ENDURE

European Network for Durable Exploitation of crop protection strategies

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PU Public	X
PP Restricted to other programme participants (including the Commission Services)	
RE Restricted to a group specified by the consortium (including the Commission Services)	
CO Confidential, only for members of the consortium (including the Commission Services)	

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Glossary

ENDURE	European Network for Durable Exploitation of crop protection strategies
SSSUP	Scuola Superiore Sant'Anna; Italy
AGROS	Agroscope Reckenholz-Tänikon Research Station ART, Switzerland
CNR	Consiglio Nazionale delle Ricerche, Italy
INRA	Institut National de la Rechèrche Agronomique, France
JKI	Julius Kuehn Institute, Germany
RRES	Rothamsted Research, UK

Definitions

Landscape scale studies (from Bàrberi et al., 2010, in press)
"The interest in landscape scale processes in agronomy requires development of new methodological approaches linking farming practices directly to land use patterns and agri-environmental processes and urges the researcher to take into account interactions that become visible only beyond the farm gate (Benoît et al., 2007). In this context, landscape need not refer to a large-scale study approach. Rather, the 'landscape scale' is that at which the effects of the interactions among farming practices, land use and agro-environmental processes on a given phenomenon become visible (Blaschke, 2006): this may vary from a field to a region. Strictly speaking, the 'landscape scale' is a general concept which does not give any numeric information about the size of the study area (Allen, 1998): it just refers to the importance of continuous information exchange and transfer through up-scaling and down-scaling."

Habitat type
All places where vegetation can grow and therefore all land use types which can be habitat for vegetation will be taken into consideration. Habitat types are landscape elements, and they can be classified as 'patchy' or 'linear'. Since the study objects are plant communities in cropped fields.

Adjacent land use
All landscape elements surrounding the sampled field, both linear elements and patchy elements.

Summary

Objectives
Within the Network of Excellence ENDURE (European Network for Durable Exploitation of Crop Protection Strategies) a group of weed scientists decided to explore the possibility of re-analysing existing weed community databases for possible surrounding landscape configuration effects. This work is meant to stimulate other weed scientists to repeat this exercise on their own databases in order to continue the discussion on parameter definition for testing of landscape effects on weed communities.

Rationale:
The work was divided in three steps. The first part of the process of testing the possibilities to analyse existing weed databases for landscape effects on weed communities consisted in discussion sessions among participants to agree on:

- √ Characterisation of the existing databases;
- √ Determination of weed measurements that seem to be most suitable for these studies;
- √ Determination of landscape descriptors or metrics that can be collected easily for testing in relation to the existing databases.

During the second phase each partner set out to re-analyse their own existing database(s) (the case studies in this report) with the aim to test if the above established indications allowed for establishing landscape effects on weed communities. The third phase consisted of an evaluation of the findings and fine-tuning of the previously defined methodologies.

Degree of validation and operability of findings:

Results from the case studies confirmed the importance of ecological interpretations of the weed flora instead of use of total species abundance, abundance data of individual species and total species richness. The studies also showed the need to define landscape metrics which express landscape mosaic structure and land use diversity at relatively small scales, varying from directly adjacent field margin types to about 200 m around the field centre. Specific land use types may affect certain groups of species, but when the interest is in diversity measures, landscape structure and diversity may be more important than the presence of a certain type of land use.

Development of a strict protocol for re-analysing of existing databases is impossible due to i) diversity in the weed measurements taken, ii) the objectives of the original databases and therefore their basic layout, and iii) differences in the degree of availability of aerial photographs and maps needed to establish landscape metrics after conclusion of the original studies. However, the outcome of the several working groups and case study results give indications as to which factors are important to take into consideration. The results of this report, which will be briefly presented at the IOBC Working Group meeting ‘Landscape management for functional biodiversity’ in Cambridge, UK (29 June – 1 July 2010), will also be transformed in a publication for an international Journal (as objective of the 4th JPA). We hope that wider dissemination of this work will stimulate other researchers, in Europe and in the world, to start re-analysing their weed databases following our examples and findings, in order to stimulate a wide scientific discussion on which landscape metrics are important for weed management. We believe that this approach is more cost effective than promoting new research at large scale to obtain similar results.

<u>Teams involved:</u>
Teams involved in this activity were Scuola Superiore Sant’Anna, Pisa, Italy (sub-sub activity leader), Agroscope Reckenholz-Tänikon Research Station ART, Switzerland (AGROS), Consiglio Nazionale delle Ricerche, Italy (CNR), Institut National de la Rechèrche Agronomique, France (INRA), Julius Kuehn Institute, Germany (JKI) and Rothamsted Research, UK (RRES).

<u>Geographical areas covered:</u>
Participants to this sub-sub activity aimed at establishing landscape configuration effects on weed communities found their origin in many parts of Europe: Italy, France, Germany, Switzerland and UK. This means that many different pedo-climatic regions were covered by the case studies included. Furthermore, a wide variety of approaches to weed sampling were represented by the case studies.

1. State of the art

Weed scientists have collected data on weed communities mainly within agricultural fields and sometimes also in the field margins. It is usually the effects of crop management on community abundance, composition and dynamics that is being investigated. These investigations take place in experimental fields which allow manipulation of crop and weed management in order to establish the effects of these controlled conditions on the weed community. Otherwise, data on weed communities and farm or field management practices are collected in real-farm fields or field margins and statistical analysis of a great number of cases can determine if and how management practices affect the weed communities. Only rarely studies have been designed to determine landscape configuration and land use diversity and intensity effects on weed communities. This is not only due to the interest in these aspects that is only recent, but it also results from the complexity of such studies. It is not feasible to design experiments which vary in landscape configuration and therefore sites must be very carefully chosen and very detailed information on land use management and intensity should be collected for vast areas, which might also be distant from each other, therefore including other factors of variability related to soil type and micro-climate. These studies require huge amounts of time and money and can therefore not be performed by many different research groups.

Since most European landscapes are shaped through planning activities of local authorities and through European regulations which affect land use types and intensity in the various regions, such as CAP, we think it would be important to have better knowledge on the effect these planning and land management decisions can have on local weed communities. However, therefore we first need to establish if and how local landscape factors affect these weed communities, in order to give indications on possible consequences of the planning decisions taken. As said before, it is not feasible to set up large-scale research projects in different European landscapes in order to determine this. Therefore, within the activity of the ENDURE Working Group on Landscape and Community Ecology for Integrated Weed Management we decided to test if existing databases with weed community data can be analysed for ‘landscape effects’ through integration of these databases with certain easy-to-be-measured land use configuration factors. We therefore examined all weed databases present within institutions of the participating ENDURE partners and developed a common approach for analysis. Therefore we had to agree on:

1. which weed measurements used in classical weed research are most suitable
2. which spatial scales (plot/field layout) are covered by the existing databases
3. which landscape descriptors or metrics can be collected easily ad hoc for testing in relation to the existing databases.

Based on this harmonisation of data to be taken into account, we could define various research hypotheses. Each hypothesis is adapted to a certain type of database. Each partner tested the appropriate hypothesis on their own database. This means that other researchers, having similar types of databases can now follow the same approach as used for our case studies. This could then create a large number of cases from all over Europe which in time would allow generalisations regarding possible landscape configuration effects on weed communities.

2. Harmonization of material and methods among the Network

The main aim of this activity was to test if and how we can analyse landscape configuration effects on weed communities by using **existing weed community databases** which were designed to analyse mostly effects of cropping systems and weed management on these communities. The first step towards the development of a common approach was harmonisation of the measurements that could be analysed and that should be collected additionally. Based on present data and the additional data that could easily be retrieved on landscape configuration descriptors connected to the existing databases, we classified types of weed community databases which can be found all over Europe and defined a set of hypothesis that can be tested for each of these database types. The next step was to test this common approach on the databases the participating partners had in hand in order to draw conclusions on:

1. the feasibility of a common framework for analysis of landscape configuration effects on existing weed databases;
2. the utility of the conclusions we could draw from our case studies regarding landscape configuration effects on weed communities;
3. possible implication for land use planning in relation to management of functional biodiversity for more sustainable weed management as a contribution to a wider view on Integrated Weed Management.

3. Parameter harmonization

In order to proceed with a common method, a discussion was held to determine:

1. which weed measurements are most suitable for this study;
2. which spatial scales (plot/field layout) are represented by the existing databases;
3. which landscape descriptors or metrics can be collected easily ad hoc for testing in relation to the existing databases.

3.1. Weed measurements

Weed communities can be expressed by various measurements. The mostly found ones are:

- counts of individuals at species level (species richness) on known surface (individuals/m^2 for each species);
- ground cover for all species at known surface or at plot/field level (% cover);
- cover-abundance scale of Barralis (1976) for all species (r, +, 1, 2, 3, 4, 5 or similar);
- biomass at species level (g/m^2 for each species);
- total weed biomass (total g/m^2);
- seedbank density at species level;
- total species richness = number of species in a field/plot;

It is assumed that for each research the most appropriate measurements are taken in relation to sampling time and research objectives. Each measurement has advantages and disadvantages and these should be carefully taken into account when using these data for other purposes. Some examples are discussed below.

Species richness data

The problem comparing species richness from different experiments is that species richness is related to the sampled surface and follows an asymptotic curve, the shape of which depends on richness of the local species pool and micro-habitat diversity. However, in theory all the sampling designs we use to measure weed communities should be selected based on the fact that with that particular design we expect to sample most species in the plot or field. Important differences may occur in the case entire plots are scanned for species with respect to a situation where a predetermined number of plots per field are sampled. In the first case more rare species can be expected and this sampling design is more suited if there is an interest in conservation of rare arable species. If the research question aims at common weeds, plot-sampling is sufficient. In relation to the question how land use configuration and land use intensity affects weed communities, it would be important to take into consideration both common weeds and the rare arable species, and therefore data collected by plot-sampling might underestimate the number of rare plant species occurring in arable fields.

Sampling time

The above-mentioned weed measurements can be taken at various moments in time, where each moment represents a particular crop stage and thus a specific interaction with the weeds. In general weed sampling moments are chosen in relation to the moment when the biggest impact on the crop are expected. Alternatively, one can chose sampling moment in order to determine the effectiveness of weed management treatments or the overall success of the weed in the crop (biomass at harvest). Since the impact weeds have on the crop is not uniform through time and differs for the different crops depending also on the weed community composition, the information the data can give is diverse for the various databases. Before one can proceed it should be determined why the weed communities were measured in that particular case. A couple of objectives were identified:

- Weed abundance is a measure of the expected yield loss. This means weed abundance should be measured at that moment in the crop life cycle when the crop is most susceptible to competition with weeds. This moment is different for many crops. For example, maize is more susceptible to competition in the early growth stage, just after emergence, whereas winter wheat is more susceptible at tillering. Winter wheat emerges in late autumn, when weeds are not germinating or if they did they are not photosynthetically active. For spring wheat, it can be expected that competition will be more severe just after emergence, since crop and weeds will emerge simultaneously.
- Information is required on composition and relative species abundances in order to adjust/plan weed control measures.
- An interest is taken in future weed problems. Since weed biomass has often been found to be correlated to weed seed production thus measuring of weed biomass in the later crop stage may be seen as an indicator for the enrichment of the seedbank and thus as a risk factor for future crops. At the same time, weed measurements in later crop stages reflect the success of the weeds in that particular crop and cropping system.

At the same time, there is only little information available on which measurement best describes the above mentioned objectives for weed community description. Should weed communities be described based on total plant densities, cover or biomass, individual species densities, cover or biomass, or ecological group abundances? It is likely that the answers to these questions depend on the initially posed research question and that it changes in time and between crops. We have the impression the choice of selected weed measures is often determined by available resources and by weed densities itself. For example, weed counts are more labour intensive than estimations of weed species cover, and in certain occasions, for example if many grasses are present, individual plant counts are is simply impossible.

We considered that all above mentioned weed measurements can be used to determine landscape effects on weeds as long as the same measurements are compared within the same study. The question on which weed measurements are expected to be the best response variables to landscape configuration and land use intensity measurements resulted in two hypothesis:

1. The seedbank is expected to be a better response variable to landscape configuration because it is less prone to short-term management practices and climate conditions and reflects the overall success of the weed species to all conditions that occurred over the past decades.
2. Different weed measurements can be used together *IF DATA WERE COLLECTED WITH THE SAME OBJECTIVE* (see list above), because if a particular weed

measurement is chosen to best represent the interaction with the crop/cropping system at that time, this means that the relative order of the weed species is important and not the exact value which was measured. A special study on this topic was performed under the ENDURE activity RA2.6c and initial results confirm that different weed measurements give similar results in terms of effects on abundance of important weed ecological groups (e.g. monocot/dicot ratio; annual/perennial ratio).

3.2. Spatial scale of plot/field layout

There are two main research approaches to establish crop/weed management effect on the weed community. The first one is based on experimental plots: Therefore, often single fields are selected which are divided in plots receiving the different treatments. The second method is to select a great number of real farmers' fields, interview them about management practices and describe the weed community in these fields. The experimental lay-out is obviously more effective in determining treatment effects because all other factors (soil, microclimate, surroundings) are homogeneous. On the other hand, the validity of the results obtained through experimentation in other soil types, microclimatic conditions or different surroundings is less predictable. The real field data are difficult to interpret because many confounding factors are present, and the treatment effects may be reduced to explain only a small part of the weed community variability. On the other hand, if clear indications about best management practices arise, these data have a higher value for a more wide-spread application. From these two main situations five more detailed spatial configurations of the sampling units have be defined which result in different hypotheses that can be tested or which need a different analytical approach:

- One field divided in several plots which received different cropping system/weed management treatments;
- Several fields in the same area divided in plots which received different treatments
  - with a similar or homogeneous land use pattern;
  - with different or heterogeneous land use pattern;
- Scattered fields in a region
  - with homogeneous land use pattern;
  - with heterogeneous land use pattern;
- All fields in a continuous area
  - with a homogenous land use pattern;
  - with heterogeneous land use pattern;
- Scattered fields regional or nation-wide, and therefore in landscapes that differ not only in land use pattern, but also in climate, soil, geography etc.

3.3. Landscape descriptors

In order to connect weed community composition to land use configuration, two main decisions have to be taken: i) which set of variables best describes land use configuration in relation to the weed community composition and ii) at which spatial scale do these variables interact with weed communities in cropped fields.

i) <u>Land use configuration measurements</u>

Since this study evolves around weed communities, '*habitat type*' was defined as '*all places where vegetation can grow*' and therefore all land use types which can be habitat for vegetation will be taken into consideration. Habitat types are landscape elements, and they can be classified as '*patchy*' or '*linear*'. Since the study objects are plant communities in cropped fields, '*adjacent land use'* is defined as ''*all landscape elements surrounding the sampled field, both linear elements and patchy elements*.'

Linear elements:

Woody
Watercourses
Verge
Road
Track
Stonewalls

Patchy elements:
- Buildings
- Water body
- Woodland
- Grassland
  - Permanent
  - Annual
  - Pasture
  - ….
- Orchard/vineyard
- Arable
  - Spring cereals
  - Winter cereals
  - Leguminous crops
  - or individual crops

The level of detail at which various land use types can be determined depends on the scale of study and on the available data. Most of these data will have to be collected ad hoc when returning to the study areas will not be possible or will be too labour intensive and information is therefore dependent on existing land use maps or aerial photographs. At the same time, the collected information should define different land use types but should allow for clustering of land use types which have similar effects on the weed communities. For example, various winter cereals may be managed more or less in similar ways, and can therefore be considered similar land use types. These decisions have to be made by the researchers, based on the expected impact of the selected land use types on the weed community.

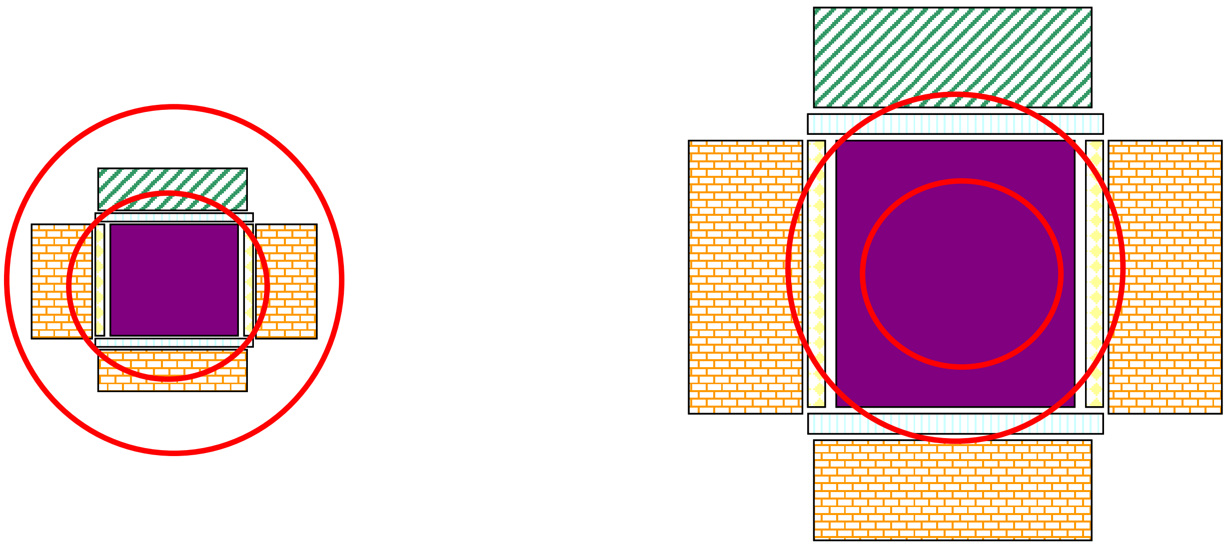
ii) <u>Spatial scale</u>

Composition and proportions of these linear and patchy landscape elements have to be defined at appropriate spatial scales around the investigated fields. The first level of interaction is between the field and its directly surrounding landscape elements, which can be various linear elements such as field margins, or patch elements in case the field is not separated from the adjacent land use type. The subsequent levels of interaction are between the field and the surrounding land use types at larger distances than the directly adjacent landscape elements. Since most weed species are not very mobile at long distances, in most cases land use configuration at a couple of hundreds of meters around the sampled field should be sufficient. In that case landscape element description 'as far as the eye can see' may be a good solution. If land use configuration has to be determined ad hoc when return to the fields is not possible any longer, land use determination from maps in a radius of a couple of hundreds of meters around the sampled field may be sufficient. If on the other hand there is an interest in establishing large landscape scale effects on weed communities, concentric circles could be drawn around the field for which weed data are available. The circles should vary in size in order to include the first layer of field margins and directly adjacent fields in the first circle, and more and more fields in the following circles (figure 3.3.1). Choice of studied circle size and landscape descriptor ought to be based on weed community composition and weed species ecological characteristics. For example, if some of the species we are interested in, either for their conservation or for better management, are animal-dispersed, the connectivity of the habitat of the dispersal agent should be an important factor to take into account in order to calculate the relation between the presence of these species in the fields and the landscape configuration. In on the other hand the species of interest are wind dispersed, it is more likely that their presence is related to the proportion of those land use types which are habitat to these species and that these relationships exist at rather long distances from the studied fields (so the studied landscape scale should be bigger than just the directly adjacent fields).

