

Supporting Information

Table S1: Indicator System. The five colour-coded indicator component titles, underlying indicators and corresponding questions, as well as short names as presented in Figure 1, that make up the set of 15 indicators for the analysis of tree seed systems

Indicator	Component		Question	Short name
Selection and innovation	1	Different sources of information are used to identify native species useful for restoration in a variety of ecosystems	Are lists of priority native species for restoration available for key ecosystems?	Species prioritized for restoration
			Are threatened species included in the priority lists for restoration?	
	2	Research into the effect of climate change on native species across different ecosystems is used to inform selection of species and seed sourcing for restoration	Is there research on the effect of climate change on key ecosystem distribution?	Climate change informs species choice
			Is there research on the effect of climate change on priority native species distribution?	
			Is there research on the effect of climate change used to inform planting decisions for restoration?	
	3	Information on species genetic diversity is used to identify goal-oriented planting material	Are there provenance trials across the country for the priority species?	Genetic data defines seed transfer zones
			Is data being collected from these trials?	
			Is the data being used to inform seed source choice for restoration?	
			Is there research on species population genetics?	
			Is there research on defining eco-geographical zones for priority species?	
			Is this information used to define seed transfer zones?	
	4	Suitable information is readily available to inform stakeholders in their restoration choices	Are there research initiatives developing improved material for those priority species used in production restoration?	Information available to stakeholders
			Is suitable information readily available to stakeholders that helps in species choice for restoration?	
			Is suitable information readily available on how to identify the most suitable seed source?	
5	Seed sources that cover the geographical range of the priority native species have been identified and are protected effectively	Is suitable information readily available on the difference between wild and selected material?	Seed sources protected	
		Have seed sources been identified for the priority species?		
		Have seed sources been identified for key ecosystems?		
		Do seed sources cover the species range?		

			Are seed sources protected effectively?	
	6	Improved material is available for those priority species used in production restoration	Is there improved material available for those priority species used in production restoration?	Improved material available
			Is improved material available for the key ecosystems?	
	7	Nurseries are able to produce the priority species adapted to each ecosystem	Are all the priority species being produced? Are they being produced across each key ecosystem?	Priority species available in nurseries
Market access, supply and demand	8	There is demand for priority native species of suitable provenance for restoration across targeted ecosystems	Is there demand for priority native species? Do people request suitable provenance?	Demand exists for priority species
	9	There is a network of suppliers able to meet the demand for priority native species of suitable provenance across targeted ecosystems	Is there a network of suppliers? Can the network meet demand (access and quantity) for natives with suitable provenance?	Suppliers work as a network
	10	Measures exist to comply with seed sourcing and harvesting standards	Does certification cover seed sourcing (population size, sampling method)? Does certification cover seed harvesting (material type, permission to collect)?	Standards for seed sourcing and harvesting
	11	Measures exist to comply with seed quality standards	Does certification cover production (phytosanitary conditions, control of origin)? Does certification cover improved seeds?	Standards for seed quality
Quality control	12	Quality control measures function as an integrated system	Do these components function as a system?	Standards integrated into a quality control system
	13	The seed system is underpinned by appropriate legislation and regulations applied to native species and implemented	Are adequate regulations being implemented that support the use of material suitable for climate change? Are adequate regulations being implemented to define seed transfer zones? Are adequate regulations being implemented to protect seed sources? Are adequate regulations being implemented that provide incentives for the use of native species? Are adequate regulations being implemented for a certification system for native species?	Appropriate legislation in place
	14	There is appropriate capacity to support a seed system	Is there sufficient capacity building for decision makers?	

			Is there sufficient capacity building for technicians?	Sufficient capacity available
			Is there sufficient capacity building for communities?	
			Is there sufficient capacity building for the general public?	
			Is there sufficient capacity building for students?	
	15	There is sufficient financial support for key research needed for seed systems	Is there sufficient financial support for baseline information on priority native species & key ecosystems and climate change?	Adequate funding available
			Is there sufficient financial support for seed source identification?	
			Is there sufficient financial support for research on material production?	

