Quessa project Final report figures, tables and mathematical equations.

Figures

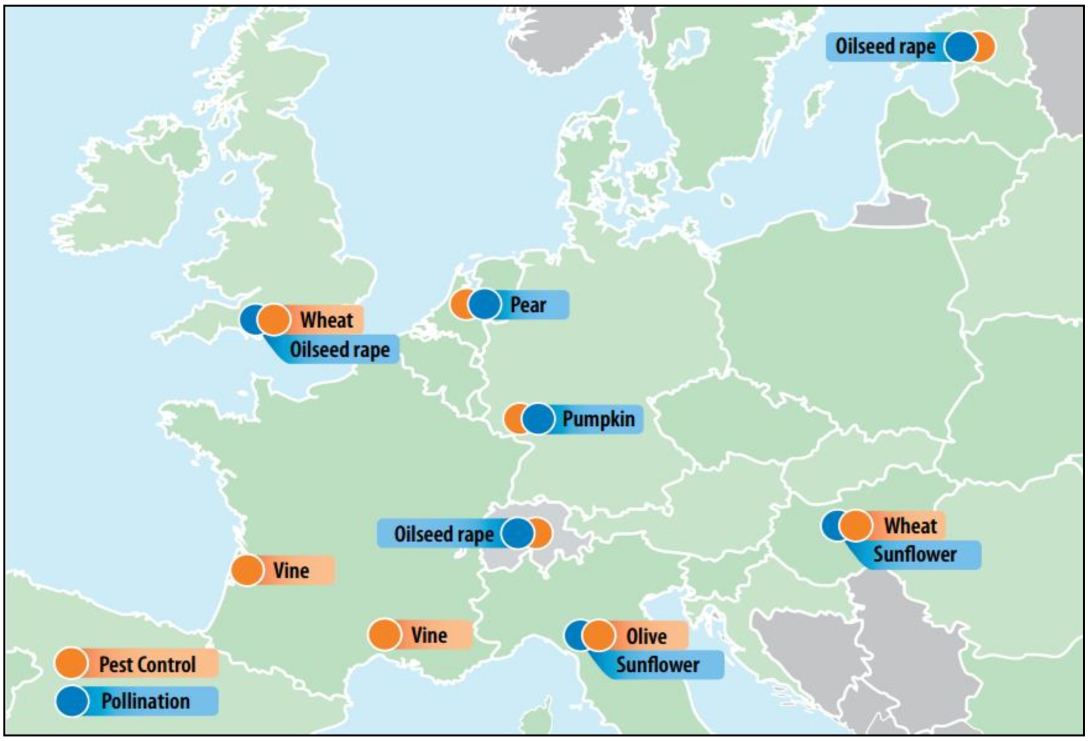


Figure 1. QuESSA Case Studies across Europe (Sites shown in orange have pest control measurements; sites shown in blue have pollination measurements)

