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Weed vegetation in conventional and organic farming in West Bohemia (Czech Republic)

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Abstract: The paper presents species richness and composition of arable weed vegetation in the region of West Bohemia (Czech Republic) in different types of farming (conventional and organic) and grown crops (winter and spring cereals, wide-row crops). During the field survey in the years 2007 to 2017, 105 phytocoenological relevés were recorded. The average species richness in one relevé was significantly higher in organic farming, as well as total weed cover. The lowest species richness was found in wide-row crops. Recently widespread species belonged to the most frequent species in our study. Based on multivariate statistics, the effects of variables on the occurrence of weed species were found as statistically significant. Most of the variability in data was explained by crop, following by type of farming. Weed species of Fabaceae Lindl. family (especially *Vicia* L.) and many perennial species positively correlated with the organic type of farming. Endangered species were found mainly in organic farming and cereals. Less intensive cultivation with a higher weed cover is beneficial for the promotion of biodiversity.

Keywords: arable land; agricultural management; crop competition; agrophytocenose; farming systems; Central Europe

Arable weed vegetation is a very dynamic and variable system. It has been developed over a long time and gradually with the course of agricultural management, and every change in the cultivation system had its effect on the structure and richness of the weed community. One of the greatest changes in agrophytocenoses has occurred with the development of intensive farming since the second half of the 20th century. These included the widespread introduction of active herbicide ingredients, intensive fertilisation with mineral fertilisers, improved seed cleaning systems, changes in crop structure (and associated depleted cropping rotations), changes in tillage and harvesting methods, etc. (Hilbig and Bachthaler 1992). Last but not least, weed communities have also been affected by the overall transformation of the landscape structure in favour of large fields, the elimination of margins, draws, landscape elements and other areas providing resources to support the wide biodiversity of plant and animal species (Baessler and Klotz 2006).

The result of intensive agriculture was a significant decrease in weed vegetation and a reduction in biodiversity (Stoate et al. 2001, Chamorro et al. 2016, Berbeć and Feledyn-Szewczyk 2018). The declines have been particularly marked amongst habitat specialists (Meyer et al. 2013). The depletion of species diversity is most evident within larger fields, where the impacts of agricultural technologies and crop competition are higher (Hald 1999). Moreover, Geiger et al. (2010) concluded that despite decades of European policy to ban harmful pesticides, the negative effects of pesticides on wild flora and fauna persist.

Organic farming has been created as a set of environmentally friendly practices that can face the negative effects of agricultural intensification and biodiversity loss in the agricultural landscape (Azeez 2000, Elsen 2000, Rahmann 2011). Most of the re-

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search work carried out so far indicates that there is a higher species diversity of weed communities in the organic management system (e.g., Bengtsson et al. 2005, Edesi et al. 2012, Berbeć and Feledyn-Szewczyk 2018, Benaragama et al. 2019), including the occurrence of endangered and rare species (Rydberg and Milberg 2000, Chamorro et al. 2016).

Monitoring of weed communities records all significant changes in this variable system, to which it is then possible to respond appropriately within the policy of cultivation technologies. In the Czech Republic, the issue of weed vegetation is relatively little studied from the point of view of conventional and organic farming methods. The aim of this study is to compare the species richness and composition of arable weed vegetation in West Bohemia in relation with the type of farming used (conventional and organic farming) and cultivated crop (winter cereals, spring cereals, wide-row crops).

MATERIAL AND METHODS

From 2007 to 2017, the phytocoenological survey of selected crops was performed on arable land in the region of West Bohemia, Czech Republic. In terms of natural and production conditions, the monitored area belongs almost exclusively to the potato production area with the following environmental characteristics: rolling hills and hills, altitude 350 to 600 m a.s.l., average annual air temperature 5 °C to 8 °C, average annual rainfall 550 to 900 mm, main soil units – Cambisols (Němec 2001).

A total of 105 phytocoenological relevés were recorded (Figure 1). The examined areas were selected based on these observed factors: I. type of farming – conventional farming (51 relevés) and organic farming (54 relevés) and II. type of crops – winter cereals (winter wheat, winter barley, spelt, triticale – 37 relevés), spring cereals (spring barley, oat, spring wheat, spring triticale – 43 relevés) and wide-row crops (potatoes, maize – 25 relevés).

