Impoverishment of the arable flora of central Germany during the past 50 years: a multiple-scale analysis

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Albrecht-von-Haller Institute for Plant Sciences
Plant Ecology /Vegetation Analysis
3 Drivers in agroecosystems
3 Changes on multiple scales
3 Needs - Outlook

Sanctuary fields on calcareous sites in Brandenburg (left) and *Legousia speculum-veneris* (right)
Arable land dominating land-use type in Europe (Stoate et al. 2009)

**Germany:** half of the country area = agricultural land (DESTATIS 2014)

~4 Mio. ha (11.5%) grassland/pastures vs. ~12 Mio. ha (35%) arable land

**High pressure on arable land!**
Trends in agriculture

→ European Union subsidy system
→ Farmers produce on a global market base (milk, meat)
→ Family farm systems vanishing
→ Overproduction (waste!)

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intensive (conventional) agriculture requires high energy use (pesticides, synthetic fertilizers), tight crop rotations, low crop species diversity….

→ increasing yields (e.g. winter wheat 2.5 higher than in the 1950s)


\[ \text{with each ton more produced wheat 10 arable plants become endangered!} \]
Strong plant diversity losses in arable habitats by agricultural intensification (Stoate et al. 2009)

- Ongoing conflict agriculture ↔ nature conservation (Hampicke 2010)
- Most endangered habitat type in Central Europe (Ellenberg & Leuschner 2010)
- ~120 arable red-listed as endangered/extinct (Hofmeister & Garve 2006)
- Global responsibility for protection/promotion of individual species in Central Europe (Welk 2001)

- (very) limited legal protection instruments (Meyer et al. 2010)
  - no NATURA-2000 habitat type
  - (only Bromus grossus FFH taxon)

'Biodiversity strategy of the federal government'

"by 2015, the species decline in the cultural landscape is stopped"

'stepchildren of nature conservation'
3 Dramatic change in field size
3 Changes particularly strong in the 1950s/60s

→ Comparisons over 5 – 6 decades needed!

Bsp. Slopes of the Saale river NW Halle Baessler & Klotz (2006)
Detect diversity change on multiple scales

1. diversity on landscape level (GIS-Analyse)
2. diversity on community level (Relevés)
3. diversity on species level (Herbarium und Literature reviews)
4. genetic diversity (AFLP-Fingerprinting)
STUDY REGION

Sand
1. Reese (1951) 31
2. Berkhof (1955) 38
3. Nuthe-Neplitz (1956) 46
4. Luckau (1960-61) 39

Loam
5. Erzhausen (1959) 45
7. Halle (1958) 40

Lime
8. Hainleite (1956-57) 39
10. Saaletal (1959-61) 40
Historical relevés locates on field level
Repeat relevés on the same field (semi-permanent plot design)
Same sample size (100 m²)
1950s/60s only field interior - 2009 field interior & margin
392 relevés each
CROP DIVERSITY

“Aerosion” of crop diversity (shifts in cultivation spectrum)
Number of crops: 21 → 16

spring cereals (rye, wheat, barley, oat) 20,3% → 7,4%
winter cereals (triticale, wheat, barley, rye) 41,4% → 60,5%

Winners & Losers
winter wheat: 13,7% → 30,6%
maize: 0,8% → 8,9%
oilseed rape: 0,0% → 16,8%
potatoes: 15,0% → 0,8%
beets: 5,3% → 2,6%
- shifts crop cover: 60% \( \rightarrow \) 95% (+45%)
- arable vegetation (field interior) 40% \( \rightarrow \) 3% cover (-92.5%)
SPECIES NUMBERS

Total species pool
- historic: 301 species
- recent: 198 species (-34%)

➢ Median total species per relevé
- historic: 24 species
- recent: 7 species (-71%)

➢ Differences in substrate types
- historic: lime (species rich 29)
- recent: lime (species poor 7) (-76%)

➢ Little differentiation in substrate
### SPECIES COMPOSITION

#### Vergleich nur Innen

<table>
<thead>
<tr>
<th>%Frequenz</th>
<th>50er I</th>
<th>2009 I</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARNOSERIS MINIMA</td>
<td>16</td>
<td>0</td>
<td>0,0005</td>
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<tr>
<td>CENTAUREA CYANUS</td>
<td>35</td>
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<tr>
<td>SPEGULA ARVENSIS</td>
<td>30</td>
<td>4</td>
<td>0,0005</td>
</tr>
<tr>
<td>PAPAVER RHOEAS</td>
<td>35</td>
<td>15</td>
<td>0,0005</td>
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<tr>
<td>ANAGALIS ARVENSE</td>
<td>46</td>
<td>7</td>
<td>0,0005</td>
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<tr>
<td>CAPSELLA BURSA-PAST.</td>
<td>56</td>
<td>25</td>
<td>0,0005</td>
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<tr>
<td>ADONIS AESTIVALIS</td>
<td>16</td>
<td>1</td>
<td>0,0005</td>
</tr>
<tr>
<td>CONSOLIDA REGALIS</td>
<td>22</td>
<td>3</td>
<td>0,0005</td>
</tr>
<tr>
<td>LATHYRUS TUBEROSUS</td>
<td>18</td>
<td>0</td>
<td>0,0005</td>
</tr>
</tbody>
</table>

