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Loss of plant species diversity in a rural German region – assessment on basis of a historical herbarium

Der Rückgang der Pflanzendiversität in einer ländlichen Region Deutschlands – eine Rekonstruktion anhand einer Herbarsammlung

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Abstract

Plant diversity change for cities and their surroundings is well documented. For rural areas such studies are difficult as literature data are mostly insufficient. We reconstructed phytodiversity change in the Feldatal community (Germany, Hesse) by comparison of historical herbarium collections (1945–1976, Hans Hupke) with a recent floristic survey (2012). The study area is a rural area typical for Central Europe, dominated by agriculture and forestry and with a stable human population. Floristic diversity decreased (683 to 497 species; 31% of the total flora), principally by disappearance of species of unimproved grassland, fields and villages. The small number of newly documented species (33 spp.; 5% of total flora) comprises mostly naturalized ornamentals and salt tolerant species along roads. Plant diversity change of the last decades in rural landscapes in Central Europe was mainly dependent on the intensification of agriculture.

Keywords: agriculture, habitat destruction, herbarium; naturalization, plant diversity

Erweiterte deutsche Zusammenfassung am Ende des Artikels

1. Introduction

Tracing plant diversity change constitutes a difficult task as detailed data on the historical situation are rare. For cities and their surroundings, the reconstruction of plant diversity change was successfully performed by herbarium collections in connection with literature data (e.g. BERTIN 2002, GREGOR et al. 2012, LANDOLT 2000, MONGE-NAJERA & PERER-GOMEZ 2010). For rural areas such studies are more difficult as literature data are mostly insufficient. But, if ample – albeit unsystematically collected – herbarium data are available it can be possible to document floristic change (GRASS et al. 2014 for the Pannonian Region of Austria).

The rich herbarium of Hans Hupke (1888–1976) offers the opportunity to test whether a comparison between herbarium data – collected between 1945 and 1976 in a low mountain range in the state of Hesse (Germany) – and a floristic survey in 2012 is able to reconstruct

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floristic change. If so, we try to answer the following questions: (1) What are the characteristics of taxa not refound in the 2012 survey? (2) What are the characteristics of taxa only found in the 2012 survey? and (3) Is it possible to infer drivers of change from these data.

2. Study area

The study area is located in the center of Germany in the state of Hesse (Fig. 1) in the Feldatal community (Vogelsberg County) with its biggest settlement Groß-Felda (50.649677° N / 9.172350° E). It ranges from 320 to 430 m a.s.l. and is part of the Vogelsberg Mountains, a volcanic massif which arose about 19 million years ago. About 30% of the area is covered by forests dominated by *Fagus sylvatica*. Settlements cover about 10%; most of the area is agriculturally used. Fields (mostly barley, wheat, triticale, corn) dominate slightly over grassland, which is predominantly used for dairy farming. The soil is base rich and agriculture is intense despite the rather high altitude. Brooks and ponds contribute to the landscape´s diversity. Fallows and reforestation areas are lacking, a typical feature of base-poor low mountainous areas in Hesse (HIETEL et al. 2004).

According to topographic maps, changes in land use over the last decades are rather subtle (Fig. 4). The ratios of forest, grassland and fields stayed more or less constant, only settled areas increased from about 5% to about 10%. Radial hedges around hills are today a typical feature of the landscape. They developed only about 50 years ago on boundary ridges of fields when the demand for wood started to decrease. Wood from hedges was traditionally used for the baking of bread, executed regularly by many farmsteads. Many of the smaller radial fields became unsuitable for modern farming and were converted into grassland. The average field size at least tripled in the last 5 decades – in Schlitz-Pfordt, 30 km east, it increased by 340% between 1953 and 2003 (from 0.38 ha to 1.3 ha cf. GREGOR & BREHM 2007).

The human population (app. 46 inhabitants/km²) of Groß-Felda and adjacent villages is rather stable (OFFHAUS 2011: 1834: 1,074 inhabitants, 1925: 1,017; 1939: 824; 1950: 1,136; 1961: 955; 1971: 946; 2005: 970). Low numbers in 1939 are connected to the expulsion of the Jewish population, high numbers in 1950 to the settlement of displaced population from the Sudetes/Czech Republic.

3. Material and Methods

Hans Hupke (1888–1976) was a prolific collector based from 1945 on in Feldatal, Germany. About half of his private herbarium of ca. 60,000 phanerogam specimens originate from Central Europe (REDEKER 1999, ANONYMOUS 2014). Between 1945 and 1976 Hupke collected more than 5,000 specimens (Fig. 2) around Groß-Felda. The Senckenberg Research Institute acquired Hupke's collection in 1977. It is deposited in the Herbarium Senckenbergianum Frankfurt/M. (FR). In the course of a project funded by the Deutsche Forschungsgemeinschaft (LIS-programme) from 2009 onwards focusing on the collections from low mountain ranges, the Hessian material of the Hupke collection was reidentified, georeferenced, databased and digitalized. Nomenclature follows JÄGER (2011). Data are available via the Senckenberg collection management system SeSam (http://sesam.senckenberg.de) and the Global Biodiversity Information Facility (GBIF) (www.gbif.de).