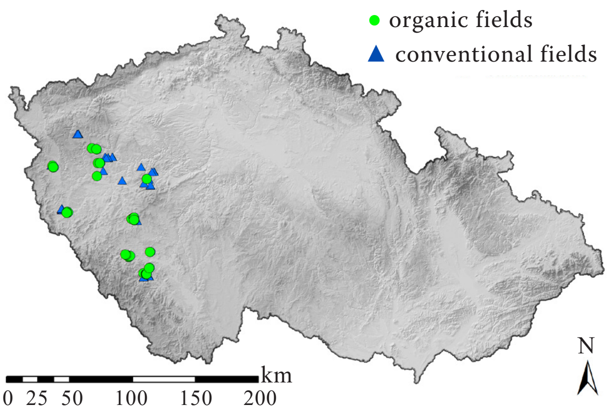

Figure 1. Map of the Czech Republic with realised relevés

Sampling took place during the period in the second half of vegetation, i.e., from June to August for cereals and July to September for wide-row crops. The evaluation was performed using an extended Braun-Blanquet cover-abundance scale (Maarel and Franklin 2013). Relevés of 100 m^2 were taken inside fields outside the headland. The botanical nomenclature is adjusted according to Kubát et al. (2002).

Elementary parameters of species diversity were determined from the obtained data – the number of species per relevé was used as a measure of the species richness (α-diversity). In relevés, total weed cover was assessed. Data were statistically processed by standard analysis of variance (ANOVA) with Tukey's test ($P \leq 0.05$).

The found plant taxa were sorted in descending order according to their frequency in the relevés. The occurrence of endangered weed taxa was taken from Grulich (2012).

The occurrence of species found in relations to observed environmental factors (type of farming and crop) was studied by multivariate statistics in the CANOCO 4.5 software (Braak and Šmilauer 2002). Braun-Blanquet values were transformed to an ordinal scale 1–9 (Maarel and Franklin 2013). First, a detrended correspondence analysis (DCA) was performed (gradient on the first canonical axis 3.465 SD units in the compositional turnover). Secondly, a direct analysis, the canonical correspondence analysis (CCA), was chosen. Net effects of all explanatory variables on the weed species occurrence were detected in partial CCAs (only one explanatory variable was used, and the effects shared with other variables were excluded using them as covariables) (Lososová et al. 2004). The ratio of an individual canonical eigenvalue to the sum of all eigenvalues (total inertia) was used to assess the proportion of the explained variation. The effects were tested by Monte Carlo permutation tests (Braak and Šmilauer 2002) (999 permutations were used).

RESULTS AND DISCUSSION

Species richness in individual relevés averaged 21.35 taxa, while in conventional farming, it reached 13.06 and 29.18 in organic farming (Table 1). Similar

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Table 1. Species richness and total weed cover per relevé in farming types and crops

		Species richness	Total weed cover (%)
Type of farming	conventional	13.06[b]	6.32[b]
	organic	29.18[a]	30.32[a]
	P-value	< 0.0001	< 0.0001
Crop	winter cereals	20.27[ab]	24.09[a]
	spring cereals	25.30[a]	18.25[ab]
	wide-row crops	16.16[b]	11.35[b]
	P-value	0.0018	0.0475

Means followed by same letter or symbol do not significantly differ (P = 0.05, Tukey's honestly significant difference)

values of species richness in the relevés in two regions of southwest Germany state Schumacher et al. (2018). Based on areas from the entire territory of the Czech Republic, Kolářová et al. (2013a) state species richness in individual relevés in conventional farming 9.17 and 21.17 in organic farming. Our slightly higher values of species richness may be related to the fact that the research was carried out only in the hills at medium to higher altitudes, where, unlike fertile lowlands, there is a lower intensity of agricultural management.

In addition to the generally used mechanical weed management methods (based on cultivation), the higher species richness of weed communities in organic farming is probably related to the fact that in organic farming, there are richer crop rotations and higher crop diversity (Rahmann 2011, Barbieri et al. 2017). An indispensable element is also usually a smaller field size and a more complex landscape structure, which increases the level of species diversity (Roschewitz et al. 2005). On the other hand, conversion to organic farming sometimes shows only small benefits for species diversity due to mechanical weeding and herbicide use for a long time before conversion (Elsen 2000). However, this aspect was not reflected in our results.