#### Vergleich hist Innen - Rand Außen

<table>
<thead>
<tr>
<th>%Frequenz</th>
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<th>Differenzen p2-p1</th>
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<tbody>
<tr>
<td>ARNOSERIS MINIMA</td>
<td>0</td>
<td>16</td>
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<td>0,00000</td>
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<tr>
<td>CENTAUREA CYANUS</td>
<td>20</td>
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<tr>
<td>SPEGULA ARVENSIS</td>
<td>9</td>
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<tr>
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<td>36</td>
<td>35</td>
<td>0,42070</td>
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<tr>
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<td>13</td>
<td>46</td>
<td>0,00050</td>
<td>0,00000</td>
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<td>56</td>
<td>0,00050</td>
<td>0,00000</td>
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<tr>
<td>ADONIS AESTIVALIS</td>
<td>5</td>
<td>16</td>
<td>0,00050</td>
<td>0,00000</td>
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<tr>
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<td>22</td>
<td>0,00050</td>
<td>0,00000</td>
</tr>
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<td>5</td>
<td>18</td>
<td>0,00050</td>
<td>0,00000</td>
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→ significant decrease of 131 species, increases of 18 species

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15 of 30
28.10.2016
### Species Composition

**Vergleich nur Innen**

<table>
<thead>
<tr>
<th>Species</th>
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<tr>
<td>ELYMUS REPENS</td>
<td>49</td>
<td>22</td>
<td>0,0005</td>
</tr>
<tr>
<td>BROMUS STERILIS</td>
<td>0</td>
<td>15</td>
<td>0,0005</td>
</tr>
<tr>
<td>CIRSIUM ARVENSE</td>
<td>62</td>
<td>13</td>
<td>0,0005</td>
</tr>
<tr>
<td>JUNCUS BUFONIUS</td>
<td>11</td>
<td>1</td>
<td>0,0005</td>
</tr>
<tr>
<td>MENTHA ARVENSIS</td>
<td>24</td>
<td>0</td>
<td>0,0005</td>
</tr>
<tr>
<td>TUSSILAGO FARFARA</td>
<td>15</td>
<td>1</td>
<td>0,0005</td>
</tr>
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<th>p</th>
<th>Differenzen p2-p1</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELYMUS REPENS</td>
<td>60</td>
<td>49</td>
<td>0,7520</td>
<td>0,75240</td>
</tr>
<tr>
<td>BROMUS STERILIS</td>
<td>54</td>
<td>0</td>
<td>0,00050</td>
<td>0,00000</td>
</tr>
<tr>
<td>CIRSIUM ARVENSE</td>
<td>41</td>
<td>62</td>
<td>0,00050</td>
<td>0,00000</td>
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<td>1</td>
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</table>

→ Frequency decline, worst weeds! new yield supressing, problematic species!
→ Complete loss of temporary wet indicator species
### SPECIES DECLINE

**Assessment Food Resource → Bees** extract from Krautzer & Grains (2014)

<table>
<thead>
<tr>
<th>Species</th>
<th>English Name</th>
<th>Honeybee</th>
<th>Wildbee</th>
<th>Trend (1950er – 2009)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Daucus carota</em></td>
<td>Wild Carrot</td>
<td>++</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td><em>Knautia arvensis</em></td>
<td>Gypsy Rose</td>
<td>+++</td>
<td>+</td>
<td>++</td>
</tr>
<tr>
<td><em>Matricaria chamomilla</em></td>
<td>Chamomille</td>
<td>+</td>
<td>++</td>
<td>++</td>
</tr>
<tr>
<td><em>Myosotis arvensis</em></td>
<td>Field Forget Me Not</td>
<td>+++</td>
<td>+++</td>
<td>++</td>
</tr>
<tr>
<td><em>Papaver rhoeas</em></td>
<td>Field Poppy</td>
<td>-</td>
<td>+++</td>
<td>+++</td>
</tr>
</tbody>
</table>
**Osmia papaveris Latreille** (Poppy Bee)

on cornflower and poppy species \( \rightarrow \) low-input management of sandy fields

