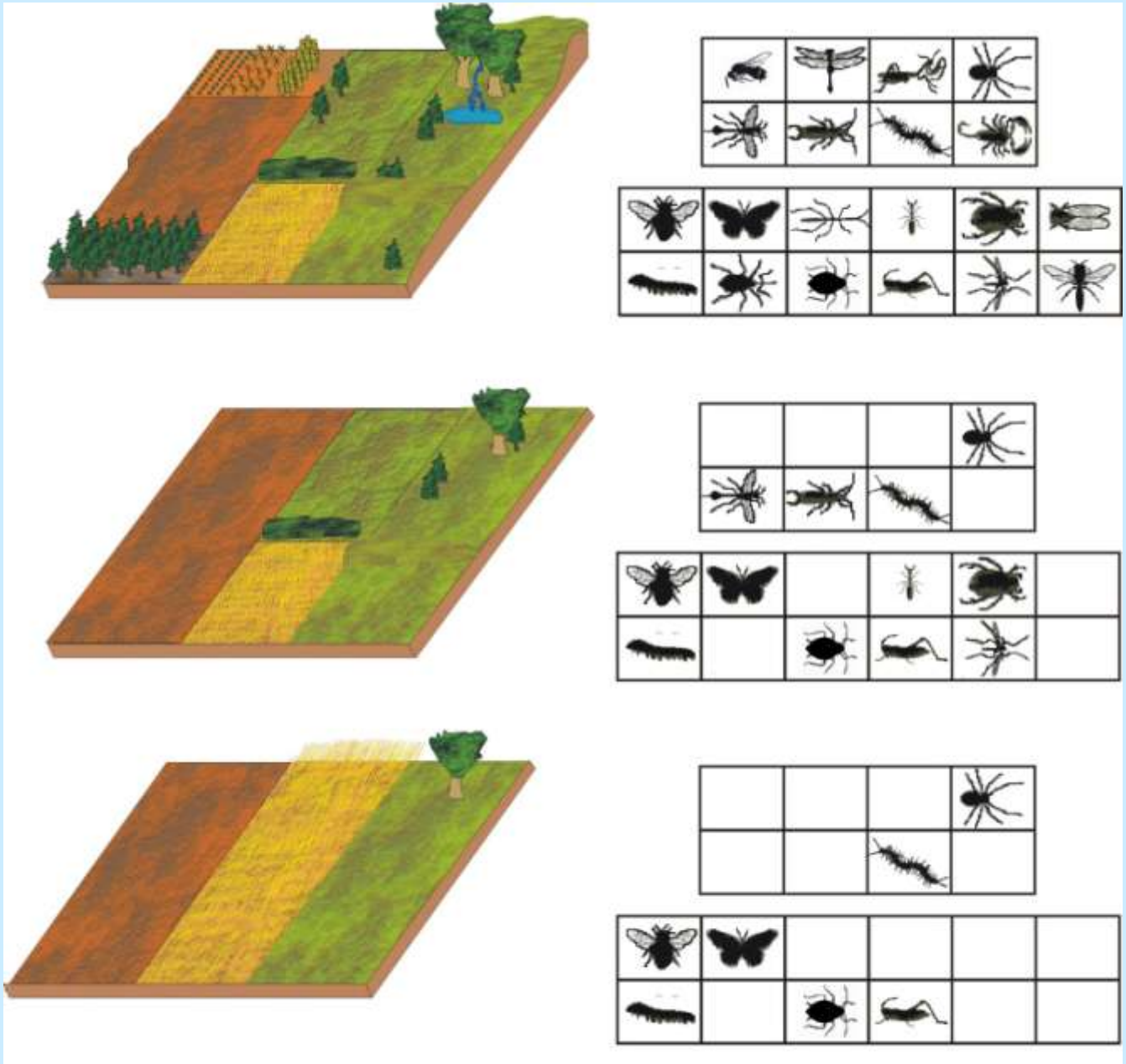
Conservation of biodiversity and associated services in agricultural landscapes

Teja Tscharntke
Agroecology, University of Göttingen, Germany

Future of Butterflies in Europe III
Wageningen 29-31 March 2012

Agriculturally driven Global Change



Tscharntke et al. 2007,
in: Stewart et al., CABI Publ

Tscharntke et al. 2005,
Ecol Letters

How on earth can agriculture contribute to biodiversity conservation?

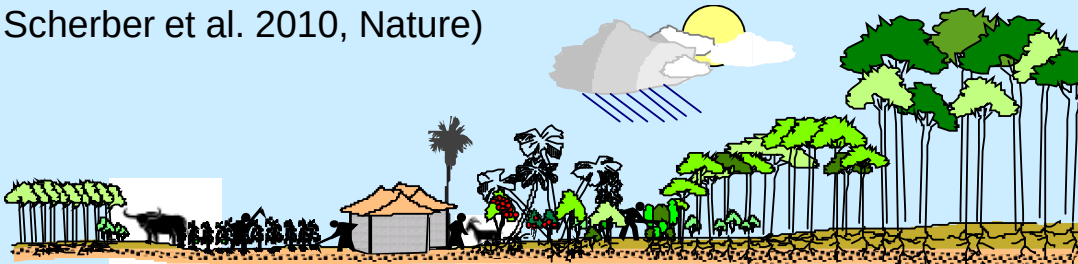
(1) Agricultural land = 40% of terrestrial area
(protected reserves = 12%) (Perfecto & Vandermeer 2010, PNAS)

(2) Spillover across managed and natural systems mitigating extinction risks (species as 'mobile links')
(Rand et al. 2006, Ecol Letters; Bianchi et al. 2006, Proc Roy Soc London B)

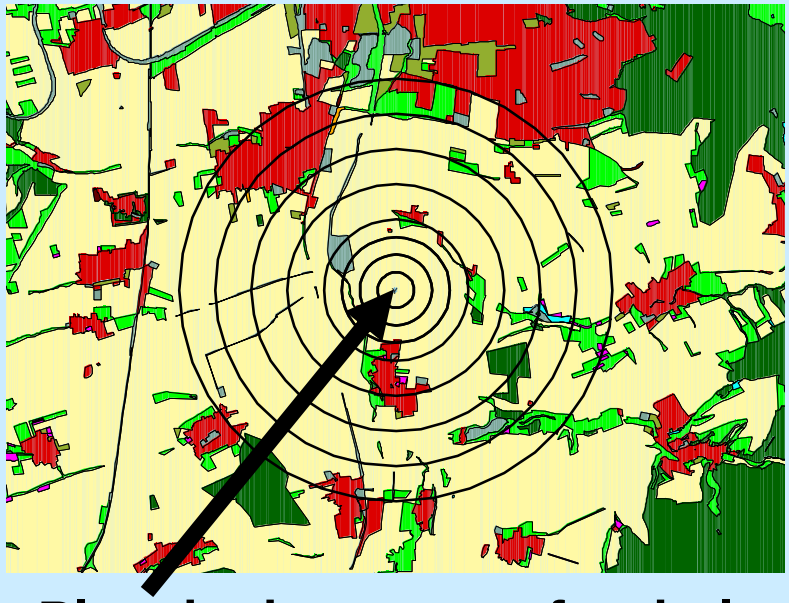
(3) Agroecosystems can support high biodiversity
(Clough et al. 2011, PNAS; Steffan-Dewenter & Tscharntke 2002, Biol Conserv)

