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The Effect of Cover Crops on Soil Water Balance in Rain-Fed Conditions

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Abstract: Soil and water conservation benefits of cover crops have been hypothesized as a way to mitigate and adapt to changing climatic conditions, but they can also have detrimental effects if rainfall is limited. Our objective was to quantify effects of winter cover crops on soil water storage and yield of silage maize under the agro-ecological conditions within Vojvodina Province in Serbia. The experiment was conducted under rain-fed conditions at three locations and included a control (bare fallow) plus three cover crop and two N rate treatments. The cover crop treatments were common vetch (*Vicia sativa* L.), triticale (x *Triticosecale* Wittm. ex A. Camus) and a mixture of the two species. All were managed as green manure and subsequently fertilized with either 120 or 160 kg N ha^{-1} before planting silage maize (*Zea mays* L.). Cover crop effects on soil water storage were calculated for two periods, March–May and May–September/October. A Standardized Precipitation Index (SPI) used to characterize drought severity for 2011/2012 and 2012/2013, showed values of 3 and 9, respectively, for the two periods. Soil water storage was reduced by all cover crop treatments, with the greatest deficiency occurring during the extremely dry year of 2012. Previous studies have shown cover crop growth reduced by soil water depletion during their growing season and negative effects on early-season growth and development of subsequent cash crops such as silage maize, but if rainfall is extremely low it can also reduce cash crop yield. This detrimental effect of cover crops on soil water balance was confirmed by correlations between soil water storage and maize silage yield.

Keywords: cover crops; soil; water storage; silage maize

1. Introduction

The intensification of agriculture has increased food production, primarily based on the use of high-productivity crop varieties and the application of fertilisers, pesticides and irrigation [1]. However, this practice of the continuous cultivation of the same soil and the application of different inputs has serious consequences for the physical, chemical and biological properties of soil [2,3].

Intensive conventional agriculture has also been used, to a greater or lesser extent, on the fertile soil in Vojvodina Province, Serbia, and over the years has decreased organic matter content and changed soil structure [4]. The studies of Belić et al. [5] and Seremesic et al. [6] confirm a decline in the soil organic matter in this region. This decline became a serious concern considering that further agricultural demands and food production under the more obvious climate changes in the 21st century will require maintaining or improving soil fertility and productivity [7]. The projections for climate change indicate increased precipitation variability rather than increased amount of annual precipitation [8], which is more likely to be mitigated on fertile and well-structured soils. The level of soil organic matter, and therefore soil carbon content, positively influence the stability of soil aggregates and soil moisture retention under extreme precipitation or drought [9–11]. Several management practices can be the bond between the requirements to adapt to the weather changes and to stop the reduction or to increase soil fertility, such as by reducing or eliminating tillage, growing cover crops, and applying organic fertilisers.

Because livestock production in Serbia and, therefore, the availability of organic fertilisers are low, research focuses on cover cropping. Additionally, reduced or no tillage is uncommon because of requirements for adequate machines, which significantly limit its application on small and medium farms. Cover crops have several uses, including preventing erosion, increasing organic matter content, improving nitrogen balance and soil properties, and suppressing weeds, among others [12,13]. Cover crops in crop rotations are not a common practice primarily because growing cover crops usually includes crops that do not result in economic return and often do not allow sufficient time for soil preparation for cash crops. Additionally, cover crops may reduce soil moisture for the subsequent crop in specific growing conditions. In the most prevalent annual crop rotation system of maize (*Zea mays* L.) and soybean (*Glycine max* (L.) Merr.), growing winter cover crops should be considered, because cover crops positively affect physical and chemical soil properties and therefore improve soil productivity and soil water storage capacity [14,15]. According to Kaspar and Singer [16], cover crops increase soil organic matter from 9 to 85% depending on biomass production and soil and climate conditions of the region. In temperate regions of Europe, winter cover crops are the most common [17], which cover the land between two cash crops that otherwise would be left bare over winter and exposed to diverse weather impacts such as wind erosion and nitrogen leaching, among other effects.

All benefits that result from cover crops in a cropping system depend on the cover crop species or mixture, type of soil and climate [18]. Legume cover crops are usually included because of their short growing season, and they provide biologically fixed nitrogen (N) for the subsequent cash crop [19,20]. When legume cover crops are used as green manure and ploughed-in, the organic matter is also incorporated, significantly increasing the input of N [13,21]. The non-legume winter cover crops of winter cereals and brassicas are also used in temperate regions. Winter cereals, such as oats (*Avena sativa* L.), barley (*Hordeum vulgare* L.), triticale (x *Triticosecale* Wittmack) and rye (*Secale cereale* L.), are grown for forage or as a green manure. Moreover, the cereals prevent erosion and suppress weeds. When increasing the content of soil organic matter is a necessity, use of cereals should be a priority because of the relatively high carbon and N ratio and slow decomposition of the residues [22]. Additionally, the extensive and dense root system of cereals stabilises soil aggregates and increases aeration and efficiently scavenges nutrients and prevents their leaching into deep soil layers [23]. Qi et al. [24] concluded that a winter rye cover crop increases soil water storage in the maize-soybean rotation. For the environmental conditions of Vojvodina, Cupina et al. [25] suggested using a mixture of legumes and cereals to reduce the problems of nitrogen deficit and low soil organic matter. Such a mixture is drought resistant [26] because of the high water use efficiency [27], which also results in less eutrophication of water courses [28].

