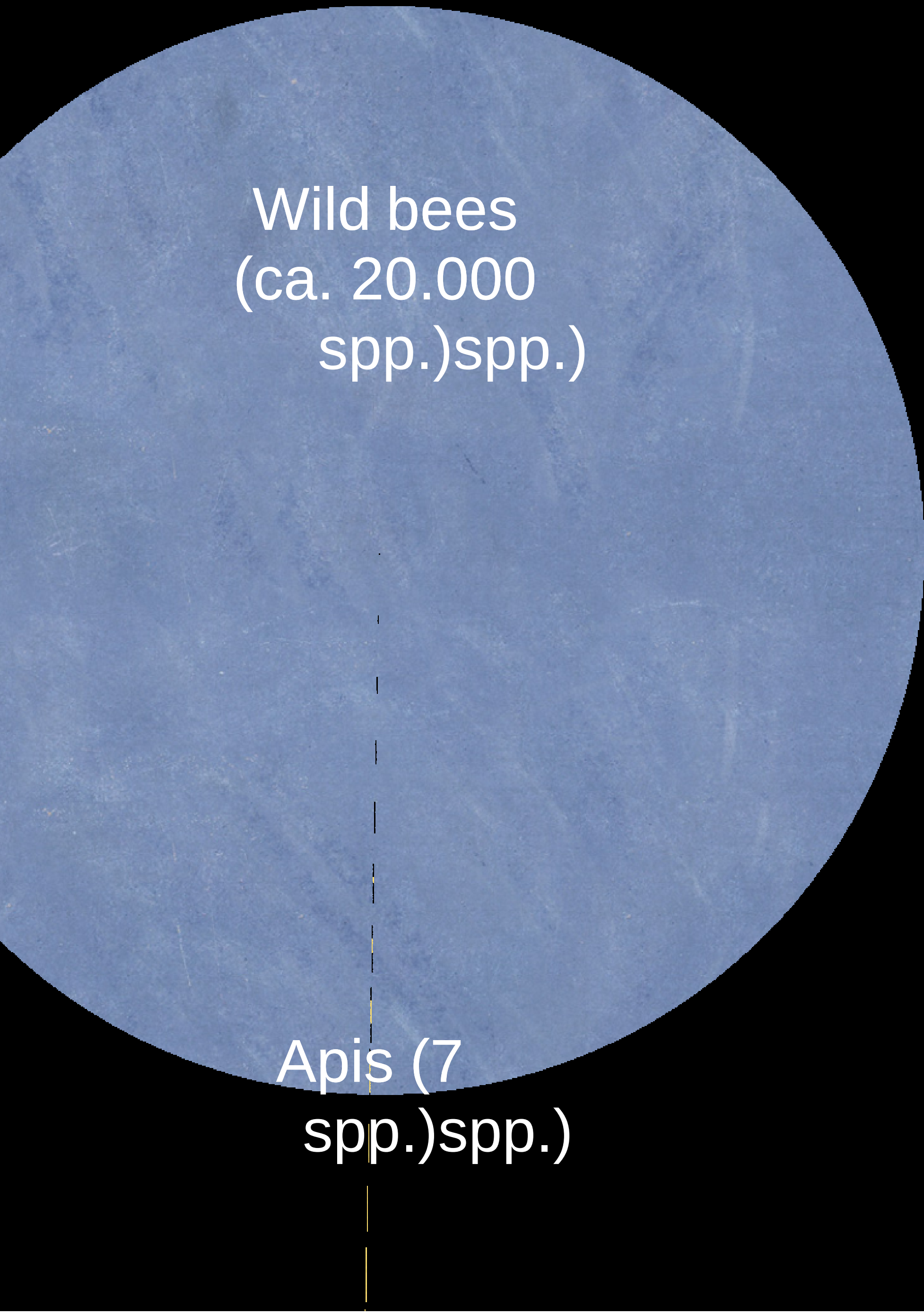
& Pollinisation

Wild bees for the agroecological transition: an overview of their ecological and economical contributions to our food systems

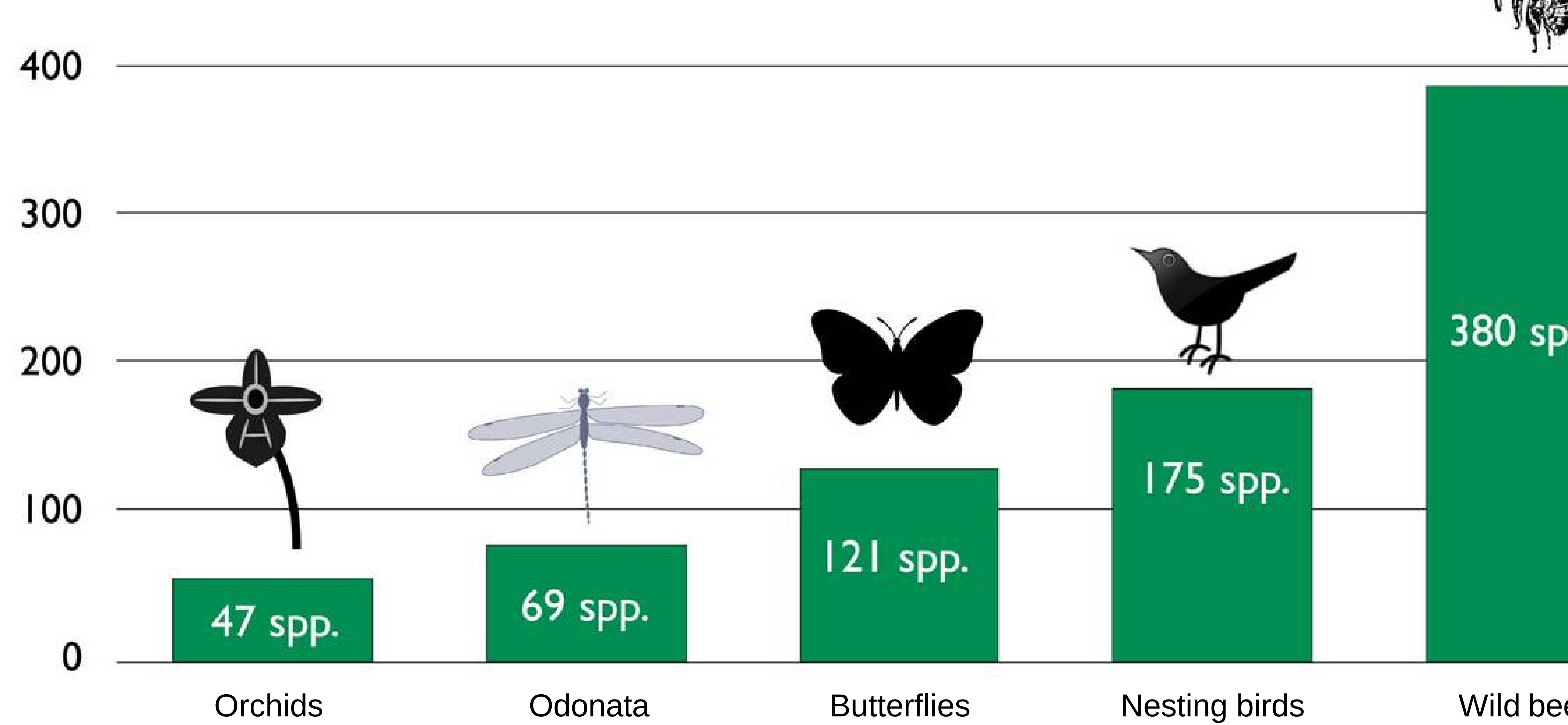
Dr Nicolas Vereecken

The bee ***or*** the bees?

Apis mellifera



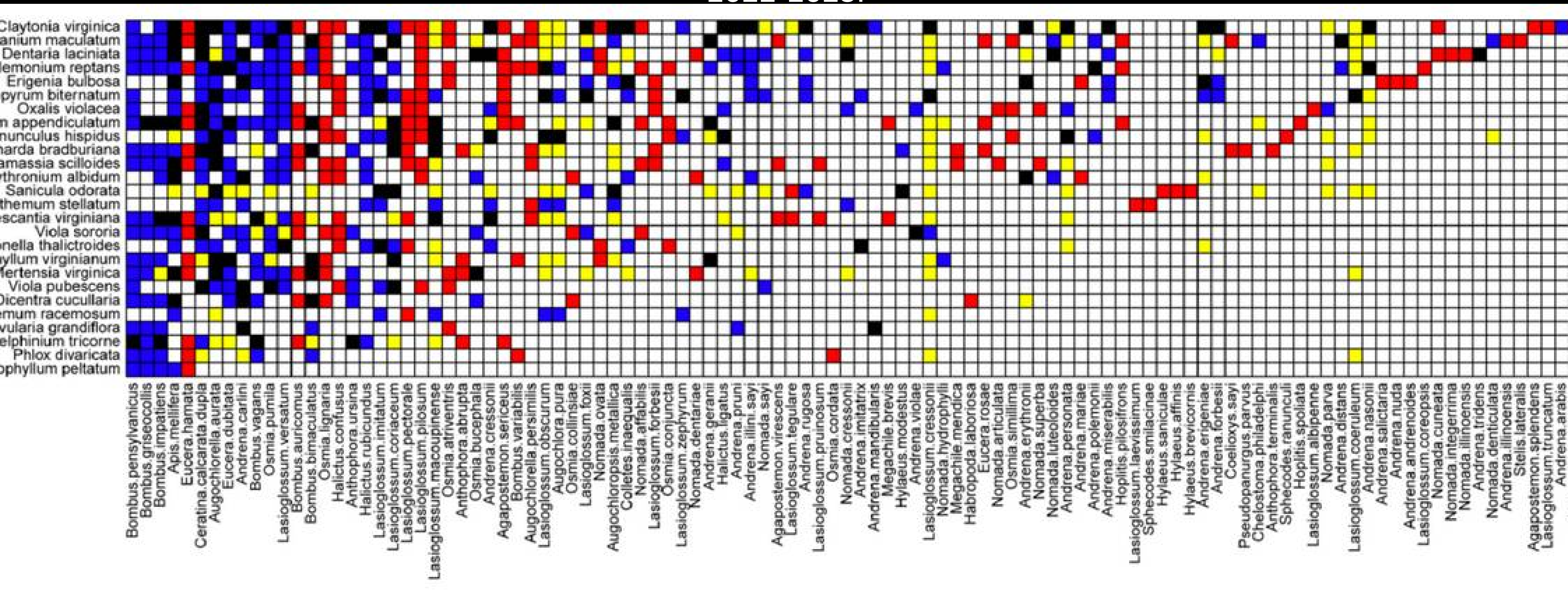
Wild bees = non-*Apis* bees


400
300
200
100
0
47 spp.
69 spp.
121 spp.
175 spp.
380 sp
Orchids
Odonata
Butterflies
Nesting birds
Wild bee


25-27mm


Bryonia dioica
Wild bees
=
n pollen specialists!

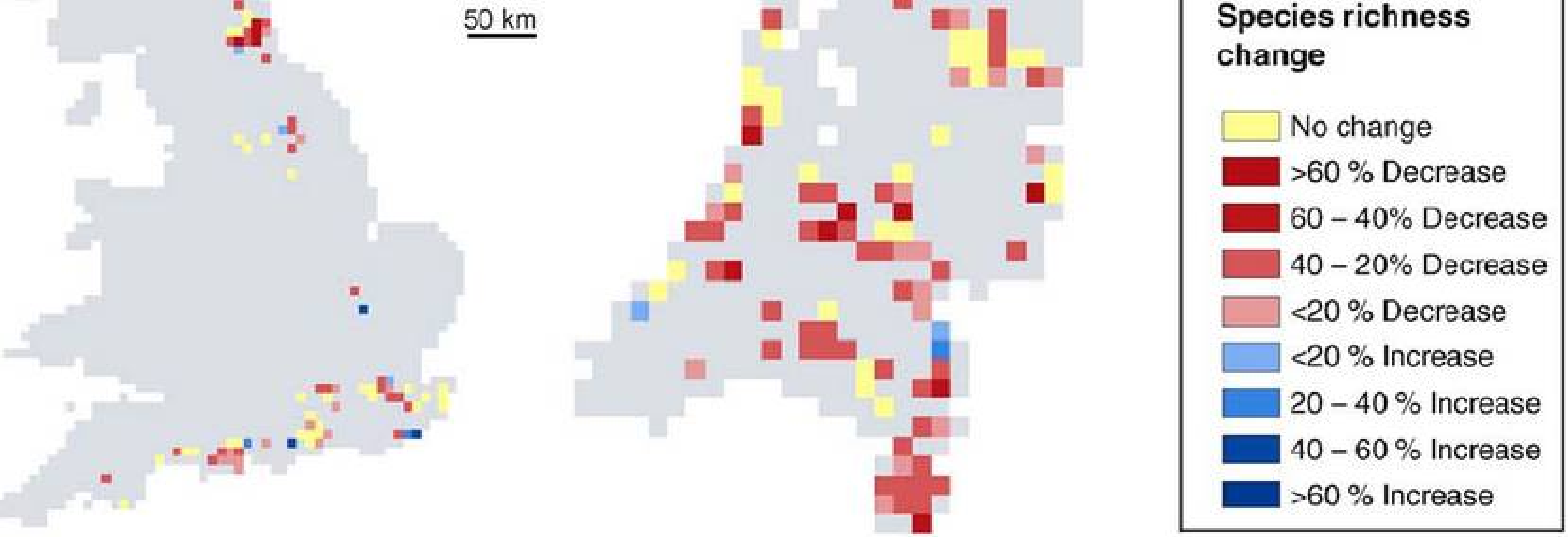
le et al. (2013) Plant-pollinator interactions over 120 years: loss of species, co-occurrence and function. *Science* 1611-1615.