In studies aiming at determination of landscape configuration effects measured at different spatial scales around the sampled fields there is one question to which no straight-forward answer can be give: should the concentric have a pre-defined diameter, or should they be drawn in relation to field size? For example, if we are to compare two fields with different size, and we want to know how directly adjacent land use influences weed community measures, the reference circle should comprise the first layer of surrounding landscape elements. If a predefined circle diameter is applied, for the small field you may include also the second layer of landscape elements whereas for the larger field, you may find the circle inside the field. It would therefore be more functional to determine the circle diameter based on field size, and therefore to calculate landscape configuration as proportions of the various land use types, in such a way that surface of the circle is not important anymore. However, it has to be taken into consideration that 'margin' effects are expected to be smaller in large fields than in smaller fields. Since weed community measures are normally taken in the central part of the field, these margin effects may not be revealed in large fields, whereas they will in small fields. A solution at the data analysis level may be to use field size as a covariable. Alternatively, use a variable circle diameter for the evaluation of directly adjacent land use on weed community measures, and fixed circle diameter for the large-scale landscape configuration effects. Based on previous studies a fixed circle radius of 100, 200, 500 1000, 2000 up to a maximum of 5000 m around the field centre can be sufficient.

There are several types of software available to calculate landscape descriptors based on GIS maps. One of these is the open source programme FRAGSTAT (http://www.umass.edu/landeco/research/fragstats/fragstats.html). FRAGSTAT allows for calculation of a large number of landscape metrics, but not all of these are relevant in relation to weed communities. Each researcher who is willing to re-analyse an existing weed community dataset should select the ones most relevant to the dataset in question. Description of adjacent land use elements is certainly an important first step. Decisions on the analysis of landscape descriptors collected at larger scales depend mostly on i) the possibility to collect such additional information and ii) the expected interaction with the weed community.

(a)



(b)

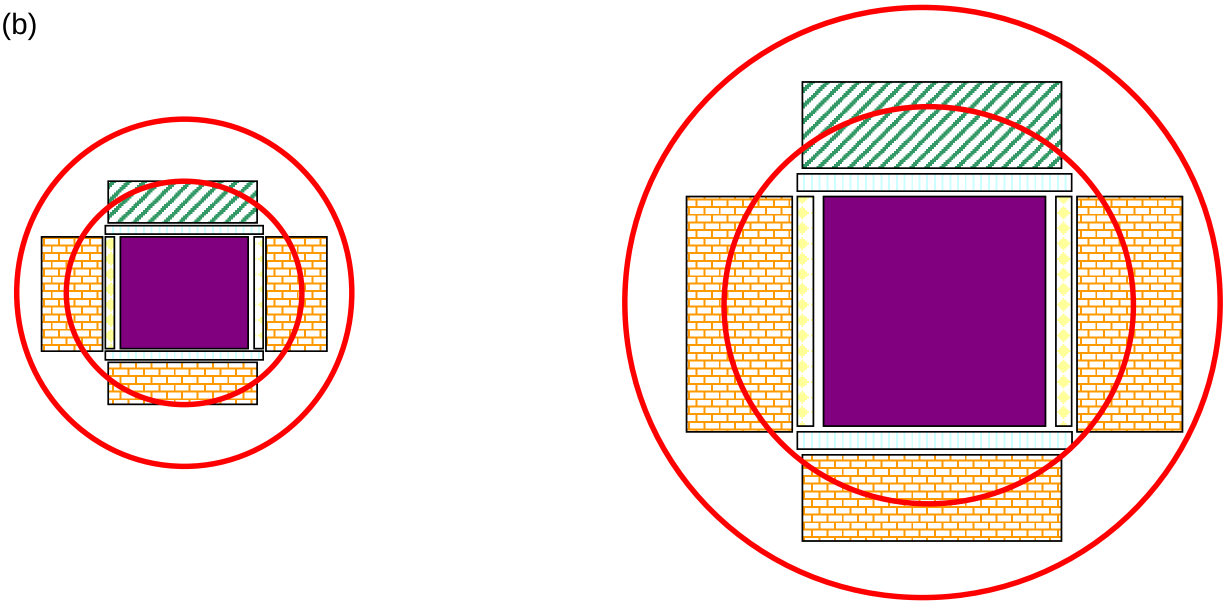


Figure 3.3.1. The dilemma of concentric circle size in relation to landscape configuration measures; (a) when circle diameter is fixed, fields of different sizes may not be comparable; (b) when circle size is dependent on field size and proportional land use configuration measures are taken, fields with different size become comparable.

3.4. Hypotheses to be tested

The case of single fields or experimental fields with data from field margin to field centre

In the case of experimental fields or studies where data from transects within a field were collected, the only hypotheses that can be tested are regarding the directly adjacent land use types and how those influence the in-field weed community. Therefore each sampling unit has to be characterised according to the distance from the nearest field margin. The central sampling units are not supposed to be affected by any of the margins in particular. Field margin or surrounding land use effects on in-field vegetation can be determined after correcting for the known variability caused by experimental treatments, soil heterogeneity and other known sources of variability.

<u>Numerous fields with data from field centre</u>
If data from several fields within a region or country are present, hypotheses that can be tested regarding the effect of land use heterogeneity and specific land use types on weed community measurements including species diversity measures are:

- √ Heterogeneity in land use patterns at 'greater than one field distance' from the investigated field results in higher variability in weed community measurements with respect to fields which are surrounded by more homogenous land use patterns.
- √ High proportions of land use type X result in different weed communities than landscapes dominated by land use type Y.

If no information is present on the scale at which land use configuration affects the specific weed communities, the best approach would be to calculate land use configuration descriptors at various spatial scales. In this case data will have to be corrected for differences in management, climate, geography and soil characteristics. However, analysis of directly adjacent land use types is likely to capture an important portion of the way in which landscapes interact with in-field weed communities.

From discussions held in various occasions (ENDURE internal meetings and workshops we organised at international meetings) some hypotheses arose which we think should be tested. We therefore invite everyone in possession of weed databases to verify if the following hypotheses can be tested:

- √ Seedbanks are a better indicator for landscape effects on weeds than above-ground flora response variables.
- √ Landscape effects are better visible in no-till systems than in tilled systems.
- √ Landscape effects are better visible in low-intensity areas then in intensively managed areas (especially related to herbicide use which kills all and does not leave room for landscape effects).

The databases in possession of the ENDURE partners in this activity allowed for testing of the following hypotheses:
First SSSUP database

1. Seedbank data provide better insight in 'landscape' effects on weed communities than above-ground weed community data because they are less subject to annual variability due to climate and crop/weed management.
2. Since the low-input system generally has higher monocot abundance due to absence of tillage, the effect of a grassy strip adjacent to the plots is expected to have a lower impact on monocot abundance/percentage than a grassy strip adjacent to a tilled system.
3. Field margins with a vegetation dominated by species which are not adapted to cultivated areas (woody vegetation, plants of typical humid areas on ditch banks etc.) are less likely to have an impact on the weed community composition and /or density in the first few meters of the cropped field than margins composed of ruderal species and grasses who are adapted to cultivated and disturbed areas.

Second SSSUP database

1. Boundary structure affects the weed community developing in the field
2. Grass strips increase monocot invasion in the first meters into the field.

AGROS database

1. Woody habitats increase the number of species and individuals of weeds (especially woody plants) and problematic weeds in the conservation headland.

CNR database

1. In organic farming the lack of herbicides and mineral fertilizers, as well as the higher variability in crop rotations and landscape can favour species richness.

INRA database

1. Weed richness and diversity within our landscape is explained by the size of the field and the identity of the preceding crop.
2. Variability in weed richness and diversity is partly due to spatial autocorrelation,
3. Surrounding landscape mosaics determine weed species richness and diversity at different spatial scales and landscape mosaic structure is more relevant than landscape mosaic composition.

RRES database

1. Local landscape diversity (richness) affects the species richness or abundance of monocotyledon or dicotyledon weeds in GB arable fields.

4. Case studies from ENDURE partners

In this chapter the ENDURE partners who contributed to this deliverable present case studies from their own existing databases. These examples cover a wide variety of databases and they represent diversity in scale of the collected data, weed response variables, landscape descriptors and in objectives of the original databases. The examples are organised in such a way that the scale of data collection increases and therefore different landscape effects can be measured. Datasets from SSSUP are from experimental plots organised at field scale. All experiments were located in a 1 km^2 area. Datasets from AGROS are from field-scale transects, but fields were scattered throughout a large part of Switzerland. Datasets from CNR were from whole fields scattered in a region in north-eastern Italy. Datasets from JKI were from field margins of fields scattered throughout a part of northern Germany where landscapes were selected based on their differences. Datasets from INRA were from fields scattered in a region of France. Data from RRES contained both transects at field scale and fields were scattered throughout UK.

4.1. SSSUP

4.1.1. Case study A

4.1.1.1. Objectives of the original study

This field experiment was designed in 1993 to determine the effect of tillage system, Nitrogen fertilisation and winter cover type on weed suppression in a maize-winter wheat biannual rotation. Other factors studied were crop management effects on yield and soil fertility [see (Bàrberi and Mazzoncini 2001; Moonen and Bàrberi 2004) for published results on weed suppression capacity of the tested cropping systems].

4.1.1.2. Description of the existing database/case study area

The Cover Crop experiment is one of the long-term experiments at the experimental farm of the University of Pisa (Interdepartmental Centre for Agro-environmental Research E. Avanzi). The area was divided in 124 plots of 12 x 24 m following a split-split plot design with 4 blocks testing for effects of tillage system (tilled system and no-till system), N fertilisation (0, 60, 120, 180 kg N/ha in winter wheat and 0, 100, 200 and 300 kg N/ha in maize) and winter cover type (rye, subterranean clover, crimson clover, crop residue). Total weed biomass at harvest was collected in all years in order to summarise weed suppression capacity of the imposed cropping systems. This was done by cutting above-ground weed biomass in one 1x1 m sample per plot. In most years additional data were collected on weed species density before weed management (early crop stage) and weed cover in winter wheat or weed density in maize after weed control treatments. Weed density in maize was sampled in quadrates of 50x50 cm (depending on the year 2 to 9 samples per plot were taken) whereas weed density in winter wheat was taken in 30x25 cm quadrates with the wheat row in the middle and the longest side of the quadrate along the row. Weed cover after weed control was sampled in 50x50 cm quadrates using the Braun-Blanquet method (Braun-Blanquet 1964). In 2001 and 2003 weed seedbank was sampled in nine sub-areas per plot excluding the treatments with the higher Nitrogen fertilisation level. In each sub-area three soil cores of 15 cm depths and 3.5 cm diameter were taken and mixed. One thirds of this total soil volume was exposed in tubs in an open glasshouse and seedlings were identified, counted and removed during one year (Moonen & Bàrberi, 2004). Seedbank was sampled at sowing of winter wheat.

D

N0	N1	N2	N2	N1	N0	N0	N1	N2	N2	N1	N0
CONV. SYSTEM			LOW-INPUT SYSTEM			CONV. SYSTEM			LOW-INPUT SYSTEM		
36 S	37 F	44 TI	52 F	53 S	60 TI	68 TS	69 S	76 F	84 S	85 TS	92 TS
35 F	38 S	43 S	51 TI	54 F	59 TS	67 F	70 TI	75 S	83 TI	86 S	91 F
34 TS	39 TI	42 TS	50 S	55 TS	58 F	66 S	71 TS	74 TI	82 TS	87 F	90 TI
33 TI	40 TS	41 F	49 TS	56 TI	57 S	65 TI	72 F	73 TS	81 F	88 TI	89 S
4 TS	5 TI	12 F	20 S	21 F	28 TI	97 F	104 S	105 S	113 TS	120 S	121 F
3 S	6 F	11 TS	19 TI	22 TS	27 F	98 TS	103 TI	106 TI	114 S	119 TS	122 TS
2 TI	7 S	10 TI	18 F	23 TI	26 S	99 S	102 F	107 TS	115 F	118 TI	123 TI
1 F	8 TS	9 S	17 TS	24 S	25 TS	100 TI	101 TS	108 F	116 TI	117 F	124 S

A (left margin) — C (right margin)

BLOCK I
BLOCK II
BLOCK III
BLOCK IV

N0 = 0 kg/ha 0 kg/ha
N1 = 100 kg/ha 60 kg/ha
N2 = 200 kg/ha 120 kg/ha

F = DURUM WHEAT
S = RYE
TI = CRIMSON CLOVER
TS = SUB. CLOVER

B

Figure 4.1.1. Lay-out of the field experiment with positioning of treatments and margin complexes A, B, C and D, showing that margin complex A only affects the conventional system, and margin complex C affects only the low-input system.

4.1.1.3. Hypotheses regarding landscape effects on weed communities that will be tested

In this study, which includes data from one experimental field, it is not possible to examine larger landscape configuration effects on the weed communities. However, the presence of two different field margins (B and D in Fig. 4.1.1) on the long sides of the field both bordering various experimental treatments (Fig. 4.1.1) allowed us to determine if the composition of the field margin strips affects the in-field weed communities and if so, whether this effect depends on crop management (tillage, N-fertilisation or cover types) or not.

The hypotheses to be tested were:

1. Seedbank data provide better insight in 'landscape' effects on weed communities than above-ground weed community data because they are less subject to annual variability due to climate and crop/weed management.
2. Since the low-input system generally has higher monocot abundance due to absence of tillage, the effect of a grassy strip adjacent to the plots is expected to have a lower impact on monocot abundance/percentage than a grassy strip adjacent to a tilled system.

3. Field margins with a vegetation dominated by species which are not adapted to cultivated areas (woody vegetation, plants of typical humid areas on ditch banks etc.) are less likely to have an impact on the weed community composition and /or density in the first few meters of the cropped field than margins composed of ruderal species and grasses who are adapted to cultivated and disturbed areas.

4.1.1.4. Materials and Methods for conversion of the original data

The weed response variables we selected for this exercise were weed densities of the above ground weed flora in the early crop stage of winter wheat in 2001 calculated as mean densities per plot based on 9 quadrates of 25x30 cm per plot. From the species specific data, we calculated total weed density, monocot density, dicot density and monocot proportion. Data were log-transformed. It was decided to concentrate the analysis on the response of monocots and dicots to the field margin composition because the margins were dominated by grasses and these can be problem weeds in these maize-winter wheat cropping systems. The same was done for the seedbank density data from 2001 and 2003 in order to compare the results for the seedbank and above-ground weed community data. The seedbank density was calculated based on emerged seedlings from 9 sub-sample areas per plot.

The two tillage systems were analysed separately since tilled and no-till systems were accounting for most of the variation in the dataset and therefore obscured any other crop management effect on weed community composition. For the above-ground weed flora, data were analysed following a linear model and treatment, block and margin A and C were inserted as confounding variables. For the weed seedbank data treatments, blocks, year (2001/2003) and margin complex A and C were added as confounding variables.

Table 4.1.1 Example of the database that was analysed for margin effects on weed density (plants m^{-2}).

Plot	tillage	Dose N	Cover	block	Complex A	Complex B	Complex C	Complex D	Total dens	Monocot	Dicot
1	A	0	RC	R1	4	4	0	0	97.78	77.04	20.74
4	A	0	TS	R1	4	1	0	0	99.26	94.81	4.44
5	A	100	TI	R1	3	1	0	0	75.56	72.59	2.96
6	A	100	RC	R1	3	2	0	0	106.67	105.19	1.48
87	S	100	RC	R3	0	0	2	2	140.74	131.85	8.89
88	S	100	TI	R3	0	0	2	1	158.52	151.11	7.41
89	S	0	S	R3	0	0	3	1	114.07	106.67	7.41
90	S	0	TI	R3	0	0	3	2	114.07	77.04	37.04
91	S	0	RC	R3	0	0	3	3	165.93	154.07	11.85
92	S	0	TS	R3	0	0	3	4	154.07	137.78	16.30
93	S	300	RC	R3	0	0	4	4	137.78	130.37	7.41
94	S	300	TI	R3	0	0	4	3	154.07	148.15	5.93
95	S	300	S	R3	0	0	4	2	1017.78	582.22	435.56
96	S	300	TS	R3	0	0	4	1	837.04	480.00	357.04
116	S	200	TI	R4	0	4	1	0	568.89	339.26	229.63
117	S	100	RC	R4	0	4	2	0	997.04	946.67	50.37
118	S	100	TI	R4	0	3	2	0	2494.81	2202.96	291.85

The numbers 0 to 4 in the margin complex columns indicate that the higher the number the closer the plots is to the field margin complex and therefore the higher the effect of the margin on the weed community of the plot.

Landscape descriptors we retrieved in addition to the original study were the characterisation of the four field margins. The 4 sides were characterised as follows: margin complex A, small ditch with wheat; margin complex B, grass strip/road with maize; margin complex C, small ditch with set-aside/hay; margin complex D, large canal with maize. Each experimental plot received a value in relation to its distance from the 4 sides. The first 4 plot rows received a value from 4 to 1 according to decreasing distance from the field margin; the other plots were considered not be influenced by the adjacent field margin-field complex. Since plots were 24 m long, 4 plots corresponds to 100 m from the field margin. Due to lack of replications, margin effects could not be distinguished from adjacent field effects and therefore the four fields sides were treated as a complex. After initial analyses, it was decided to concentrate only on margin B and D, since they were adjacent to all different treatment combinations, whereas margin complex A and C were very different and both had only 1 tillage systems and N-level directly adjacent to the strip so that differences between weed communities adjacent to the margins could not be attributed unequivocally to margin type or crop management.

4.1.1.5. Results

Tilled and no-till systems were analysed separately since the various response variables responded differently to the two tillage systems and strong interactions with distance from the adjacent boundary were found.

Nitrogen fertilisation and cover type were not interacting with adjacent boundary type.
Different types of boundaries affect the in-field vegetation composition differently: the grassy margin (B) increased the amount of monocots in tilled systems which were naturally low in monocots (Fig. 4.1.2), whereas the margin with fewer monocots, or monocots which were not compatible with cropped fields such as giant reed grass (D), even suppressed the monocot density and increased dicot densities (data not shown). The different field margin types did not affect weed community composition in no-till systems.

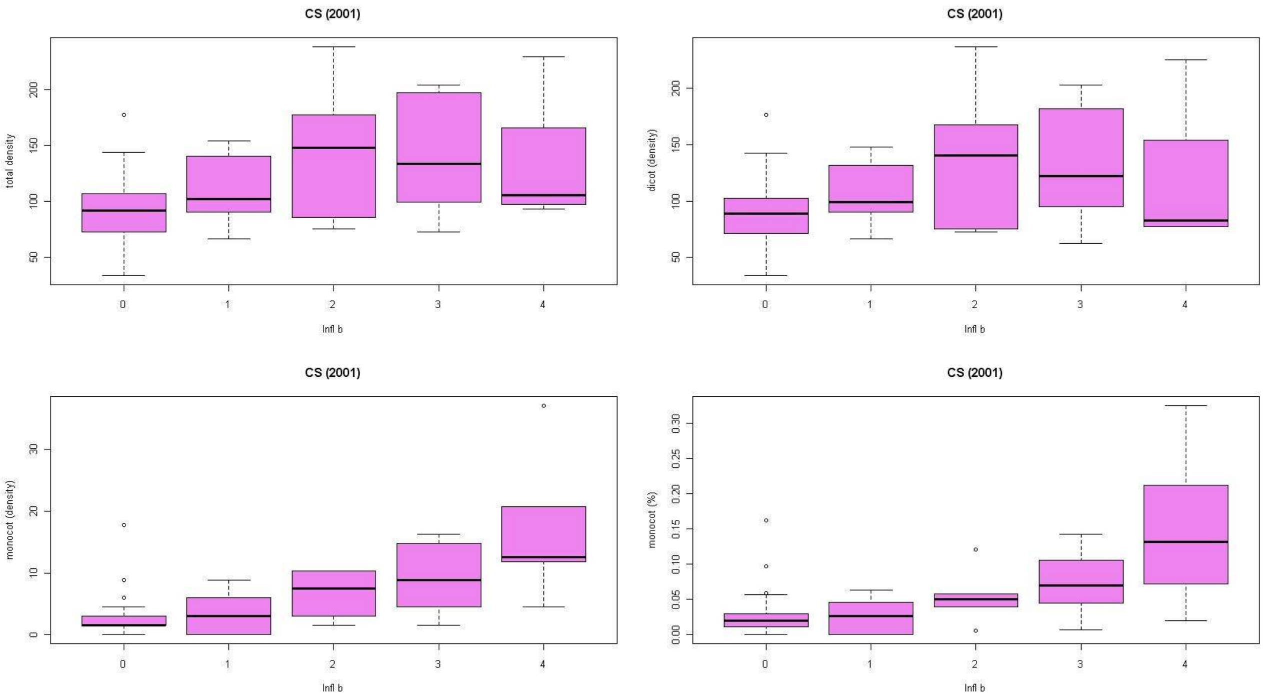


Figure 4.1.2 Min, max and median values of total above-ground weed density, dicot density, monocot density and monocot % before weed control in a tilled system in relation to distance from margin complex B, a grassy strip, where number 4 indicates the plot directly adjacent to margin B and 0 all plots that are more than 4 plots away from this margin (> 100 meter). Monocot density and percentage are higher in the plot next to grassy field margin.

