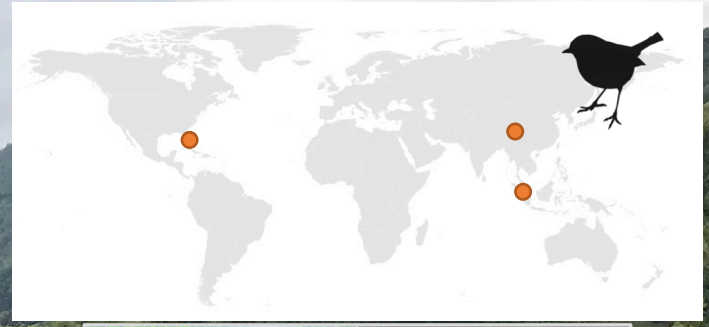
Landscape under reforestation in mountainous Sichuan Province (southwestern China)

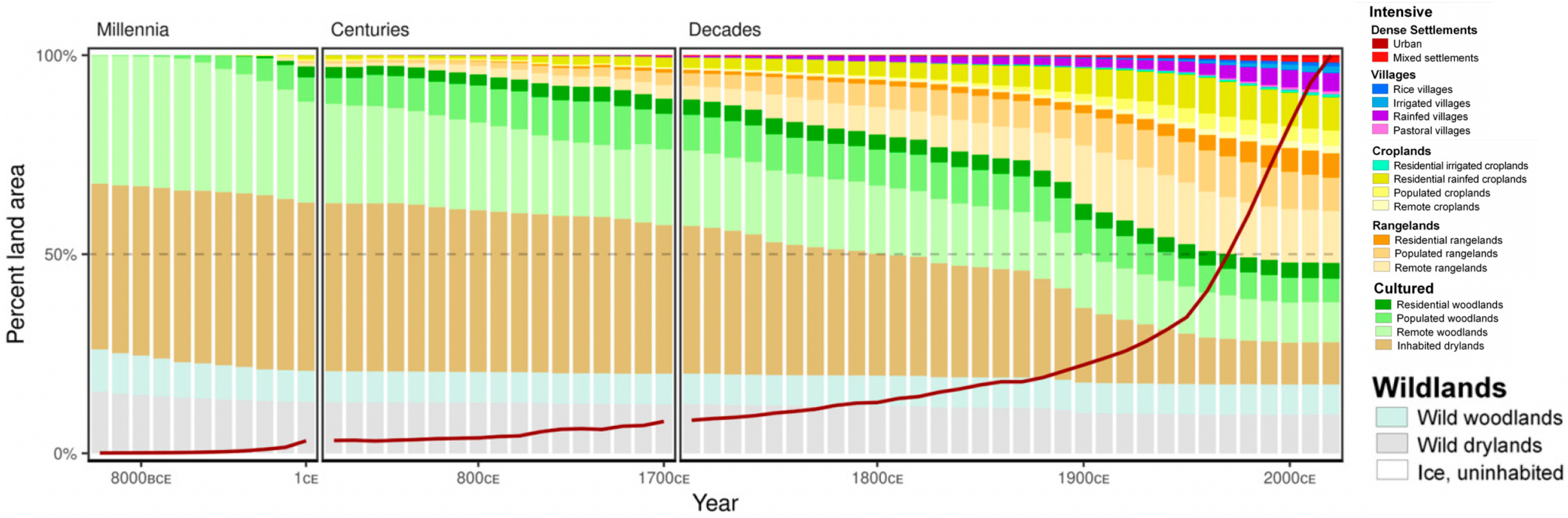


Scaling up forest restoration: achieving the full potential of biodiversity gains

Fangyuan Hua | Institute of Ecology, Peking University | fhua@pku.edu.cn | www.conservationee.org

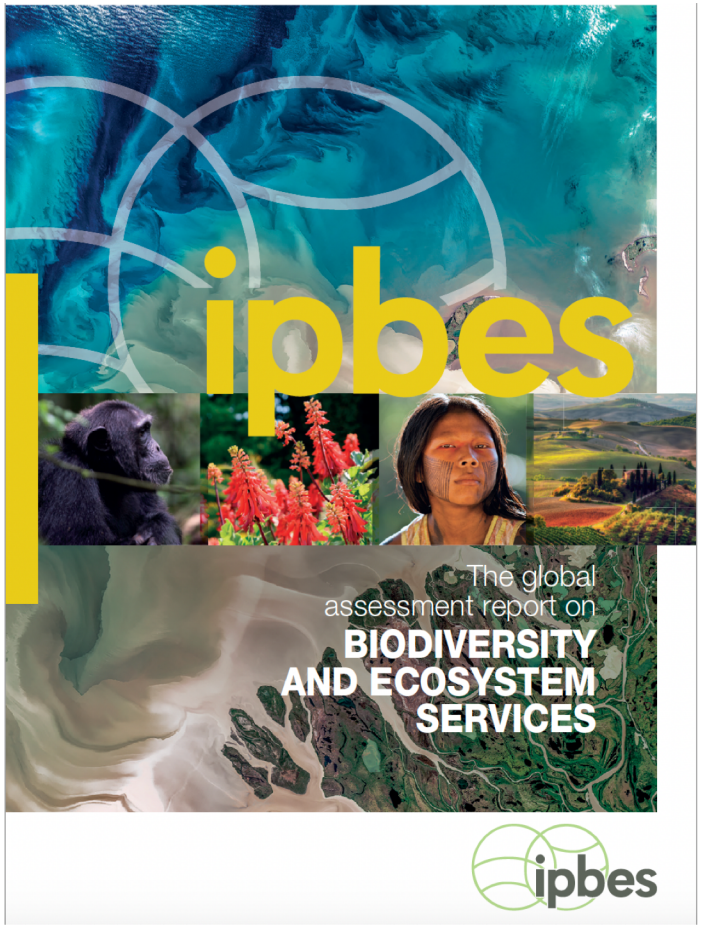
People have shaped most of terrestrial nature for at least 12,000 years

Erle C. Ellis (艾尔青)[a,1], Nicolas Gauthier[b,c], Kees Klein Goldewijk[d,e], Rebecca Bliege Bird[f], Nicole Boivin[g,h], Sandra Díaz[i], Dorian Q. Fuller (傅稻镰)[j,k], Jacquelyn L. Gill[l], Jed O. Kaplan[m], Naomi Kingston[n], Harvey Locke[o], Crystal N. H. McMichael[p], Darren Ranco[q], Torben C. Rick[r], M. Rebecca Shaw[s], Lucas Stephens[t], Jens-Christian Svenning[u], and James E. M. Watson[v,w]



Cited from: Ellis et al. 2021, PNAS

Of major conservation concern: the issue of habitat loss/degradation and restoration



Habitat loss, degradation, fragmentation:
leading threats to global biodiversity

Four overarching goals

A. Halt loss, restore nature

B. Use lands & seas sustainably

to be met by 2050

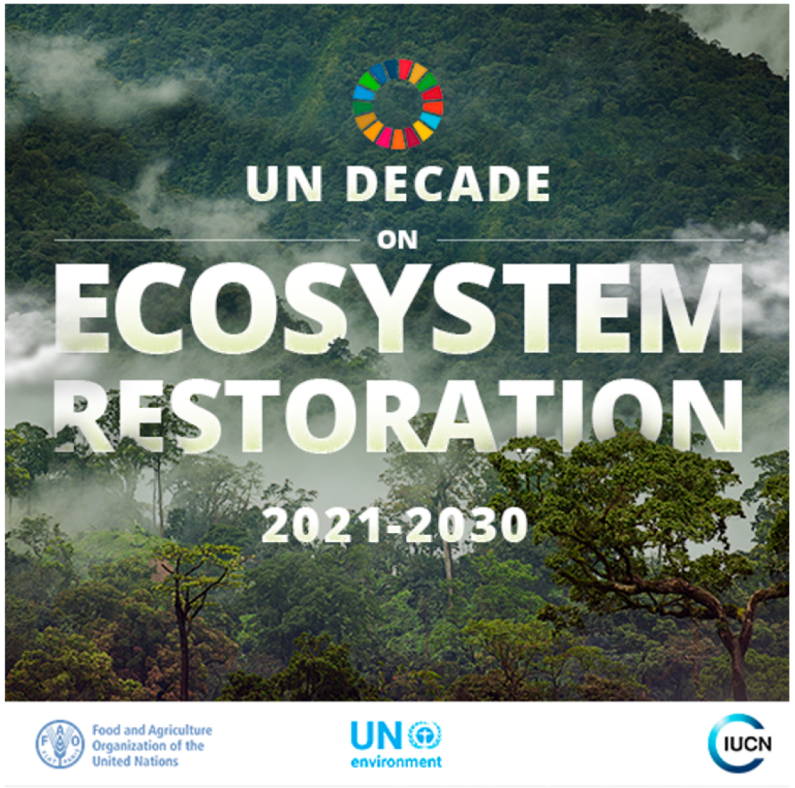
>> 2. Effectively restore 30% of degraded nature
>> 3. Effectively conserve 30% of lands and seas

Cited from: IPBES 2019, Global Assessment Report on Biodiversity and Ecosystem Services; ©Vidgis Vandvik

Exciting and enormous potential of biodiversity recovery

Convention on Biological Diversity

United Nations Framework Convention on Climate Change



BONN CHALLENGE

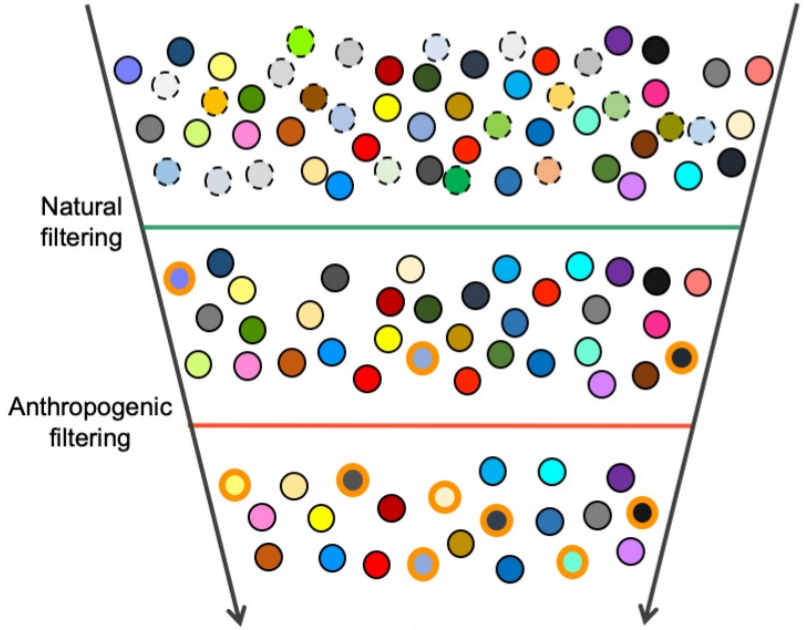
THE GLOBAL PARTNERSHIP ON FOREST AND LANDSCAPE RESTORATION

Can we cash in on this potential?

