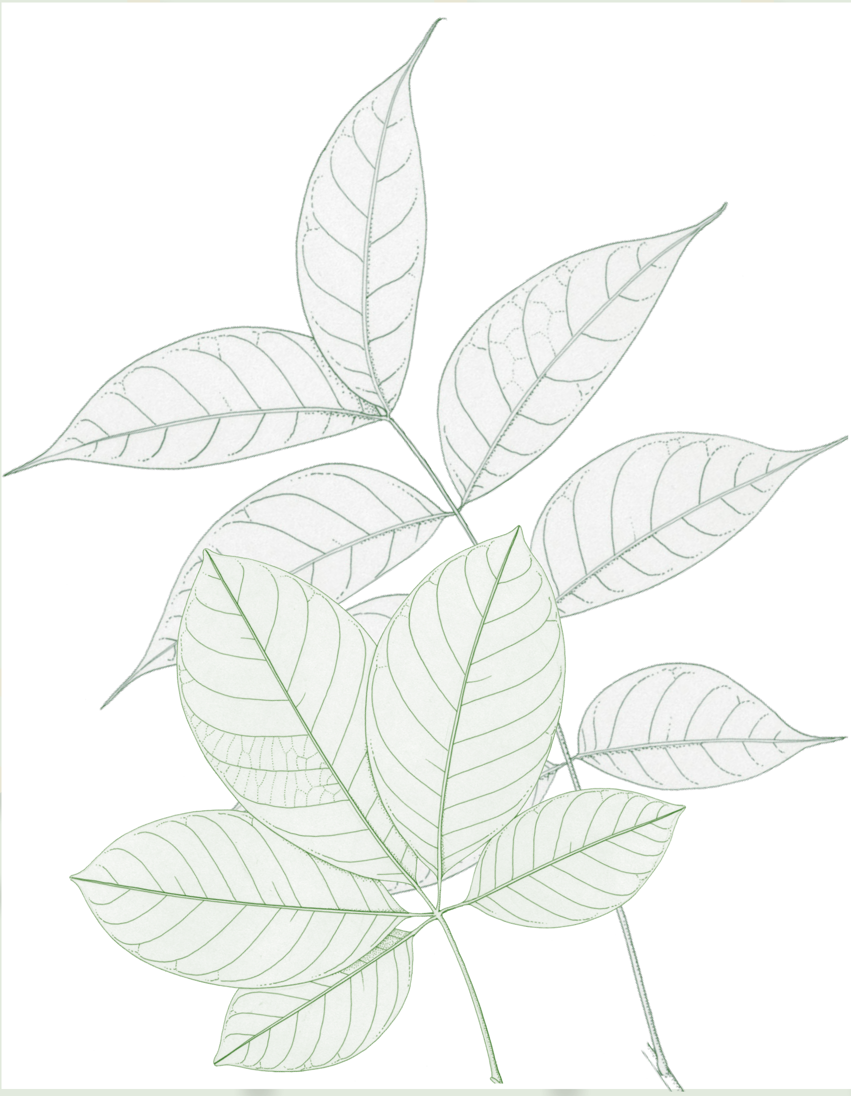
Forest Genetic Resources Training Guide

# MODULE 2
# Trees outside of forests

## Teacher's notes 2.2

# Devising options for conservation of two tree species outside of forests

**David Boshier**



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Bioversity International
Via dei Tre Denari, 472/a
00057 Maccarese
Rome, Italy

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# Module 2
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## Teacher's notes 2.2

## Devising options for conservation of two tree species outside of forests

*David Boshier, Department of Plant Sciences, University of Oxford*

These Teacher's notes aim to assist teachers in using the **Case study 2.2 Devising options for conservation of two tree species outside of forests** in classes. The notes:

- Describe the key concepts covered in the case study, with references to forest genetic resources textbooks or papers where explanations of these principles can be found (full references at the end of these notes).
- Give tips on how to prepare and run the exercise and discuss the main learning points (genetic and other) that students should be able to derive from the case study.
- Give an outline commentary to the PowerPoint presentation which is used to introduce the case study to the students. The presentation contains pictures of the species, sites where it occurs, relevant land-use issues in the area, and figures/tables from the exercise.