Lost interaction (pollinator lost) | Lost interaction (unknown reason) | New interaction observed

ee-flower interaction networks have dramatically changed in the co the last century in N-America

n estimated 50% of all bee species observed regionally sappeared altogether in just over a century



Andrena hattorfia

Bombus gerstaeck

	Britain				Netherlands			
	Solitary bees							
	Trait category (proportion declining)		*P*	*n*	Trait category (proportion declining)		*P*	*n*
range	Narrow (0.90)	Wide (0.25)	0.0001	32	Narrow (0.83)	Wide (0.53)	0.090	29
specificity	Oligo (0.86)	Poly (0.41)	0.034	34	Oligo (0.55)	Poly (0.76)	0.198	36
length	Long (0.70)	Short (0.41)	0.099	56	Long (1.00)	Short (0.51)	0.028	49
ions	Uni (0.60)	Multi (0.14)	0.042	44	Uni (0.76)	Multi (0.55)	0.433	42

Biesmeijer *et al.* (2006) *Science* 313: 351-354

Eupavlovskia obscura s

Populations of wild bees, particularly “ecological specialist

TIME

A WORLD WITHOUT BEES

BY BRYAN WALSH

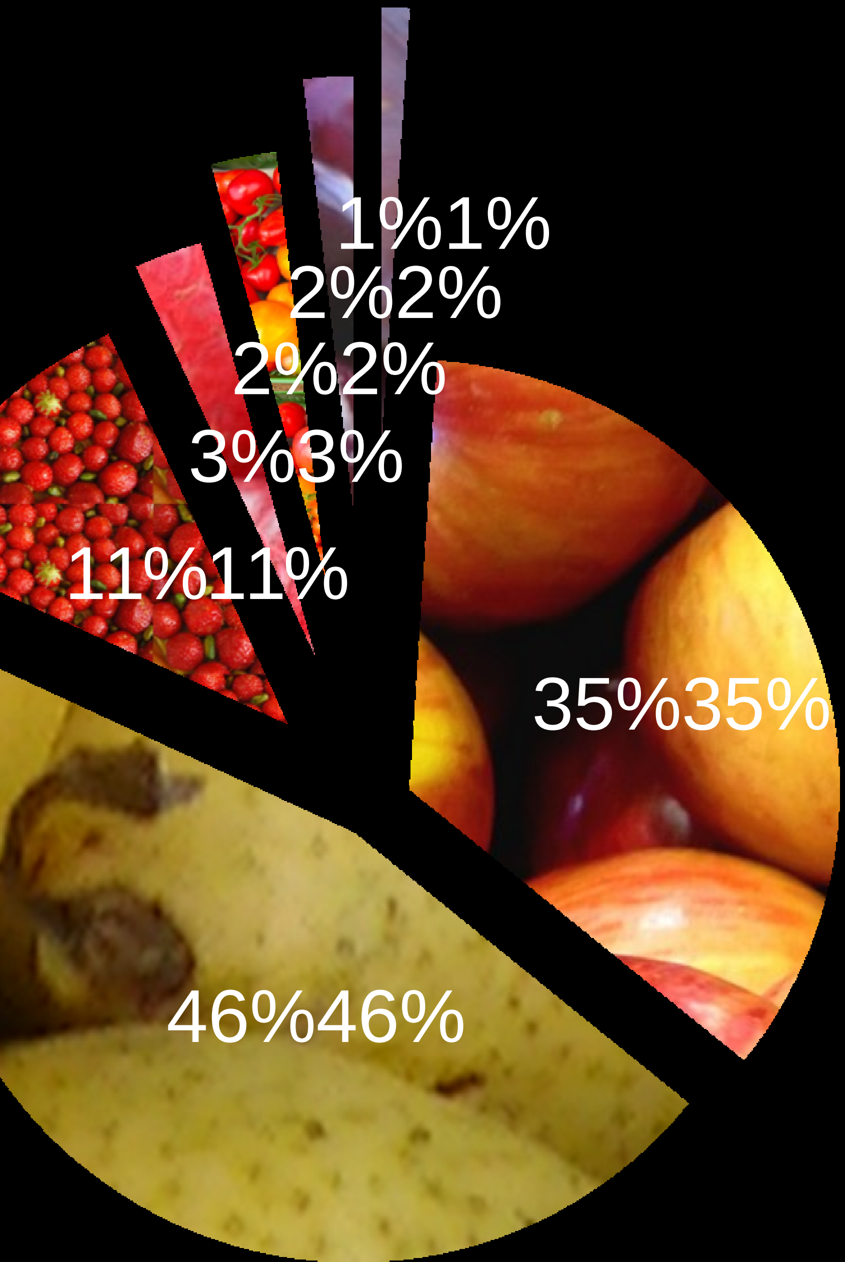

survival

An estimated 80% of all flowering plants in temperate zones sexua reproduce, survive and diversify thanks to pollinators

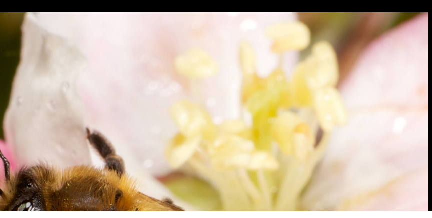
Some 150 crops at the European scale (84%) are dependent up pollinators for the production of fruits, vegetables and seeds

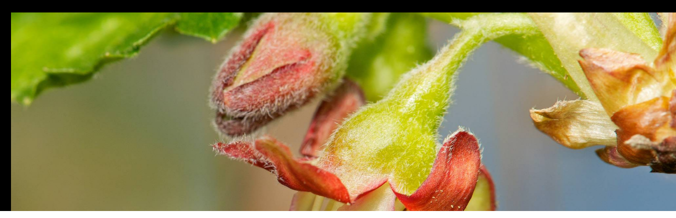
The economic value of crop pollination by insects is estimated to ran between 153 and 285 billion euros per year (Gallai *et al.* 200 Lauterbach *et al.* 2012)

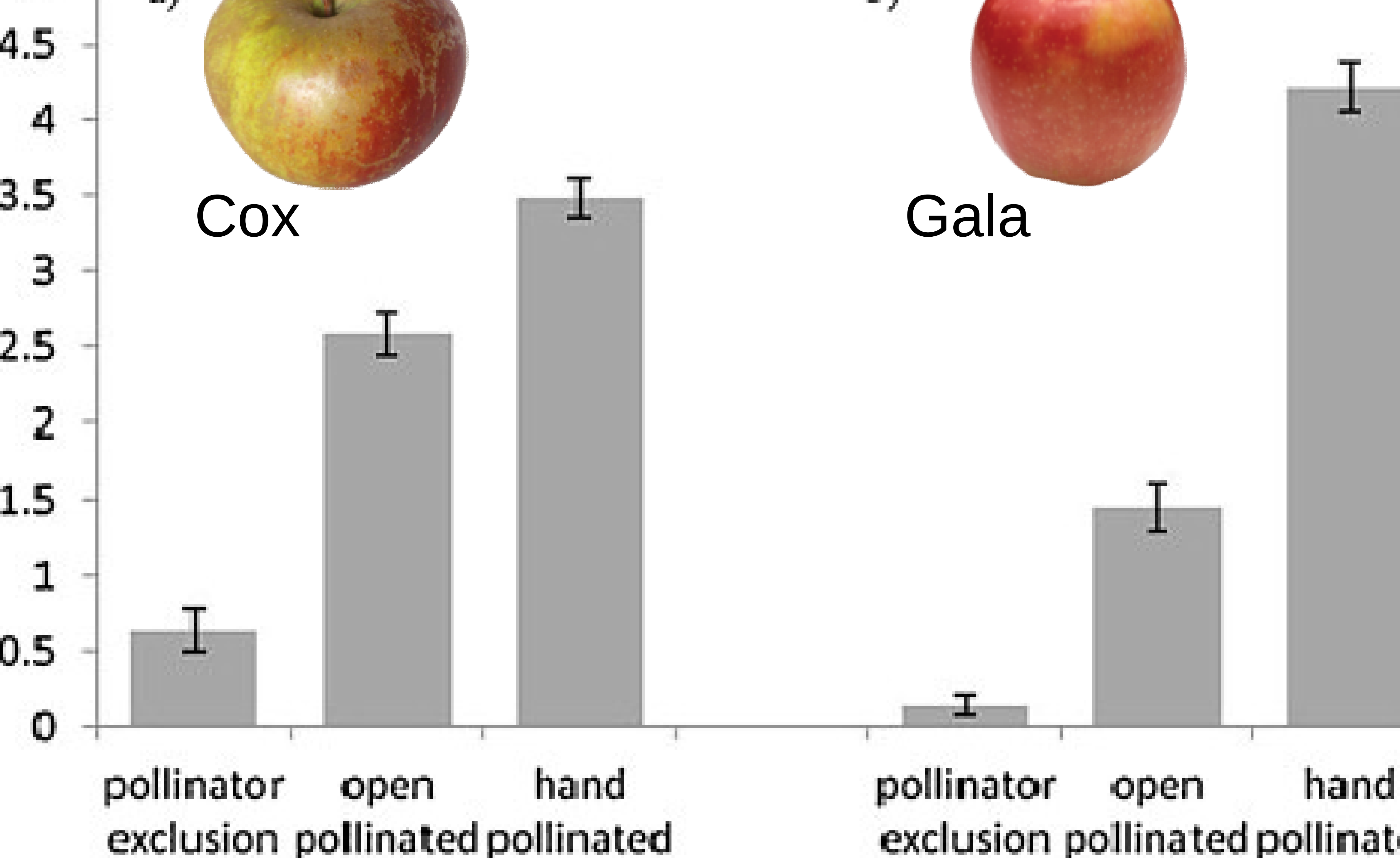
The economic value of crop pollination by insects was also estimat n Europe (16,2 billion €), France (2,7 billion €) (Gallai *et al.* 2009) a the UK (1,265 billion €) (Breeze *et al.* 2011)



- Pears, apples, strawberries raspberries are the main pollin dependent crops in Belgium
- The economic value of pollin dependent crops in Belgium amo to 7 billion euros per year
- This represents approximately of the total annual value agricultural products in Belgium





seeds per apple for Cox & Gala is significantly greater per apple in

Can’t **honey bees** replace all **other bee species?**

Is the **biodiversity** of pollinators **relevant to crop production**?