Some issues important to ensuring the biodiversity benefit of forest restoration

What type of forest to restore

Spatial scale of restoration planning



What biodiversity to benefit

Issue 1: biodiversity side-lined by plantation-dominated reforestation

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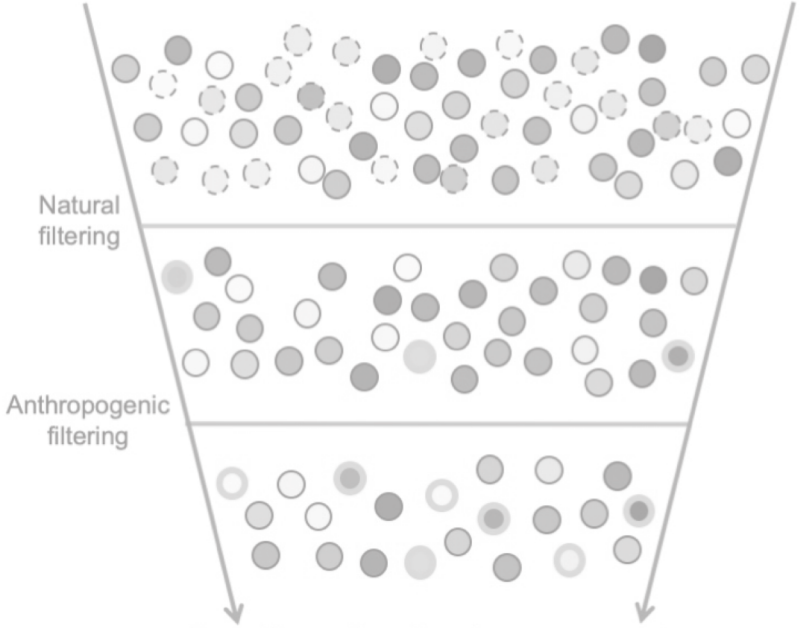


What biodiversity to benefit

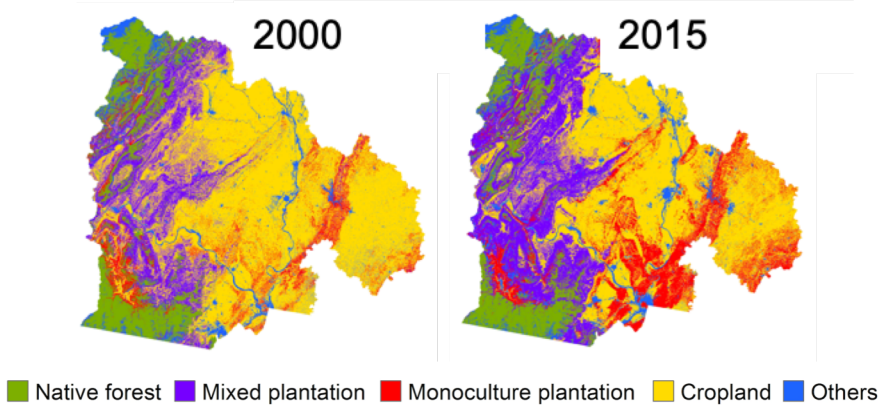
Issue 1: biodiversity side-lined by plantation-dominated reforestation

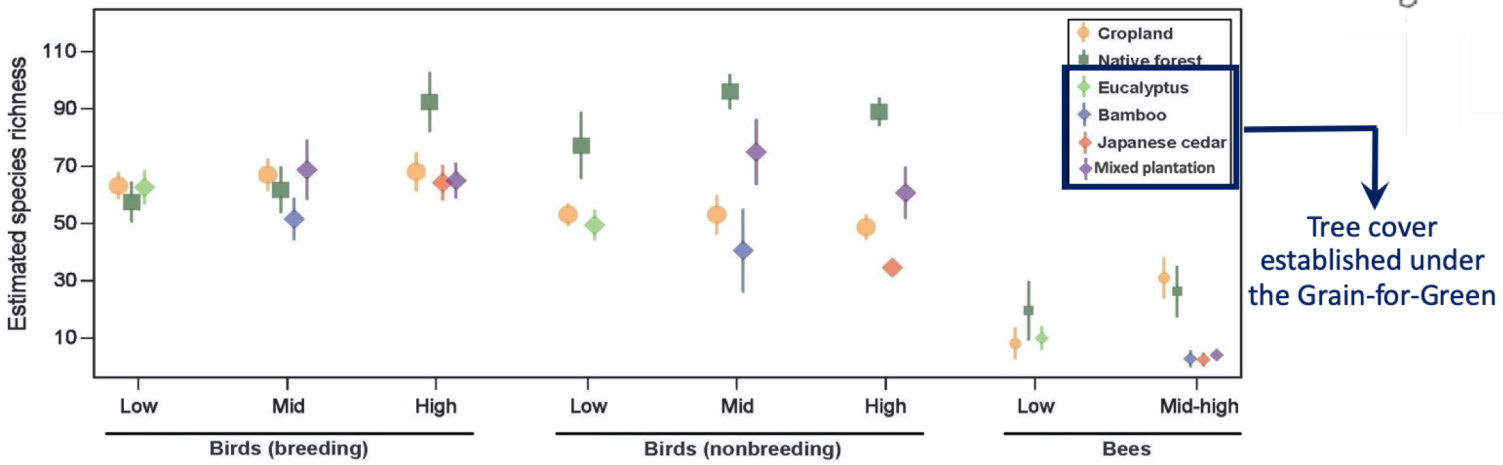
The case of the Grain-for-Green Program (world's largest reforestation program)

- Main goal: to curb soil erosion on sloped terrain, but also poverty alleviation
- Covered ~34 million ha of land across China during 1999–2019
- Seemingly used/encouraged a plantation-dominated reforestation approach
- Allows the harvesting of tree plantations for income, given harvesting permit

Issue 1: biodiversity side-lined by plantation-dominated reforestation

The case of the Grain-for-Green Program (world's largest reforestation program)





Region-wide change in land cover:

- Dominant change: marginal cropland to monocultures
- Native forest area: direct (~7%) and indirect loss

Biodiversity outcomes (avian and bee communities):

- Notable shortfall from reference native forest
- Outcomes depend on tree cover: monoculture typically renders losses rather than gains

Hua et al. 2016, Nature Communications; Hua et al. 2018, Biological Conservation

Issue 1: biodiversity side-lined by plantation-dominated reforestation

Root of the issue

- Functionality-oriented goals (even though often environmental)
- The assumption that tree plantations can effectively serve these goals

Larix principis-rupprechtii plantation, Inner Mongolia
Purpose: to curb dust storms (wind erosion)

Poplar plantation, Chongqing Province
Purpose: to curb soil erosion

Pinus tabuliformis plantation, Heibei Province
Purpose: to sustain water provisioning

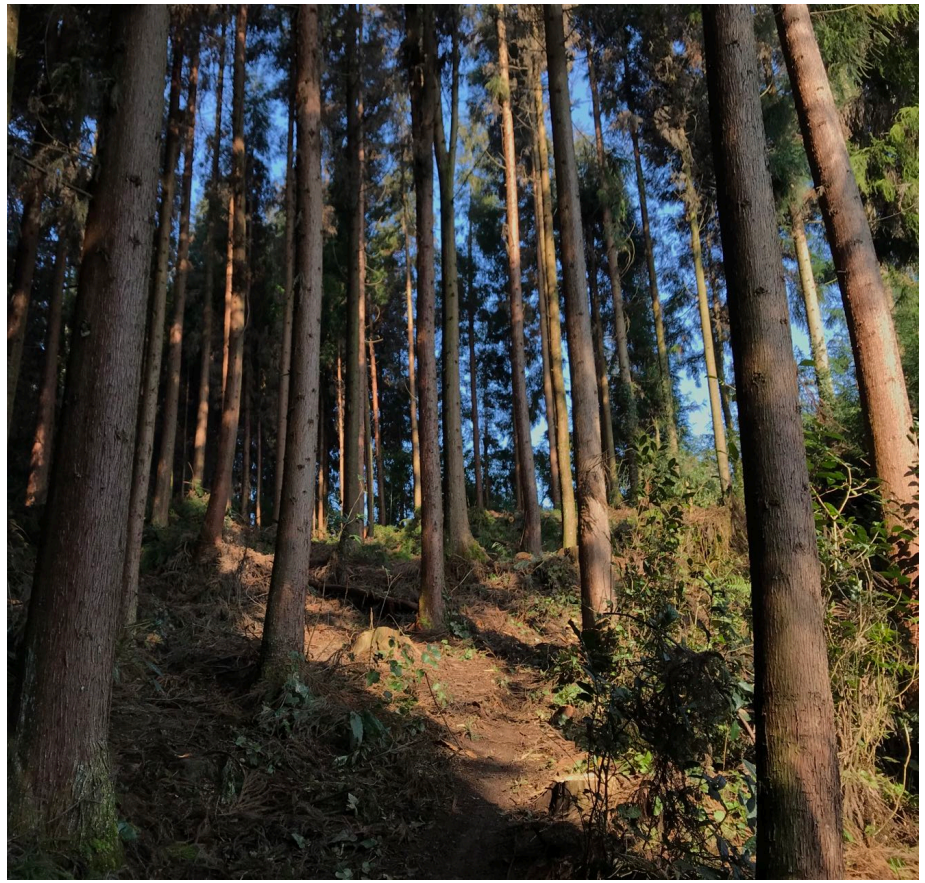
Prevalence is added by reforestation related to “carbon farming” and, obviously, wood production

But does the above assumption stand?

Issue 1: biodiversity side-lined by plantation-dominated reforestation

Some plantations established under the Grain-for-Green Program in Sichuan

Magnolia-bark (*Magnolia officinalis*) plantation (mid elevations)



Japanese cedar (*Cryptomeria japonica*) plantation (mid-high elevations)

But does the above assumption stand?

Issue 1: placing biodiversity back into the “benefit space” of forest restoration

Do carbon, soil, water, and wood production services align or trade-off with biodiversity in the relative performance of plantations *versus* native forests?

Global synthesis of paired data, on matching plantations and native forests

5 metrics:

- Aboveground biomass (Mg ha^{-1})
- Soil erosion control (kg m^2 y^{-1})
- Water yield (% rainfall)
- Wood production yield (m^3 ha^{-1} y^{-1})
- Species-specific abundance (individuals ha^{-1})

Hua, Bruijnzeel, et al. 2022, Science

Issue 1: placing biodiversity back into the “benefit space” of forest restoration

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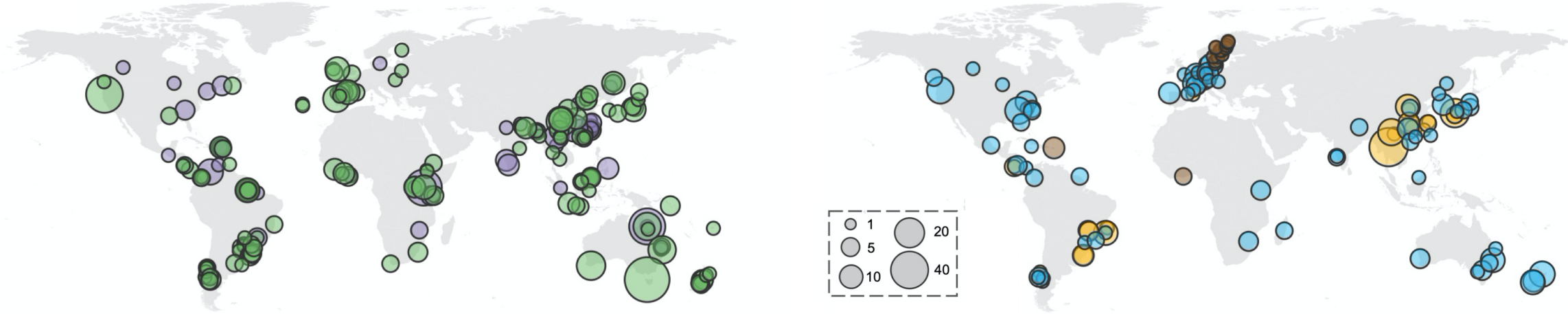