(4) Agroecosystems provide more food resources
(Westphal et al 2003, Ecol Letters; Holzschuh et al. 2011, Proc Roy Soc B)

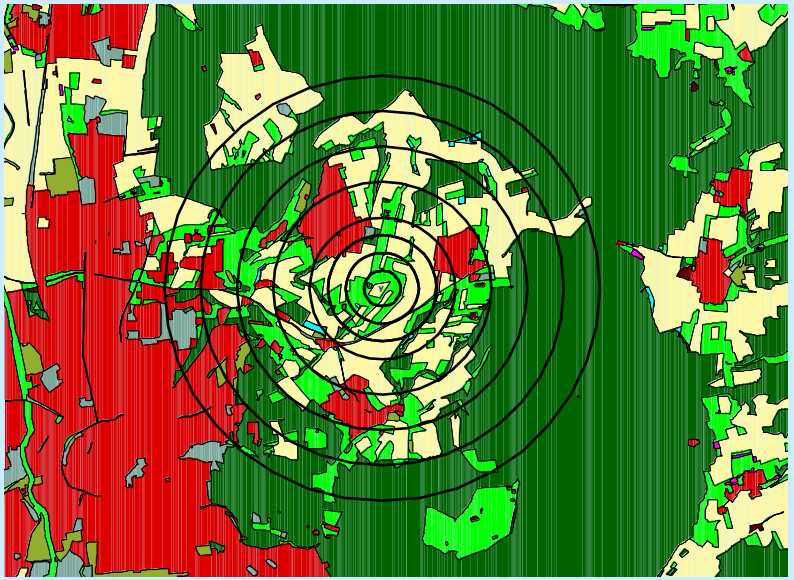
(5) Agroecosystem functioning needs biodiversity
(Cardinale et al. 2006, Nature; Scherber et al. 2010, Nature)

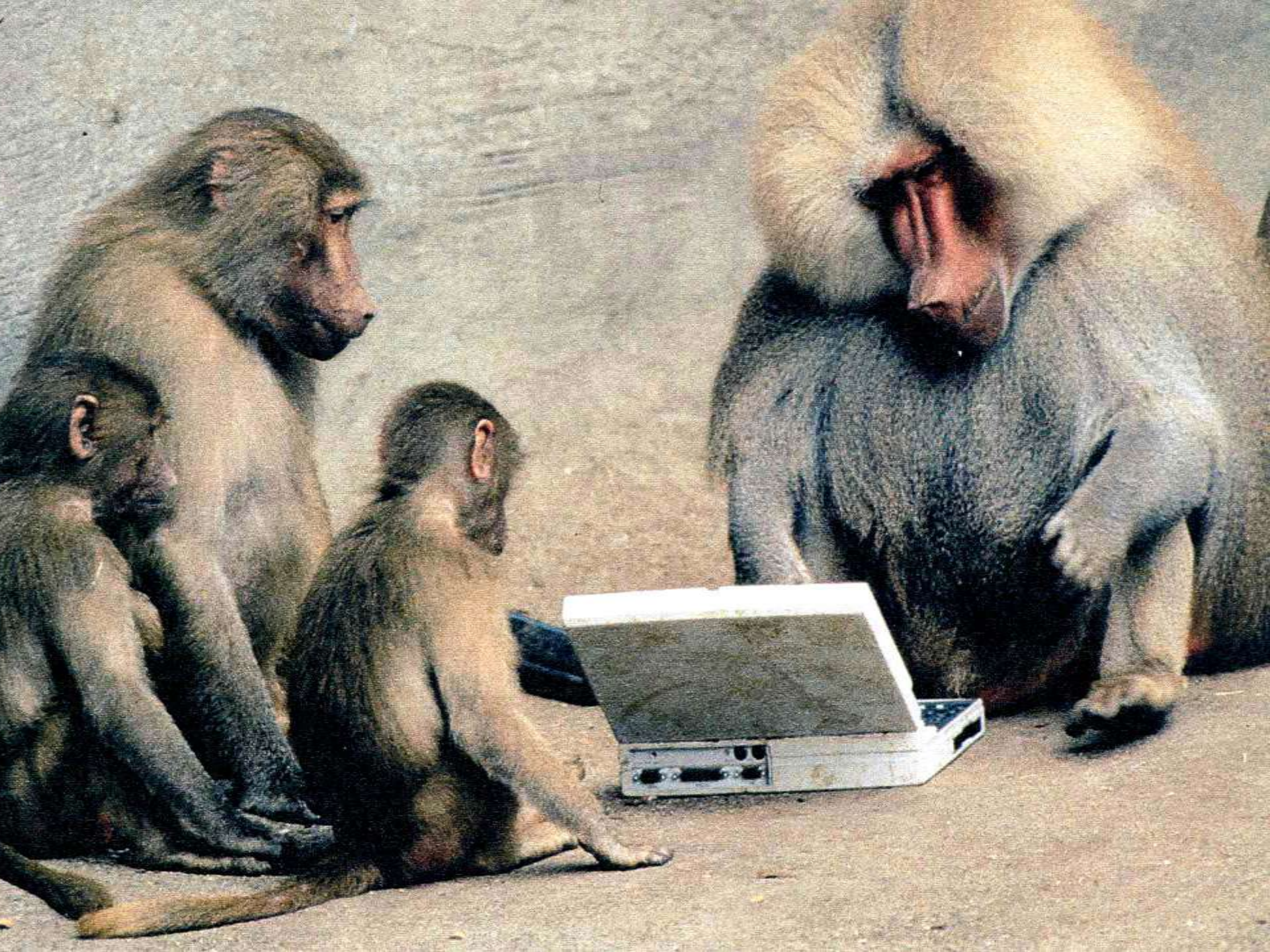


Simple landscapes (>90% annual crops)
Complex landscapes (>50% noncrop area)