Species richness in relevés reached 20.27 in winter cereals, 25.30 in spring cereals and 16.16 in wide-row crops. However, differences between winter and spring cereals were not significant. Statistically significant differences were found only between spring cereals and wide-row crops (Table 1). Also, Pyšek et al. (2005) state that higher species richness

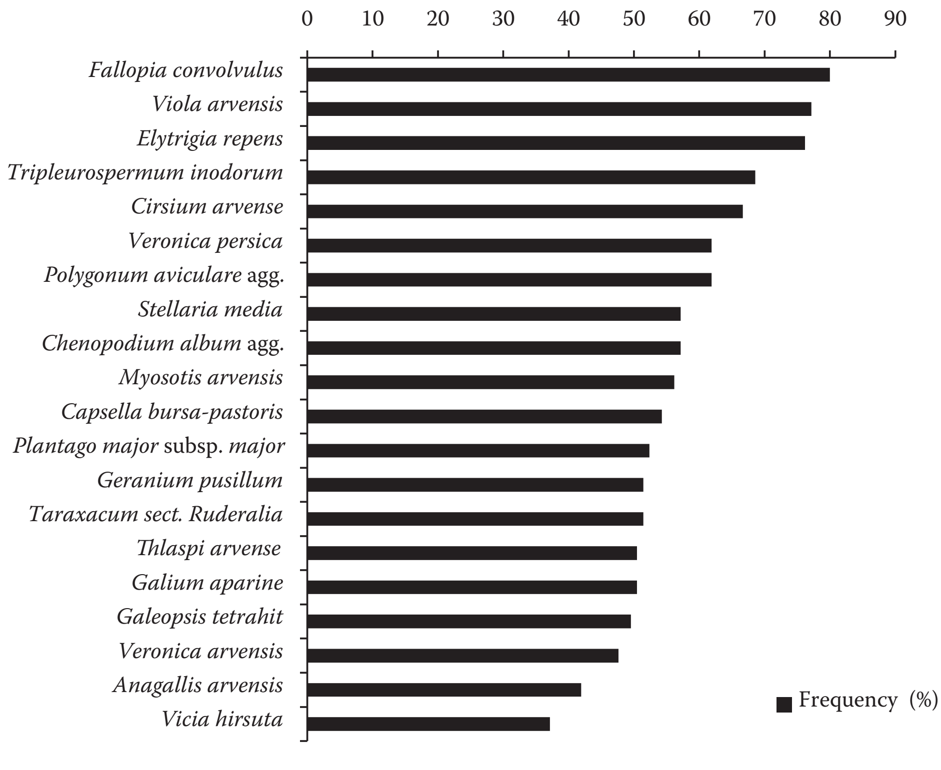

Figure 2. Frequencies of weeds – all types of farming and crops (20 taxons with the highest frequency)

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Table 2. Net effects of examined variables on the occurrence of weed species

	Eigenvalue	%	*F*-ratio	*P*-value
All	0.206	7.6	2.797	0.001
Type of farming	0.080	3.1	3.253	0.001
Crop	0.122	4.5	2.487	0.001

Eigenvalue – sum of all canonical eigenvalues (total inertia = 2.69); % – percentage of explained variance; *F*-ratio for the test of significance of all (first) canonical axes; *P*-value – corresponding probability value obtained using the Monte Carlo permutation test (999 permutations)

is represented in spring cereals (barley, oats), while maize stands are the poorest in species. In our research, maize accounted for the majority (60%) of wide-row crops, and its species richness was 12.33. Jursík et al. (2018) add that a wide range of weeds from many biological groups (winter, early spring and some late spring weed species) can grow in spring cereals and confirm the above results that maize stands are often species-poor.

Total weed cover per relevé was almost five times higher in organic farming (6.32% conventional, 30.32% organic) (Table 1). Looking back, in earlier species-rich weed communities before the introduction of intensive agriculture, weed cover was also much higher in crops. Meyer et al. (2013) state average weed cover of 30% in the 1950s/60s to only 3% cover in 2009. Species-developed weed communities are thus usually associated with a higher weed cover. Fields with organic farming reach a higher weed cover (Chamorro et al. 2016). Albrecht and Mattheis (1998) add that communities with a higher weed cover contain a higher number of rare species.