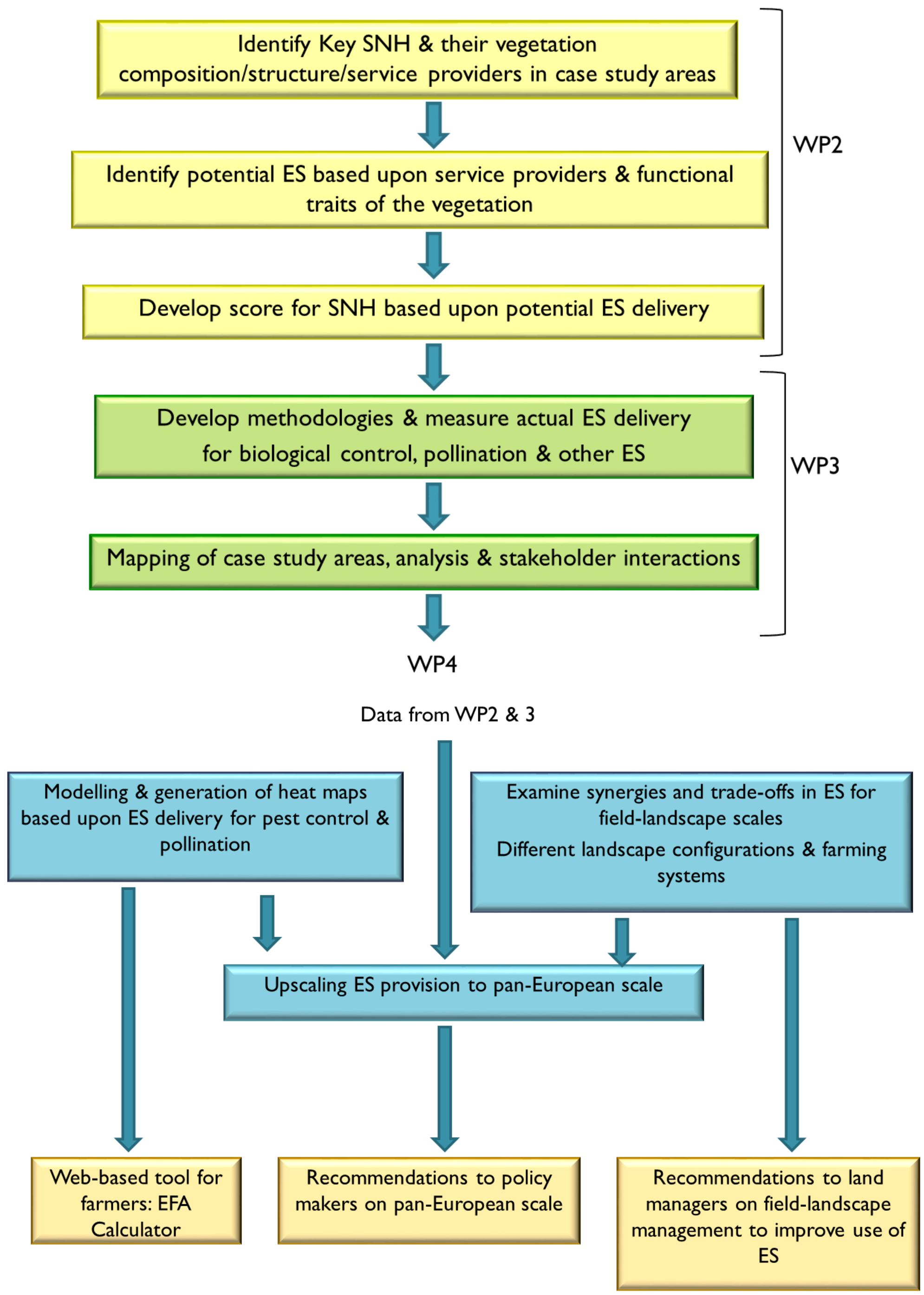


Figure 2. QuESSA Project structure and main information flows

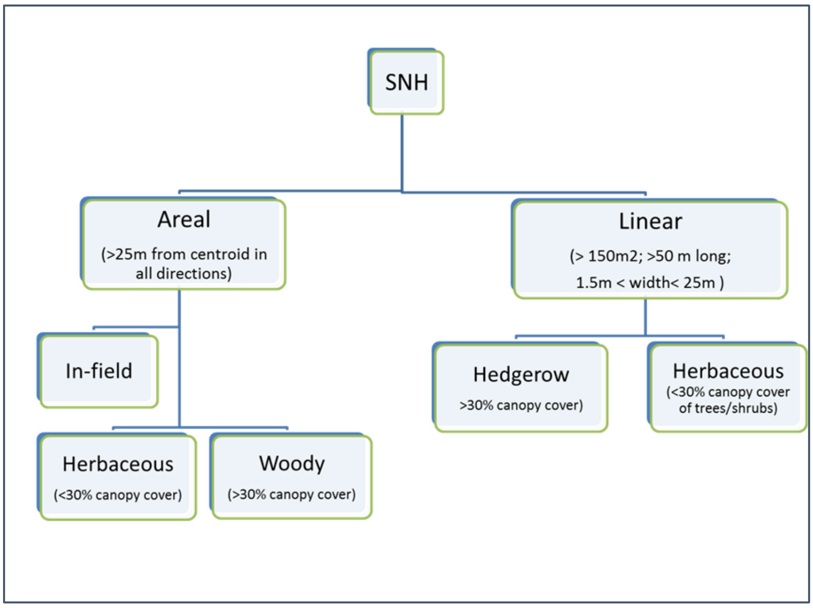
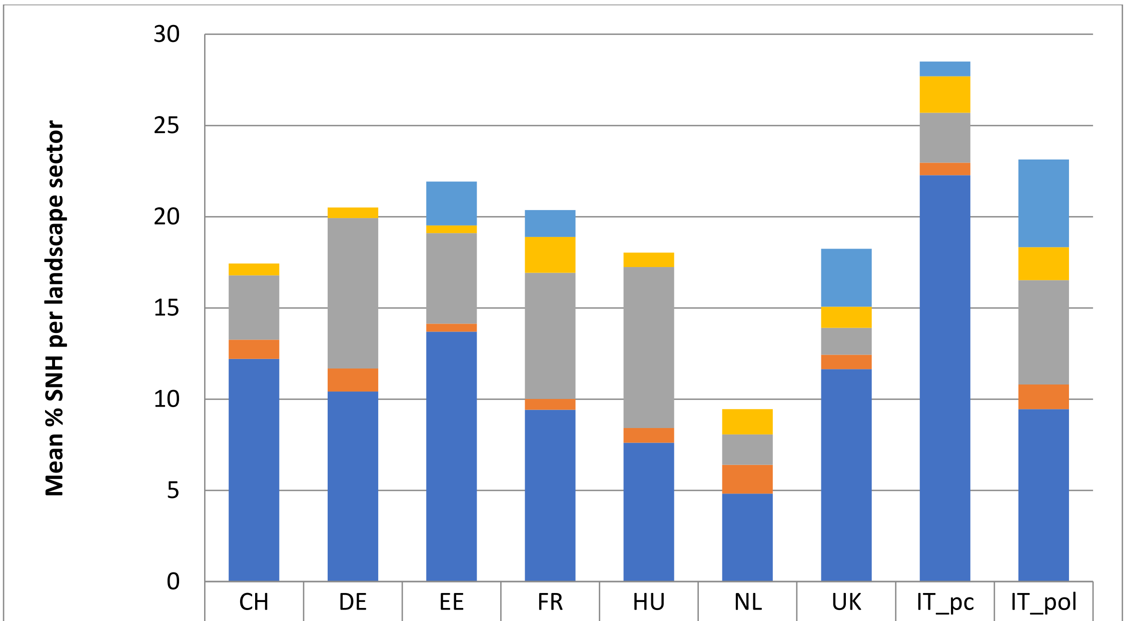


Figure 3. Semi-natural habitat classification resulting in five main SNH types based on shape and vegetation structure: FA, in field fallow; HA, herbaceous areal; WA, woody areal; HL, herbaceous linear; WL, woody linear.



	CH	DE	EE	FR	HU	NL	UK	IT_pc	IT_pol
St. dev FA	0.00	0.00	2.39	1.47	0.00	0.00	3.17	0.82	4.81
St. dev HL	0.65	0.58	0.42	1.98	0.78	1.38	1.16	1.99	1.82
St. dev HA	3.52	8.25	4.98	6.90	8.82	1.66	1.48	2.73	5.71
St. dev WL	1.07	1.27	0.43	0.61	0.81	1.59	0.78	0.69	1.35
St. dev WA	12.20	10.41	13.69	9.41	7.62	4.82	11.65	22.27	9.45

Figure 4. Mean percentage land cover and standard deviation in the 18 landscape sectors of 2014 for the 5 SNH types (woody areal - WA, woody linear - WL, herbaceous linear - HL, herbaceous areal - HA and fallow land – FA) in the eight QuESSA case study countries.

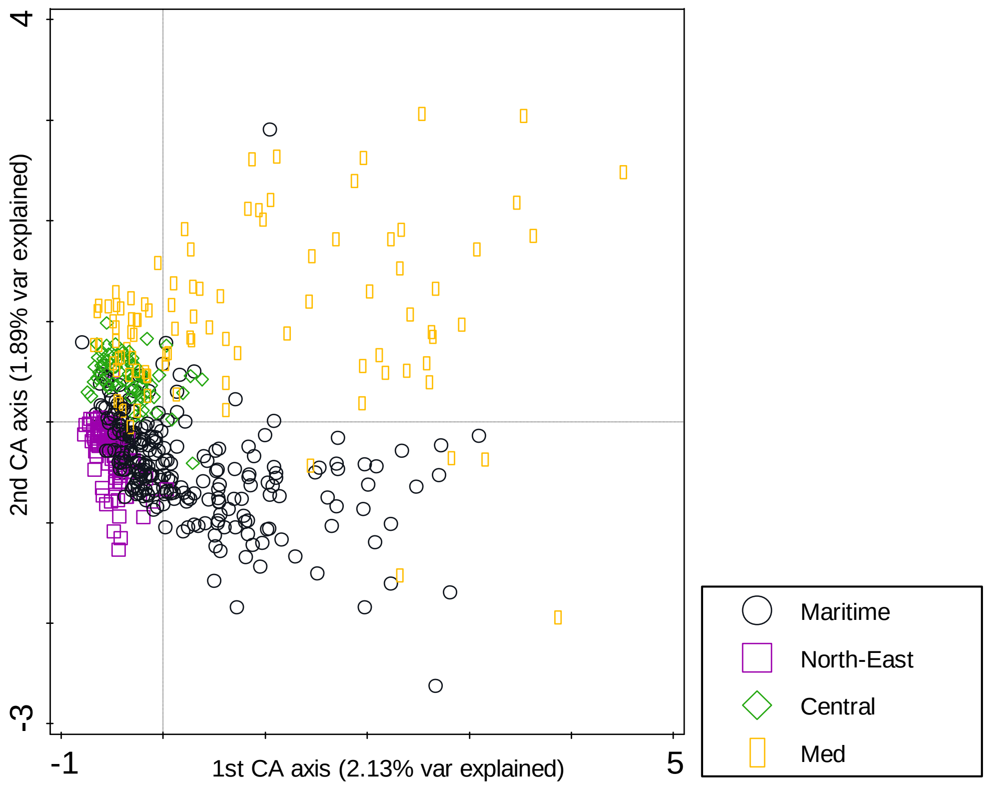


Figure 5. CA of 355 SNH based on plant genera. In the CA the Italian olive grove sites (IT-OLI) were made supplementary because species composition was so different that it eliminated all differences between the remaining sites. Different colours represent the four agro-climatic zones the case study areas belong to following Bouma (2005).