Table S2: Experts survey questionnaire.

Indicator		Question	0	1	2	3	Score	Comments
Selection and innovation								
1	Different sources of information are used to identify native species useful for restoration in a variety of ecosystems	Are lists of priority native species for restoration available for key ecosystems?	No	There are lists of priority native species for a few priority ecosystems	There are lists of priority native species for most priority ecosystems	There are lists of priority native species for all priority ecosystems		
		Are threatened species included in the priority lists for restoration?	No	A few threatened species are included	Many threatened species are included	All threatened species are included		
2	Research into the effect of climate change on native species across different ecosystems is used to inform selection of species and seed sourcing for restoration	Is there research on the effect of climate change on key ecosystem distribution?	No	One or a few key ecosystems have been studied	Many key ecosystems have been studied	All key ecosystems have been studied		
		Is there research on the effect of climate change on priority native species distribution?	No	Some priority species have been studied	Many priority species have been studied	All priority species have been studied		
		Is there research on the effect of climate change used to inform planting decisions for restoration?	No	There are few examples of this research being used to inform planting decisions	There are several examples of this research being used to inform planting decisions	Research is used in inform planting decisions		
3	Information on species genetic diversity is used to identify goal-oriented planting material	Are there provenance trials across the country for the priority species?	No	There are provenance trials for a few priority species	There are provenance trials for many priority species	There are provenance trials for the priority species		
		Is data being collected from these trials?	No			Data is being collected		
		Is the data being used to inform seed source choice for restoration?	No	Data is used to inform seed source choice for	Data is used to inform seed source choice for restoration of many priority species	Data is used to inform seed source choice for restoration of priority species		

5	Seed sources that cover the geographical range of the priority native species have been identified and are protected effectively	Have seed sources been identified for the priority species?	No	Seed sources have been identified for at least one priority species	Seed sources have been identified for many priority species	Seed sources have been identified for the priority species		
		Have seed sources been identified for key ecosystems?	No	Seed sources have been identified for at least one key ecosystem	Seed sources have been identified for many key ecosystems	Seed sources have been identified for the key ecosystem		
		Do seed sources cover the species range?	No	Identified seed sources cover a small part of the species range	Identified seed sources cover most of the species range	Seed sources cover the species range		
		Are seed sources protected effectively?	No	Seed sources received little protection	Seed sources receive some protection	Seed sources are protected effectively		
6	Improved material is available for those priority species used in production restoration	Is there improved material available for those priority species used in production restoration?	No	There is improved material available for at least one priority species	There is improved material available for many priority species	There is improved material available all priority species used in production restoration		
		Is improved material available for the key ecosystems?	No	There is improved material available for at least one key ecosystem	There is improved material available for many key ecosystems	There is improved material available for the key ecosystem		
7	Nurseries are able to produce the priority species adapted to each ecosystem	Are all the priority species being produced?	No	A few priority species are being produced	Most priority species are being produced	The priority species being produced across		
		Are they being produced across each key ecosystem?	No	Production occurs in at least one key ecosystem	Production occurs in many key ecosystems	Production occurs in the key ecosystems		
Market access, supply and demand								
8	There is demand for priority native species of suitable	Is there demand for priority native species?	No	There is little demand for priority native species	There is some demand for priority native species	There is demand for priority native species		