**Andrena saxonica StoecKert**
manuell classification of relevés, phytosociological character species

- historic: 74% on association level, 24% alliance
- recent: 5% on association level, 20% alliance, 69% order / class, 7% not assignable on class level
Massive changes since the 1950s/60s:

- Communities lost characteristic species, phytosociological assignment often impossible
- Homogenization / leveling species pool
- Median species numbers (-71%)
- Loss on calcareous sites particularly dramatic

Effects on the population level: Genetic structure?
Populations in Central Germany

Profiling study RAPD-Fingerprinting
10-20 individuals each / study plot

(Brütting, Meyer et al. 2012a, b)
Profiling study

Populations in Central Germany: fragmentation effect

- Genetic diversity partly low: 0.06 – 0.32

<table>
<thead>
<tr>
<th></th>
<th>Ad. aest.</th>
<th>An. arve</th>
<th>An. foem</th>
<th>B. rotu</th>
<th>C. rega</th>
<th>N. arve</th>
</tr>
</thead>
<tbody>
<tr>
<td>N (Pop)</td>
<td>11</td>
<td>8</td>
<td>10</td>
<td>13</td>
<td>6</td>
<td>5</td>
</tr>
<tr>
<td>Median population size</td>
<td>40</td>
<td>75</td>
<td>50</td>
<td>150</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>Mean heterozygosity</td>
<td>0.167</td>
<td>0.159</td>
<td>0.055</td>
<td>0.071</td>
<td>0.317</td>
<td>0.245</td>
</tr>
</tbody>
</table>
Profiling study

Populations in Central Germany: fragmentation effect

- Genetic diversity partly low: 0.06 – 0.32
- ΦST-values ranges 0.12 and 0.68
  - A. foemina + B. rotundifolium
  - strong genetic impoverishment

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<th>N. arve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Variation (%) Among pops</td>
<td>16</td>
<td>18</td>
<td>68</td>
<td>54</td>
<td>12</td>
<td>26</td>
</tr>
<tr>
<td></td>
<td>84</td>
<td>82</td>
<td>32</td>
<td>46</td>
<td>88</td>
<td>74</td>
</tr>
<tr>
<td>ΦST</td>
<td>0.155</td>
<td>0.182</td>
<td>0.679</td>
<td>0.538</td>
<td>0.116</td>
<td>0.264</td>
</tr>
</tbody>
</table>
Detailed study on *Bupleurum rotundifolium*

**AFLP-study**

- Two large groups Central Europe
  1: Poland, Czech Republic, France, Austria, Hungary
  2: Central Germany
- Genetic diversity very low: 0.04 – 0.13
- Strong fragmentation (ΦST)
  Region 1: 0.51 / Region 2: 0.56

Survey in German botanical gardens, seeds of *ex-situ cultivation*

- Per species 3-6 garden populations, official ex-situ conservation only 1
  (*Bupleurum rotundifolium*, Potsdam)
- Accessions unclear in 55% of cases
- Garden populations less species than in wild populations

Brütting et al. *Plant Biology* 2013
Detailed study *Ex-situ conservation*

Survey in German botanical gardens,
seeds of **ex-situ cultivation**

- Per species 3-6 garden populations,
  official ex-situ conservation only 1
  (*Bupleurum rotundifolium*, Potsdam)

- Accessions unclear in 55% of cases

- Garden populations less species than in wild populations

- genetic diversity lower in bot. gardens
  (exceptions *Anagallis foemina*)

- genetic differences *ex-situ* – *in-situ* wide
  ($\Phi$ST 0.29 – 0.84)
Dramatic losses in communities, species numbers and characteristic species since the 1950s/60s. Significant impact on genetic structure: low diversity. *Ex-situ* conservation insufficient: few and often small populations, low genetic diversity, incomplete gene-set. Suggestion: Refreshment with 'wild' accessions every 3-5 years or cryopreservation.

Improved *in-situ/on-farm* biodiversity concepts urgently needed. First (limited) step: '100 fields for diversity'.
100 FIELDS FOR DIVERSITY

Stefan Meyer

28 of 30

28.10.2016
OUTLOOK / CONCLUSION

- Loss of arable land = increasing intensification pressure
- Biomass cultivation = energy & management intensive
- Climate change = can species–rich communities absorb potential negative effects on crop yields?
- Complete change in the agro-policy subsidies of the EU!!!
  → AES and EFA are not able to achieve political biodiversity goals
  → Cancellation 1st CAP-pillar! KEY: biodiversity consulting!

HOW MUCH BIODIVERSITY DO WE NEED TO PRESERVE ECOSYSTEM FUNCTIONS IN STABLE CONDITIONS?
DBU & Stifterverband für die Deutsche Wissenschaft for funding our research,

... all the local farmers,

... all the members from the project team,

... & you for your attention!

funded by:

Deutsche Bundesstiftung Umwelt

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