Considering that the effects of cover crops depend on the weather conditions of a region, the aim of the research was to analyse the effect of winter cover crops on the soil water balance in the agro-ecological conditions of Vojvodina Province. Additionally, the effect of cover crops on water availability for the main crop was compared with that of bare soil as a usual practice of the maize-based cropping system.

2. Experiments

2.1. Site Descriptions and Weather Characteristics

The field experiments were conducted between 2011 and 2013 at three locations in Vojvodina Province in the northern part of Serbia: Novi Sad-Rimski Šančevi (45°19′N, 19°50′E, 80 m a.s.l.), Sombor (45°44′N, 19°08′E, 84 m a.s.l.), Senta (45°54′N, 20°05′E, 77 m a.s.l.).

Most of this region is a flat area located in the southern part of the Pannonian lowland. The climate is characterised as moderate continental with extreme seasonal variation in temperature and precipitation towards a continental climate. Based on long-term data (1981–2015), the mean annual temperature is 11.3 °C, annual precipitation sum is 610.3 mm, the mean temperature for the growing period (April–September) is 18.2 °C and the precipitation sum for the growing period (April–September) is 359.6 mm.

The mean monthly temperature and monthly precipitation data for the given period at the three locations are presented in Table 1.

The data were collected from on-site weather stations. The period October-December 2011 had a significantly lower amount of precipitation than the long-term average (Figure 1). From January to May 2012, the drought period continued, and in May 2012, precipitation was approximately the same as or slightly higher than the average. During the summer months, the extreme drought occurred again at all locations. The hydrological year 2011/2012 was characterised by a mild winter and extremely warm summer, with temperatures in July that were higher than the long-term average by 2.7–3.3 °C depending on the site and in August by 2.4–3.0 °C. In 2012/2013, weather conditions were more favourable for plant production. From October to March 2012/2013, monthly precipitation was above the long-term average. During summer months, temperatures were slightly above the average, followed by an adequate precipitation amount.

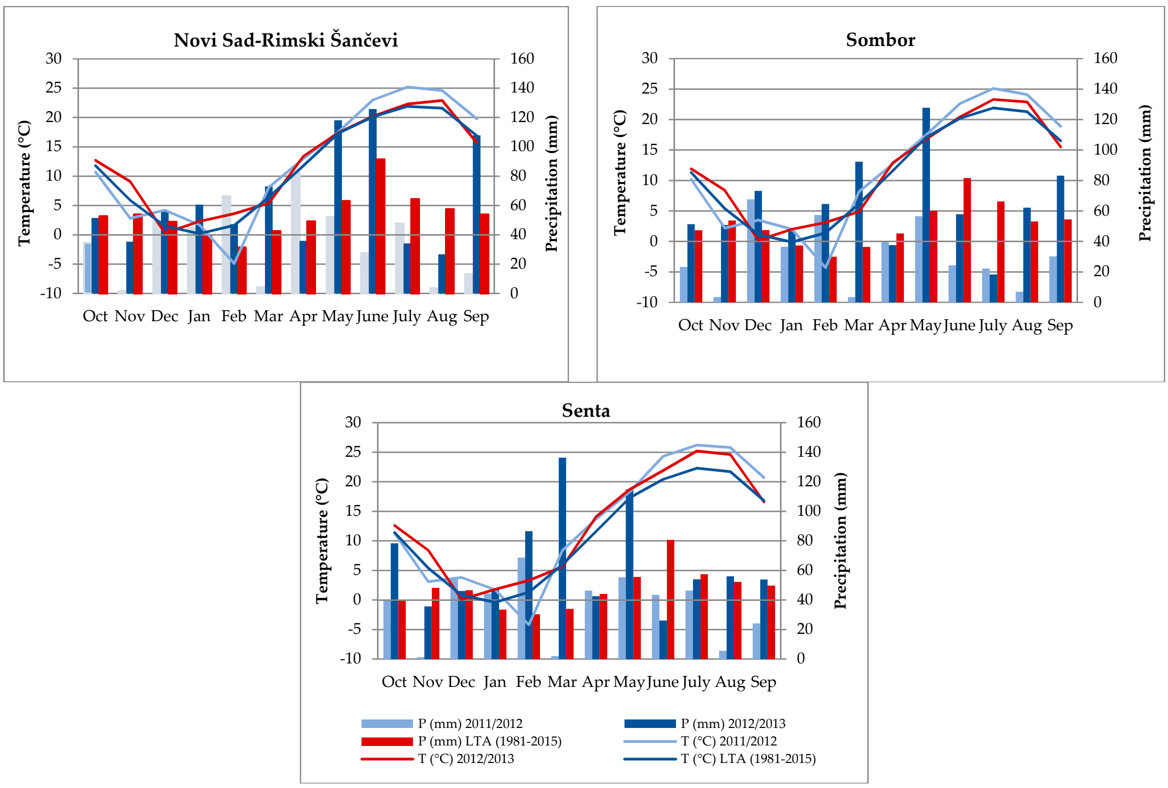

Figure 1. Long-term average (LTA), mean monthly temperature (T) and monthly precipitation (P) for hydrological years 2011/2012 and 2012/2013.