EMBARGOED UNTIL 2:00 PM US ET THURSDAY, 28 FEBRUARY 2013

Wild Pollinators Enhance Fruit Set of Crops Regardless of Honey Bee Abundance

ucas A. Garibaldi,[1*] Ingolf Steffan-Dewenter,[2] Rachael Winfree,[3] Marcelo A. izen,[4] Riccardo Bommarco,[5] Saul A. Cunningham,[6] Claire Kremen,[7] Luísa G. arvalheiro,[8,9] Lawrence D. Harder,[10] Ohad Afik,[11] Ignasi Bartomeus,[12] Faye enjamin,[3] Virginie Boreux,[13,14] Daniel Cariveau,[3] Natacha P. Chacoff,[15] Jan H. udenhöffer,[16] Breno M. Freitas,[17] Jaboury Ghazoul,[14] Sarah Greenleaf,[7] uliana Hipólito,[18] Andrea Holzschuh,[2] Brad Howlett,[19] Rufus Isaacs,[20] Steven . Javorek,[21] Christina M. Kennedy,[22] Kristin Krewenka,[23] Smitha Krishnan,[14] ael Mandelik,[11] Margaret M. Mayfield,[24] Iris Motzke,[13,23] Theodore Munyuli,[25] rian A. Nault,[26] Mark Otieno,[27] Jessica Petersen,[26] Gideon Pisanty,[11] Simon G. otts,[27] Romina Rader,[28] Taylor H. Ricketts,[29] Maj Rundlöf,[5,30] Colleen L. eymour,[31] Christof Schüepp,[32,33] Hajnalka Szentgyörgyi,[34] Hisatomo Taki,[35] eja Tscharntke,[23] Carlos H. Vergara,[36] Blandina F. Viana,[18] Thomas C. anger,[23] Catrin Westphal,[23] Neal Williams,[37] Alexandra M. Klein[13]

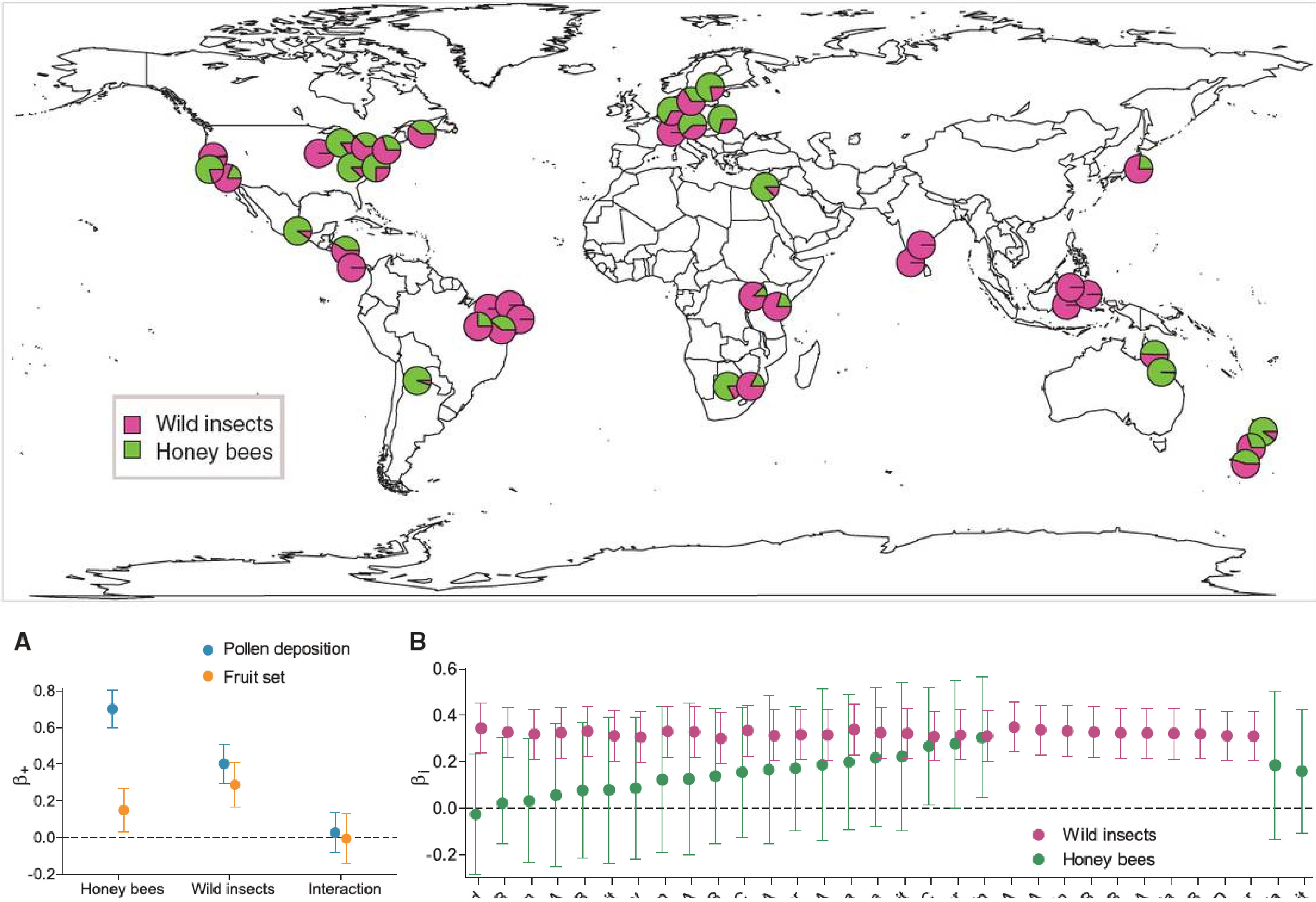
o whom correspondence should be addressed. E-mail: lgaribaldi@unrn.edu.ar

complementary pollination species (*14*, *15*), facilitation or "sampling effects" (*18*) other mechanisms (*19*, *20*). P evenness may enhance frui complementarity, or diminis dominant species (e.g., hone the most effective pollinator date, the few studies on portance of pollinator rich crop pollination have reveale results (*22*), the effects of on pollination services remai unknown, and the impact insect loss on fruit set has evaluated globally for pollinated crops.

We tested four prediction from the assumption that wil effectively pollinate a broad crops, and that their role ca placed by increasing the ab of honey bees in agricultur (1) for most crops, wild-in

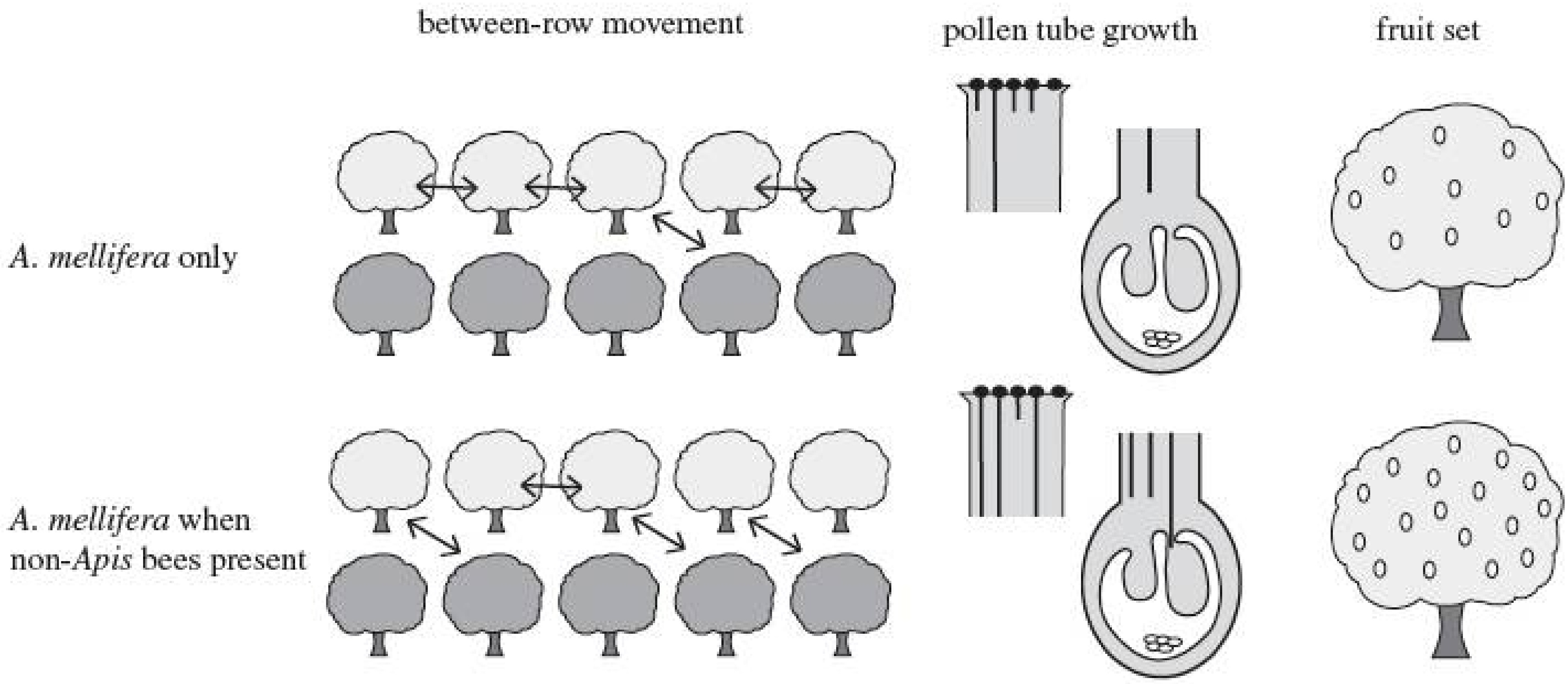
he diversity of pollinators is a significant crop production factor, irrespecti e density of honey bee hives

00 agricultural plots, 41 crops at the worldwide scale, incl. annual & pere

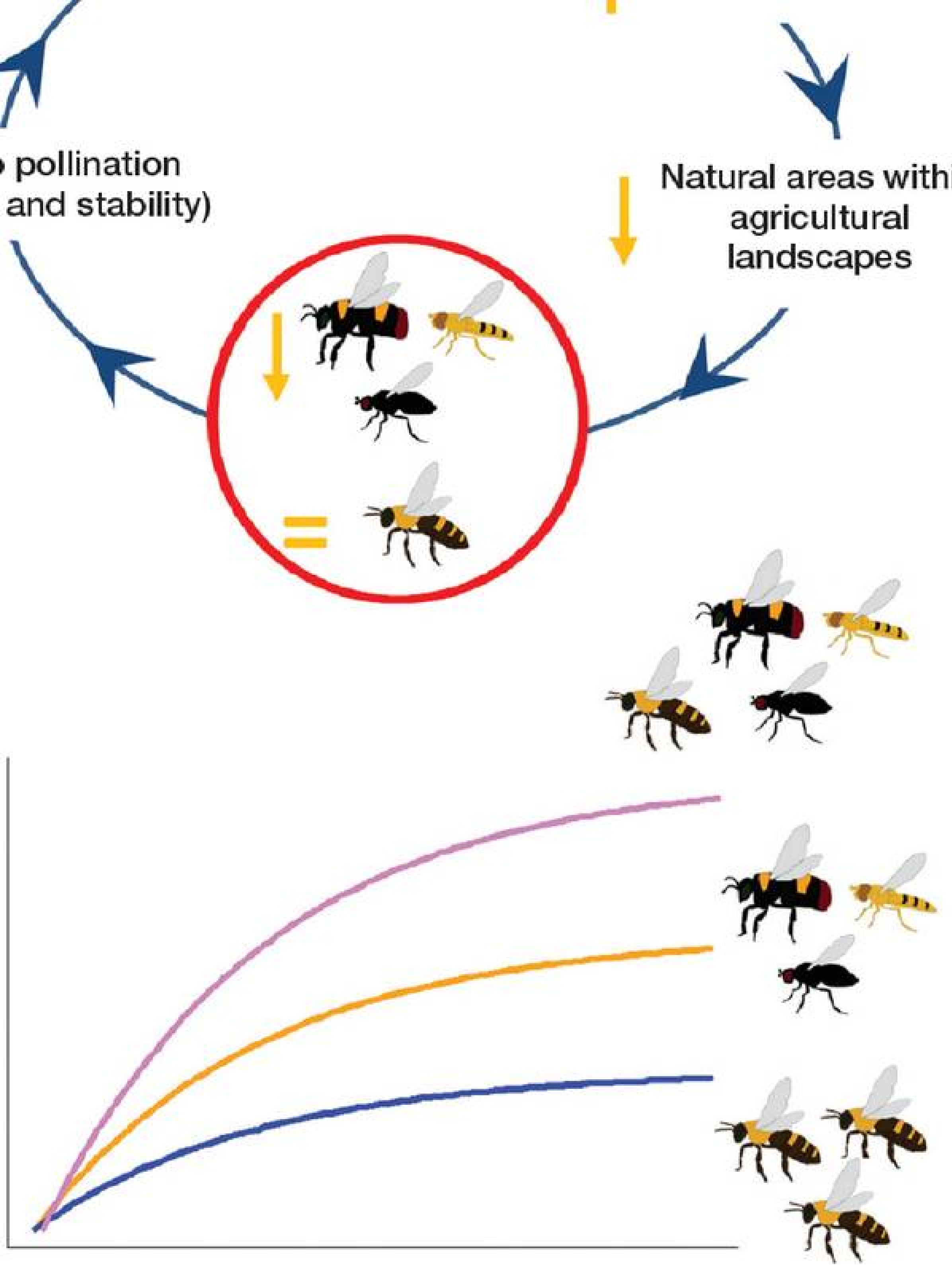


Wild insects
Honey bees
A
Pollen deposition
Fruit set
β+
0.8
0.6
0.4
0.2
0.0
-0.2
Honey bees
Wild insects
Interaction
B
βi
0.6
0.4
0.2
0.0
-0.2
Wild insects
Honey bees

Photos NJ Vereecken



Wild pollinator decline and **mainstream approach** to sustain pollination services



