# THESIS OF DOCTORAL (PhD) DISSERTATION

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# INVESTIGATION OF ARABLE WEED VEGETATION IN MUREŞ COUNTY

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# 1. INTRODUCTION

Weeds presence on the arable lands are closely related to human activities. With the frequent soil disturbance we provide them the optimal living conditions. But, their judgment is bilateral. On one hand, weeds represent an important part of agroecosystems. Maintaining complex food webs, weed species offer a wide range of resources for invertebrates, seed- and insect eating birds, mammals, raptors and predators, may support important crop pollinators. On the other hand, these species are the opponents of the crops in competition for the environmental factors and may be host-plants for many pathogens and pests. In consequence, weed species may cause significant economical losses for farmers. Weed control became the most expensive agricultural practice aimed at improving crop production. In order to elaborate efficient, sustainable- and environment-friendly weed control practices, it is urgent to understand the drivers of weed presence and abundance on cultivated lands. However, it is advisable the monitoring of the evolution/development of weed flora of arable lands, since the change in the floristic composition of the vegetation may provide information on the effectiveness of weed control methods. We also need to investigate how the interaction between farming and weed management systems and the environment affects the composition and diversity of weed vegetation in different croplands.

# 2. AIMS OF THE STUDY

Since detailed surveys of weed vegetation from Mureş county have been scarce and the existing studies provided little mechanistic understanding of the persistence of weed species in traditional landscapes, the main goal of this research was to fill this gap by recording the weed communities throughout the territory of the county.

Weeds have elevated importance for the health of agricultural ecosystems. As a second objective of my study I set out to assess the role of arable lands in the ecosystem in Mureş county. For this reason I have analysed the weed vegetation of the two most commonly cultivated crops in the region. Cereals (and stubbles) occupy a significant area between arable fields, and maize is one of the most important arable crop worldwide.

Weed species composition is influenced by numerous environmental and agrotechnical factors, which interact with each other. The third goal of this research was to determine the importance of the cropping methods and environmental conditions influencing the weed species composition of cropland fields.

# 3. MATERIALS AND METHODS

## 3.1. Site description

We carried out our survey in Mureş county, Romania. Our study covered an elevational gradient ranging between 260–543 m. The lower elevations included the Transylvanian Plateau, more suitable for agriculture due to wide valleys and a milder climate. The higher elevation North-Eastern corner of the county consisted of the Călimani and Gurghiu Mountain foothills, where arable fields were more rare. The most widely cultivated crops in the county are cereals and maize.

## 3.2. Circumstances during the fieldwork

We selected a total of 299 arable fields for the survey, 101 fields were cereal crops and 97 maize. The remaining 101 sites were stubbles of cereal fields. The cereal fields were surveyed between May and June, and the maize and the cereal stubble fields between July and August.

Within each field we sampled weed vegetation in six randomly selected, 4 $m^2$ plots (2×2 m), altogether 1794 plots. Three plots were located on the field edge (within the outermost seed drill line), and three were in the field centre. Within each 4 $m^2$ plot, we estimated visually the percentage ground cover of all species, including crop species, and the vegetation data recorded was subsequently digitized and stored in TURBOVEG format.

### 3.3. Collecting abiotic and agrotechnical information

We used soil chemical and physical properties as local environmental variables. From each field we collected one soil sample. Further analyses were performed at UIS Ungarn GmbH (Mosonmagyaróvár, Hungary). Soil variables included: soil pH, texture, salt and humus content, $CaCO_3$, $P_2O_5$, $K_2O$, Na and Mg. In addition, we used three proxies of regional environmental conditions quantified as the geographic latitude, longitude and elevation above sea level of each field, as recorded by a GPS device.

We interviewed landowners for information on crop management of each investigated field. We recorded the cropping history (indicating the preceding crop as either cereal or hoed crop), the amount of organic manure applied, whether farmers used chemical fertilisers (N, $P_2O_5$, $K_2O$), as well as crop sowing season (previous fall or spring) and field size. Information on weed management (type of herbicides used and number of times mechanical weed control treatments were applied) were also recorded.

Finally, we considered two site variables: plot location (edge or field core) and neighbouring habitat arable field, road margin, meadow, fallow or ditch) to represent composite management and environmental effects.

### 3.4. Statistical analyses

Prior to analyses we averaged the abundance of species across field edge and field core plots respectively, which we subsequently transformed following the Hellinger approach.

To analyse the relationship between the composition of weed vegetation and site, environmental and management variables, we performed a Redundancy Analysis (RDA). We reduced the number of explanatory variables using stepwise backward selection with a $P<0.05$ threshold. We then compared the gross and net effects of each explanatory variable. The importance of each explanatory variable was 'ranked' using the adjusted R-squared ( $R^2_{adj}$ ) values of the pRDA (i.e. net effect) models.

We report only the RDA ordination diagrams of the reduced model with the finally selected 22 variables.

In addition, we performed a variation partitioning analysis to assess the relative effects of site, environmental and management variables on weed species composition either within each cropland type separately or across all the fields, and separated by edge vs. centre position.