The following support materials can be found on the accompanying DVD or at the Forest Genetic Resources Training Guide webpage at www.bioversityinternational.org

- Teacher's PowerPoint presentation
- Short video
- The Case study

## Key concepts to cover/introduce in this Case study

The exercise explores the following issues, with respect to the conservation of trees outside of forests.

### General conservation

- **Conservation of species and genotypes:** see FAO et al. (2004a) pp. 11-14; FAO et al. (2001) pp. 7-10; FAO et al. (2004b) pp. 3-4; Finkeldey (2005) pp. 183-185; Geburek & Turok (2005) pp. 304-306, 391-399, 545-554.
- **Biological corridors, fragmentation, connectivity – gene flow and maintenance of viable populations:** see FAO et al. (2004a) pp 43-44; FAO et al. (2001) pp 45-47, 64; Boshier et al. (2004); Finkeldey (2005) pp. 93, 177-178; Geburek & Turok (2005) pp. 426-432, 440-443.
- ***In situ*, *ex situ* conservation:** see FAO et al. (2004a) pp. 5-16, 33; FAO et al. (2001); FAO et al. (2004b); Finkeldey (2005) pp. 181-198; Geburek & Turok (2005) pp. 6-8, 535-562, 567-581, **and conservation through use on farms - *circa situm*:** Boshier et al. (2004).
- **Reproductive materials: source and collection:** see FAO et al. (2004a) pp. 47; Geburek & Turok (2005) pp. 569-570.

### Genetic concepts

- **Genetic processes associated with small populations - increased genetic drift, bottleneck, increased inbreeding:** see FAO et al. (2004a) pp. 43-44; Finkeldey (2005) pp. 75-76; Geburek & Turok (2005) pp. 426-432.
- **Population differentiation Gst/Fst:** see FAO et al. (2004a) pp. 41; Finkeldey (2005) pp. 111-115; Geburek & Turok (2005) pp. 264-266.
- **Self-incompatibility mechanisms:** see Finkeldey (2005) pp. 91-93; Geburek & Turok (2005) pp. 177-180, 428.

## How to run the exercise

The exercise can be run in a number of ways depending on the time available and size of the class. The exercise works best if students work in groups of 4-5 (no more than six). It is best if the students have already read the case study before they start the exercise. This way valuable class time is not lost with students reading the paper during the class. So give the case study out in a prior class with instructions to read it before the next class. It perhaps goes without saying that it is vital that the teacher and any assistants are fully familiar with the whole text. NB: The exercise is set in the context of the mid 1990s, both in terms of the species status and the social context. Therefore, more recent information and changed status are **not** included as they are not relevant to the exercise.

Ideal number of students: 4-15.

Ideal length of class: 3 hours, broken down as follows:

- ***Introduction***: use the video followed by the PowerPoint - *approx 40 minutes*.
- ***Group work***: suits 1-3 groups of 4-5 in each group. Each group devises an action plan. Each group tends to take a different approach and different issues are raised, so that overall, most points are covered. Students discuss the case study amongst themselves, responding to the ***specific*** points and developing their plan. The teacher should be around to answer any queries the groups have. However it is not essential that all of the time is spent with the whole class together with the teacher. Once the teacher and groups are happy they understand the assignment and issues, each group could meet, discuss and prepare the strategy outside of class time - *1.5 hours*.
- ***Presentations***: each group presents its plan verbally to the class (supported by main points written on large paper or on a **PowerPoint** presentation) - *10 minutes per presentation*, plus 5 minutes after each presentation for questions/comments by the rest of the class and teacher - *15 to 45 minutes depending on the number of groups.*
- ***Final discussion***: led by the teacher allowing them to make general comments about what was good, what was missed, etc. - *10 minutes.*

## Background information

Depending on the time and facilities available, the teacher can use any combination of the following resources to provide background and introduce the exercise: i) IUCN video on forest landscape restoration to introduce the general topic; ii) PowerPoint presentation.

***Video***: lasts 4.5 minutes and is entitled: '*Forest landscape restoration – see the bigger picture*'. It is produced by IUCN and presents a global overview of issues related to forest landscape restoration.