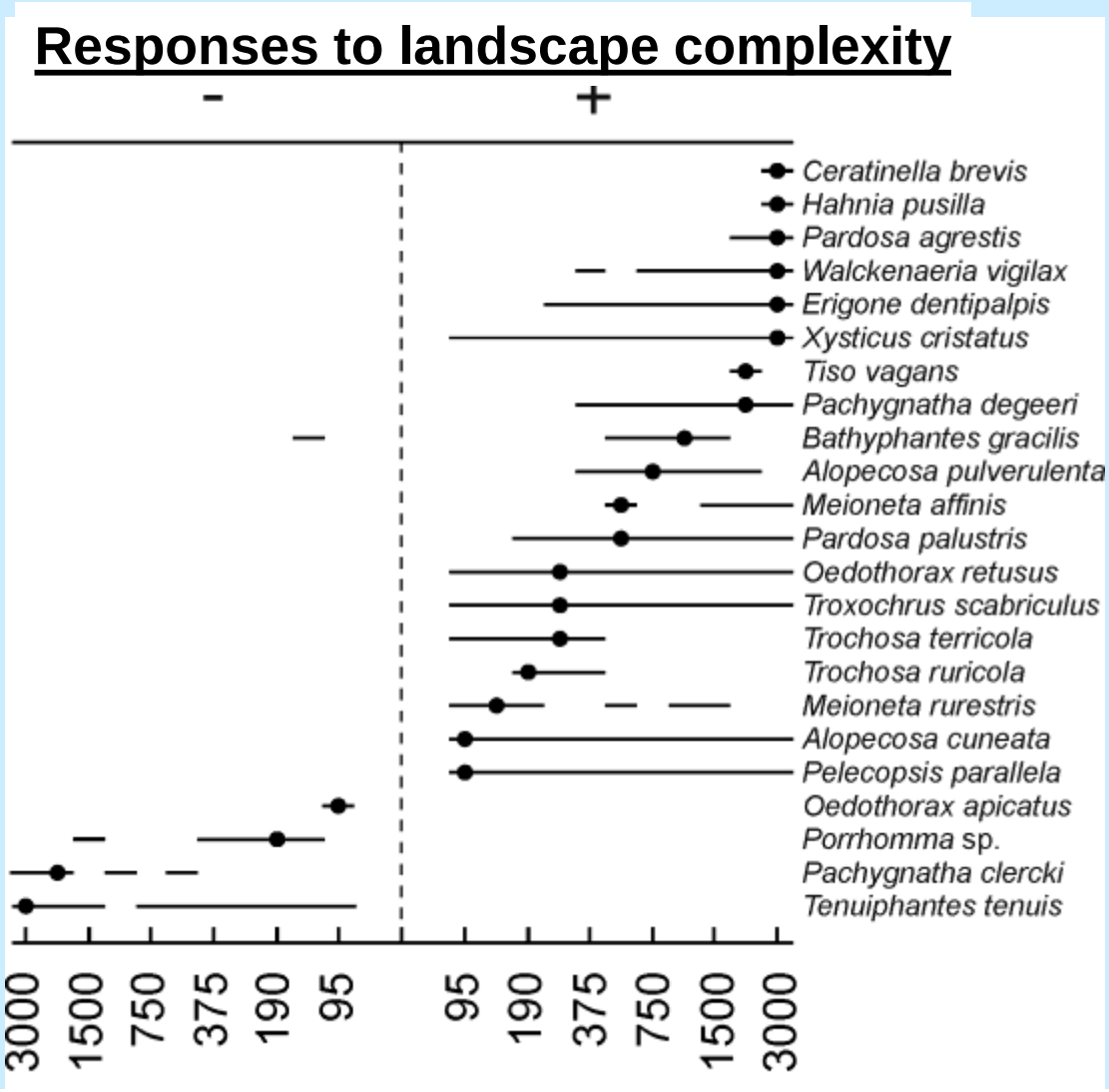


Plots in the centre of a circle





Species-specific functional spatial scales



Arable spiders
In wheat fields

Martin Schmidt
et al. 2008, J Biogeogr

Spatial scale = radius of landscape circle (m)

(best relations of % noncrop area to local spider density)