To compare Hupke's herbarium data with the present situation we selected 45 study areas where Hupke had collected sizeable numbers of herbarium specimens. The mean number of herbarium specimens collected by Hupke in these study areas was 46 (standard deviation "SD" 35.5); altogether 2,075 herbarium specimens. The size of the study areas ranged between 1 and 10 ha. The flora of the study

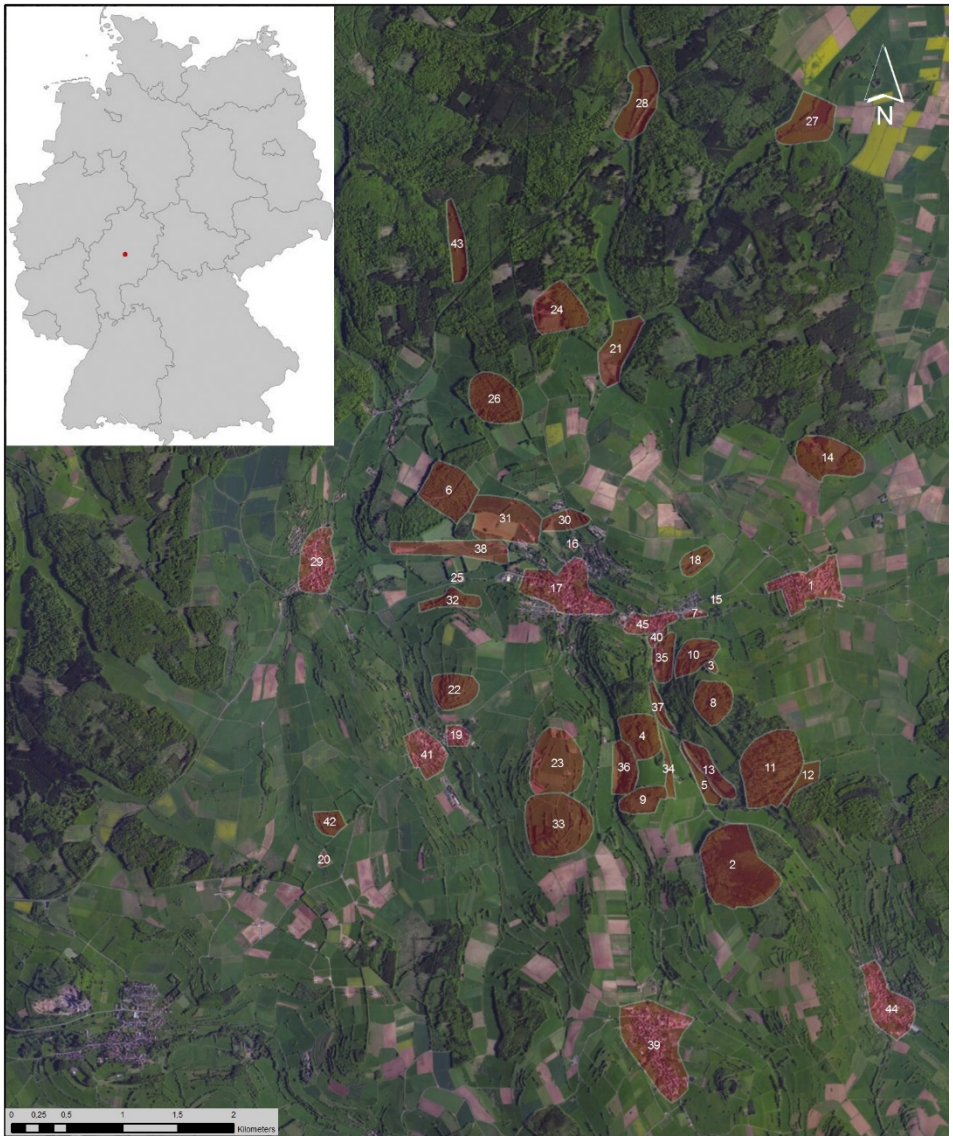


Fig. 1. Location of the study areas (with numbers) in Central Hesse. The 45 study sites were sampled by H. Hupke, we resampled in 2012 (for species list see the electronic appendix), the study areas had been collection sites of Hupke.

Abb. 1. Lage der Untersuchungsgebiete. In den 45 Untersuchungsflächen sammelte H. Hupke Herbarbelege, 2012 wurden Artenlisten erstellt (siehe elektronischer Anhang).

areas was investigated monthly between April and September 2012 and partly documented by herbarium vouchers deposited in the Herbarium Senckenbergianum in Frankfurt/Main (FR). Altogether, we accumulated 3,478 records (mean 77 (SD 38) per study area).