In the seedbank a similar trend was detected and again the grassy margin (B) increased monocot density and percentage in the vegetation in tilled plots whereas total weed density did not vary at various distances from the grassy field margin (Fig. 4.1.3). In case of the seedbank an effect of field margin complex D could be detected in the no-till systems. Monocot densities were not affected, but presence of the drainage channel decreased total weed density and dicot density in the plots closest to this field margin (Fig. 4.1.4)

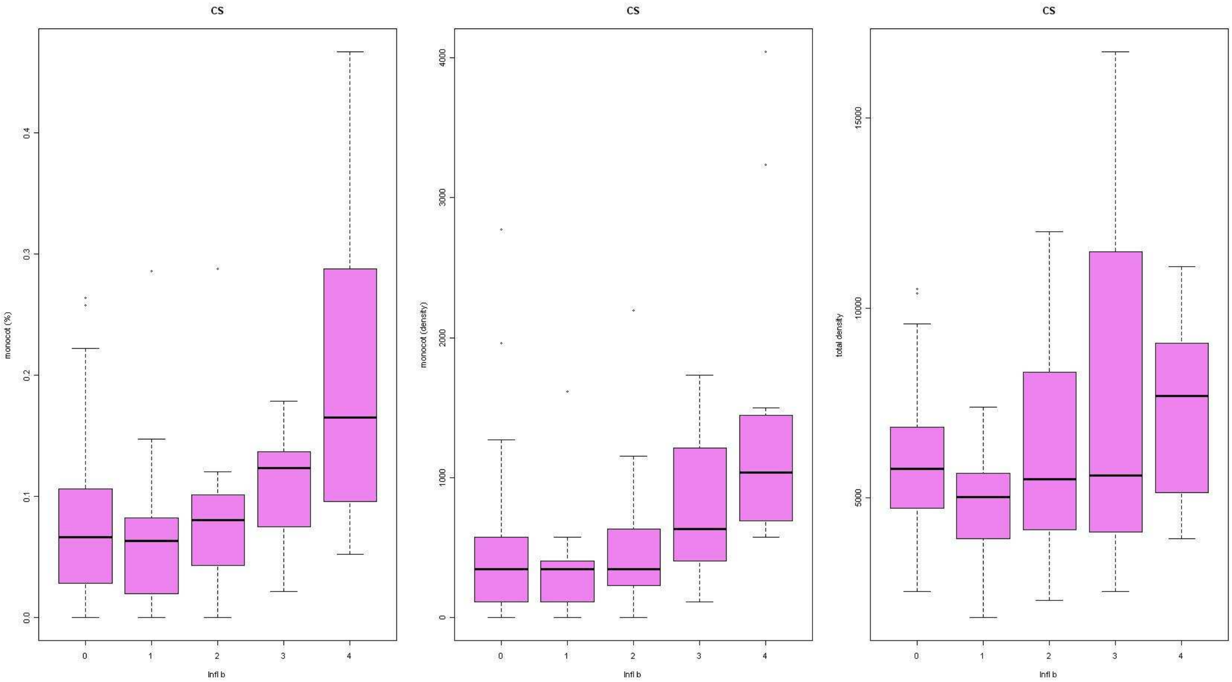


Fig. 4.1.3. Min, max and median of monocot proportion, monocot density and total weed density in the weed seedbanks sampled in 2001 and 2003 in conventionally tilled systems in relation to distance from the adjacent grassy strip, margin complex B.

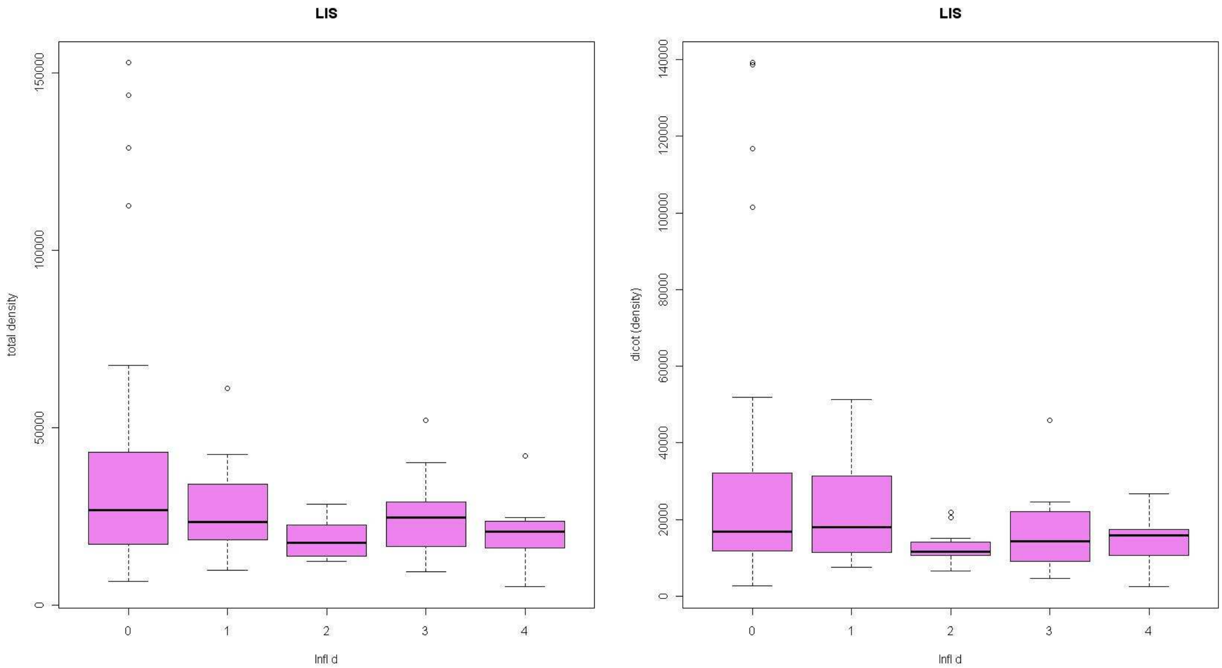


Fig. 4.1.4. Min, max and median of total seedbank density and dicot density in no-till systems sampled in 2001 and 2003 in relation to distance from margin complex D, a deep draining channel.

4.1.1.6. Discussion and Conclusions

The first observation is that if field margins surrounding a field are all different, it is not possible to make a distinction between margin and adjacent field. The surrounding land use should be considered as a complex.

These data confirm that the seedbank is a more sensitive response variable for 'landscape' effects than above-ground weed composition because more detailed significant effects of the field margin appeared. However, also the weed density data in winter wheat gave good results. This probably means that the effect of grassy strips on the weed composition in the field is quite strong and that none of the crop management systems was able to suppress this effect.

The hypothesis that grassy strips have less effect on the weed species composition of no-till plots than on conventionally managed and tilled plots was confirmed.

Other interesting ecological groups to be analysed in the future are life strategy groups (Competitors, Ruderals, Stress-tolerators) or dispersal type groups. It can be expected that fields or plots characterised by ruderals are less affected by landscape effects than plots or field with a higher proportion of competitors. Stress tolerators are expected to be less abundant in agricultural landscapes since management aims at limiting stress and creating favourable conditions for plant growth.

Overall we can say that the method is valid. Despite all variability caused by treatments, some effects of the surrounding land use types (in this case field margins) can be detected both in the above-ground vegetation as in the seedbank. In order to be able to perform such an analysis, a dataset is needed where a great number of quadrates are sampled covering the entire field and quadrates should be present from positions close to the field margin towards the field centre. The more data are available on factors causing heterogeneity with the field, the better the field margin effect can be analysed.

4.1.2. Case study B

4.1.2.1. Objectives

The original aim of this study was to determine if pre-existing field boundary structure and composition had an effect on the in-field weed species composition and how this weed community and surrounding field margins in turn affected the presence of aphids and their natural predators.

4.1.2.2. Description of the existing database/case study area

A 6 ha square field of 2nd-year alfalfa (2003'04) on an organic farm in a nature reserve (Parco di Migliarino - San Rossore - Massaciuccoli) was selected for diversity in field margins. The preceding crops were barley (2001/'02), *Vicia fava minor* (2000/'01) and before that it was a pasture for horses. Weed composition and abundance were measured in 12 transects (3 per side, at about 20 m distance) with 8 distances from the field margin (centre of the margin, attached to the margin, and at increasing distance between the samples (1, 2, 4, 8, 16 and 32 m) so that the last sample was at a distance of 64 m from the field margin. Weed cover per species was recorded in 1m^2 quadrates in June and July 2004. These two sampling times were relevant in relation to crop development and the presence of aphids and their beneficials. At the same time bare ground cover and alfalfa cover was recorded in each 1m^2 quadrate. Species richness was calculated as number of species per quadrate.

4.1.2.3. Hypotheses regarding landscape effects on weed communities that will be tested

In this study, which includes data from one experimental field, it is not possible to examine larger landscape configuration effects on the weed community. The field was selected for diversity in field margins and the objective was to test if and how far the field margin can affect the composition of the weed community in the field, and if this effect depends on the structure of the field margin. We tested the following hypotheses:

1. Field margin structure affects the weed community developing in the field;
2. Grass strips increase monocot invasions in the first meters into the field.

4.1.2.4. Materials and Methods for conversion of the original data

- √ Presumed link between weed response variable and landscape descriptor

Since the hypotheses to be tested are rather similar to the original objectives, no additional information needed to be collected. From the cover percentage of each weed species in each plot on the transects, we calculated some general weed response variables: species richness in 1x1m quadrates, total weed cover, monocot cover, dicot cover and percentage monocot cover. Total weed cover can exceed 100% because of stratification of weed species in different layers.

The landscape descriptors were limited to those describing the field margins. Margins were codified according to their position: N, north; E, east; S, south and O, west.

- √ The northern margin (N) is composed of a fence and a hedge which covers about 40% of the surface, with scattered trees in a row. The distance to the next field is large because this field margin structure separates the field from a country road (not asphalted), where the road sides are wide grass strips with a line of old trees and a 2 m wide drainage channel.
- √ The eastern margin (E) is a fence with a dense hedge (covering about 80% of the surface) and a dense tree row. On the other side of this structure there is a small drainage channel (about 0.5 wide) and a grass lane which serves as a passage for agricultural vehicles.
- √ The southern field margin (S) is a line of old and tall trees with a big crown (crown cover is almost continuous all along the length of the margin) planted on the edge of a 1-m wide drainage channel. Only few shrubs are present between the trees. A disturbed grass strip runs from the drainage channel 4 m into the field.
- √ The western border (O) separates the field from the wood. It consists of a small drainage channel (about 0.5 m wide) behind which the wood edge begins with a rather dense (about 60%) undergrowth of shrubs.

A linear model with field margin and distance from field margin as explanatory variables was used to analyse data. In the central part of each margin three transects were sampled which were used as replicates. We expected that the presence of a grass strip in the field margin would increase monocot invasion in the alfalfa crop in the first meters.

4.1.2.5. Results

Crop cover
Alfalfa cover in June was heterogeneous and on average varied between 20 and 60% (Fig. 4.1.5). It increased towards the middle of the field and in the first few meters cover depended on field margin type. Next to the southern boundary alfalfa cover remained low until 8 m into

the field whereas alfalfa cover was maximised at 1 m from the boundary next to the western boundary.
Alfalfa cover in July varied between 50 and 90% cover (Fig.4.1.6). Some plants were present in the field margin (at distance "0") due to sowing right up to the field margin. Plant cover was heterogeneous in the field and for the eastern and northern border there was no consistent increase from the field border towards the centre. The western side of the field had a lower crop cover in the first meter of the field whereas the crop established badly in the first 8 meters next to the southern field margin. This was likely due to shading effect of the high trees and the large grass strip bordering the field on that side.

Bare ground cover
Percentage bare ground in June was overall very low (less than 20 % and in most plots almost zero) and it seemed unrelated to distance from the boundary, with the exception of the southern margin which had up to 70% bare ground in the first crop meter (Fig. 4.1.7).
Bare soil cover in July increased drastically after the first 2 meters from the boundary (Fig 4.1.8). The southern border had a higher bare soil percentage (from 20 up to 70%) up to 4 m into the field. Bare soil percentage was high in the field margin regardless of the boundary whereas it was almost zero in June. This may be due to drying of the herbaceous vegetation in the warm and dry summer months.

Dicot percentage cover of total vegetation cover
In June the percentage dicots increased from boundary into the field and dicot percentage was almost 100% in the centre of the field, independent of boundary type (Fig. 4.1.9).
Percentage dicots in the weed cover in July (Fig. 4.1.10) was overall high but its patter from field margin to field centre differed per boundary type. Only next to field margin N and S there was an increase of dicots towards the field centre.

Dicot absolute cover
Dicot cover was lower next to the boundary than in the centre of the field but the pattern of increase differed per margin type (Fig. 4.1.11). Total dicot cover varied between 10 and 95% and highest overall cover was found in the transects of the northern boundary. Lowest dicot cover was found in the first 4 meters next to the southern margin, probably due to shading and the infestation of grasses from the wide grass strip present underneath the trees.
Dicot cover in July fluctuated between 20 and 40% near the northern and eastern margin and between 10 and 30 % in the western and southern margin (fig. 4.1.12). Except next to the southern margin no pattern of increase or decrease has been detected. In the first 4 meters next to the southern margin, dicot cover was lower than in the field centre.

Monocot percentage cover of total vegetation cover
Monocot cover in June decreased from field margin to field centre but the magnitude and shape of decrease curve depended on margin type (Fig. 4.1.13). Monocots represented between 10 and 40% of the total weed cover next to the eastern and northern margin, and between 20 and 60% of the total weed cover next to the western and southern margin.
Monocots in July (Fig. 4.1.14) represent between 0 and 40% of the total weed cover and they decreased towards the centre of the field next to the northern and southern margin whereas no pattern could be detected next to the other two margins. Monocots were absent in the eastern margin (distance "0") whereas the southern border had a high percentage of monocots and they invaded the field up to almost 8 meters.

Monocot absolute cover
Percentage of monocots in the vegetation decreased with increasing distance from the boundary. The exact pattern of decrease was dependent on boundary type. Monocot cover reached up to 60% in the field margin and decreased to about 5% in the field centre. Monocot percentage was lowest in the eastern margin (only 20%) (Fig. 4.1.15).

Monocot density in July (Fig.4.1.16) was about zero in all plots, independent of field margin type or position in the field, even next to the southern margin.

Leguminous cover

In June legumes were only a small proportion of the vegetation cover (hardly ever exceeding 10%) and no relation with distance from the field margins was found. In July legumes never covered more than 5% of the soil surface and were absent in most plots. No relation with field margin type or position in the field was found (data not shown)

Species richness

Mean species richness in June varied between 15 and 20 species per m^2 and was not related to distance from the boundary. The field sites close to the eastern and northern margins had a slightly higher species richness than the other two boundaries (Fig. 4.1.17).
Species richness in July was low (less than 10 species per m^2) and was not affected by distance from the boundary or boundary type (Fig. 4.1.18).

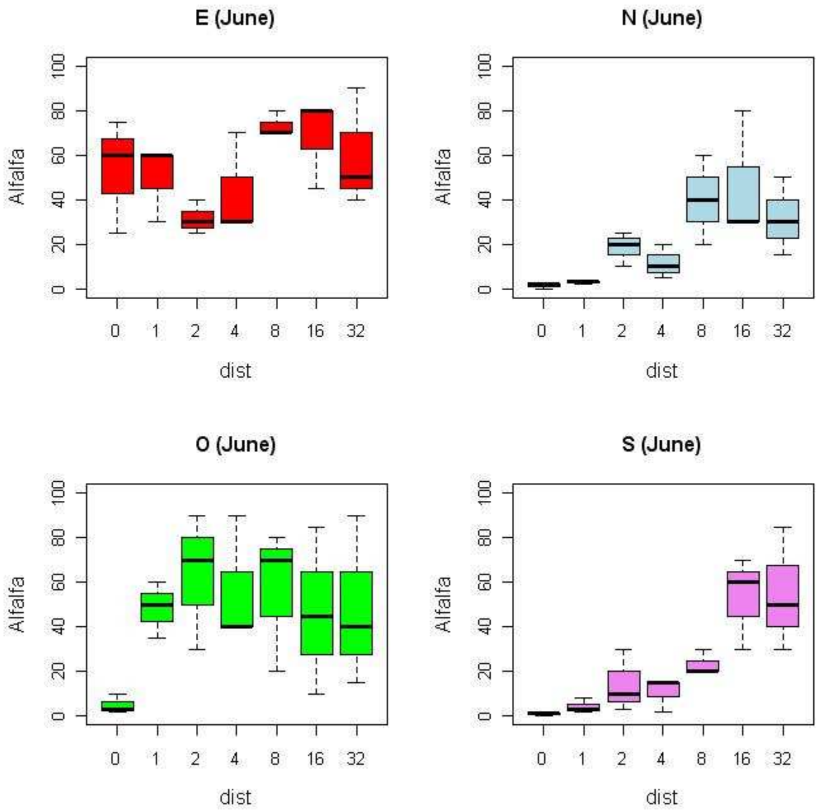


Fig 4.1.5 Alfalfa cover in June at different distance from the four pre-existing field margins (E, N, O and S).