***PowerPoint:*** about 30 minutes to go through. It covers general concepts of conservation and, in particular, the idea of conservation on farms (*circa situm*).

It also allows explanation of some specific issues raised in the Case Study, in particular understanding the data from the more complex genetic studies.

*Slide 1*: title; shows the focus is on trees outside forests, rather than the traditional focus on intact forest.

*Slides 2-3* (*optional*): an optional exercise the teacher can use near the start to get the students thinking is to ask them to verbally suggest along the following lines (their answers can be written on a board below headings of 'impacts' and 'genetic impacts'):

*What are the impacts of human interventions on trees?*

*What are the genetic impacts of human interventions on trees?*

This will allow the teacher to understand some of the ideas that the students already have about the topic and to see what areas might need to be explored which the students have never thought about. Once this is done, *Slide 3* can be used to show the main points raised by a previous class of students.

*Slide 4*: summarizes some of the impacts. It stresses the importance of maintaining viable populations.

*Slide 5*: emphasizes that genetic impacts should not be seen in isolation, but as part of the bigger picture, with emphasis on understanding where they may be limiting.

*Slides 6-11*: summarize traditional approaches to conservation *in situ*/*ex situ* and associated problems. The emphasis should be on their complementary nature, rather than either/or. The emphasis will however shift depending on the characteristics of the species and population of concern.

*Slide 6*: the two principal conservation approaches.

*Slide 7*: points out that selection of the most protected areas tends to be for conservation of 'megafauna' – large furry animals, leading to bias in what is conserved.

*Slide 8*: deforestation and fragmentation is not random – usually the best land/lowland is cleared for agriculture and we are left with the forests on the hillsides (picture taken from a hill of a biological reserve in Costa Rica, looking towards a national park on the other hill. The intervening lowland has been cleared for growing rice). So we may well have lost both species and populations adapted to the lowlands and good soils. The remnant trees in these situations may represent the only examples of this gene pool and therefore are important for conservation.

*Slide 9*: summarizes the issues and limitations related to *in situ* conservation.

*Slide 10*: the two principal conservation approaches - now we want to look at *ex situ* conservation.

*Slide 11*: shows examples of and some of the limitations of *ex situ* methods.

*Slides 12-14*: introduce the idea and debate around whether trees found in agricultural landscapes may be important for conservation of some species (sometimes known as *circa situm* conservation) and the negative view that they are not. The "living dead" quote is from noted US ecologist/conservationist Dan Janzen (for more detail see Introduction to Module 2: *Trees outside of forests*).

*Slide 13*: the threatened species *Leucaena colinsii* subsp. *zacapana* and *L. esculenta* conserved on farms in Guatemala and Mexico where the forest has disappeared, i.e. *in situ* is no longer an option. Agroforestry systems where valuable timber trees are conserved. *Cedrela odorata* in a coffee plantation in Costa Rica and *Cordia alliodora* in a cocoa plantation in Honduras.

*Slide 14*: raises some of the main genetic issues of concern that need to be addressed if the potential of *circa situm* conservation is to be established.

*Slide 15*: theoretical genetic impacts of fragmentation: on the left of the slide, the direct impacts that are observable; on the right, the expected genetic effects that will follow fragmentation.

*Slides 16-18*: potential impacts of fragmentation on genetic diversity and genetic differentiation between remnant forest patches:

*Slide 16*: photos show real examples of fragmentation (uniform landscape - wheat fields in southern Ontario, Canada; heterogeneous landscape - from hill of a biological reserve in Costa Rica, looking to a national park on the other hill; intervening lowland has been cleared for growing rice) and relates these to theoretical distributions of alleles across the landscape. A forest with three alleles (x,y,z); in A) with the alleles randomly distributed (low genetic structure) immediately after fragmentation the fragments are genetically similar (i.e. low Gst), in B) there is high genetic structure, e.g. alleles may reflect adaptation to different environmental conditions – hills/lowlands. Fragmentation leads to high genetic differentiation between the fragments (ie high Gst – see references on page 1 for detailed explanations).

*Slide 17*: post fragmentation A) fragments are isolated, drift leading to loss of diversity within fragments, greater differentiation between them with some later loss of fragments B) fragments are not isolated, drift is reduced so diversity within fragments is maintained and fragments stay genetically similar.