We recorded each study area only once. We investigated all habitats types (grassland, fields, forests, settlement) in spring, summer and autumn. We probably did not miss any at least moderately common species occurring in the study areas. But we certainly missed rare species, especially those

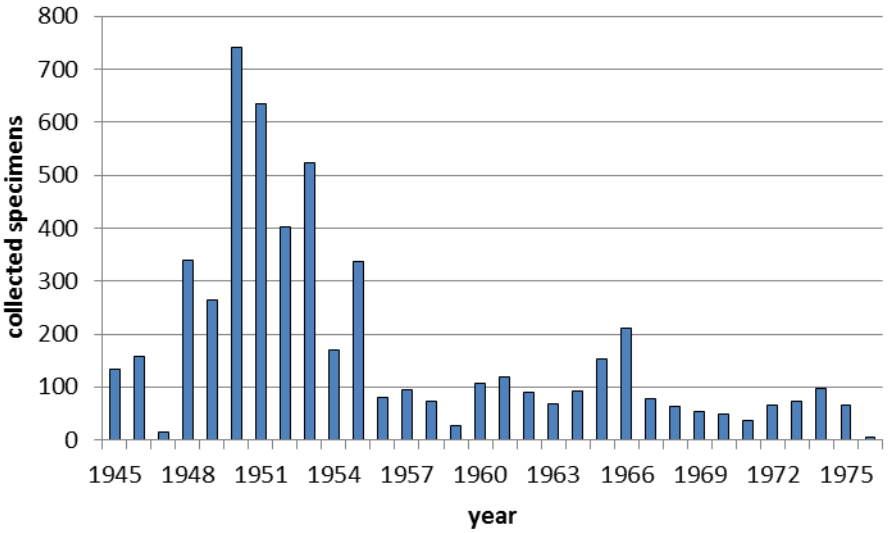


Fig. 2. Number of plant collections by H. Hupke around Groß-Felda (Germany, Hesse, Vogelsberg County, Feldatal community) per year.

Abb. 2. Anzahl der jährlich von H. Hupke um Groß-Felda (Hessen, Vogelsbergkreis, Gemeinde Feldatal) gesammelten Pflanzen.

with erratic appearance. We estimate that further floristic investigations in the study areas could increase the number of species by 10–20%. Therefore, we consider an arbitrary but rather liberal threshold of 25% for not re-recorded species as margin error in the comparison of habitat types. For the geographical representation of the collection points ArcGIS v10.1 (Esri, USA) software with the Esri World Topographic Map layer was used.

We considered four categories to analyze biodiversity change: (a) Species recorded by Hupke (1945–1976), (b) Species recorded in 2012, (c) Species only recorded by Hupke – but not in 2012, (d) Species only recorded in 2012 – but not by Hupke. We excluded casual taxa and the critical ones of apomictic groups (*Alchemilla*, *Hieracium*, *Rubus*, *Taraxacum*). The status of alien plants in the study area is evaluated according to PYŠEK et al. (2004). Twenty-seven taxa found in 2012 are missing in the Hupke collection from the particular study areas but were collected by Hupke elsewhere around Groß-Felda. We include these taxa in group "Species recorded by Hupke (1945–1976)". Furthermore, we include another 21 taxa in this group albeit Hupke made no herbarium collections around Groß-Felda. This refers mostly to trees and shrubs of widely distributed taxa; woody species are generally underrepresented in Hupke's collection.

For each species, we extracted introduction time and ecological preferences from JÄGER (2011), Raunkiaer life form (RAUNKIAER 1905) and Ellenberg indicator values (EIV) for temperature, humidity and nutrient preference from ELLENBERG et al. (1992). We calculated ecological preferences in the categories "ruderal sites", "dry unimproved grassland", "fields without herbicides", "permanent wet places", "wet unimproved grassland", „forests" and "others". The conservation status of the species follows the Hessian Red Data book of vascular plants (HEMM et al. 2008) and comprises the categories "Extinct", "Critically endangered", "Endangered", "Vulnerable" and "Least concern". Strategy types were extracted from GRIME (1979) and complemented from FRANK & KLOTZ (1990).

To investigate changes in the composition of the local flora, we checked differences between pairs of the four above mentioned groups with Pearson's chi-squared test for significant changes in distribution of EIV for temperature, humidity and nutrient preference. In addition we tested single EIV for temperature, humidity and nutrient preference for significant changes between species recorded by Hupke (1945–1976) and species recorded in 2012 in the study areas with a one sided paired Wilcoxon

test. The test was performed separately for each category in the three EIV classes where at least one species was found. Rank sums were computed using the results of the 45 study areas. We used R (R DEVELOPMENT CORE TEAM 2011) for computations. Significance levels are denoted as "* = < 0.05", "** = < 0.01" and "*** = < 0.001".

We recorded changes in land use by comparison between maps (1 : 25 000) from ca. 1910 and ca. 2010.

4. Results

Hupke recorded 683 plant species 1945–1976. In 2012, we recorded only 497. 219 of Hupke's species were missing in 2012 and only 33 of species recorded in 2012 were missing from Hupke's investigation. The total number of plant species recorded by both studies is 716.