In terms of crops, weed cover was 24.09% in winter cereals, 18.25% in spring cereals and 11.35% in wide-row crops. Here, too, the differences between winter and spring cereals were not significant and statistically significant differences were found only between winter cereals and wide-row crops (Table 1).

An overview of the most important weeds in terms of their frequency within both monitored management systems and crops is given in Figure 2. The overview shows that in the monitored area, there is a weed spectrum characterising medium and higher altitudes with a colder and wetter climate with less fertile and more acidic soils (e.g., *Galeopsis tetrahit* L., *Myosotis arvensis* (L.) Hill, *Sonchus arvensis* L., *Raphanus raphanistrum* L., *Centaurea cyanus* L. etc.). Completely absent or only in low proportion are thermophilic species growing preferentially in the fertile fields of the lowlands (Jursík et al. 2018). However, the most important weeds include species that are generally widespread without deeper ties to the natural conditions of the habitat, e.g., *Viola arvensis* Murray, *Fallopia convolvulus* (L.) Á. Löve, *Stellaria media* (L.) Vill., *Cirsium arvense* (L.) Scop., *Tripleurospermum inodorum* (L.) Schultz-Bip. etc. (Lososová et al. 2008).

Within multivariate statistics, the net effects of all examined variables (type of farming, crop) on the occurrence of weed species were found as statistically significant (Table 2). These variables all together explained 7.6% of the total variation in the species

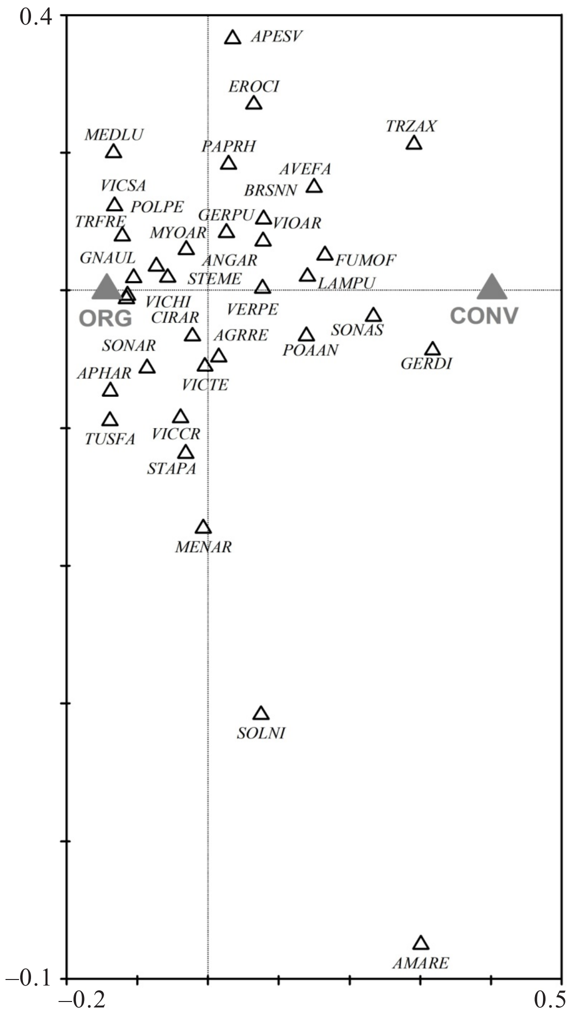

Figure 3. Ordination diagram (pCCA). Occurrence of weed species in analysed types of farming. Minimum species fit 6% – 34 species out of 138. Species marked according to EPPO Code (EPPO 2020). CONV – conventional farming; ORG – organic farming

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data. Most of the data variability is explained by crop (4.5%), following by the type of farming (3.1%). Cimalová and Lososová (2009) state, too, that on the regional level with the relatively homogeneous area, the crop has the strongest effect on species composition of arable weed vegetation.