Table 1. The chemical characteristics of the soil for Rimski Šančevi, Sombor, and Senta in 2011 and 2012.

Location	Year	pH in H_2O	$CaCO_3$ %	Organic Matter %	P_2O_5	K_2O
					mg 100 g^{-1} Soil	
Rimski Šančevi	2011	7.77	8.01	2.07	34.74	26.96
	2012	7.60	5.48	2.49	46.04	24.13
Sombor	2011	7.60	6.80	3.08	22.50	22.05
	2012	7.50	7.40	3.12	21.80	21.10
Senta	2011	7.29	13.81	3.95	18.31	26.20
	2012	7.31	12.41	3.48	19.57	24.32
Average	2011	7.55	9.54	3.03	25.18	25.07
	2012	7.50	8.43	3.03	29.14	23.18

Experiments at all locations were setup on a slightly carbonated chernozem. Soil characteristics are presented in Table 1.

2.2. Experimental Design

A rain-fed experiment with 25 m^2 (5 m × 5 m) plots was established using a random block design with three replicates, a bare fallow control, three cover crop treatments (common vetch (*Vicia sativa* L.), triticale, or a mixture of the two), and two N fertilizer rates for a subsequent cash crop—silage maize. The control was plowed in autumn and remained bare until spring. The cover crops were planted during the first half of October in 2011 and 2012 at seeding rates of 120 kg ha^{-1}, 220 kg ha^{-1}, and 90 + 30 kg ha^{-1} for the common vetch, triticale, and mixture of common vetch and triticale [13]. Mineral fertilizer (N_1—120 or N_2—160 kg N ha^{-1}) was applied prior to plowing the cover crops during May 2012 and 2013. Silage maize was sown in 22 cm rows at a seeding rate of 65,000 plants ha^{-1}. All operations used during the project are presented in Table 2.

Table 2. Field operations at Novi Sad-Rimski Šančevi, Sombor and Senta for each year of the study during the seasons 2011/2012 and 2012/2013.

Field Operations	2011/2012			2012/2013		
	Novi Sad-Rimski Šančevi	Sombor	Senta	Novi Sad-Rimski Šančevi	Sombor	Senta
Cover crop sowing	26/10/2011	27/10/2011	24/10/2011	22/10/2012	24/10/2012	14/10/2012
Cover crops ploughing-in and application of N mineral fertilisers	29/05/2012	23/05/2012	26/05/2012	16/05/2013	30/05/2013	25/05/2013
Silage maize sowing	30/05/2012	26/05/2012	28/05/2012	20/05/2013	02/05/2013	30/05/2013
Silage maize harvest	11/09/2012	13/09/2012	12/09/2012	02/09/2013	05/10/2013	16/09/2013
Soil sampling						
I term	05/03/2012	08/03/2012	07/03/2012	13/03/2013	10/03/2013	17/03/2013
II term	30/05/2012	27/05/2012	27/05/2012	17/05/2013	30/05/2013	30/05/2013
III term	12/09/2012	15/09/2012	14/09/2012	08/09/2013	06/10/2013	18/09/2013

2.3. Measurements and Data Analyses

To analyse the effect of cover crops on soil water storage, soil samples were collected from all sites three times in each trial year:

I. at the beginning of the cover crop growing season, after the winter period (March),
II. after ploughing-in of cover crops (end of May),
III. after harvest of silage maize (September/October).

The soil was sampled in four soil layers: 0–30, 30–60, 60–90 and 90–120 cm. The soil moisture content was determined by thermo-gravimetric technique in which soil samples were dried to a constant weight at 105 °C for 24 h [29]. This parameter was used for calculating soil water storage (θ) in each depth by following formula [30]:

$$\theta_i = W \times 10 \times d \times \rho \quad (1)$$

where θ_i is the soil water storage for a given depth of soil (mm), W is the soil moisture content for a given soil depth (%), d is the soil depth (cm) and ρ is the dry bulk density of the soil for the calculated soil depth (g cm^{-3}). The values of the dry bulk density of the soil for each layer and location are given in Table 3.

The water storage of the soil profile (P) was calculated by summing water storage values of each depth from 0 to 120 cm:

$$P = \sum_{0}^{120} \theta_i \quad (2)$$

Table 3. Soil bulk density (g cm^{-3}) for the 0–30, 30–60, 60–90 and 90–120 cm soil depth for Novi Sad-Rimski Šančevi, Sombor and Senta.

Depth (cm)	Novi Sad-Rimski Šančevi	Sombor	Senta
0–30	1.39	1.45	1.45
30–60	1.49	1.39	1.60
60–90	1.24	1.28	1.29
90–120	1.55	1.49	1.38

To specify received and lost water in the periods March-May and May-September/October, the changes in soil water storage (Δ) were analysed for these two periods, that is, before the main crop and during the growing season of the main crop, respectively. In each period, the changes in soil water storage were calculated using the following formula:

$$\Delta = W_B - W_E + P_{B+E} \quad (3)$$

where W_B is the soil water storage at the beginning of the examined period, W_E is the soil water storage at the end of the examined period and P_{B+E} is the sum of precipitation in the period.

The differences in the changes in soil water storage between cover crop treatments and fallow treatments were calculated. The calculation was performed by subtracting the average changes in soil water storage from all cover crop treatments (CC) and the average changes in soil water storage from all fallow (F) treatments (N_1, N_2, and Control). The analysis was performed for both periods, that is, March–May and May–September/October.