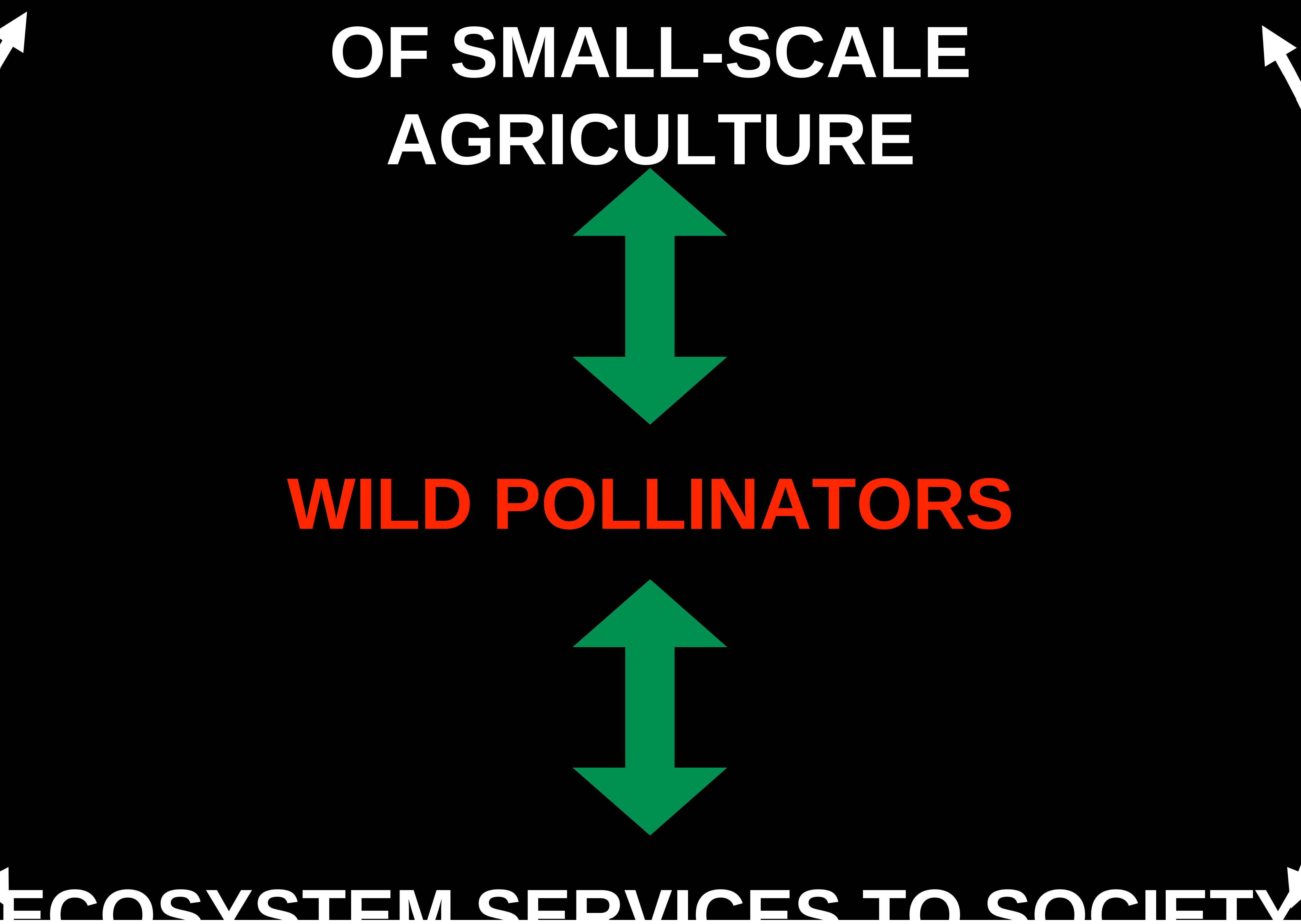
ldi et al. (2014) Front Ecol Environ 12(8): 439-447

= Vicious circl

Production ends up being reliant upon a single pollinator species

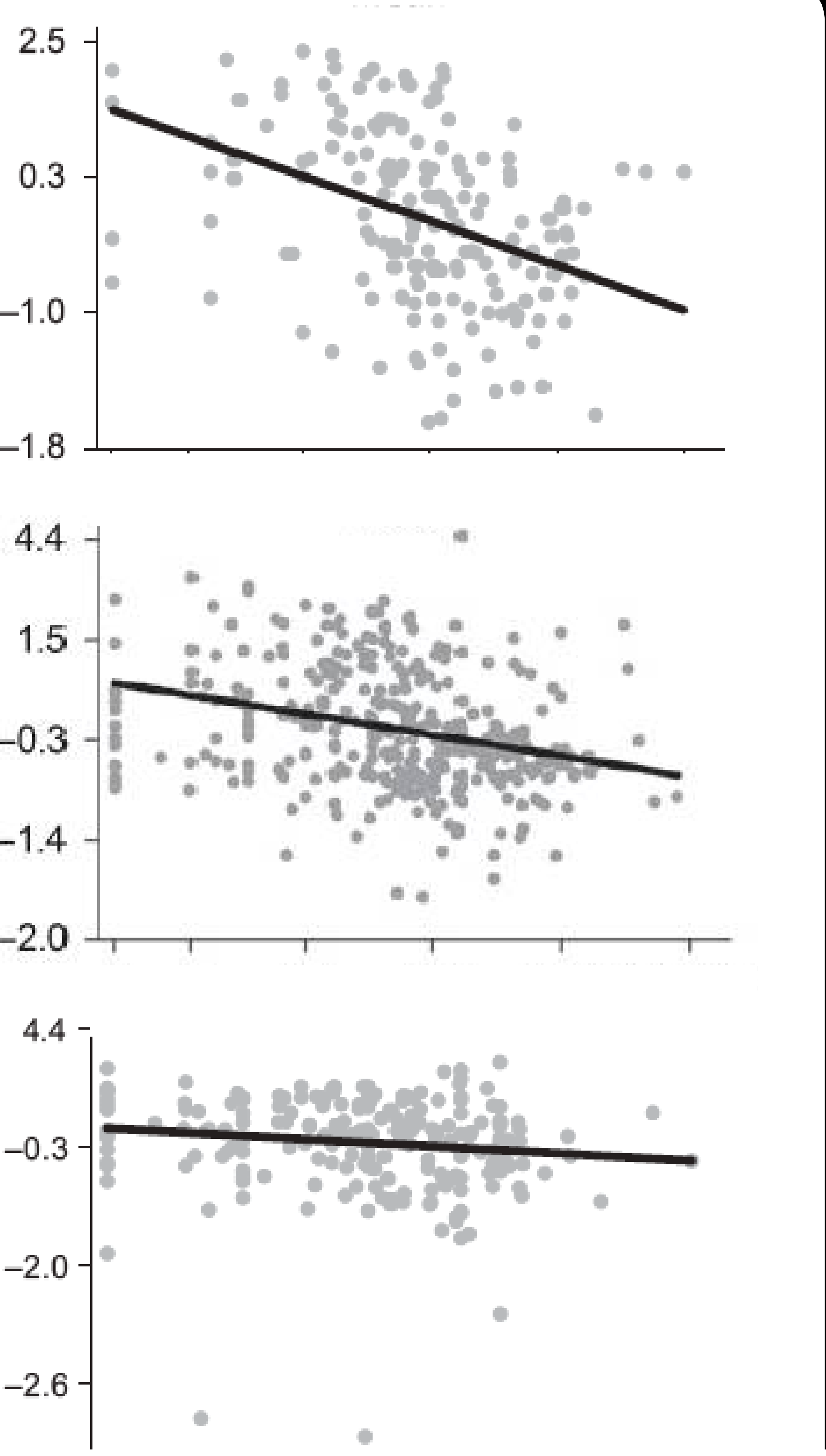
= Less resilien

Are there alternatives?


OF SMALL-SCALE
AGRICULTURE
WILD POLLINATORS
ECOSYSTEM SERVICES TO SOCIETY

resources

Nesting

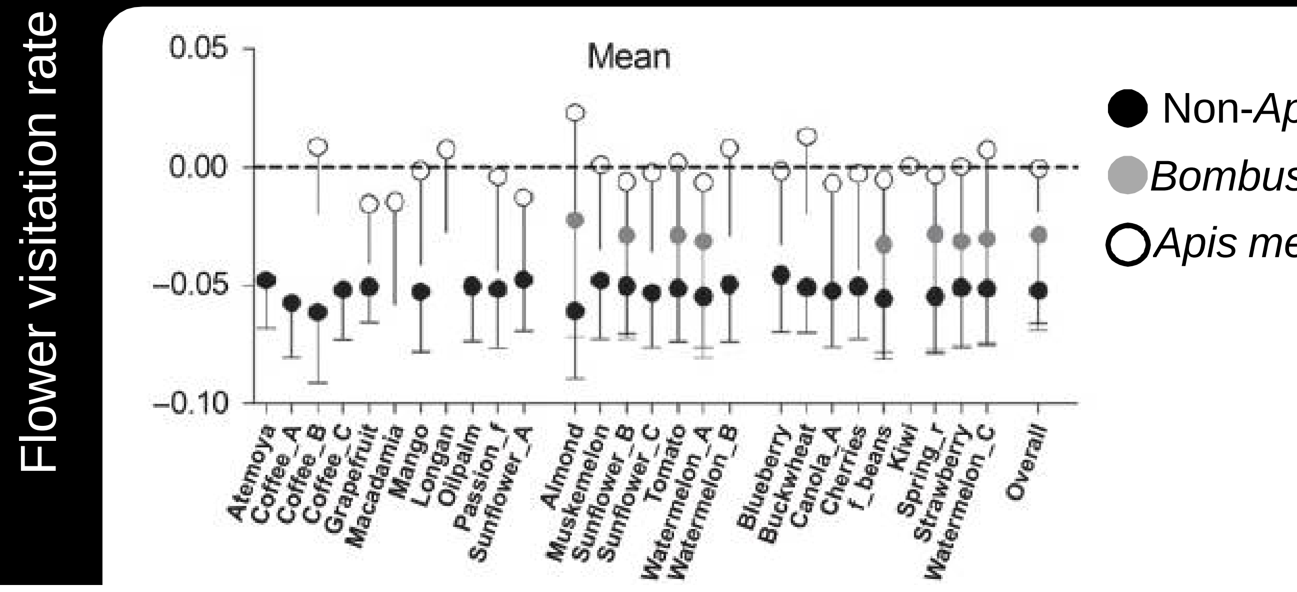


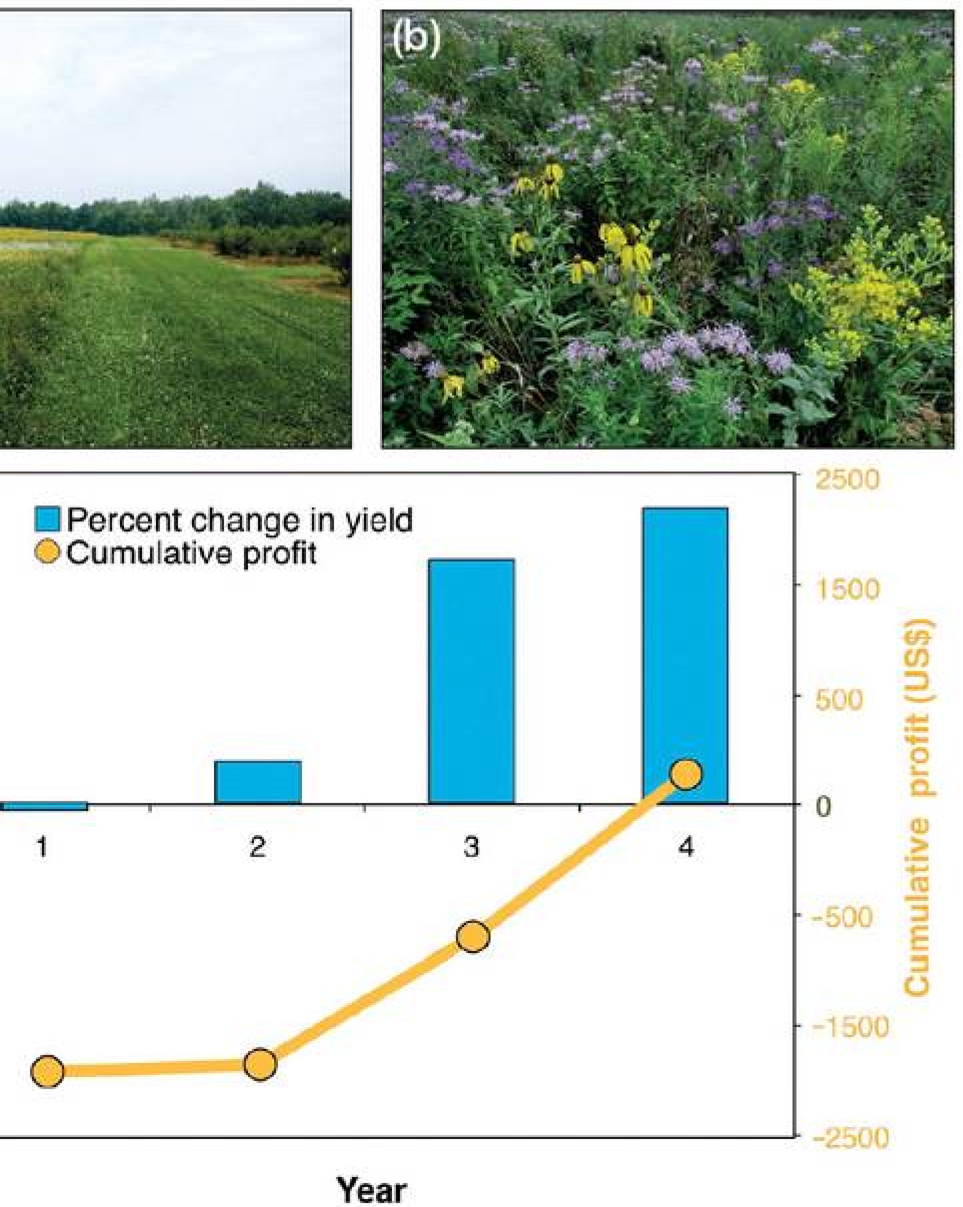
- A review of 29 independent studies on pollination and semi-natural habitats