In terms of the type of farming (Figure 3), a considerable number of weed species tend to organic farming. Among others, many species of the genus *Vicia* L. and other species from the family Fabaceae Lindl. are represented here. Jursík et al. (2018) state that due to the fixation of atmospheric nitrogen, they also grow in habitats that are poor in nitrogen and have a competitive advantage over other plants. Minerally unfertilised extensive organic stands are a suitable environment for the growth and existence of vetch weeds. At the same time, the vetch is controllable using herbicides and thus strongly suppressed in conventional agriculture. With organic farming, many perennial species are correlated (*Cirsium arvense* (L.) Scop., *Sonchus arvensis* L., *Stachys palustris* L., *Tussilago farfara* L. etc.). Hemicryptophytes or geophytes together with Fabaceae Lindl. weed species are preferred in organic areas (Roschewitz et al. 2005).

The occurrence of individual species of weeds in terms of crops (Figure 4) is often related to the growing technology of the crop, resp. to the date of its sowing or planting. It is influenced by the biological character of the weed species and their compatibility with the biology and cultivation of the given crop. Weeds with a similar biological characteristic will usually be a more successful competitor (Zimdahl 1999). It is thus clear from the ordination diagram that winter weeds have an affinity for winter cereals (e.g., *Apera spica-venti* (L.) P.B., *Aphanes arvensis* L., *Consolida regalis* S. F. Gray), early spring weeds for spring cereals (e.g., *Silene noctiflora* L., *Spergula arvensis* L.) and late spring weeds for wide-row crops (e.g., *Amaranthus retroflexus* L., *Chenopodium ficifolium* SM.).

From the group of endangered species (Grulich 2012), 12 taxa were found in the monitored areas (Table 3). Their highest occurrence was found in organic farming (25 cases, sum of cover 34.43%), while in conventional farming, there were recorded only 7 cases of endangered species (sum of cover 0.22%). The largest representation was achieved at *Aphanes arvensis* L. (in 12 relevés of organic farming) and *Silene noctiflora* L. (6 relevés, 5 of which in organic fields). Although *Odontites vernus* subsp. *vernus* (Bellardi) Dum. appeared in only two organic farming relevés, its coverage in one relevé reached 18.75%. Other species occurred only individually and with minimal cover.

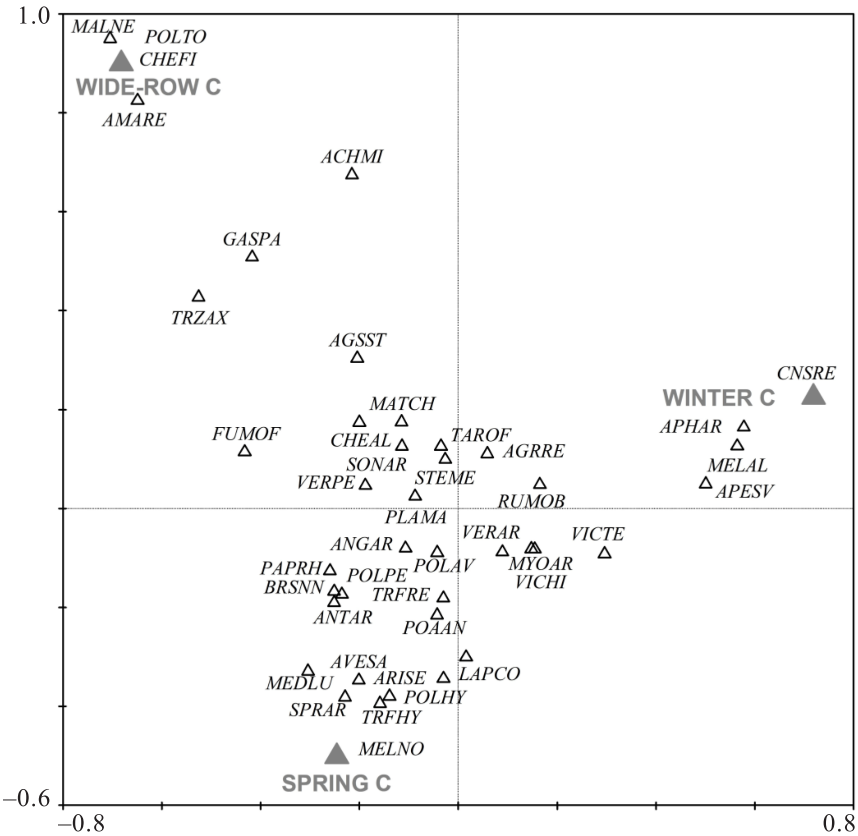

Figure 4. Ordination diagram (pCCA). Occurrence of weed species in analysed crops. Minimum species fit 4% – 42 species out of 138. Species marked according to EPPO Code (EPPO 2020). WINTER C – winter cereals; SPRING C – spring cereals; WIDE-ROW C – wide-row crops

