Effects of different management types on plant diversity in Romanian vineyards

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Vienna, March 2017

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ACKNOWLEDGEMENT

I want to thank my supervisors DI Dr. Silvia Winter and Ao. Univ. Prof. DI. Dr. Monika Kriechbaum for supporting me during the working process. Also, I want to thank all project colleagues, that were cooperating with me in terms of data exchange, especially Thomas Bauer from Bundesamt für Wasserwirtschaft. A special thanks goes to Daniela Popescu and her affectionate support during my stays in Romania. Also I want to thank the University of Natural Resources and Life Sciences Vienna for the scholarship by which I was able to finance my research stay abroad. Further thanks go to my flat mates Magdalena Bäuerl and Peter Flödl for their mental and methodical support. Special thanks go also to my parents Marek and Wieslawa Penke, which always trust in me and my decisions, so that I can follow my own path.

ABSTRACT

Intensification of agricultural management is considered as a main trigger of biodiversity loss. Sustainable land use could contribute to biodiversity and ecosystem services provision. Since management has strong effects on biodiversity, three management intensities (tillage, permanent and alternating vegetation cover) were investigated regarding their effects on taxonomic and functional diversity of plants in 23 Romanian vineyards. Vegetation cover and trait values of species were investigated and analysed with generalized linear mixed models. Additionally, detrended correspondence analysis was used to identify main factors in the vegetation data matrix.

Results showed differences between inter-row and in-row vegetation: Alternating vegetation cover showed highest values for species number (means: 12.04 alternating cover, 8.75 permanent cover, 6.48 tillage) and Shannon diversity (means: 1.85 alternating cover, 1.6 permanent cover, 1.25 tillage) of the in-row vegetation, whereas species richness decreased with increased tillage frequency of the inter-row vegetation.

No significant effects of management intensity on functional diversity indices were found, but management did favour specific traits and life strategies. Decreased management intensity increased leaf area and leaf dry mass. Coverage of Grime's C-strategists increased with decreasing management intensity, whereas R-strategists increased.

Results of an indicator species analysis showed that *Elymus repens* and *Taraxacum officinale* agg. were strong indicators for permanent vegetation in the inter-row, whereas *Stellaria media, Portulaca oleracea, Capsella bursa-pastoris* and *Chenopodium album* agg. indicated tilled inter-row vegetation. There could not be found a clear correlation between functional and taxonomic diversity.

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1. INTRODUCTION

The loss of biodiversity is considered as one of the main global challenges of our society. Intensification of agriculture - through frequent soil tillage, use of pesticides and fertilizers - is considered as the main trigger of the decrease of habitat quality and species diversity (Martens et al., 2003; Matson, 1997; Tilman, 2001). On the landscape scale, intensification in viticulture becomes visible in simplified landscapes with only small scattered patches of semi-natural vegetation (Nascimbene et al., 2013). While semi-natural habitats are often replaced by monocultures of vineyards (Viers et al., 2013), these cultivated areas have a potential to contribute to nature conservation by providing space between the wine rows for natural vegetation. They can contribute to the aesthetic value through cover crops (Miglécz et al., 2015). Thus, associated with a high economic and cultural value, cultivation of vineyards should ensure economic and environmental sustainability (Christ & Burritt, 2013).

Several research projects outline that sustainable agricultural practices, such as cover cropping, can improve ecosystem services in vineyards. Besides the mitigating effect on soil erosion, there are positive effects on soil fertility, soil structure, water holding capacity and microbial biomass correlated with vegetation ground cover (Chupanov et al., 2014; Steenwerth & Belina, 2008; Virto et al., 2012). In this context, the risk of water competition between cover vegetation and vines is mentioned, but Monteiro and Lopes (2007) showed, that cover crops can lead to increased shoot growth. Vegetative growth is reduced through water competition between grapevine and cover crop vegetation. Thus, a more favourable balance between vegetative and fruit growth can be achieved. Additionally, there is a wide range of scientific studies concerning vegetation cover and abundance of insects. Flowering cover crops provide food and shelter for insects, which results in increased abundance of natural enemies, while pest species densities can be reduced (Altieri et al., 2005; Sanguenko & León, 2011; Tompkins, 2010). However, to avoid harmful densities of pest species, the use of native vegetation cover has to be assessed regarding pest species abundance in order to benefit from the pest control (Danne et al., 2010). In regard to this issue, findings about the beneficial effects of certain plant species that enhance beneficial invertebrates can be of interest (Tompkins, 2010). In addition, Nicholls et al. (2001) found, that vegetation corridors in vineyards can expand the function of adjacent habitat, such as forests and hedges which are refuges for beneficial insects.

Biodiversity affects ecosystem services, as the strength and capacity of ecosystems to provide goods and services is reduced if diversity is low (Balvanera et al., 2006; Edwards & Abivardi, 1998; Martens et al., 2003). Therefore, sustaining and increasing biodiversity should be an essential goal for our society, especially regarding changes caused by climate change. Research and policy can contribute to the improvement of management practice.

For many years the main focus of biodiversity surveys considered only species richness, but an universal relationship between species richness and ecosystem functioning is questionable (Chapin et al., 2000). This phenomenon becomes clear when one or few species have strong functional effects on an ecosystem. Several researchers figured out that species *traits* affect ecosystem processes by influencing energy and material flows or abiotic conditions (Díaz & Cabido, 2001; Hooper, 1997; Tilman et al., 1997). Plant traits can be defined as “any morphological, physiological or phenological feature measurable at the individual level” (Violle et al., 2007), for example the type of growth form, specific leaf area or root length. Functional traits in particular are considered as any traits which affect fitness indirectly through its effects on growth, reproduction and survival (Violle et al., 2007). It can be represented by the flowering period, the surviving strategy or life cycle.

The traits of the dominant species strongly influence ecosystem processes (Díaz & Cabido, 2001). Species composition, desirable for maintaining or enhancing ecosystem services and functioning, has to be identified and thereupon the best practice that supports those services has to be determined and applied. Several research points out the importance of functional diversity, which appears to be more relevant compared to taxonomic diversity, especially on local scale, and it might be the key factor influencing ecosystem functioning (Chapin et al., 2000; Díaz & Cabido, 2001; Hooper et al., 2005; Loreau et al., 2001; Naeem & Wright, 2003). Díaz & Cabido (2001) consider functional diversity in relation to species richness and consequential niche occupation. They point out, that a balanced relation between functional and taxonomic diversity seems to be desirable. However, under certain circumstances, low species richness can also sustain the delivery of ecosystem processes.

Management practice is the key instrument to establish a favourable state of biodiversity. Wilmanns (1993) studied the vegetation composition under different types of vineyard management and named management as the key factor influencing plant communities. Her study points out, that plant community types can be predicted by the type of management (e.g. soil tillage, mulching and herbicide treatment). The community type can be changed, if the seed bank in the soil remains intact. Concerning the effects of management, a study in Czech Republic showed that mulching leads to increased species richness of plants compared to soil tillage (Lososova et al., 2003). The results of an Italian study suggest a low mowing frequency, which increases plant diversity, especially on steep slopes (Nascimbene et al., 2013). According to a survey in Portugal, cover crops were compared with tilled vegetation regarding their plant community structure. It was found that cover crops can enhance plant diversity in vineyards without favouring troublesome weed species (Monteiro et al., 2012), which is an important factor.

The VineDivers project, funded by the BiodivERsA initiative from the European Research Area Network (ERA-NET), was established to examine questions concerning ecosystem services and their interlinkages with biodiversity provided by viticultural agroecosystems. Researchers from Spain, France, Germany, Romania and Austria work together to analyse the effects of different management intensities in vineyards on soil biota, pollinators and plant biodiversity and their associated ecosystem services (Zaller et al., 2015). For this purpose, typical viticultural study areas were selected in Spain (Montilla-Moriles, Andalucía), France (Loire Valley), Austria (Carnuntum and Neusiedlersee-Hügelland) and Romania (Târnave wine region) to collect data at the plot, field and landscape scale. Specific work packages address the components of regulating and supporting services, cultural as well as provisioning services of viticultural ecosystems. The results shall be formulated into recommendations for winegrowers and policy.

The present thesis addresses the study of plant diversity as a part of the VineDivers research project and aims at analysing the effects of different management intensities on vascular plant diversity in Romanian vineyards. The focus is on soil management, e.g. soil tillage, alternating and permanent vegetation cover. Before mentioned results of Lososova et al. (2003) and Nascimbene et al., (2013), showed that plant biodiversity is lower with intensification of management (concerning mulching versus tillage and mowing frequency). Further research of Nascimbene et al. (2012) showed higher values of plant diversity in organic than conventional vineyards located in intensive agricultural landscapes. With respect to these results, **it is hypothesized that biodiversity increases with decreasing management intensity.** Since functional diversity is considered a key factor influencing ecosystem services (Chapin et al., 2000; Díaz & Cabido, 2001; Hooper et al., 2005; Loreau et al., 2001; Naeem & Wright, 2003), biodiversity will be measured on taxonomic and functional level.

2. MATERIAL AND METHODS

Figure 1 shows the work flow to achieve the research objectives. In 2015 research area and survey plots were selected and soil data was collected by Thomas Bauer and Peter Strauß from Bundesamt für Wasserwirtschaft in Petzenkirchen, Austria. Consultations with winegrowers were conducted by Daniela Popescu, Researcher at Jidvei Company, Romania. Work steps implemented in this thesis are marked as bold and include a literature review, two vegetation surveys as well as data accumulation and analysis. Results will be discussed considering the state of research.

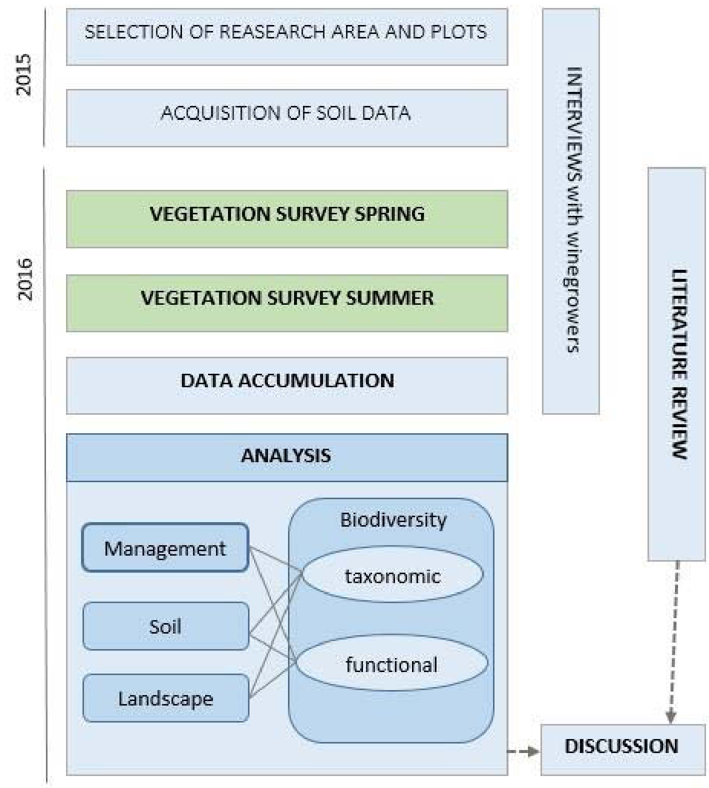

Figure 1: Work flow. Working steps marked as bold were conducted within this thesis.

2.1. Research Area and Study Design

The studied vineyards are situated in Alba county near Blaj, which is located in the Carpathian basin of Transylvania (see figure 2). The region is known as Târnave wine region, which is the largest and of the oldest wine regions in Transylvania. It is characteristic for the production of white wines (Daniela Popescu personal communication, 2016).

Most vineyards are under conventional cultivation (> 90 %) and are not irrigated. Vegetation cover in vineyards consists, if existent, predominantly of spontaneous plants.