	provenance for restoration across targeted ecosystems	Do people request suitable provenance?	No	There is little demand for suitable provenance	There is some demand for suitable provenance	There is demand for suitable provenance		
9	There is a network of suppliers able to meet the demand for priority native species of suitable provenance across targeted ecosystems	Is there a network of suppliers?	No	There are local networks of suppliers	There are regional networks of suppliers	There is a national network of suppliers		
		Can the network meet demand (access and quantity) for natives with suitable provenance?	No		The network can meet demand for natives but there is no provenance information	The network can meet demand for natives with suitable provenance		
Quality control								
10	There is a certification system for seed quality for restoration planting	Does certification cover seed sourcing (population size, sampling method)?	No	Some aspects are covered	Most aspects are covered	All aspects are covered		
		Does certification cover seed harvesting (material type, permission to collect)?	No	Some aspects are covered	Most aspects are covered	All aspects are covered		
11	Measures exist to comply with seed quality standards	Does certification cover production (phytosanitary conditions, control of origin)?	No	Some aspects are covered	Most aspects are covered	All aspects are covered		
		Does certification cover improved seeds?	No	Some aspects are covered	Most aspects are covered	All aspects are covered		
12	Quality control measures function as an integrated system	Do these components function as a system?	No	There is some relation between the components	Most of the components are linked	All the components are linked		
Enabling environment								
13	The seed system is underpinned by appropriate legislation and regulations	Are adequate regulations being implemented that support the use of materia suitable for climate change?	No	Not adequate or implemented	Adequate but not implemented or not adequate but implemented	Adequate and implemented		

	applied to native species and implemented	Are adequate regulations being implemented to defined seed transfer zones?	No	Not adequate or implemented	Adequate but not implemented or not adequate but implemented	Adequate and implemented		
		Are adequate regulations being implemented to protect seed sources?	No	Not adequate or implemented	Adequate but not implemented or not adequate but implemented	Adequate and implemented		
		Are adequate regulations being implemented that provide incentives for the use of native species?	No	Not adequate or implemented	Adequate but not implemented or not adequate but implemented	Adequate and implemented		
		Are adequate regulations being implemented for a certification system for native species?	No	Not adequate or implemented	Adequate but not implemented or not adequate but implemented	Adequate and implemented		
14	There is appropriate capacity to support a seed system	Is there sufficient capacity building for decision makers?	No	There is little capacity building	There is some capacity building	Capacity building is sufficient		
		Is there sufficient capacity building for technicians?	No	There is little capacity building	There is some capacity building	Capacity building is sufficient		
		Is there sufficient capacity building for communities?	No	There is little capacity building	There is some capacity building	Capacity building is sufficient		
		Is there sufficient capacity building for the general public?	No	There is little capacity building	There is some capacity building	Capacity building is sufficient		
		Is there sufficient capacity building for students?	No	There is little capacity building	There is some capacity building	Capacity building is sufficient		
15	There is sufficient financial support for key research needed for seed systems	Is there sufficient financial support for baseline information on priority native species and key ecosystems for climate change?	No	There is little financial support	There is some financial support	There is sufficient financial support		
		Is there sufficient financial support for seed source identification?	No	There is little financial support	There is some financial support	There is sufficient financial support		

		Is there sufficient financial support for research on material production?	No	There is little financial support	There is some financial support	There is sufficient financial support		
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S3: Questionnaire for FLR practitioners about the origin of seeds and seedlings for restoration in Southeast Asia

This survey is for organisations and businesses who are involved in planting or propagating native tree species in Southeast Asia. Your answers will help us to understand challenges in the seed supply chain and to develop free tools that support forest and landscape restoration. The results of this research will contribute to creating a more sustainable seed supply and develop a tool to document seed sources.

It would really help us if you could respond to this survey. The survey will only take about 15-20 minutes to complete. Your responses will remain confidential and will be anonymised during the analysis.

The term "seed" in this survey refers to any planting material, including seeds, seedlings, wildlings and vegetative material.

If you are working on several separate projects, please describe your latest project or fill in a survey for each project.

Thank you in advance for your help.

Privacy Notice

This privacy notice tells you about the information we collect from you when you agree to participate in our survey. The survey on Origin of seeds and seedlings for restoration in southeast Asia is aimed at organisations who are involved in planting native trees for restoration efforts in southeast Asia. The results of this study will enable us to understand challenges in the seed supply chain and to help with the development of an application called SeedIT, which will be used to document seed sources. The survey is developed as part of a master thesis research project at ETH Zurich in consultation with the Alliance of Bioversity International and CIAT and the Asia Pacific Forest Genetic Resources Programme (APFORGEN).

