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The Current Stage of Greening Vegetation in Selected Wine-Regions of South Moravian Region (Czech Republic)

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Abstract: Viticulture, as a large part of the agriculture sector of the South Moravian Region, represents significant erosion-prone land use in which soils face various agronomic issues, such as poor organic carbon levels, erosion, and fertility loss. Service crops providing a so-called ecosystem service can reduce erosion and runoff, regulate pests and weeds and increase soil organic matter and fertility. However, these crops may generate some disservices, such as water and nutrient competition; and thus, it is important for winegrowers to find applicable options for service crops depending on local soil, climate conditions, and the expected service. Inter-row management in the South Moravian Region varies from bare soils to grass cover to different types of cover with herbaceous (flowering) species. A total of 113 vineyard sites were evaluated during the years 2016 and 2017. This study presents the actual state of inter-row management in vineyards and comparison within six wine-growing regions. A two-year evaluation shows significant differences in prevalent greening management between regions. Bare soil in vineyards, the most erosion-prone vineyard floor management, appear from 10% (e.g., Bzenec, Valtice) to 19% (e.g., Mikulov, V. Bílovice) of vineyard area within evaluated regions. Bare soil management is mostly used in new plantations to reduce water and nutrient competition; however, the erosion and the runoff rates are generally higher on this variant compared to other types of cover crop management, especially on slopes. Although, alternate greening is the most used type occurring from 50% to 74% of vineyards area in five of the six selected regions, the type of inter-row vegetation differs considerably. While in Bzenec and Mikulov there is a higher appearance of herbaceous cover with native species in later succession stages, in Velké Bílovice and Valtice grass cover and commercial plant mixtures are more frequent. Knowledge current stage can be useful for planning new plantation or anti-erosion measures.

Keywords: greening management; ecosystem service; viticulture; service crops

1. Introduction

The conservation of biodiversity is crucial to maintaining or increasing the sustainability and stability of farming systems. Vineyards in many parts of the world can be regarded as monocultures with little remaining native vegetation [1]. One of the practices to increase and support biodiversity can be intercropping. In vineyards, intercrops (grass and herbaceous cover in the inter-rows) are now being introduced for potential positive impacts on grapevines and their environment [2]. Various effects of cover crops have been evaluated by many authors in France [3,4], Spain [5,6], Italy [7] Germany [8], Portugal [9] or California [10].

Ecosystem service covers a variety of environmental benefits expected from cover/service crops, such as soil protection, improvements to the physical and biological properties of soil, including decreased soil erosion and increased biodiversity in general [11].

Soil nutrients and organic matter content can be affected by the presence of service crops [12]. Service crops provide various services in relation to soil fertility, such as nitrogen (N) supply (green manure, e.g., mowing and tillage of cover crops), or leaching reduction (catch crops) [13]. Crop mixtures, including leguminous (e.g., *Medicago lupulina* L., *Onobrychis viciifolia* Scop., *Trifolium repens* L., *Astragalus glycyphyllos* L.) and non-leguminous species (*Leucosinapis alba* L., *Phacelia tanacetifolia* Benth., *Plantago lanceolata* L., *Lolium multiflorum* Lamk.) combining those two effects improve N use in cropping systems [14]. Conservation of biological control is another important beneficial service supported by cover crops. Flowering cover crops (*Linaria vulgaris* Mill., *Phacelia tanacetifolia* Benth., *Trifolium pretense* L., *Daucus carrota* L.) provide pollen, nectar and shelter for beneficial organisms (parasitic wasps, hover flies, etc.) [15]. The attractiveness of plant species for herbivorous insects and beneficial species differs; thus, the chosen plant mixture should be assorted carefully and have maximum benefit for natural enemies of pests and minimal or no benefit for pests [16–18]. Some authors suggest this role would be improved if the selected service crop species are native plants, which have greater attractiveness and cover a larger flowering period than non-native ones [19]. If the soil covering rate and service crop establishment are sufficient, cover crops can suppress weed growth, thus, decreasing herbicide use [20,21]. All of the expected ecosystem services or disservices (water and nutrient competition and pest habitats) differ in dependence on local soil and climate conditions and type of cover crop (spontaneous/native × sown/introduced; annual × perennial; monocotyledonous × dicotyledonous; flower type and bloom period; root system) [22]. Currently, in the Czech Republic, several commercial plant mixtures are being produced by a few producers. Mixtures generally consist of nectar-rich flowering plants (e.g., *Trifolium repens* L., *T. incarnatum* L., *Phacelia tanacetifolia* Benth., *Fagopyrum esculentum* Moench) accompanied by grass species (e.g., *Festuca rubra* L., *Festuca ovina* L., *Poa pratensis* L.).