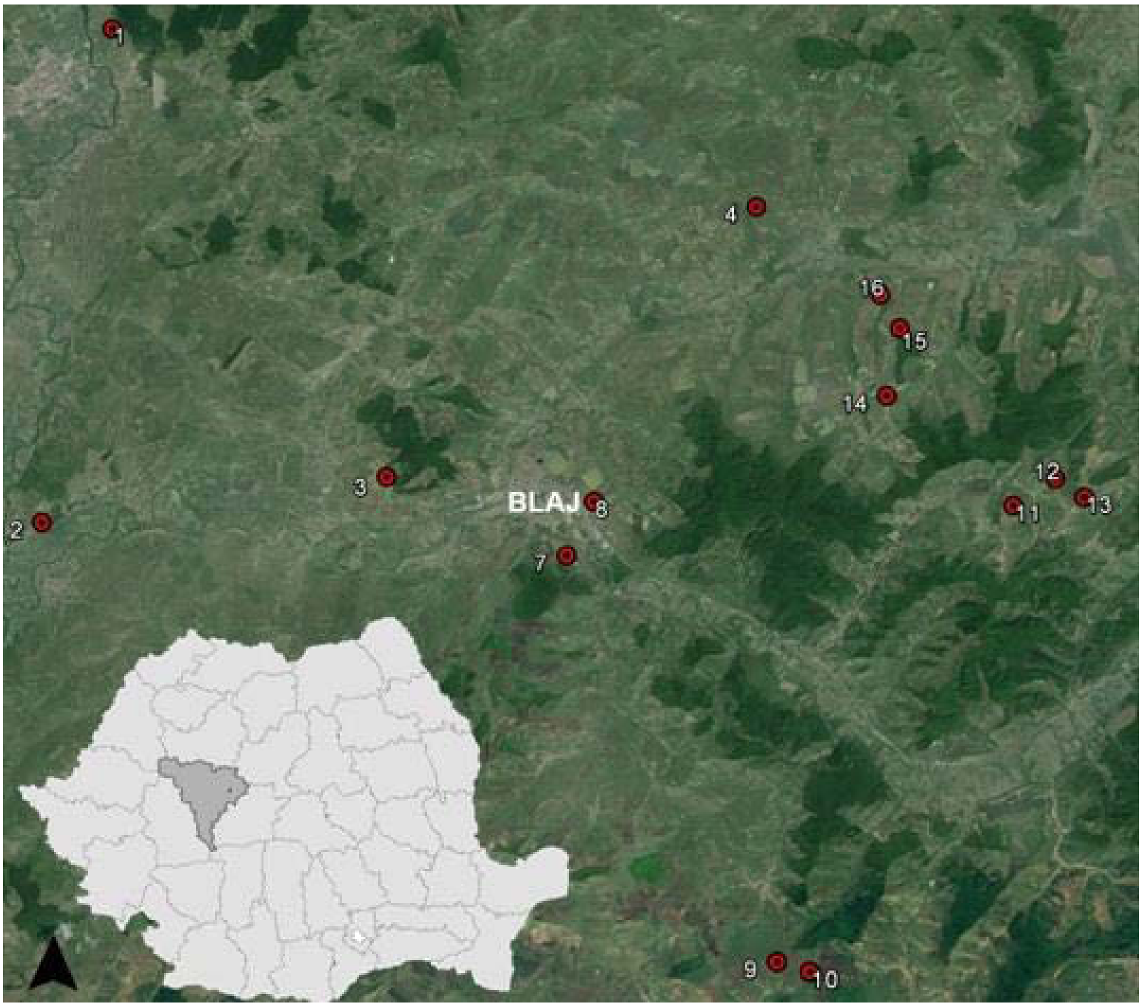

Figure 2: Localization of surveyed landscape circles. Plots with the numbers 5 and 6 were excluded. Source: Google Earth and public vector data from www.geoidea.ro, 2016.

The regional climate is classified as "Dfb" (D: snow, f: fully humid, b: warm summer) after Köppen-Geiger Climate Classification (Kottek et al., 2006). Average temperature is 10.8 °C and precipitation measures 544.6 mm per year (Daniela Popescu pers. Com., 2016). The vegetation period starts from beginning of April and ends by the end of October and lasts 165-175 days (Daniela Popescu pers. com., 2016).

The region has a neogene geology, mainly consisting of sedimentary rock with largely clayey and sandy soil (Federal Institute for Geosciences and Natural Resources & UNESCO, 2016 and 2013, Speta & Rakosy, 2010). The dominant soil type is brown soil (Marginean, 2013). Seventy percent of the vineyards are situated in flat lands and 30 % are situated on slopes (Daniela Popescu pers. com., 2016).

Figure 3: Impressions of the studied region. Here, especially vineyards with vegetation cover (alternating and permanent) can be seen.

Management of the studied vineyards differs between plots. The following types were defined as treatment levels in the VineDivers project and are illustrated in figure 4 with exemplary plot photos in figure 5:

- **High management intensity** with frequently **tilled** inter-rows and in-rows.
- **Intermediate** management intensity with **alternating soil tillage**, where every second row is tilled. Tilled rows change every year. In-row vegetation is controlled by tillage or herbicides.
- **Low management intensity** with **permanent vegetation cover** in the inter-rows and herbicide application in in-rows. Inter-rows are mulched.

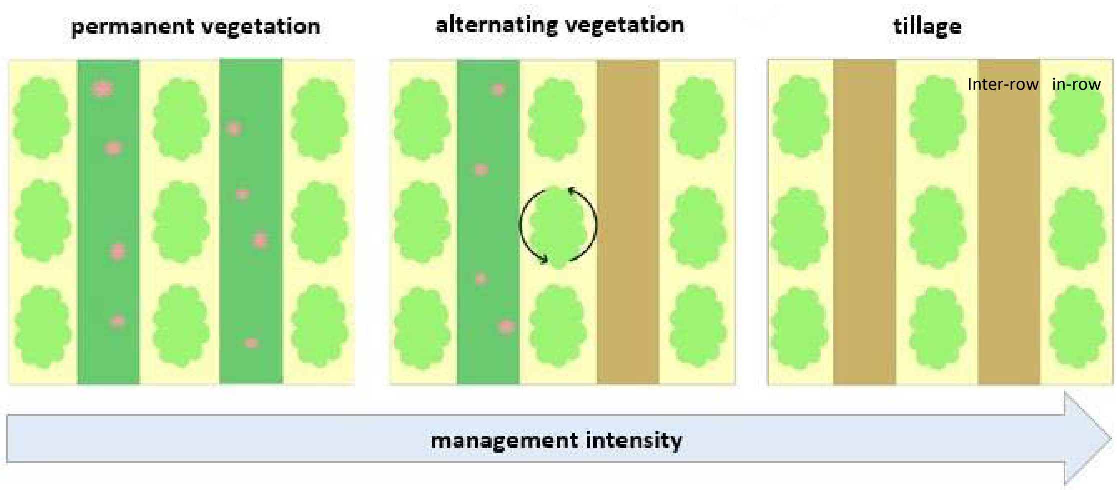

Figure 4: Studied management types. Tilled rows are changed every year at alternating management.

Figure 5: Vegetation of management types from left to right: Permanent, alternating, tillage

2.2. Data Collection

Data about soil and management practices was collected during the project. Soil data was collected in 2015 by Thomas Bauer and Peter Strauss from Bundesamt für Wasserwirtschaft and measured according to standard methods.

Interviews with wine growers were conducted by project partner Daniela Popescu and provided information about management practices, such as duration of current management type, type of cover crops (natural versus seed mixture), frequency of tillage and date of tillage or mowing.

Plant trait data for functional diversity indices was obtained from the TRY Database (Kattge et al., 2011) and covers about 66 % of species that have been found in the field. For this study specific leaf area [mm^2], leaf dry mass [g/g], leaf nitrogen content [mg/g], plant height [m], seed mass [mg] and life span [annual, biennial, perennial] where selected due to their availability and application in other related research projects (Ma & Herzon, 2014; Negoita et al., 2016). Additionally, information about start of flowering month and Grime strategy types (Grime, 1977) was collected from the BiolFlor database (Klotz et al., 2002). Some strategy types after Grime were changed based on expertise knowledge.

Vegetation surveys were performed in spring (22nd April until 11th May) and summer (6th July until 15th July), in order to capture seasonal variation. To avoid surveys after tilling, mowing or herbicide spraying, sample dates were set after consultations of winegrowers by Daniela Popescu. However, it was not always possible to survey the vegetation without any previous disturbance.
The sampling design for vascular plants was defined for all study areas of the VineDivers project by Silvia Winter and is visualized in figure 6. Throughout the study area there are 16 landscape circles with a radius of 750 m. Some circles contain 2-3 vineyards with different management types for a better comparison of management effects, thus 25 vineyards can be studied in total in Transylvania. Because of mentioned problems with winegrower consultations, two of them were excluded due to disturbance prior to vegetation survey, thus 23 vineyards were studied.
In each vineyard, vegetation surveys were conducted in four pseudoreplicates of the size 1 x 1 m, which were established in the inter-rows between two poles marked with coloured bands. Additionally, next to each inter-row replicate the in-row vegetation was studied by sampling plots of the size 1 x 0.4 m, which were established, if possible, alternating left and right of the inter-row (see figure 6). The outermost 5 m at the beginning or end of the vineyard and positions of changing slope morphology within one vineyard were excluded from sampling. The four pseudoreplicates were situated next to four consecutive poles within one inter-row. Selected poles and replicates within the vineyard were marked with a GPS device and the distance to the next poles of the right and left edge of the 1 x 1 m square were measured and recorded for exact relocation.

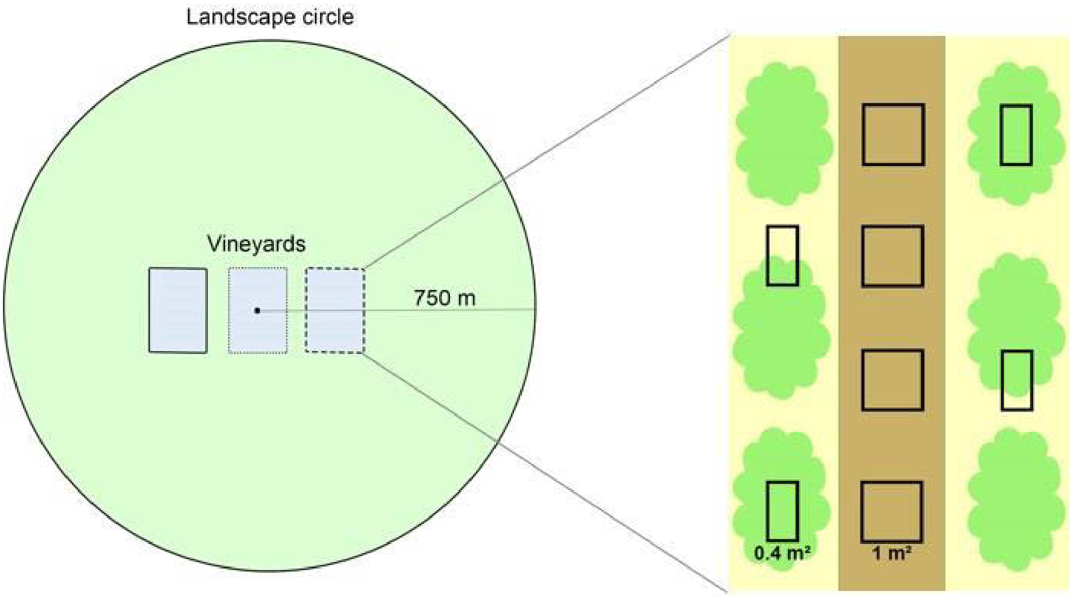

Figure 6: Study design at landscape and vineyard scale.

Within the 1 x 1 m plots all vascular plant species and their coverage were recorded. In addition, total vegetation, bare ground, litter and bryophyte cover were estimated. Cover percentages of individual plant species followed the scale of Londo (1976), shown in table 1. A 1 x 1 m metal frame consisting of 10 x 10 cm quadrats was used for sampling (see figure 7). Average plant height was recorded by measuring the largest plants within each 10 x 10 cm quadrat at the four 1 x 1 m square edges and within the centre of the metal frame. Photos were taken of each plot.

Figure 7: Metal frame for coverage estimation. Plant height was measured at red quadrats.

Table 1: Vegetation coverage scale after Londo (1976)

Cover (%)	< 1	1-<3	3-<5	5-<15	15-<25	25-<35	35-<45	45-<55	55-<65	65-<75	75-<85	85-<95	95-≤100
Scale	0.1	0.2	0.4	1	2	3	4	5	6	7	8	9	10

Adjacent to each of the 1 x 1 m sampling square in the inter-rows, 0.4 x 1 m samples were established underneath the vines (in-row) to estimate total vegetation, bare ground, litter and moss cover. In addition, each vascular plant species within these sampling plots was recorded and their cover percentage estimated in a simplified scale (see table 2).

Table 2: Simplified scale conceptualized by Silvia Winter

Cover (%)	< 1	1-<5	5-<25	25-<50	50-<75	75-<100
Scale	very rare (vr)	rare (r)	common (c)	frequent (f)	dominant (d)	highly dominant (hd)

Any species that were not identifiable were collected as a voucher specimen including information on plot number and date for later identification. Species, that could not be identified on species level were listed on family or genus level.
Plant names follow taxanomy used in Rothmaler Exkursionsflora von Deutschland, (Jäger, 2011).

Table 3 gives an overview of sampled vineyards and the related management types from which data was analyzed.

Table 3: Overview of sampled vineyards and their management

Plot No.	Plot Name	Location	Coordinates		Elevation	Management		
			x	y	[m]	**bare soil**	**alternating**	**permanent**
1	VDR_1HI	Ciumbrud	46°19'12.3"	23°45'41.9"	292	x		x
2	VDR_2LO	Mihalt	46°10'46"	23°43'10.7"	276		x	
3	VDR_3HI	Craciunel	46°10'57.7"	23°51'50.8"	321	x	x	
4	VDR_4HI	SanMiclaus	46°15'0.8"	24°1'46.3"	345	x		x
excluded	VDR_5HI	Blaj	46°10'29.3"	23°52'58.24"	299	x		
excluded	VDR_6HI	Blaj	46°9'36.12"	23°55'47.88"	318	x		
7	VDR_7HI	Blaj	46°9'20.7"	23°56'10.4"	290	x		
8	VDR_8HI	Blaj	46°10'13.9"	23°56'57.7"	290	x, x		x
9	VDR_9LO	Cenade	46°2'8.9"	24°0'31.9"	443		x	
10	VDR_10LO	Cenade	46°1'55.8"	24°1'17.7	454		x	
11	VDR_11LO	Tauni	46°9'27.6"	24°7'21.9"	418		x	
12	VDR_12LO	Tauni	46°9'51.4"	24°8'28.9"	423		x	
13	VDR_13LO	Tauni	46°9'28.8"	24°9'8.4"	498		x	
14	VDR_14LO	Balcaci	46°11'30.6"	24°4'27.8"	437		x, x	x
15	VDR_15LO	Jidvei	46°12'45.4"	24°4'58.9"	402		x	
16	VDR_16HI	Jidvei	46°13'24.1"	24°4'34.6"	315	x	x	x

2.3. Data Analysis

Since not all plants could have been identified on species level, some were summarized for statistical analysis on condition that

- no other species within the genus occurred in the vineyard.
  For example, if the species Myosotis could not be identified on species level (listed as Myosotis sp.), but no other Myosotis species than Myosotis arvensis occurred in the vineyard, then ***Myosotis sp.*** *was* ***merged*** *with* ***Myosotis arvensis****.*

  or

- same species were identified on species level but with uncertainty (marked with “cf.”).
  For example, if Myosotis arvensis was identified with uncertainty (listed as Myosotis cf. arvensis), but there could be certainly identified Myosotis arvensis in the vineyard, then ***Myosotis*** **cf.** ***arvensis*** *was* ***merged*** *with* ***Myosotis arvensis.***

Also, in one vineyard tomato and eggplant was cultivated in the in-rows. These plants were excluded from the analysed dataset. A list of all sampled species can be found in the appendix.