The dominance of beta diversity hypothesis

Dissimilarity of local communities

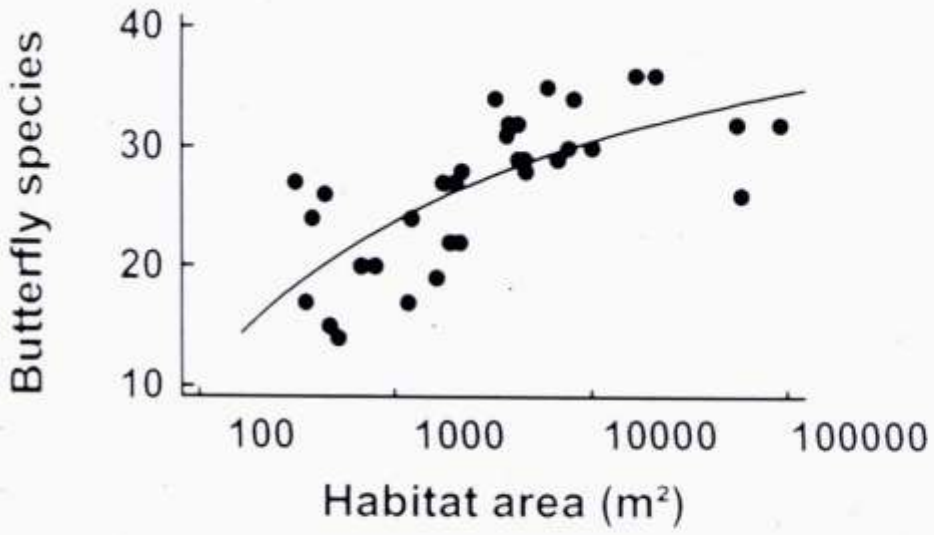
determines landscape-wide biodiversity

much more than

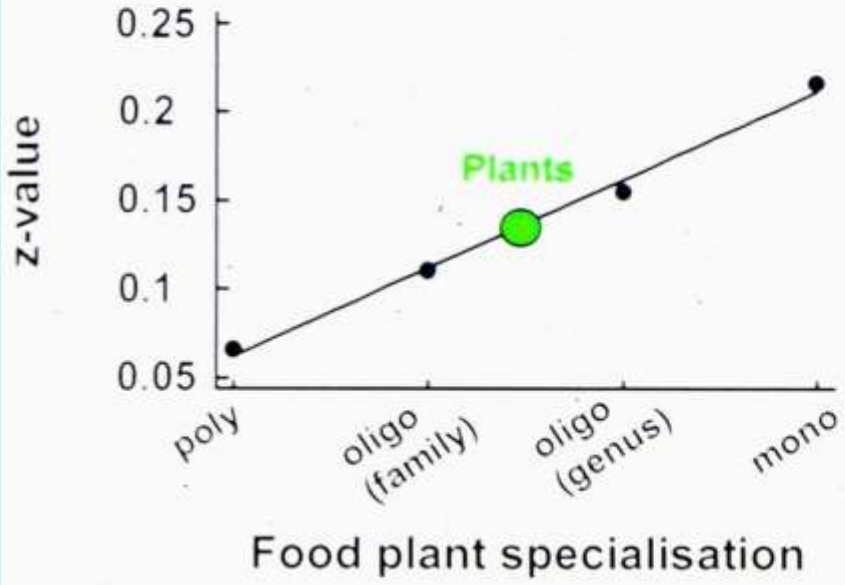
the fragmentation level of habitat

Tscharntke et al. 2012, Biol Reviews

The dominance of beta diversity hypothesis

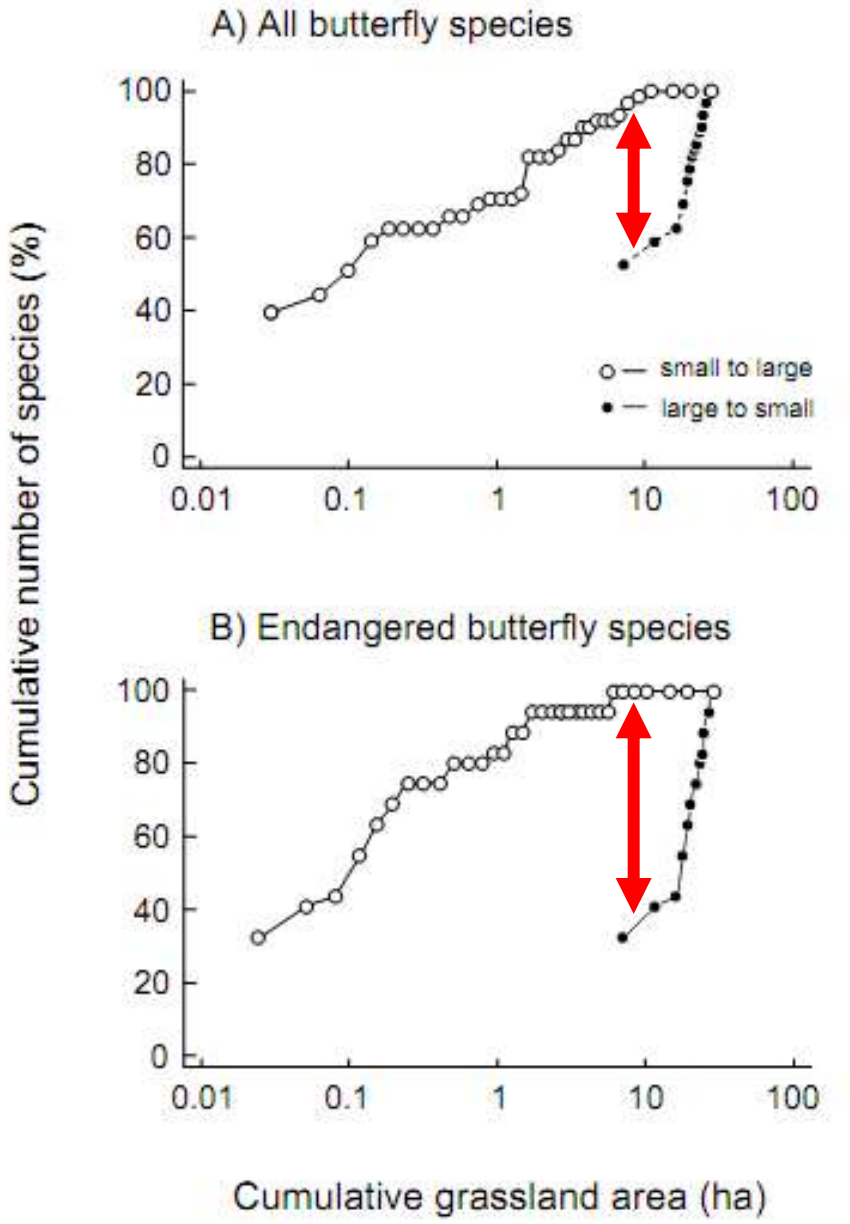


Butterflies on calcareous grasslands



Ingolf Steffan-Dewenter & Tscharntke 2000, Ecol Letters

The dominance of beta diversity hypothesis



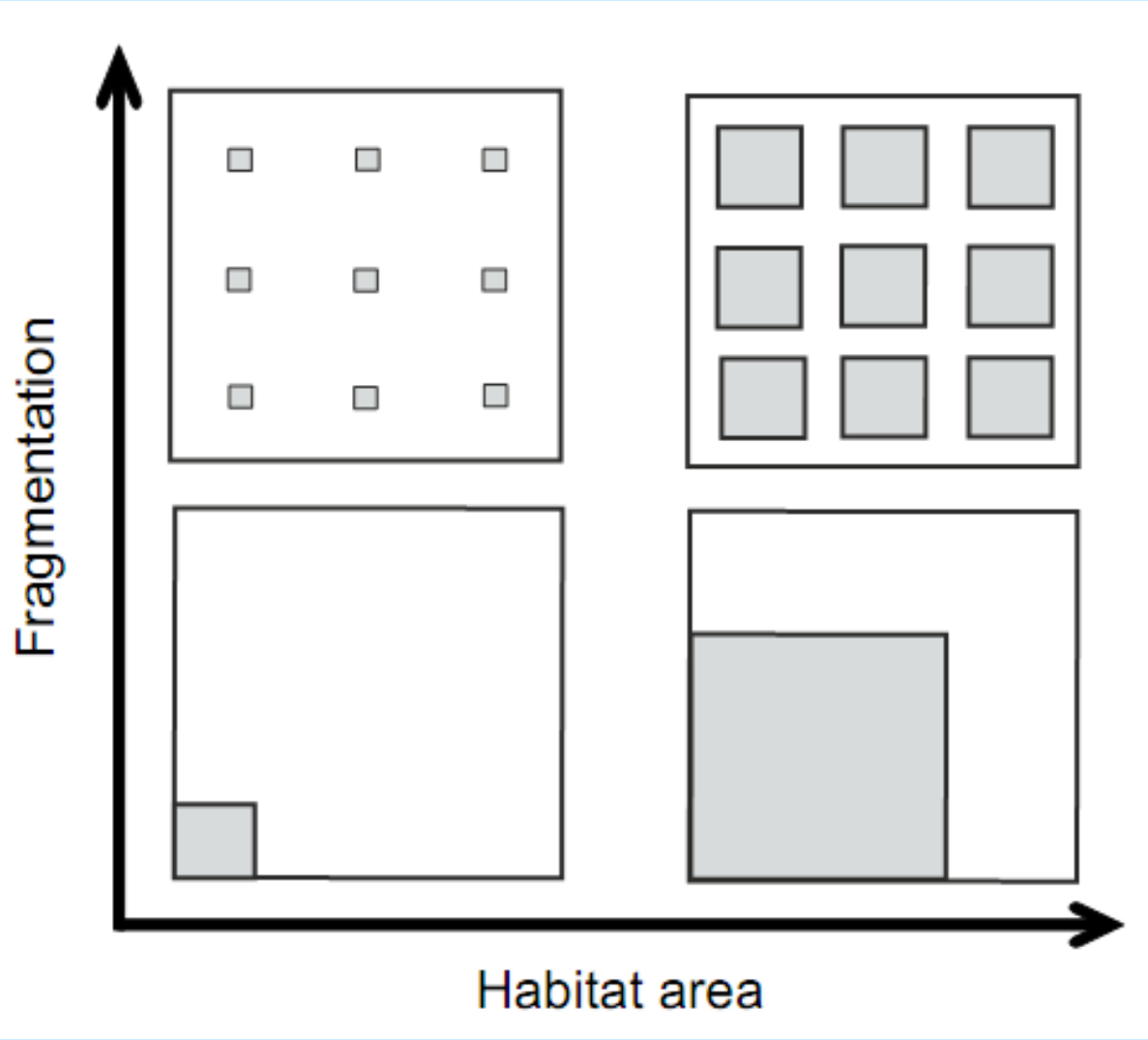
The SLOSS debate

Many small habitats capture more heterogeneity determining biodiversity

Intermediate fragmentation strategy (large & small Fragments)

Tscharntke et al. 2002, Ecol Appl
(33 grassland fragments, 61 butterfly species)

The dominance of beta diversity hypothesis



In real landscapes of a given extent:
having many fragments = usually spread over larger distances

Tscharntke et al. 2012, Biol Reviews

The dominance of beta diversity hypothesis

Experimental exposure of standardized nests
for bees, wasps and their parasitoids
(Tscharntke et al. 1998, J Appl Ecol)