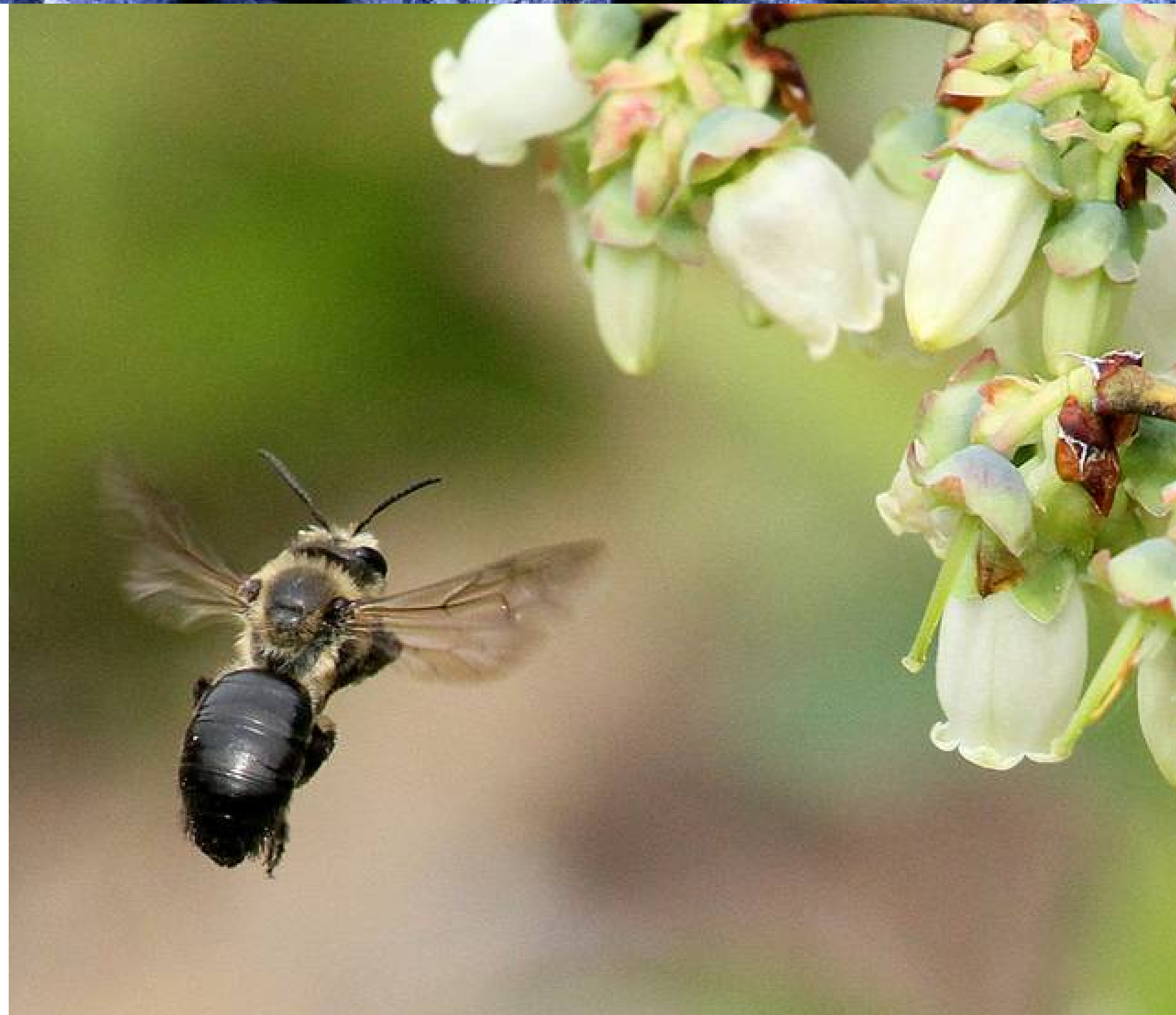
- **<u>Significant decrease of</u>** :

  - wild bee diversity
  - wild bee visitation rates to flowers of c
  - seed set rate

  when the distance between the culti plot to the nearby semi-natural increases



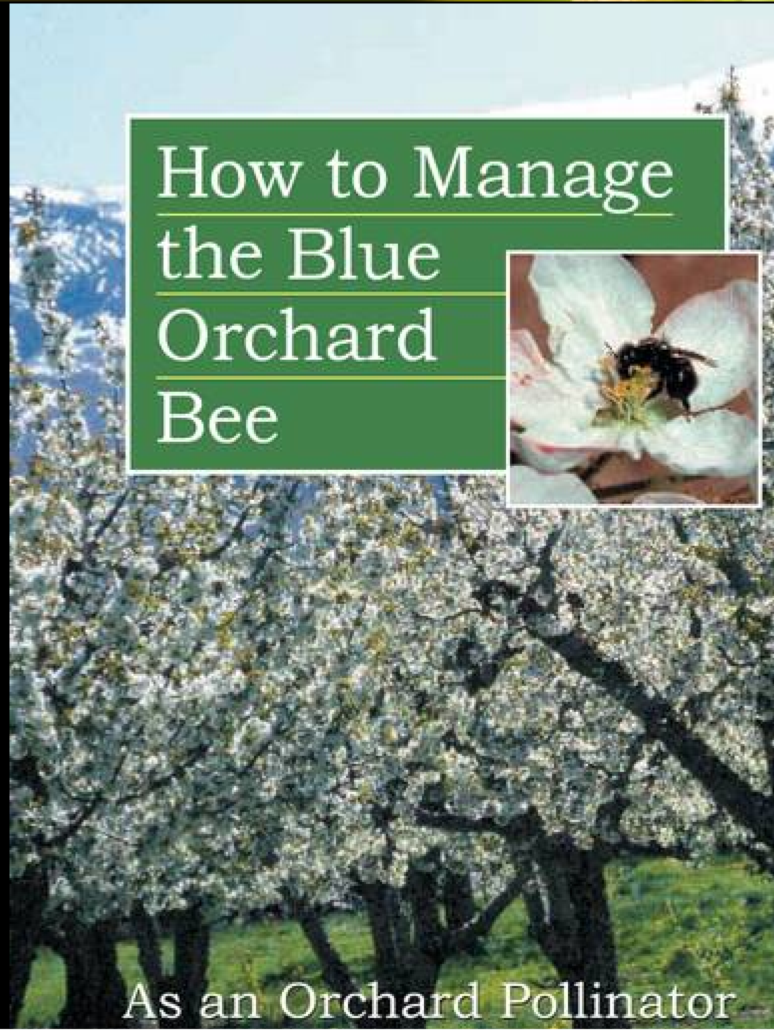


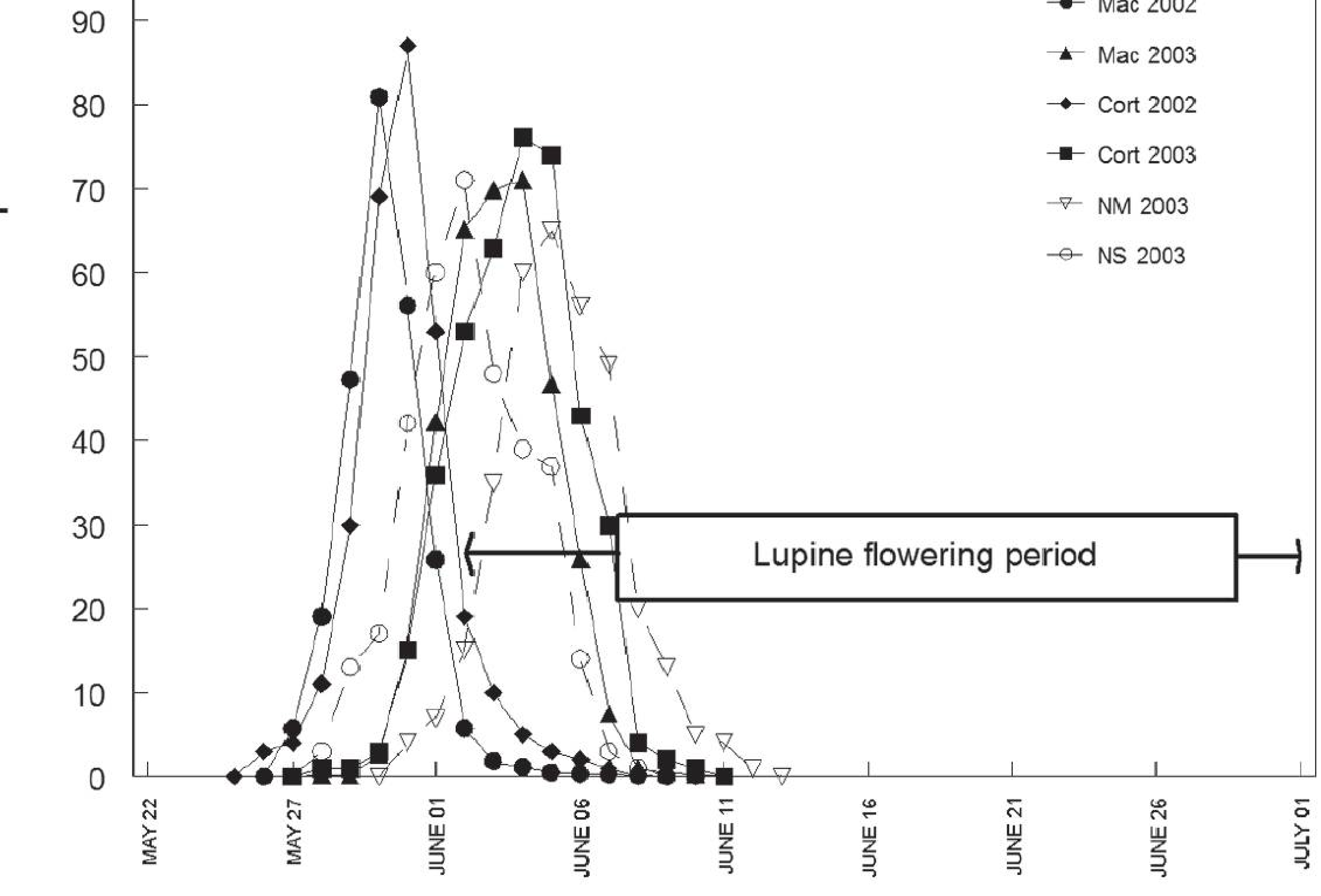


Blaauw BR & Isaacs R. 2014. Flower plantings increase wild bee abundar
pollination services provided to a pollination-dependent crop. *J Appl Ecol* **51:**