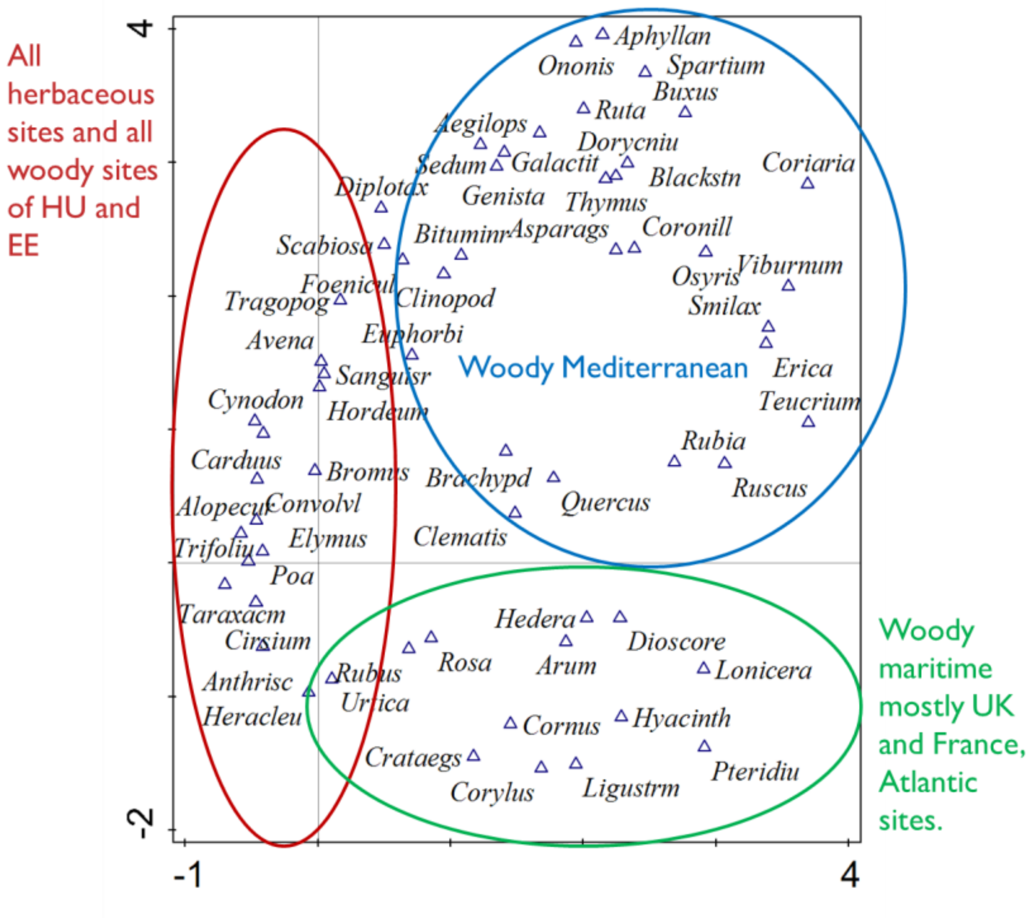


Figure 6. CA of 355 SNH based on plant genera. In the CA the Italian olive grove sites (IT-OLI) were made supplementary because species composition was so different that it eliminated all differences between the remaining sites. The coloured circles indicate the position of SNH types from different agro-climatic zones.

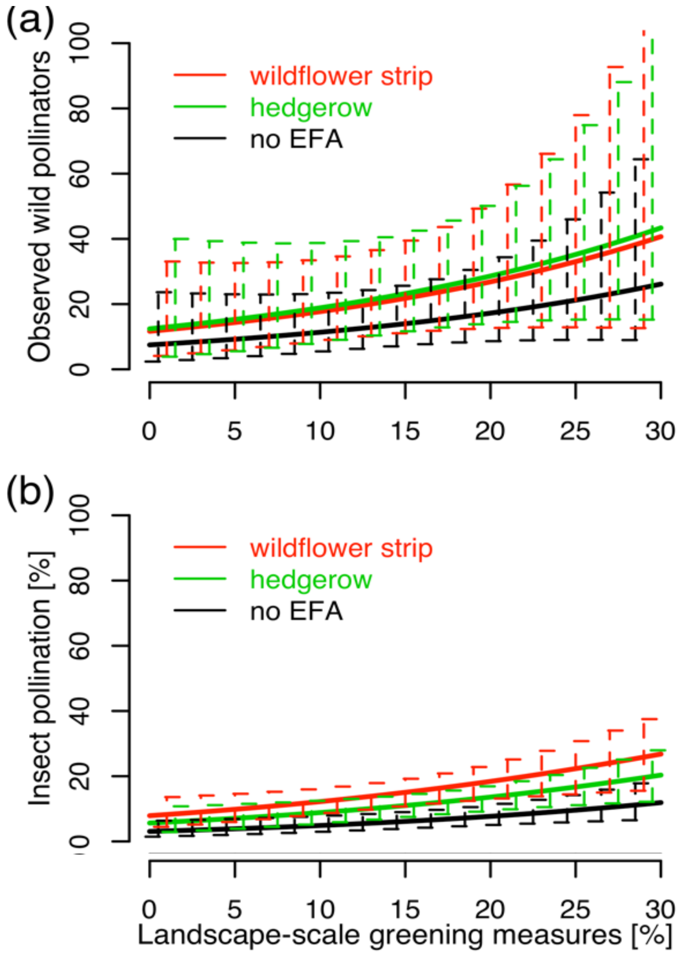


Figure 7. Swiss case study on oilseed rape showing effects of landscape-scale greening measures and adjacent EFA (wildflower strip (red), hedgerow (green), and no EFA (black)) on (a) number of observed wild pollinator, (b) increase of seed set driven by insect pollination (%). Predicted values ± 95% confidence interval for the investigated gradient (6–26%) of landscape-scale greening measures (n = 18 fields). Where no differences between adjacent habitat types occurred, only the average values for all three habitat types is shown (from Sutter et al. under revision in Journal of Applied Ecology).