EIV for the whole dataset had low variability and we did not find significant differences between species recorded in 1945–1976 and 2012. At the level of the study areas we found significant differences (paired Wilcoxon test; Table 1): (1) Species with intermediate temperature values increased while the number of species with low (categories 3, 4) and high (categories 7, 8) demands decreased. (2) Species with intermediate humidity values (categories 5–7) increased. (3) Species with low nutrient values (categories 1, 2) decreased while the number of species with high demands (categories 6–8) increased.

Table 1. Number of species according to Ellenberg indicator values (EIV). Analyses of temperature, moisture and nutrient preferences for species recorded in: 1945–1976, 2012, only 1945–1976, or only 2012. Significance levels of one sided paired Wilcoxon test of single categories for study areas: $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

Tabelle 1. Anzahl der Arten der einzelnen Ellenberg-Zeigerwerte für Temperatur, Feuchte und Nährstoffe für Arten die 1945–1976, 2012, nur 1945–1976 oder nur 2012 festgestellt wurden. Einseitig-gepaarte Wilcoxon-Tests. $*p < 0{,}05$; $**p < 0{,}01$; $***p < 0{,}001$.

	not rated	EIV category												mean	SD
Categories		**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**		
EIV temperature															
1945–1976	196	0	0	5*	22***	154	264	40**	2*	0	-	-	-	5.65	0.755
2012	153	0	0	3	13	131***	181**	16	0	0	-	-	-	5.56	0.684
only 1945–1976	53	0	0	2	10	30	95	27	2	0	-	-	-	5.84	0.85
only 2012	10	0	0	0	1	7	12	3	0	0	-	-	-	5.74	0.752
EIV moisture															
1945–1976	66	0	8	46	139	180	69	45	65	35	15	7	8**	5.67	2.03
2012	57	0	5	21	85	141***	60***	36*	52	23	9	4	4	5.76	1.89
only 1945–1976	16	0	3	28	59	45	13	12	18	12	6	3	4	5.44	2.25
only 2012	7	0	0	3	5	6	4	3	5	0	0	0	0	5.50	1.71
EIV nutrients															
1945–1976	88	12***	82***	75	74	89	85	91	66	21***	-	-	-	5.05	2.12
2012	76	9	35	47	56	65	73***	71***	52***	13	-	-	-	5.31	2.01
only 1945–1976	21	3	48	30	24	25	19	23	18	8	-	-	-	4.55	2.24
only 2012	9	0	1	2	6	1	7	3	4	0	-	-	-	5.50	1.96

For Raunkiaer life forms (Table 2), strategy types (Table 3) and habitat preferences (Table 4) we did not find significant differences in species numbers recorded in 1945–1976 and 2012 (Table 2). At the level of the study areas we found significant differences (paired Wilcoxon test): (1) Hemikryptophytes and phanerophytes increased while therophytes declined; (2) c-strategists increased, while sr- and r-strategists decreased.

Settlements lost 43% of the taxa recorded 1945–1976; for fields, wetlands and meadows this figure was close to 35%. Hedges with their fringes display rather stable plant diversity, with only 7% of the taxa missing in the 2012 study. In forests, we were unable to re-record 23% of the species. The number of currently endangered species (HEMM et al. 2008; Table 5) decreased (***) between the periods 1945–1976 and 2012.

Table 2. Raunkiaer life forms for species recorded 1945–1976, species recorded 2012, species only recorded 1945–1976 and species only recorded 2012. A: hydrophytes, C: chamaephytes, G: geophytes, H: hemicryptophytes, P: phanerophytes, T: therophytes. First line: absolute species numbers, second line: relative species numbers. Significance levels of one sided paired Wilcoxon test of single categories for study areas: * < 0.05 resp. > 0.95, ** < 0.01 resp. > 0.99, *** < 0.001 resp. > 0.999.

Tabelle 2. Spektren der Lebensformen für Arten 1945–1976 festgestellt, Arten 2012 festgestellt, Arten nur 1945–1976 gefunden und Arten nur 2012 gefunden. A: Hydrophyten, C: Chamaephyten, G: Geophyten, H: Hemikryptophyten, P: Phanerophyten, T: Therophyten. Erste Zeile: Absolute Artenzahlen, zweite Zeile: Relative Artenzahlen.

	A	C	G	H	P	T	sum
1945–1976	26**	25	85	322	58	167	683
	0.02	0.04	0.12	0.47	0.08	0.24	1
2012	15	20	64*	250***	53***	95***	497
	0.03	0.04	0.13	0.5	0.11	0.19	100
only 1945–1976	11	9	25	90	9	75	219
	0.05	0.04	0.11	0.41	0.04	0.34	1
only 2012	0	4	4	18	4	3	33
	0	0.12	0.12	0.55	0.12	0.09	1

Table 3. Strategy types for species recorded 1945–1976, species recorded 2012, species only recorded 1945–1976 and only 2012. c: competitive strategy, s: stress strategy, r: ruderal strategy and intermediate types (cs, cr, csr, sr). First line absolute numbers, second line proportions.