Viticulture is an important sector in agriculture in South Moravian Region. The total area of vineyard sites in this region covers currently almost 52,000 hectares, for must production is used 17,500 hectares. On this area more than 18,000 agricultural subjects are working; from that 75% work on vineyards with acreage less than 0.2 ha, 14% on less than 0.5 ha, 9% of subjects own vineyards of size from 1 to 5 ha, and 2% are growing on vineyards larger than 5 ha [23].

According to Czech Government Regulation No. 75/2015 coll., on the conditions of implementation of agro-environmental-climatic proceedings and amending Czech Government Regulation No. 79/2007 coll. § 2; the integrated production of grapevines requires at the latest in the third year a commitment to sow a defined mixture of plants (must be certified or controlled seeds). The minimal sowing amount is 20 kg·ha^{-1}. The sowing mixture must consist of at least five species from the fabaceae family (50%–70% of the content of the total mixture by weight), at least two grass species (10%), and at least three other dicotyledonous species (20%–40%) [24].

The current stage of inter-row vegetation is not described in the Czech Republic; and such knowledge can be useful for planning agroecological and anti-erosion measures and also current findings can serve as initial data for further studies (e.g., monitoring of insect species, quality and yield of grapes etc.). The aim of this study was to evaluate and compare the similarity of greening management and the current stage of inter-row vegetation within six selected wine-producing regions.

2. Materials and Methods

In the Czech Republic, a vineyard site is a legislatively-defined area designated for grapevine growing; however, this area is not used only for grapevine growing. The wine-growing municipality is defined as a municipality that contains at least one or more vineyard site. During the years 2016 and 2017, the greening management in 113 vineyard sites of a total area of 6 900 hectares in six wine-growing regions of South Moravia was evaluated (Table 1, Figure 1). Vineyards for this study were selected in regions of historically based grapevine growing; thus, they are representing the traditional wine-growing districts of South Moravian Region. All six evaluated regions are located in the south-eastern part of the Czech Republic (Figure 1); long-term mean temperature is 9 °C with an annual sum of precipitation from 500 to 550 mm [25]. Data were recorded real-time on-site for every parcel with the special GIS application 'Naše Mapy' (HF Biz s.r.o.) using land register data, ortho-imagery maps, ZM10–ČÚZK (Cadastre of Real Estate) and GPS coordinates. All vineyard sites within chosen wine-growing municipalities were evaluated.

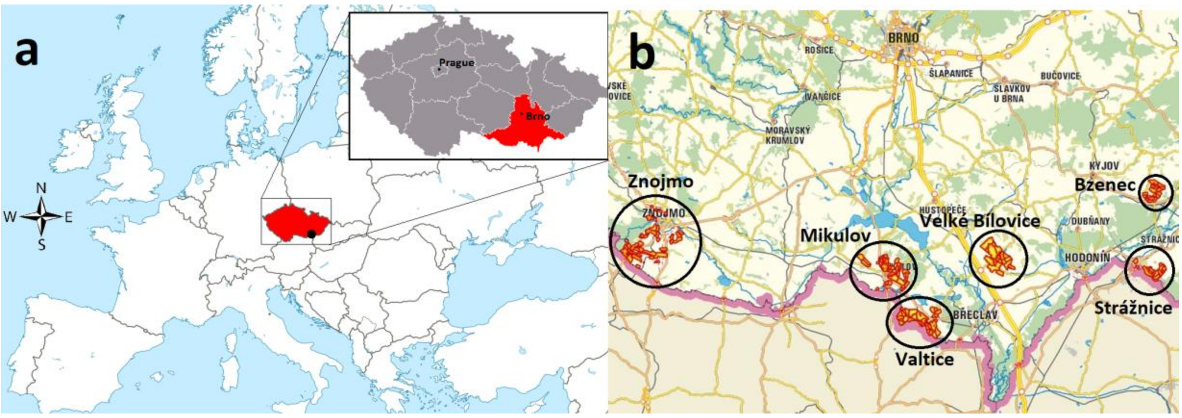

Figure 1. Location of the Czech Republic and South Moravian Region (SM) (**a**) and location of evaluated vineyard sites in 6 regions within SM (**b**) [26,27].