- Species-specific abundance (individuals ha^{-1})
- Aboveground biomass (Mg ha^{-1})
- Soil erosion control (kg m^2 y^{-1})
- Water yield (% rainfall)
- Wood production yield (m^3 ha^{-1} y^{-1})

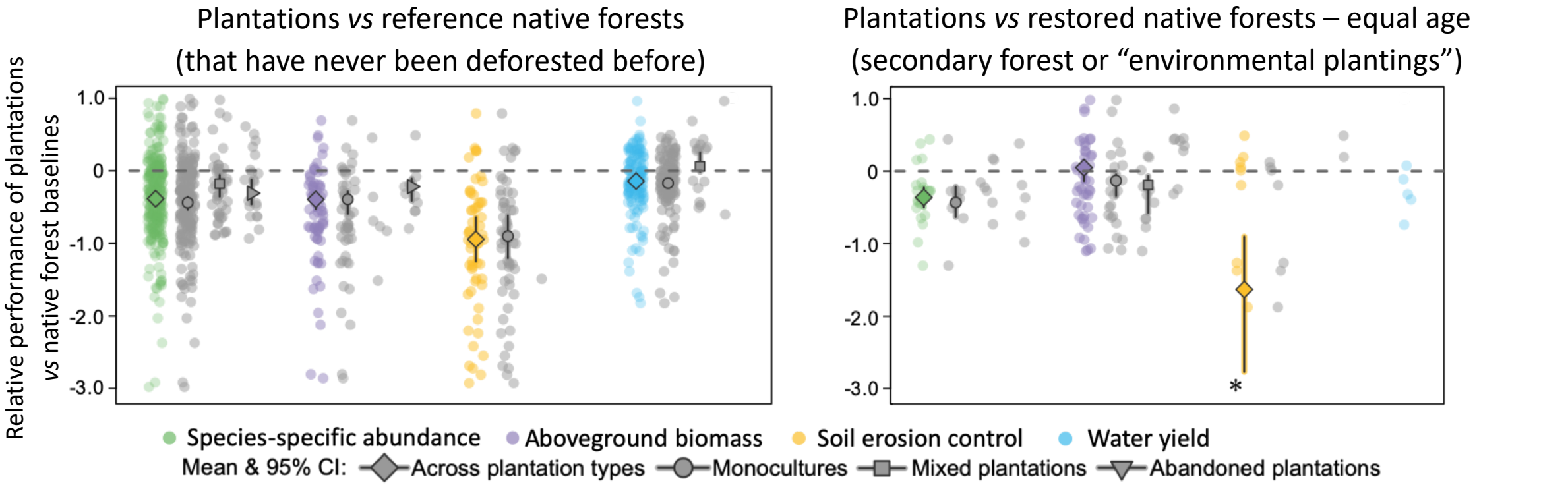
Database: 25,950 records from 264 studies in 53 countries

Hua, Bruijnzeel, et al. 2022, Science

Issue 1: placing biodiversity back into the "benefit space" of forest restoration

Do carbon, soil, water, and wood production services align or trade-off with biodiversity in the relative performance of plantations *versus* native forests?

Environmental services



- All environmental goals assessed: align with biodiversity in benefiting more from native forest restoration
- Soil erosion control: biggest "loser" environmental goal in plantation-dominated forest restoration

Hua, Bruijnzeel, et al. 2022, Science

Issue 1: placing biodiversity back into the "benefit space" of forest restoration

Do carbon, soil, water, and wood production services align or trade-off with biodiversity in the relative performance of plantations *versus* native forests?

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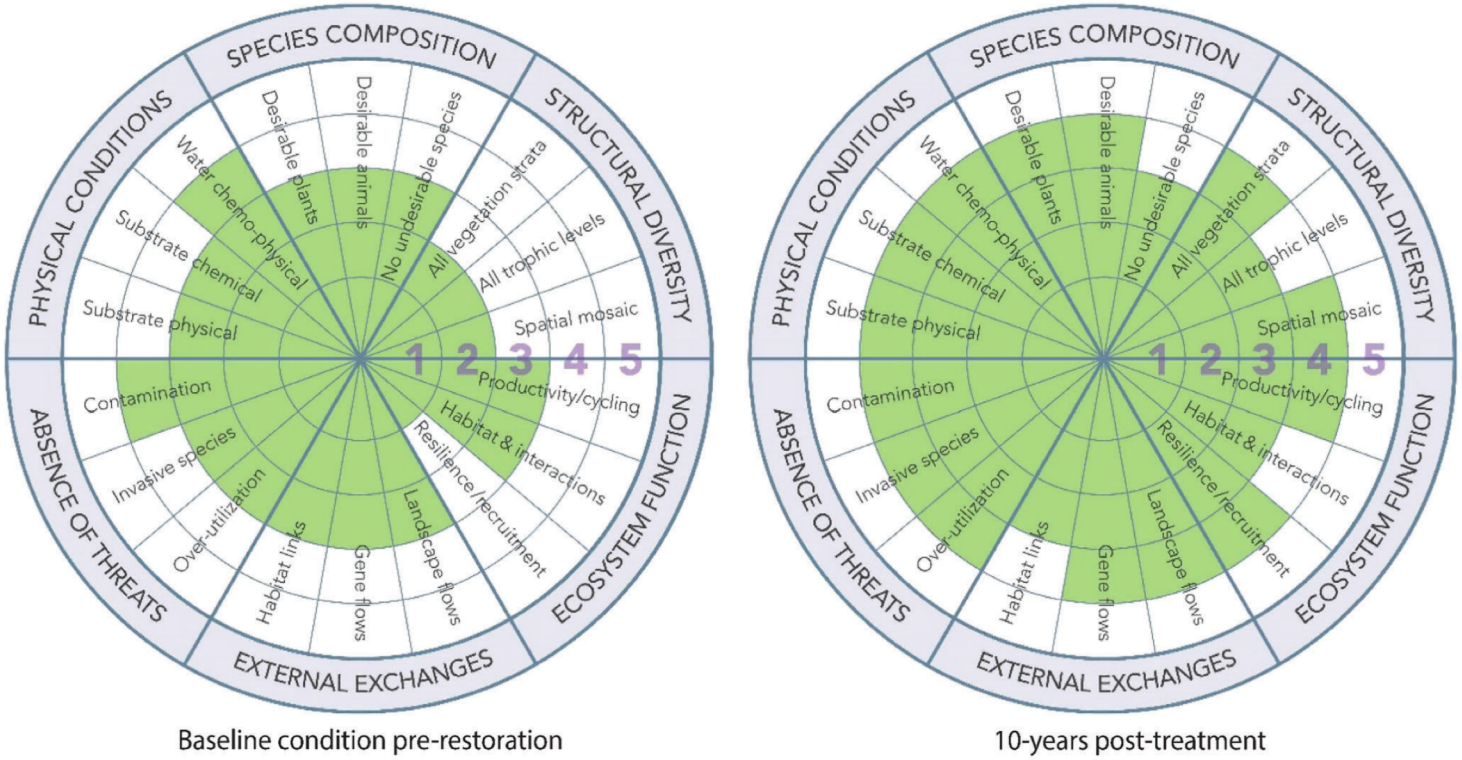

Baseline condition pre-restoration

10-years post-treatment

→

Synergies of a wide range of environmental outcomes with biodiversity

(Biodiversity–ecosystem functioning)

- All environmental goals assessed: align with biodiversity in benefiting more from native forest restoration
- Soil erosion control: biggest "loser" environmental goal in plantation-dominated forest restoration

Gann et al. 2019, SER International Standards

Issue 1: placing biodiversity back into the “benefit space” of forest restoration

Do carbon, soil, water, and wood production services align or trade-off with biodiversity in the relative performance of plantations *versus* native forests?

Environmental services

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Issue 1: placing biodiversity back into the “benefit space” of forest restoration

Do carbon, soil, water, and wood production services align or trade-off with biodiversity in the relative performance of plantations *versus* native forests?

Environmental services

→

Perverse biodiversity impacts should not have been there given the main goal on soil erosion control

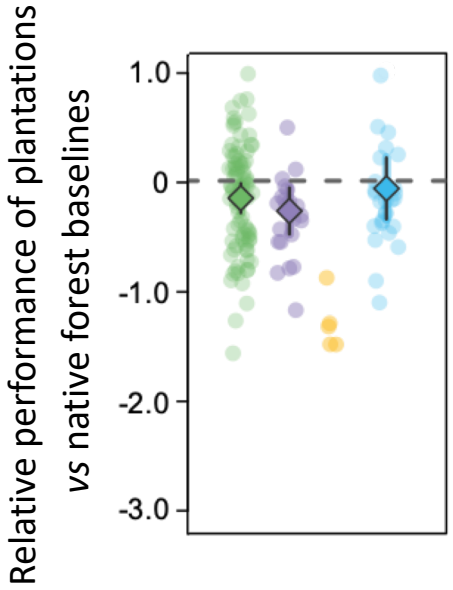
- All environmental goals assessed: align with biodiversity in benefiting more from native forest restoration
- Soil erosion control: biggest “loser” environmental goal in plantation-dominated forest restoration

Issue 1: placing biodiversity back into the "benefit space" of forest restoration

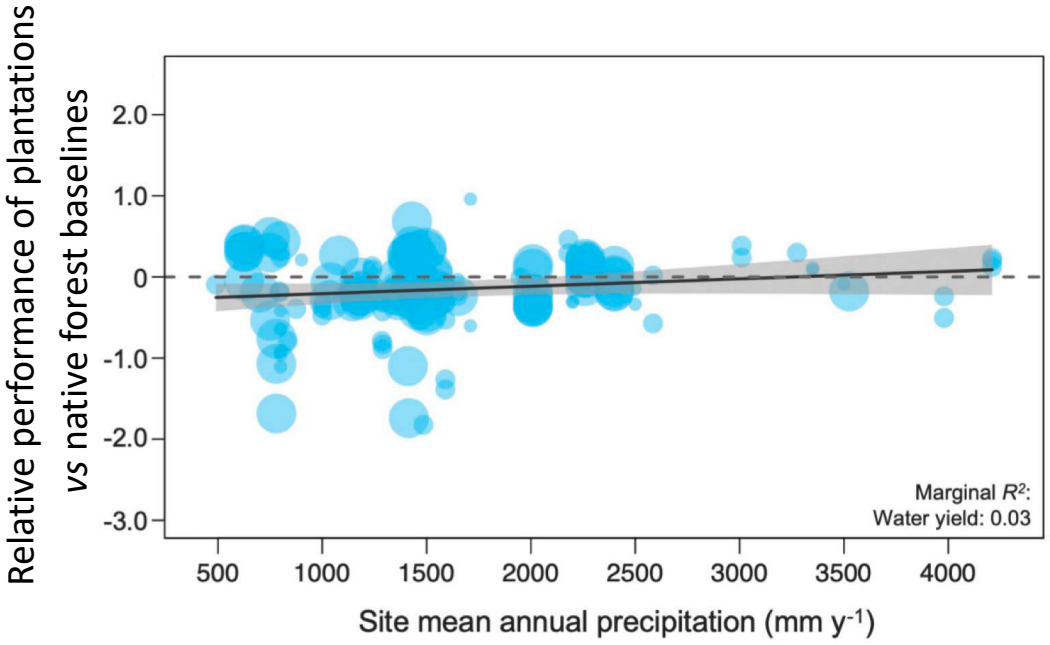
Do carbon, soil, water, and wood production services align or trade-off with biodiversity in the relative performance of plantations *versus* native forests?