Statistical analyses were performed using the *vegan* (version 2.3-3) and *car* (version 2.0-25) packages in R 3.1.2 (R Development Core Team). Species fit on the constrained ordination axes was calculated using the 'inertcomp' function of *vegan* package.

Furthermore, weed species were grouped according plant families, life-form categories, chorological units, social behaviour

types, pollination mechanism and their useful as birdseeds. The share of individual groups was expressed with species mean cover percentage. These spectras are presented in diagrams made in Microsoft Office Excel (2010). We also established weed species rankings according to their mean cover and frequency values.

# 4. RESULTS AND DISCUSSIONS

## 4.1. Characterization of the arable weed flora of Mureş county

### 4.1.1. The dominance and frequency of the weed species

Across the 1794 plots sampled from 299 arable fields we found a total of 141 weed species, 110 in cereals, 88 in stubble fields and 76 in maize crops. From these *Convolvulus arvensis* had both the largest mean cover and frequency values within each cropland type. *Cirsium arvense* appeared to be also a dominant and frequent species on the surveyed fields.

Furthermore, weed species characteristic of the cropland types were registered as abundant species: e.g. *Adonis aestivalis*, *Consolida orientalis*, *Galium aparine*, *Papaver rhoeas* in cereal crops, *Anagallis arvensis*, *Setaria* spp., *Stachys annua* on stubbles and *Chenopodium album*, *Echinochloa crus-galli*, *Hibiscus trionum* in maize.

Among the registered weed species were nine invasive neophytes. These can cause significant economic losses for farmers, but at the same time they represent a major threat for human health. Species *Amaranthus retroflexus*, *Conyza canadensis*, *Oxalis stricta*,

*Xanthium italicum* and *Veronica persica* appeared in all cropland type. Furthermore, *Ambrosia artemisiifolia* and *Erigeron annuus* were found both in maize and on stubble, *Sorghum halepense* appeared only in maize and *Helianthus tuberosus* on stubble.

From our list of species *Lathyrus aphaca* is listed on the Hungarian Red List, although it is not classified as threatened species in Romania.

### 4.1.2. Spectra of plant families

The recorded weed species belong into 33 (in cereals), 31 (on stubbles) and 28 (in maize) plant families. The *Convolvulaceae* family outperformed other families in case of the cereal crops and stubbles (21.41% vs 31.81%), while in maize ranked the 2$^{nd}$ among the families (29.81%), including only two species (*Convolvulus arvensis* and *Calystegia sepium*) cover. In maize the *Poaceae* plant family is dominating (with 31.28%).

Worldwide with the highest number of weed species, the *Asteraceae* plant family has also important role. In cereal crops and on stubbles is the 2$^{nd}$ (with 17.96% and 19.53%), in maize fields the 3$^{rd}$ (with 12.71%) in the order.

### 4.1.3. Spectra of chorological units

The order of the dominance according to chorological units is the same for all three cropland type. The Cosmopolitans had the largest mean cover (in cereals: 48.81%, on stubbles: 60.29%, in maize: 74.34%). This group was followed by Eurasian elements (in

cereals: 23.17%, on stubbles: 18.53% and in maize: 10.83%) and Adventive species respectively (in cereals: 16.50%, on stubbles: 7.74% and in maize: 6.76%).

### 4.1.4. Spectra of life-form categories

Based on weed species life-form, the geophytes are dominating in every cropland type. Among the therophytes, winter annuals can be associated with cereal crops, while summer annuals predominantly occur in maize and stubble.

### 4.1.5. Spectra of species social behaviour types

Based on species social behaviour types, in every cropland type the ruderal competitors showed the largest mean cover values (cereals: 35.08%, stubbles: 46.59%, maize: 43.13%). The 2$^{nd}$ in the order were the native weed species (cereals: 33.63%, stubbles: 33.56%, maize: 25.69%), followed by disturbance-tolerant species in cereal crops and on stubbles (15.60% and12.46% respectively) and aggressive alien competitors in maize (13.46%).

### 4.1.6. Spectra of the mode of pollination and useful as birdseeds

The mean proportion of insect-pollinated weeds was the highest in cereal crops (55.26%), followed by stubbles, where 46.81% of the species needed insects for pollination. The proportion of insect-pollinated weeds decreased in maize, reaching only 33.10%.

In turn, the proportion of species pollinated by wind was the highest in maize (42.79%), followed by stubbles (21.24%). In cereal

crops only a tiny fraction (11.10%) of the weeds were part of the wind-pollinated species group. The majority of these species belong to the *Poaceae* plant family.

Weeds form a major part of the diet of many species of farmland birds. Their seeds are particularly important for granivorous bird species during the winter, although some depend on them all year. According to our analyses, the proportion of weed species which provide food for birds was high on stubbles and in maize (84.46% and 83.91% respectively). In cereal crops these species reached only 57.16%.

