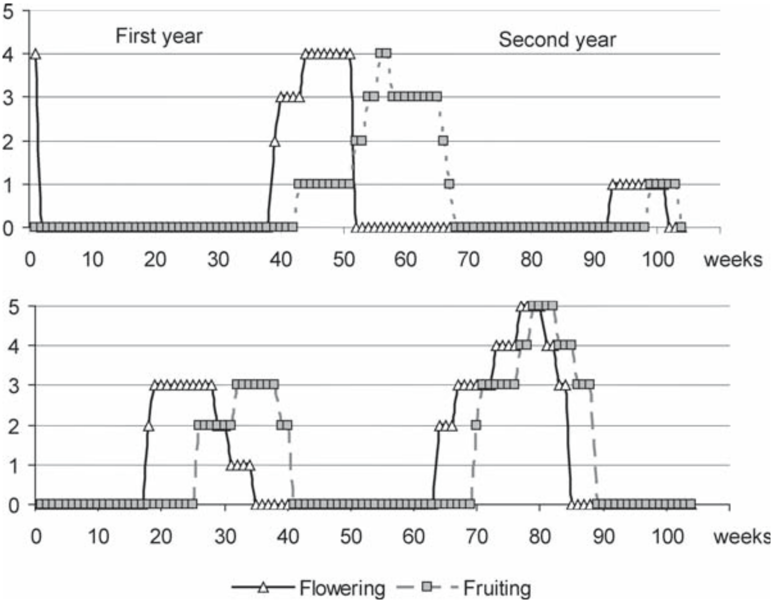


Fig. 33.2 Differences in flowering and fruiting of *Clethra revoluta* between the study areas RBSF (*above*) and 'El Bosque' (*below*). Adapted from Günter et al. (2004)

The seasonality of flowering and fruiting of *Myrica pubescens* was less pronounced at RBSF, as compared with 'El Bosque', reflecting the more pronounced dry and wet seasons in the latter area.

33.3.3 Collection and Germination Potential of Seeds

For practical purposes of seed collection Cabrera and Ordoñez (2004) and Jara and Romero (2005) produced a calendar for selected tree species at RBSF, and Diaz and Lojan (2004) for 'El Bosque'. An example is shown in Fig. 33.3.

Whenever possible, ripe fruits were harvested from the trees. Seeds were detached from the fruits and after drying on paper in the shade were kept in plastic boxes in the dark until sowing. In some cases seeds were also dried while still enclosed in the fruits (*Cedrela*, *Heliocarpus*, *Piptocoma*) which were then scarified for the germination assay.

The germination rates of the seeds varied greatly from species to species (see Table 33.1), but also for the same species from year to year. *Cedrela montana*, *Tabebuia chrysantha* and *Inga acreana* were fast-germinating species while *Isertia laevis*, *Piptocoma discolor* and *Clethra revoluta* required almost a quarter of a year for the seedlings to emerge. *Piptocoma*, *Myrica* and *Isertia laevis* germinated satisfactorily only after pretreatment of the seeds. A still unresolved problem is the propagation of Podocarpaeceae