In collecting this information, we are acting as a data controller and, by law, we are required to provide you with information about us, about why and how we use your data, and about the rights you have over your data.

1. Who are we?

We are the Alliance of Bioversity International and the International Center for Tropical Agriculture (CIAT). Our address is Via dei Tre Denari 472/a, 00054, Fiumicino, Rome, Italy. You can contact us by post at the above address or by email at bioversity-ds-requests@cgiar.org

2. What personal data do we collect?

You can participate in the survey without giving your details, but if you are interested in learning more about SeedIT or about the related App, and would like us to contact you, we ask for the following information: Name, Organisation, City/Town, Country and Email Address

3. Why do we collect this information?

If you supply your personal data we will only use it to send you information regarding the results of the survey, a more in depth explanation of the SeedIT project and the related App.

4. What do we do with your information?

The survey is hosted and collected through monkey survey. The privacy conditions and notice of Monkey Survey can be accessed here: https://www.surveymonkey.com/mp/legal/privacy-basics/?ut_source=survey_pp . The survey is developed as part of a master thesis research project at ETH Zurich.

5. How long do we keep your information for?

The data will be retained for 9 months, at which time the information you have supplied will be anonymized , however, you can request at any time for us to remove it from the database by sending an email to [bioversity-ds-requests@cgiar.org]

6. Your rights over your information

By law, you can ask us what information we hold about you, and you can ask us to correct it if it is inaccurate. You can also ask for it to be erased or ask us to stop using your information. The simplest way to do this is to withdraw your consent, which you can do at any time, either by emailing or writing using the contact details above.

7. Your right to complain

If you have a complaint about our use of your information, you can contact the Italian Data Protection authority at http://www.garanteprivacy.it/web/guest/home_en

Origin of seeds and seedlings for restoration in southeast Asia

1. What kind of organisation are you?

- ☐ Government organisation
- ☐ Non-governmental organisation
- ☐ Commercial nursery
- ☐ Other (please specify)
- ☐ Community-based nursery
- ☐ Academic or research organisation

2. Which country are you based in?

3. Please tell a bit about which tree species you are propagating or planting.

What are the main tree species you work with?

Please provide the scientific name.

Do you work with threatened tree species, and if yes, which ones?

How many native tree species are you working with?

What proportion of all planted trees species belong to native species (%)?

Total number of seedlings propagated or raised per year (including vegetative propagation and wildlings):

Total number of seedlings planted per year:

4. If you are involved in planting native tree species: What are the main objectives of your project?

	Main purpose	Secondary purpose	N/A
Restoring habitats for native animals and plants	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Conserving rare or threatened species	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Carbon sequestration	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Timber production	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Food production	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Producing other non-timber forest products	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Agroforestry	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improving soil quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cultural or aesthetic values	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Education	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

* 5. Does your organisation collect some seed on your own?

- ☐ Yes
- ☐ No, we buy all the seed we need

Origin of seeds and seedlings for restoration in southeast Asia

6. Why do you collect seed yourselves?

- ☐ Cost
- ☐ Lack of suppliers
- ☐ Want to ensure quality
- ☐ Other (please specify)

7. Would you be interested to buy seed under the following circumstances?

	Yes	Probably yes	Probably no	No
If it was easier to get in touch with suppliers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If they sold cheaper seed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If they sold the species you prefer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If they sold the provenance you prefer	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
If they provided more information about the origin of seed	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

* 8. Does your organisation also buy seed?

- ☐ Yes
- ☐ No

Origin of seeds and seedlings for restoration in southeast Asia

9. What kind of organisation do you usually buy from? Please rank at least one option (1 being most important) and leave the other options empty.