https://doi.org/10.17221/6/2021-PSE

Table 3. Occurrence of endangered species in types of farming and crops – the number of relevés with the occurrence of species, the sum of cover in parenthesis (%)

Taxon	RL	Conventional farming			Organic farming		
		WC	SC	WRC	WC	SC	WRC
Aphanes arvensis L.	C3	–	–	–	9 (10.34)	3 (0.06)	–
Fumaria rostellata Knaf	C3	–	1 (0.02)	–	–	–	–
Lappula squarrosa (Retz.) Dum.	C3	–	–	–	–	1 (0.02)	–
Odontites vernus subsp. *vernus* (Bellardi) Dum.	C2	–	–	–	1 (18.75)	1 (0.10)	–
Papaver argemone L.	C4a	1 (0.02)	–	–	–	–	–
Silene noctiflora L.	C4a	–	1 (0.10)	–	–	5 (5.06)	–
Stachys annua (L.) L.	C2	–	–	–	–	1 (0.02)	–
Urtica urens L.	C3	–	1 (0.02)	–	–	–	–
Valerianella dentata subsp. *dentata* (L.) Pollich	C4a	–	–	–	–	1 (0.02)	–
Veronica agrestis L.	C2	–	–	1 (0.02)	–	–	–
Veronica hederifolia L.	C4b	1 (0.02)	1 (0.02)	–	–	1 (0.02)	–
Viola tricolor subsp. *tricolor* L.	C4b	–	–	–	1 (0.02)	1 (0.02)	–
Total		2 (0.04)	4 (0.16)	1 (0.02)	11 (29.11)	14 (5.32)	–

RL – Red List categories (Grulich 2012): C2 – endangered taxa; C3 – vulnerable taxa; C4a – lower risk – near threatened; C4b – lower risk – data deficient; WC – winter cereals; SC – spring cereals; WRC – wide-row crops

This shows that organic farming promotes the occurrence of endangered weeds. Chamorro et al. (2016) found four times higher occurrence of rare species in organic farming compared to conventional fields. On the other hand, Albrecht and Mattheis (1998) found that the frequencies as well as densities of rare weeds remained constant in fields under intensive organic management and point out that the effect of organic cultivation systems on rare weed species is neutral to positive. It will therefore depend on the specific conditions of the habitat and the intensity of farming. Extensively cultivated fields provide refuges for the survival of rare species (Májeková et al. 2019). The number of Red List species in the vegetation is higher in complex than in simple landscapes and decreased when the percentage of arable land cover increased (Roschewitz et al. 2005). Our monitoring took place in the potato production area, which is characterised by a more complex landscape and a lower share of arable land than in the lowland areas (Němec 2001).

From the point of view of the representation of endangered species in crops, their higher representation is clearly based on cereals. Kolářová et al. (2013b) also report the highest incidence of endangered weed species in cereals, especially spring. In Slovakia, Májeková et al. (2019) confirm the priority occurrence of endangered weeds in cereals and at least in root crops. This is associated with the fact that endangered weeds mostly include therophytes, with winter or early spring germination regime having its optimum development in cereals.

Organic farming has the ability to support biodiversity, including the presence of endangered species. On the other hand, some organic farms have poorer weed communities, which may correlate with the strong use of acceptable weed control methods in conjunction with a dense canopy of crops and catch crops. Thus, a less intensive degree of cultivation with a higher weed cover is generally beneficial for the promotion of biodiversity. A cultivated crop also plays a very important role – cereal stands are characterised by higher species richness and the occurrence of endangered species. Conservation of biodiversity in agricultural areas is fundamental for maintaining ecological services that provide soil fertility and productivity of ecosystems (Clergue et al. 2005).

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