The dominance of beta diversity hypothesis

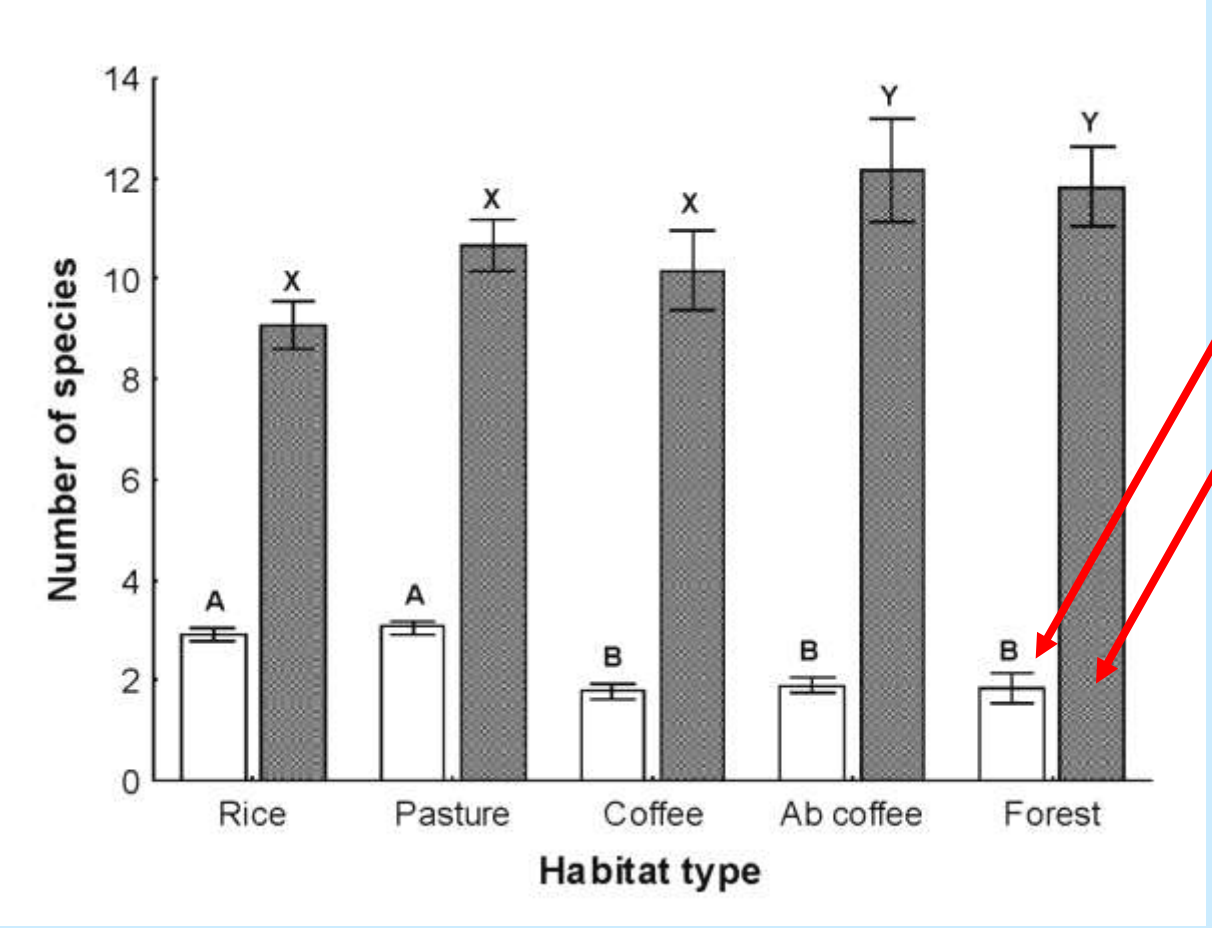
Gradient of increasing land-use intensification in coastal Ecuador

Highly replicated study
48 quantitative host-parasitoid food webs

Jason Tylianakis et al. 2005, Ecology; Tylianaklis et al. 2007, Nature

The dominance of beta diversity hypothesis

Land-use intensification gradient in coastal Ecuador
Additive partitioning of cavity-nesting bee and wasp diversity



Alpha diversity (9 nests/site)

Beta diversity (12 months) monthly turnover

Jason Tylianakis et al. 2005, Ecology

The intermediate landscape-complexity hypothesis

Effectiveness of conservation management

is highest in structurally simple,

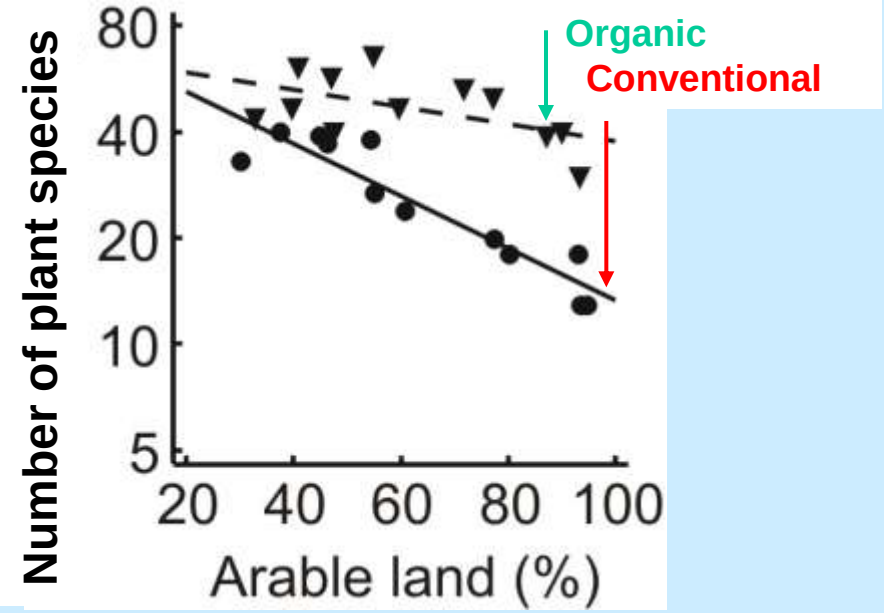
rather than in cleared (i.e. extremely simplified)

or in complex landscapes.