Community nursery



Commercial nursery



Governmental nursery



Individual seed collectors

10. How do you choose which suppliers to buy seed from? Please select up to three most important reasons in order of priority (number 1 being most important) and leave the other options empty.



They sell the species we want



They sell the provenance (=geographic origin of the seed) we want



They give information about seed quality



Good price



They are able to supply the amount needed



They are reliable and supply on time



They are the nearest supplier



We don't know other suppliers

11. What information about seed do you receive from the suppliers?

	never	rarely	sometimes	often	always
Species	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Provenance	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Type of source: natural forest, planted forest, seed stand, seed orchard, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Forest condition, e.g. level of degradation, habitat fragmentation, etc.	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Type of propagation material: propagated from seed, propagated vegetatively, wildling (wild seedling)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Recommendations on the suitability of the species' provenance for our project	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Germination rate	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Number of trees which the seeds are collected from (for each species)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Comments

12. What other information would you like to get from the suppliers? Why would this be important to you?

13. How often are you facing the following challenges when it comes to dealing with suppliers?

	never	rarely	sometimes	often	always
Overall lack of suppliers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Difficult to reach suppliers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Suppliers are not able to meet the quantity required	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
We do not know which suppliers have which material	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Difficult to find out when seed is available	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Difficult to get information about seed quality	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

14. Would your organisation be interested to buy more seed, if it was easier to deal with suppliers?

- ☐ Yes, definitely
- ☐ Yes, but we currently do not have the funding to do so
- ☐ No, we are happy with the current supply
- ☐ Other (please specify)

15. How happy are you with the quality of the seed you buy, and why? What could be improved?

16. Would you consider paying a higher price for seed than what you currently pay, if these seed met your criteria better?

- ☐ Yes, definitely
- ☐ Yes, but we currently do not have the funding to do so
- ☐ Maybe, if the benefits are very clear
- ☐ No, we are happy with the current quality

Comments

Origin of seeds and seedlings for restoration in southeast Asia

17. What do you perceive as high quality seed? Please rank only the three most decisive characteristics from 1 to 3, 1 being the most important one.



Clean seed, no pests, not rotting

☐ N/A



Good provenance

☐ N/A



High germination rate

☐ N/A



Documented seed origin

☐ N/A



Seeds are sourced from many mother trees per species

☐ N/A



Seed from large forest areas

☐ N/A



Locally sourced seed

☐ N/A

18. How often are you facing the following challenges regarding the quality of seed supply?

	never	rarely	sometimes	often	always	I don't know
Overall lack of seed to meet the demand	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of preferred species	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of preferred provenance or origin	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Available material is too expensive	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Origin of available material is unknown	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Seeds are only available at irregular times	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Seed is not clean, rotting, has pests	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Too low germination rate/seedlings grow slowly or die	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Seeds are from too less mother trees	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Other (please specify)

19. Do you keep records of the following in your project (select all that apply)?

	No	Yes, but not systematically	Yes, by year	Yes, by species	Yes , by seed source or supplier
Germination rate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Seedling growth rate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Seedling survival rate	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Comments

20. If you keep records, please explain briefly why this information is important for you.

21. If your project is funded by another organisation: Is keeping records of the above information required from the funders/donors of your project?

- ☐ Yes
- ☐ No
- ☐ Comments

22. To support documenting seed sources and communication between seed suppliers and buyers, we are developing a free phone-based application "[SeedIT](#)". With this app, users will be able to maintain records about collected species and origin, and get updates from the suppliers. It also works offline for remote areas without internet connection. Would your project be interested to try SeedIT?

- ☐ Yes, please send me more information
- ☐ Yes, but we do not have access to phone-based apps
- ☐ No, we are happy with the current communication with the suppliers
- ☐ No, we have already other ways to document seed sources (please explain)
- ☐ Comments

23. Please provide your contact details if you want us to contact you for further information.

Name

Organisation

City/Town

Country

Email Address