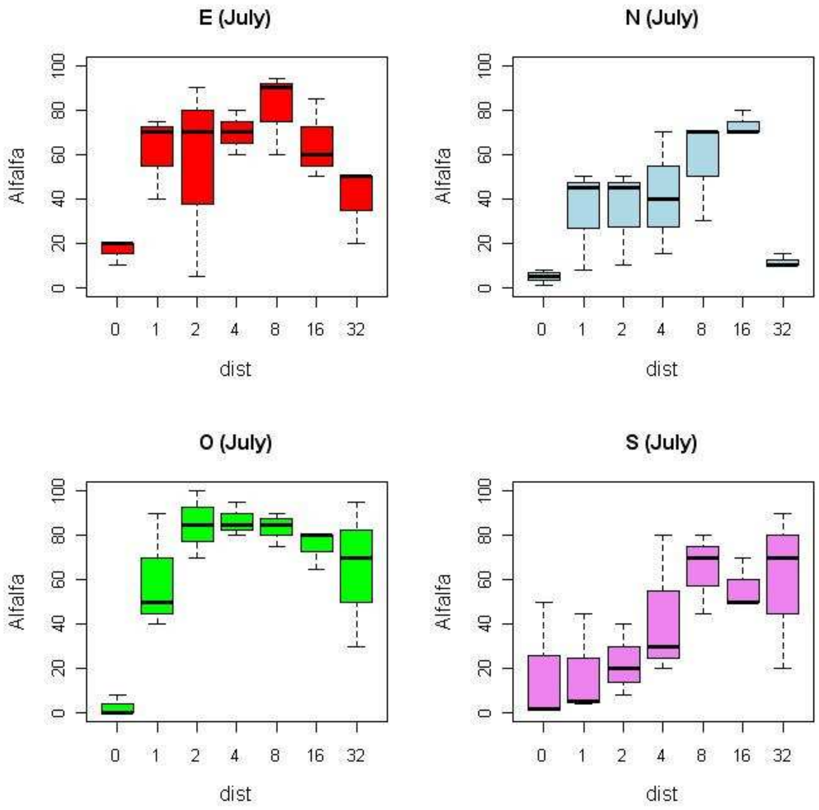


Fig. 4.1.6 Alfalfa cover in July at different distance from the four pre-existing field margins (E, N, O and S)

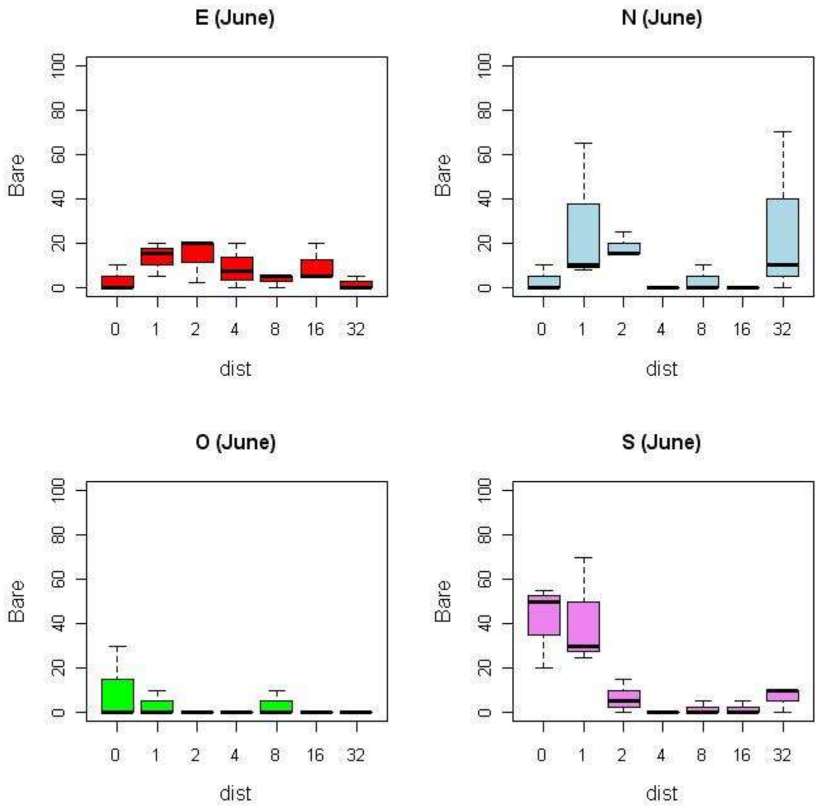


Fig.4.1.7 Bare ground cover in June at different distances from the four pre-existing field margins (E, N, O and S)

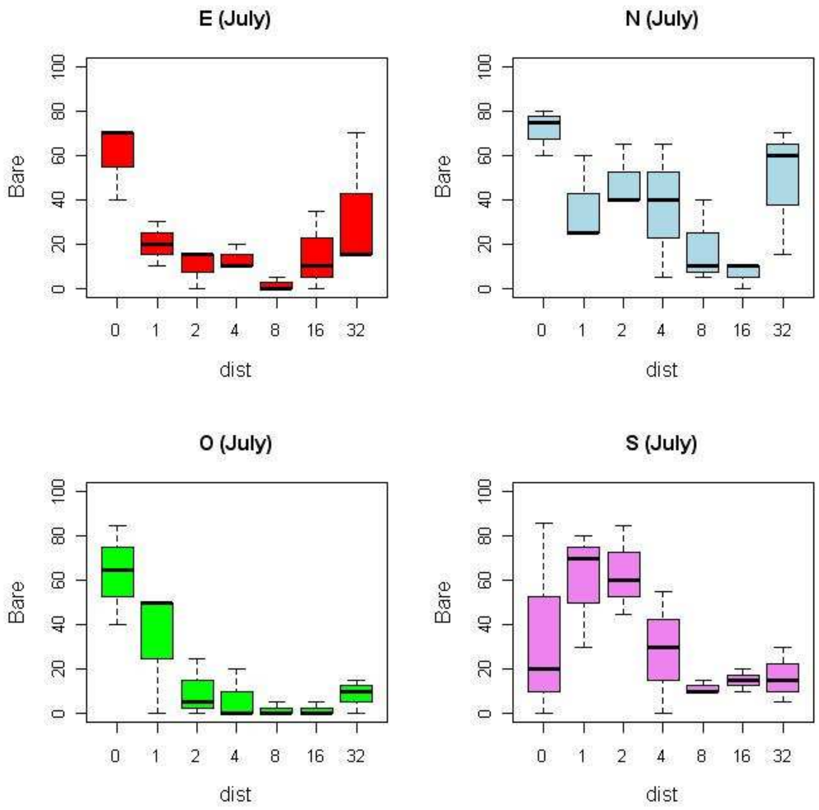


Fig. 4.1.8. Bare ground cover in July at different distance from the four pre-existing field margins (E, N, O and S)

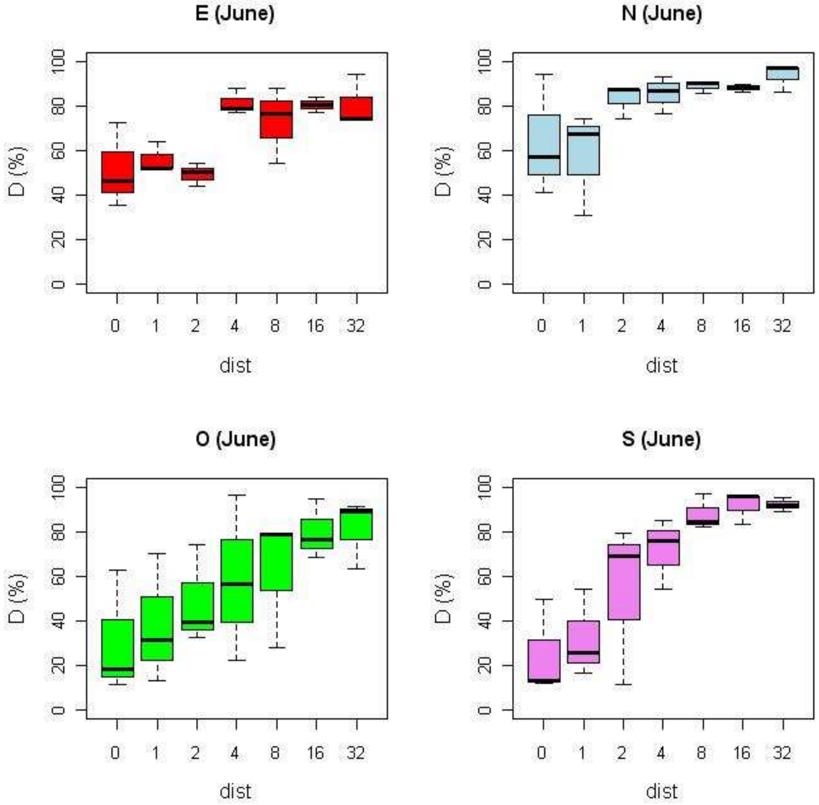


Fig. 4.1.9. Dicot cover as percentage of total weed cover in June at different distance from the four pre-existing field margins (E, N, O and S)

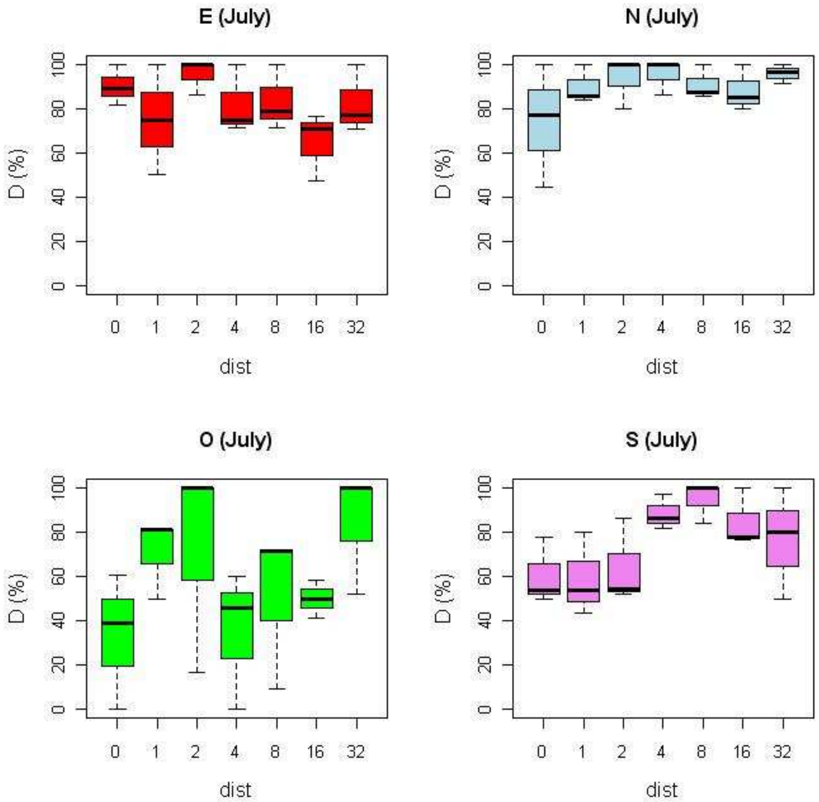


Fig. 4.1.10. Dicot cover as percentage of total weed cover in July at different distance from the four pre-existing field margins (E, N, O and S)

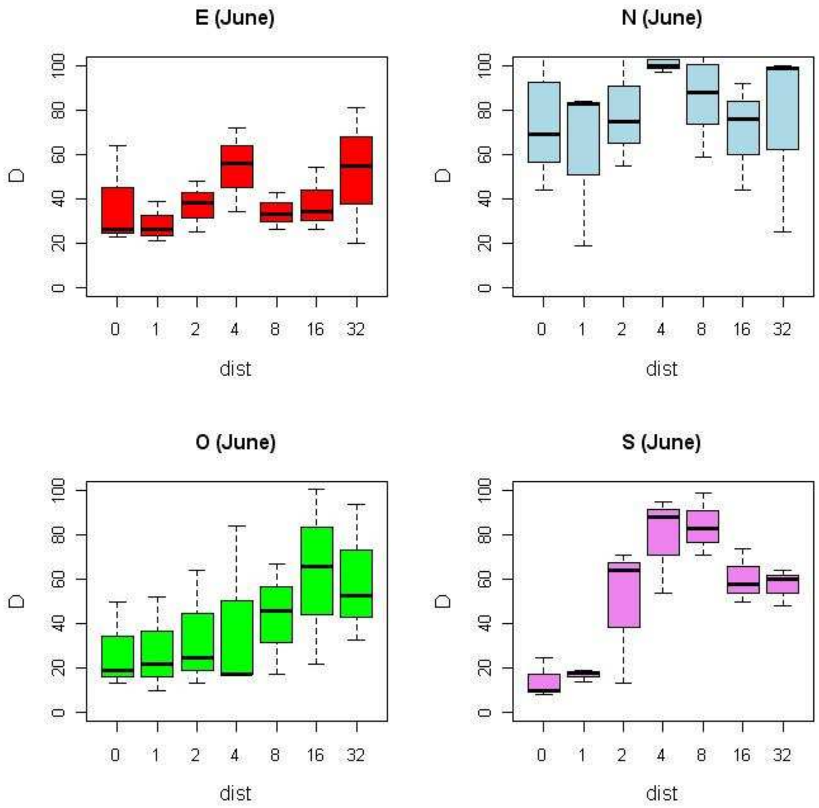


Fig. 4.1.11. Dicot cover in June at different distance from the four pre-existing field margins (E, N, O and S).

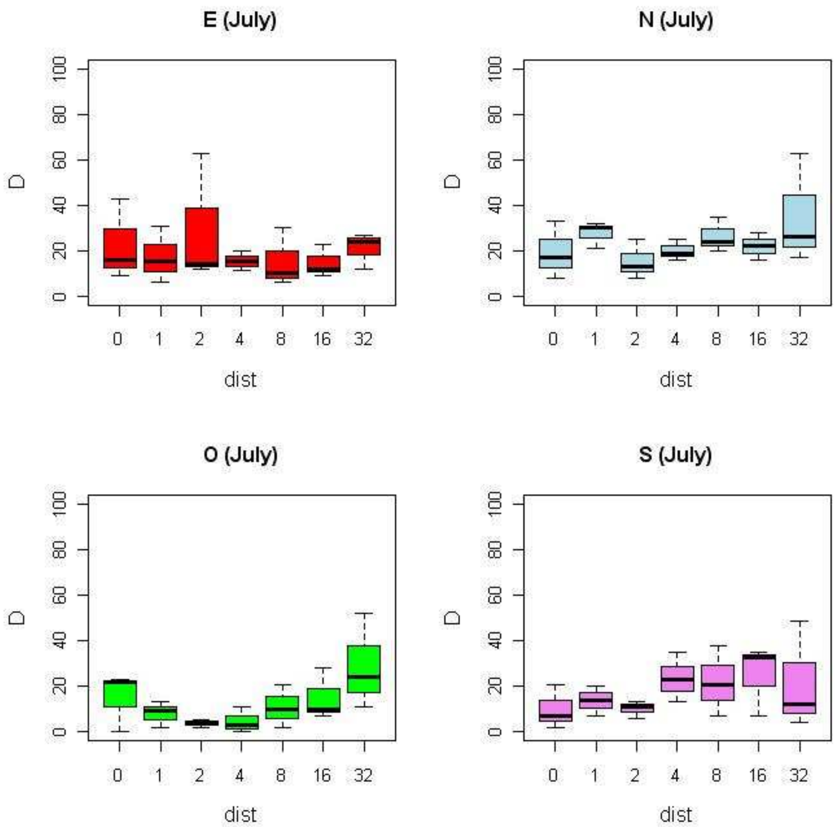


Fig. 4.1.12. Dicot cover in July at different distance from the four pre-existing field margins (E, N, O and S).

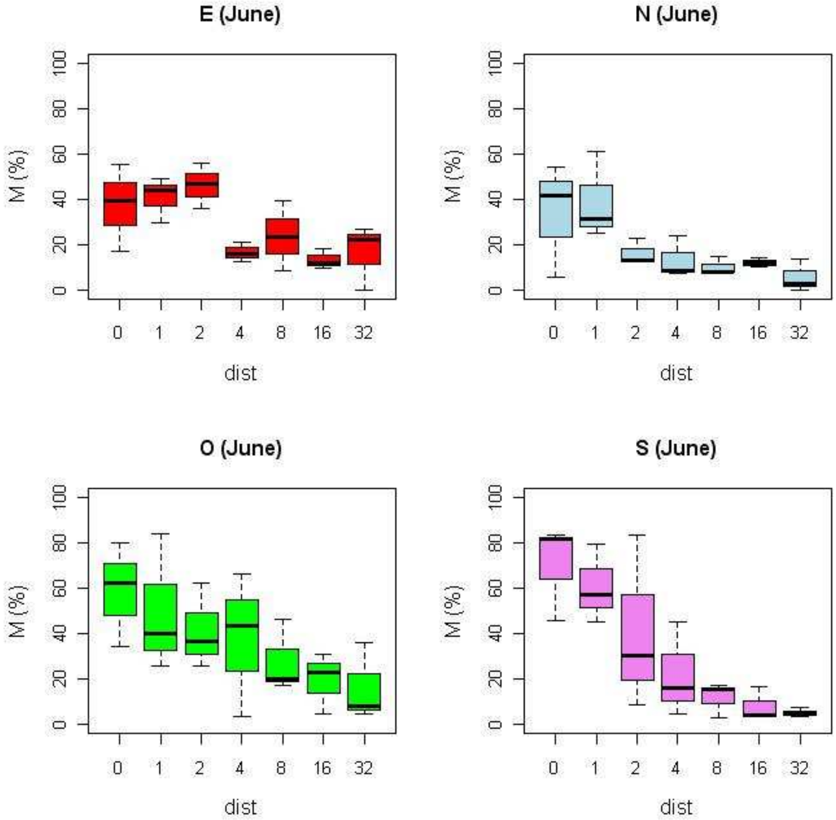


Fig. 4.1.13. Monocot cover as percentage of total weed cover in June at different distance from the four pre-existing field margins (E, N, O and S)

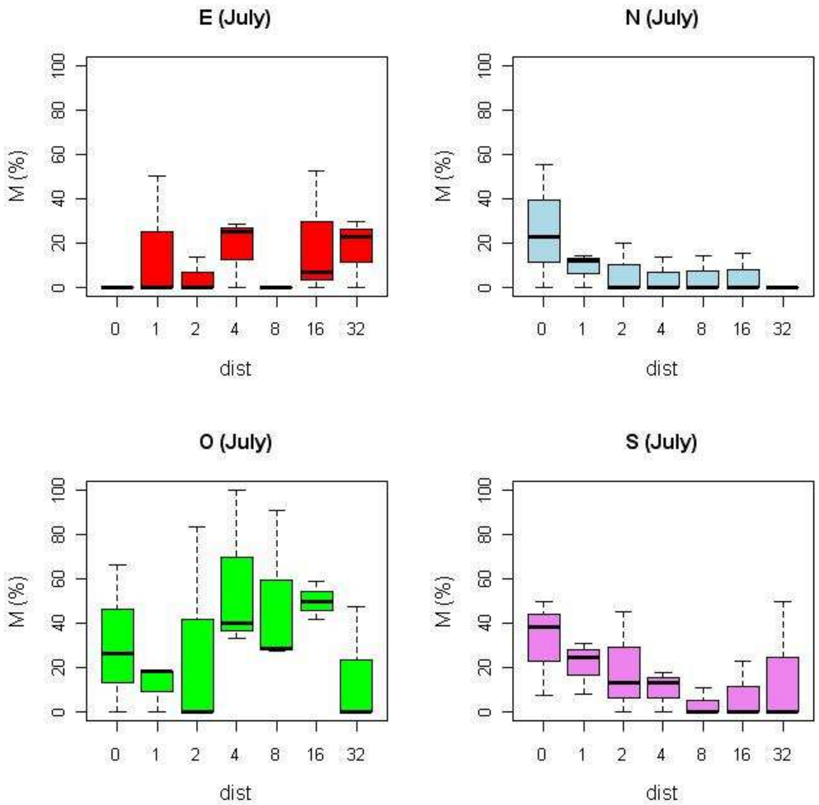


Fig. 4.1.14 Monocot cover as percentage of total weed cover in July at different distance from the four pre-existing field margins (E, N, O and S)