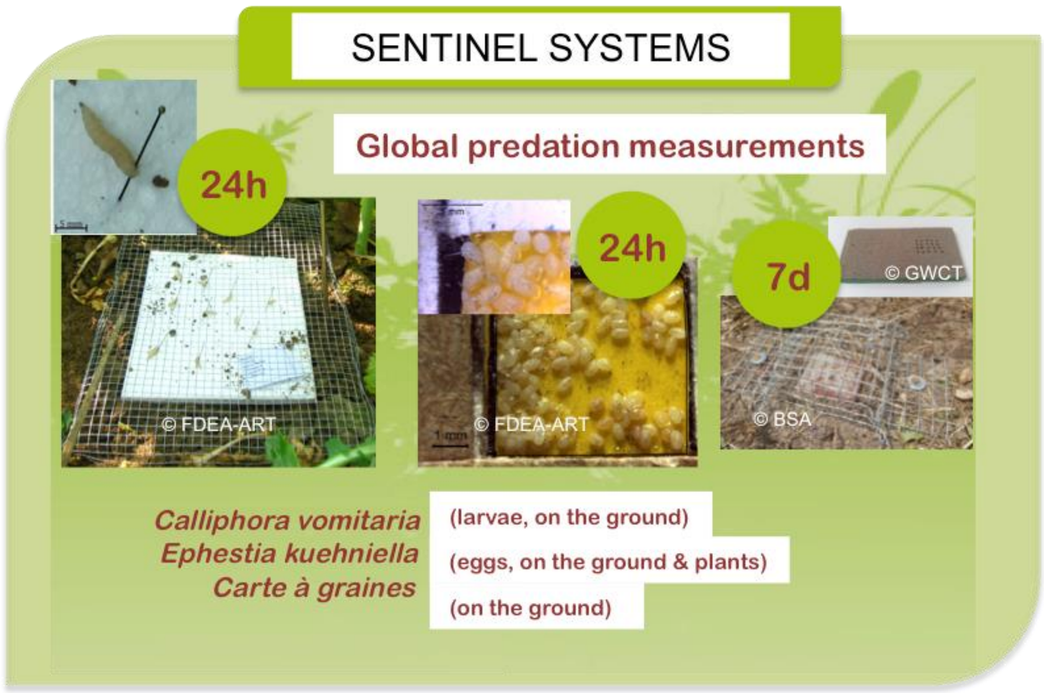


Figure 8. Sentinel systems were used in fields to confirm the presence of predators and estimate the general predation.

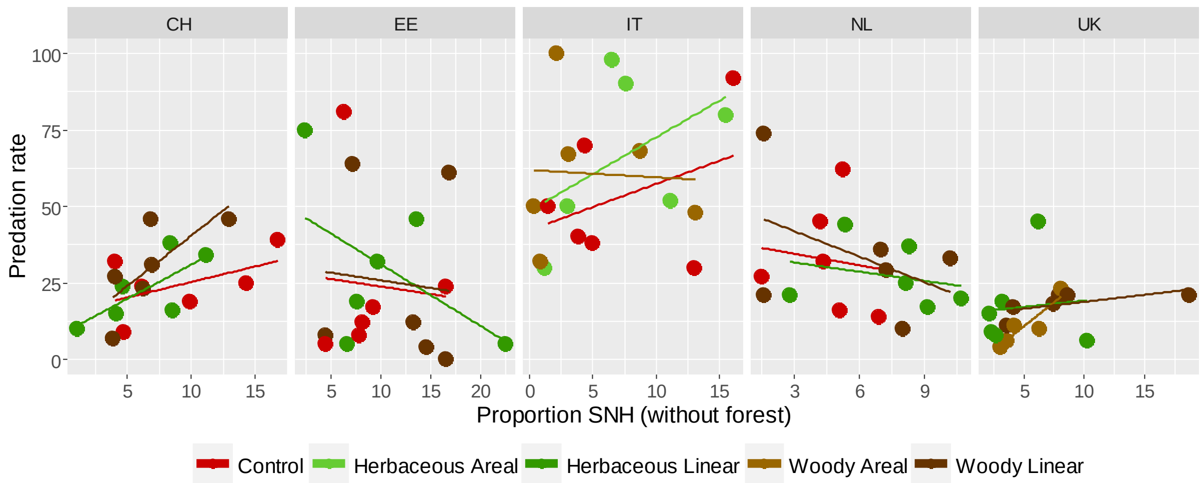


Figure 9. Except for the predation rate of the pollen beetle in the Swiss oilseed rape fields, no significant impact of the SNH proportion around crop fields (1 km radius) could be demonstrated in the case studies. Case studies: CH = Switzerland, EE = Estonia, IT = Italy, NL = The Netherlands, UK = United Kingdom.