Data analysis was conducted using software R (R Core Development Team, 2016), using the packages *vegan* (Oksanen, 2015), *FD* (Laliberté et al., 2014), *lme4* (Bates et al., 2016), *labdsv* (Roberts, 2016) and *effects* (Fox, 2003). Relations were analysed with generalized linear mixed models (GLMM) because of a nested design.

Pseudoreplicates were nested in landscape circle and vineyard. Selected data, for which soil data was available, was analysed using generalized linear models (GLM). For the models poisson familiy was chosen for count data (e.g. species number) and gaussian family for index values. Models were selected by comparing the Akaike Information Criterion (AIC) value. The probability of a model being correct depends on the difference of AIC values. At a difference of 2, there is a chance of 73 % that the model with the smaller AIC value is correct (Motulsky & Christopoulos, 2003). Therefore, the best model was selected based on the smallest AIC value with a minimum difference of 2 to the next model at least. For the taxonomic diversity, species number and Shannon diversity were chosen as dependent variables. The Shannon index describes the proportion of species relative to the total number of species and was computed according to the description of Oksanen et al. (2016) with the *vegan* package. Here, instead of individual numbers the relative coverage of each species was used for calculation.

Functional diversity is described by functional richness, functional divergence and Rao's quadratic entropy. The Indices were computed using the *FD* package with plant trait data (see chapter 2.2.) obtained from the TRY database (Kattge et al., 2011). Functional richness represents the amount of niche space occupied by a community, whereas functional divergence represents how abundance of species is distributed along a trait axis occupied by the community (Mason et al., 2005). Therefore, divergence is high when trait values of dominant species are far from each other on the trait axis. Rao's quadratic entropy integrates the pairwise differences of trait values between species, and weighs them by their relative abundance (Botta-Dukát, 2005). Here, instead of abundance, coverage of species was used.

The following explanatory variables were slected:

- Management type (tillage, alternating and permanent vegetation)
- Frequency of soil treatments per year
- Last soil tillage event (in years)
- Frequency of herbicide treatment (only for in-row vegetation)
- Duration of current management practice
- Previous land use type (vineyard, grassland/apple orchard and arable)
- Soil characteristics (pH, $CaCO_3$, total organic carbon [TOC], silt content, sand content, dry bulk density, percolation stability)

Data on soil structure existed only for 9 plots and was analysed with a separate GLM, where indices were aggregated. Unfortunately, the low amount of data did not allow to create reliable results and will be not presented here.
Graphical output was computed with simple boxplot function in R and effect plot function from the R package *effects* (Fox, 2003). For the boxplots, data was shown by the mean values for each vineyard. Means of Grime-strategy and life span were calculated based on relative species coverage and aggregated by the means of all four pseudoreplicates for each vineyard.

Additionally, the vegetation composition was explored using multivariate statistical technique. Detrended correspondence analysis (DCA) was computed with the R package *vegan* (Oksanen et al., 2016) and indicator species analysis (ISA) was computed using the package *labdsv* (Roberts, 2016). DCA is considered a better and more robust method for community ordination than principle component analysis (PCA) for large but sparse data matrices. Latter computes faults with long ecological gradients, which occur in this data set (Oksanen et al., 2016).

3. RESULTS

Table 4 shows all compared models with the best model for each dependent variable. A difference of the AIC by the value 2 was considered significant (see chapter 2.3). Since combinations of variables within one model did not lead to an improvement of the AIC value, every variable was tested individually. Models for soil data are not included here, since no reliable results could have been computed because of low data amount.

Table 4: Model selection for taxonomic and functional diversity. Models were selected by comparing the AIC values. Differences by the value 2 were considered significant (best model, marked as bold).

Statistical model and family	Compared models	AIC inter-row	AIC in-row	Best model inter-row	Best model in-row
GLMM – poisson	Species number ~ 1 [null-variant] + circle/plot	498,64	476,19	Soil treatment frequency + duration of current management	Management
	Species number ~ management + circle/plot	499,22	**466,92**		
	Species number ~ soil treatment frequency + circle/plot	**495,55**	474,53		
	Species number ~ duration of current management + circle/plot	**496,54**	478,19		
	Species number ~ last soil tillage + circle/plot	500,46	477,47		
	Species number ~ previous cultivation + circle/plot	501,91	475,59		
	Only in-row: Species number ~ herbicides + circle/plot	-	475,93		
GLMM - gaussian	Shannon ~ 1 [null-variant] + circle/plot	**80,06**	116,76	Null-variant	Management
	Shannon~ management + circle/plot	84,79	**114,67**		
	Shannon ~ soil treatment frequency + circle/plot	85,59	118,72		
	Shannon ~ duration of current management + circle/plot	90,13	126,19		
	Shannon ~ last soil tillage + circle/plot	87,91	122,51		
	Shannon ~ previous cultivation + circle/plot	86,49	120,09		
	Only in-row: Shannon ~ herbicides + circle/plot	-	119,15		
GLMM - gaussian	FRic ~ 1 [null-variant] + circle/plot	**-692,81**	**-698,83**	Null-variant	Null-variant
	FRic ~ management + circle/plot	-671,49	-673,42		

	FRic ~ soil treatment frequency + circle/plot FRic ~ duration of current management + circle/plot	-682,66 -681,53	-685,63 -687,78		
	FRic ~ last soil tillage + circle/plot	-676,07	-681,76		
	FRic ~ previous cultivation + circle/plot	-670,96	-674,49		
	Only in-row: FRic ~ herbicides + circle/plot	-	-684,68		
GLMM - gaussian	FDiv ~ 1 [null-variant] + circle/plot	**-143,27**	**-143,28**	Null-variant	Null-variant
	FDiv ~ management + circle/plot	-130,31	132,38		
	FDiv ~ soil treatment frequency + circle/plot	-134,03	136,58		
	FDiv ~ duration of current management + circle/plot	-132,36	131,36		
	FDiv ~ last soil tillage + circle/plot	-132,88	132,88		
	FDiv ~ previous cultivation + circle/plot	-131,57	-131,57		
	Only in-row: FDiv ~ herbicides + circle/plot	-	-135,71		
GLMM - gaussian	RaoQ ~ 1 [null-variant] + circle/plot	**-528,07**	**-528,07**	Null-variant	Null-variant
	RaoQ ~ management + circle/plot	-511,45	-511,46		
	RaoQ ~ soil treatment frequency + circle/plot	-517,06	-516,18		
	RaoQ ~ duration of current management + circle/plot	-513,54	-513,53		
	RaoQ ~ last soil tillage + circle/plot	-513,95	-513,95		
	RaoQ ~ previous cultivation + circle/plot	-508,02	-508,02		
	Only in-row: RaoQ ~ herbicides + circle/plot	-	-515,52		

3.1. Inter-row vegetation

3.1.1. Taxonomic diversity

There could not be found a significant effect of management type on species number, neither on Shannon diversity in the inter-row vegetation. Boxplots show that values are relatively similar to each other with slightly higher values at alternating vegetation and lowest in tilled vineyards. Mean Shannon values are 2.03 for alternating vegetation cover, 1.93 for permanent vegetation cover and 1.83 for tilled vineyards. Means of species number are 15.33 for alternating vegetation, 15.58 for permanent vegetation and 13.39 for tilled vineyards (see figure 8).

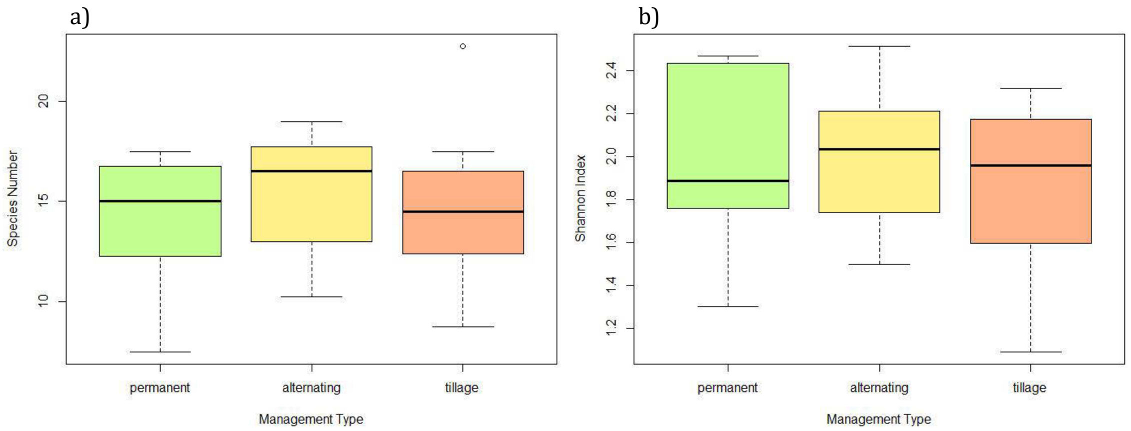

Figure 8: Species number (a) and Shannon diversity (b) by management. Differences between management types are not significant (n =23).

However, the frequency of soil treatment events does show a negative effect on species number (estimate: -0.0536, standard error: 0.0279). In this case, species number is lower with increasing soil tillage events (see figure 9). A similar effect occurs with the duration of current management, where species number decreases the longer current management is applied (see figure 10). This effect is likely due to tilled vineyards, since the seed bank is reduced through frequent tillage over time. However, the negative effect is relatively small (estimate: -0,0091, standard error: 0.0338).

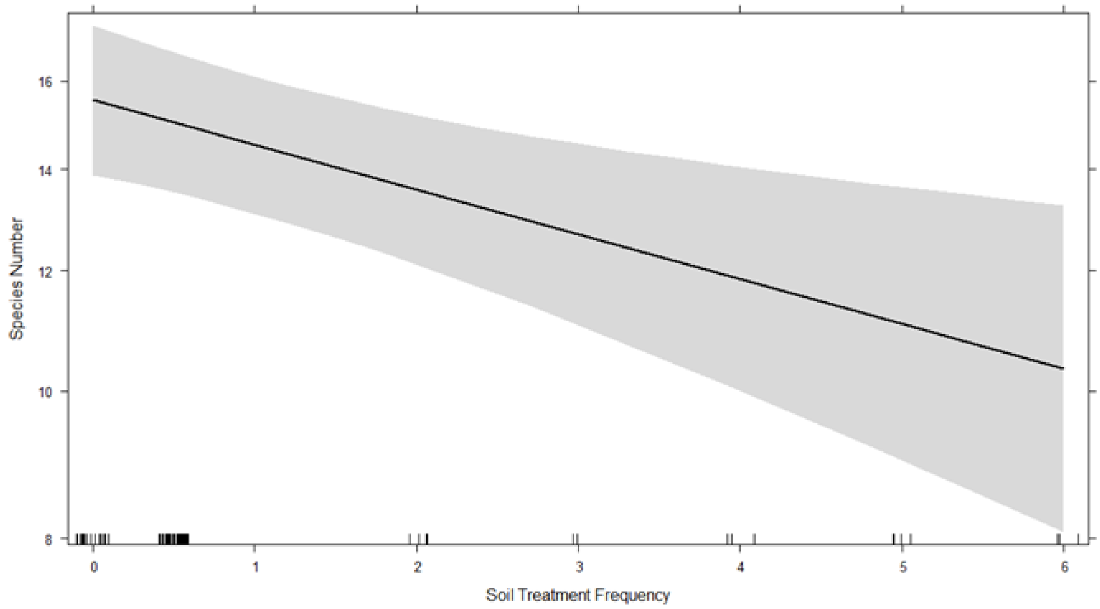

Figure 9: Effect of annual soil treatment frequency on species number. Species number decreases with increasing soil tillage frequency (n = 23).

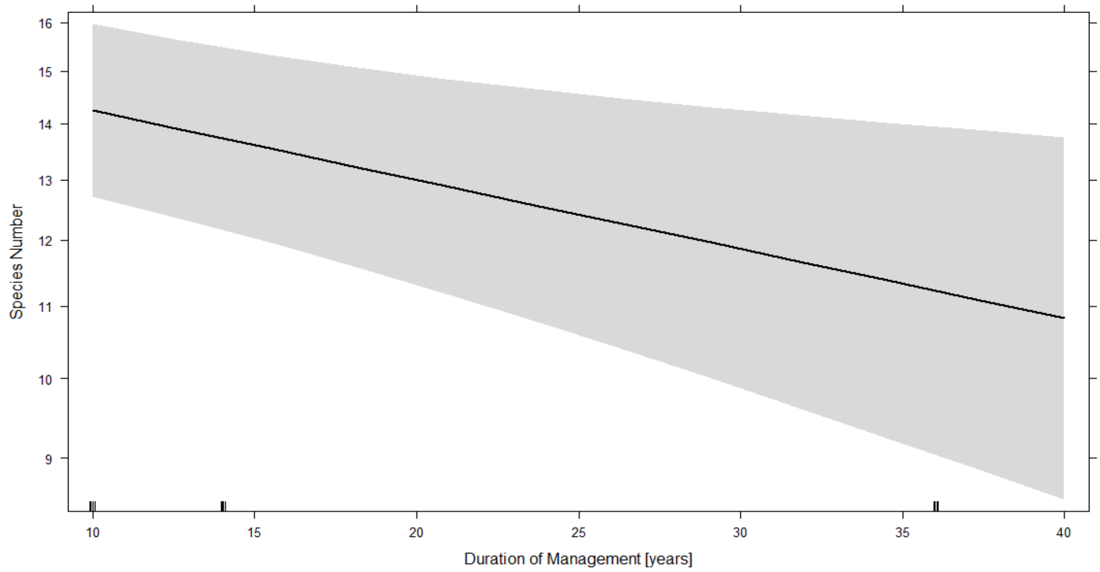

Figure 10: Effects of duration of current management on species number. Species number decreases the longer current management is applied (n = 23).