*Slide 18*: A) fragments are isolated and drift leads to loss of diversity within fragments and differentiation between them; B) (photo shows the landscape of the *S. humilis* study) 'isolated' trees on farms may act as mediators of gene flow (pollen or seed) between forest fragments and so reduce or negate the impacts of fragmentation, i.e. reduce genetic drift and stop loss of alleles and genetic differentiation between the fragments.

*Slides 19*: given the theory covered in the previous slides, there may be a number of benefits of trees persisting on farms. If this is reality then we may need to have a broader vision of the land-use types that constitute a biological corridor (this is referred to in the opening IUCN video).

*Slides 20 and 21*: raise the practical issue of whether isolated trees are suitable for seed collection? Is seed from these trees mostly inbred with consequences of low fitness due to inbreeding depression and low levels of genetic diversity? The second slide shows theoretical predictions of how mating patterns will be altered for isolated trees after forest fragmentation.

*Slide 22*: raises the central question to the exercise. Answering this requires studies to generate real data!

*Slide 23*: photo of one of the study species (*S. humilis*) in El Salvador where the forest has disappeared, but the species occurs often on farms. Text indicates the IUCN threatened category for the species and main features of its reproductive biology. Map shows the species distribution.

*Slides 24-35:* allow the teacher to explain the main features of the genetic studies:

*Slide 24:* photo and map of the fragmented population of *S. humilis.* The forest is now mainly restricted to the hills. The arrow shows the distance of pollen flow to the 'isolated' tree.

*Slide 25:* as the size of the fragment decreases, so the proportion of pollination from outside the fragment increases, i.e. fragmentation is not leading to isolation. From the trees' viewpoint they are not 'isolated'.

*Slide 26:* within a fragment, trees are pollinated both by the trees from the same fragment (61%) and from outside (39%). A tree isolated by 1km does not self - it is pollinated by trees 2.0-4.5 km distant.

*Slide 27*: the answer lies in the reproductive biology of *S. humilis*: controlled crosses show that where cross pollen is in short supply (i.e. at greater distances) self-pollination does not produce seed.

*Slide 28*: main features of the other study species (*Pachira quinata*).

*Slide 29*: aerial photos contrast the conditions of the two study areas: continuous dry forest and pasture with a low density of remnant trees.

*Slide 30*: maps of the two study sites for *P. quinata* showing a higher density and more clumped distribution of trees in the dry forest area.

*Slide 31*: outcrossing rate values theoretically range from 0 (selfing) to 1 (randomly outcrossing to the population). A value of 0.926 shows a high outcrossing rate with most trees showing similar outcrossing rates (i.e. the correlation of $t_m$ value is low: close to 0).

*Slide 32*: trees in the pasture show a lower outcrossing rate, i.e. there is more selfing than in the forest.

*Slide 33*: gives results from another study on the same species. At a greater isolation distance (>500m), the pasture trees show a higher degree of selfing (0.777). However, the high correlation of tm value is important at 0.636. It shows that the pasture trees vary greatly in the extent to which they show selfing (i.e. some show high selfing rates, others low selfing rates).

*Slide 34*: the trees that show selfing are not the most isolated, i.e. the results do not follow the prediction.

*Slide 35*: the answer lies in the reproductive biology of *P. quinata.* Controlled crosses show that a) where cross pollen is in short supply (i.e. at greater distances), self pollen can be successful and b) the ability to self varies between trees.

*Slide 36*: makes the point that a large number of tree species are designated as being threatened. However, there is a problem in the accuracy of assessment as evidenced by this study. You can ask the students whether on the basis of the evidence in the case study they agree. Evidence from the study suggests *S. humilis* (the 'threatened' species) is surviving well outside of forests, whereas *P. quinata* is fairing poorly. *S. humilis* is classified by IUCN as Vulnerable (VU) using the criteria A1cd (see support file for full list of IUCN categories and criteria). A taxon is Vulnerable when it is not Critically Endangered or Endangered but is facing a high risk of extinction in the wild in the medium-term future, as defined by the criteria: A) Population reduction in the form of: 1) An observed, estimated, inferred or suspected reduction of at least 20% over the last ten years or three generations, whichever is the longer, based on (and specifying) any of the following: c) a decline in area of occupancy, extent of occurrence and/or quality of habitat. d) actual or potential levels of exploitation.