Environmental services: some additional notes

Old/abandoned plantations *vs* reference native forests (that have never been deforested before)



Water provisioning shortfall of plantations *vs* reference native forests: related to site precipitation



- "Forgotten" plantations: should be restored to native conditions for greater environmental benefits
- Water provisioning: regions with greater water scarcity should particularly avoid relying on plantations

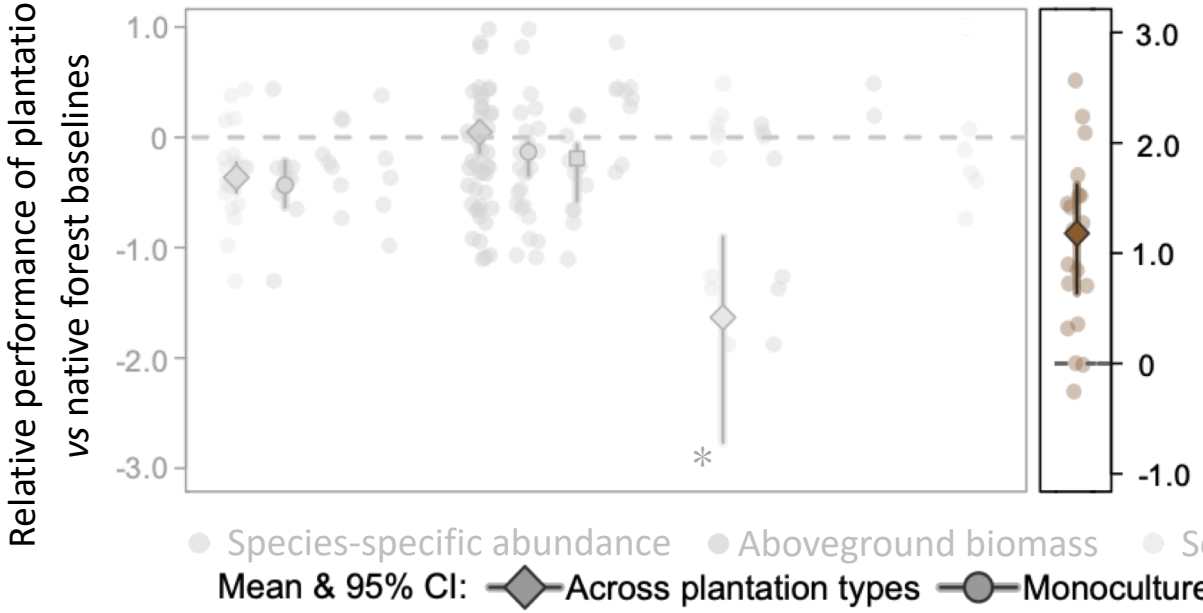
Hua, Bruijnzeel, et al. 2022, Science

Issue 1: placing biodiversity back into the "benefit space" of forest restoration

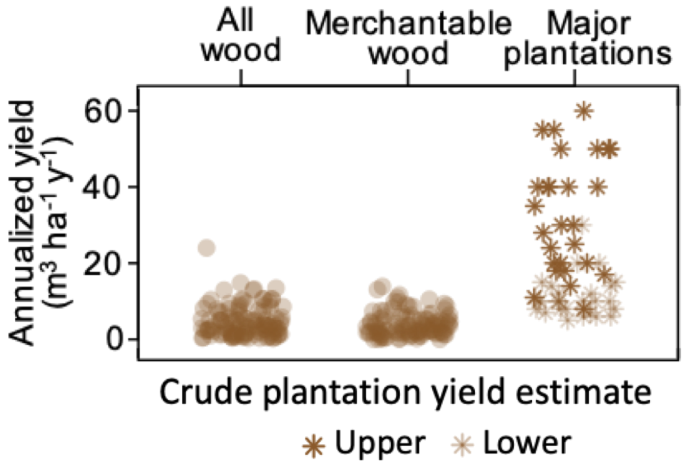
Do carbon, soil, water, and wood production services align or trade-off with biodiversity in the relative performance of plantations *versus* native forests?

The trade-off: wood production service

Plantations *vs* restored native forests – equal age (secondary forest or "environmental plantings")



(Non-paired data) Restored native forests *vs* major monoculture plantations



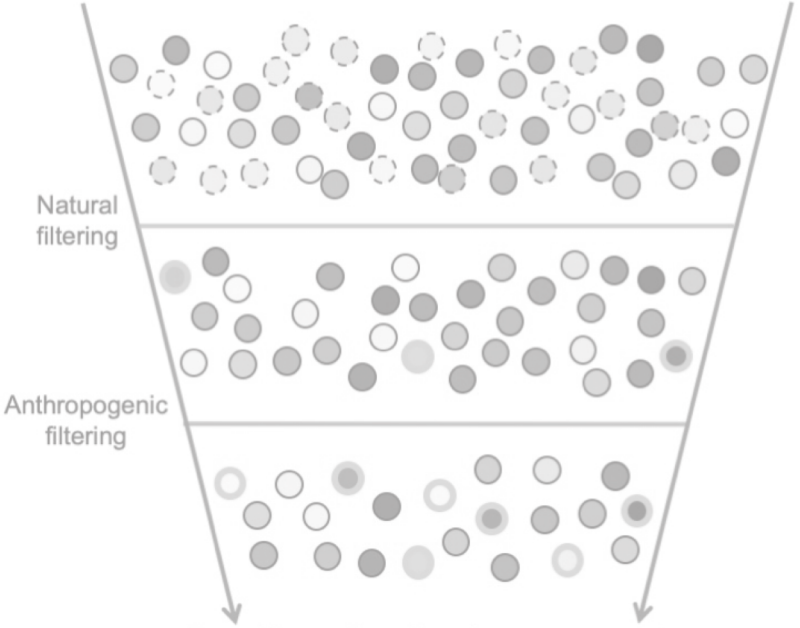
- Wood production: will benefit more from tree plantations over restored native forests
- **Inevitable trade-offs between environmental and production goals** → goal-appropriate restoration approaches

Hua, Bruijnzeel, et al. 2022, Science

Issue 2: trade-offs among restoration goals and implications for restoration planning

What type of forest to restore

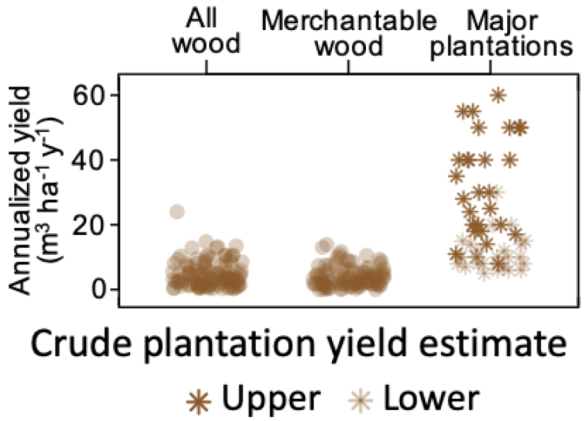
Spatial scale of restoration planning



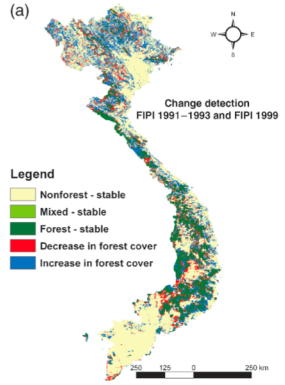
What biodiversity to benefit

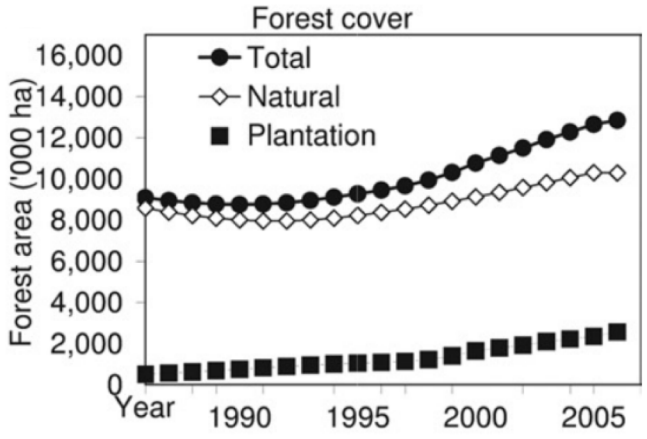
Issue 2: trade-offs among restoration goals and implications for restoration planning

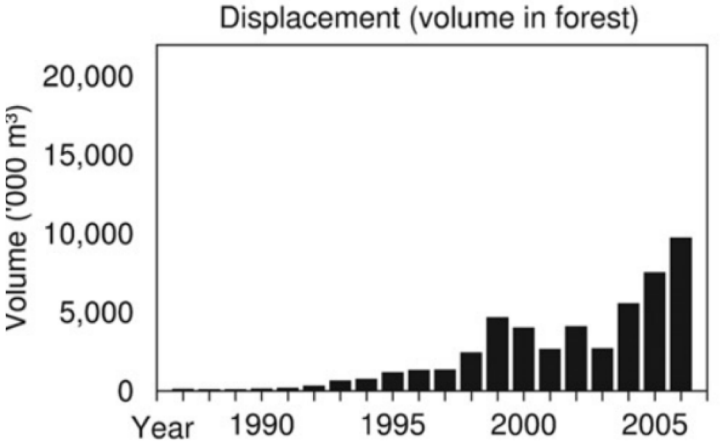
The potential "sparing" effect of tree plantations

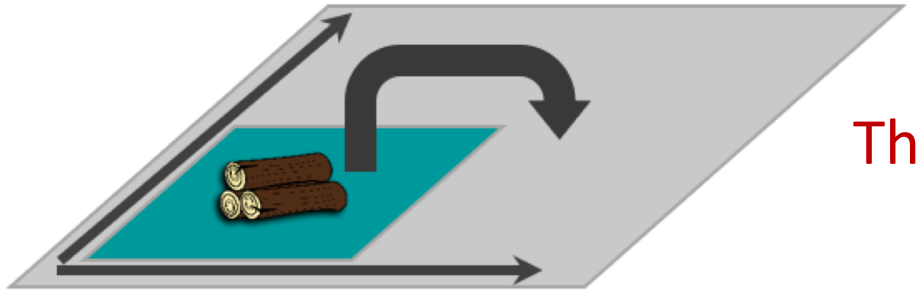


The "leakage" impacts of displaced land use: the case of Vietnam's forest recovery