3.1.2. Functional diversity

Statistical tests did not show any effects of management on functional diversity indices. However, graphical output of selected traits shows clear differences between management types. Leaf area (see figure 11, a) increases with decreased management intensity, the arithmetic means (in mm^2) are 1272.55 for permanent vegetation, 1114.9 for alternating and 833.67 for intensive tillage. Dry mass (figure 11, b) shows a similar trend: 0.42 is the mean for permanent cover, 0.28 for alternating cover and 0.167 for tillage (means in g/g, dry mass per fresh mass).

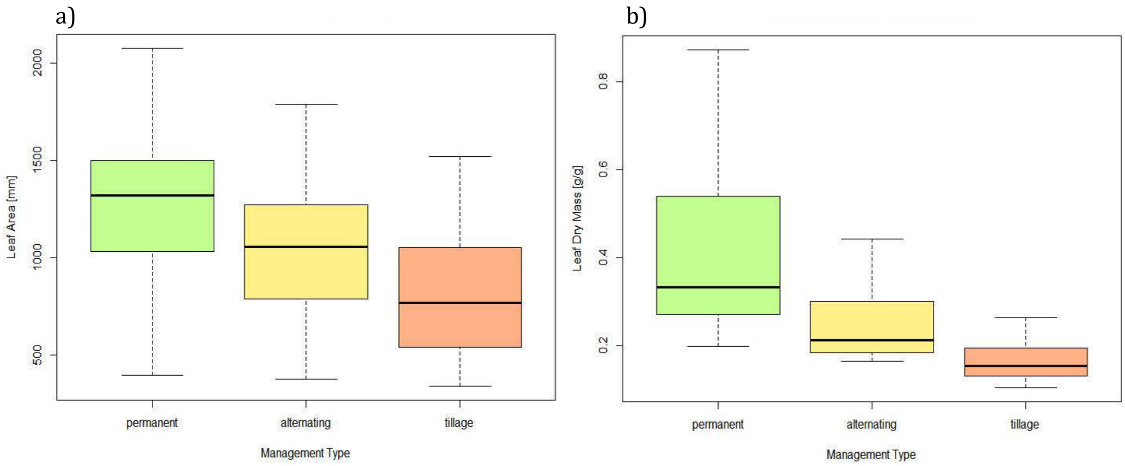

Figure 11: Leaf Area [mm^2] (a) and Leaf Dry Mass [g dry mass per g fresh mass] (b) related to management types (n =23).

Life span types differ as expected between management types. The relative coverage of perennial species is higher at permanent (mean: 0.69) and alternating management type (0.61) compared to tillage (0.17) as shown in figure 12, whereas the annuals are more abundant at tilled vineyards (0.8) compared to alternating (0.34) and permanent (0.24) cover (see figure 13). The relative coverage of biennial species is in general low, with slightly higher values in vineyards with permanent vegetation (0.06) compared to alternating vegetation cover (0.05) and tilled (0.03) vineyards (see figure 12).

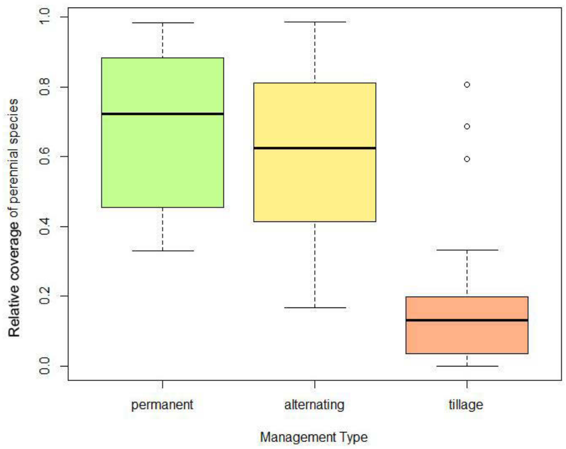

Figure 12: Relative coverage of perennial species by management type (n = 23).

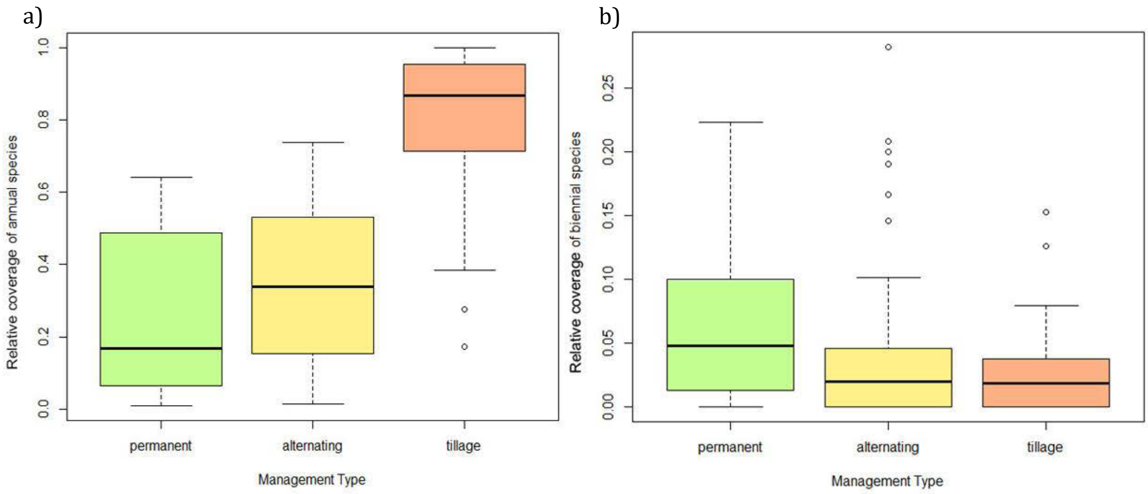

Figure 13: Relative coverage of annual (a) and biennial (b) species by management type (n = 23).

Tilled vineyards also differ in regard to the start of flowering period of plants compared to vineyards with vegetation cover. Plants in tilled vineyards flower slightly earlier (mean: 4.66) than vineyards with permanent (5.17) or alternating (5.25) cover (see figure 14). This correspond the high coverage of annual species in tilled vineyards, since annual species usually bloom early in the vegetation period.

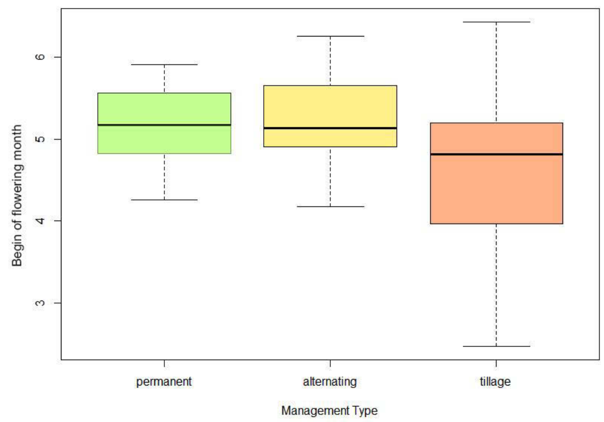

Figure 14: Begin of flowering month of surveyed species by management type (n = 23).

Similar results can be seen for Grime strategy types: C-strategists (competitors) are more abundant with decreasing management intensity (means: permanent 0.27, alternating 0.15, tillage 0.04) whereas R-strategists (ruderals) are more abundant in frequently tilled vineyards (means: 0.73 tillage, 0.31 alternating, 0.22 permanent) as shown in figure 15.

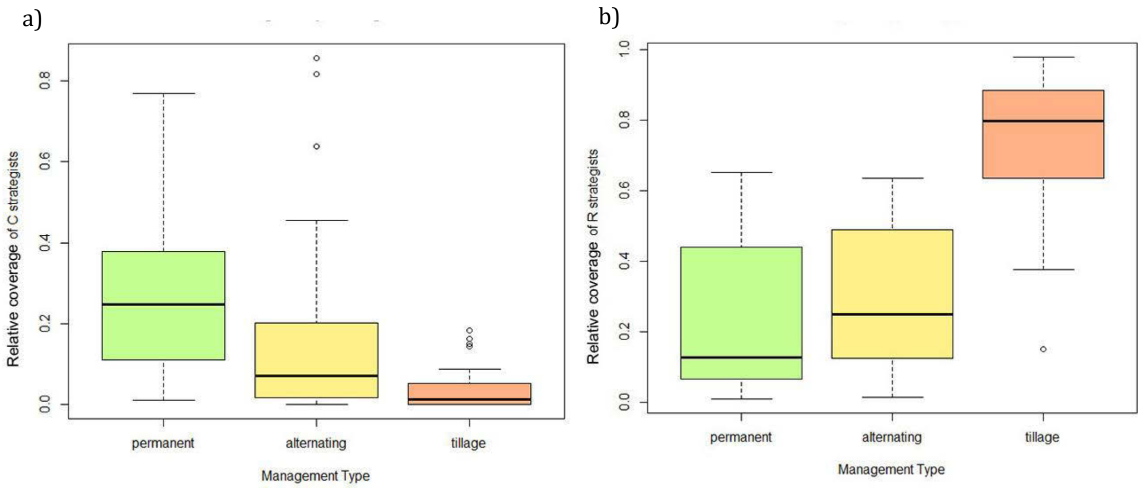

Figure 15: Relative coverage of C- (a) and R- (b) strategists by management type (n = 23).

Especially for the ruderals, the difference of tilled vineyards compared to vineyards with vegetation cover is strong. In this study *Elymus repens, Cardaria draba, Cirsium arvense, Dactylis glomerata, Mentha longifolia and Lathyrus tuberosus* are representing the C-strategists. Dominant R-strategists are *Setaria viridis, Bromus tectorum, Stellaria media, Portulaca oleracea, Digitaria sanguinalis* and *Veronica hederifolia.*

The plant communities of studied vineyards also contain other strategy types, e.g. CS (competitors-stress tolerant), CR (competitor-ruderals), SR (stress tolerant-ruderals) and CSR (competitor-stress tolerant-ruderals), but there were no differences found between management types. Plants of these types are not dominant in the data set.

3.1.3. Multivariate Analysis

DCA plots give a better understanding of the plant community structure. For the inter-row data, the first axis explains 66 % of the variances and the second axis 46 %. It is interesting, that the vineyard plots are arranged according to the management type (see figure 16). Therefore, differences between management intensities are obvious, especially tilled vineyards segregate from the other management types. Differences between alternating and permanent management seem to be less pronounced.

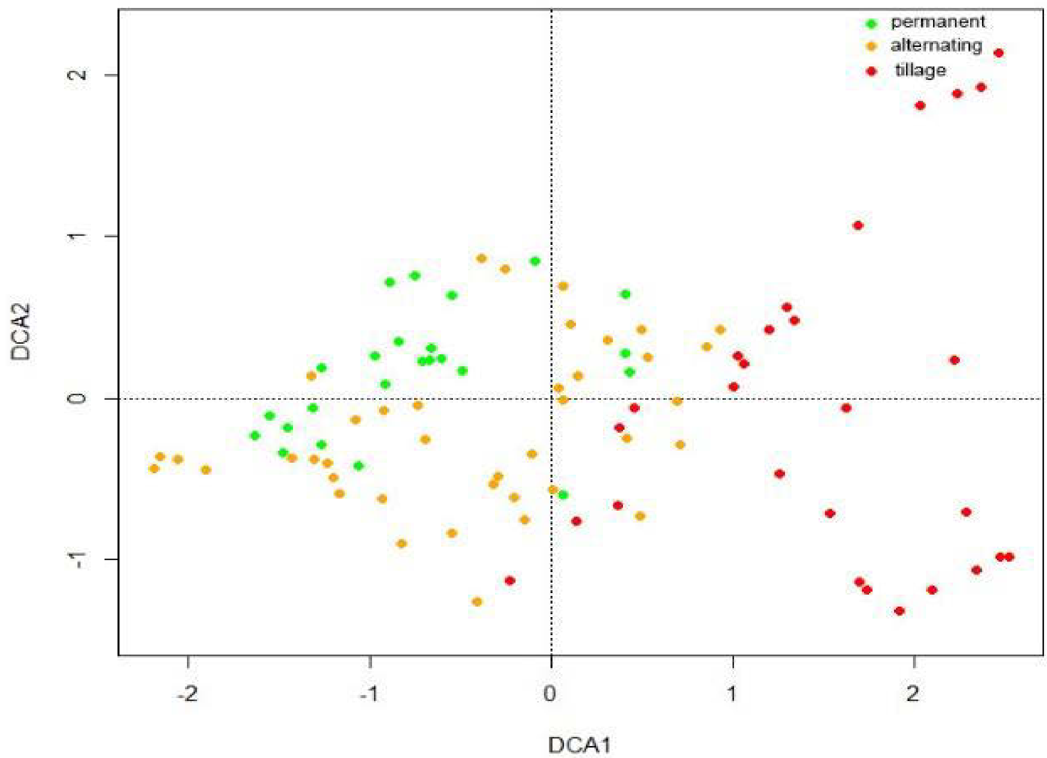

Figure 16: Detrended correspondence analysis (DCA) plot of vegetation community data with indicated management types.