Tscharntke et al. 2012, Biol Reviews

Local vs. landscape management

on plant, bee and bird diversity



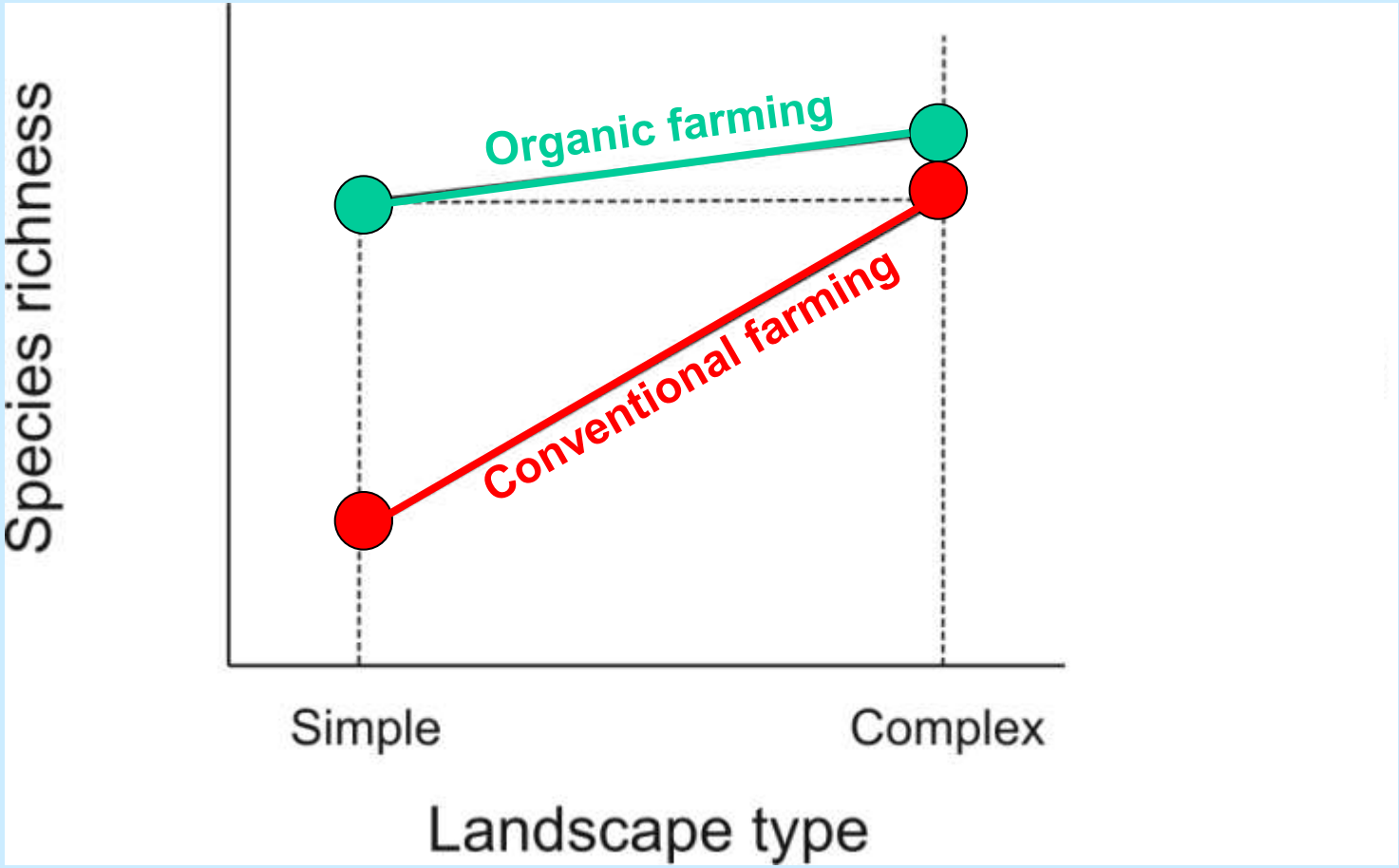
Plants: Indra Roschewitz et al. 2005, J Appl Ecol
Doreen Gabriel et al. 2006, Ecol Appl

Bees: Andrea Holzschuh et al. 2007, J Appl Ecol

- Organic vs. conventional winter wheat
- paired farms per landscape (Ø 2km)
- Birds: hedge length most important

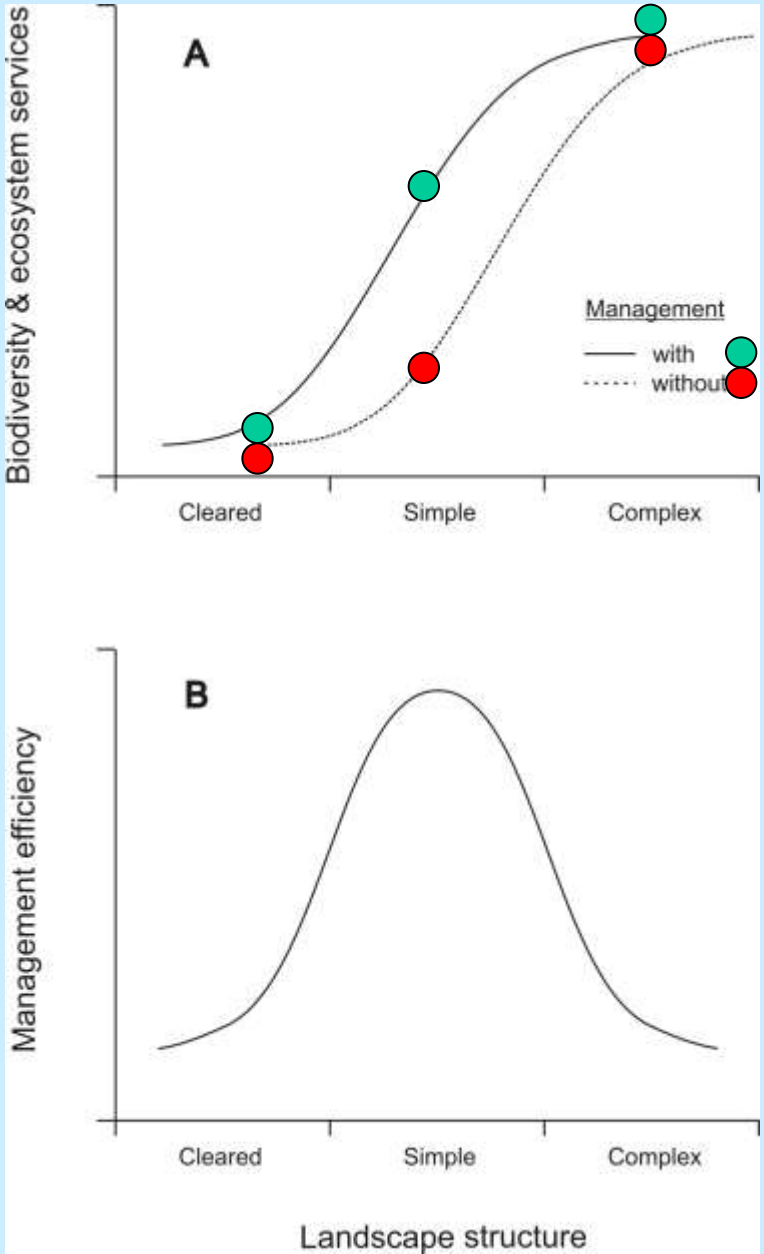
Birds Peter Batary et al. 2010 Biol Conserv

Compensation of local land-use intensity by landscape complexity



Tscharntke et al. 2005, Ecol Letters; Batary et al. 2010, Proc Roy Soc B

The intermediate landscape-complexity hypothesis



In simple landscapes, effectiveness of agri-environment management is highest (biodiversity, pest control)

Tscharntke et al. 2005, Ecol Letters
Tscharntke et al. 2012, Biol Reviews

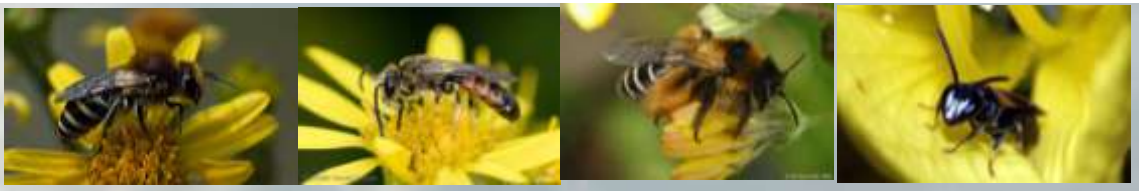
The landscape-moderated concentration and dilution hypothesis

Spatio-temporal changes in landscape composition

can cause transient concentration or dilution of populations.