Table 1. Evaluated vineyard sites sorted by wine-growing municipalities.

Region	Wine-Growing Municipalities	Total Area of Evaluated Vineyard Sites	Total Number of Vineyard Sites in Municipalities
Bzenec	Bzenec, Domanín	499 ha	13
Mikulov	Mikulov, Bavory, Březí u Mikulova	1245 ha	21
Strážnice	Strážnice, Petrov, Sudoměřice	570 ha	16
Velké Bílovice	Velké Bílovice, Moravský Žižkov	1578 ha	12 *
Valtice	Valtice, Úvaly u Valtic	1510 ha	23
Znojmo	Chvalovice, Havraníky, Hnanice, Šatov, Znojmo, Podmolí, Nový Šaldorf-Sedlešovice	1506 ha	29

* One site in this region was not included in evaluation.

Firstly, the use of vineyards sites and greening management was evaluated. Greening management was divided into three types: Bare soil, alternate greening (50% of vineyards inter-rows are covered) and full-area cover crop (Figure 2). Exported data from the GIS application provides data about the area (m^2) of greening management used per parcel in agreement with land register data, thus, the total area for each management per vineyard track was calculated as the sum of the area of all the parcels that were marked as specific greening management (bare soil, alternate greening or full-area cover crop) and other uses (e.g., cropland, non-crop vegetation, hobby-gardening areas, orchards, routes and buildings, etc.). The analyzed data are in hectares.

Figure 2. Examples of vineyard floor management: (**1**) Total area bare soil (BS) (V. Bílovice, 2017), (**2**) Alternate greening with commercial plant mixture (variant A) (V. Bílovice, 2017), (**3**) Full-area cover crop with 90% of grass species in mixture (variant B) (V. Bílovice, 2017), (**4**) Full-area cover crop with combination of grass covered rows and commercial plant mixture (variant A + B) (Valtice, 2017) (Photography: L. Ragasová).

The inter-row vegetation was classified depending on the composition of the plant mixture: (a) Commercial plant mixture (A), (b) 90% and more grass in the mixture (B), (c) between 10% and 20% of dicotyledonous (herbaceous) plants (C) and (d) more than 20% dicotyledonous plants (D) (Figure 2). The estimation of the ratio of grass species and herbaceous plants was done by visual assessment and phytosociological survey [28] The total area of different plant mixtures was calculated from GIS application data collected in situ. The area of alternate greening with the use of a specific plant mixture (A/B/C/D) presents 50% of vineyard area covered with mixture, and 50% is defined as bare soil (BS); full-area cover crop represents 100% of vineyard area covered by specific mixture; in case of combinations 50% represents one and 50% another plant mixture. The data of total area covered by different kinds of plant mixtures (A/B/C/D) were analyzed using the Canoco 5 software for multivariate analysis of ecological data. According to preliminary principal component analysis (PCA), where the length of the main gradient was found to be short (2.5 units of standard deviation), redundancy analysis was used as a statistical method. The statistical evaluation of results was calculated with the Monte-Carlo permutation test (999 permutations) [29]. The analyzed data were in hectares.

3. Results

The largest area used for growing grapevines is in the Velké Bílovice (770 ha) and Mikulov regions (750 ha) (Figure 3). In those two regions there is also the highest relative vineyard area; Velké Bílovice (49%) and Mikulov (60%). Those percentages represent the use of vineyard track for growing grapevines. In Bzenec, Strážnice, and Valtice, the proportion of the area used for growing grapevines is only around 30%. Other uses than for growing grapevines are usually field crop (e.g., wheat, corn or rapeseed), especially in the Znojmo and Valtice regions, then fruit orchards (typical in Velké Bílovice) or hobby gardening areas. Figure 3 shows the total area (ha) of all evaluated tracks from six different regions; area planted with grapevines differentiated by the greening management used (bare soil, alternate greening or full-area cover crop) and other use (e.g., cropland, non-crop vegetation, hobby-gardening areas, orchards, routes and buildings, etc.).