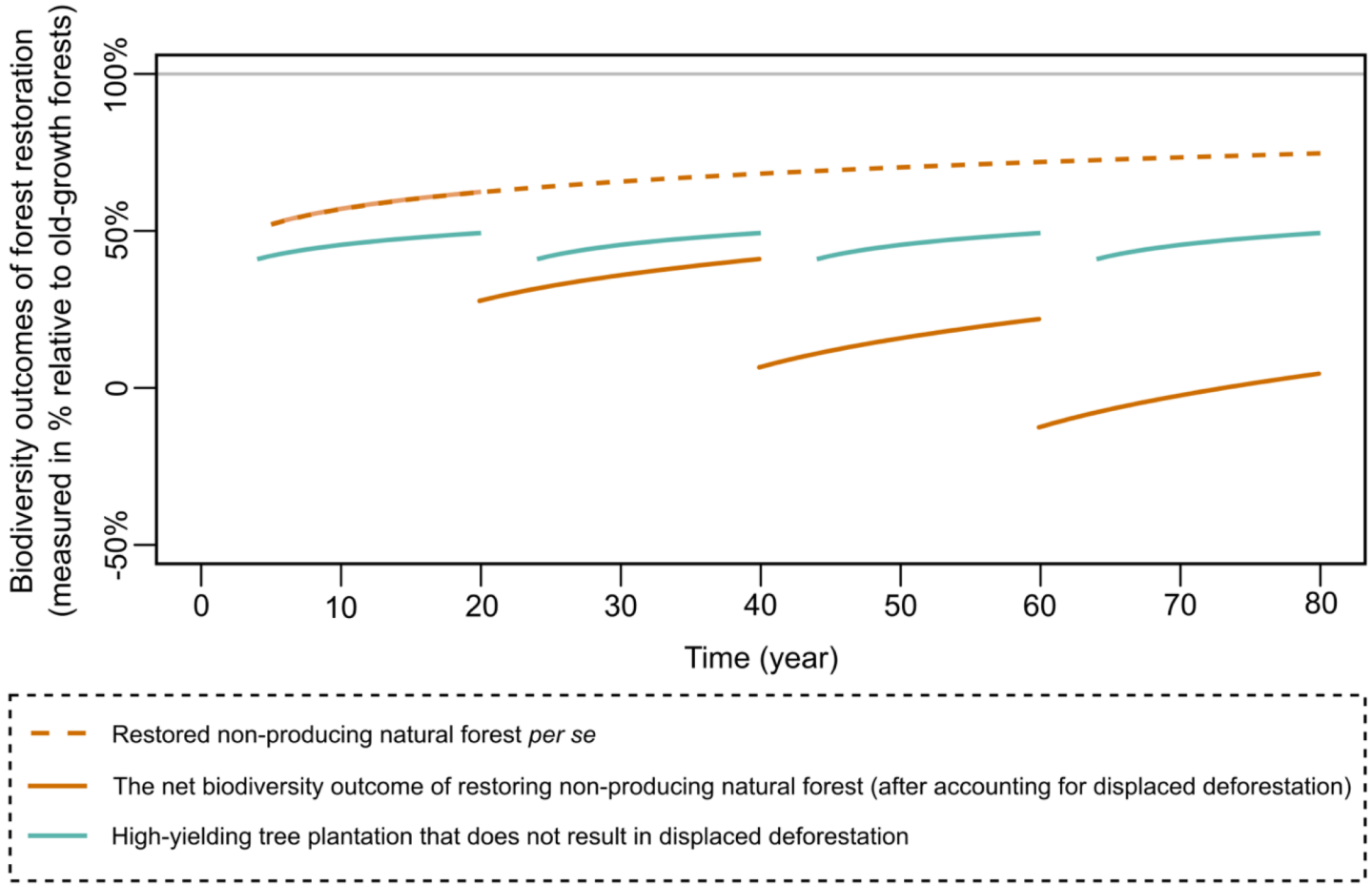
The offsite impacts of forest restoration

The long time scale of forest restoration

Cited from: Meyfroidt and Lambin 2008, Global Change Biology; Meyfroidt and Lambin 2009, PNAS

Issue 2: trade-offs among restoration goals and implications for restoration planning

The offsite impacts of forest restoration (with long time scale)

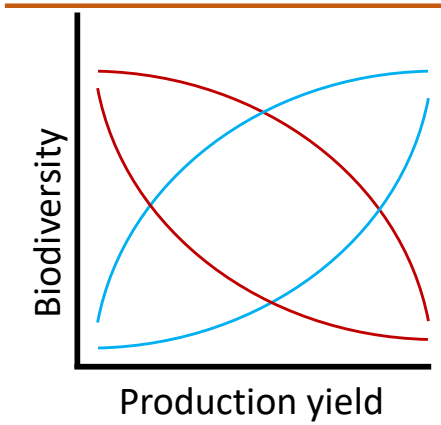


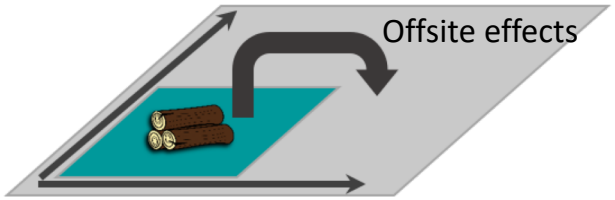
The "net effects" of forest restoration: must be measured – and managed – on a large enough spatial scale that includes related land *not* under restoration

Liu et al., under review

Issue 2: trade-offs among restoration goals and implications for restoration planning

Key: accounting for both onsite and offsite effects of forest restoration



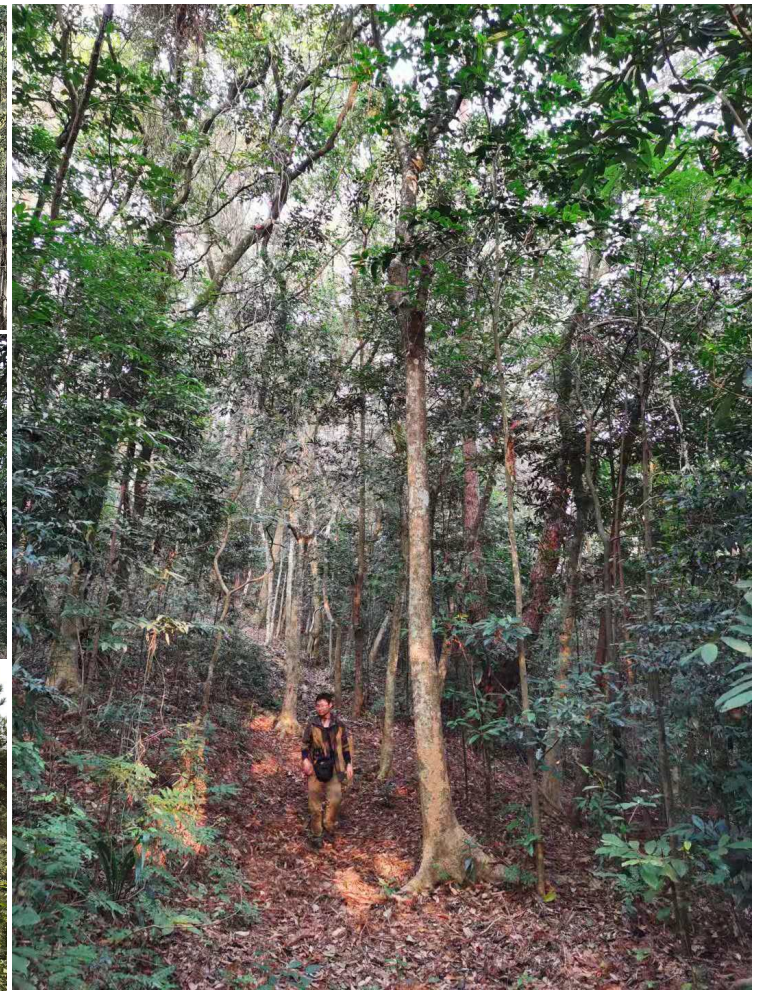


- China's most important wood production region (~50% of domestic volume)
- Fast-growing *Eucalyptus*, *Pinus*, and *Cunninghamia* plantations
- In early stages of rolling out monoculture diversification efforts
- Forest restoration has been happening under Grain-for-Green

Given the hard demand of wood production, how should we design land use pertaining to forest restoration (land allocation among protected areas, restored native forests, and different plantations)?

Issue 2: trade-offs among restoration goals and implications for restoration planning

Ecological insights for “optimal” land use design: understanding the trade-off relationship across a range of production/restoration regimes within the same study system



- *Eucalyptus* monoculture (high yielding, short cycle)
- *Eucalyptus*–native mixed culture (longer cycle)
- Restored native forest (with production potential)
- Mature native forest inside reserves (not for production)

Field survey of bird and bee communities, carbon storage, and wood production yield

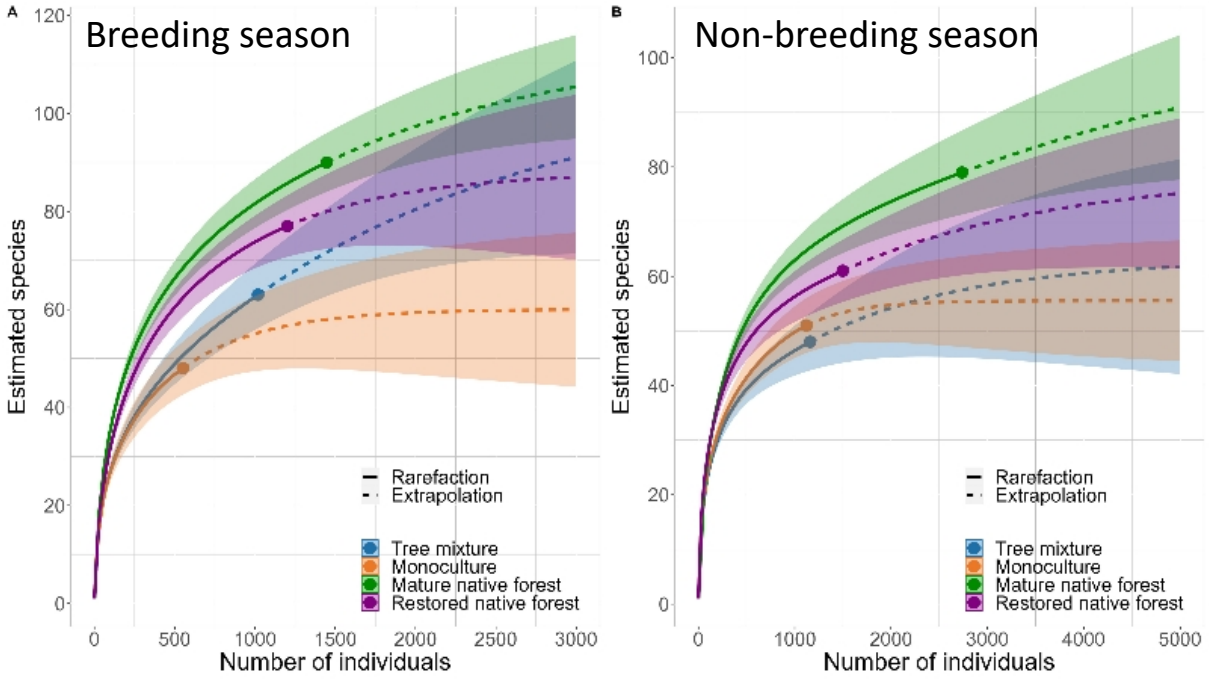
Jiang et al. 2023, Forest Ecology and Management

Issue 2: trade-offs among restoration goals and implications for restoration planning