Figure 17 shows how studied plots are characterized by occurring species. Typical species of grassland communities can be found on the negative side of the first axis (*Taracacum officinale* agg., *Poa pratensis, Trifolium repens, Lolium perenne*), whereas typical ruderal species are located on the positive axis, where mostly tilled vineyard plots are located (*Chenopodium album* agg., *Lamium amplexicaule, Veronica hereifolia, Stellaria media, Capsella bursa-pastoris, Portulaca oleracea*). This outcome fits to the subjective assessment of management regimes in the field.

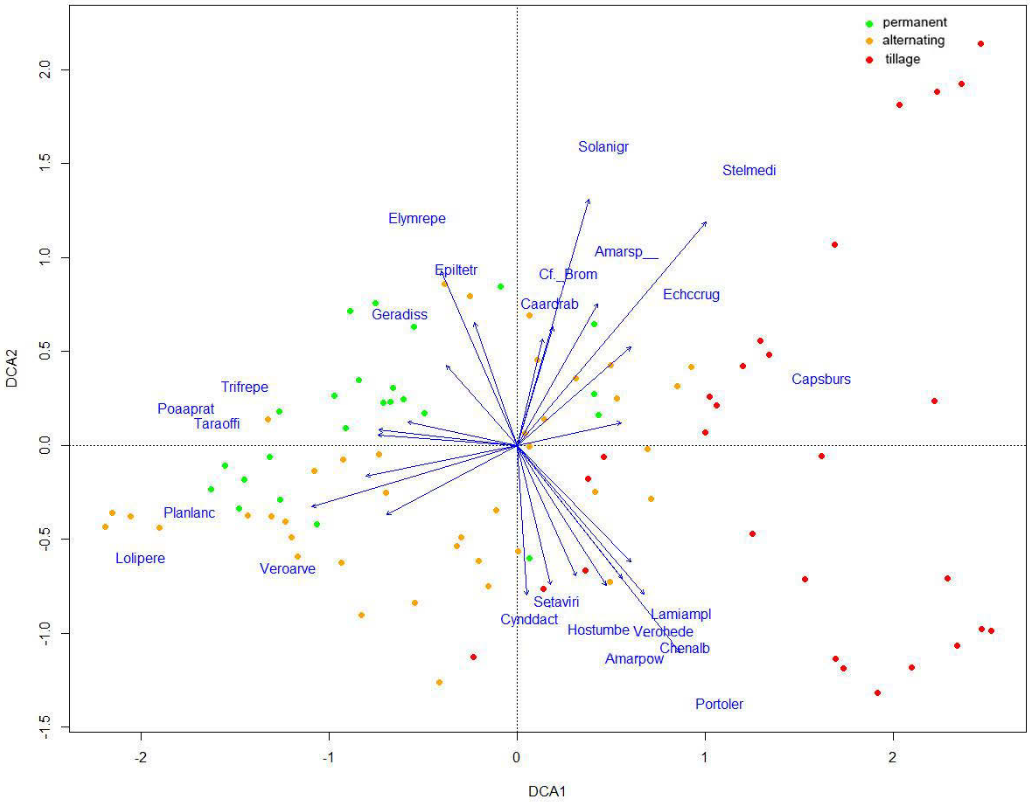

Figure 17: DCA plot of vegetation community data with indicated management types. Species gradients explain the community structure of the plots.

The characterization of the data by diversity indices shows an interesting outcome: Functional diversity indices are not correlated with taxonomic diversity (see figure 18). This result is coherent with a study from Trivellone et al. (2014), where indicator species were identified for taxonomic and functional diversity indices. Even though an effect of management on functional indices could not be found with the comparison of mixed models, gradients of functional indices (FRic, FDiv, RaoQ) extend towards plots with permanent vegetation cover in the DCA plot. Furthermore, gradients of species number, and Shannon diversity seem to extend towards plots with alternating vegetation cover.

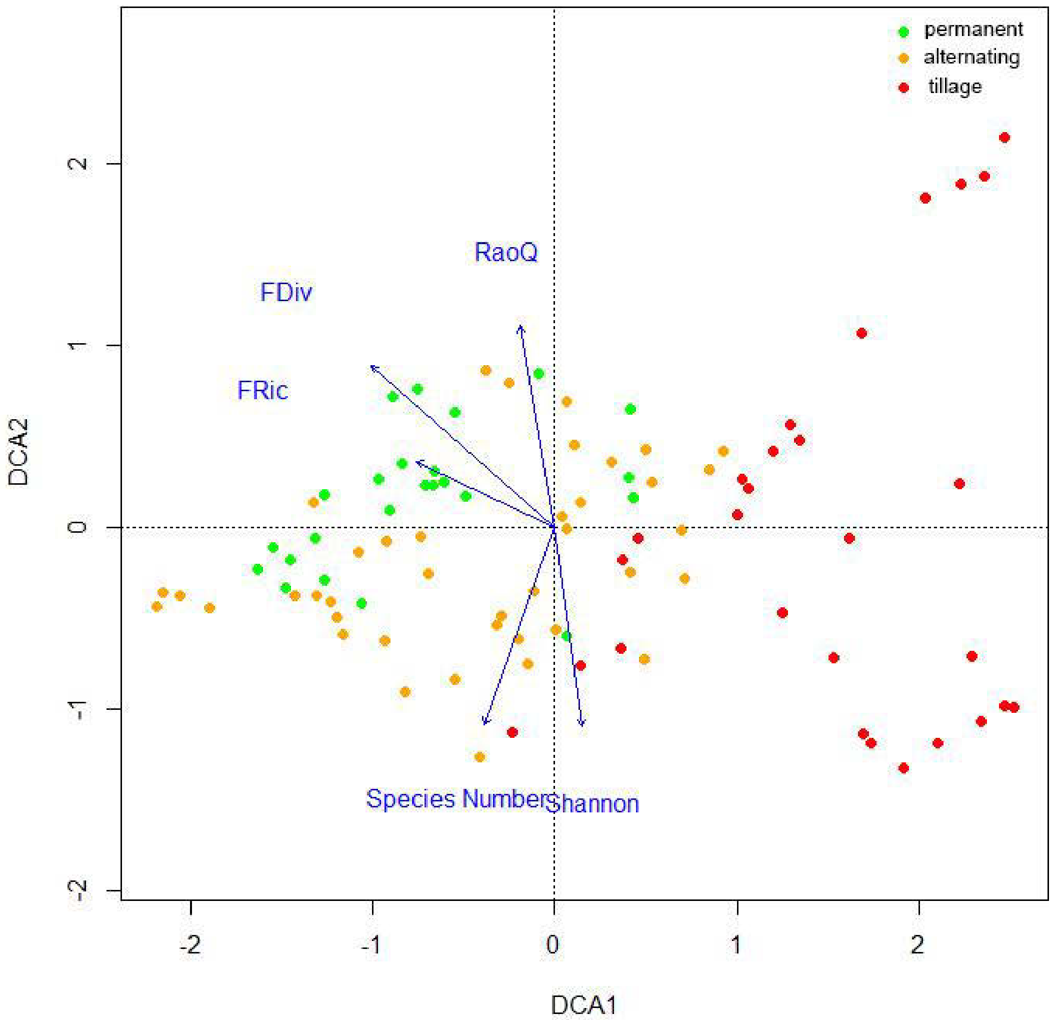

Figure 18: DCA plot of vegetation community data with indicated management types with diversity gradients.

Some traits seem to be more correlated to a specific management type. In figure 19, the Grime strategy types clearly directs to tilled vineyards. This outcome is consistent with the results in 3.1.2 (figure 15), where the relative coverage of C- and R-strategists in tilled vineyards strongly differed from permanent and alternating management. However, life span extends to the negative side of the first axis, where mostly permanent and alternating vineyards are located. Overall, traits related to the life strategy of species (Grime strategy, life span, start of flowering) are located on the negative side the second axis and are not correlated to other functional traits. Relatively close together are gradients of plant height, seed mass, leaf area and dry mass, which characterize vineyards with permanent vegetation cover.

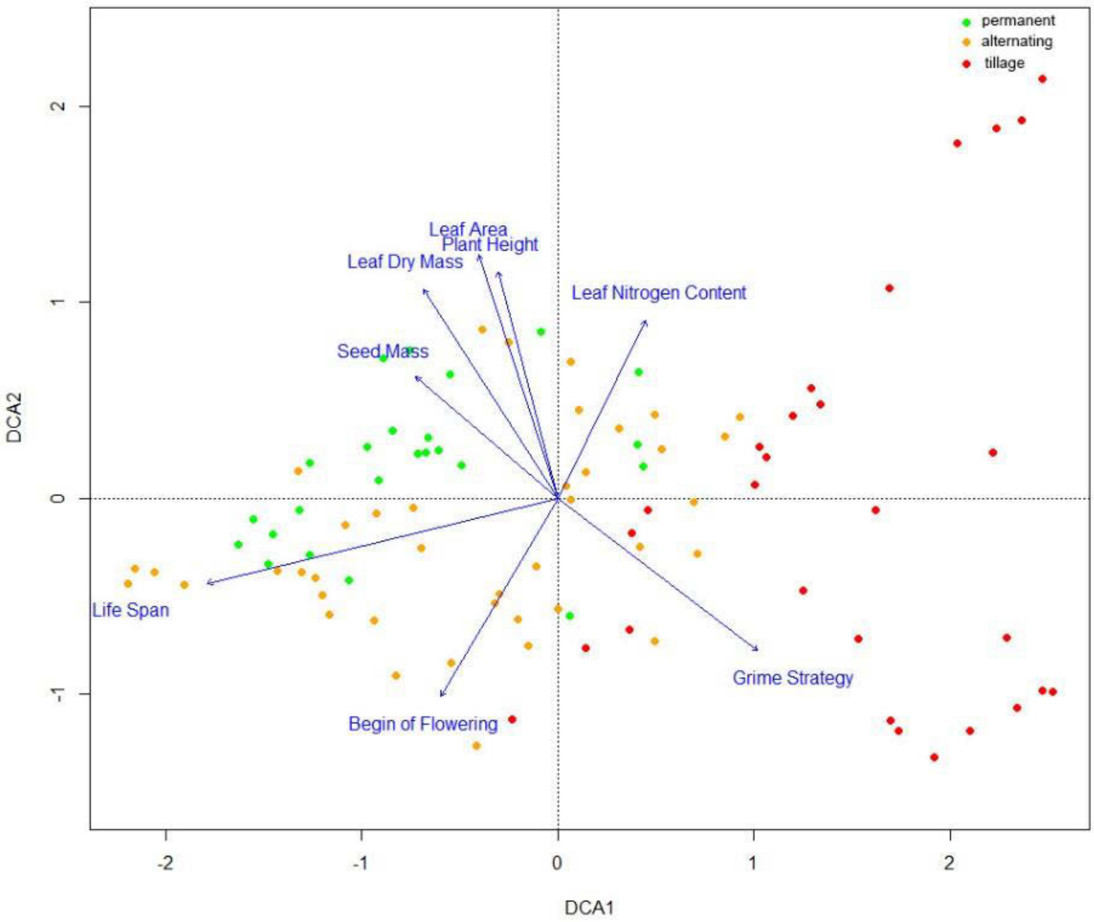

Figure 19: DCA plot of vegetation community data with indicated management types. Grime strategy, begin of flowering and life span are separated from the other functional traits.

The indicator species analysis (ISA) displayed in table 5 shows the significant indicator species for cluster groups defined by management types. *Elymus repens* is indicating permanent vegetation with a high indicator value of 0.6 and Ta*raxacum officinale* agg. with the value 0.47. These species have a high ability to regenerate after disturbance. Highest indicator value for alternating management shows *Plantago lanceolata* (0.46). For tilled vineyards, several species were identified with high values: *Stellaria media* (0.73), *Portulaca oleracea* (0.5), *Capsella bursa-pastoris* (0.47) and *Chenopodium album* agg. (0.45). These species are characteristic for ruderal areas with frequent disturbance. Species indicating permanent and tilled vineyards are mostly typical for these disturbance regimes, but it seems hard to characterize the alternating management, since only three significant species were selected. This can be probably explained by cover crop seed mixtures in three of eight vineyards with alternating management.

Table 5: Significant indicator species for each studied management type.

Permanent	Alternating	Tillage
Elymus repens (0.6)	*Plantago lanceolata* (0.46)	*Stellaria media* (0.73)
Taraxacum officinale agg, (0.47)	*Viola arvensis* (0.32)	*Portulca oleracea* (0.5)
Geranium pusillum (0.39)	*Sonchus oleraceus* (0.26)	*Capsella bursa-pastoris* (0.47)
Poa pratensis (0.38)		*Chenopodium album* agg. (0.45)
Veronica arvensis (0.37)		*Echinochloa crus-galli* (0.39)
Trifolium repens (0.37)		*Lamium amplexicaule* (0.36)
Lolium perenne (0.36)		*Veronica hederifolia* (0.36)
Medicago lupulina (0.28)		*Solanum nigrum* (0.25)

3.2. In-row vegetation

3.2.1. Taxonomic diversity

Regarding the in-row vegetation, the model comparison showed a significant effect of management on taxonomic diversity (see table 4, model selection). Species numbers are highest at alternating management (mean: 12.04) and lower at permanent (mean: 8.75) and tilled management (mean: 6.48). Shannon diversity is also highest at alternating management with a mean of 1.85 and lower at permanent with a mean of 1.6 and tillage with a mean of 1.25 (see figure 20). It must be noted that vegetation of tilled vineyards is controlled by tilling and in-row vegetation of vineyards with alternating vegetation is controlled by tillage or herbicides. However, the use of herbicides is more frequent in the rows of vineyards with permanent cover. Therefore, permanent vegetation cover cannot be clearly classified as the lowest management intensity at the in-row vegetation.