NB: *before these studies, P. quinata was not classified as VU, hence the classification in the slide.*

*Slide 37*: allows the teacher to go over what the students should be doing in the exercise. The teacher should stress: a) the need to be specific in what the plan includes - students tend to be too general in their recommendations; b) the need to prioritise - students tend to recommend doing everything, failing to recognise that resources for actions are extremely limited; c) they should indicate what information or evidence they used to justify each activity; d) they need to present a convincing case that would sway a donor/government to give them funds and/or enact policy or legislation to aid conservation; e) they do not need to answer all the questions, but the questions are things they need to think about in developing a plan.

## Important points to draw out in discussion and to cover in students' presentations

### Comments about the questions

- *What is the mating system of each species?*

Both species show predominant outcrossing in undisturbed forest. This is a feature typical of many tree species.

- *Do trees self and if so under what circumstances?*

*P. quinata* shows an increase in selfing in isolated pasture trees, whereas there is no evidence of increased selfing in *S. humilis* pasture trees*.* With *P. quinata,* the degree of selfing increases with spatial isolation. However individual trees vary in their ability to self, so that not all isolated trees show high levels of selfing.

- *How do the pollen and seed dispersal vectors respond to fragmentation or isolation?*

In both species, pollinators are able to move between the forest fragments or the spatially isolated pasture trees. Pollinators respond to fragmentation by moving greater distances than normally.

- *Does maintenance of the species in agroecosystems lead to reduced levels of genetic variation and if so what management strategies can be used to avoid such a reduction?*

It is evident from Table 1 that *S. humilis* occurs in as high a proportion of farms as in forest, indicating it is unlikely to have suffered a large loss of genetic diversity through preferential clearing and maintenance on farms. Nor is there evidence of inbreeding in on-farm trees, which would also lead to reduced levels of genetic variation. In contrast, *P. quinata* is likely to have suffered loss of genetic variation due to a reduced occurrence on farms compared to forest, and through increased inbreeding by trees in certain types of agroecosystems (e.g. largely treeless pastures). Page 5 suggests *S. humilis* appears ecologically suited to *circa situm* conservation through use on the farms where tillage is minimal, livestock movement controlled, and fallows sporadically allowed. *P. quinata*, however, appears less suited, being far more susceptible to losses in forest cover. Management strategies are discussed below in more detail under 'specific actions'.

- *What are the threats/factors limiting maintenance of P. quinata and S. umilis (short-term/long-term) in the fragmented farm landscape? Are they the same* *or different for each species?* ***Think of problems*** *by type* ***- genetic*** *(e.g. selfing),* ***ecological*** *(e.g. lack of regeneration),* ***social*** *(e.g. land tenure, use).*

The threats/factors limiting maintenance of *P. quinata* and *S. humilis* are certainly different for each species requiring different actions for each species (see page 5 of exercise).

***Pachira quinata,*** **Short-term:** a) ***genetic*** - increased inbreeding in some (approx. 25%) pasture trees with expected reductions in vigour of seed collected from such trees and hence reduced growth of trees established from such seed; b) ***ecological*** - lack of regeneration; c) ***social*** - continued felling. **Long-term:** a) ***genetic –*** loss of genetic diversity, with associated impacts, through: i) loss of populations; ii) reduced population size; iii) increased inbreeding. b) ***ecological*** – none evident that differ from the short-term impact; c) ***social*** - in the long-term, use of the species is a potential benefit, as it provides incentives to support efforts to re-establish the species. This also requires that use is regulated and monitored to balance availability and not increase the species' decline.