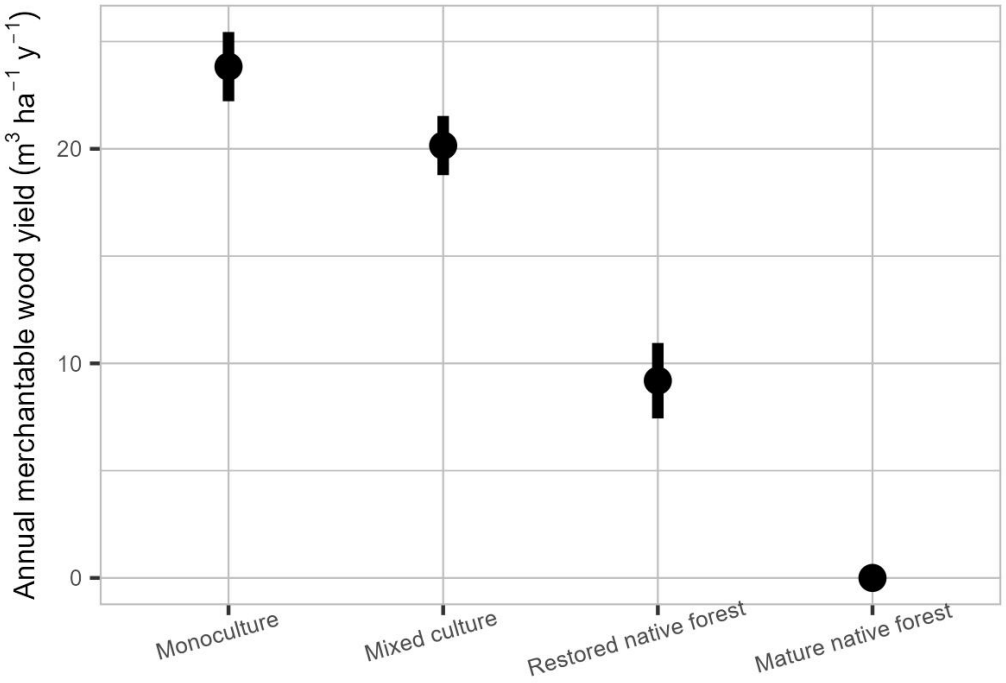
Ecological insights for “optimal” land use design: understanding the trade-off relationship across a range of production/restoration regimes within the same study system

Early findings

Limited avian diversity benefit of mixed culture and (young) restored native forest over monoculture



Yield penalty of mixed culture and restored native forest



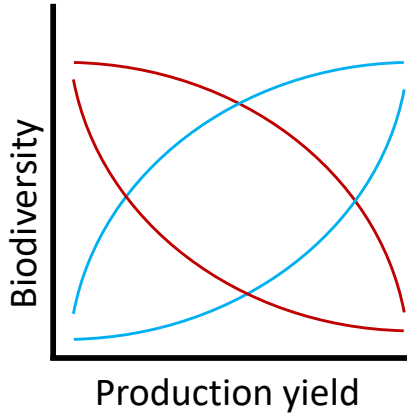
Jiang et al. 2023, Forest Ecology and Management

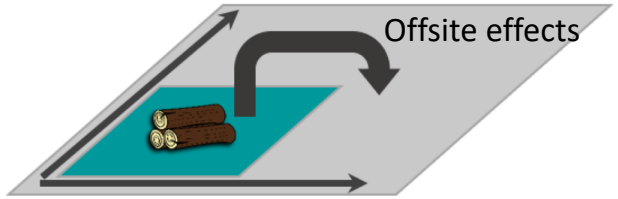
Issue 2: trade-offs among restoration goals and implications for restoration planning

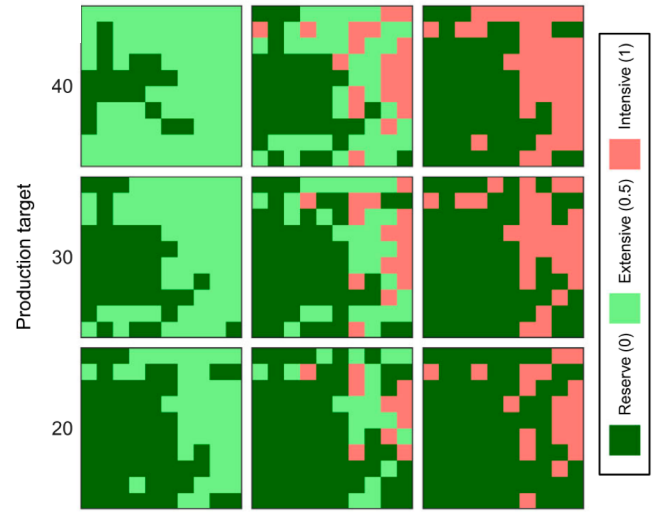
Ecological insights for “optimal” land use design: understanding the trade-off relationship across a range of production/restoration regimes within the same study system

Next steps

- Quantify the (trade-off) relationship between biodiversity and per-unit-area wood yield
- Land-use scenario modelling to identify “optimal” land-use allocation for the region
- Offsite impacts should consider potential long-range impacts as well (*e.g.* international trade)





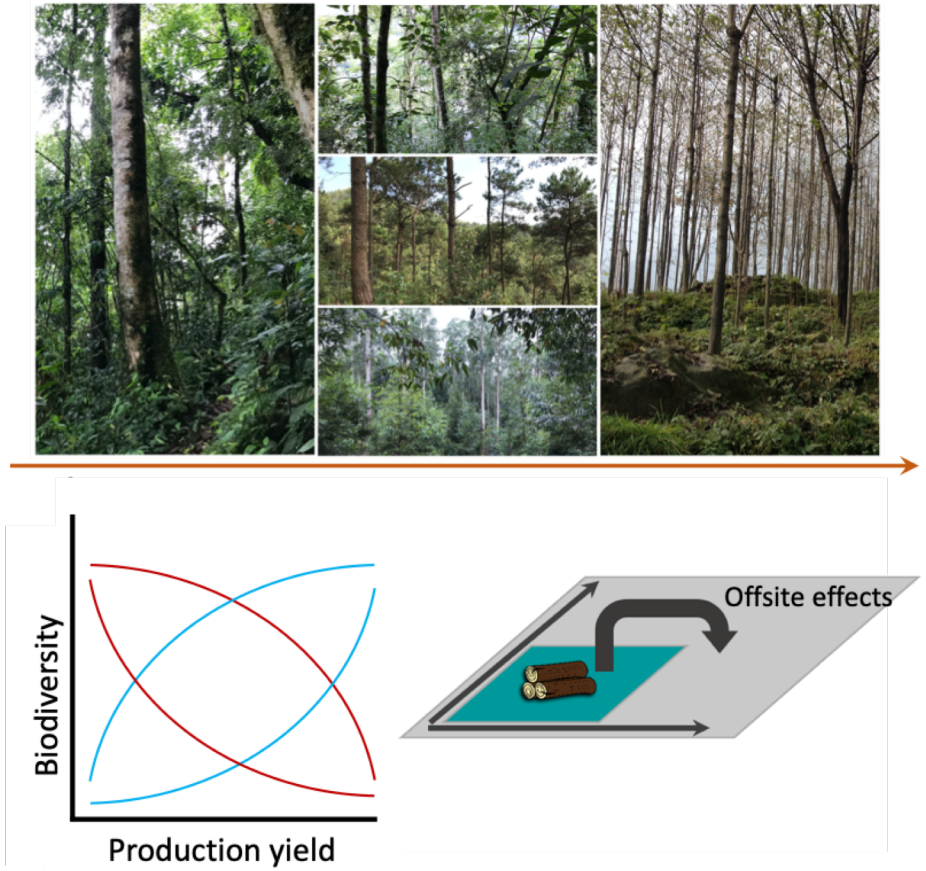


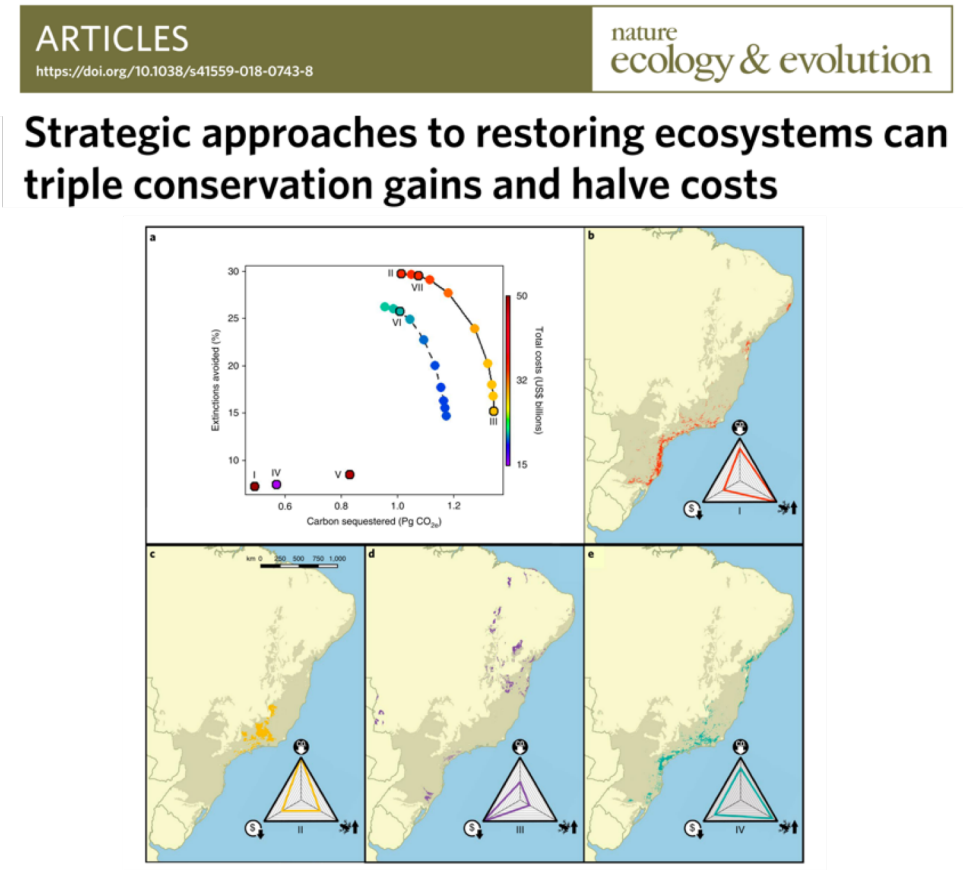
Our early findings signal that production-oriented monoculture diversification and native forest restoration may not be a beneficial approach from a biodiversity perspective

Cited from: Betts et al. 2021, Biological Reviews

Issue 2: trade-offs among restoration goals and implications for restoration planning

A further note on methodological needs





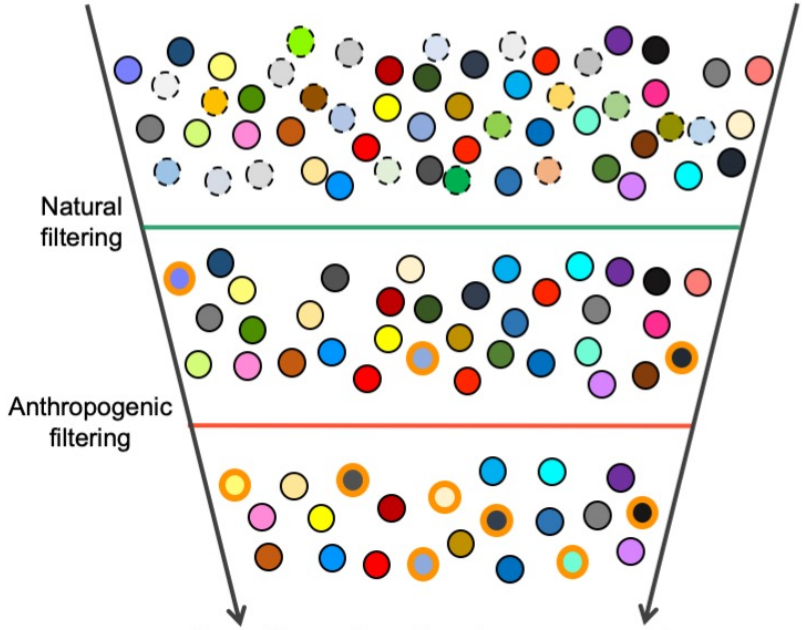
Needed: spatially-explicit assessment of the outcome across a spectrum of restoration approaches and other land uses (including conservation)