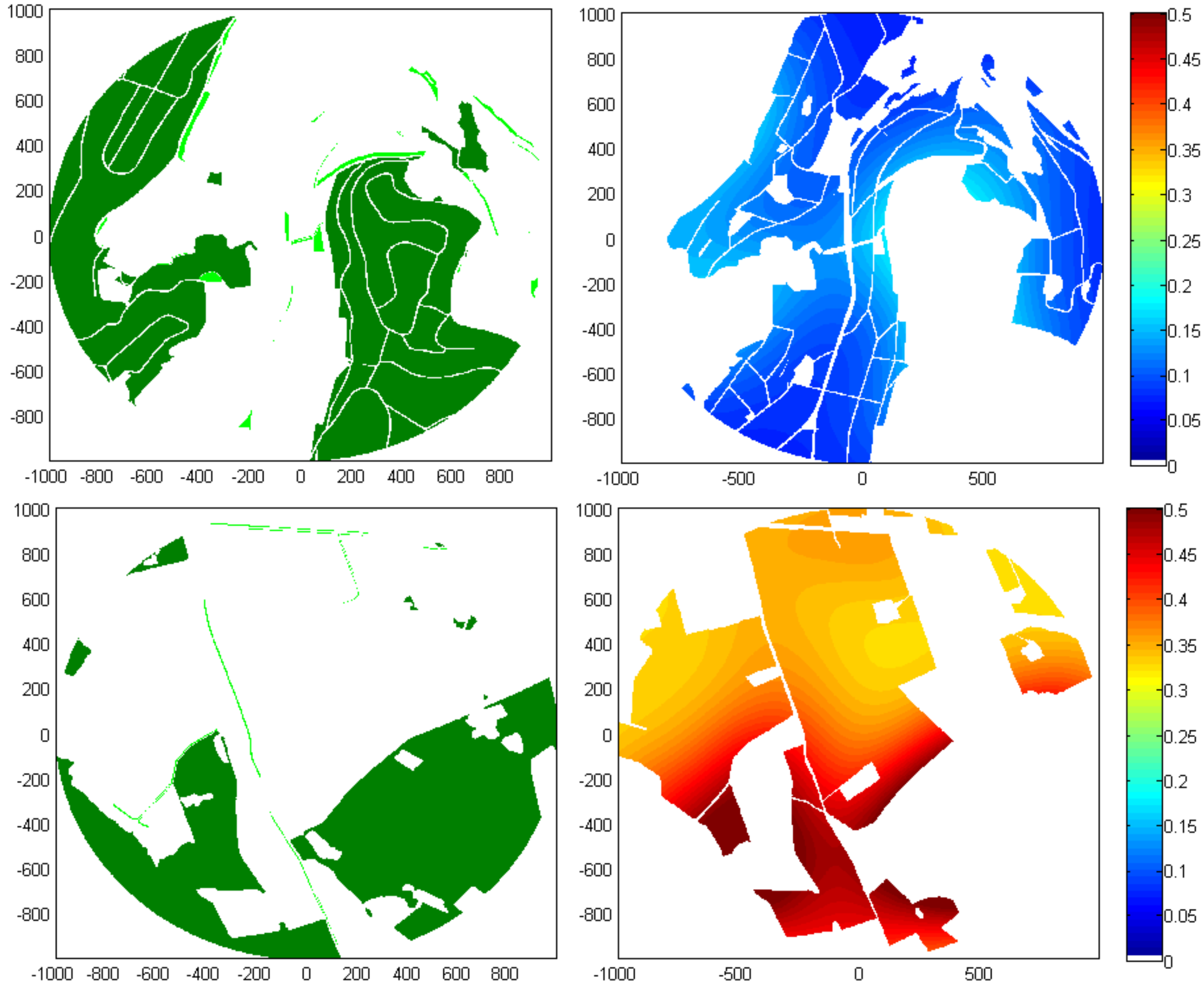


Figure 10. Predicted effect of herbaceous linear elements (light green) and forest (dark green) in a landscape sector of Switzerland (top left) and a landscape sector of Estonia (bottom left) on larval parasitism rates (proportion) of the rape pollen beetle in agricultural fields, taking into account the differences in basic parasitism rates between Switzerland (top right) and Estonia (bottom right). The colour bar depicts the range of the predicted parasitism rates and is expressed in units of proportion parasitization.

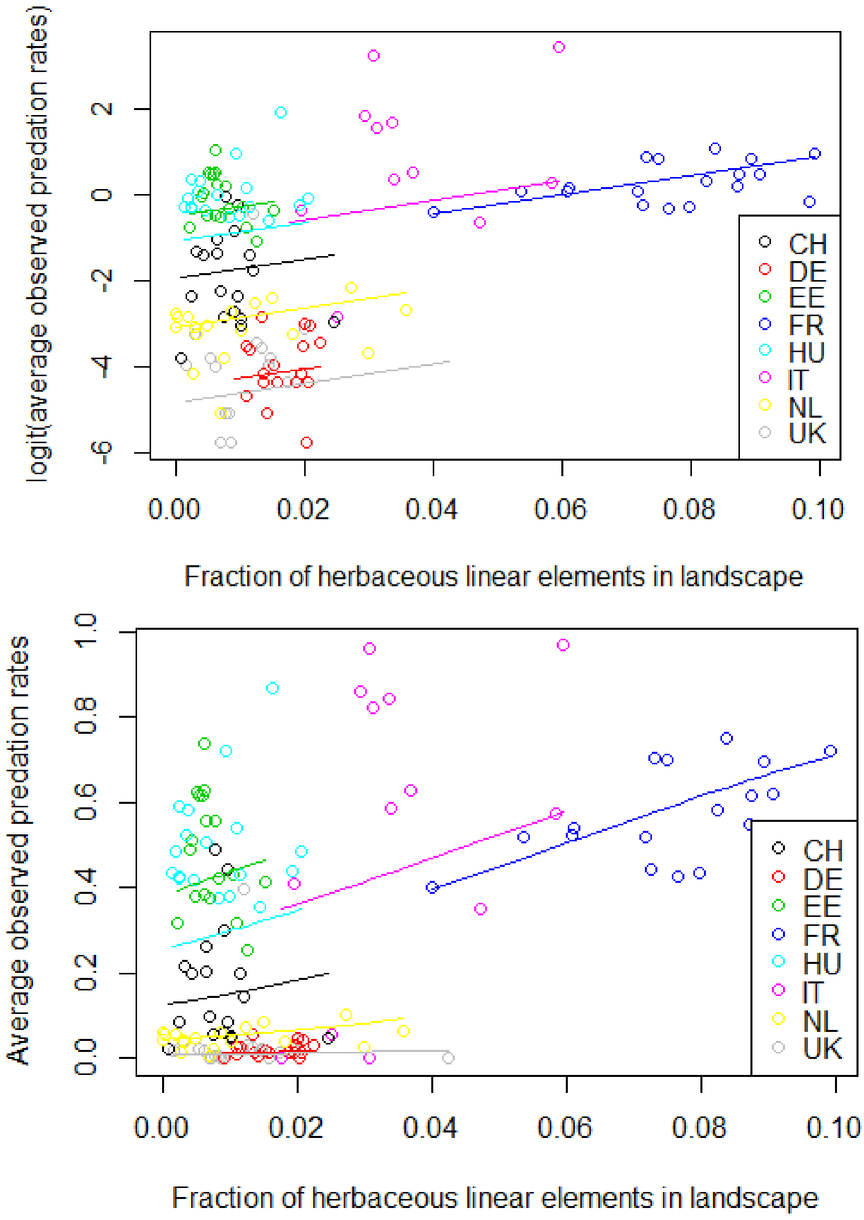


Figure 11. Variation in the relationship between predation on the seeds of Rough-meadow grass, *Poa trivialis,* and the proportion of herbaceous linear elements in the landscape. The figure exemplifies the large variability in predation rate between case studies that is not explained by landscape factors. Panel a shows data (open circles) and fitted relationship using a logit scale to plot predation proportion. The bottom panel has predation rate back transformed to the original proportion scale of measurement.

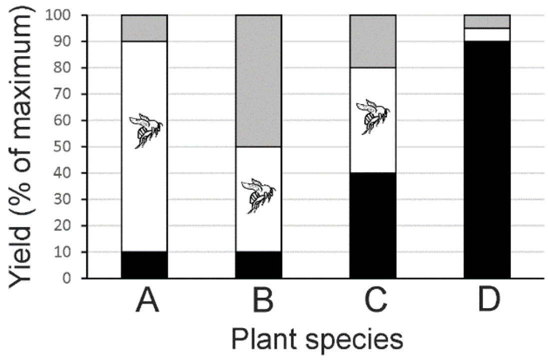


Figure 12. Pollinator dependence and pollination deficits in four hypothetical crop species, A, B, C and D. In each column, black fill indicates the percentage of maximum yield that is achieved in the absence of visits by animal pollinators. Open fill indicates the realised contribution of insects to yield under ambient conditions (denoted ΔY_{insect}) and grey fill indicates unachieved yield, or the pollination deficit (denoted ΔY_{open}). In this case, crop A has received the greatest contribution from animal pollinators (ΔY_{insect} = 80%) and B has the highest deficit (ΔY_{open} = 50%) and would benefit most from more frequent pollinator visits. If we assume that a saturating level of pollination is delivered by hand-pollination, the difference in yield between open-pollinated and hand-pollinated flowers estimates the pollination deficit. Using standard nomenclature (Klein et al. 2007), crops A and B are 'highly' pollinator-dependent, C has 'modest' dependence, and D has 'little' dependence.