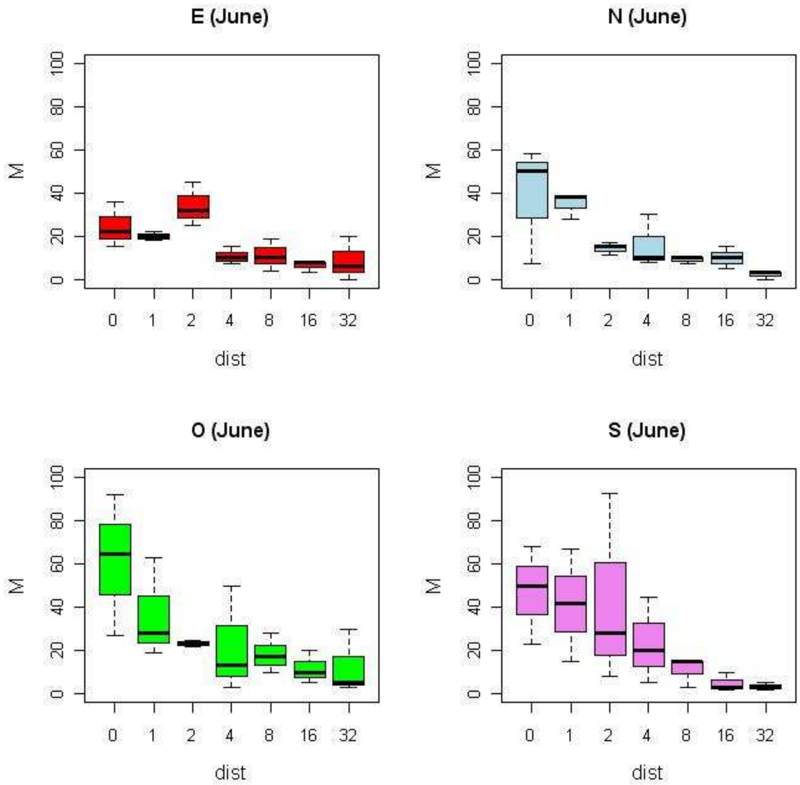


Fig. 4.1.15. Monocot cover in June at different distance from the four pre-existing field margins (E, N, O and S)

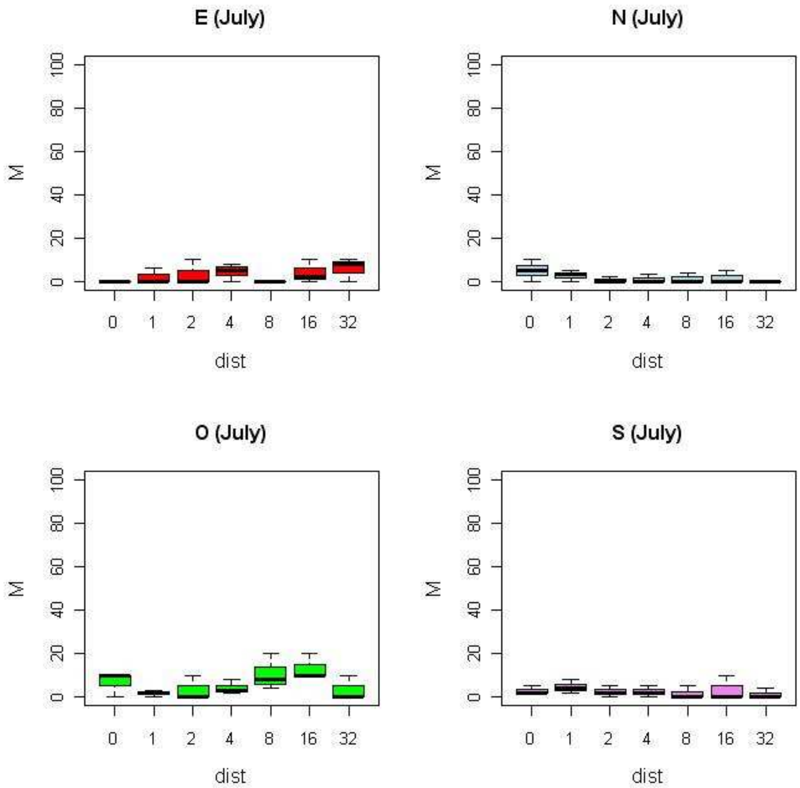


Fig. 4.1.16 Monocot cover in July at different distance from the four pre-existing field margins (E, N, O and S)

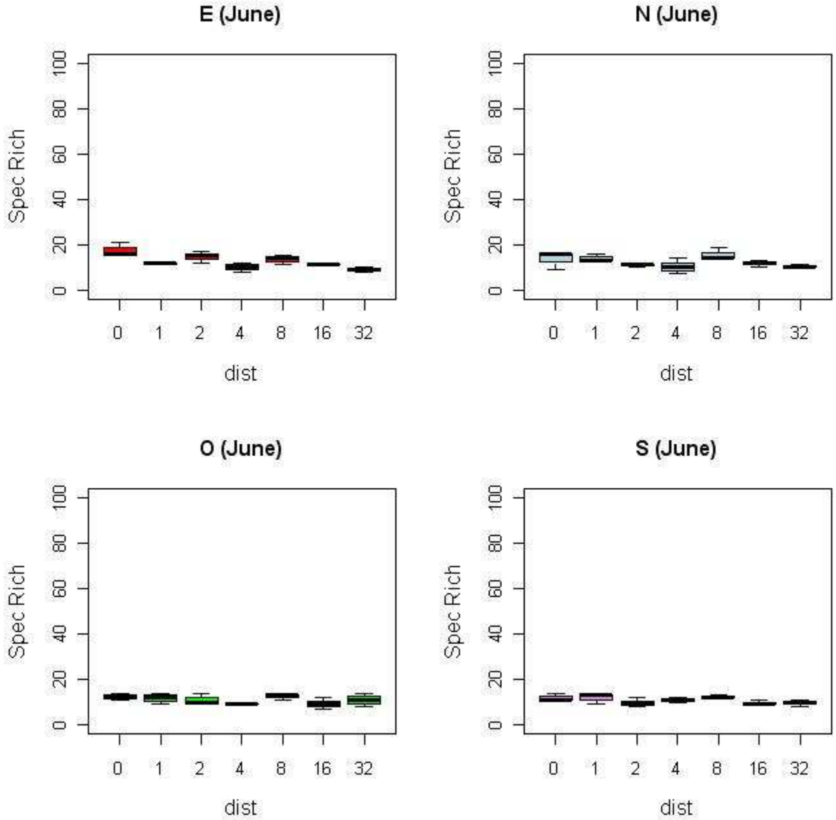


Fig. 4.1.17. Weed species richness in June at different distance from the four pre-existing field margins (E, N, O and S)

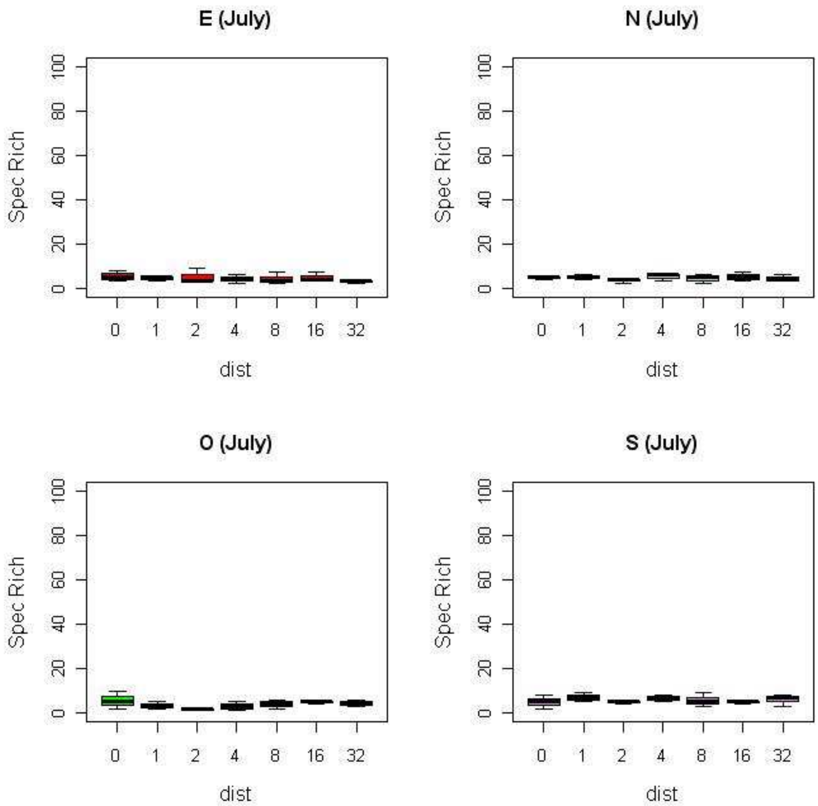


Fig. 4.1.18. Species richness in July at different distance from the four pre-existing field margins (E, N, O and S)

4.1.2.6. Discussion and Conclusions

The impact of field margins on the in-field weed composition was limited to the outer 4 meters, if an impact could be detected at all. This means that the relative impact of field margins on the in-field vegetation depends on field size, where small fields are more prone to margin impacts than large fields. Grass strips sustain monocot invasions in the fields. These data also showed that the effect of field margins on the in-field vegetation depends on sampling time. In dry Mediterranean climate July is not the best time to determine interactions between field margins and in-field vegetation because many weed species have already flowered and have disappeared. In June however, when vegetation is at full development, clear effects from field margin structure and vegetation composition can be detected.

The use of transects is a very effective method to establish field margin effects on in-field vegetation composition.

4.2. AGROS

4.2.1. Case study A

4.2.1.1. Objectives of the original study

The objective of the original study was to examine if conservation headlands are a suitable tool in arable landscapes in Switzerland to protect the arable flora (Richner 2006).

4.2.1.2. Description of the existing database/case study area

Definition of conservation headlands in Switzerland:

Strips of three to twelve meters width at the crop edge; crops are mainly cereals, but also oilseed rape, sunflower, peas, faba bean and soya. The strips are neither fertilised with nitrogen nor treated with insecticides. Only few herbicides are authorised to control *Rumex obtusifolius*, *Cirsium arvens*e, *Agropyron repens* and bindweeds plant by plant if necessary. Because of the absence or very restricted use of herbicides arable plants find suitable conditions to germinate and grow in the conservation headlands. Additionally, sometimes native arable weeds such as cornflower or field poppy are sown. The strips are kept for at least two years at the same location. The main crop is harvested when it is ripe. Conservation headlands are part of the Swiss agri-environment scheme.

Case study area and experimental design:

28 conservation headlands were studied; 15 on organic farms and 13 on integrated farms, scattered from west to east in the lowland part of Switzerland (Fig. 4.2.1), with a relatively heterogeneous land use pattern. In all cases there were neither pesticide nor nitrogen fertilizer applications in the conservation headlands.

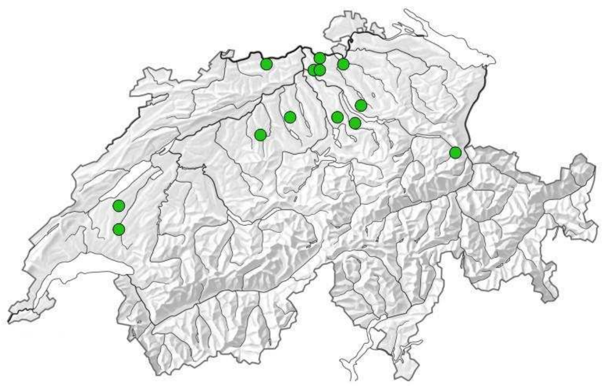


Figure 4.2.1: Locations of the 28 conservation headlands.

The arable flora was recorded between end of May and end of June 2006. In each conservation headland the arable flora was recorded in ten quadrates (Fig. 4.2.2). Each of the quadrates had a size of 0.5 m^2. In the quadrates the individuals of all phanerogams were counted and the species determined. No sown weed species were considered. For the analyses, the ten recordings per conservation headland were pooled. (To evaluate the flora of the conservation headlands recordings were also done in the rest of the crop, which was managed in the usual way. These recordings are not considered here).

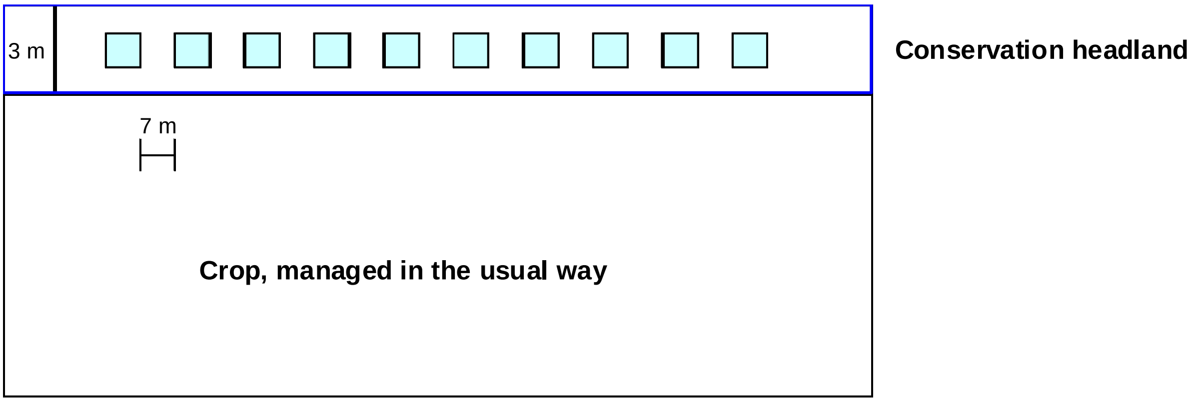


Figure 4.2.2: Experimental design with conservation headland and rest of the crop. The arable flora was recorded in ten quadrates; each quadrate measured 0.5 m^2.

<u>Variables examined:</u>

- Number of individuals
- Species number (= species richness)
- Number of forb individuals/species
- Number of grassy individuals/species (*Poaceae* and *Juncaceae* together = monocots)
- Number of woody individuals/species
- Number of problematic weed individuals/species (agronomically problematic species, i.e. sum of individuals of *Agropyron repens, Calystegia sepium, Convolvulus arvensis, Cirsium arvense* and *Rumex obtusifolius*)

Red list species were not examined because they were only present in very few cases.

4.2.1.3. Hypotheses regarding landscape effects on weed communities that will be tested

The aim is to examine if dominant linear or patchy elements along conservation headlands and around the field influence the weed variables mentioned above. It is assumed that woody habitats increase the number of species and individuals of weeds (especially woody plants) and problematic weeds in the conservation headland.

4.2.1.4. Materials and Methods for conversion of the original data

Before re-analysing the data information about the landscape elements in the direct neighbourhood of the conservation headlands were collected.

<u>Determination of the directly adjacent landscape elements:</u>

The landscape elements were determined using own pictures and observations or air photos (sources: Google Earth, map.search.ch, Twix Route). It was distinguished between patchy elements, i.e. forest, arable crop and grassland, and between linear elements, i.e. hedges, streets, paths and field margins. The length of each element directly adjacent to the conservation headland/surrounding the conservation headland and the whole field, respectively, was measured using Google Earth and indicated as percentage (100% = circumference of conservation headland or field, respectively). Classes were defined for the proportions (Table 4.2.1).

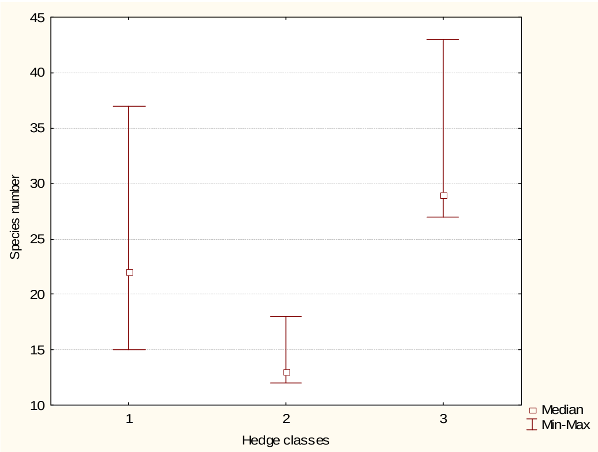
Table 4.2.1: Classes of the proportions (%) of the landscape elements adjacent to the conservation headland. Woody = hedges and woodland together. No. of obs. = Number of observations.

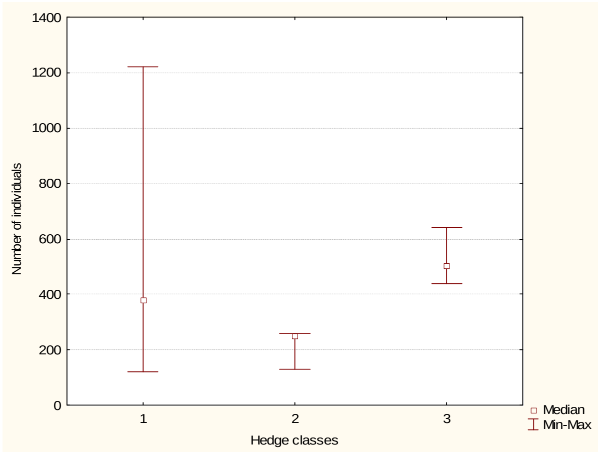
	Hedges		Crops		Grassland		Woodland		woody	
Class	%	No. of obs.	%	No. of obs.	%	No. of obs.	%	No. of obs.	%	No. of obs.
1	0	21	up to 25	7	0	11	0	14	0	10
2	20 to 29	3	26 to 55	8	1 to 30	5	1 to 20	6	1 to 20	7
3	> 29	4	56 to 79	6	31 to 50	8	> 20	8	21 to 39	7
4			> 80	7	> 50	4			> 40	4

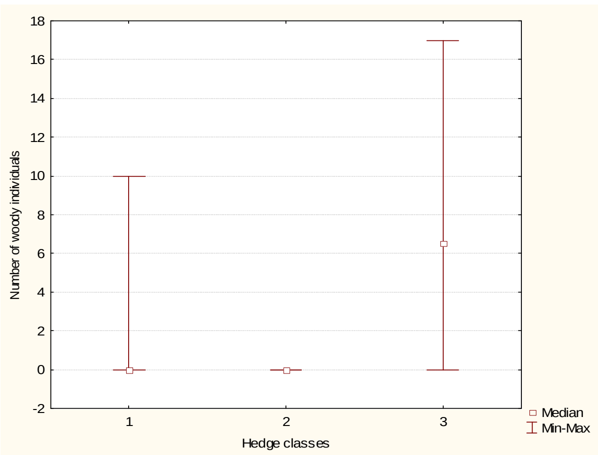
Figures were then created with different weed traits on the y-axis and different classes on the x-axis.

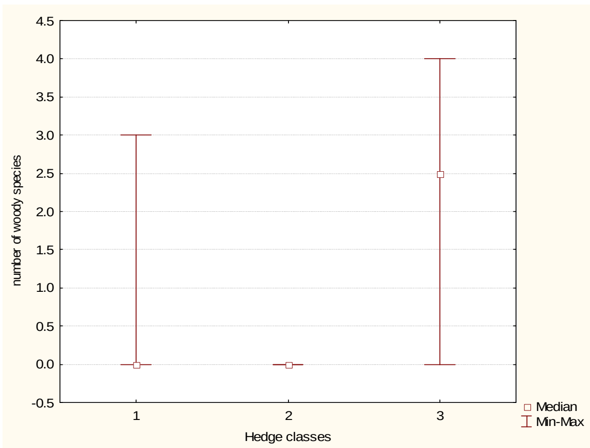
4.2.1.5. Results

Not many trends could be detected; only figures with a trend are shown here.