Cited from: Strassburg et al. 2019, Nature Ecology & Evolution

Issue 3: not all biodiversity can equally benefit from (any form of) forest restoration

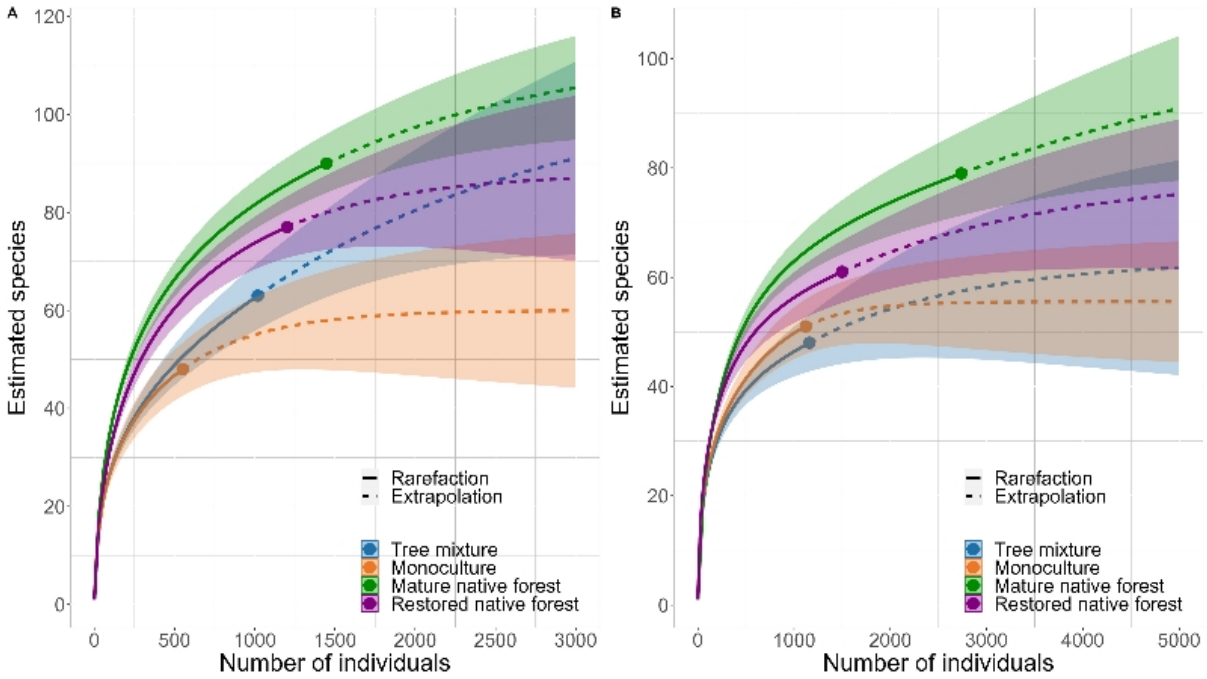
What type of forest to restore

Spatial scale of restoration planning



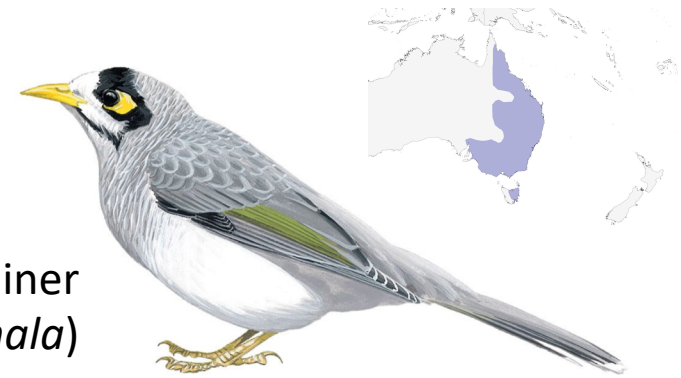
What biodiversity to benefit

Issue 3: not all biodiversity can equally benefit from (any form of) forest restoration



©Chris Rose

Paradise riflebird
(*Ptiloris paradiseus*)



©Tim Worfolk

Noisy miner
(*Manorina melanocephala*)

- Species differ in their habitat needs and conservation importance
- These two aspects are typically related: species more dependent on intact habitats tend to also be of greater conservation concern

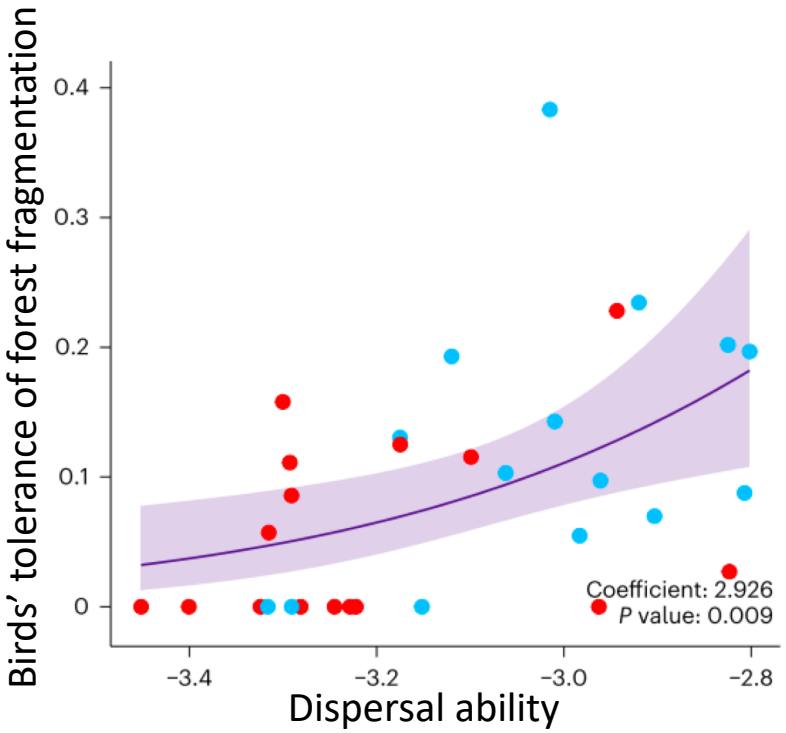
Cited from: Birds of the World

Issue 3: not all biodiversity can equally benefit from (any form of) forest restoration

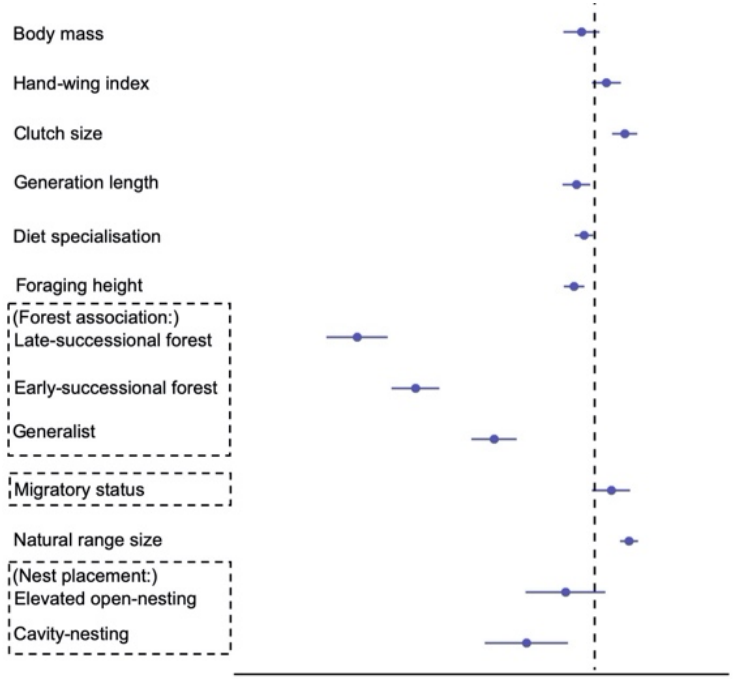
For a given ecosystem, there tends to be a subset of "loser" species sensitive to forest loss or degradation, and that are unlikely to benefit from forest restoration unless it restores large expanses of mature forest

Birds' tolerance of forest loss and degradation

Fragmentation

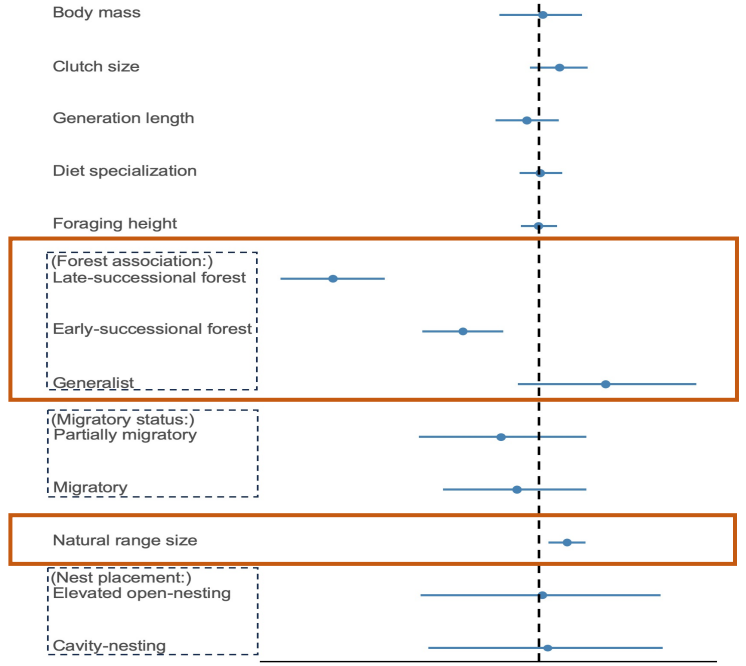


Deforestation (to agriculture)