Considering that weather conditions in Serbia are characterised by extreme variations in temperature and precipitation, the Standardised Precipitation Index (SPI) was used for drought identification and severity. This index depends only on precipitation and permits monitoring of water sources and groundwater supplies significant in rain-fed agricultural production [31]. The SPI was calculated for 1, 3 and 9 months for each month in the hydrological years 2011/2012 and 2012/ 2013 for Vojvodina Province using a sum of monthly data for a 30-year annual sequence [32]. The drought classification was based on the SPI classification modified by the Republic Hydrometeorological Service of Serbia for the conditions of Serbia and includes ten categories of drought/humidity conditions [33]. The modified categories are presented in Table 4.

Statistical analyses were performed using the STATISTICA 13 software package (TIBCO Software Inc., Palo Alto, CA, USA) [34]. Differences among the treatments for all mean values were tested by ANOVA, and Duncan's multiple range test was used to compare means at 0.05. In the same software, correlations and regression equations were determined between the changes in soil water storage and silage maize yield (previously published in Cupina et al. [13]).

Table 4. Modified drought classification of the Standardized Precipitation Index (SPI).

Abbr.	Drought/Moisture Conditions	Value	Range
EcD	Exceptional drought	SPI ≤ −2.326	Usual moisture conditions
EtD	Extreme drought	−2.326 < SPI ≤ −1.645	
SD	Severe drought	−1.645 < SPI ≤ −1.282	
MoD	Moderate drought	−1.282 < SPI ≤ −0.935	
MiD	Minor drought	−0.935 < SPI ≤ −0.524	
N	Near normal	−0.524 < SPI < +0.524	
SM	Slightly increased moisture	+0.524 ≤ SPI < +0.935	
MM	Moderately increased moisture	+0.935 ≤ SPI < +1.282	
CM	Considerably increased moisture	+1.282 ≤ SPI < +1.645	
EtW	Extremely wet	+1.645 ≤ SPI < +2.326	
EcW	Exceptionally wet	SPI ≥ +2.326	

Different colors represent different moisture conditions.

3. Results

Based on SPI values, the hydrological year 2011/2012 was characterised as a year with severe drought (Table 5). In October, SPI3 was −1.67, and SPI9 was −1.92. The year 2012 was extremely dry, with positive SPI values for SPI1 and SPI3 in February (1.17 and 0.80, respectively) and in April (1.27 and 0.76, respectively). The lowest SPI1 values from January to September 2012 were recorded in March (−2.18), June (−1.95), and August (−1.92), showing extremely dry weather conditions in these months.

Table 5. The SPI 1, 3 and 9 for each month in hydrological years 2011/2012 and 2012/2013 for Vojvodina Province.

Year	Month	Value			Abbreviation		
		SPI1	SPI3	SPI9	SPI1	SPI3	SPI9
2011/2012	10	−0.07	−1.67	−1.51	N	EtD	SD
	11	−3.31	−1.61	−1.92	EtD	SD	EtD
	12	0.30	−1.07	−1.75	N	MD	EtD
	1	0.44	−0.85	−1.53	N	MiD	SD
	2	1.17	0.80	−1.29	MM	MM	SD
	3	−2.18	0.20	−1.38	EtD	N	SD
	4	1.27	0.76	−1.17	MM	MM	MD
	5	−0.14	−0.02	−0.55	N	N	MiD
	6	−1.95	−0.42	−0.87	EtD	N	MiD
	7	−0.28	−1.33	−0.82	N	SD	MiD
	8	−1.92	−1.98	−0.75	EtD	EtD	MiD
	9	−1.30	−1.71	−1.02	SD	EtD	MD
2012/2013	10	0.36	−1.49	−1.11	N	SD	MD
	11	−0.30	−0.68	−1.47	N	MiD	SD
	12	0.49	0.09	−1.05	N	N	MD
	1	0.98	0.42	−1.24	MM	N	MD
	2	0.67	0.85	−1.09	MM	MM	MD
	3	1.26	1.34	−0.32	MM	CM	N
	4	−0.29	0.81	−0.33	N	MM	N
	5	1.57	1.33	0.90	CM	CM	MM
	6	0.92	1.14	1.33	MM	MM	CM
	7	−0.73	0.86	0.94	MiD	MM	MM
	8	−0.49	−0.20	0.74	N	N	MM
	9	1.60	0.11	1.05	CM	N	MM

Different colors represent different moisture conditions.

The SPI values characterised the hydrological year 2012/2013 with normal to moderate moisture. In October, SPI1 was 0.36 and SPI3-1.49. In the growing season, that is, from the beginning of April to the end of September, negative SPI1 values were recorded in April (−0.29), July (−0.73), and August (−0.49). In this period, the SPI3 was negative in August (−0.20) in which drought intensity was characterised as near normal.

At the locality Novi Sad-Rimski Šančevi, the soil water storage was lower in 2012 than that in 2013 in all soil layers and all terms (Table 6a,b). In the first layer, the highest soil water storage was in March of both years and ranged from 79.2 mm in the treatment with common vetch in 2012 to 90.1 mm in the mixture of common vetch and triticale in 2013. In this period, in the layers 60–90 and 90–120 cm, no significant differences were detected among the treatments. In this layer in September 2012, the lowest value was recorded in the mixture of common vetch and triticale (28.5 mm), followed by the treatment with triticale (29.5 mm). In regard to fallow treatments, in May and September 2013, the highest soil water storage was registered in the first two layers in the N_1 variant.