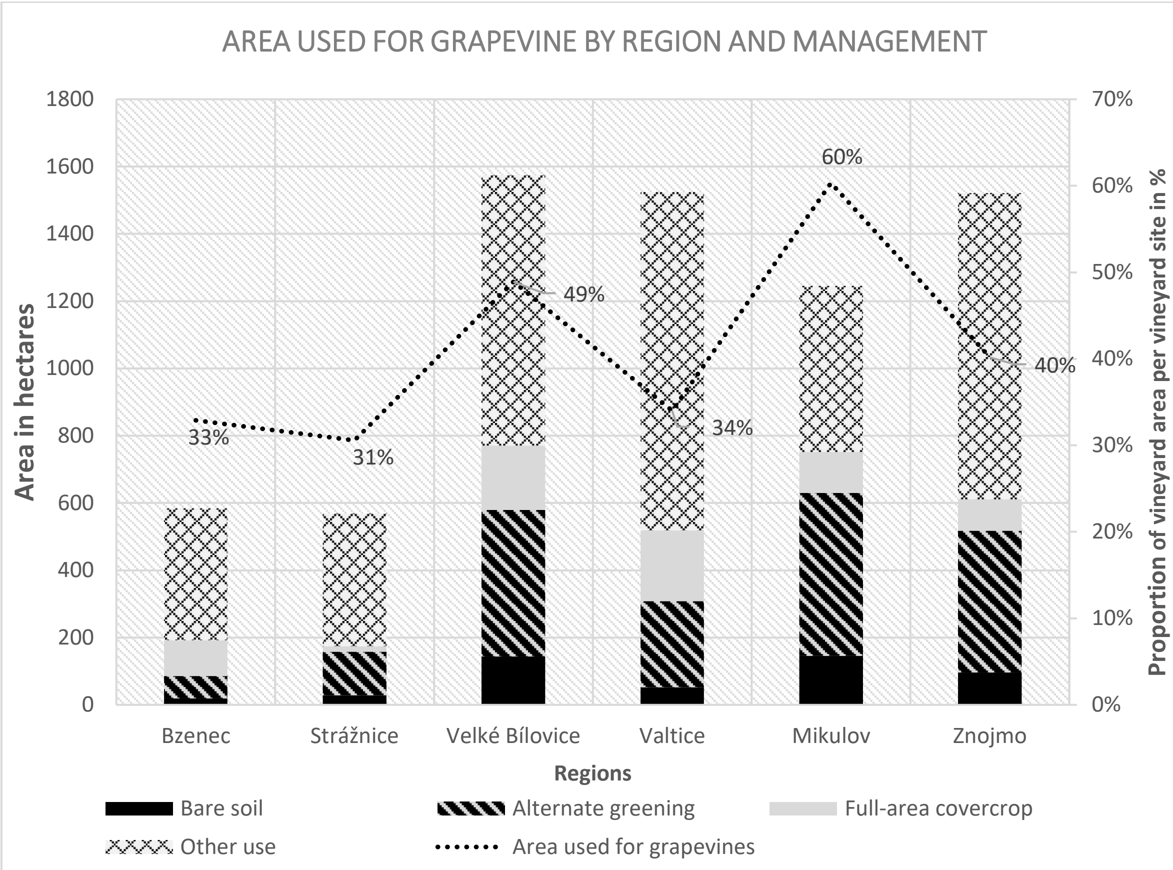

Figure 3. Area (in hectares) used for growing grapevines differentiated by greening management.

The total vineyard area in the Czech Republic is almost 18 000 hectares [23]. Integrated grapevine production (IP) together with ecological production covers around 75% of the Czech grapevine production by acreage. [30,31]. In both of those regimes, the conditions include green cover in inter-rows. In six selected regions bare soil vineyards represent a minority (from 10% up to 19%) of greening management used. The highest appearance of bare soil vineyards is found in Velké Bílovice and Mikulov and can be related to renewing old plantations and setting up new plantations (Table 2).

Table 2. The proportion of three types of inter-row management in six observed regions (area of a given type per total area of vineyards in the region).

	Bzenec	Strážnice	V. Bílovice	Valtice	Mikulov	Znojmo
Bare soil	10%	16%	19%	10%	19%	16%
Alternate greening	35%	74%	57%	50%	65%	69%
Full-area cover crop	55%	9%	25%	40%	16%	15%

Almost in every region assessed in this study alternate greening is the most used management, especially in regions with intensive production, as this practice can reduce competition with grapevines, but at the same time, the ability to control runoff and soil erosion is reduced. Besides, in areas where production is extensive, full-area cover crops dominate (e.g., Bzenec).