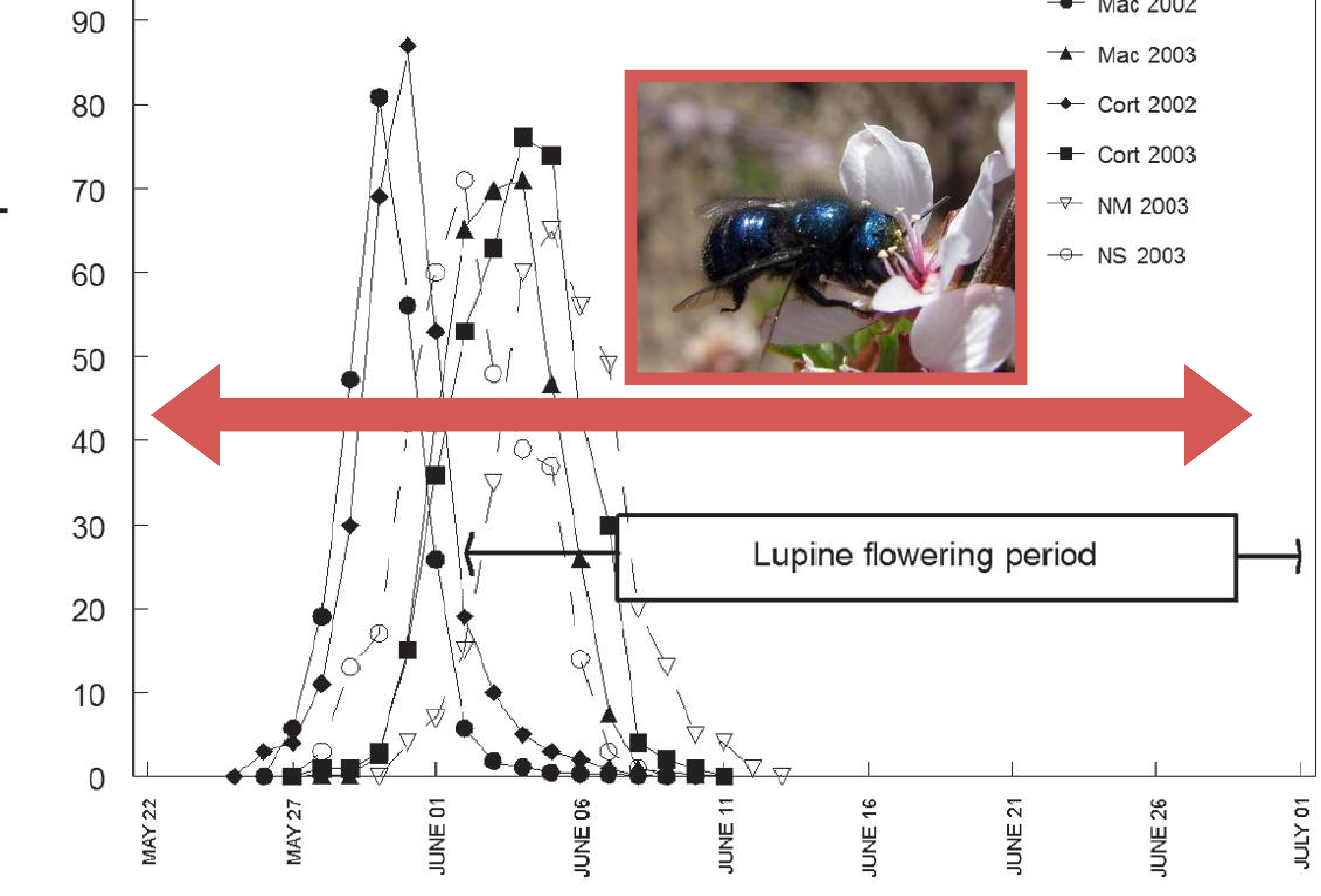
ntings of native wildflower species selected for support of pollinators en
eberry yield and profit in Michigan (USA)


© Marcel Rawady


How to Manage the Blue Orchard Bee
As an Orchard Pollinator



Mac 2002
Mac 2003
Cort 2002
Cort 2003
NM 2003
NS 2003
Lupine flowering period
90
80
70
60
50
40
30
20
10
0
MAY 22
MAY 27
JUNE 01
JUNE 06
JUNE 11
JUNE 16
JUNE 21
JUNE 26
JULY 01



Mac 2002
Mac 2003
Cort 2002
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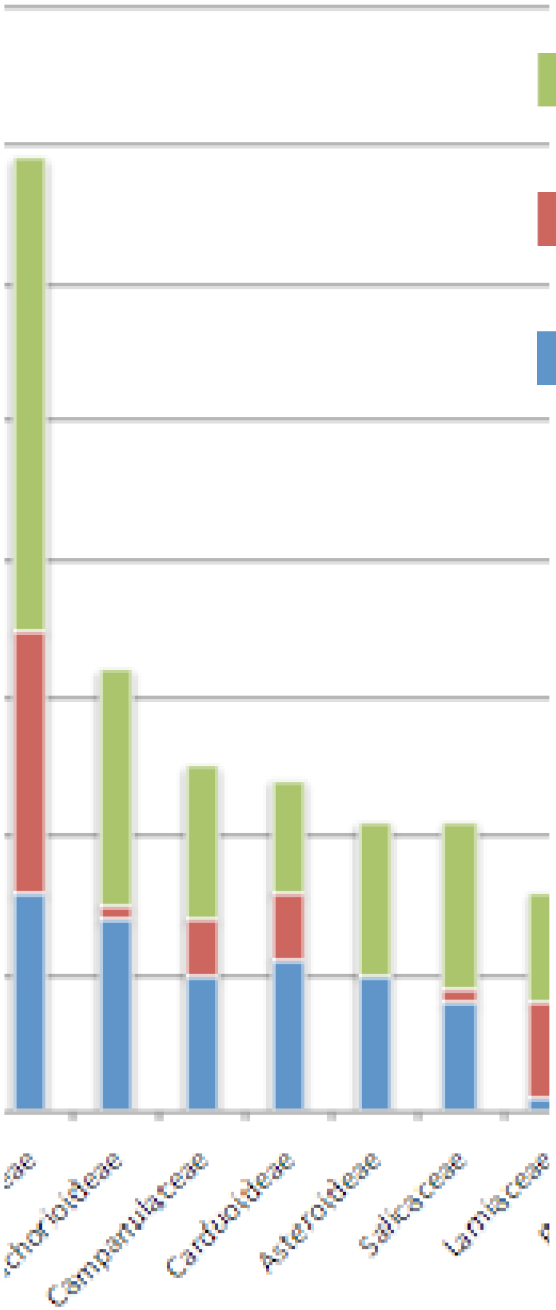
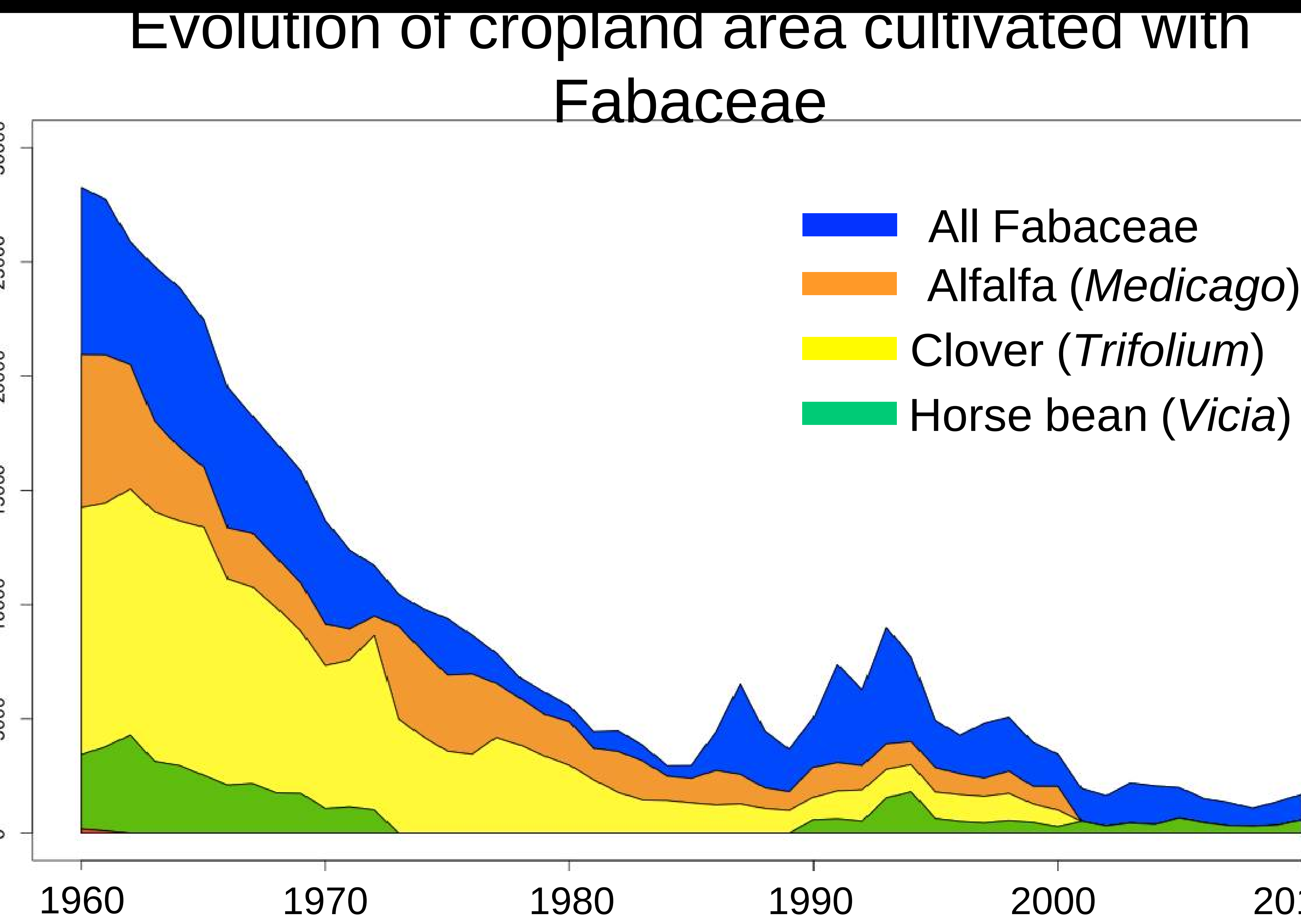
Lupine flowering period
90
80
70
60
50
40
30
20
10
0
MAY 22
MAY 27
JUNE 01
JUNE 06
JUNE 11
JUNE 16
JUNE 21
JUNE 26
JULY 01

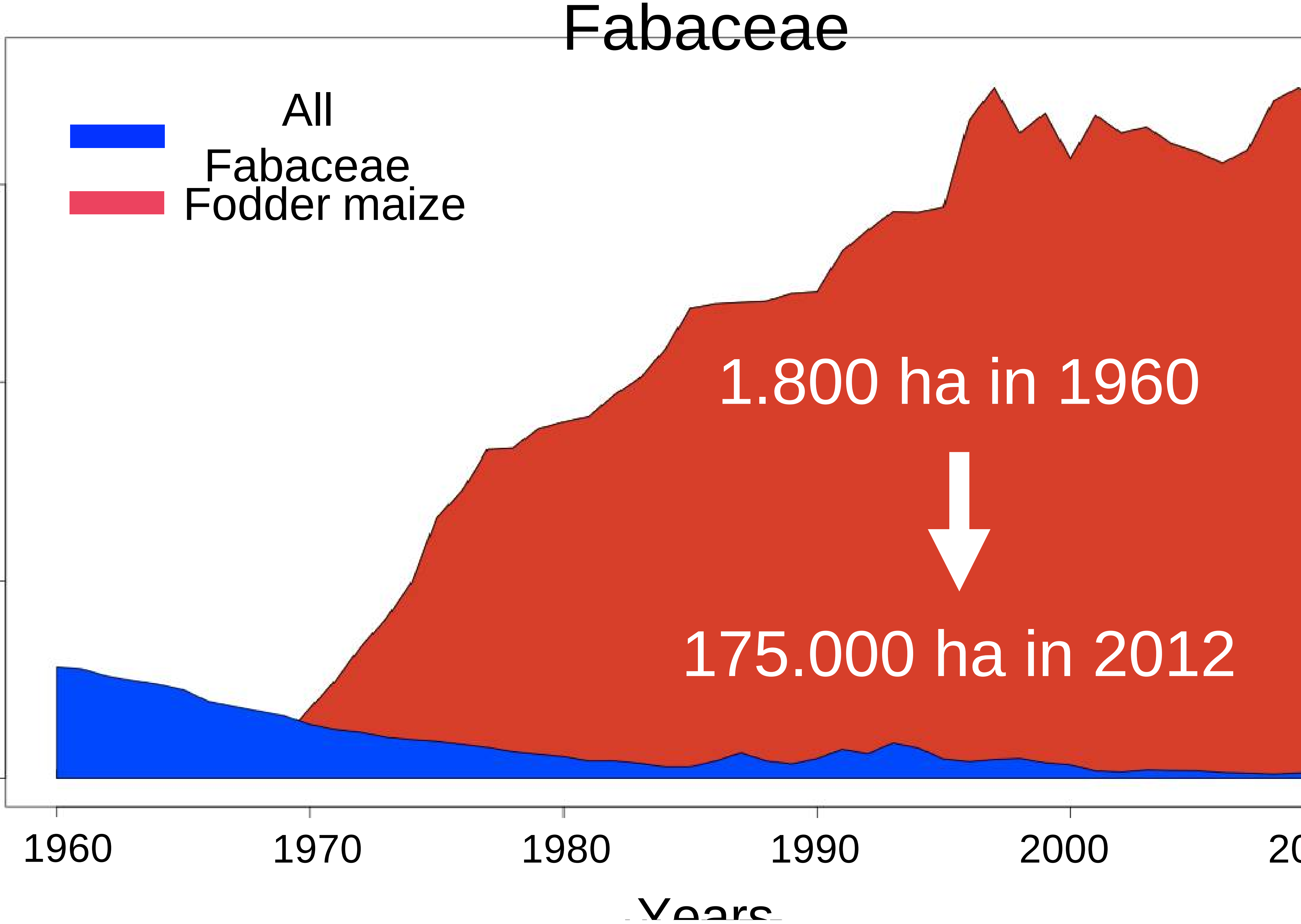
Which **flowering plants** should be promoted in Belgium & N-France to **enhance wild bee populations**?