Table 6. The effect of cover crop and nitrogen rate on soil water storage (mm) from (**a**) 0 to 60 cm, (**b**) 60 to 120 cm at Novi Sad-Rimski Šančevi in 2012 and 2013.

(a)

Soil Depth (cm)	Sampling	Year	Treatments						
			Common Vetch	Triticale	Common Vetch/Triticale	N_1	N_2	Control	Average
0–30	March	2012	79.2e	80.2de	80.5cde	80.3cde	80.0de	79.7e	80.0B
		2013	85.7ab	84.3bcd	90.1a	79.0e	84.8bc	80.6cde	84.1A
		Average	82.4AB	82.3AB	85.3A	79.6B	82.4A	80.2B	82.0
	May	2012	48.2de	42.2e	42.1e	71.2a	68.1ab	70.1a	57.0B
		2013	66.2abc	57.5cd	58.7bc	67.0abc	62.0abc	64.9abc	62.7A
		Average	57.2B	49.9C	50.4BC	69.1A	65.1A	67.5A	59.9
	September	2012	33.6bc	31.4c	31.4c	41.8b	33.6bc	33.9c	34.3B
		2013	67.8a	63.1a	65.8a	70.4a	67.4a	65.4a	66.7A
		Average	47.3B	48.6B	49.6AB	50.5AB	50.7AB	56.1A	50.5
30–60	March	2012	89.8b	91.2ab	90.3b	92.7ab	90.4b	90.9ab	90.9A
		2013	96.8a	87.0b	93.1ab	89.9b	92.7ab	91.3ab	91.8A
		Average	93.3A	89.1A	91.7A	91.3A	91.6A	91.1A	91.3
	May	2012	50.9c	51.0c	50.8c	72.9ab	76.7ab	79.9a	63.7B
		2013	71.7b	56.7c	55.1c	78.7ab	73.8ab	73.9ab	68.3A
		Average	61.3B	53.8C	53.0C	75.8A	75.3A	76.9A	66.0
	September	2012	40.9def	36.4ef	34.6f	49.9bc	44.9cd	43.1cde	41.6B
		2013	54.7ab	53.ab	59.0a	57.3ab	53.3ab	57.2ab	55.8A
		Average	47.8B	44.8B	46.8B	53.6A	49.1AB	50.2AB	48.7

(b)

Soil Depth (cm)	Sampling	Year	Treatments						
			Common Vetch	Triticale	Common Vetch/Triticale	N_1	N_2	Control	Average
60–90	March	2012	80.5a	79.2a	79.0a	78.2a	78.7a	79.2a	79.2A
		2013	80.6a	77.3a	78.4a	76.3a	80.0a	81.3a	79.0A
		Average	80.5A	78.3A	78.7A	77.3A	79.4A	80.2A	79.1
	May	2012	46.9e	52.8de	58.0cd	70.8ab	66.5abc	75.0a	61.7A
		2013	62.5bc	49.6de	48.1e	68.8ab	64.5bc	64.6bc	59.7A
		Average	54.7B	51.2B	53.0B	69.8A	65.5A	69.8A	60.7
	September	2012	33.6bc	31.9bc	29.5c	34.7b	34.3bc	32.5bc	32.7B
		2013	44.6a	46.7a	43.9a	47.6a	45.7a	44.7a	45.5A
		Average	39.1AB	39.3AB	36.7B	41.1A	40.0AB	38.6AB	39.1
90–120	March	2012	75.4a	77.3a	78.0a	76.6a	76.3a	76.9a	76.7A
		2013	78.4a	76.7a	79.7a	77.5a	78.7a	77.2a	78.0A
		Average	76.9A	77.0A	78.9A	77.0A	77.5A	77.0A	77.4
	May	2012	48.0f	55.1def	60.3cde	73.5ab	69.6abc	76.7a	63.9A
		2013	64.4bcd	52.6ef	49.6f	73.2ab	68.4abc	68.7abc	62.8A
		Average	56.2B	53.9B	55.0B	73.4A	69.0A	72.7A	63.3
	September	2012	32.6bc	29.5c	28.5c	34.6b	31.6bc	31.0bc	31.3A
		2013	42.9a	44.5a	41.7a	44.8a	43.5a	42.2a	43.3B
		Average	37.8AB	37.0AB	35.1B	39.7A	37.6AB	36.6B	37.3

Small letters represent the differences between the treatments within one sampling; capital letters represent the differences between the average values of the treatments within one sampling and among the average values of the years within one sampling. Values followed by the same letter are not significantly different ($p \leq 0.05$).

Compared with other locations, the lowest soil water storage in March was registered in Sombor in the 0–30 cm soil layer (Table 7a). In May in this layer, no significant differences were observed in soil water storage between fallow treatments in 2012 and cover crop treatments in 2013. In regard to treatments with cover crops, in both years and layers at the time of silage corn sowing (May), the highest soil water storage was in the treatment with common vetch (Table 7a,b). The lowest value of 26.8 mm was registered in September 2012 in the treatment with the mixture of common vetch and triticale.