Birds' tolerance of deforestation

Degradation to secondary forest



Birds' tolerance of forest degradation

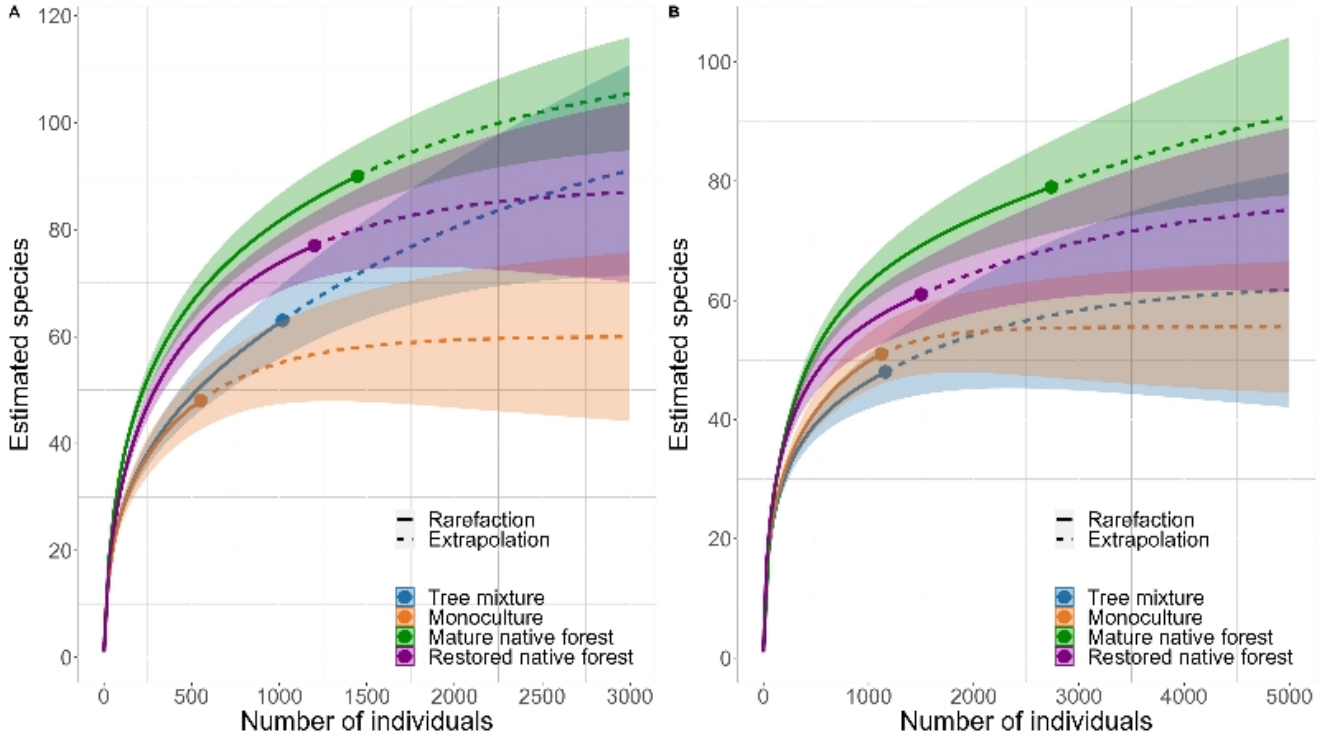
Specie's "vulnerability profile": winners and losers

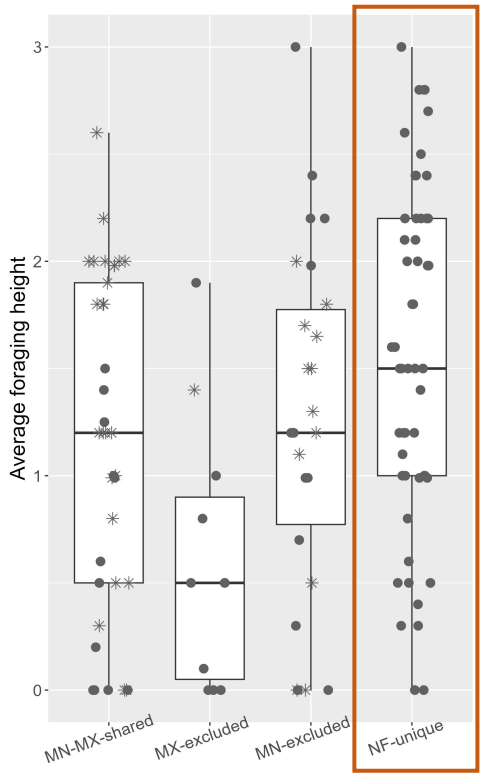
Hua, Wang, et al. accepted, Nature Ecology & Evolution
Cited from: Weeks et al. 2023, Nature Ecology & Evolution

Issue 3: not all biodiversity can equally benefit from (any form of) forest restoration

Reconceptualizing some restoration approaches presumed beneficial for biodiversity: losing-out of “loser” species

Mixed-culture plantations





The Guangxi equivalent of:

Paradise riflebird (*Ptiloris paradiseus*)

©Chris Rose

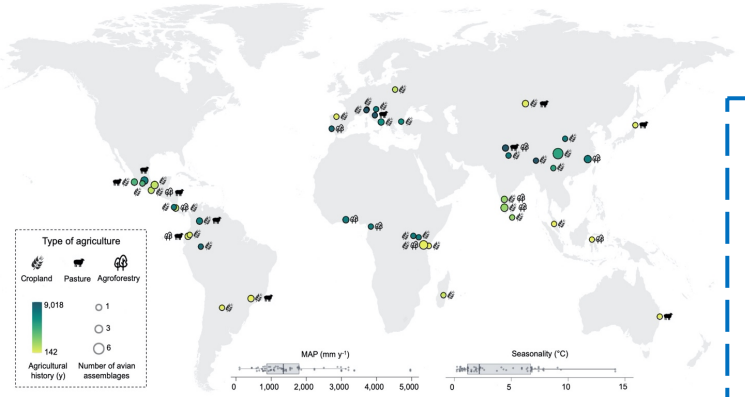
Noisy miner (*Manorina melanocephala*)

©Tim Worfolk

Jiang et al. 2023, Forest Ecology and Management

Issue 3: not all biodiversity can equally benefit from (any form of) forest restoration

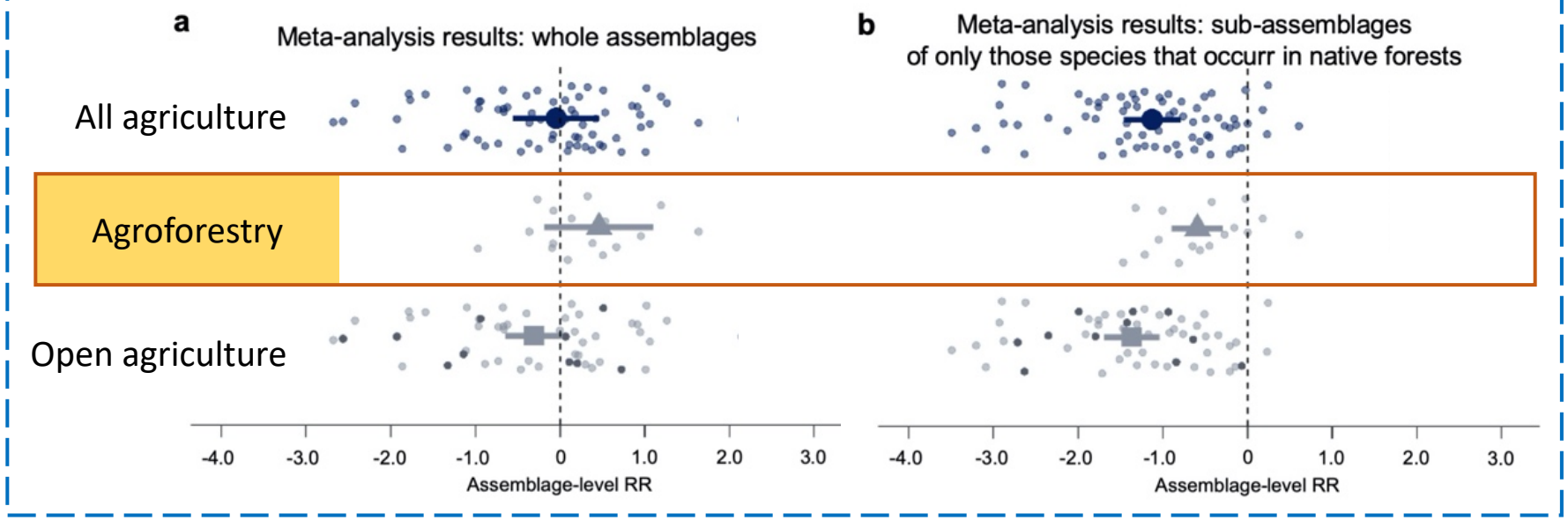
Reconceptualizing some restoration approaches presumed beneficial for biodiversity: losing-out of “loser” species

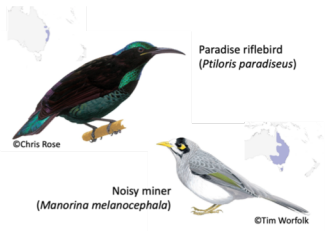


Species abundance response: $RR_i = ln\frac{\lambda_{i,\,agriculture}}{\lambda_{i,\,forest}}$

$$RR_{assemblage} = \frac{\sum_{i=1}^{i=n} RR_i}{n}$$

Agroforestry





Hua, Wang, et al. accepted, Nature Ecology & Evolution

Issue 3: not all biodiversity can equally benefit from (any form of) forest restoration

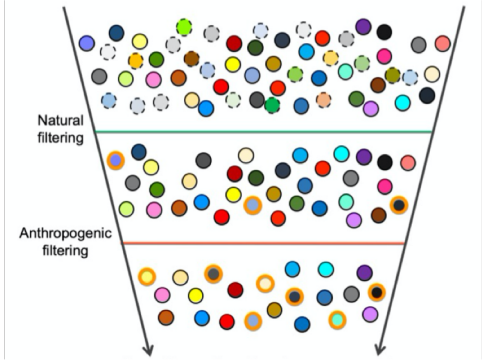
Reconceptualizing some restoration approaches presumed beneficial for biodiversity: losing-out of “loser” species

- Mixed-culture plantations and agroforestry do bring biodiversity benefits over monocultures and “open” agriculture (*i.e.* more simplified agricultural landscapes)
- But the benefits they bring mostly concern ”generalist” species that are at least somewhat adapted to human-modified landscapes – and that are usually less of conservation concern
- Restoration design should make room for the restoration of large, connected, mature forest ecosystems

Some issues important to ensuring the biodiversity benefit of forest restoration

What type of forest to restore

Spatial scale of restoration planning



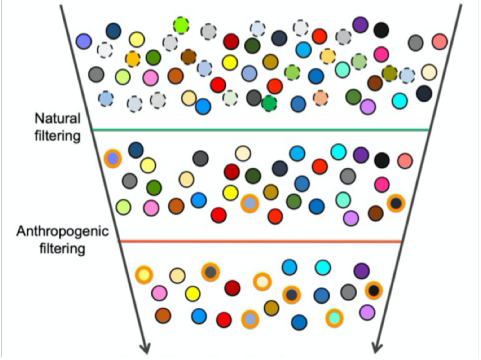
What biodiversity to benefit

- Goal-appropriate restoration approach
- The environmental argument for – and imperative of – greater focus on native ecosystems
- Planning should be done on large spatial scales – to accommodate and address potential offsite impacts – in concerto with conservation and management of other land uses
- Planning should also accommodate the need of ”loser” species: the need for the restoration of large, connected, mature forest ecosystems (yet more reason for integrating conservation of existing ecosystems)

Some issues important to ensuring the biodiversity benefit of forest restoration

What type of forest to restore

Spatial scale of restoration planning

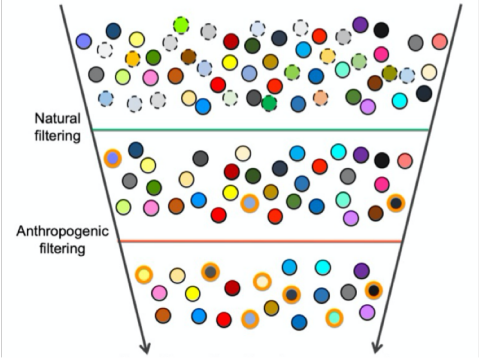


What biodiversity to benefit

Some issues important to ensuring the biodiversity benefit of forest restoration

What type of forest to restore

Spatial scale of restoration planning



What biodiversity to benefit

The critical importance of:

Science, traditional and indigenous knowledge, standards/guidelines

Thank you!

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