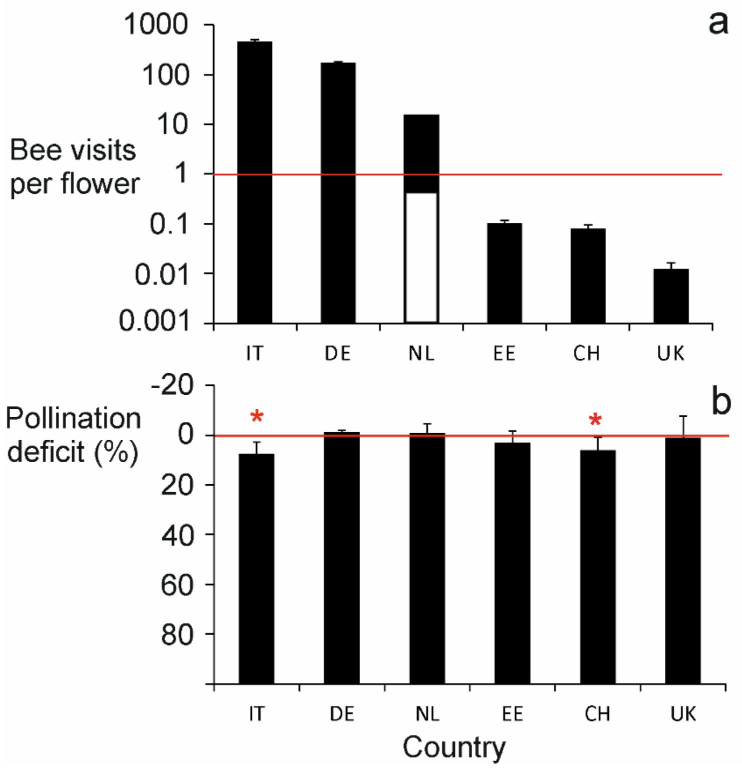


Figure 13. Rates of visits to flowers by eusocial bees (a) and pollination deficits (b) in bee-attractive crops in six European countries. Key to countries and crops:- IT: Italy (sunflower); DE: Germany (pumpkin); NL: Netherlands (pears); EE: Estonia (oilseed rape); CH: Switzerland (oilseed rape); UK: United Kingdom (oilseed rape);.

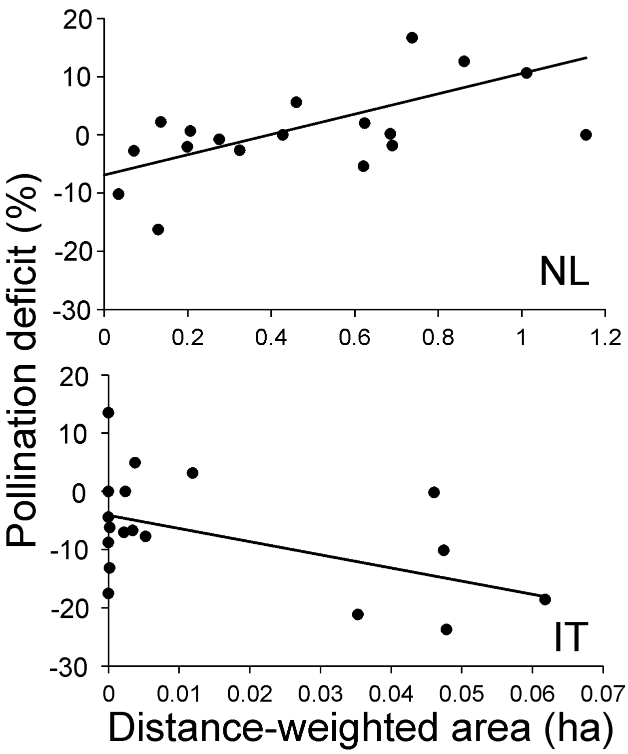


Figure 14. Site-to-site variation in pollination deficit (relative yield of open-pollinated and fully-pollinated flowers) in pear orchards in the Netherlands (upper panel: NL) and sunflower fields in Italy (lower panel: IT) in relation to the distance-weighted area (ha) of woody linear features in the surrounding landscape up to 1 km radius.