Tabelle 3. Strategietypen (c = Konkurrenz, s = Stress, r = ruderal sowie Mischformen cs, cr, csr, sr) für Arten 1945–1976 festgestellt, Arten 2012 festgestellt, Arten nur 1945–1976 gefunden und Arten nur 2012 gefunden. Erste Zeile: absolute Anzahl der Arten. Zweite Zeile: Proportionaler Anteil.

	c	cs	cr	csr	s	sr	r	no class	sum
1945–1976	159	100	78	196	8	29	83	30	683
	0.24	0.15	0.12	0.30	0.01	0.04	0.12		1
2012	142	72	56	148	6	10	50	13	497
	0.29	0.15	0.12	0.31	0.01	0.02	0.10		1
only 1945–1976	31	31	25	56	5	19	35	17	219
	0.15	0.15	0.12	0.28	0.02	0.09	0.17		1
only 2012	14	3	3	8	3	0	2	0	33
	0.42	0.09	0.09	0.24	0.09	0.00	0.06		1

Table 4. Habitat preferences for total set of species documented 1945-1976, species recorded 2012, species only recorded 1945–1976 and only 2012. First line absolute numbers, second line proportions.

Tabelle 4. Habitatpräferenzen für Arten 1945–1976 festgestellt, Arten 2012 festgestellt, Arten nur 1945–1976 gefunden und Arten nur 2012 gefunden. Erste Reihe absolute Zahlen, zweite Reihe Prozentzahlen.

	disturbed sites	fields	wetlands	meadows	forests	hedges	sum
1945–1976	144	88	73	203	109	66	683
	0.21	0.13	0.11	0.30	0.16	0.10	1
2012	104	57	48	135	88	65	497
	0.21	0.11	0.10	0.27	0.18	0.13	1
only 1945–1976	62	32	26	69	25	5	219
	0.28	0.15	0.12	0.32	0.11	0.02	1
only 2012	22	1	1	1	4	4	33
	0.67	0.03	0.03	0.03	0.12	0.12	

Table 5. Number and proportion of red-listed (RL) and not red-listed species recorded in 1945–1976, in 2012, only in 1945–1976 and only in 2012.

Tabelle 5. Anzahl und Anteil der Rote Liste (RL)-Arten die in den Zeiträumen 1945–1976, 2012, nur 1945–1976 und nur 2012 festgestellt wurden.

	RL	% RL	not RL	sum
1945–1976	84	14.0	599	683
2012	22	4.6	475	497
only 1945–1976	62	39.5	157	219
only 2012	0	0	33	33

Settlements lost 43% of the taxa recorded 1945–1976; for fields, wetlands and meadows this figure was close to 35%. Hedges with their fringes display rather stable plant diversity, with only 7% of the taxa missing in the 2012 study. In forests, we were unable to re-record 23% of the species. The number of currently endangered species (HEMM et al. 2008; Table 5) decreased (***) between the periods 1945–1976 and 2012.

Neophytes are significantly (***) more common among plants only found in 2012 (21 of 33, 62%) than in any other groups (6% in plants recorded 1945–1976, 11% in plants recorded 2012). Among plants only recorded in 2012 naturalized garden plants (62%) and salt tolerant plants occurring on roadsides (14%) are the most diverse groups. Nearly all Orchidaceae and Orobanchaceae were no longer found; Asteraceae and Fabaceae have lost the highest absolute numbers of species (22 and 13). As far as appearance of new species is concerned, Poaceae and Asteraceae are the leading families (6 and 4 additional species).

5. Discussion

A comparison between herbarium data and a recent survey yielded meaningful results for the analysis of changes in species diversity for a rural area. As similar areas are common in Central Europe, we consider the results as representative.

Principal problems of this study are the different survey intervals. Hupke collected over 29 years, our survey lasted just one year. But the majority (65%) of Hupke's collection dates from the years 1945–1955 and documented the era before the widespread utilization of herbicides and mineral fertilizers.

Differences in EIVs and life strategies between the two datasets (1945–1975 vs. 2012) have been generally low. This result is not surprising as changes in land use are relevant mostly for species with special requirements, not to the bulk of the flora. The number of species not re-recorded in 2012 is high (32%). Settlements and farmed areas (meadows, fields) lost 35–43% of their plant taxa. Plant diversity in hedges and forests probably did not change significantly in the last decades. An invasion of neophytes in forest is not eminent, maybe because there are no large settlements in the area (ESSL 2010). Our results confirm ratings of Red Data books for Hesse (HEMM et al. 2008) or Germany (KORNECK et al. 1996): Plants of nutrient poor, unimproved grassland are disappearing from the countryside, 50% (30 out of 60) of all threatened plants documented only 1945–1976 belong to this group. Another 14 not re-recorded species (23%) are typical for agricultural fields and thrive well only when no herbicides are applied. Wet unimproved grassland is still present on app. 5 ha in a study area in the nature conservation area "Buchhölzer Teich". This area is isolated from other remaining patches of wet unimproved grassland and may be too small for long term survival of the characteristic species. Furthermore, survival is dependent on public resources. Annual maintenance costs for this nature conservation area are app. 1,400 € per ha.