***Swietenia humilis,*** **Short-term:** a) ***genetic*** - there do not appear to be any genetic issues. There is still genetic connectivity across a highly fragmented landscape and so population sizes have not been reduced to levels where genetic diversity will be lost rapidly due to drift. There is no evidence of increased selfing with fragmentation/isolation and so there are no expected problems with seed fitness due to inbreeding depression; b) ***ecological*** - there do not appear to be any short-term ecological issues: both seed production and regeneration are good in agroecosystems; c) ***social*** - CITES listing and associated restrictions on use of the species (actual or perceived) may help to limit felling and use, but may also lead to increases in both if farmers perceive that this restricts their management options and ability to use their own trees. **Long-term:** a) ***genetic*** - if numbers declined over the long term there could be loss of genetic diversity; b) ***ecological*** - there do not appear to be any long-term ecological issues; c) ***social*** - in the long-term, the value that farmers place on this species is a benefit as it provides a motivation to foster regeneration of the species. This also requires that use is regulated and monitored to balance availability and not increase the species' decline. As for short-term impacts, CITES listing may have a detrimental impact on long-term maintenance of the species by farmers.

■ *Is any other information needed to allow more definitive conclusions?*

An important issue from an intervention perspective is from where farmers/ projects source-seed, with respect to viability and vigour of seed from farmland trees versus forest trees. The case study suggests that there may be reduced vigour in seed and seedlings from isolated *P. quinata* pasture trees due to inbreeding depression from the increased selfing, whereas for *S. humilis*, we might expect similar levels of performance. Such seed/seedling growth studies could also be used as proxy indicators of where fragmentation or other human interventions are causing reduced viability impacts, rather than much more expensive, laboratory-based genetic studies. It must be remembered, however, that taking action cannot always wait for the availability of all desirable information.

## Action plans should cover the following

■ *Main biological features of the species and implications for conservation.*

This can come mostly from the information on page 2. Immediate implications for conservation of the biological features are mainly: the greater degree of pollinator specificity for *P. quinata* compared to *S.humilis* and the poor natural regeneration of *P. quinata* compared to *S. humilis.*

■ *Factors limiting the maintenance of these species in the fragmented farm landscape – differences between the species.*

These are detailed on the previous page of these notes.

- *Specific actions to ensure both use and conservation of both species in this agroecosystem (including maintenance of genetic diversity). Should they be the same or different for each species and if different, in what way(s)?*

The limitations for natural regeneration of *P. quinata* mean that management must focus on increasing the number of *P. quinata* trees on farms through planting. This is an easy and successful method of establishing this species (see species details on page 2 of student exercise). This requires collection of *P. quinata* seed and raising seedlings in nurseries. The danger of inbreeding in seed collected from isolated trees means that such trees should be avoided in collections. However, ease of access often dictates which trees are collected from. Recognising the likelihood of some inbred seed being collected, there should be rigorous selection of seedlings from the nursery to avoid use of any weaker, slower growing material which is most likely to be inbred. It is important also that collections are made from a minimum number of trees (i.e. >20) if sufficient genetic diversity is to be maintained in the planted trees.

For *S. humilis,* little action appears to be necessary. There is a need for monitoring to ensure that the current healthy position in terms of both numbers and regeneration continues. CITES listing does not preclude local use and there is a need to ensure that this is understood, so that any additional protection measures do not act as a disincentive to farmers who maintain and actively foster regeneration on their land.

- *How will you implement the action plan? **Who** will do **what**, **where** and **how** will you pay for it?*

Efforts to maintain genetic diversity and adaptive capacity are irrelevant if current management drastically alters a target species' persistence. Multidisciplinary action is needed to integrate conservation and development and, more specifically, ensure both species can be sustainably used and conserved in such systems. Given resource limitations, conservation efforts are most likely to be effective if they link into existing rural development initiatives with local communities. This can potentially be achieved mainly through the redirection of existing resources towards actions that favour re-establishment of the target species. Thus, the specific actions identified above could be incorporated into existing development programmes.

Any action plan must seek to promote the complementary benefits of such agroecosystems. There is a need to raise awareness among rural development professionals and organisations of the value of native species and their natural regeneration as both conservation and socio-economic resources. Pushing the planting and use of a limited range of species, often exotics, by development agencies may reduce the potential genetic and conservation benefits of such systems. However, among conservation planners who are more accustomed to *in situ* methods, there is also a need for them to consider the possibility that tree populations found outside protected areas have a role in biodiversity conservation. This, in turn, necessitates direct involvement of development organisations in biodiversity conservation and an effective interaction with traditional conservation organisations to ensure both conservation and development benefits.