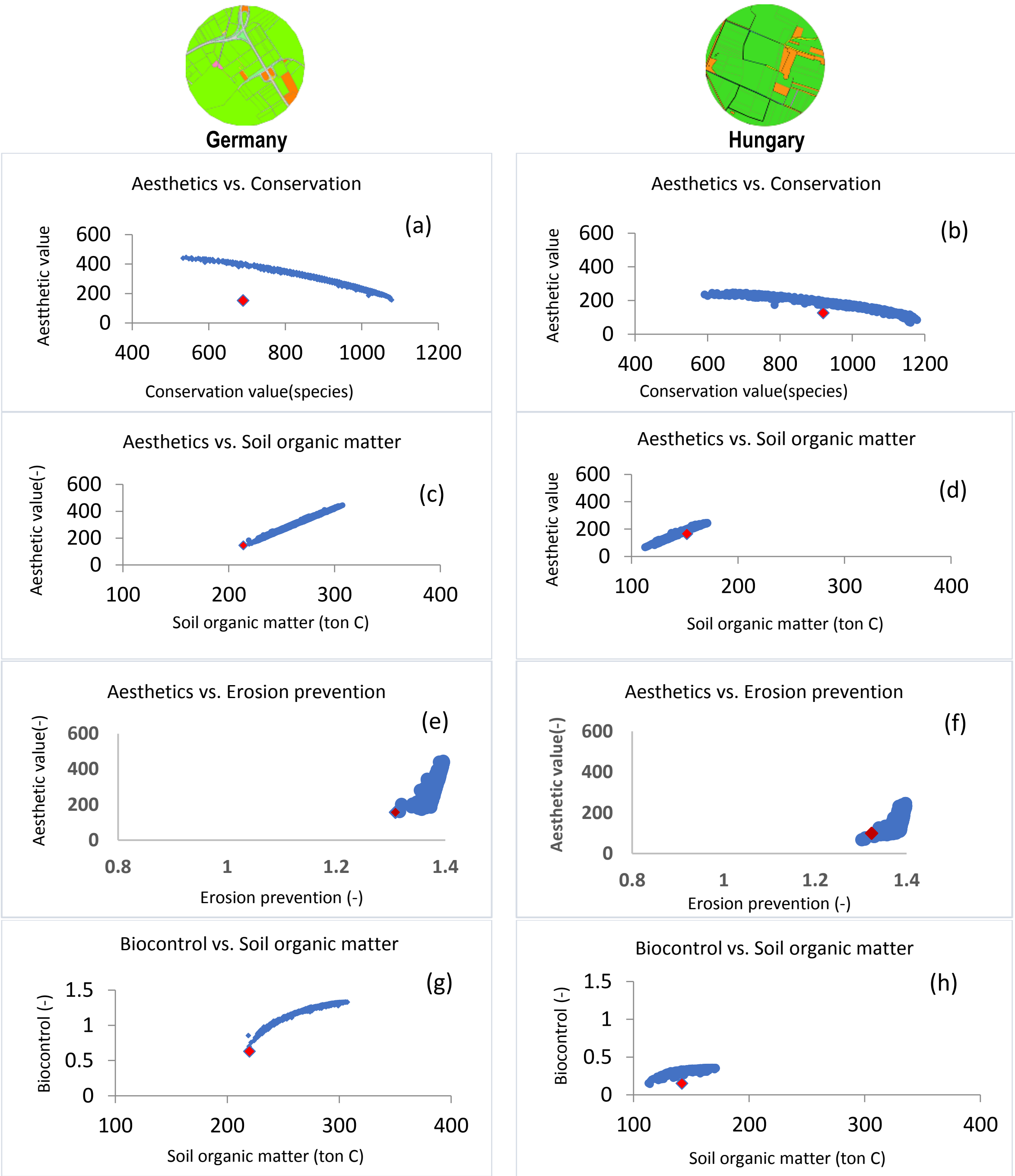


Figure 15. Trade-off/synergy curves for five ecosystem services in the German (left) and the Hungarian case study (right). The red diamonds show the ecosystem service provisioning level of the current landscape configuration, while blue dots show ecosystem service provisioning levels for alternative (Pareto-optimal) landscape configurations.

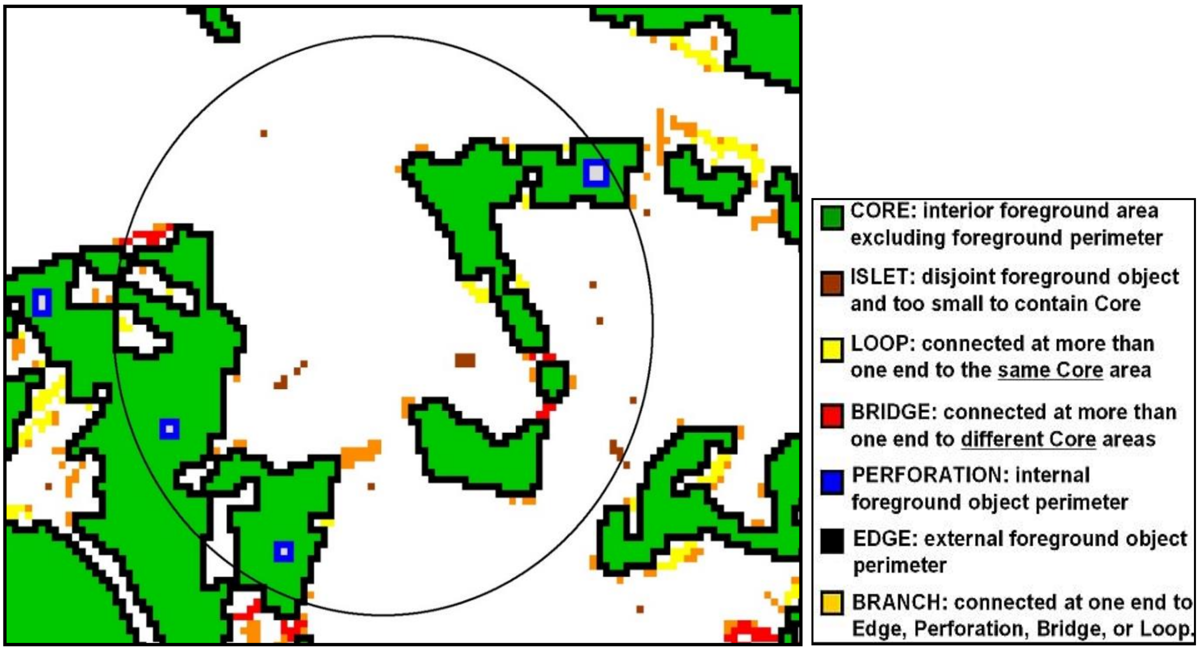
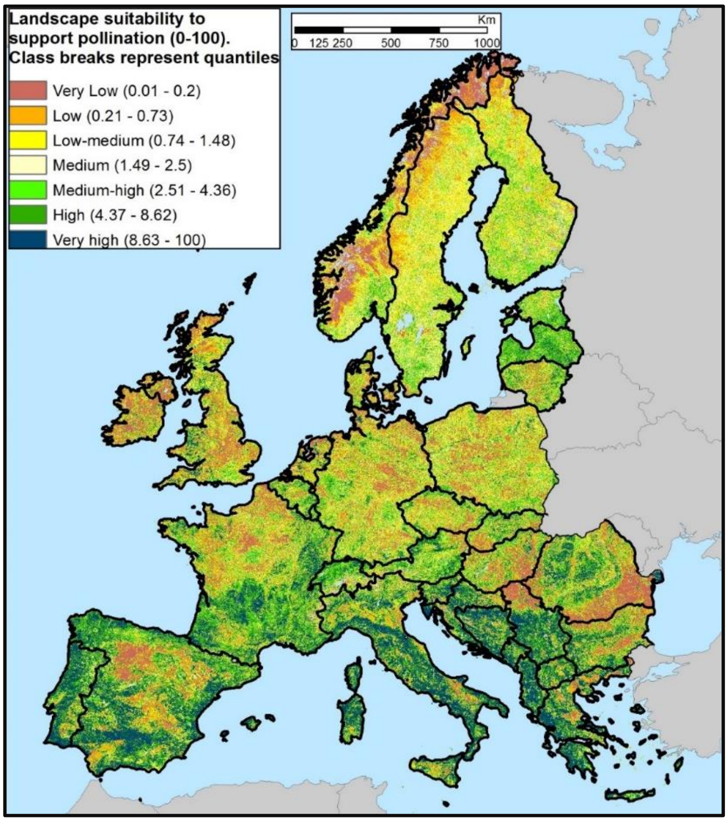


Figure 16. Example of Morphological spatial pattern analysis in a QUESSA landscape sector (black circle, 1 Km radius) to identify core (green) and edgy (black) woody areal SNH and Woody linear features (other colours) in agricultural land.

a)



b)