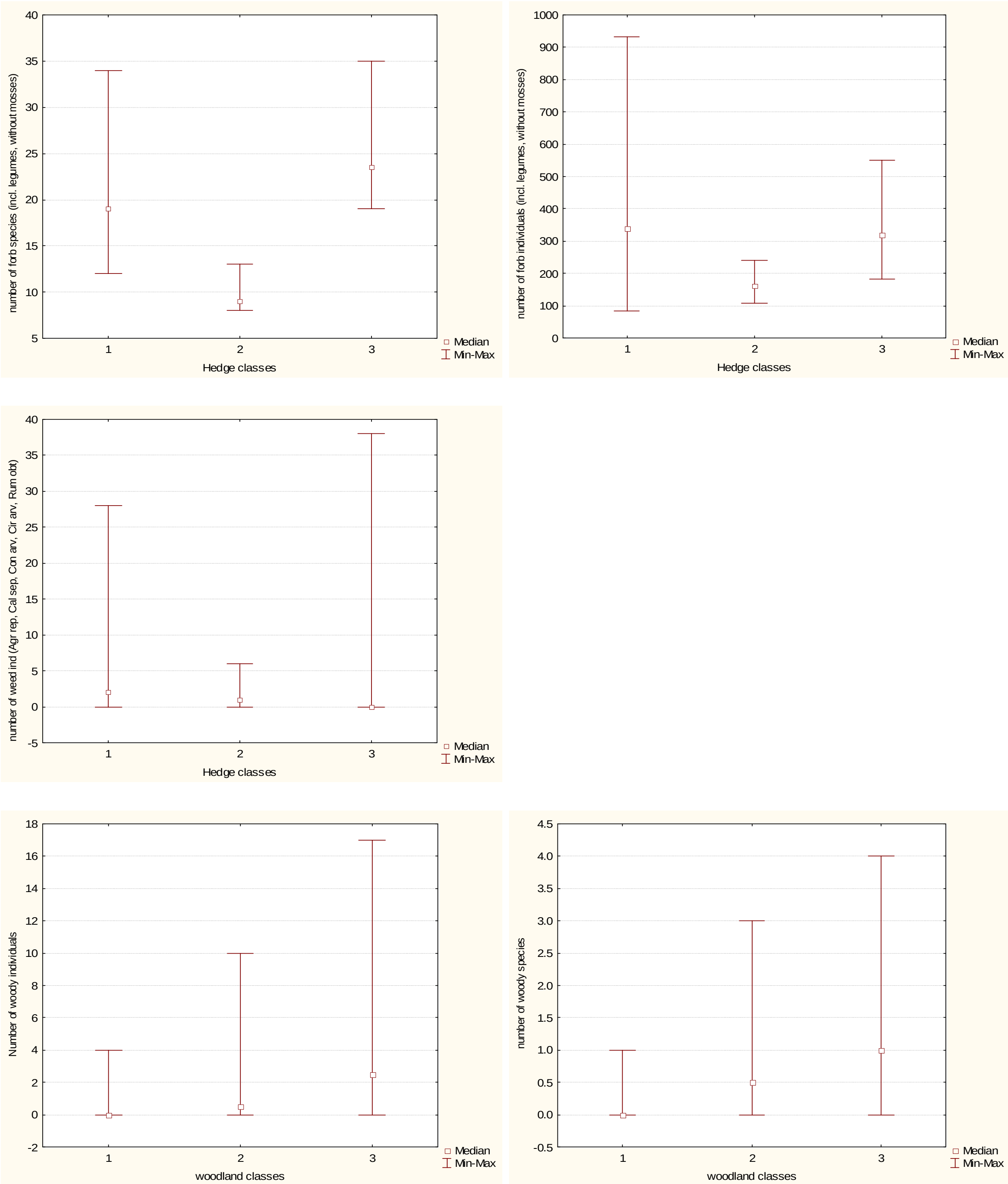


Figure 4.2.3: Different classes and weed traits (median, min, max; n = 28).

As the dataset is small it is important to be careful with interpretations. The results only show indications and trends (Figure 4.2.3):

- Hedges dominating → highest species richness
- Hedges/woodland dominating → most woody individuals/species
- Hedges dominating → most forb species
- Hedges dominating → highest number of individuals of problematic weeds (but generally not many individuals of problematic weeds present)
- No hedges adjacent → highest number of individuals/forb individuals

4.2.1.6. Discussion and Conclusions

Although the analysis is very rough, the results seem to confirm most of our hypotheses. However, there were also many weed traits where it was not possible to find the slightest correlation to landscape descriptors. This might be due to our small dataset and the variations which were often quite high. It would be favourable to have a broader dataset than ours for such analyses. Moreover, the management of the fields has an important influence on the composition and density of the weed flora present. This might have blurred possible effects of landscape elements on the weed flora.

In future analyses not only the directly adjacent landscape elements but also elements further away should be considered.

In order to analyse existing weed flora data together with landscape elements information on these parameters should be sampled already while doing the recordings of the flora. This saves time and more accurate information can be collected. However, when re-analyses are planned, i.e. information is collected some time after flora recordings were done, it is important to focus on questions which can really be answered and not to go too much into details.

4.3. CNR

4.3.1. Case study A

The case study focused on assessment of landscape effect on weed seed bank and weed vegetation in fields where pesticides are not used in a pre-alpine valley in northern Italy. This contribution on DR2.18 is based on a paper submitted the 22 February 2010 to the Journal of Applied Ecology (Evaluating the effect of landscape complexity on weed species diversity with classical and innovative indices, by S. Otto, V.P. Vasileiadis, R. Masin, G. Zanin).

Cultivated fields form a mosaic of crops interconnected by ecological infrastructures (ditches, hedges, canal banks) that have no yield importance but produce positive externalities. Diversity can be measured in various ways, for example with classical indices based on the relative abundance of the species, i.e. Simpson’s dominance or Shannon’s diversity. An index that takes also into account the homogeneity of individuals’ distribution between species by means of a scale parameter is the Réyni diversity.

An increasingly detailed description of the communities is possible with the quadratic entropy (Q) that considers not just the relative abundances of the species but also the “distances” between them and it can therefore be used to compare different agro-ecosystems or sites. The key point of the calculation of Q is in defining the matrix of the distances to each pair of species, and it is generally expected that a high value of Q is indicative of a community with high ecological value, whereas a low Q value might be symptomatic of a simplified or highly specialised one.

4.3.1.1. Objectives of the original study

The aim of this case study was to assess weed diversity and its link with the surrounding landscape elements. The abundance and diversity of weeds, both in terms of seed bank and vegetation, were evaluated in fields of organic farms with various landscape elements and located in an area of the Italian pre-alps where pesticides are not used. Evaluations were done utilizing the classical indices based on species abundance only, together with the Rényi diversity and the quadratic entropy. Distances were calculated accordingly to classification of species in biological, eco-physiological, seed dispersal, seed longevity and ecological groups. The proportion and type of landscape elements in a circular sector without prefixed radius were used as an indicator of landscape complexity.

4.3.1.2. Description of the existing database/case study area

The study was conducted at Val di Gresta, a small valley of approximately 3000 ha, 400–1300 m a.s.l., situated in north-eastern Italy between Lake Garda and the River Adige, which had been organically farmed, and pesticides not used, since 1986.

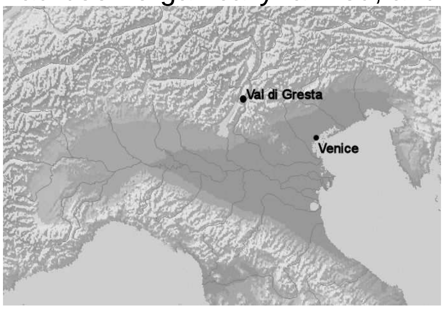


Fig. 4.3.1. Geographical position of the study area.

4.3.1.3. Hypotheses regarding landscape effects on weed communities that will be tested

The hypothesis is that in organic farming the lack of herbicides and mineral fertilizers, as well as the higher variability in crop rotations and landscape can favour species richness and indices based on ecological characteristics can highlight this effect more effectively than simpler diversity measurements which are based on species richness only. Hypotheses regarding landscape effects on weed communities that will be tested are that 1) the higher variability of the landscape can favour species richness, and 2) indices based on ecological characteristics can highlight this effect more effectively than simpler diversity measurements which are based on species richness only.

4.3.1.4. Materials and Methods for conversion of the original data

For germinable seed bank assessment, 25 soil samples were taken from 16 selected fields with a core sampler 7 cm in diameter by 25 cm depth. The evaluation was then done according to the seedling emergence method. The vegetation (or emerged flora) was monitored in other 10 selected fields within three permanently marked small plots of 1.0 m^2. Each weed species was classified accordingly to life-form, periodicity, ecological type, seed dispersal and seed longevity.

Six classical diversity indices were calculated: Species richness (S), Total abundance (N), Simpson's Dominance (D), Shannon's Diversity (H), Pielou's Equitability (E), Margalef's Index (M). The Réyni diversity (R) and the quadratic entropy (Q) were also calculated. For weed species distances were defined after classification in 5 biological, eco-physiological, seed dispersal, seed longevity, ecological groups.

A very simple and operative method for measurement of landscape complexity was chosen. In each selected field the weed sampling was done approximately in the centre of the field, and the landscape survey was done simply by standing in that point and reporting the stable and permanent elements observed in a complete horizon view, without a fixed radius. The landscape elements considered were the same as used for the ecological classification of weeds, i.e. non-cropped land, pasture, meadow, weed, crop, hedgerow, stone wall. Vertical structure are not (over) favoured because 1) if one can see through them, what is beyond them can be taken into account; 2) if one cannot see through them, then they can be considered with a null porosity even for weeds. In the area no lake or rivers are present, but of course when present they must be taken into account because both can be starting point for the spread of particular species. A landscape complexity index (C) was finally calculated.. Link between diversity and landscape complexity was tested with Principal component and classification analysis and Pearson's correlation.

4.3.1.5. Results

A total of 102 weed species belonging to 33 families were observed in the 26 sampled fields, and the weed community structure was highly variable between fields. For seed bank, the number of species ranged from 25 to 41, and the number of seeds from 3473 to 19760 seed m^{-2}. For vegetation, the number of species ranged from 15 to 30, and the number of plants from 431 to 1759 plants m^{-2}.

For both seed bank and vegetation R varies when $0<alfa<5$, then becomes asymptotic. For seed bank, R(alfa=0) is higher in respect to vegetation because of the higher number of species. For both seed bank and vegetation, the R lines for the various fields have a similar curvature and constitute a continuous series and various intersections were found.
Considering together seed bank and vegetation, the Q variation was from 6.5 to 34.0 and the distribution was not normal. Detailed analysis of results highlight the important fact that Q is able to emphasize and isolate the "best and the worst fields", although it could be deeply affected by a particular combination of species proportion and distances. There is no correlation with the other classical diversity indices, indicating that Q can provide original information.

For seed bank, C was significantly correlated only with Q. The C-Q correlation was expected as Q includes the same ecological categories, even if considered in a different way, as C. Landscape complexity has then an influence in weed communities.

Results of the Principal components and classification analysis can be summarized by a division of the factor plane (after Principal component, plots are made of points located in a (Cartesian) plane where x and y are the first and the second factor): the first factor can be interpreted as "Balance", (a field/site is balanced when there is no single dominant species, i.e. a species representing more than 40% of the total abundance) the second factor can instead be interpreted as a "Species richness" factor. The space of the factors is therefore divisible in 4 quadrants with the four combinations Balance-Richness. The link with landscape complexity is very weak and holds only for particular communities, see discussion below.

4.3.1.6. Discussion and Conclusions

A large number of species is no guarantee of high diversity because high species richness does not prevent one species from dominating the community. On the contrary, a community can be balanced even with only few species. With the classical diversity indices is then difficult to set a unique criteria of "balance". The Rényi diversity adds to the analysis a further dimension that can overcome this limit. Another general evaluation of diversity can be obtained with the quadratic entropy, which takes into account also biological and ecological aspects. So this index is not strictly correlated with the classical indices and can bring really new information on "balance" conditions.

The complexity of the surrounding landscape had an influence on the quadratic entropy of a field weed community, but the effect was low and detected only for particular communities (data not shown), i.e. very balanced in terms of biological, ecological, dispersal types, or, on the contrary, very simplified. It is likely that the importance of landscape complexity is higher in conventional farming, where the selective pressure of herbicide is high. The reason can be in the fact that, where the environment is very unfavourable for the major part of weed

species because of herbicides pressure, the presence of some areas free from chemicals can be very remarkable (some species can enter fields starting from the perimeter). In organic farming all the margins, or even the fields, are per se favourable habitats for a large number of species, so the effect of landscape can be confounded and hardly detected. This is the situation in Val di Gresta.
The opposite situation, where organic farming permits full expression of landscape, can be found where landscape structures are of a bigger magnitude than simple field margins, and/or where landscape structures are too small to overcome the effect of herbicides. Furthermore, local conditions are often considered to influence plant species richness. Finally, as for any diversity index, the quadratic entropy is completely neutral on the desirability of certain species.

The effect of landscape on weed community diversity is often supposed and sometime proved to be positive, but links between different landscape elements still need hard evidences. Results of this study show that this effect is low both for seed bank and vegetation, and can be detected applying various diversity indices: those with high complexity and flexibility can potentially grasp better that effect.

4.4. JKI

4.4.1. Case study A

4.4.1.1. Objectives of the original study

For the JKI Case study data of a floristic quality survey of field margins adjacent to agricultural land (arable and permanent crops) was used (Jüttersonke & Arlt, 2006). The dataset was originally sampled to determine the floristic quality of field margins in different German landscape units (Golla et al., 2002).

4.4.1.2. Description of the existing database/case study area

The survey of field margins took place in the year 2000/2001. Sampling sites were placed in 14 of 480 landscape units (Meynen & Schmithüsen, 1953-62) with agricultural land use. They were spread randomly across Germany (Fig. 4.4.1). The sampling protocol followed Braun-Blanquet (1964). All plant species were recorded along 50m of the margin and the actual margin width. The floristic data stem from one sampling time. No sampling was done within the field and no seed bank data was collected.

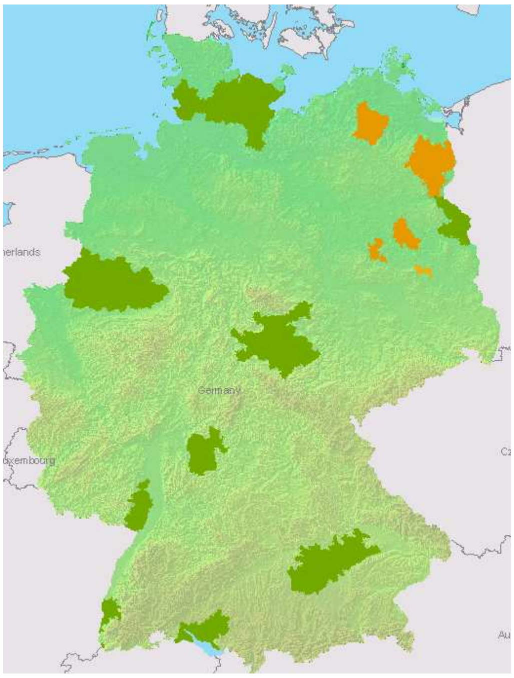


Figure 4.4.1 Landscape units (Meynen & Schmithüsen, 1953-62) where sampling sites were located

For the analysis presented here the floristic dataset of 366 sites was reanalysed to gain explicit information on weeds within the margins. Species richness and weed abundance data is thereafter available for monocotyledon and dicotyledon species.

The landscape analysis was based on spatial data of the national Authoritative Topographic Cartographic Information System (ATKIS BDLM). ATKIS is a project of the German Surveying Authorities, which is performed uniformly at the Federal level. It provides digital topographic base data suitable for computer-assisted digital processing. ATKIS describes the topographic features of a landscape in vector format and suits the scale range 1 : 10.000 to 30.000 (AdV, 2001). In a first step, the 366 sample sites under investigation were georeferenced using a GIS proximity analysis, different buffer zones (1000m, 2000m, 3000m, 4000m, 5000m) around the point coordinate of the sample site were created. For each of the buffer zones land use composition was calculated and given in percent of the buffer zone area. For the purpose of our study land use classes were aggregated to 7 landscape variables.

Table 4.4.1. ATKIS land use classes and landscape variables used in the analysis.

Land use classes and ATKIS object type numbers according to AdV (2001)	Aggregation
urban surfaces (21XX, 23XX,31XX;3501,4120 except 2101)	urban1
arable fields (4101)	agri1
grassland (4102,4105,4106)	grass1
permanent crops (4109)	agri1
small tree groups (4108)	forest1
forests (4107)	forest1
ditches (5101,5103)	water1
lake (5112,5101,5202,3401,3402)	water1
arable fields (4101), permanent crops (4109), grassland (4102,4105,4106)	open1 (open land)

Agricultural intensity was considered based on the SYNOPS database (Gutsche & Strassemeyer, 2008), which stores pesticide treatment data for arable fields in Germany. The treatment index was summarized on community level to reflect the difference in number of arable fields.

4.4.1.3. Hypotheses regarding landscape effects on weed communities that will be tested

We tested the hypothesis 'landscape composition and spatial arrangement affects the abundance of weeds and the floristic species richness in German arable field margins'. Here we limited the analysis to land use data of a circle with a 1000m radius around the sampling sites. The expectations were tested using multivariate statistics in JMP.

4.4.1.4. Materials and Methods for conversion of the original data

For the analysis we excluded data of field margins next to permanent crops. In cases that sampling was done on both field margins of an agricultural road, the mean of the weed abundance data and the floristic species richness were calculated. The data on floristic species richness was derived from Jüttersonke & Arlt (2006).

4.4.1.5. Results

The data used here indicate no relationship between monocotyledon (monoc) or dicotyledon (dic) weed species abundance (richness) and any of the tested landscape composition parameters (Fig. 4.4.2). There was also no relationship between floristic richness (Bpt_mean) and the landscape composition parameters observed. Also the pesticide treatment variable representing agricultural intensity (T1_95) did not correlate with floristic richness and weed species abundance.

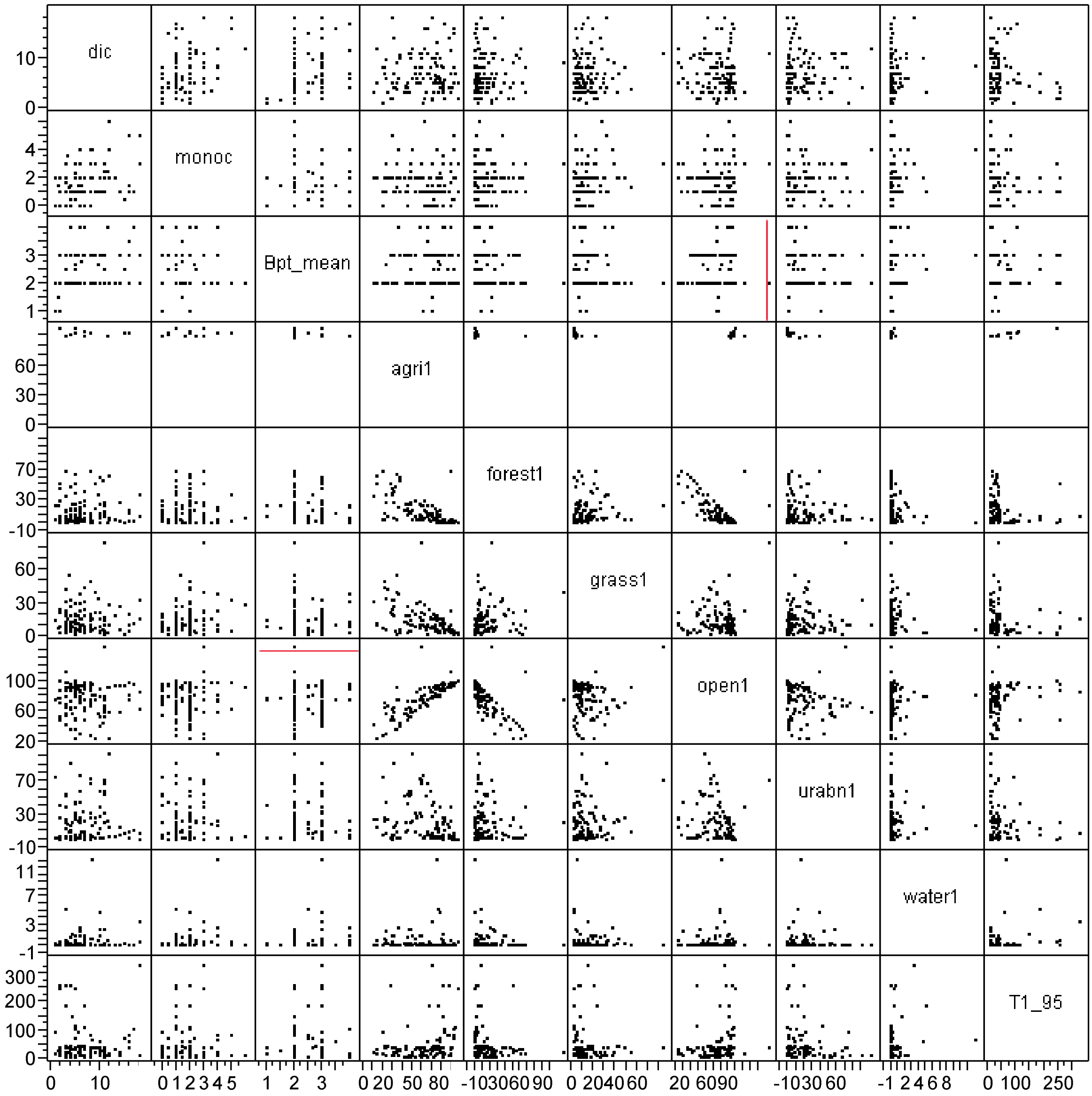


Figure 4.4.2. Scatter plots displaying the relationship between the variables.