Tscharntke et al. 2012, Biol Reviews

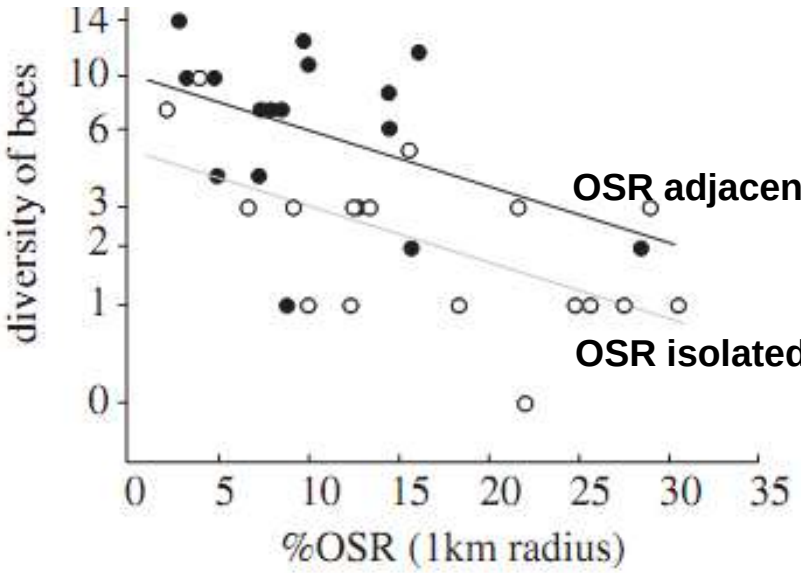
Enhancement but transient dilution of wild bee populations in oilseed rape landscapes



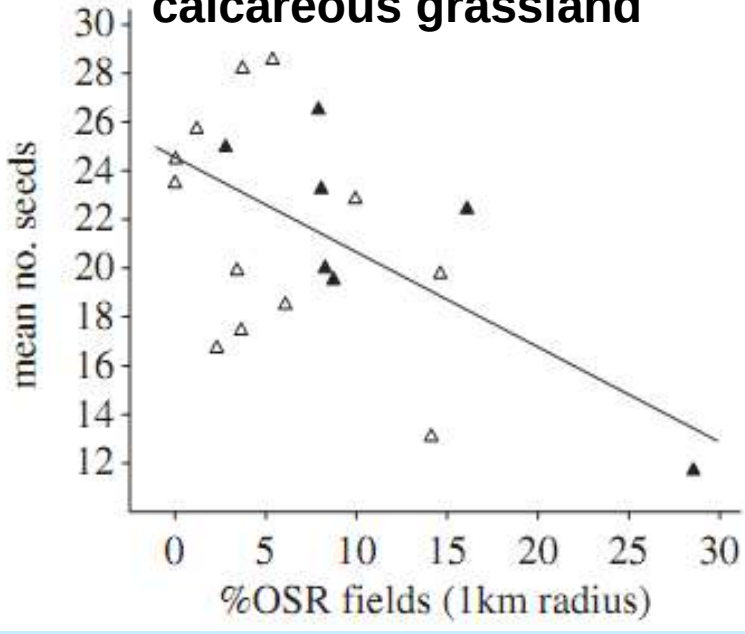
Catrin Westphal et al 2003, Ecol Letters
Andrea Holzschuh et al. 2011, Proc Roy Soc London B

Transient dilution of wild bees

Oilseed rape



***Primula veris* on adjacent calcareous grassland**



Andrea Holzschuh et al. 2011
Proc Roy Soc London B

The landscape-moderated insurance hypothesis

Structurally complex landscapes

provide spatio-temporal insurance,

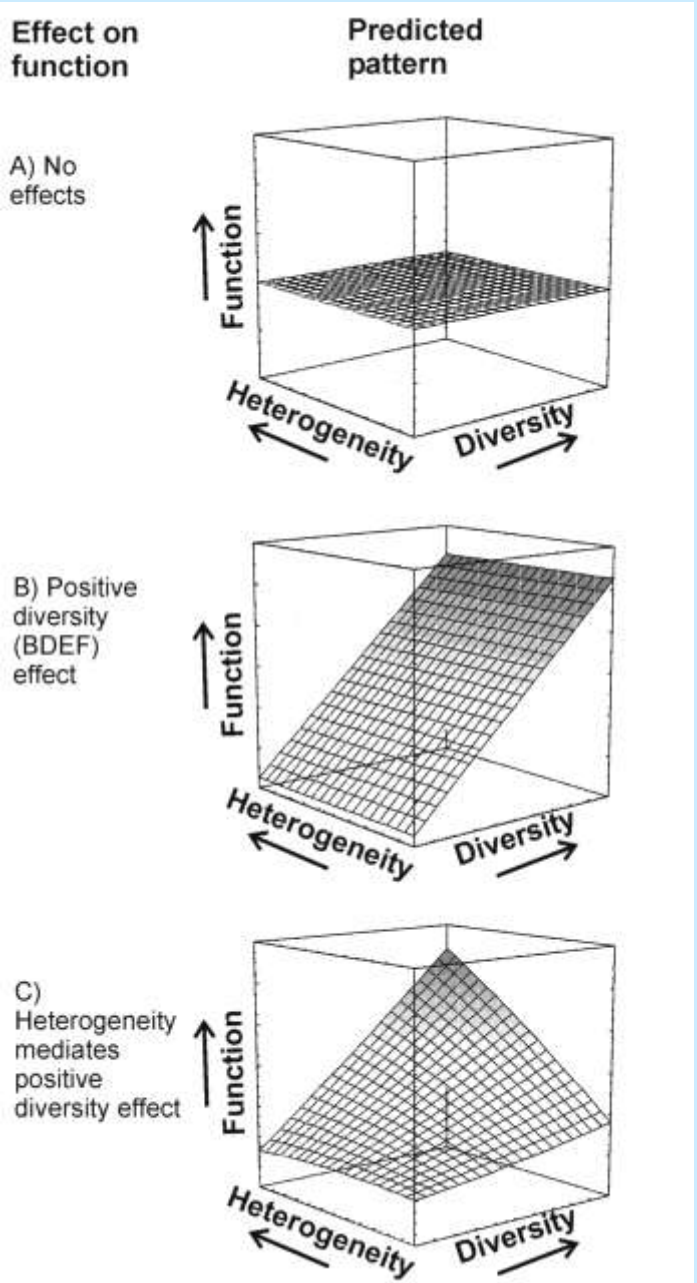
i.e. higher resilience and stability

of patterns and processes

in changing environments.