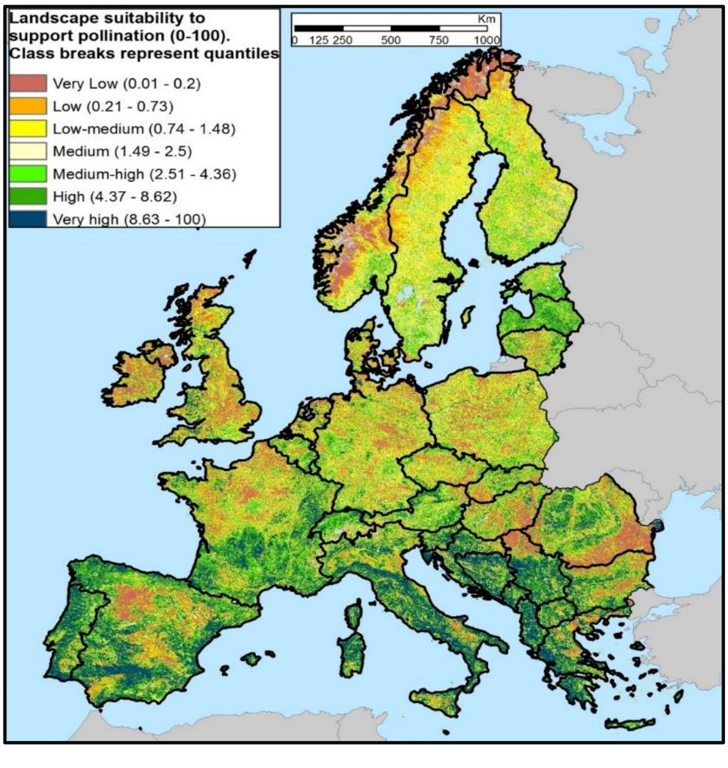


Figure 17. a) The potential of the landscape to provide pollination by wild bees **b)** the potential abundance of beneficial flying predators providing pest control in agricultural land. The values are expressed on a 0-100 scale and represent an index score.

Tables

Table 1. Qualitative summary table of all investigated country-crop-ecosystem service combinations of QuESSA. (+ = SNH increases the ecosystem service, **-** SNH reduces the ecosystem service, 0 = no effect of SNH on ecosystem service detected, NA = data not available / not measured, values in brackets show effects on service providers if no effect on ecosystem service was found)

ES	cty	investigated crop	Proportion SNH in the surrounding landscape	locally bordering SNH			interaction LS x adj
				WL/WA	HL/HA	others?	
pollination	CH	oilseed rape	+	+	+	NA	+
pollination	UK	oilseed rape	0	0	0	NA	0
pollination	IT	sunflower	WL+ HA-	-	+	NA	0
pollination	DE	pumpkin	+	+	+	NA	0
pollination	EE	oilseed rape	0	(+)	(+)	NA	0
pollination	NL	pear	0	0	0	NA	0
pollination	HU	sunflower	0	0	0	NA	0
pest control	CH	oilseed rape	+	0	0	NA	0
pest control	UK	wheat	HA + WL/WA	-	+	NA	0
pest control	IT	olive	0	0	0	garrigue +	0
pest control	DE	pumpkin	0	0	0	NA	0
pest control	EE	oilseed rape	+	0	+	NA	0
pest control	NL	pear	0	0	0	NA	0
pest control	HU	wheat	0	0	0	NA	0
pest control	FR	vine	0	0	0	NA	0
Landscape aesthetic	EU	diverse	+	+	+	NA	0
Soil erosion	FR	vine	0	0	0	NA	0
Soil fertility	EE	oilseed rape	0	+	+	NA	0
Soil fertility	FR	vine	0	+	+	NA	0
Soil fertility	HU	wheat	0	0	0	NA	0
Carbon sequestration	UK	wheat	NA	+	+	WA+	NA
Carbon sequestration	HU	wheat	NA	+	+	WA+	NA
Carbon sequestration	EE	oilseed rape	NA	+	+	NA	NA
Biodiversity conservation	DE	pumpkin	0	+	+	NA	0
weed invasion	IT	sunflower	0	-	-	NA	0
weed invasion	HU	sunflower	0	-	-	NA	0
Bird damage	NL	pear	0	(+)	0	NA	0

Table 2. Land uses that affect *Poa* predation in each case study. Results are based on model selection with dredge in *R* for the optimal length scale *u* of the kernel model (Eq. 1) and the set of at maximum 3 land uses that can explain the observed predation rates the best (selection based on lowest AIC). Land uses written in green increase *Poa* seed predation, whereas land uses written in red decrease *Poa* seed predation. Estimates for α are marked red if the resulting basic predation level is smaller than 0.5 and green when the resulting basic predation rates are larger than 0.5 (high basic predation). The optimal length scale *u* is marked with a dash if there was no effect of distance within the 1 km radius. SNH are in bold.

Case study	Key habitats			α	*u*	AIC
Estonia		wheat		-0.4	-	186.2
France M.	**in-field SNH**		orchards (vineyard)	-1.2	400	172.7
Germany			orchards	-4.1	200	105.3

Hungary		wheat	roads	-1.4	-	183.3
Italy	**herbaceous linear**	wheat		-7.7	500	124.7
Netherlands	**herbaceous linear**	maize	roads	-2.6	200	116.3
Switzerland	**herbaceous linear**	**forest edges**	grasslands	-0.4	100	175.6
UK	**forest edges**	maize	grasslands	-4.9	50	104.6

Table 3. QuESSA Impact categories

Impact category	Units
Soil erosion	Tonnes of soil per hectare (t ha^{-1})
Pollinators	Functional Plant Cover Index pollinators (FPCIpoll)
Pest control	Functional Plant Cover Index pest control (FPCIpest)
Aesthetics	Landscape attractiveness (unitless)
Carbon sequestration	Tonnes of carbon per hectare (t C ha^{-1})
Habitat diversity	Shannon index of SNH diversity

Equations

Equation 1

$$K_{2Dt}(r) = \frac{\nu-1}{2\pi\nu u^2}\left(\frac{\nu u^2}{\nu u^2+r^2}\right)^{\frac{1}{2}(\nu+1)}$$

Where:

r is the distance from the source (m)

u is the length scale (m)

ν is a number ("degrees of freedom") that determines the fatness of the tails

Equation 2

$$A_j^* = \sum_{i\in j}\left[ae^{-\left(\frac{r_i}{\alpha}\right)}\right]$$

Where:

A^*_j denote the distance-weighted area of the j^{th} type of semi-natural habitat in the locality of the focal field

a denotes the area of each pixel (m^2)

α governs the strength of the distance-weighted attenuation of influence on the field's pollination deficit

Equation 3

$$\Delta Y = E_0 + E_{0,1}A_1^* + E_{0,2}A_2^* \ldots + E_{0,i}A_i^*$$

Where:

ΔY, denotes pollination deficit

$E_{0,i}$ denotes the importance of each type of SNH in influencing the focal field

Equation 4

$$P_x = N_x \frac{\sum_{m=1}^{M} F_m * f(D_m, u)}{\sum_{m=1}^{M} f(D_m, \alpha)}$$

Where:

P_x is the potential suitability of cell x to support the presence of wild bees.

N_x and F_m are respectively the nesting suitability and floral availability score of cell x;

$f(D_m, \alpha)$ Is the value of the kernel function at cell x; *M* is the number of cells within the maximum bees flying distance from cell x

D_m is the Euclidean distance between cell *m* and cell x;

α length scale parameter governing the distance-weighted decline in influence

Equation 5

$$P_o = \frac{\sum_{m=1}^{M} P_{xm} f(D_m, \alpha)}{\sum_{m=1}^{M} f(D_m, \alpha)}$$

Where:

P_o = total (potential) pollination service delivered to cell *o*

P_m = potential suitability of cell m to support insect pollination.