## 4.2. The effect of cropping methods, environmental conditions and site context on the composition of the weed vegetation of arable lands

The full RDA model comprising all 28 explanatory variables explained 20.25% of the variance, while the reduced model with 22 explanatory variables still explained 19.15% of the total variation in species composition. All 22 variables (cropland type, geographic position, altitude, soil parameters, plot location and neighbouring habitat) had significant net effects at a $P<0.05$ level.

### 4.2.1. Management effect

We found that 11 of the 22 significant predictors of weed composition were elements of the management system. Of these, cropland type had the most pronounced effect. This can be explained

by major differences in cultivation practices between cereals and hoed crops.

Fertilisation was an important filter of weed species and a selective driver of weed abundance. Several species responded to organic manure with increased abundances (e.g. *Convolvulus arvensis*, *Setaria pumila*, *Echinochloa crus-galli*), while chemical fertilisers could be linked to higher abundances of only three species (*Rubus caesius*, *Hibiscus trionum*, *Elymus repens*). Almost all weed species that responded positively to higher organic manure were associated with maize fields (e.g. *Echinochloa crus-galli*, *Chenopodium album*, *Amaranthus retroflexus*).

In our study the effect of the field size, albeit significant, was less pronounced (field size ranked only 12$^{th}$ among the explanatory variables), as our data covers only a narrow range of field sizes (most fields in our survey were small, 59% had ≤1 ha).

The sowing season was an important driver of weed composition in our survey, where we investigated winter- and spring-sown cereals and spring sown maize. Winter annual weed species (*Veronica persica*, *Consolida orientalis*, *Galium aparine*, *Papaver rhoeas*) were strongly associated with autumn-sown cereals, while summer annual weed species (*Amaranthus retroflexus*, *Chenopodium album*, *Hibiscus trionum*, *Setaria pumila*, *Echinochloa crus-galli*) preferred spring-sown cultures, many of the latter being typical weeds of hoed crops.

Among preceding crops, winter cereals usually favour winter annuals, while hoed crops summer annuals. In our analysis preceding crop ranked only the 15$^{th}$ among the predictors.

### 4.2.2. Environmental effect

We found nine environmental variables having significant net effects on weed composition, including both regional and local factors.

Longitude ranked the 2$^{nd}$, altitude the 3$^{rd}$ and latitude the 13$^{th}$ among all predictors. These variables have been used as proxies of regional climate conditions such as precipitation and mean temperature.

As expected, soil physical and chemical properties such as texture, Ca, K, Mg, P and humus content exerted significant effects on the occurrence of certain weed species.

### 4.2.3. Site effect

The plot location (edge vs core position) and the neighbouring habitat type had moderate effects on weed composition (the 6$^{th}$ and the 14$^{th}$ most important predictors, respectively). Most weeds preferred field edges and only one species, *Convolvulus arvensis* had higher abundance towards field interiors. It is well known from other agricultural ecosystems that crop margins support higher species richness and the principle is applied in weed conservation.

### 4.2.4. Environment vs management factors

The variation partitioning within each cropland type revealed that environmental variables outperformed the management and site variables, with nearly equal values in stubbles and maize, and slightly lower in cereals (6.6%, 6.5% and 4.8% respectively). The management variables had the highest relative effect in maize and equally lower in cereals and stubbles. The relative effects of site and management variables were similar in cereals (2.5% vs. 2.6% respectively), but in maize and stubbles site explained only a tiny fraction of the variance (0.9–0.2%). Variation partitioning over all the 299 fields resulted the highest influence of management variables, explaining three times more of the total variance compared to the environmental variables (10.9% vs. 3.4%). The variation partitioning of the RDA according to the plot location revealed that the effect of environmental variables is only slightly higher in field edges than in the cores (3.2% vs. 2.6% respectively), while the influence of management was nearly equal (10.4% vs. 10.5).

# 5. NEW SCIENTIFIC RESULTS (THESIS)

1. I performed a comprehensive survey of weed vegetation of cereal crops, stubbles and maize fields across Mureş county.
2. I showed that however the traditional small-scale mosaic landscape have been preserved in Central Transylvania, the effect of agricultural intensification is detectable. Mostly the 'common' weed species were registered.
3. In cereal crops and stubbles I did record typical cereal weeds reported to decline in other parts of Europe (ex. *Adonis aestivalis*, *Centaurea cyanus*, *Lathyrus aphaca*, *Ranunculus arvensis*). Therefore, these croplands may serve as refuges for rare weed species and could be used for weed species conservation strategies.
4. I assembled the dominance and frequency sequences of the weed species.
5. According to the recorded species list the habitat provider role of these croplands is outstanding. They maintain diverse pollinator communities and serve as refugee for many farmland birds.
6. The effects of cropping practices, albeit strong, were not decoupled from the environmental- and site context, which influenced the crop type and cultivation practice.
7. These remnants of traditionally managed landscapes are a rich resource of weed species and could be incorporated in biodiversity conservation strategies.

# 6. LIST OF PUBLICATIONS

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