In March 2012 and 2013 at Senta in the 0–30 cm soil layer, the soil water storage did not significantly differ among treatments (Table 8a). In the second and third term in all treatments, the soil water storage was higher in 2013 than that in 2012. In May 2012 and 2013, no significant difference occurred among cover crop treatments, and they significantly differed from fallow treatments (Table 8b). Among the soil layers examined, the highest soil water storage was in the 30–60 cm layer in March 2012, and among treatments, the highest value was in the mixture of common vetch and triticale (96.4 mm).

Table 7. The effect of cover crop and nitrogen rate on soil water storage (mm) from (**a**) 0 to 60 cm, (**b**) 60 to 120 cm at Sombor in 2012 and 2013.

(a)

Soil Depth (cm)	Sampling	Year	Treatments						
			Common Vetch	Triticale	Common Vetch/Triticale	N_1	N_2	Control	Average
0–30	March	2012	65.0b	66.3b	66.7b	64.6b	70.0b	65.5b	66.4B
		2013	77.2a	78.2a	80.3a	78.3a	78.6a	77.8a	78.4A
		Average	71.1A	72.2A	73.5A	71.4A	74.3A	71.7A	72.4
	May	2012	47.7c	45.5c	46.8c	63.8b	65.3b	61.6b	55.1B
		2013	65.0b	63.7b	61.1b	74.5a	76.3a	78.2a	69.8A
		Average	53.9B	54.6B	56.4B	69.1A	69.9A	70.8A	62.5
	September	2012	51.8b	46.9b	29.5c	47.6b	47.4b	46.8b	45.0B
		2013	69.2a	68.7a	69.2a	67.1a	67.3a	68.5a	68.4A
		Average	60.5A	57.8A	49.4B	57.4A	57.4A	57.6A	56.7
30–60	March	2012	73.0d	78.4cd	75.3d	78.6bcd	78.3cd	76.7d	76.7B
		2013	85.9a	84.4ab	86.6a	82.9abc	86.0a	83.5abc	84.9A
		Average	79.4A	81.4A	81.0A	80.8A	82.1A	80.1A	80.8
	May	2012	55.7f	47.4g	48.8g	69.4cd	73.8bc	68.7cd	60.6B
		2013	64.0de	64.0de	60.6ef	80.9a	78.8ab	82.0a	71.7A
		Average	59.9B	55.7C	54.7C	75.1A	76.3A	75.4A	66.2
	September	2012	48.7b	47.0b	32.5c	46.8b	41.6b	46.8b	43.9B
		2013	74.9a	76.9a	77.5a	72.3a	79.0a	79.0a	76.6A
		Average	61.8A	61.9A	55.0B	59.5AB	60.3AB	62.9A	60.2

(b)

Soil Depth (cm)	Sampling	Year	Treatments						
			Common Vetch	Triticale	Common Vetch/Triticale	N_1	N_2	Control	Average
60–90	March	2012	70.1cd	67.4d	68.4d	68.9d	70.9bcd	70.1cd	69.3B
		2013	74.4ab	73.8abc	75.6a	75.1a	76.6a	74.6ab	75.0A
		Average	72.2AB	70.6B	72.0AB	72.0AB	73.7A	72.4AB	72.2
	May	2012	51.0c	35.6e	42.0d	56.5b	56.4b	56.3b	49.6B
		2013	54.8bc	55.2bc	51.4c	69.4a	67.6a	70.1a	61.4A
		Average	52.9B	45.4C	46.7C	62.9A	62.0A	63.2A	55.5
	September	2012	44.0c	43.9c	27.8e	38.1d	36.9d	37.9d	38.1B
		2013	64.2ab	64.2ab	65.2a	62.1ab	62.7ab	61.3b	63.3A
		Average	54.1A	54.1A	46.5C	50.1B	49.8B	49.6B	50.7
90–120	March	2012	65.2cd	62.7d	63.6d	64.1d	65.9cd	65.2cd	64.5B
		2013	73.1a	71.2ab	68.7bc	71.1ab	71.7ab	72.5a	71.4A
		Average	69.1A	67.0AB	66.1B	67.6AB	68.8A	68.9A	67.9
	May	2012	53.2de	38.8f	40.1f	49.2e	52.8de	51.7de	47.6B
		2013	53.6cd	57.8bc	53.3de	62.1ab	64.8a	65.8a	59.6A
		Average	53.4C	48.3D	46.7D	55.7BC	58.8A	58.7AB	53.6
	September	2012	46.4c	42.0d	26.8f	40.8d	36.0e	39.8de	38.6B
		2013	59.3ab	61.1ab	61.3a	60.9ab	57.2b	58.3ab	59.7A
		Average	52.9A	51.5AB	44.0E	50.9AB	46.6DE	49.0CD	49.2

Small letters represent the differences between the treatments within one sampling; capital letters represent the differences between the average values of the treatments within one sampling and among the average values of the years within one sampling. Values followed by the same letter are not significantly different ($p \leq 0.05$).

Table 8. The effect of cover crop and nitrogen rate on soil water storage (mm) from (**a**) 0 to 60 cm, (**b**) 60 to 120 cm at Senta in 2012 and 2013.