Differences in EIV on the basis of study areas between species recorded 1945–1976 and those recorded in 2012 reflect the disappearance of nutrient poor grassland which harbours many species with high temperature and low nutrient demands. Intensification of agriculture was also identified as a main driver for the depletion of local floras in Switzerland (STEHLIK et al. 2007), England and Scotland (RICH and WOODRUFF 1996), Northern France (VAN CALSTER et al. 2008), the decline of specialized arable plants in Central Europe (MEYER et al. 2013), the decline of grassland in the Czech Republic (PRACH 2008) or of alluvial grassland in Northern Germany (WESCHE et al. 2012). The most noticeable effect is probably caused by high nitrogen input (WALKER et al. 2009).

However, the study also reveals substantial changes in villages. Among the plant species only found 1945–1976, plants of ruderal sites in villages form a large group (28%). The decline of species typical for nitrogen rich sites connected with traditional animal husbandry like *Chenopodium bonus-henricus* or *C. murale* has been often discussed (e.g. KORNECK et al. 1998). But, the change of the village flora is more profound. This is connected with changes in the agricultural practices. According to data received from Hessisches Statistisches Landesamt the number of farms in Feldatal community (Germany, Hesse) decreased steadily: 1950: 551, 1960: 424, 1970: 292, 1980: 220, 1990: 150, 2000: 92, 2010: 50. Small scale farming was widely abandoned and farmsteads disappeared from villages (Fig. 3), albeit general features of land use remained rather constant (Fig. 4). Also HUWER & WITTIG (2013) found a "de-ruderalization" of the flora in villages in Germany/North Rhine-Westphalia in the last decades. While the ruderal plants disappeared the area size of the villages has substantially increased: Groß-Felda is today at least 175% of its size in 1950.

Among species found only between 1945–1976 two life forms stand out: Therophytes (34% loss) and hydrophytes (41% loss). A decline of therophytes was also found in other studies on the effect of land use change, e.g. by FISCHER and STÖCKLIN (1997) for extensively used calcareous grassland. Trends in strategy types coincide with other studies: For the Sheffield area (central England) HODGSON (1986a) reported a replacement of plant commu-



Fig. 3. Photos from ca. 1950 (left) and 2014 (right). Upper row: Kestrich, village center: agriculture has been given up, the street has been bituminized, the brook runs in a concrete embankment and open spaces turned to front gardens with many conifers. Central row: Groß-Felda, market place: the sandstone bridge was substituted by a concrete construction. Access to the Felda river, formally used by livestock, is blocked, and the embankment is solidified. Lower row: Groß-Felda, street "Pfingstweide": after agricultural use of the buildings ceased, they were intensively remodeled. The street and nearly all free space are now bituminized.

Abb. 3. Gegenüberstellung von ca. 1950 (links) und 2014 (rechts) aufgenommenen Fotos. Obere Reihe: Kestrich, Dorfzentrum: Die Landwirtschaft wurde aufgegeben, die Straßen sind asphaltiert, der Bach verläuft in einem Zementkanal und offene Flächen sind umgewandelt in koniferenreiche Vorgärten. Mittlere Reihe: Groß-Felda, Marktplatz: Die Sandsteinbrücke wurde durch eine Betonkonstruktion ersetzt, der ehemals vom Vieh genutzte Zugang zum Fluss ist blockiert und das Ufer befestigt. Untere Reihe: Groß-Felda, Straße "Pfingstweide": Nach dem Ende der landwirtschaftlichen Nutzung wurden die Gebäude stark verändert und die Straße und nahezu alle Freiflächen wurden asphaltiert.



Fig. 4. View of Kestrich and Windhausen (upper right corner) ca. 1950 (above) and 2014 (below) and the surrounding agricultural area. The settlements did not expand conspicuously. Wind power stations were installed near Windhausen. Hedges and groves had increased. The size of the agricultural area remained more or less constant.

Abb. 4. Gegenüberstellung von ca. 1950 (oben) und 2014 (unten) aufgenommenen Fotos von Kestrich und Windhausen (oben rechts) und deren Flur. Die Siedlungen haben sich nicht auffallend ausgeweitet. Oberhalb von Windhausen wurden Windkraftanlagen errichtet.

nities dominated by stress tolerant species by those with competitive and ruderal strategies. VAN CALSTER et al. (2008) found an association between species decline and relatively higher stress tolerance in a rural landscape in Northern France.

Species loss differs considerably between plant families. Two ecologically specialized families lost almost all their representatives: *Orchidaceae* and *Orobanchaceae*; only *Rhinanthus minor* L. was refound. High (local) extinction rates of orchids have been reported several times (e.g., BERTIN 2002); TURNER et al. (1994) regard their persistence as a good indicator for "habitat health". The locally extinct Orobanchaceae are specialized hemiparasites dependent on plants of unimproved meadows. High extinction rates of *Boraginaceae* are connected to the ruderal lifestyle of many of its members. Families rather unaffected by the landscape change of the last decades are *Onagraceae*, *Apiaceae*, *Poaceae* and *Rosaceae* – families comparatively successful in the surroundings of man.