4.4.1.6. Discussion and Conclusions

The floristic and weed data used in this analysis stems from one sampling time. No information was recorded whether the fields were under conventional pesticide management or organic practice. The land use data comes only from a buffer of 1000m radius around each sample side. The type of field margin according to Gutsche & Enzian (2004) was not included in the analysis.

The results do not support our hypothesis, but considering the "difficult" data sets, with respect to a number of unknown possible explanatory variables, the results do not astonish much. As there are landscape studies referencing landscape effects on weed abundance and floristic species richness the spatial approach should be extended to more buffer distances, at least a 5km radius and a local landscape describing the type of ecotone and to include landscape metrics reflecting the edge density and diversity of the landscape.

4.5. INRA

4.5.1. Case study A

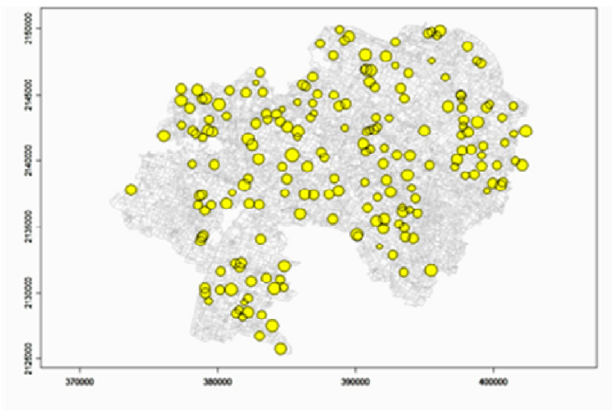
4.5.1.1. Objectives of the original study

The original study was an inventory of weeds over a large region with the aim of relating weed abundance/diversity to other taxa (farmland birds, grasshoppers, carabids).

4.5.1.2. Description of the existing database/case study area

The study area is an intensively managed agricultural landscape located in western France (46°11'N, 0°28'W) ; 450 km2). The 18000 fields in t his area are mainly devoted to autumn sown cereal production (c.a. 70%) and perennial crops (*Lolium perenne* L. or *Medicago sativa* L. and *Trifolium pratense* L.). The typical and most frequent three-year crop rotation in the area was winter wheat, followed by either winter oilseed rape or sunflower for two years.

Weed occurrence was recorded in 123 winter wheat fields between March and June in 2006 (n = 84 fields) and in 2007 (n= 39 fields). Fields were selected based on random sampling of their latitude and longitude. At the centre of each sampled field, we positioned a star-shaped array of 32 plots of 2x2 m. The occurrence of individual weed species was recorded along the 8 arms of the star, each arm having four 4m2 plots located at 4, 12, 38 and 60 m from the centre of the star. The outermost plot of the array was at least 5m from any field margin (Fig. 4.5.1).



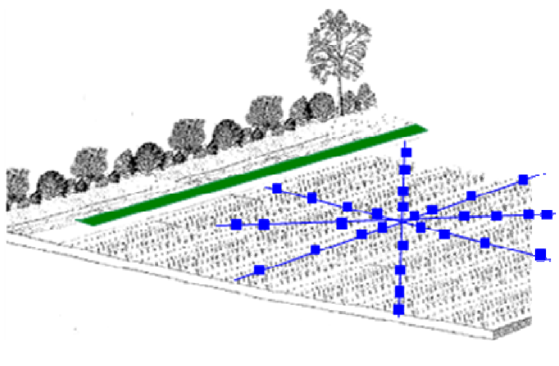


Figure 4.5.1: The study area and sampled fields. Weed sampling design in individual fields

In total, 135 weed species (from 31 families and 93 genera) were observed. Mean species richness per field was 17.85 species and ranged from 5 to 47 species. Mean species diversity was 3.31 and ranged between 1.01 and 4.99. Sample accumulation curves revealed a high heterogeneity in weed richness among the sampled winter wheat fields e.g. to observe 80% of the weed species found in the landscape required a sample size of fifty individual fields (Figure 4.5.2).

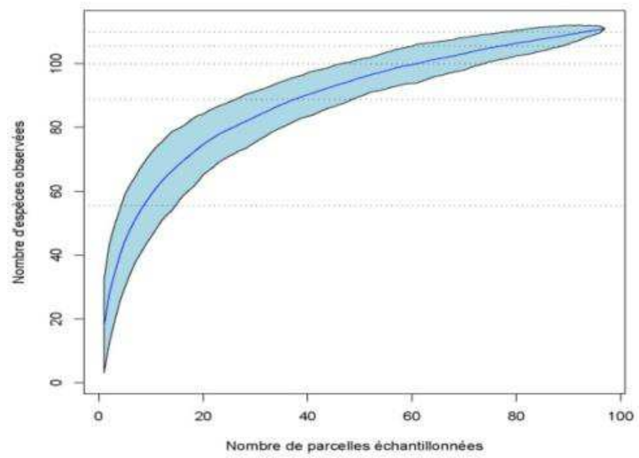


Figure 4.5.2: Weed species accumulation curve in 97 winter wheat fields in the study area. This shows the large variability found in the winter wheat weed community composition in the study area.

4.5.1.3. Hypotheses regarding landscape effects on weed communities that will be tested

- √ We hypothesised on weed species richness and diversity in winter wheat is partly explained by the landscape mosaics surrounding the field;
- √ We hypothesised that this effect is stronger than spatial autocorrelation;
- √ We hypothesised that landscape mosaic structure has more weight than landscape mosaic composition.

4.5.1.4. Materials and Methods for conversion of the original data

- √ Weed response variables measured/calculated/extracted were weed diversity at the field level (based on presence/absence data recorded in the 32 plots within each field) and weed species richness at the field level.

- √ Landscape descriptors retrieved or extracted from the original study were spatial autocorrelation (LAT, LONG) and the field characteristics Field Size and Preceding Crop. At various radiuses around the centre of the star-array (Figure 4.5.3) the following landscape mosaic measures were determined: Landscape composition (%Wooded, %Winter Crop, %Spring Crop, % Set aside, % Grassland) and Landscape structure (No Field, No Land Use Types).

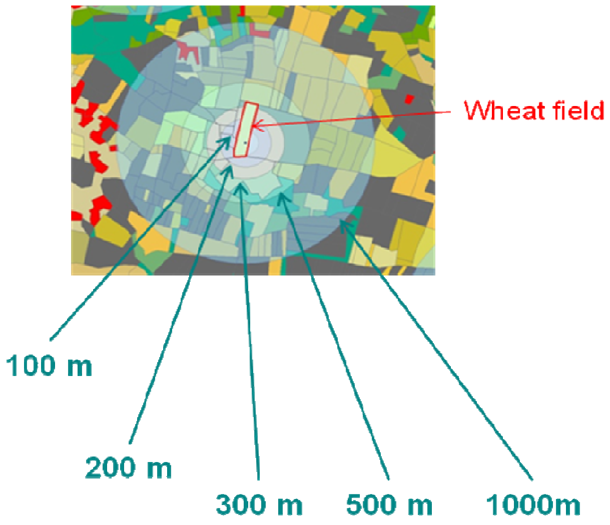


Figure 4.5.3: Landscape composition and structure was assessed at 5 radiuses around the focal field, ranging from a 100m to 1000m.

The relative weight of landscape descriptors was assessed using hierarchical variance partitioning techniques as the method allows segregating between independent and joint effects of explanatory variables (colinearity between descriptors).

4.5.1.5. Results

Similar patterns were found for species richness and species diversity and we present here results related to species richness. At the 200 m radius the global model explained 18.9 % of the variation observed in weed richness. Three variables had a significant independent contribution: Field size, Number of Fields within the radius and Number of Land use types within the radius. The combined independent contribution of all the variables was lower than the joint effects, i.e. 39.0% of the explained variance (Figure .4.5.4). This was mostly the result of high joint contributions of Landscape structure (30.7%) and Field characteristics (13.4%), while Landscape composition, with 5 variables, had a lower joint contribution (6.3%).

4.5.1.6. Discussion and Conclusions

In this case study:

- The effect of landscape descriptors was the strongest at a small scale, i.e. 200m around the weed sampling unit
- Descriptors of landscape structure were the best variables to explain variations in weed species richness and weed diversity
- Landscape composition had a very limited explanatory power.

It would be relevant to re-analyse this dataset using weed species biological traits to go further in our understanding of how landscape structure affect weed communities. Obvious candidate traits would be attributes related to spatial dispersion as well as ability to develop in field margins.

Future experiments designed to analyse landscape effects on weeds should be designed at fine rather than large scales. It would be relevant to analyse weed distribution using systematic sampling design on grids over a limited geographical extent (mosaic of parcels over a 1km^2).

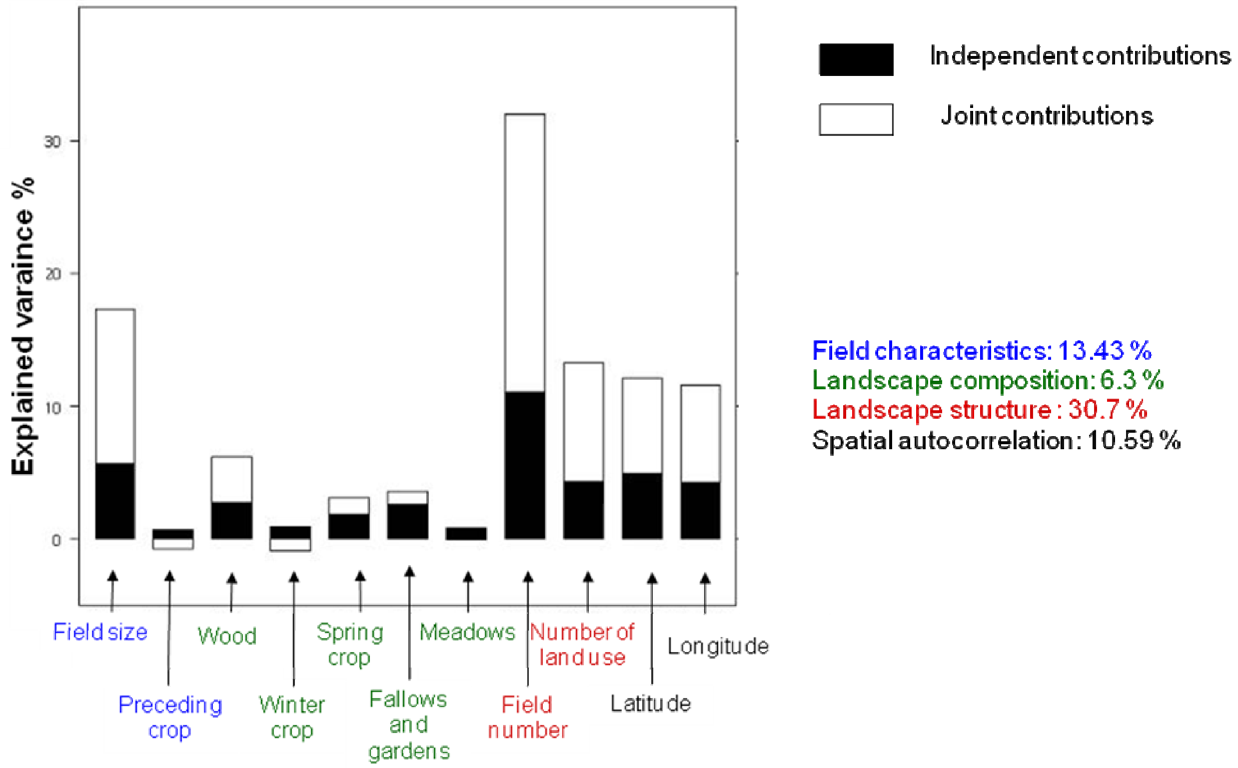


Figure 4.5.4: Independent and joint contributions of landscape descriptors to explain the variation in weed species richness in 135 winter wheat fields located in the study area.

4.6. RRES

4.6.1. Case study A

4.6.1.1. Objectives of the original study

The data used for the RRES Case study came from a nation-scale data-set originally gathered to test for significant effects of genetically modified, herbicide-tolerant crops and their management on farmland wildlife. These Farm Scale Evaluations (FSEs), sampled within-field and margin weeds and invertebrates using a number of different protocols (Firbank et al. 2003; Heard et al, 2003) and also gathered information on local landscape structure.

4.6.1.2. Description of the existing database/case study area

The fields sampled in the FSEs were spread across the lowland arable areas of Great Britain (Figure 4.6.1). Four GMHT crops, spring-sown maize, beet and oilseed rape, and winter-sown oilseed rape, were grown alongside their conventional counterparts in a half-field design. Sampling occurred between 2000 and 2004, with approximately 1/3 of fields being sampled in each year. In each half of a field, twelve transects were used for sampling weeds. These went from the field margin up to 32 m into the cropped area of the field (Figure 4.6.2). 5 sampling points were arrayed down each transect at 2, 4, 8, 16 and 32 m. A 0.25m x 0.5m quadrat was used to sample for weed plants. In exceptional cases where plant numbers were high the quadrat area was halved or quartered. Moribund individuals were not counted. All counted weed plants were identified to species.

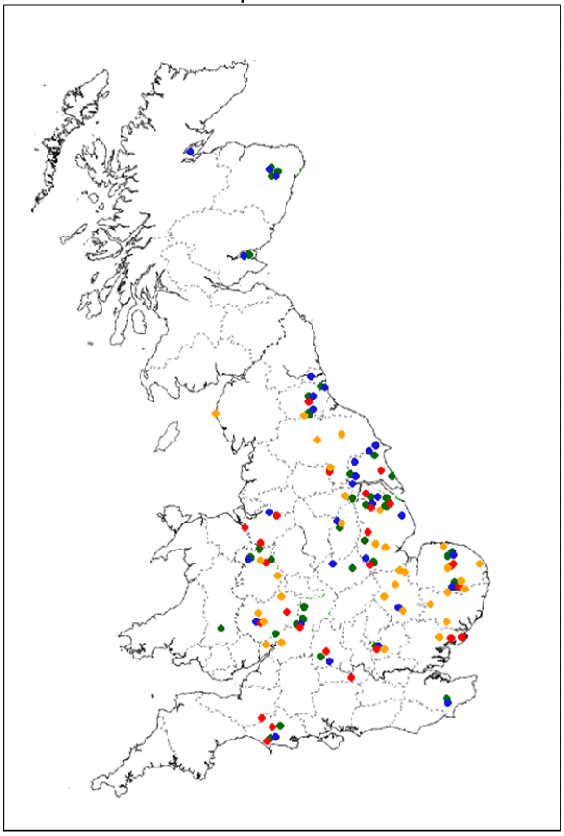


Figure 4.6.1. Distribution of the 66 spring-sown beet (●), 59 spring maize (●), 67 spring oilseed rape (●) and 65 winter oilseed rape (●) fields, across GB, sampled as part of the Farm Scale Evaluations (FSE) of Genetically Modified, herbicide-tolerant (GMHT) crops (Bohan et al. 2005; Champion et al. 2003).

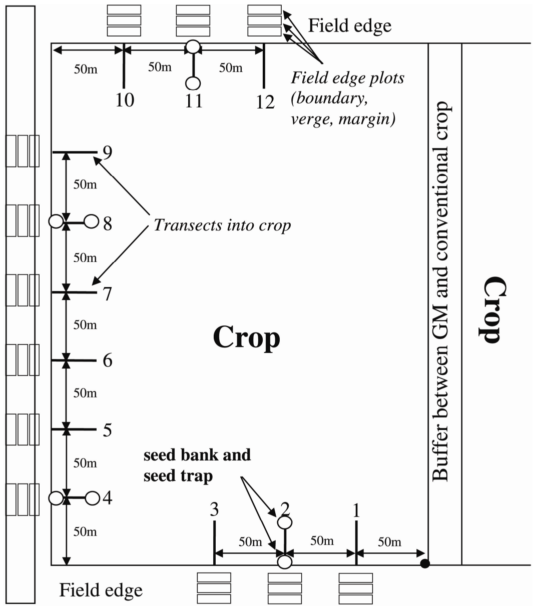


Figure 4.6.2. Layout of the vegetation sampling of a half-field experiment unit of variable total area. Twelve transects extend 32 m into the crop, with sample locations at 2, 4, 8, 16 and 32 m. The distances between them are ideally located at 50-m intervals, and should be no less than 30 m apart. They are positioned along the field boundaries using random offsets, set on the basis of date. Vegetation counts and crop assessments take place at all locations, weed biomass samples taken at locations 2 and 32 m, as are seed bank samples and soil seed rain samples, but only on transects 2, 4, 8 and 11 (circles). Edge vegetation records are made at boundary, verge and margin locations, where the margin is a ploughed but unsown strip, the verge a grassy or herbaceous border between the ploughed edge, and the boundary defined as a physical feature that is an interface between the field and another land cover type. Not all of these are present at every field.

Weed counts were taken at important ecological and management occasions throughout the year (Firbank et al. 2003; Heard et al. 2003). Here we use only weed data from the conventionally managed half- fields. The weed abundance data, for monocotyledon and dicotyledon species, was totalled across these sampling dates and across all transects and sampling positions to achieve a yearly half field total. Species richness, of monocotyledon and dicotyledon species, was also computed for each conventional half field across the year.

Landscape variables were scored by observers, standing at the end of each of the 12 transects. Looking out of the field, along the line the transects would take into the next field, the observers scored all landscape attributes (Table 4.6.1) from the structure that bounded the field out to the far edge of the adjacent field. This gave an indication of the local landscape structure and diversity around each experimental field site.

Table 4.6.1. Table of Landscape attributes to be scored around each field, using a landscape assessment protocol. The protocol considered landscape features up to one field away, in any direction, from the experimental field.

LANDSCAPE ATTRIBUTE CODES	
ATTRIBUTE CODE	**ATTRIBUTE DESCRIPTION**
F1	POND
F2	STREAM <3M
F3	ROAD
F4	VEHICLE TRACK
F5	WALL
F6	FENCE
F7	WOODLAND
F8	BELT OF TREES
F9	URBAN
F10	FERTILE AGRIC. GRASS
F11	NEWLY SOWN GRASS
F12	OTHER GRASSLAND
F13	OTHER SEMI-NATURAL
F14	WHEAT
F15	BARLEY
F16	SUGARBEET
F17	OILSEED RAPE
F18	OTHER CROP
F19	PLOUGHED FIELD
F20	OTHER

Farm management intensity was scored using farm management questionnaires answered by farmers who took part in the FSEs. The intensity score was computed from a self-assessed intensity score, yield responses and previous inputs, alongside field size and conservation practices (Firbank et al. 2003).