(a)

Soil Depth (cm)	Sampling	Year	Treatments						
			Common Vetch	Triticale	Common Vetch/Triticale	N_1	N_2	Control	Average
0–30	March	2012	78.0a	77.3a	78.6a	77.3a	77.4a	77.6a	77.7A
		2013	77.7a	77.1a	75.8a	77.2a	77.0a	77.1a	77.0A
		Average	77.9A	77.2A	77.2A	77.2A	77.2A	77.3A	77.3
	May	2012	53.0e	53.9e	52.9e	64.8bc	63.7cd	68.4abc	59.5B
		2013	62.6cd	62.4cd	58.1de	71.1a	70.7ab	70.4ab	65.9A
		Average	57.8B	58.2B	55.5B	67.9A	67.2A	69.4A	62.7
	September	2012	62.9bc	60.1cd	58.9cd	58.7cd	59.7cd	56.7d	59.5B
		2013	66.8ab	67.6ab	67.7a	67.9a	69.1a	70.0a	68.2A
		Average	64.8A	63.9A	63.3A	63.3A	64.4A	63.4A	63.8
30–60	March	2012	94.6ab	93.4ab	96.4a	91.4ab	92.0ab	92.1ab	93.3A
		2013	89.1c	89.8bc	91.3ab	88.8c	88.9c	90.3bc	89.7B
		Average	91.8AB	91.6AB	93.8A	90.1B	90.4AB	91.2AB	91.5
	May	2012	61.5cde	48.0h	55.7egf	70.0ab	70.7a	71.8a	71.5A
		2013	59.5def	51.7gh	52.5fgh	67.7abc	67.7abc	63.1bcd	70.0A
		Average	60.5B	49.9C	54.1C	68.9A	69.2A	67.4A	70.8
	September	2012	60.8b	60.5bc	60.8b	59.6bc	54.3c	58.5bc	59.1B
		2013	77.0a	78.5a	74.4a	74.2a	76.9a	80.0a	76.8A
		Average	68.9A	69.5A	67.6A	66.9A	65.6A	69.2A	67.9

(b)

Soil Depth (cm)	Sampling	Year	Treatments						
			Common Vetch	Triticale	Common Vetch/Triticale	N_1	N_2	Control	Average
60–90	March	2012	76.2abc	77.5a	76.8ab	75.7abc	76.0abc	76.1abc	76.4A
		2013	74.0bc	73.2c	73.0c	74.6abc	73.6bc	74.3abc	73.8B
		Average	75.1A	75.3A	74.9A	75.2A	74.8A	75.2A	75.1
	May	2012	61.5cde	48.0h	55.7egf	70.0ab	70.7a	71.8a	62.9A
		2013	59.5def	51.7gh	52.5fgh	67.7abc	67.7abc	63.1bcd	60.4A
		Average	60.5B	49.9C	54.1C	68.9A	69.2A	67.4A	61.7
	September	2012	53.3ab	55.1ab	55.0ab	47.0c	46.5c	45.9c	50.4B
		2013	55.8ab	57.2a	58.2a	57.4a	50.3bc	54.0ab	55.5A
		Average	54.5AB	56.1AB	56.6A	52.2BC	48.4C	49.9C	53.0
90–120	March	2012	76.2abc	77.5a	76.8ab	75.7abc	76.0abc	76.1abc	76.4A
		2013	74.0bc	73.2c	73.0c	74.6abc	73.6bc	74.3abc	73.8B
		Average	75.1A	75.3A	74.9A	75.2A	74.8A	75.2A	75.1
	May	2012	61.5cde	48.0h	55.7egf	70.0ab	70.7a	71.8a	62.9A
		2013	59.5def	51.7gh	52.5fgh	67.7abc	67.7abc	63.1bcd	60.4A
		Average	60.5B	49.9C	54.1C	68.9A	69.2A	67.4A	61.7
	September	2012	53.3ab	55.1ab	55.0ab	47.0c	46.5c	45.9c	50.4B
		2013	55.8ab	57.2a	58.2a	57.4a	50.3bc	54.0ab	55.5A
		Average	54.5AB	56.1AB	56.6A	52.2BC	48.4C	49.9C	53.0

Small letters represent the differences between the treatments within one sampling; capital letters represent the differences between the average values of the treatments within one sampling and among the average values of the years within one sampling. Values followed by the same letter are not significantly different ($p \leq 0.05$).

The highest soil water storage in the profile was in the first term (Figure 2). In regard to locality, the lowest soil water storage was in Sombor in 2012 (273.2 mm in the treatment with common vetch), and the highest soil water storage was in Novi Sad in 2013 (341.5 mm in the treatment with common vetch). In May, the soil water storage decreased in the profile with the lowest values in the treatments with cover crops. In the third term in 2012, the soil water storage was higher in all treatments at Senta than that at the other two research areas. At Senta, the lowest values were observed in N_2 (206.0 mm) and control (209.0 mm) treatments, whereas the highest was registered in the treatment with common vetch (233.0 mm). In September/October in 2013, at Sombor and Senta, values were the highest in the treatments with cover crops, whereas at Novi Sad, values were generally similar in all treatments.