The number of species only found in 2012 is rather low. About one third of these 33 species have been intentionally introduced as ornamentals. This phenomenon is well known from cities. In Frankfurt/Main originally introduced ornamentals comprise 48% of all naturalized species (GREGOR et al. 2012). Another group of newly naturalized plants can be linked to the use of deicing salts on roads in winter, e.g. *Puccinellia distans* or *Spergularia salina*. Altogether, neophytes predominate among plants only found in 2012.

Growth of human population is often linked to a decrease in species diversity (i.e., ROBINSON et al. 1994, THOMPSON & JONES 1999, BERTIN 2002, GREGOR et al. 2012, ARONSON et al. 2014), but other studies show that in Europe high plant diversity is positively correlated to human population density (ARAÚJO 2003). In Feldatal community, a steep decline in plant diversity occurred in an area with a stable human population. Intensification of agriculture – and the drastic change of land use in villages linked to it – seems to be the sole cause for the loss of biodiversity in this part of Germany. Similar results were found by HODGSON (1986a) for the Sheffield area in central England, by VAN CALSTER et al. (2008) in Northern France and by HODGSON (1986b) for Europe.

We could link changes to different aspects of land use change and regard our results as important for understanding the changes in rural habitats and for designing future conservation concepts, especially for the low mountain areas in Germany and probably all Central Europe. Scientific collections like herbaria hold a wealth of information to assess and understand biodiversity changes. However, most of these data are not easily accessible. Digitization of these historical collection data is highly recommended as a contribution to conservation and thus to national and international biodiversity strategies.

Erweiterte Deutsche Zusammenfassung

Einleitung – Die Rekonstruktion von Veränderungen der Pflanzenbiodiversität auf der Grundlage von Literatur- und Herbardaten gelingt am ehesten für Städte und ihre Umgebung. Für den ländlichen Raum sind solche Studien dagegen schwierig, da die Datengrundlage meist unzureichend ist. Im Rahmen eines durch das LIS-Programm der Deutschen Forschungsgemeinschaft geförderten Projektes wurde das umfangreiche Herbarium von Hans Hupke (1888–1976) aufgearbeitet, das zwischen 1945 und 1976 in einem ländlich geprägten deutschen Mittelgebirge (Gemeinde Feldatal, Hessen; Abb. 1) gesammelt wurde. Es bot sich damit die Gelegenheit, einen Vergleich zwischen den Herbardaten und einer 2012 durchgeführten floristischen Erfassung durchzuführen und daraus Veränderung der Pflanzenbiodiversität zu rekonstruieren.

Methoden – Das Untersuchungsgebiet liegt in der Gemeinde Feldatal in Hessen relativ zentral in Deutschland (Abb. 1). Es reicht von 320 bis 430 m ü. NN und ist Teil des Vogelsbergs, eines Vulkan-Massivs mit basenreichen Böden. Über 30 % der Gemeindefläche ist von Wäldern mit Buche (*Fagus sylvatica*) als dominierender Baumart bedeckt. Siedlungen bedecken etwa 10 % der Fläche; der Rest wird von Acker und Grünland eingenommen, wobei Felder (zumeist Winter-Gerste, Weizen, Triticale, Mais) einen etwas höheren Flächenanteil einnehmen. Die Böden sind basenreich und werden trotz der relativ großen Meereshöhe intensiv genutzt. Brachen und Aufforstungen, die in anderen basenarmen Gebieten Hessens in ähnlicher Höhenlage meist große Flächen einnehmen (HIETEL et al. 2004), sind in der Gemeinde Feldatal kaum vorhanden. Die Bevölkerung (ca. 46 Einwohner/km²) ist langfristig stabil (OFFHAUS 2011).

Hans Hupke (1888–1976) hatte zwischen 1945 und 1976 im Bereich von etwa 10 km um Groß-Felda über 5.000 Belege gesammelt (Abb. 2). Dieses reiche Herbarmaterial befindet sich heute im Senckenberg-Museum (FR) in Frankfurt am Main. Um Hupkes Herbar-Daten mit der aktuellen Situation zu vergleichen, wählten wir 45 Untersuchungsgebiete zwischen 1 und 10 ha Größe um Groß-Felda (50.649677° N / 9.172350° E) aus, in denen Hupke Belege gesammelt hatte (im Mittel 46 Belege,

Standardabweichung: 35,5 pro Untersuchungsgebiet; insgesamt 2075 Belege]. 2012 wurde die Flora dieser Untersuchungsgebiete zwischen April und September inventarisiert. Jedes Untersuchungsgebiet wurde einmal untersucht, es wurde aber darauf geachtet, dass alle wesentlichen Habitattypen sowohl im Frühjahr, Sommer und Herbst untersucht wurden.