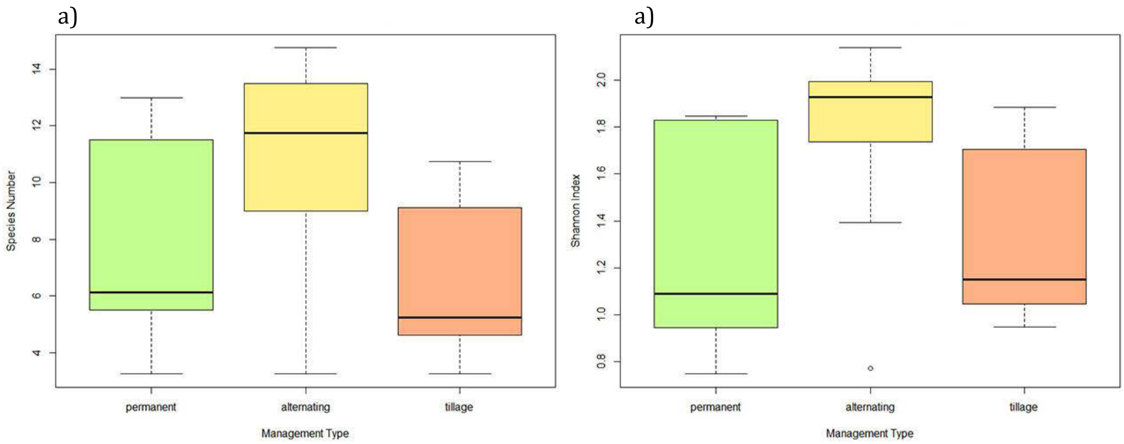

Figure 20: Species number (a) and Shannon diversity (b) by management types. Alternating management cover shows highest values for both indices (n = 23).

3.2.2. Functional diversity

Statistical tests did not show any effect of selected variables on functional indices, but the boxplot of functional richness shows a trend of higher richness for alternating vegetation cover for the in-row vegetation (see figure 21). In this case, functional richness would be correlated to taxonomic diversity (see chapter 3.2.1), which is inconsistent with the DCA plot of the inter-row vegetation (chapter 3.1.3, figure 18). However, differences between arithmetic means are relative small with 0.012 for alternating management and 0.011 for both, permanent cover and tillage.

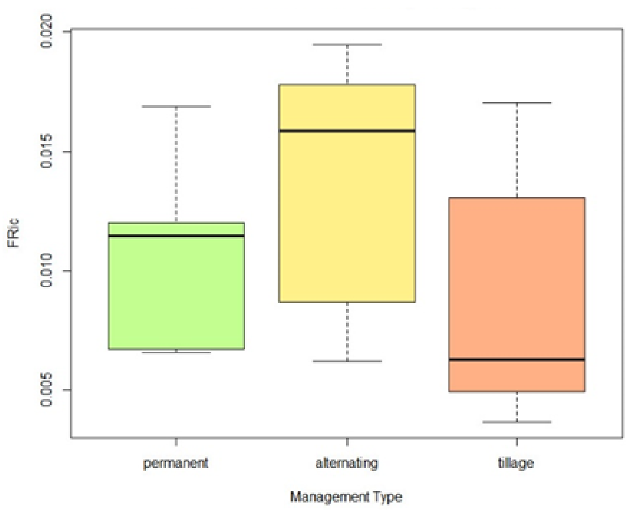

Figure 21: Functional Richness (FRic) by management types (n = 23).

Looking at specific traits, there is a trend of seed mass being highest at permanent vegetation (mean: 1.93), intermediate at alternating management (1.88) and lowest with tillage (1.48) as shown in figure 22.

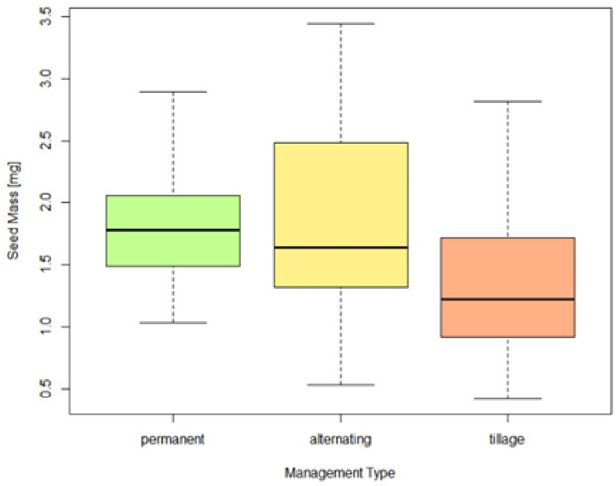

Figure 22: Seed mass values by management types (n = 23).

Concerning life span, it is interesting that relative coverage of perennials is highest at alternating management (mean: 0.61) compared to permanent cover (0.47) and tillage (0.3). Also there is just little difference in the coverage of annuals between permanent and alternating vegetation (means: 0.42 and 0.37) (see figure 23). However, like for inter-row vegetation, coverage of annuals was highest in tilled vineyards (0.67).

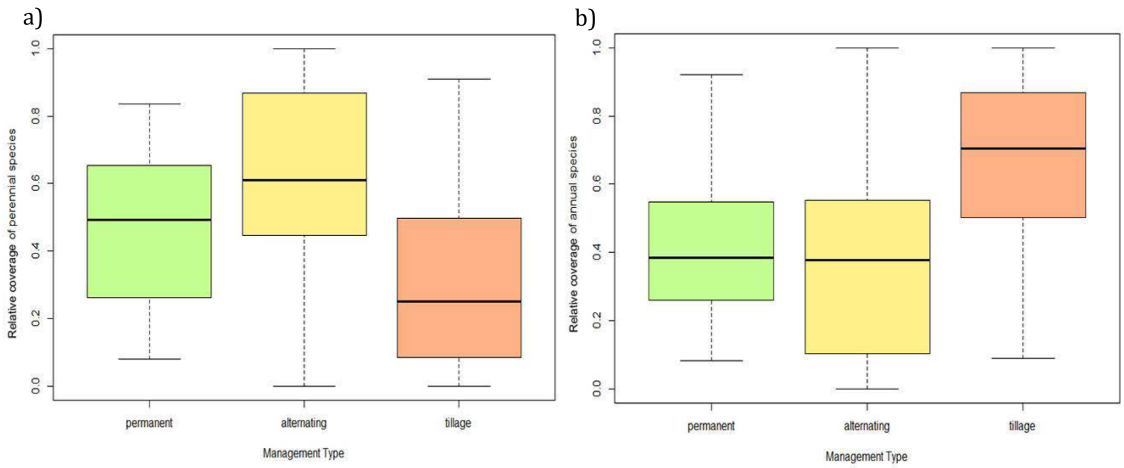

Figure 23: Relative coverage of perennial and annual species by management type (n = 23).

Relative coverage of biennial species is generally low, but there is a trend of higher coverage for plots under permanent management (means: 0.12 permanent, 0.03 tillage, 0.02 alternating) as shown in figure 24.

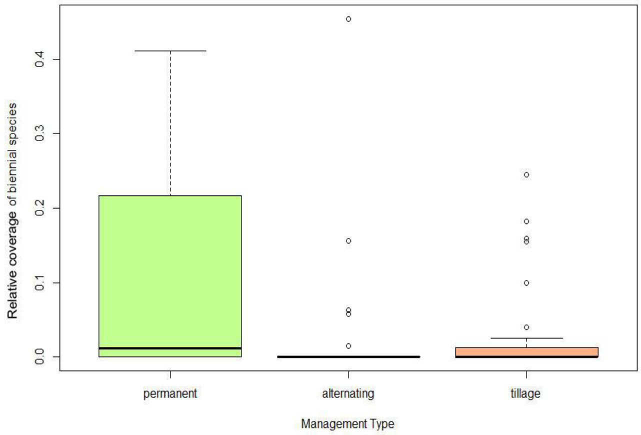

Figure 24: Relative coverage of biennial species by management (n = 23).

There were no differences found between management types for the average start of flowering. Relative coverage of Grime strategy types according to management intensities are similar to inter-row communities, but more effects can be seen (see figure 25). Besides the effect on C- and R-strategists, CR-strategy type increases in coverage with decreasing management intensity. Mean relative coverage of CR strategists are 47.96 for permanent, 32.71 for tilled and 23.43 for alternating management. CSR-strategists increase with decreasing management intensity: permanent vegetation has a mean value of 12.04, whereas alternating cover has a value of 3.68 and tillage of 1.46.

Dominant CR-strategists are *Ballota nigra, Echinochloa crus-galli, Geranium pusillum* and *Lolium perenne*. Dominant CSR-strategists are *Achillea millefolium, Geranium dissectum, Medicago lupulina, Plantago lanceolata* and *Poa pratensis.*

Like in the inter-rows, C-strategists increase with decreasing management intensities, while R-strategists decrease. Mean relative coverage for C-strategist show the clear effect and are 26.83 for permanent, 18.05 for alternating and 4.32 for tilled management, whereas means for R-strategists are 77.82 for tilled vineyards, 33.78 for alternating and 27.42 for permanent cover.

Here, *Cardaria draba* and *Elymus repens* represent the dominant C-strategists and dominant R-strategists are: *Bromus tectorum, Capsella bursa-pastoris, Digitaria* *sanguinalis, Hordeum murinum, Polygonum aviculare, Portulaca oleracea, Setaria viridis, Solanum nigrum, Stellaria media* and *Viola arvensis.*

Relative coverage of CS- and SR-strategists are too low for identifying any differences between management types.

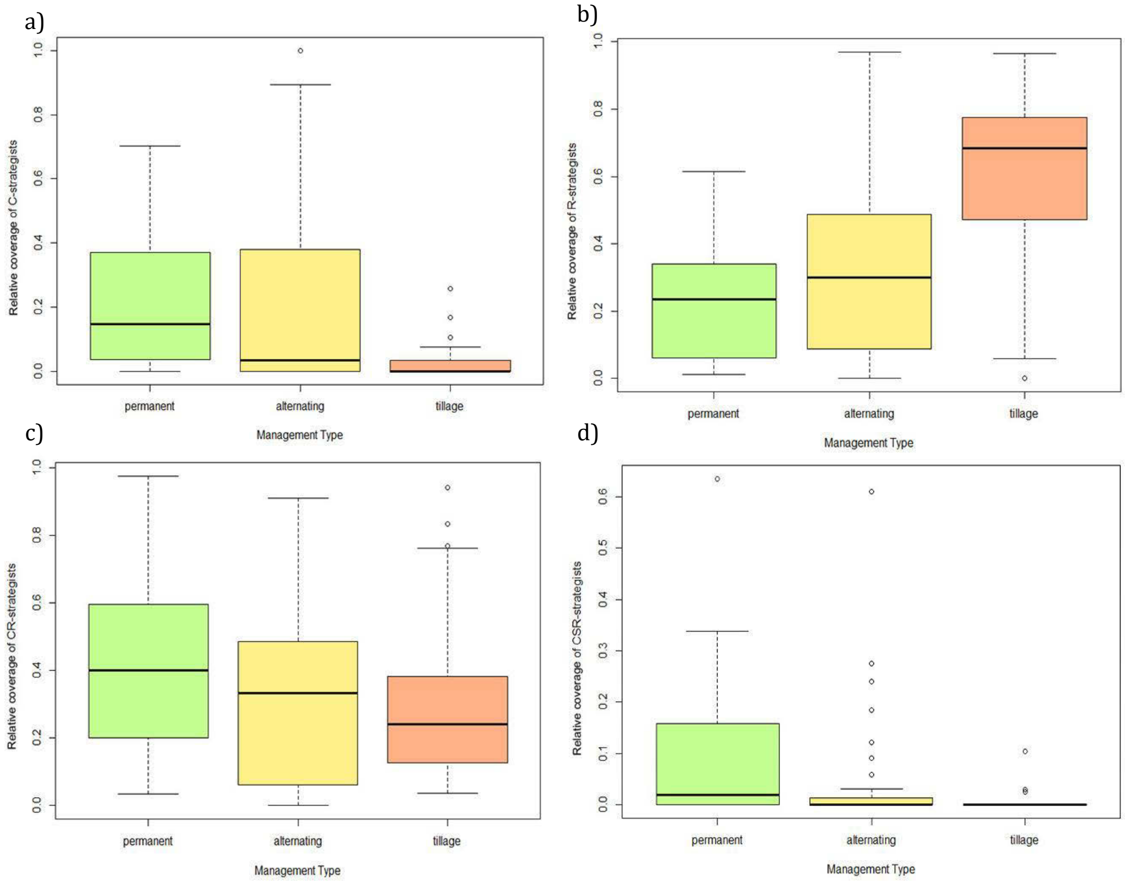

Figure 25: Relative coverage of C-strategists (a), R-strategists (b), CR-strategists (c) and -CSR-strategist (d) by management types. (n = 23).

3.2.3. Multivariate Analysis

The DCA plots of the in-row data have a low informative value, probably due to the generally low number of species present in the field. It is hard to recognize any patterns here (see figure 26). Therefore, an interpretation of any explanatory gradients is renounced.