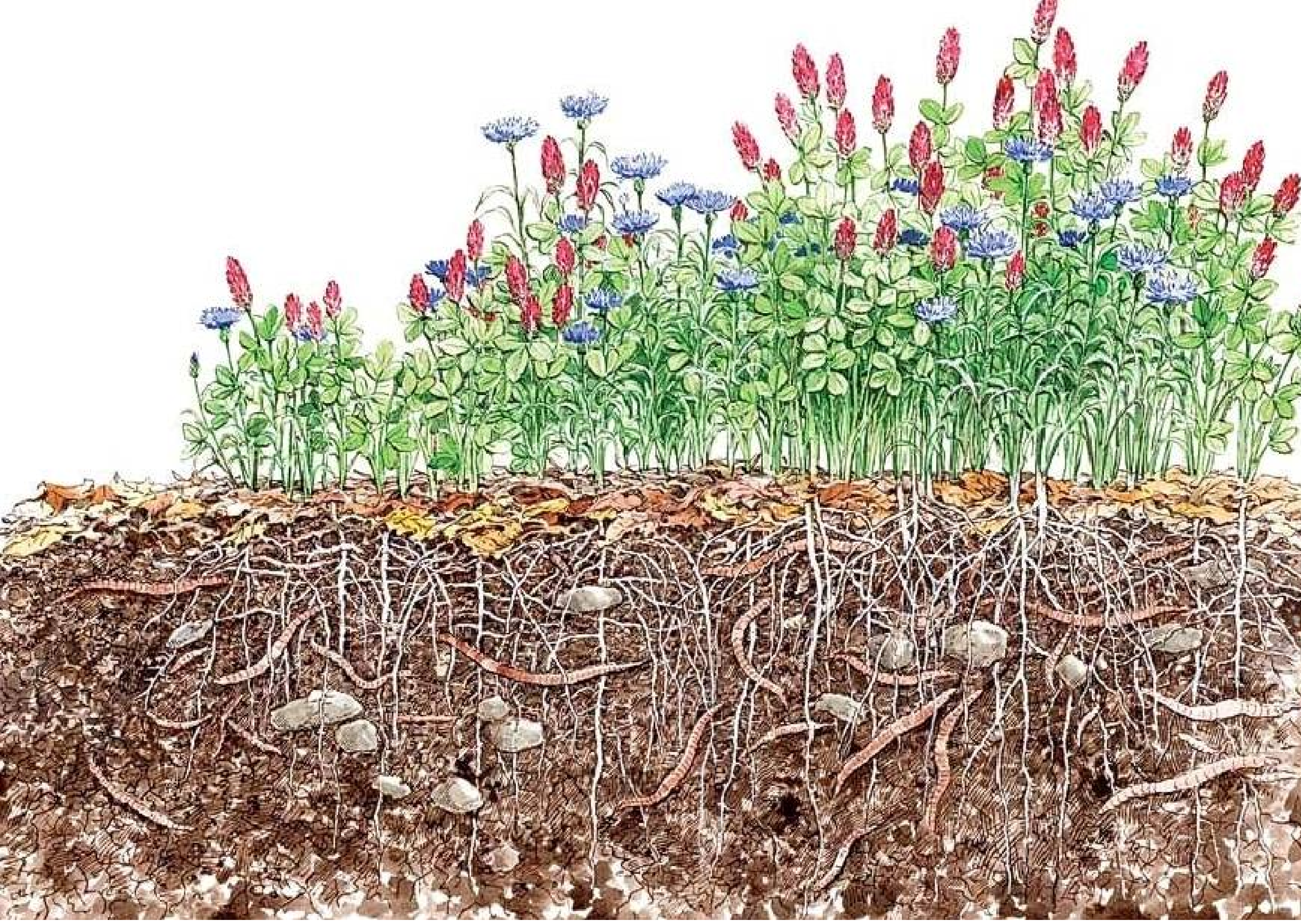


- Cleptoparasitic bees with hosts displaying a c[redacted] for plants belonging to one or more plant famili[redacted]
- Wild bees displaying a clear preference for p[redacted] to one or more plant families
- Wild bees displaying a clear preference for p[redacted] to one plant family

Vereecken et al., in prep


Evolution of cropland area cultivated with
Fabaceae
All Fabaceae
Alfalfa (*Medicago*)
Clover (*Trifolium*)
Horse bean (*Vicia*)
1960
1970
1980
1990
2000


Fabaceae
All Fabaceae
Fodder maize
1.800 ha in 1960
175.000 ha in 2012
1960
1970
1980
1990
2000
20
Years



Photo

JARDIN pour les
ABEILLES SAUVAGES

ent les accueillir, les observer et les protéger

QUI SONT ces ABEILLES TERRICOLES ?

L'andrène à pattes jaunes
(*Andrena flavipes*)

C'est une espèce de taille moyenn
dont les brosses de récolte su
postérieures sont beiges, tout comm
de poils continues qui parcourent l'a
Elle produit généralement deux gé
an (printemps/été) et elle visite de
fleurs dans les parcs et jardins, no
pissenlits, les pâquerettes, les trèfle
Elle nidifie le plus souvent de m
mais elle forme occasionnellemen
bourgades dans les jardins.

L'andrène cendrée
(*Andrena cineraria*)

C'est une espèce de taille moyenn
au corps entièrement noir, y compr
de récolte sur les pattes postérieure
est recouvert d'une pilosité blan
interrompue entre les ailes par u
poils noirs caractéristique.
Elle produit une seule génératio
printemps, et elle visite de nomb
dans les parcs et jardins.
Elle nidifie le plus souvent de m
mais elle forme occasionnellemen
bourgades dans les jardins.

L'andrène au cul rouge
(*Andrena haemorrhoa*)

C'est une espèce de taille moyenne (
thorax roux et aux flancs du corps r
une légère pilosité blanche. L'e
l'abdomen présente une frange d
caractéristique.
Elle produit une seule génératio
printemps, et elle visite de nomb
dans les parcs et jardins, notamme
fruitiers, les pissenlits, etc.
Elle nidifie le plus souvent de ma
rarement en bourgade, mais ell
localement très abondante.

JARDIN pour les ABEILLES SAUVAGES

ent les accueillir, les observer et les protéger

DES MASSIFS MONOFLORAUX pour les ABEILLES

La **Lysimaque commune** ou **grand** (*Lysimachia vulgaris*) est une plant pousse dans les prairies relativement proximité des points d'eau (étangs, rivi inflorescences peuvent atteindre 1m sont d'un jaune vif. C'est une plante-clé *europaea* et *M. fulvipes*.

J	F	M	A	M	J	J	A	S

La **Salicaire commune** ou **herbe a** (*Lythrum salicaria*) est une plante vivace proximité des points d'eau (étangs, rivi inflorescences peuvent atteindre pl hauteur et sont d'un rose pourpré. C'est de *Melitta nigricans* et une ressource i général, notamment pour les bourdons.

J	F	M	A	M	J	J	A	S

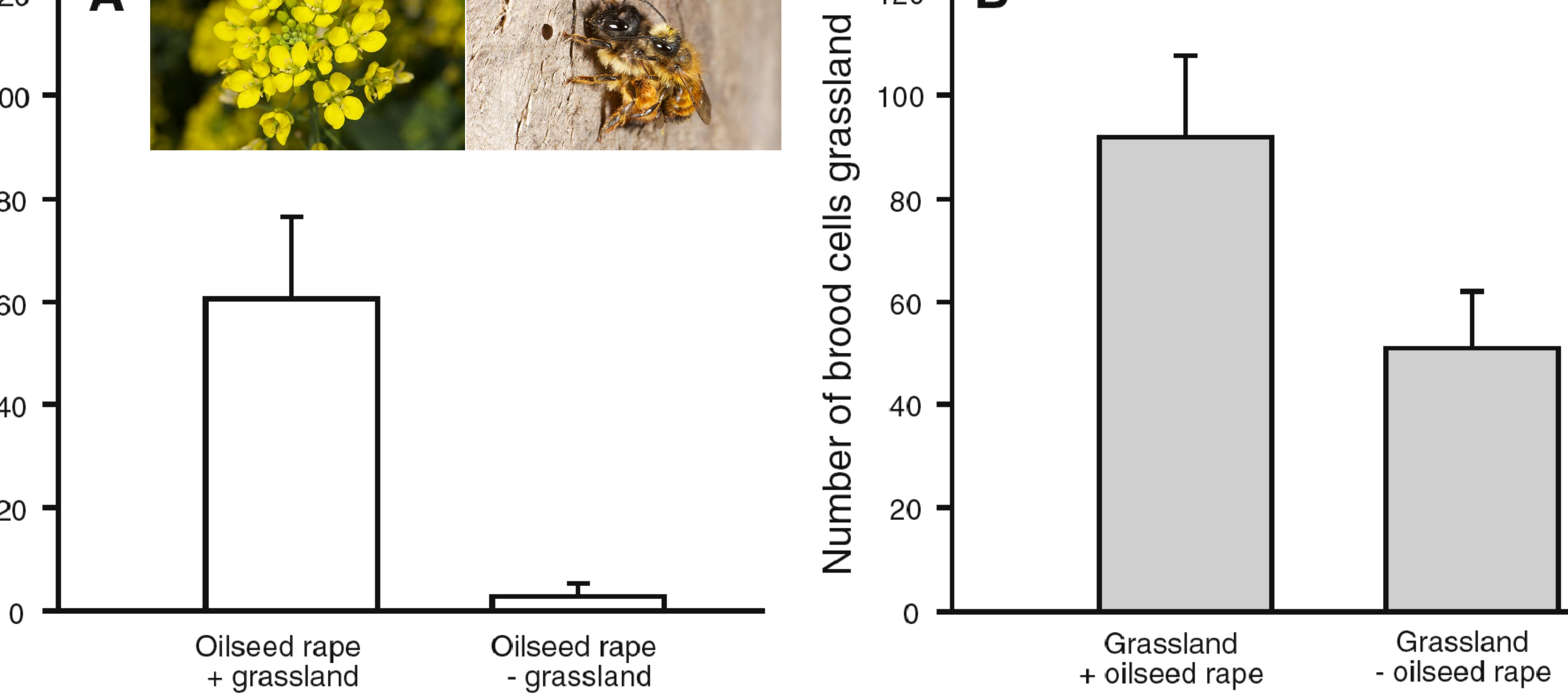
Le **Pois vivace** ou **gesse à larges feuil** *latifolius*) est une légumineuse vivace grimpante qui peut former des bu florifères atteignant 3m de hauteur. C'e très visitée par les abeilles à langue long mégachiles et les bourdons, et on y ob l'abeille charpentière *Xylocopa violacea*.

J	F	M	A	M	J	J	A	S

La **Callune** ou **bruyère commune** (*Call* est une plante vivace et arbustive qui p 50cm de hauteur sur des terrains acide et bien drainés. Sa floraison estivale ressource importante à la fin de la sai nombreuses abeilles sauvages, et c'est n plante-clé d'*Andrena fuscipes* et de *Collet*

J	F	M	A	M	J	J	A	S

Combining a **mass-flowering crop** and **semi-natural habitats** to enhance wild bee abundance



Holzschuh et al. (2013) Oecologia 172: 477-484

he probability that the bee *Osmia bicornis* colonized trap nests in oils
ape fields increased from 12 to 59 % when grassland was nearby

n grasslands, the number of brood cells of *O. bicornis* in trap nests ngle-species bee management is a common practice in agricultural productio

his approach fails to build up **RESILIENCE** in commercial farms

** Single pollinators are vulnerable to pathogens, diseases & predators*

** Species-rich communities of pollinators significantly increase yield*

** Species-rich ecosystems provide a wider array of ecosystem services*

groecological practices embracing biodiversity should be encouraged in west
urope to sustain the development of wild bee communities in orchards

AIN ISSUE = locally fulfilling the ecological requirements of wild bees, particul
eir alternative pollen/nectar host plants

BIOETHICS A call to regulate human embryos made for research p.27

HISTORY The fitful release of Newton's papers p.30

SPACE Cooperation is needed to safeguard the final frontier p.32

POLICY Scotland's resear say that they benefit fr being part of the UK p.3

UK farmers in the Duchy Originals Future Farming Programme.

Engage farmers in researc

A new wave of small-scale agricultural innovation will boost yields and protect the planet, contend **Tom MacMillan** and **Tim G. Benton**.

Climate change threatens a creaking food system in which harvests are already lagging behind rising demand[1,2]. A sustainable supply of food hinges on agricultural innovation, but current investments neglect a key area for improving yields.

Since the 1970s, agricultural research and development (R&D) has invested mainly in a few research institutes equipped with cutting-edge instruments. For example, the Biotechnology and Biological Sciences Research Council, responsible for much of the public research spending in food security in the United Kingdom, invested 27% of its 2010–11

global crop yields increased by 56% between 1965 and 1985, and by 20% from 1985 to 2005, underpinned by increasing inputs of non-renewable resources.

But advances are slowing. According to a 2013 study[4], yields have plateaued in some of the world's most important food-producing regions, including east Asia (for rice) and northwest Europe (for wheat). In some countries, yields have declined.