Tscharntke et al. 2012, Biol Reviews

The landscape-mediated insurance hypothesis

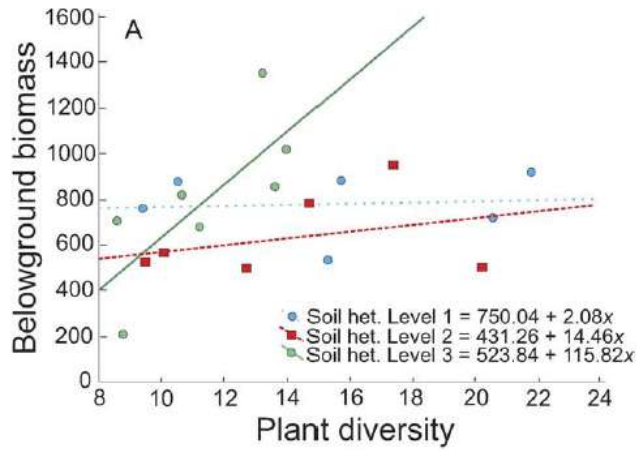


Biodiversity-function relationships
(yield, predation, pollination)

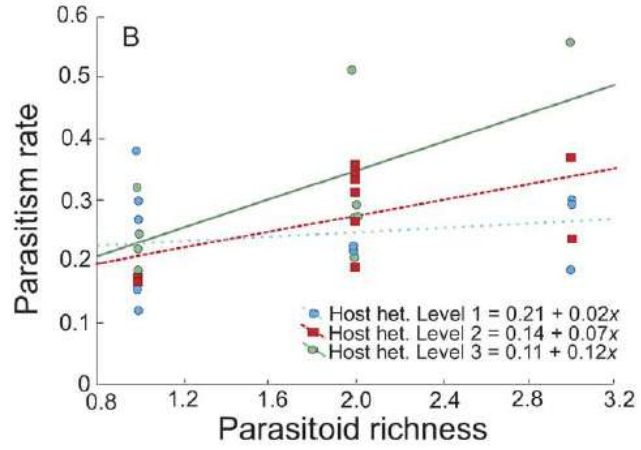
promoted by
resource heterogeneity?

Jason Tylianakis et al. 2008, PloS Biology

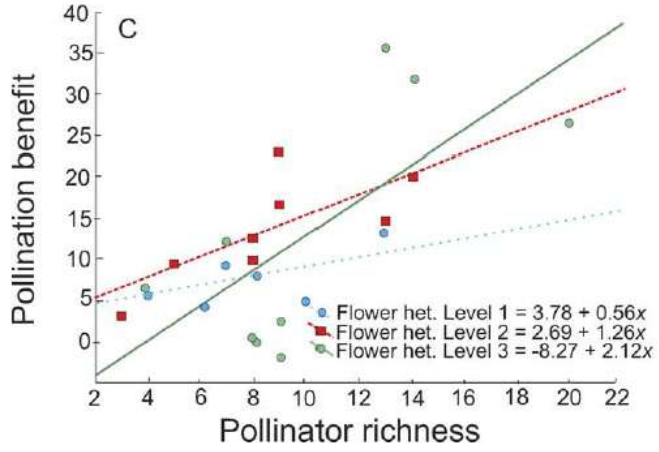
Resource heterogeneity promotes the biodiversity-function relationship in real world ecosystems



Plant diversity
vs. belowground productivity

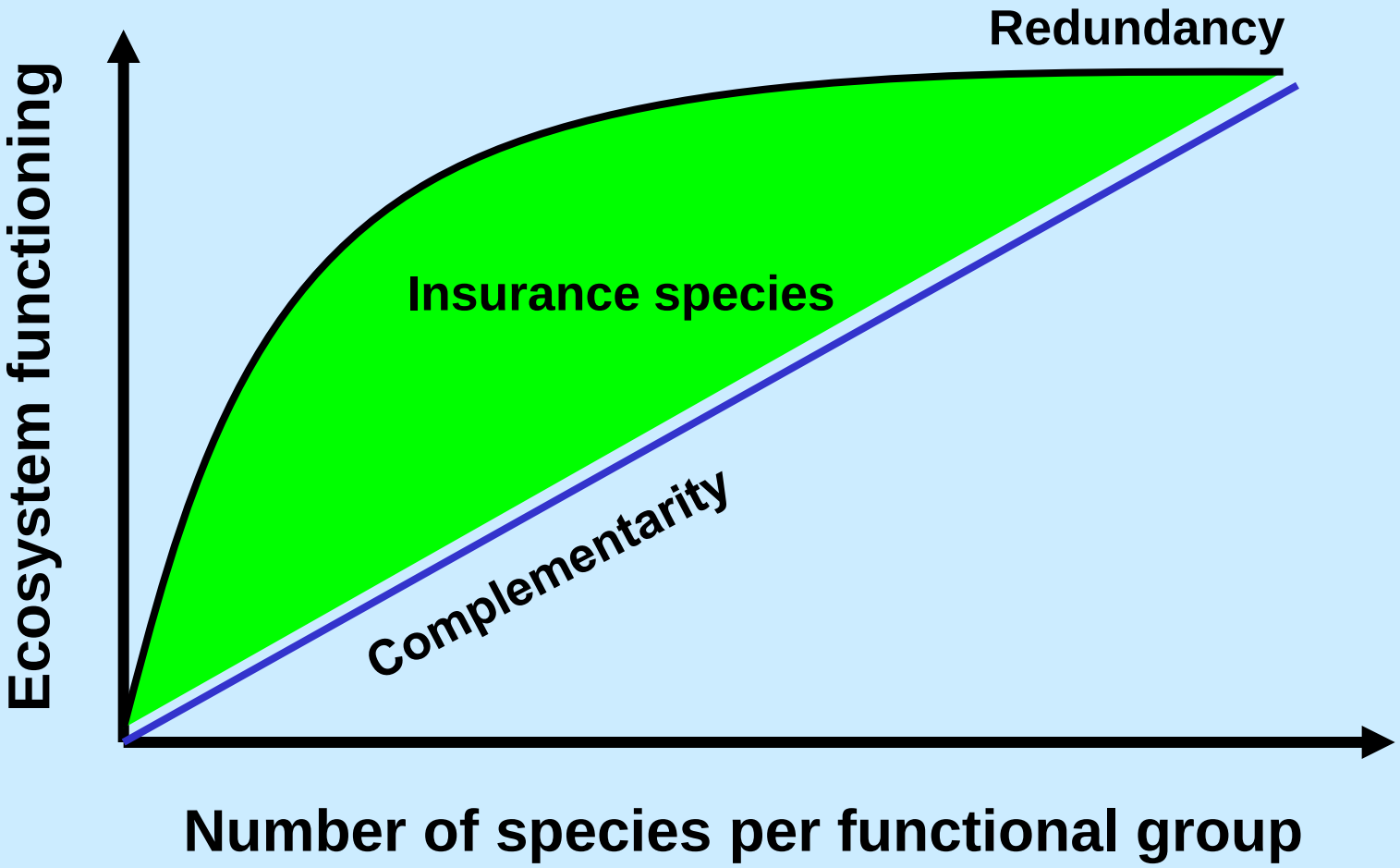


Parasitoid diversity vs. parasitism



Pollinator diversity vs. pollination

Tylianakis et al. 2008, PloS Biology



High species diversity increases

- Functional complementarity due to niche differences
- Functional redundancy under changing environments (response diversity)
- Insurance value under Global Change
  Evidence only when real-world heterogeneity considered!

Tscharntke et al. 2005, Ecol Letters; B2012, Biol. Reveiws; Tylianakis et al. 2008, PloS Biology

Management conclusions

(1) Broadening the view from local to landscape-moderated effects is essential for effective biodiversity and ecosystem service management

(2) Higher trophic levels are often more affected by habitat fragmentation (or disturbance), but only when specialised

(3) Beta (not alpha) diversity drives the landscape-wide biodiversity

(4) Local management is more effective in simple than complex landscapes

(5) Landscape-moderated concentration and dilution effects can be a driver of local patterns and processes (e.g. pollination)

(6) Complex landscapes provide insurance to disturbances, as only high functional biodiversity can cope with the real spatio-temporal heterogeneity