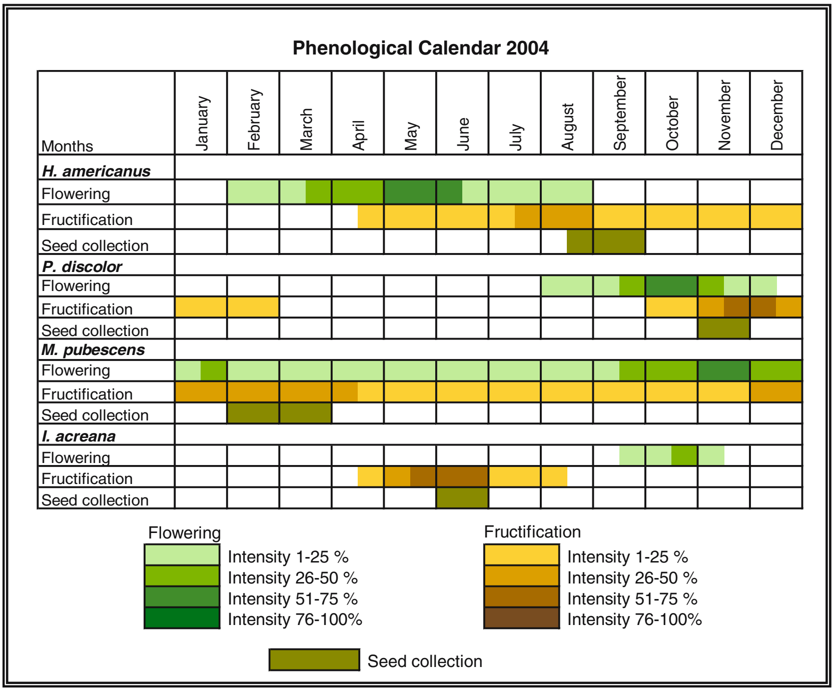


Fig. 33.3 Phenological calendar of four native tree species (after Jara and Romero 2005)

from seeds from provenances of Southern Ecuador. Germination protocols of various species have been elaborated and are presented in detail elsewhere (e.g. Leischner 2005).

33.3.4 Early Development of Seedlings

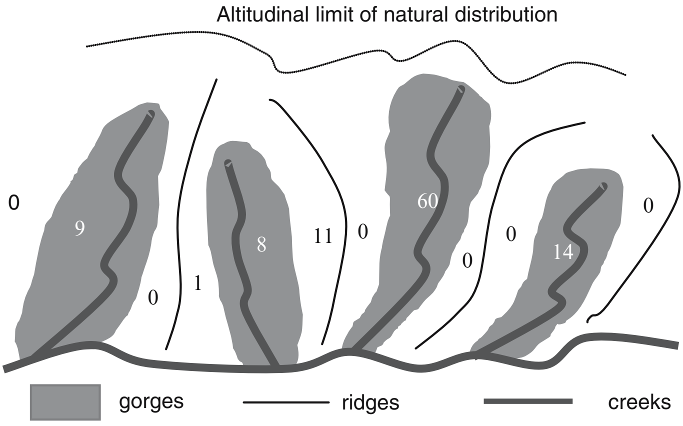
After germination, seedlings of several species, such as *Isertia*, *Clethra* and *Vismia* did not readily establish but remained tiny and susceptible to getting mouldy, even when subjected to adjusted light intensities in the nursery. Various substrates (with and without fertilizer) were examined in a comprehensive study (Leischner 2005) but the addition of soil from the natural stand was most effective in promoting early growth. This observation suggested that inoculation of a mycorrhiza could play an essential role in the production of young plants for reforestation. To evaluate the possibility of mycorrhizal inoculation Urgiles (2003) set up an exploratory experiment. She inoculated native plant seedlings of *Alnus acuminata* and *Erythrina edulis* growing under controlled environmental conditions with several VA mycorrhiza fungi. An evaluation of the tree seedlings six months after sowing showed that the rate of mycorrhization and biomass production was best after addition of forest soil as inoculum source.

33.3.5 The Problem of Isolated Subpopulations in the Study Area

The rugged morphology of the eastern Cordillera in South Ecuador creates a high patchiness in the vegetation, where similar habitats, e.g. deeply incised gorges are separated by strongly differing ecotones, such as wind-exposed ridges. Figure 33.4 shows the distribution of *Cedrela montana* in four catchment areas of the RBSF valley where clusters of that species are separated from each other by pronounced ridges. Under these marked topographical structures it is questionable whether gene flow between the individual subpopulations could efficiently take place. The situation could be complicated by the phenomenon of functional dioecy in *Cedrela* (Smith et al. 2004).

We also examined the distribution of *Prumnopitys montana* in the four catchments and identified three clusters of this species. *P. montana* is a highly exploited dioecious species and an unfavorable female:male ratio in subpopulations could have a severe impact on its fitness.

It is noteworthy that the remaining subpopulations of *Cedrela* or *Prumnopitys* are at the upper boundary of their natural distribution. We argue that these subpopulations located in the catchments may become endangered by isolation because pollen and seeds may hardly be transported over the surrounding natural barriers (Fig. 33.4).