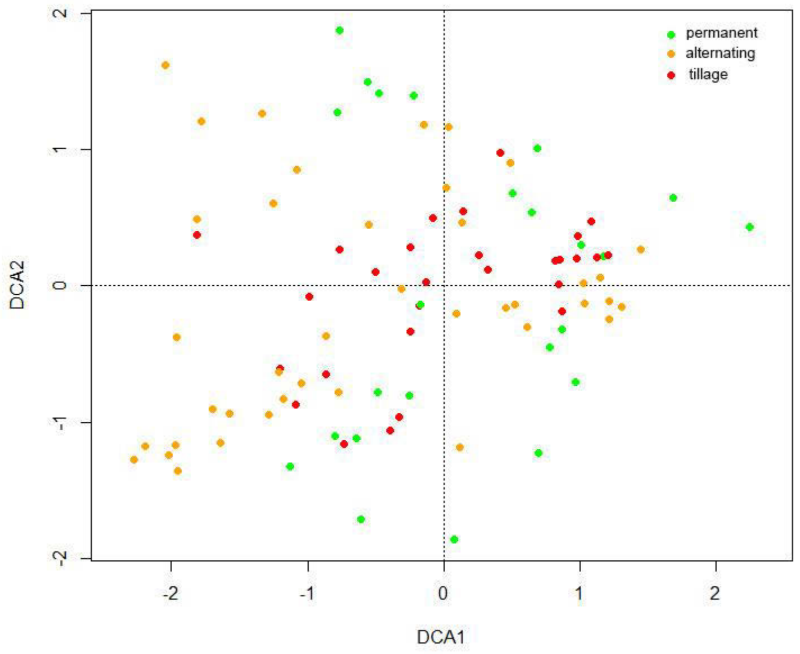

Figure 26: DCA plot of vegetation community data with indicated management types for in-row vegetation.

The indicator species analysis (ISA) could identify significant indicator species for permanent vegetation, which are: *Geranium pusillum* (0,55), *Elymus repens* (0,5), *Bromus tectorum* (0,42), *Veronica polita* (0,4), *Lolium perenne* (0,25), *Lactuca saligna* (0,26), *Cardaria draba* (0,25) and *Medicago lupulina* (0,25). There were no identifiable patterns for alternating vegetation cover or tilled vineyards.

4. DISCUSSION

The effect of management intensity on biodiversity is ambiguous. Taxonomic diversity of the inter-row vegetation decreases with management intensification when tillage frequency is considered, but boxplots show a tendency of higher diversity values at alternating management. The in-row vegetation clearly benefits from intermediate disturbance intensity (alternating vegetation cover). This ambiguous outcome can be due to the differences of management practices between inter- und in-row vegetation of vineyards with permanent vegetation cover. While inter-row vegetation is mowed and mulched, in-row vegetation of vineyards with permanent vegetation cover is mostly controlled by herbicides. Thus, "permanent vegetation cover" should not be classified as low intensity, but intermediate, for the in-row situation. The negative effect of herbicide treatments on biodiversity is noted in related research. Untreated cover crop cultivation had 15 times higher plant diversity compared with herbicide treatments in a Californian study (Sanguenko & León, 2011). A positive effect on plant diversity was also found for organic farming in vineyards, where the main difference between organic and conventional systems was the use of herbicides (Nascimbene et al., 2012). However, these findings are in contrast to investigations by Bruggisser et al. (2010), which could not show a positive relationship between organic farming and biodiversity. The authors refer to the theory of intermediate disturbance, at which biodiversity is found to be highest (Connell, 1978; Grime, 1977; Horn et al., 1975). Phenomena concerning biodiversity do not follow simple principles, but can be influenced by multiple factors. Further investigations of effects on plant diversity, including local conditions, e.g. slope, soil parameters and landscape structure, could provide more clarification about the present data. Influences of landscape diversity will be investigated within the VineDivers project. The landscape structure of the Târnave region differs between small wine growers and huge, intensive wine growing fields of the Jidvei company, so that influence of landscape structure is possible. Ma and Herzon (2014) outlined the importance of landscape structures for the plant functional diversity in agricultural landscapes. In their study, plant diversity decreased with agricultural landscapes becoming simplified.

Overall, it seems that lower intensity, e.g. permanent vegetation cover, increases taxonomic diversity in the Târnave region, under condition that no herbicides are applied. Of course, this will not be likely in practice. It can be said, that mowing leads to higher species richness compared to intensive tilling, which is consistent with the results of Lososova et al. (2003).

The results of the inter-row indicator species analysis (ISA) show no clear differentiation for the alternating management, although most studied vineyards belonged to that management type. The DCA plot implies that differences between permanent and alternating vegetation are blurry. The ISA of the in-row vegetation could not identify any indicator species for alternating covered or tilled vineyards. This becomes clear, as alternating management represents a mixed form between permanent vegetation cover and tilled vineyard. However, for farmers the alternating management type could be of high interest, since permanent vegetation favours *Elymus repens* and *Cardaria draba,* which are considered as troublesome weeds (Holzner & Glauninger, 2005). This result is not as pleasing for farmers as that of the study in Portugal, where cover crops did not favour troublesome weeds (Monteiro et al., 2012). From the agricultural point of view, another benefit of alternating vegetation cover is the reduced workload compared to intensive tilling and mitigation of soil erosion. Additionally, vegetation covered inter-rows feature better conditions for passing with land machines.
In a Hungarian research project where different seed mixtures where investigated in vineyards, *Plantago lanceolata* – one of the species in the seed mixtures – established particularly high cover scores (Miglécz et al., 2015). The dominance of *Plantago lanceolata* in some Romanian vineyards with alternating vegetation occurred probably due to the use seed mixtures.

Even though vineyards with permanent vegetation cover do contain troublesome weeds with high coverage, other benefits should not be forgotten. These concern the effects on soil structure, pollinators, invertebrates and the aesthetic value, which are also investigation goals of the VineDivers project and have already been investigated in related studies, which showed positive effects (Altieri et al., 2005; Chupanov et al., 2014; Danne et al., 2010; Sanguenko & León, 2011; Steenwerth & Belina, 2008; Tompkins, 2010; Virto et al., 2012). For example, cover crops in vineyards do enhance N soil dynamics and microbiological processes of N mineralization, nitrification and denitrification (Steenwerth & Belina, 2008).

Another study showed a positive correlation between permanent grass cover and greater aggregate stability, soil-available water capacity, microbial soil biomass and enzymatic activity in the soil (Virto et al., 2012). A study in Australia showed, that native cover crops enhance the abundance of beneficial invertebrates better than oat cover (Danne et al., 2010).

Missing significances for the effect of management on functional diversity indices are unclear, but the composition of Grime strategy and life span types indicate different functional composition. Therefore, different life spans and Grime strategies are distributed more equally in vineyards with permanent vegetation cover. An intermediate competition, e.g. the co-occurrence of different strategy types, is outlined to contribute to functional divergence, which indicates a high degree of niche differentiation (Kazakou et al., 2016; Navas & Violle, 2009).
Especially frequent tillage resulted in high coverage of annual species and R-strategists as expected, which is similar to other research results (Kazakou et al., 2016; Zanin, 1997). Differences occur between inter- und in-row vegetation, due to different management practices. However, results of a study on arable crops (corn, soy bean and white wheat) did not show this simple relationship: Densities of perennial species such as *Elymus repens* and *Cirsium arvense* where not basically higher in non-tilled crops compared with reduced and intensive tillage (Frick & Thomas, 1992). This shows that plant diversity and plant community composition cannot be explained solely by management.

The absence of a correlation between taxonomic and functional diversity raises questions about their relationship. As mentioned at the beginning, this absence becomes clear, when few species have strong functional effects on an ecosystem (Chapin et al., 2000). However, for the in-row vegetation with a general low amount of species, there seems to be a connection between species diversity and functional richness. This connection can probably be explained by the low species number, since a minimum number of species is considered essential for ecosystem functioning (Loreau et al., 2001). A higher number of species probably enhances the stability of ecosystems and would be desirable for changing environments. This is also promoted by Isbell et al. (2011), in order to maintain multiple functions in time and multiple places. Concerning the interrelation of species richness and consequential niche occupation, Díaz and Cabido (2001) recommend a balanced relation between functional and taxonomic diversity as an environmental goal.

A trait-based examination on the individual level could help to identify drivers of functional diversity, as shown by Trivellone et al. (2014). In their study, specific species were identified as indicators for certain functional and taxonomic indices. The analysis for the relationship between identified indicator species from the ISA and biodiversity indices could be a further step.

The fact that there does not exist any correlation in the DCA between phenological traits (leaf area, leaf dry mass, seed mass, plant height) and those related to life strategies (Grime types, life span, begin of flowering) is an unexpected outcome. It shows that the consideration of phenological features is a complementary approach to the classical consideration of life strategies, e.g. life span or Grime strategy.

The response of selected traits to management indicates a more likely occurrence of specific ecosystem processes. In this study, values for leaf area, leaf dry mass, life span and, to some point, seed mass showed higher values at permanent vegetation cover. In the case of life span, it means that coverage of perennial species was highest at permanent vegetation. According to Diaz et al. (2007) leaf area and dry mass are connected to productivity and decomposition, which influence net mineralization. The relationship of leaf traits and soil fertility was also studied and illustrated by Hodgson et al. (2011). Life span regulates carbon sequestration through accumulation of standing biomass and seed traits express the persistence of seeds in the soil bank (Diaz et al., 2007). From the agricultural point of view, looking at specific traits is promising for favouring desirable ecosystem processes. Based on results of this study, enhanced net mineralization through decomposition could be achieved by permanent vegetation cover, where leaf area is highest.

The understanding of functional traits can also help to develop and maintain resilient ecosystems. This scientific goal is already mentioned in other trait-based research. A study of de Bello et al. (2010) outlines, that single services depend on multiple traits, while several individual traits can simultaneously affect the delivery of multiple service. This results in clusters of associated traits and services. Kazakou et al. (2016) promote several steps for a better understanding of these linkages and takes management as a development tool for plant community structure into account. First, species that respond similar to a management should be recognized.

Second, traits that are closely related to specific ecosystem services should be identified. The plant diversity and ecosystem service should be compared under different types of management. Then linkages between traits and services should be tested to establish quantitative relationships (Kazakou et al., 2016). With these insights, the use of traits could be possible from the scale of plant species and communities to the ecosystem function level. In this study, the first and a part of the third step were already conducted. Species that respond similar to a management where identified through indicator species analysis and species gradients within the DCA. Also diversity and trait values were compared under different managements. For the use of traits in terms of "environmental modelling" as meant by Kazakou et al. (2016), variables of specific ecosystem processes, such as water capacity or nitrogen content, might be compared with studied trait values.

The results of the present study underlie the limitations of scientific work under field conditions. Firstly, the heterogeneity of the sampled vineyards regarding the duration of current management practice, the age of the vineyards and the frequencies of disturbance limit the similarity within management types and complicate clear classifications. Furthermore, sampling difficulties occurred through freshly mowed or tilled vineyards. Actual species richness is probably higher on some permanent plots due to this issue. The available trait data is also limiting a comprehensive analysis, since about 66 % of sampled species included in the data set were covered, excluding some frequent species such as *Crepis rhoeadifolia, Amaranthus powellii* and *Vicia angustifolia,* because of missing trait values. Regarding the methods of trait-based investigations, Gaba et al. (2014) criticize the use of trait data obtained from trait data bases, because of deficient transferability. They promote the establishment of guidelines for sampling plant traits in relation to the crop development, to address the intraspecific variability of traits in the cropping system. However, such a method would have been too time-consuming considering the framework of this thesis.

5. CONCLUSION

On the one hand, this study gave another insight in the effects of management on taxonomic and functional plant diversity in viticulture, but on the other hand further questions have arisen. Since the characterization of alternating vegetation cover in vineyards are blurry, further investigations regarding the plant communities of alternating management would be interesting. Especially since taxonomic and functional diversity was found to be highest for the alternating vegetation cover in the in-row vegetation. In this study, seed mixtures played a role within this management type. Since seed mixtures influence the composition of cover crops, especially when one or few species of the mixture become highly dominant, it would be interesting to compare spontaneous vegetation cover with seeded cover crops in terms of biodiversity.

Further investigations could be performed by including further local parameters, such as local morphology (e.g. slopes), soil characteristics and landscape diversity. The latter is already defined as an investigative goal of the VineDivers project.

For future investigations, it is proposed to constitute the linkages between plant species, functional traits and ecosystem processes for aiding decision making in agriculture and conservation. Knowledge about specific cause-effect relationships – e.g. the quantitative responses of ecosystem processes to specific traits – should be gathered. It is recommended to use a single-trait indices approach, because single-trait indices can better link the variation of environmental gradients (Butterfield & Suding, 2013). Through this approach, the relationship of traits and ecosystem functions can be investigated independently. However, for a holistic image of ecosystem services in a landscape, both, single- and multi-trait indices have to be considered.

Management is considered as the key factor influencing plant community structure and diversity. Therefore, the type of management that favours plant species that contribute to desirable ecosystem services, should be identified, as suggested by Kazakou et al. (2016).