Action will have to be on a local scale to influence what individual farmers do on their land. This requires a certain scale of action, i.e. it will have little impact if only one or two farmers implement actions, due to the small area held by any one farmer. For example, maintaining native timber trees over large areas of coffee is likely to have beneficial genetic effects for gene flow, population numbers, and conservation of particular populations. In contrast, the same system in only a small area may lead to a reduced genetic base in seed production through related or bi-parental mating. Thus, the area or management unit should be measured in numbers of participating households or numbers of land units in which land uses beneficial to conservation of the target species are practiced. Given the speed with which land management practices may change in response to market prices, this measure in itself may require monitoring.

## Additional questions

If time is available or if you want to set follow-up work, as an additional question or exercise you can ask students '*Are there any lessons you can apply to other species and ecosystems from your country?*' This is an open-ended question. Students may be able to relate this to: a) other species that are taxonomically closely related (e.g. Meliaceae or Bombacaceae) or that share similar ecological or reproductive features (e.g. similar pollination or seed dispersal vectors - specialist bat vs a generalist); b) the context of trees in deforested agroecosystems in their own countries.

a) Evidence suggests that for many species, populations and individuals of trees, gene flow may be high across agroecosystem landscapes with little apparent forest cover. The view that forest fragmentation produces genetic isolation may be more a human perception than a true reflection of actual gene flow. The need for more immediate action in many situations requires pragmatic best-guess approaches to identify which species will be favoured by gene flow between agroecosystems and those which will not. The ability to make more general recommendations depends on basic biological information (e.g. incompatibility and pollination mechanisms, dispersal, and seedling regeneration) that enables species to be classified into management categories (combining ecological guild, spatial distribution, and reproductive biology). Available information suggests the following species types are unlikely to show genetic conservation benefits from agroecosystems: i) outcrossing species that are self-compatible; ii) slow-growing species that reproduce only when large (the extreme being monocarpic species, i.e. those that flower only once in their life); iii) species with poor regeneration under human disturbance; iv) species with highly specific pollinators or seed dispersers susceptible to disturbance; v) rare species with low population densities.

b) The more general lesson is that trees in a whole range of agroecosystems may play an important but varied role in the long-term genetic viability of some native tree species by: i) facilitating gene flow between existing reserves; ii) conserving particular genotypes not found in reserves; iii) maintaining minimum viable populations; iv) acting as intermediaries and alternative host habitat for pollinators and seed dispersers. It is important to recognize the complementary role that maintenance of trees on farms is already playing to *in situ* conservation. Underestimating the capacity of many species to persist in large numbers in these agroecosystems under current practices could lead to the misdirection of limited conservation resources toward species not under threat. The fact that some tree species living in such disturbed vegetation can be conserved through existing practices can free resources for the conservation of more critically threatened species needing more conventional, resource-intensive approaches.

However, the benefits and possibilities of such *circa situm* conservation may be limited to certain types of species and ecosystems. In an area of high forest cover, agroforestry systems may be valued principally for gene flow, whereas in much more highly deforested areas a fuller complement of benefits may be sought from particular systems. Thus, in the highly deforested dry forest zone of Honduras, traditional fallow systems in which farmers manage naturally regenerated shrubs, fruit trees and timber trees among their crops, are likely to provide a variety of genetic conservation benefits for a range of native tree species. Other complex systems, such as traditional shaded coffee or jungle rubber, may rate highly for all the possible genetic conservation benefits. In contrast, simpler agroecosystems such as pasture trees and living fencerows offer fewer genetic conservation benefits and are unlikely to prove effective mediators of pollen flow for species without a self-incompatibility mechanism. In most cases, assessments of the genetic conservation benefits of agroecosystems must take account of the farming systems context of an area, the density of trees, and their origin (natural regeneration or planted).

We should not overestimate the extent to which agroecosystems will benefit the genetic conservation of forest tree species. In addition to some of the complications raised in this exercise, it is evident that many tree species found in such areas already exist in adequate numbers in existing reserves. Similarly, some of the species threatened by low population numbers are not of the type that will easily persist in such systems. The greatest potential role will be in highly deforested areas where reserves are very small or non-existent and where the trees maintained in agroecosystems represent an important part of the gene pool of a particular population or species.

## Further information

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