*estimated area of watersheds from left to right: 13, 10, 20 and 8 hectares

Fig. 33.4 Distribution of subpopulations of *Cedrela montana*. Numbers illustrate the number of trees with a dbh >10 cm in the four investigated catchments of the RBSF forest (from Günter et al. 2004)

33.3.6 Aspects of the Provenance of Seed Material: Delineation of Gene-Ecological Zones

Based on these observations and on the findings about the conspicuous differences in reproductive phenology between sites the delineation of so-called “gene-ecological” zones is suggested, where the variation of environmental conditions is investigated and uniform zones are identified. To delineate gene-ecological zones (i.e. provenance regions) which can act as seed sources for sustainable forest management programs as well as for the conservation of forest tree genetic variation, the maps of the environmental conditions and the vegetation cover in the Province of Loja were overlaid. After the identification of these zones and their size it can be decided whether the areas will be sufficient for an in situ conservation and sustainable management or whether additional measures have to be undertaken (e.g. establishment of seed orchards, clone archives, amplification of conservation areas; see Günter et al. 2004).

Three environmental parameters (temperature, humidity, soil types) were used for the delineation of gene-ecological zones. A very broad range of environmental conditions can be observed in the Province of Loja (see also Chapter 1 in this volume). The mean annual temperatures vary from 8 °C to 26 °C, the humidity varies between 0 and 12 humid months and 11 major soil types have been stated in the provincial watershed management plan. On the basis of these data four classes of temperature ranges and six classes of humidity were defined. Superimposing the three ecological maps resulted in a map of potential gene-ecological zones (Günter et al. 2004). For the Province of Loja the authors calculated a total of 134 potential gene-ecological zones, 46 of them being smaller than $10\,km^2$ and only 17 being protected in National Parks.

For a proper management urgent aims are the verification of the gene-ecological seed zones, mapping of target individuals and an assessment of potential barriers for gene flow.

33.4 Conclusions and Implications for Reforestation

Tropical forest plants may respond to environmental change through phenotypic plasticity, adaptive evolution, migration to more suitable sites, or extinction. However, the potential to respond is limited by the rapidness of change and the lack of alternative habitats due to past and present trends of deforestation (Bawa et al. 1998).

There are extremely marked differences in flowering and fruiting behavior between the species at the same site and also for the same species at different sites. Despite our attempt to classify species to different groups with similar phenological characteristics, the variability in timing and intensity is still very high within and between groups. According to Bendix et al. (2006c), irregular events may be responsible for the variation in phenology.

Mass flowering, sometimes termed general flowering, is an irregularly occurring phenomenon of perennial plants that is common in the tropics but is also known from temperate forests (Herrera et al. 1998). During more than four years of monitoring phenological events in the Ecuadorian mountain rain forest, mass flowering was not recorded.

Which climatological factors affected flowering and seed development in some species is still an open question. Cold rather than drought presumably affects flowering and seed production as some of the respective species, e.g. *Piptocoma discolor* and *Vismia tomentosa*, are at the upper boundary of their altitudinal range and are typical representatives of the lower, i.e. warmer, montane forest.

Because of high interspecific and interzonal variability seed-harvesting calendars in the study region must be elaborated on a species level and separately for different seed zones. A first approach for the delineation of seed zones in Southern Ecuador has been presented by Günter et al. (2004).

To receive sufficient genetical amplitude for large-scale reforestation it is necessary to harvest a minimum of 50 (better 500) seed trees of one provenance and species (Graudal et al. 1997). Because some species had relatively low flowering and fruiting probabilities (representatives of Podocarpaceae, *Myrica pubescens*, *Vismia tomentosa* among others) it is necessary to monitor a higher number of individuals of a certain seed zone for seed harvesting. This, however, is very difficult in the tropics where many species appear with very low abundance.

Germination experiments with our species showed the need for developing species-specific appropriate propagation techniques and protocols; otherwise planting material for reforestation purposes might not meet the qualitative standards and the required numbers (Cabrera and Ordoñez 2004; Diaz and Lojan 2004; Leischner 2005).

The establishment of competent national and regional tree seed centers (seed banks) in Ecuador is of utmost importance. Inter alia those institutions must be in charge of the founding and appropriate management of a network of seed production stands, which is a prerequisite of sustainable seed and seedling production.