Wir unterscheiden vier Kategorien von Artvorkommen: (A) durch Hupke erfasst, (B) 2012 erfasst, (C) nur durch Hupke erfasst, (D) nur 2012 erfasst. Unbeständig vorkommende Arten und apomiktische Kleinarten (Gattungen *Alchemilla*, *Hieracium*, *Rubus*, *Taraxacum*) wurden von der Auswertung ausgeschlossen. 27 Arten, die 2012 erfasst wurden, fehlen in den Aufsammlungen Hupkes aus den Untersuchungsgebieten, wurden von ihm aber anderenorts um Groß-Felda erfasst. Diese sind in die Gruppe A eingeschlossen. Darüber hinaus haben wir 21 weitere, 2012 nachgewiesene Arten in die Gruppe A einbezogen, die mit großer Sicherheit ebenfalls zur Sammelzeit Hupkes im Gebiet vorhanden waren, aber in Hupkes Aufsammlungen fehlen. Dies sind vor allem weit verbreitete Baum- und Strauch-Arten.

Für jede Art ermittelten wir nach JÄGER (2011) Einführungszeit, Raunkiaer-Lebensform sowie Ellenberg-Zeigerwerte für Temperatur, Feuchtigkeit und Nährstoffe. Die ökologischen Präferenzen der Arten wurden nach Angaben aus JÄGER (2011) und eigener Erfahrung in die Kategorien „Ruderalstandort", „trockenes Grünland", „Felder ohne Herbizide", „permanent feuchte Stellen", „nasses Grünland", „Wald" und „andere" eingeteilt. Der Rote Liste-Status für Hessen wurde HEMM et al. (2008) entnommen. Statusangaben folgen PYŠEK et al. (2004). Strategie-Typen wurden aus GRIME (1979) extrahiert und nach FRANK & KLOTZ (1990) ergänzt. Änderungen in der Zusammensetzung der lokalen Flora wurden mit paarweisen Pearson-Chi-Quadrat-Tests untersucht. Wir testeten Unterschiede der Zeigerwerte in den Untersuchungsgebieten mit einem zweiseitigen Wilcoxon-Test. Wir verwendeten R V3.0.2 (R DEVELOPMENT CORE TEAM 2011) für Berechnungen. Signifikanzen werden wie folgt angegeben: * < 0,05; ** < 0,01; *** < 0,001. Unterschiede in den Landnutzungsanteilen wurden durch einen Vergleich von ca. 1910 und ca. 2010 erstellten Karten des Maßstabs 1 : 25000 ermittelt.

Ergebnisse – Insgesamt erfassten wir 3.478 Artvorkommen, im Mittel 77 (SD 38) pro Untersuchungsgebiet. Hupke sammelte 683 Pflanzenarten, wir konnten 2012 nur 497 nachweisen. 219 Arten wurden nur von Hupke und lediglich 33 nur 2012 nachgewiesen. Die Verteilung von Zeigerwerten (Ellenbergzahlen), Lebensformen und Strategietypen (Tab. 1–3) zeigt zwischen beiden Gesamterhebungen keine signifikanten Unterschiede. Signifikant ist aber die Verringerung der Zahl der gefährdeten Arten (Tab. 5). Ruderalflächen verloren 43 % ihrer Arten; Felder, Feuchtgebiete und Wiesen 35 %. Neophyten waren 2012 signifikant häufiger; es handelte sich um verwilderte Gartenpflanzen und salztolerante Pflanzen der Straßenränder.

Diskussion – Die Intensivierung der Landwirtschaft wurde bereits vielfach als wesentliche Ursache des Biodiversitätswandels ermittelt (u. a. RICH & WOODMASTER 1996, STEHLIK et al. 2007, MEYER et al. 2013). Dass dies auch mit einem starken Wandel in der Artenzusammensetzung der Dörfer einhergeht, wurde seltener gezeigt. HUWER & WITTIG (2013) prägten den treffenden Begriff der „Deruderalisierung" deutscher Dörfer. Der starke Rückgang der Biodiversität ist im ländlichen Bereich nicht mit einer Bevölkerungszunahme verknüpft. Im Gegensatz zu städtischen Gebieten wie Frankfurt am Main (GREGOR et al. 2012) ist die Zahl neu einwandernder Arten gering. Wie im städtischen Umfeld (z. B. Frankfurt am Main) sind auch im ländlichen Raum Gärten die Hauptquelle für Neueinwanderungen. Artenverluste sind zwischen Familien deutlich verschieden, von der Intensivierung der Landwirtschaft besonders betroffen sind die ökologisch spezialisierten Orchidaceen und Orobanchaceen.

Unsere Ergebnisse dürften in ähnlicher Form für viele Mittelgebirgsregionen Mitteleuropas zutreffend sein. Die landwirtschaftliche Nutzungsintensität ist der wesentliche Faktor für den Biodiversitätswandel. Anstrengungen zur Erhaltung der Biodiversität müssen hier ansetzen.

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