The results of redundancy analysis (RDA) (Figure 4) indicate similarities in vineyard greening management between regions. The greening management evaluated as commercial plant mixture (A), and grass cover (B) are present in similar proportions in the Valtice and Velké Bílovice regions; however, ordination analysis diagrams show a closer relationship between type A and Valtice than with Velké Bílovice. Type B is more related to Velké Bílovice than variant A and also the appearance of bare soil is higher in Velké Bílovice than in Valtice. Bzenec and Mikulov are represented by both herbaceous cover types (C and D) that are prevalent there. Bare soil appearance in Mikulov and Bzenec is similar to Valtice. Within the variability in greening management found in Znojmo and Strážnice it was not possible to precisely assess the prevalent type in this analysis. The results are statistically significant at a significance level $\alpha = 0.001$.

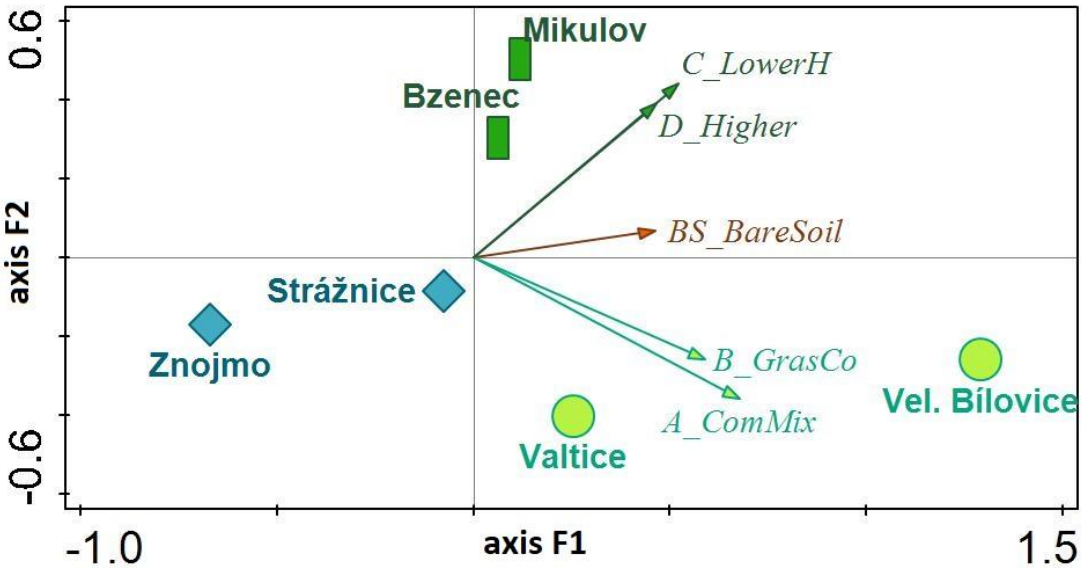

Figure 4. Ordination diagram of RDA analysis of variants of greening management within selected regions (pseudo $F = 5.4$, $p = 0.001$). According to the distances of the points presenting the localities from all arrows, the diagram is divided into groups showing some similarities. Arrows presenting the vegetation types with same or resembling direction indicate similarity in the use of the given type of vegetation. Explanatory notes: A_ComMi—commercial mixture; B_GrasCo—grass cover, C_LowerH—lower herbaceous level; D_Higher—higher herbaceous level; BS_BareSoil—bare soil inter-rows.

4. Discussion

The use of grass cover and commercial plant mixture indicated that in regions Valtice and Velké Bílovice are inter-rows more cultivated than in regions where grapevine growers keep natural vegetation or left commercial plant mixture in later succession state. The commercial plant mixtures in later successional stage naturally modify in locality according to surrounding vegetation (native or most successful weeds of the locality), soil type, weather conditions and microclimate. These types of vineyard greening can have advantages, as some authors suggested that native service crops can cover a larger flowering period than non-native introduced plants [19]. According to ordination analysis, herbaceous cover (types C and D in this study) was found mostly in Mikulov and Bzenec. The Pálava Protected Landscape Area is a good example of a high-quality source of native flowering plant species that can be spread to vineyard inter-rows. Vineyards provide conditions for the survival of many rare or even endangered species [32]; therefore, a perceptive approach to inter-row management should be applied to support not only such a species, but also biodiversity and the whole agroecosystem itself.