The next wave of innovation must be at smaller scales. What one farmer can do to boost yield or efficiency is not necessarily the same as for a farmer hundreds of kilometres away with different soil, micro-

flowing from institute to farm n complemented by local knowledge.

Enhancing farmers' own R&D co big rewards for minimal extra cost ers everywhere are practical expe talists who understand the idiosyn of their land[5]. Modern agronomy out of practices such as rotating c rebuild soil nutrients, fertilizing fie manure, and adding lime to soil to a Even technologies not invented by — new kit, seeds or chemicals — are by them to fit their circumstances.

Such essential contributions ar recognized in official assessments

MACMILLAN & BENTON

ngle-species bee management is a common practice in agricultural productio

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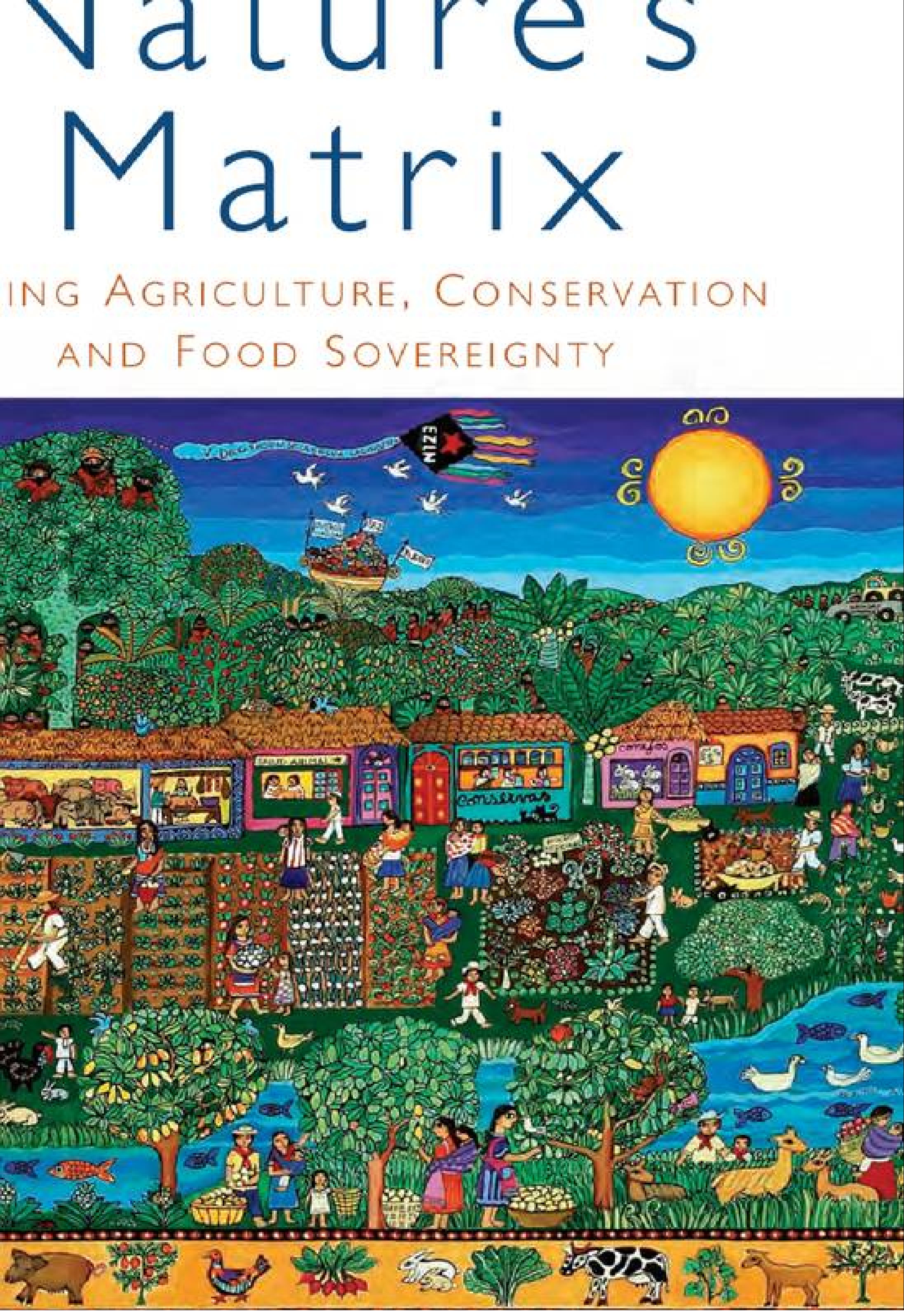
AIN ISSUE = locally fulfilling the ecological requirements of wild bees, particul eir alternative pollen/nectar host plants

oosting populations of wild bees will benefit agriculture and ecosystems, a "w n" solution for many who still think that agriculture should be disconnected fr ature



PNAS

Ivette Perfecto[a,1] and John Vandermeer[a,b]

[a]School of Natural Resources and Environment and [b]Department of Ecology and Evolutionary Biology, University of Michigan,

Edited by Richard Levins, Harvard University, and accepted by the Editorial Board January 29, 2010 (received for review May 18

Among the myriad complications involved in the current food crisis, the relationship between agriculture and the rest of nature is one of the most important yet remains only incompletely analyzed. Particularly in tropical areas, agriculture is frequently seen as the antithesis of the natural world, where the problem is framed as one of minimizing land devoted to agriculture so as to devote more to conservation of biodiversity and other ecosystem services. In particular, the "forest transition model" projects an overly optimistic vision of a future where increased agricultural intensification (to produce more per hectare) and/or increased rural-to-urban migration (to reduce the rural population that cuts forest for agriculture) suggests a near future of much tropical aforestation and higher agricultural production. Reviewing recent developments in ecological theory (showing the importance of migration between fragments and local extinction rates) coupled with empirical evidence, we argue that there is little to suggest that the forest transition model is useful for tropical areas, at least under current sociopolitical structures. A model that incorporates the agricultural matrix as an integral component of conservation programs is proposed. Furthermore, we suggest that this model will be most successful within a framework of small-scale agroecological production.

food crisis | biodiversity | fragmented landscapes | matrix quality | small-scale farmers

The current food crisis calls attention to the need for construction of sustainable ecosystems more generally. As Robert Watson, the cochair of the International Assessment of Agricultural Knowledge, Science and Technology for Development (IAASTD) stated in a press conference when the report was released in 2008, "Business as usual is not an option." Although the particulars are variable, the underlying sense is clear—the *longue durée* of economic, social, and political development in which environmental variables are regarded as externalities has come to a close. Within this awakening, the loss of biodiversity is regarded as one of the more important environmental issues related to both sustainability and food production. With extinction rates currently at greater levels than natural background, some have suggested that we are in the midst of another mass extinction comparable to the one that occurred at the end of the Cretaceous (1), except this time it is driven by humans rather than a natural catastrophic event, and the major human activity involved is agriculture, which clearly links the biodiversity crisis with the current food crisis.

In this article, we focus on one aspect of these crises—the debate about the application of the traditional forest transition (FT) model to the tropics in general, a debate that has subtle but important relations with the world food system. We contrast this model with what we refer to as the "matrix quality" model, in which agriculture is seen as an intimate and inextricable component of the biodiversity conservation agenda.

The Forest Transition Model

The European colonization of eastern North America began with massive deforestation that accompanied the expansion of agriculture. But then, through industrialization and the urbanization that accompanied it, agriculture declined and forests returned (2).

The dynamics that drove this process are
itative level—wealth from agriculture drive
that, in turn, acts as a magnet for labor,
countryside, leaving natural succession to
general view has many complications tha
and sociopolitical dynamics, as an over
American forest history it seems historicall
referred to as the "forest transition mod
cesses have been described for some Euro
rural U.S. South (6), and, most import
location, Puerto Rico (7–10). Based on t
some have proposed that the FT model co
understanding tropical landscape dynamic
used for promoting a conservation agenda

Although the argument is usually mad
itative sense, there is an underlying quant
the conclusions. Understanding that log
standing exactly where the argument is w

Consider a defined land area of total
portion that is agricultural (a) and ano
servation (c); p represents the units of pr
unit area), N_L is the local (rural) populat
energy requirements of a single person.

$$pa = N_L e, \text{ or}$$

$$a^* = N_L e/p,$$

which suggests that we can minimize a^* b
maximizing p (assuming e will always re
most simplistic level, this is the land-spar

The argument is elementary, based
suggesting that there are basically two s
forces in operation: first, a spatial concen
tion of agricultural production and, second
population to industrializing urban center
forces reduce the demand for cropland,
farmlands and leading to recovery of
become common and is sometimes taken a
worthy of paradigmatic status for conserv

Obvious complications arise with only
the population that must be serviced by ag
example, that the total population, N_T, co
rural population, N_L, and the urban po
ulation not involved in agricultural prod
products of agriculture), N_U; in other w
Modifying Eq. **1**, we have $a^* = e(N_L +$

Author contributions: I.P. and J.V. designed research, per
and wrote the paper.

The authors declare no conflict of interest.

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See Commentary article on page 5697.

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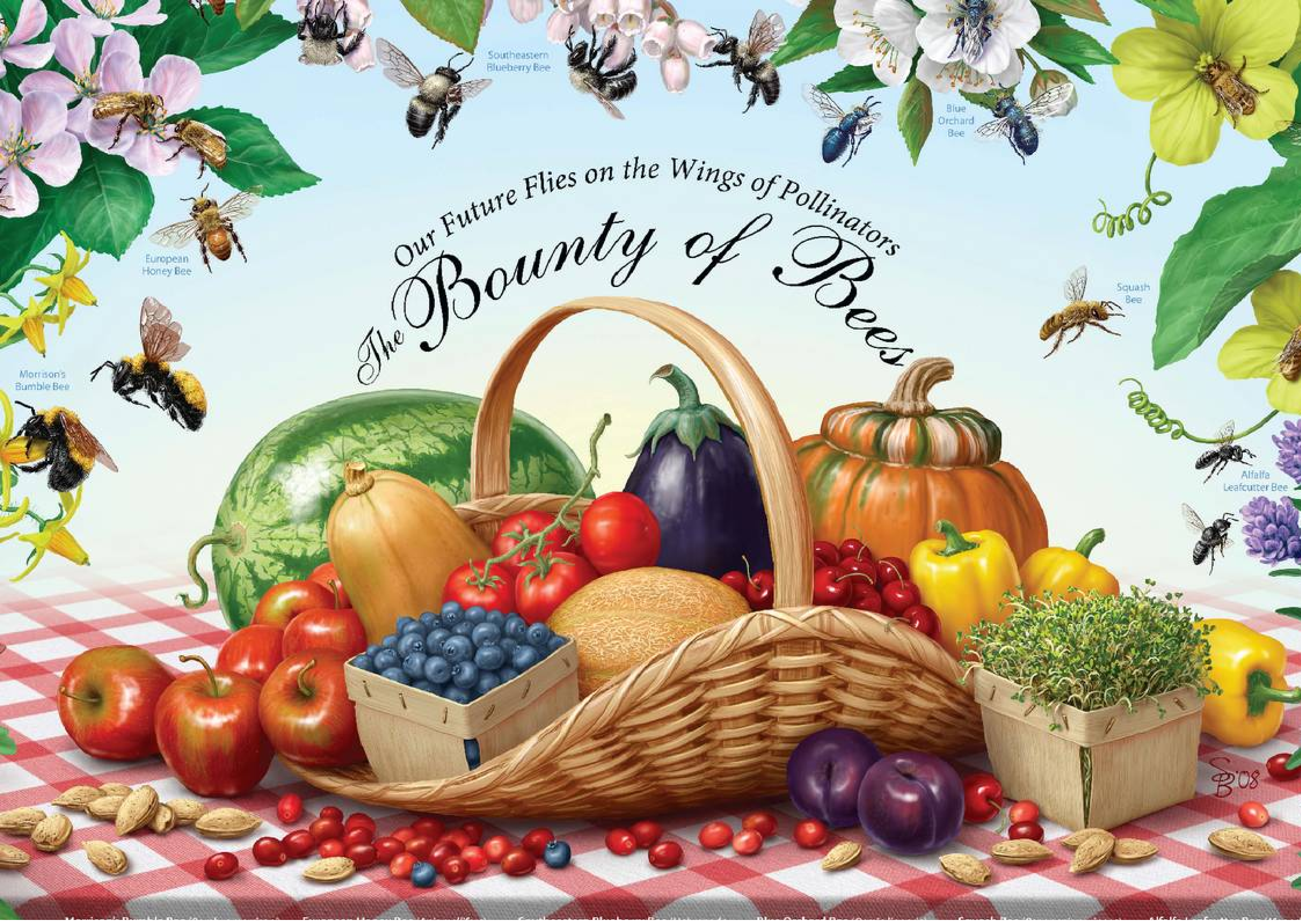
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pollination in orchards?

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