The number of bee pollinators visiting the field for forage was assessed using a transect walk protocol (Haughton et al. 2003, Bohan et al. 2005). Bees were counted using a modified version of the line-transect method developed for the BMS (Pollard & Yates 1993) and used as a standard method for bee surveys (Banaszak 1980). Transects were each walked once in June, July and August for all crops, with an additional record in May for beet to take account of the timing of herbicide application (see Perry et al. 2003). Where possible, counts were recorded for maize and spring oilseed rape sites when the crop was in flower. The two halves of the field were walked on the same day, with the order being chosen at random because time of day affects flight activity. Walks took place between 10.00 and 17.30 when the weather conformed to BMS standards (temperature above 13 ℃ with at least 60% clear sky or above 17 ℃ in any sky conditions apart from heavy rain; Beaufort wind speed of less than 5). Four well-spaced 100 m sections were walked into the crop parallel to transects 1, 3, 10 and 12 (Figure 2). Standard transect walks were impracticable in flowering maize owing to the height of the crop. On these occasions, four well-spaced 5 m x 5 m areas of flowering crop were sampled by watching from a stepladder (3 m above ground level) for 10 min (Kearns & Inouye 1993). During transect walks, bees were counted within 2 m and butterflies within 5 m of the transect line. Given the need to identify the bees in flight, counts were made for groups of *Bombus* (bumble-bee) species based on colour type, according to Prŷs-Jones

& Corbet (1991). Separate counts were also made for honeybees (*Apis mellifera*), cuckoo bees (*Psithyrus* spp.) and solitary bees. In all cases, only actively foraging individuals or nest-searching queens were counted. Data for the abundance bee was totalled across these sampling dates and across all transects and sampling positions to achieve a yearly half field total for all foraging bees.

Each site was also assigned a level of a factor (*Zone*) for one of the six Environmental Zones of the ITE Land Classification of Great Britain (Firbank *et al.* 2003) to describe the fundamental environmental and geographical properties of each site. Four zones, defined as the more southerly and easterly lowlands of England and Wales (Zone 1), the more northerly and westerly lowlands of England and Wales (Zone 2), the uplands of England and Wales (Zone 3) and the lowlands of Scotland (Zone 4) were represented in the data-set.

4.6.1.3. Hypotheses regarding landscape effects on weed communities that will be tested

The expectation to be tested was 'local landscape diversity (richness) affects the species richness or abundance of monocotyledon or dicotyledon weeds in GB arable fields'. This expectation arose from a series of mechanistic hypotheses that landscape diversity might be related to farmer behaviour, which would lead to changes in monocotyledon and dicotyledon weed metrics, and/or that diverse landscapes would sponsor greater numbers of pollinators that would tend to increase the diversity and abundance of flowering, dicotyledon weeds.

Expectations were tested using Generalised Linear Models in Genstat. The weed variates were used as the response variables, with landscape richness as a fixed term and *Zone* and the year of sampling as random terms.

4.6.1.4. Materials and Methods for conversion of the original data

Here we use only weed data from the conventionally managed half-fields. The weed abundance data, for monocotyledon and dicotyledon species, was totalled across the sampling dates and across all transects and sampling positions to achieve a yearly half field total. Species richness, of monocotyledon and dicotyledon species, was also computed for each conventional half field across the year. The count of unique landscape descriptors surrounding each field (Table 4.6.1) was used to calculate local landscape richness, as a measure of local landscape diversity. Data for the abundance bee was totalled to achieve a yearly half field total for all foraging bees.

4.6.1.5. Results

We found no relationships between monocotyledon or dicotyledon weed species richness and local landscape richness. No relationship between monocotyledon abundance and local landscape was observed. A strong effect of local landscape structuring was found on dicotyledon abundance ($F_{1,236} = 16.47$, $P < 0.001$, Figure 4.6.3), explaining some 13% of the variation in dicotyledon weed abundance and suggesting that with increasing local landscape richness the abundance of dicotyledon weeds increased. This relationship differed between crops ($F_{1,236} = 16.47$, $P < 0.001$) and between environmental zones ($F_{1,236} = 16.47$, $P < 0.001$, Figure 4.6.3). Importantly, however, there was no significant interaction between the effect of landscape and these covariates. The direction of effect remained the same in all crops and zones. Similar effects on weed abundance were also apparent in separate analyses done on the weed data totalled at 2m and 32m into the crop.

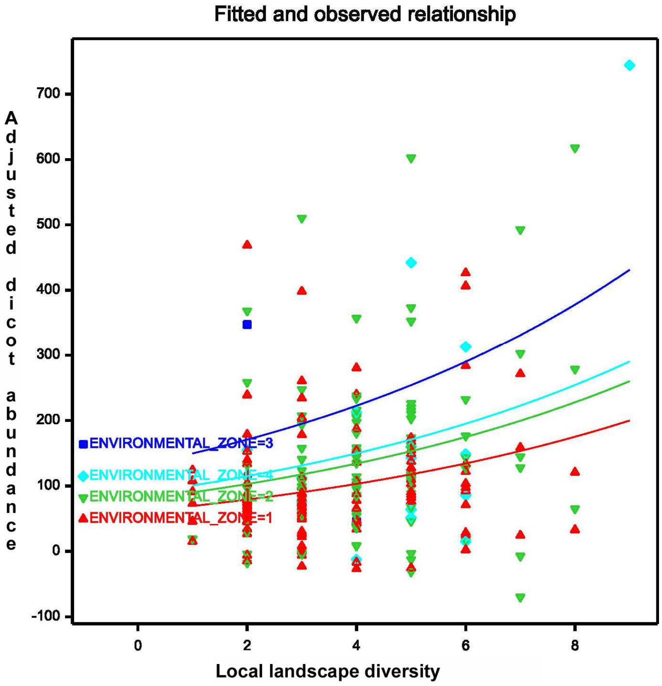


Figure 4.6.3. Fitted and observed relationships between dicotyledon abundance (dicot abundance) and the score of local landscape diversity.

We found that dicotyledon abundance was partly explained by the score of intensity of management ($F_{1,236}$ = 6.50, P = 0.011), and bee abundance was a highly significant explanatory variate ($F_{1,237}$ = 12.35, P < 0.001). No significant relationships between intensity or bee abundance and local landscape diversity were observed, and these two variates do not appear to explain why there is a local landscape effect on dicotyledon weed abundance.

4.6.1.6. Discussion and Conclusions

This analysis suggests that there are local landscape effects on in-field dicotyledon weed abundance across the national scale. The crop grown and the environmental zone in which the field was sited did appear change the landscape effect. But, given that there were no interactions between landscape and crop and landscape and zone, the direction of the local landscape effect remained. Across all fields analysed, increases in dicotyledon weed abundance were correlated with increases in local landscape richness.

We hypothesised that these landscape correlations might be driven by changes in farmer behaviour and/or changes in the amount of pollinator bees supported by the local landscape. Intensity and local landscape richness, as we have measured it, might be related because both are reflections of farmer behaviour. It is also known that local habitat diversity, which might be reflected in our score of local landscape richness, is extremely important for maintaining bee numbers in farmland (Osborne et al. 2008). As expected, we found that both the intensity of management score and local bee abundance were important in explaining dicotyledon weed abundance. However, we also found that neither of these variates were related to the local landscape score. Alone, the variates of management intensity and bee abundance could not have driven the local landscape response we found in the dicotyledon weed abundance data. Consequently, we cannot explain the estimated dicotyledon weed-landscape effect.

This problem could be approached by fitting each landscape descriptor, in Table 4.6.1, or combinations of descriptors in turn to the dicotyledon weed data. This purely statistical approach would highlight those landscape descriptors that would appear to explain a significant amount of weed variation. However, this approach would not be hypothesis led and might be construed as data-mining. It highlights one of the clear problems with the landscape descriptor approach – it is geographic in nature and the descriptors themselves often have an unknown ecological value for the response variables. An alternative approach might be to move to a resource-based approach, based around the value of element of the landscape for the response variable as part of hypothesis testing. Such elements could be graded on their resource value, such as habitat (refuge) or food value.

It is important to try and explain why we found no effects of landscape on weed species richness, particularly as other landscape studies have suggested there should be strong effects. Using data from the FSEs, Smith et al. (2007) found that the composition of weed species in farm fields was strongly determined by the crop grown. Fields of a particular crop had similar weed compositions, with the species present not changing markedly between fields, even at the national scale. This might suggest that there is little latitude at the national scale for weed species to change with landscape, and thus explain why we estimated no significant relationships between weed species and local landscape richness.

5. Conclusion

Table 5.1 summarises the weed measurements and landscape metrics used in the various case studies. Table 5.2 summarises the hypotheses tested and whether data confirmed or denied these hypotheses.

Weed measurements

The main question was whether all weed measurements are equally suited for evaluating landscape configuration effects on weed communities. In general weed community compostion depends to a great extent on management strategy and intensity. The above-ground weed flora within the same field varies throughout the year in response to crop management strategies that are applied, and between years in response to crop type and variations in climate. The hypothesis was postulated that the weed seedbank would better reflect landscape configuration effects than the more variable above-ground weed flora. This was confirmed by one of the case studies (SSSUP-A). If this result can be confirmed by other cases, this could allow for a strong recommendation to use seedbank data for the study of landscape effects on weed communities instead of field weed counts that are more dependent on crop type, sampling moment and recent crop management.

A second hypothesis was postulated, namely that individual weed species response to landscape metrics depends on their ecological and biological characteristics such as dispersal mechnism, seedbank longevity, seed dormancy, Raunkiaer life form (Raunkiaer, 1934) and life strategy. We expected that by uniting weed species in ecological groups, landscape effects could be more easily detected. Given that many non-chemical weed management strategies are aimed at either monocots or dicots, several case studies used this classification to detect landscape effects on weed communities (RRES, SSSUP, JKI). Two case studies demonstrated that structure and composition of small-scale landscape elements affect percentage monocots in the first 8 meters of the cropped field, both in annual crops and perennial crops (SSSUP-A and SSSUP-B).The AGROS case study showed that directly adjacent land use affects species composition in conservation headlands (not-treated but cropped margins of arable fields). Another case study showed that dicot abundance in the weed vegetation increased if land use heterogeneity in the directly surrounding fields increased (RRES). This trend was shown independent of crop type and environmental zone. An attempt was made to explain this through the contempory increase in bee abundance. Despite this positive correlation, data did not allow to determine any causal relationship between these two factors. Therefore the question remained; is dicot diversity affected through increased habitat diversity or through increased pollination activities? Although we have no clear response to the question why ecological groups of weeds better represent landscape effects on weed communities, this approach can overcome part of the problem caused by studying individual weed species in communities which is very dependent on crop type, recent weed management and sampling time, because it overcomes part of the variability casue by differences in individual species by grouping them in more general clusters with similar ecological behaviour. Defining general hypotheses relating landscape configuration charactersitics in relation to responses of these ecological groups, it will be easier to compare case stusies from different regions and from weed communities which differ in individual species composition but which may be similar in composition of ecological groups.

Some case studies concentrated on the determination of landscape effects on weed species richness and diversity (CNR and INRA). One case study showed that landscape structure was more important in determining species richness and diversity than landscape composition (INRA). Another case study (CNR) compared indices of ecological diveristy to the more classically used species diversity indices and concluded that surrounding landscape composition effects on these indices were relatively low, both for seedbank and above-ground vegetation data. This findings agree with those of the previous study which reported an important effect of landscape structure but not of landscape composition.

Landscape metrics

The level of detail at which various land use types can be determined depends on the scale of study and on the available data. Most of these data will have to be collected *ad hoc*, particularly where returning to the study areas is not possible or would be too labour intensive, and the information is most likely to be extracted from existing land use maps or aerial photographs. The collected landscape information should define different land use types, but should also allow for clustering of land use types which have similar effects on the weed communities. For example, various winter cereals may be managed in more or less similar ways, and can therefore be considered similar land use types. These decisions have to be made by the researchers, based on the expected impact of the selected land use types on the weed community.

Composition and proportions of these linear and patchy landscape elements have to be defined at different spatial scales around the investigated fields. This can be done by drawing concentric circles around the field for which weed data are available. The circles should vary in size in order to include the first layer of field margins and directly adjacent fields in the first circle, and more and more fields in the following circles.

A question that remains open is whether the circles should have a pre-defined diameter, or whether they should be drawn in relation to field size. For example, if fields with different size have to be compared for the impact of directly adjacent land use on the weed community measures, the reference circle should comprise the first layer of surrounding landscape elements. Therefore circle diameter will be variable. It has to be taken into consideration that ‘margin’ effects are expected to be smaller in large fields than in smaller fields. Since weed community measures are normally taken in the central part of the field, these margin effects may not be revealed in large fields, whereas they will be in small fields or when transects from the field margin are taken. It was concluded that additional covariables might have to be included to correct for differences between fields, especially in field size. In case the interest is limited to the directly surrounding land use types, determination through aerial photographs or maps is similar to the visual observations made directly in the field as done in case studies of RRES and CNR.

The case studies which were performed on regional (CNR, INRA, JKI) or nation-wide (RRES) basis all confirmed that effects of surrounding land use configuration is determined on relatively small scale, from field margins to about 200 m from the centre of the fields. Studies including only information on land use typology did not find any or only very weak correlations with weed measurements, whereas studies including landscape metrics describing landscape mosaic structure (diversity of land use types) indicated there were effects on weed measurements.

Table 5.1 Weed measurements and landscape metrics included in the study

Partner	Weed measurements	Landscape metrics
SSSUP-A	Total weed density; dicot and monocot density; percentage monocot both of seedbank and above-ground weed flora in same crop and same year within an annual crop.	Field margin structural typology
SSSUP-B	Monocot and dicot absolute cover and cover percentage in relation to total weed cover within a perennial crop	Field margin structural typology
AGROS	Nr of individuals; species richness; Nr of forb individuals/species; Nr of grassy individuals/species; Nr of woody individuals/species; Nr of problematic weed individuals/species	Percentage of headland (length) adjacent to land use types: hedges, crops, grassland, woodland, hedge + woodland.
CNR	Species richness (S); Total abundance (N); Simpson's Dominance (D); Shannon's Diversity (H); Pielou's Equitability (E); Margalef's Index (M); Réyni diversity (R) and the quadratic entropy (Q)	Landscape complexity expressed as fraction of stable and permanent landscape elements surrounding the field (i.e. pasture, non-cropped land, hedges, …).
JKI	Moncot and dicot abundance; species richness.	Land use defined in 7 land use classes and percentage cover for each land use class in 1000m radius buffer around field margins was established
INRA	Weed species richness in each field	spatial autocorrelation (LAT, LONG) and the field characteristics (Field Size and Preceding Crop). At various radiuses around the field centre the following landscape mosaic measures were determined: Landscape composition (%Wooded, %Winter Crop, %Spring Crop, % Set aside, % Grassland) and Landscape structure (No Field, No Land Use Types).
RRES	Year total counts of monocot and dicot and year total richness were calculated and analysed for each field	Number, or richness, of different land use types surrounding the field at eye distance

Table 5.2 Hypotheses tested and weed community response

Partner	Hypothesis	Response
SSSUP-A	1. Seedbank data provide better insight in 'landscape' effects on weed communities than above-ground weed community data 2. Field margin structure and composition effect on in-field weed community depends on crop management	1. confirmed 2. confirmed
SSSUP-B	3. Field margin structure affects the weed community developing in the field; 4. Grass strips increase monocot invasions in the first meters into the field.	3. confirmed 4. confirmed
AGROS	5. It is assumed that woody habitats increase the number of species and individuals of weeds (especially woody plants) and problematic weeds in the conservation headland	5. confirmed
CNR	6. variability in the surrounding landscape increase species richness	6. weak but confirmed
JKI	7. landscape composition and spatial arrangement affects the abundance of weeds and the floristic species richness in German arable field margins	7. denied
INRA	8. weed species richness and diversity in winter wheat is partly explained by the landscape mosaics surrounding the field 9. this landscape effect is stronger than spatial autocorrelation, 10. landscape mosaic structure has more weight than landscape mosaic composition	8. confirmed 9. confirmed 10. confirmed
RRES	11. local landscape diversity (land use type richness) affects the species richness or abundance of monocotyledon or dicotyledon weeds in GB arable fields	11. expectation accepted for dicot abundance, rejected for monoct abundance and both monocot and dicot species richness

It can be concluded that:

1. Despite great variability in the used databases, all were able to effectively test some landscape effects on weed community measurements. Differences in databases consisted both in scale at which data were collected: metrics varied from plots in an experimental field to fields is an entire nation, and landscape metrics that could be collected (from field margin structural data (SSSUP and AGROS) to land use typologies (CNR, JKI) and land use diversity (INRA and RRES).
2. In order to analyse landscape effects on weed communities we have to shift from the often used 'abundance' measures or simple diversity measures (such as Shannon Diversity Index), to ecologically and biologically functional weed community measures. Whether or not certain landscape metrics affect the weed communities

likely depends on the ecological and biological characteristics of the weed species. Therefore, the weed community should not be considered in absolute terms, but in terms of the ecological characteristics of the species we are most interested in. Only if we ever manage to determine how certain landscape metrics affect abundance of the species belonging to these ecological groups we can start to program landscape management for manipulation of the weed communities. In fact, most partners did not only consider species richness or weed total abundance as a weed community response variable, but either developed new measures for weed community diversity based on the ecological and biological qualities of the species composing the community (CNR) or calculated abundance for ecologically important weed groups, such as monocots and dicots (RRES, SSSUP, JKI). These groups are important especially in relation to integrated weed management because most management strategies alternative to broad-spectrum herbicides are selective for either monocots or dicots.

3. Most case studies confirmed that landscape metrics do affect in-field weed communities and the diversity of responses showed that no generalizations can be made. Both small-scale landscape elements such as field margins, and larger scale landscape configuration affect weed community composition and diversity. The RRES study also showed that even in the case we can detect statistical correlations between landscape metrics and weed community measures, this does not give any indication on the ecological explanation for such correlations. This shows we should be very careful with interpretation of these data and future research should focus on finding such ecological justifications. Only then will we be able to fully exploit landscape configuration manipulation for weed management as part of Integrated Weed Management strategies.
4. We defined three objectives at the start of the project which can now be evaluated:
    - √ <u>determine the feasibility of a common framework for analysis of landscape configuration effects on existing weed databases;</u> the discussions in working sessions were useful for definition of commonly divided ideas and hypotheses. The application of case studies was useful because some common results appeared and confirmed or rejected some hypotheses whereas others were put on hold. Variability in databases and in availability of additional information on landscape metrics makes it almost impossible to define rigid guidelines for definition of landscape effects on weed communities, but indications and reflections from this report could be a useful start for other researchers who want to try out a similar study, in order to increase the number of case studies and confirm or reject the initial conclusions we were able to draw.
    - √ <u>discuss the utility of the conclusions we could draw from our case studies regarding landscape configuration effects on weed communities</u>; there certainly seem to be landscape configuration effects on weed communities and increasing the number of case studies could possibly contribute to provide more solid conclusions regarding the magnitude of these interactions and the range of situation in which these conclusions are valid. For example, it seems seedbank data provide more robust answers regarding weed community responses to landscape configuration, but more case studies should confirm this result in order to allow us to release strong recommendations for future weed measurement protocols. The same is valid for the use of ecological weed groups instead of individual weed species composition data.
    - √ <u>indicate the possible implication for land use planning in relation to management of functional biodiversity for more sustainable weed management as a contribution to a wider view on Integrated Weed Management</u>. The results from the case studies indicate that landscape configuration management can be an effective tool for Integrated Weed Management. Land use diversity seems to have some effect on weed community composition and can affect species richness in fields and can

affect abundance of certain ecological groups of weeds. It is obvious that the entity and magnitude of these effects should be studied in much more detail before guidelines for landscape management can be written but results look promising.

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