More than 50% of agricultural land in the Czech Republic is underwater erosion threat [33], and generally, the viticulture is one of the most erosion-prone land uses [34]. Keeping the bare soil all-year-around in vineyards, often with poor organic carbon level in soil, especially planted on slopes, can cause even more serious problems of soil erosion and runoff during intensive storms [35–38] (Figure 5). The positive finding is that bare soil as inter-row management was, in most cases, used minimally (Figure 3). By contrast in different climate conditions of Mediterranean vineyards, the most commonly used management are tillage and chemical weeding, both resulting in bare soil whole year and only 5% of the covered ground by cover crops in old vineyards was estimated [39,40]. Considering the weather conditions in the Czech Republic during recent years (e.g., long drought periods and strong irregularity of rainfall distribution) green cover or at least mulch should be used as soil erosion protection. According to the study by Čížková et al. in South Moravian vineyards soil erosion occurred when the rainfall was over 20 mm per day and the highest losses were up to 0.15 Mg ha^{-1} during year 2017 in uncovered (bare soil) inter-rows, while the use of mulch (cereal straw, wood chips) reduced soil erosion up to 0.01 Mg ha^{-1} [40]. In research of Novara et al., the average soil erosion rates from nine years' measurements in Sicilian vineyards varied from 0.77 to 8.57 Mg ha^{-1}. After the first two years, soil erosion rates were significantly reduced by cover crops relative to control variant (bare soil). Regarding the coverage rates of different cover crops, Novara et al. found out that mixture of grass cover crops (*Trifolium subterraneum* L., *Festuca rubra* L., *Lolium perenne* L.) reduced soil loss by 76%, while *Vicia faba* L. cover crops have a 39.6% reduction compared to bare soil. On the other site, cumulative runoff per one year was lowest (34.79 mm) on mixed cover crop consisting of species *Vicia faba* L. and *Vicia sativa* L. than on other evaluated cover crops. Even so, all cover crops reduced runoff compared to bare soil inter-row [41]. Investigation of different cover crop treatments (*Phacelia tanacetifolia* Benth., grass-legume mixture) in the Czech hop gardens' inter-rows confirmed the significant reduction of washed organic matter in both treatments, and it ranged from 16% to 37% compared to bare soil [42].

Figure 5. Bare soil in inter-rows leads to serious problems with runoff, soil erosion and damage of soil structure (photography: L. Ragasová, Velké Bílovice, 2018).

However, regarding soil erosion issues grass cover is a better option than bare soil, this variant is not optimal. Green cover consisting of more than 90% of species from the botanical family Poaceae (variant B in this study) (e.g., a monoculture of *Lolium perene* L.) provides a limited ecosystem service and represents a considerable water and nitrogen competitor for grapevines [10,30,43]. Moreover, some authors suggest that grass cover may act as a host for soil-borne pathogens or nematodes [44].

Since commercial plant mixtures, rich in flowering species, became a part of the regulation (definition in the introduction above) in IP, they are widely used in the vineyards of the Czech Republic. Plant mixtures should be chosen and composed in relation to the locality. A full ecosystem service provided by this type of vegetation (variant A in this study) cannot be expected in the first year after sowing, as the coverage rate in the first years is not high; thus, soil erosion and runoff can occur, and moreover, undesirable weed species are present [41,44]. Long-term, uninterrupted progress of the succession state is important for the proper functioning of this vegetation type [30].

5. Conclusions

This large-scale study provides a picture of the situation in the greening management of South Moravian vineyards. From the results of this study, it is obvious that there are differences between regions and localities in greening management. Such differences probably originate in the historical use of land in those areas, the size of companies growing grapevines and the surrounding landscape types (e.g., Protected Landscape Area or agricultural land). According to many studies, proper inter-row vegetation is important for optimal ecosystem service provision. Even though the majority of grapevine growers belong to integrated production, there are still many localities where inter-row vegetation is missing, or in the case of grass cover could be improved by spontaneous or introduced flowering plant species. The problem of erosion on bare soil is most considerable on steep vineyards, which should be covered to prevent the erosion and degradation of soil and description of the current stage are important for planning agroecological measures (biocorridors, anti-erosion measures).

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