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List of sampled species

Achillea millefolium
Agrostis stolonifera
Ajuga genevensis
Amaranthus powelii
Amaranthus retroflexus
Amaranthus retroflexus
Anagallis arvensis
Anthemis austriaca
Apiaceae
Aremonia agrimonoides
Arenaria serpyllifolia
Artemisia vulgaris
Atriplex patula
Ballota nigra
Bromus inermis
Bromus tectorum
Buglossoides arvensis
Capsella bursa-pastoris
Cardaria draba
Carduus crispus
Cerastium brachypetalum
Cerastium pumilum
Chenopodium album agg.
Cichorium intybus
Cirsium arvense
Cirsium vulgare
Clematis sp.
Convolvulus arvensis
Conyza canadensis
Crataegus sp.
Crepis rhoeadifolia
Cynodon dactylon
Dactylis glomerata
Daucus carota
Digitaria sanguinalis
Echinochloa crus-galli
Elymus repens
Epilobium tetragonum
Equisetum arvense
Erigeron annuus
Erodium cicutarium
Euphorbia cyparissias
Euphorbia helioscopia
Falcaria vulgaris
Fallopia convolvulus
Festuca arundinacea
Festuca sp.
Fraxinus excelsior
Quercus robur
Galium aparine
Galium mollugo
Rosa canina
Geranium dissectum
Geranium pusillum
Glechoma hirsuta
Hibiscus trionum
Hieracium sp.
Holosteum umbellatum
Hordeum murinum
Inula britannica
Kickxia spuria
Lactuca saligna
Lactuca serriola
Lamium amplexicaule
Lamium purpureum
Lappula squarrosa
Lathyrus nissolia
Lathyrus tuberosus
Lepidium campestre
Leucanthemum vulgare
Lolium perenne
Lotus corniculatus
Lotus corniculatus ssp. *hirsutus*
Medicago lupulina
Medicago minima
Melilotus officinalis
Mentha longifolia
Myosotis arvensis
Oreganum vulgare
Papaver dubium
Pastinaca sativa
Phleum pratense
Picris hieracioides
Plantago lanceolata
Plantago major
Poa pratensis
Polygonum aviculare
Polygonum persicaria
Potentilla sp.
Prunella vulgaris
Potentilla sp.
Ranunculus bulbosus
Rorippa sylvestris
Ranunculus bulbosus
Rumex sp.
Sclerochloa dura
Setaria viridis
Solanum lycopersicum
Solanum nigrum
Sonchus oleraceus
Cf. *Stachys annua*
Stellaria media
Taraxacum officinale agg.
Teucrium chamaedrys
Thlaspi perfoliatum
Torilis arvensis
Tragopogon dubius
Tragopogon orientalis
Trifolium repens
Tripleurospermum inodorum
Verbascum phoeniceum
Verbena officinalis
Veronica arvensis
Veronica hederifolia
Veronica persica
Veronica polita
Veronica triphyllos
Vicia angustifolia
Vicia hirsuta
Vicia pannonica
Viola arvensis
Vitis vinifera

Trait values

Species name	Leaf Area	Leaf dry Mass	Leaf Nitrogen	Plant Height	Seed Mass	Life Span	Grime Strategy	Flowering Begin
Achillea millefolium	566.042641	0.246633738	26.65611603	0.395676203	0.17926491	perennial	csr	6
Amaranthus retroflexus	3385.35263	0.216477059	32.875	0.531578947	0.420521739	annual	cr	7
Anagallis arvensis	53.7697249	0.139301819	26.1523875	0.105223761	0.480042105	annual	r	6
Arenaria serpyllifolia	10.0419279	0.24016419	10.17717	0.145944444	0.069029091	annual	sr	5
Artemisia vulgaris	2827.7135	0.273790726	30.14205867	1.122759655	0.150927273	perennial	cr	7
Ballota nigra	1532	0.222		0.759782609	0.945908333	perennial	cr	6
Bromus tectorum	262.562508	0.15655	20.47857143	0.265793749	2.836039357	annual	r	5
Buglossoides arvensis	562.600159	0.140729823	37.73081667	0.31866	6.177291667	annual	cr	4
Capsella bursa-pastoris	1035.7661	0.14679321	37.61035833	0.258405172	0.124271395	annual	r	1
Cardaria draba	1390.28571	0.161666667		0.352083333	1.784409091	perennial	c	5
Carduus acanthoides	5280.32714	0.126352857		0.894117647		biennial	csr	6
Cerastium brachypetalum	83.7322709	0.118876507	1.764010667	0.17	0.058234783	annual	sr	4
Chenopodium album agg.	1085.43672	0.155520018	34.86253352	0.485560669	0.764051282	annual	cr	7
Cichorium intybus	4185.10571	0.177688644	28.306556	0.772528767	2.267094605	perennial	sr	7
Cirsium arvense	2123.28667	0.160534039	23.80126313	0.692443249	1.22642619	perennial	c	7
Cirsium vulgare	10409.265	0.154965	32.5	1.071111111	2.582512903	biennial	csr	6
Convolvulus arvensis	610.173333	0.17429	33.2788875	0.409690909	11.986145	perennial	cr	6
Conyza canadensis	194.415945	0.2337477	30.30362	0.63127907	0.074499926	annual	r	7
Cynodon dactylon	179.783333	0.23633695	28.6659175	0.211294741	0.182052289	perennial	cs	7
Dactylis glomerata	1655.50989	0.259193168	24.97228023	0.668598826	0.837610269	perennial	c	5
Daucus carota	1156.37692	0.256323733	22.0318456	0.518073874	1.112890844	perennial	sr	6
Digitaria sanguinalis	1686.2944	0.18058117	26.29347625	0.374583333	0.515142857	annual	r	7
Echinochloa crus-galli	2813.90313	0.205459944	17.05390857	0.771666667	1.644166667	annual	cr	7
Elymus repens	1838.37876	1.116863284	26.28418704	0.757178875	2.648917272	perennial	c	6
Epilobium tetragonum	316			0.564655172	0.100722667	perennial	cs	7
Erigeron annuus	1442.43554	0.231873162	16.55448934	0.78792	0.04	biennial	r	6
Erodium cicutarium	832.714787	0.195871949	29.51361429	0.223353846	1.87755625	annual	r	4
Euphorbia helioscopia	480.893755	0.173788153	24.750722	0.232608696	2.371095238	annual	r	6
Falcaria vulgaris	6396.288	0.1859135		0.561363636	0.871428571	perennial	sr	7
Fallopia convolvulus	1533.06667	0.2		0.808823529	4.026894737	annual	r	7
Fraxinus excelsior	8303.58651	0.334559731	22.11445526	18.98759602	59.4569701	perennial	c	4
Galinsoga parviflora	544.564546	0.248647		0.371666667	0.216833333	annual	cr	5
Galium aparine	222.088612	0.124763936	26.94186889	0.548333103	8.798792956	annual	cr	6
Galium mollugo	153.866787	0.236655719	22.70785202	0.374	0.937816432	perennial	csr	5
Geranium dissectum	250.841271	0.217764084	8.731899333	0.146818182	2.435	annual	cr	5
Geranium pusillum	1503	0.201666667		0.23875	0.807684211	annual	r	5
Hibiscus trionum			25.5275	0.539285714		annual	r	7
Holosteum umbellatum	552.539244	0.155904		0.1225	0.108	annual	r	3
Hordeum murinum	292.314734	0.218073804	38.30297167	0.3084375	6.903767762	annual	r	6
Lactuca saligna				0.546428571	0.581706667	biennial	cr	7
Lactuca serriola	2051.15837	0.182201225	28.620682	1.063541667	0.51702	biennial	cr	7
Lamium amplexicaule	154.173976	0.128464397	25.78522667	0.163684211	0.56407619	annual	r	4
Lamium purpureum	450.089231	0.165191436		0.242391304	0.79819573	annual	r	
Lathyrus tuberosus	432.914286	0.202807143		0.708933333	32.3695827	perennial	c	6
Lolium perenne	283.557907	0.208509209	28.33887721	0.37473672	1.918207246	perennial	cr	5
Lotus corniculatus	203.273182	0.22550902	32.78709403	0.349271823	1.257652622	perennial	csr	6
Medicago lupulina	407.414685	0.22870256	31.50849	0.263379167	1.472007774	perennial	csr	5
Melilotus officinalis	474.6	0.237666667	38.474	0.944	2.79686102	biennial	cr	6
Mentha longifolia	1954.19091	0.18956	30.75042	0.736461538	0.054928571	perennial	c	7
Myosotis arvensis	368.302257	0.144604049	13.4665	0.303185294	0.425886364	annual	r	4
Pastinaca sativa	13131.4273	0.196273534	38.81809	0.7925	3.5215	biennial	csr	7
Phleum pratense	725.667054	0.334954054	26.24484197	0.674094643	0.402179407	perennial	csr	7
Picris hieracoides	1901.80079	0.179572202	22.92347268	0.474008867	1.115852941	perennial	sr	5
Plantago lanceolata	1140.37937	0.177380179	21.07781784	0.232672061	1.517442276	perennial	csr	5
Plantago major	6631.08071	0.161270695	33.81506428	0.274289091	0.228348541	perennial	csr	6
Poa pratensis	595.254517	0.337685476	19.29091248	0.410491887	0.267951699	perennial	csr	5
Polygonum aviculare	203.45	0.266056863	29.50363636	0.414848485	1.359676471	annual	r	5
Portulaca oleracea	162.742846	0.084997379	24.62664473	0.099234043	0.231794688	annual	r	6
Prunella vulgaris	472.63094	0.182000234	18.58514038	0.351602877	2.66693927	perennial	csr	6
Rorippa sylvestris	897.888889	0.1065		0.365668	0.138431314	perennial	cs	5
Rosa canina	1224.79944	0.430514343	20.1693775	2.336645833	112.2015	perennial	c	5
Setaria viridis	879.641667	0.265762716	23.43706635	0.517037037	1.141071429	perennial	r	6
Solanum nigrum	1818	0.1315		0.512	1.123687113	annual	r	6
Stellaria media	214.307369	0.11395221	38.55865905	0.322176923	0.4066425	annual	r	1
Taraxacum officinale	2801.44671	0.162793185	29.34163469	0.226912276	0.643114502	perennial	cr	3
Torilis arvensis		0.198404	20.12	0.5475	1.9	annual	cr	7
Tragopogon dubius	690.388846	0.221507143	25.71285714	0.476550649	8.405155171	biennial	sr	5
Trifolium repens	497.28547	0.209442161	43.45593295	0.220236274	0.603118844	perennial	csr	5
Tripleurospermum inodorum	310.5			0.601826087	0.182553109	annual	r	6
Verbena officinalis	384.96125	0.236402		0.422941176	0.360575	perennial	cr	7
Veronica arvensis	87.3271691	0.155149619	17.3784475	0.14564375	0.112540476	annual	r	3
Veronica hederifolia	165.233482	0.109690859	14.48806333	0.237368421	4.065476923	annual	r	3
Veronica persica	242.310904	0.155743255	15.61359167	0.205948387	0.637258065	annual	r	1
Veronica polita	89.19125	0.144666667		0.229736842	0.335377778	annual	r	3
Veronica triphyllos	38.1883333	0.164656		0.1046875	0.396152381	annual	r	3
Vicia hirsuta	367.506667	0.240333333	43.2098	0.47902439	6.062854545	annual	r	6
Vicia pannonica				0.445454545	39.98066667	annual	cr	5
Viola arvensis	238.987785	0.199887714	24.39974	0.197727273	0.620750586	annual	r	4

Data entry form for vegetation sampling (designed by Silvia Winter)

Area:		Foto no.	
Official plot number:		Plot no:	
Date and investigator:			
Owner of vineyard (contact phone number, address):			
Visible management (herbicides, insecticides, tillage, etc.)			
Inter-row distance & number of vine rows:			
In which inter-row research plots:			
Number of pole from vineyard limit start of research plots:			

Plot 1 Inter-row (1 x 1 m) (f … flowering)	Plot 1 In-row, underneath vines (1 x 0.4 m)
GPS Position (center 1 m^2):	
Distance to left pole/vine:	
Distance to right pole/vine:	
Vegetation cover (%) spring: summer:	spring: summer:
Bare ground cover (%) spring: summer:	spring: summer:
Litter cover (%) spring: summer:	spring: summer:
Moss cover (%) spring: summer:	spring: summer:
Vegetation height (5 Positions) spring: summer:	spring: summer:

Plot 2 Inter-row (1 x 1 m) (f … flowering)	Plot 2 In-row, underneath vines (1 x 0.4 m)
GPS Position (center 1 m^2):	
Distance to left pole/vine:	
Distance to right pole/vine:	
Vegetation cover (%) spring: summer:	spring: summer:
Bare ground cover (%) spring: summer:	spring: summer:
Litter cover (%) spring: summer:	spring: summer:
Moss cover (%) spring: summer:	spring: summer:
Vegetation height (5 Positions) spring: summer:	spring: summer:
Plot 3 Inter-row (1 x 1 m) (f … flowering)	Plot 3 In-row, underneath vines (1 x 0.4 m)
GPS Position (center 1 m^2):	
Distance to left pole/vine:	
Distance to right pole/vine:	
Vegetation cover (%) spring: summer:	spring: summer:
Bare ground cover (%) spring: summer:	spring: summer:
Litter cover (%) spring: summer:	spring: summer:
Moss cover (%) spring: summer:	spring: summer:
Vegetation height (5 Positions) spring: summer:	spring: summer:

Plot 4 Inter-row (1 x 1 m) (f … flowering)	Plot 4 In-row, underneath vines (1 x 0.4 m)
GPS Position (center 1 m^2):	
Distance to left pole/vine:	
Distance to right pole/vine:	
Vegetation cover (%) spring: summer:	spring: summer:
Bare ground cover (%) spring: summer:	spring: summer:
Litter cover (%) spring: summer:	spring: summer:
Moss cover (%) spring: summer:	spring: summer:
Vegetation height (5 Positions) spring: summer:	spring: summer:

Inlay

Species coverages per pseudoreplicate for inter-row and in-row vegetation

Data CD-ROM

Contains:

Data entry form

Plot and landscape photos

Data tables (species list, plant traits, species coverage, plot data, diversity values)

R-Scripts