In both periods and at all localities, the changes in soil water storage were higher in 2013 than that in 2012 (Table 9). In the first period in 2012 in Novi Sad-Rimski Šančevi and Senta, the lowest values were in the control treatment (114.5 and 145.1 mm, respectively). In 2012, the highest value of the changes in soil water storage was in Novi Sad in the treatment with common vetch (252.2 mm). At the first locality, the lowest value was in the treatment with common vetch as the cover crop (172.7 mm in 2012 and 314.4 mm in 2013), whereas the highest was in the control (280.7 mm in 2012 and 416.9 mm in 2013). In Sombor, the lowest value of the changes in the soil water storage was in the triticale variant in 2012 (110.8 mm) and in the variant with common vetch in 2013 (334.3 mm). In the period May-September/October, the changes in soil water storage were the lowest in the cover crop treatments. At this locality, the highest values were in N_2 in 2012 (209.6 mm) and in the control in 2013 (499.8 mm). The changes in soil water storage in Senta in 2012 ranged from 101.2 mm in the triticale cover crop treatment to 201.6 mm in the control. In the second year, the lowest value was in the treatment with common vetch (336.2 mm), and the highest was in the N_2 treatment (460.0 mm).

Table 9. The effect of cover crops and nitrogen rate on the changes in soil water storage (mm) for the periods March–May and May–September/October at the localities Novi Sad-Rimski Šančevi, Sombor, and Senta in 2012 and 2013.

Period	Locality	Year	Treatments					
			Common Vetch	Triticale	Common Vetch/Triticale	N_1	N_2	Control
March–May	Novi Sad-Rimski Šančevi	2012	252.2	245.1	235.0	157.9	165.2	144.5
		2013	410.0	438.8	449.7	396.1	309.9	293.7
	Sombor	2012	168.9	211.0	199.8	140.7	140.2	142.7
		2013	327.3	329.9	328.9	260.2	230.7	210.7
	Senta	2012	200.2	228.6	216.4	154.9	152.1	145.1
		2013	359.4	366.0	377.9	324.8	272.1	262.4
May–September/October	Novi Sad-Rimski Šančevi	2012	172.7	191.2	206.6	246.8	256.0	280.7
		2013	314.4	346.2	347.0	385.0	411.9	416.9
	Sombor	2012	140.0	110.8	184.2	188.8	209.6	190.3
		2013	334.3	394.6	392.2	457.7	489.4	499.8
	Senta	2012	124.8	101.2	118.3	184.1	197.5	201.6
		2013	336.2	416.1	410.1	440.4	460.0	458.6

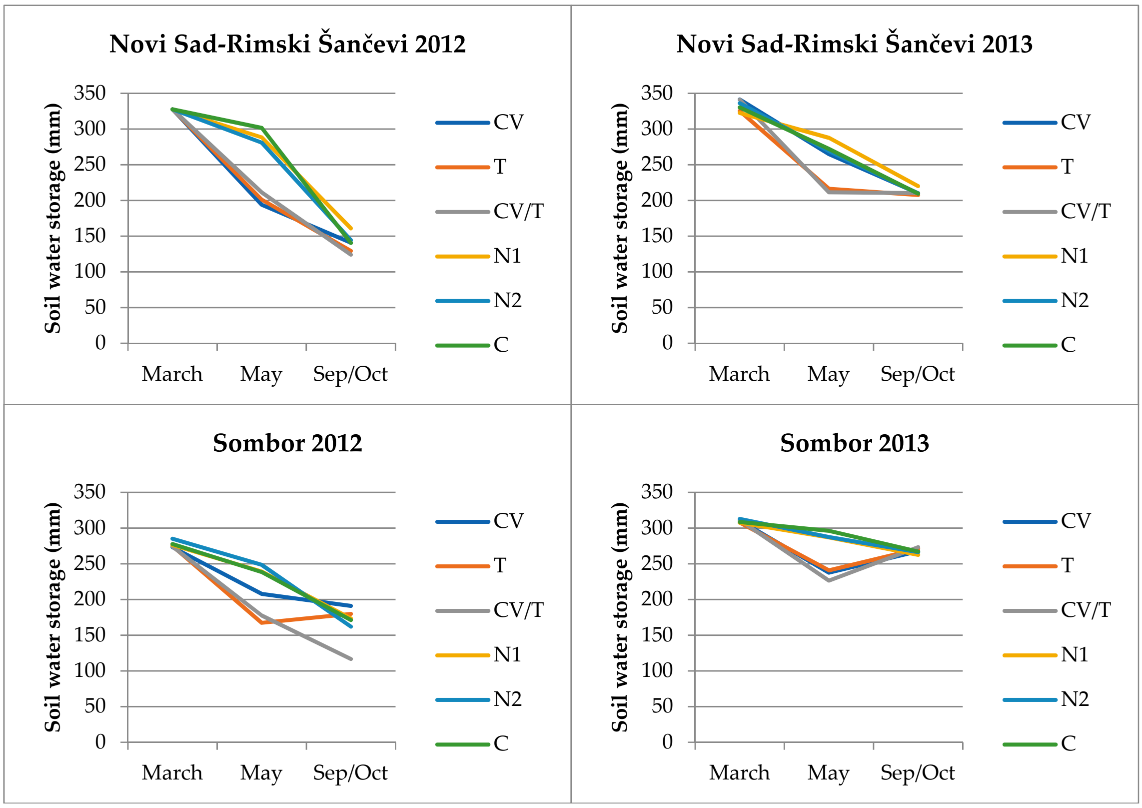

Figure 2. *Cont.*

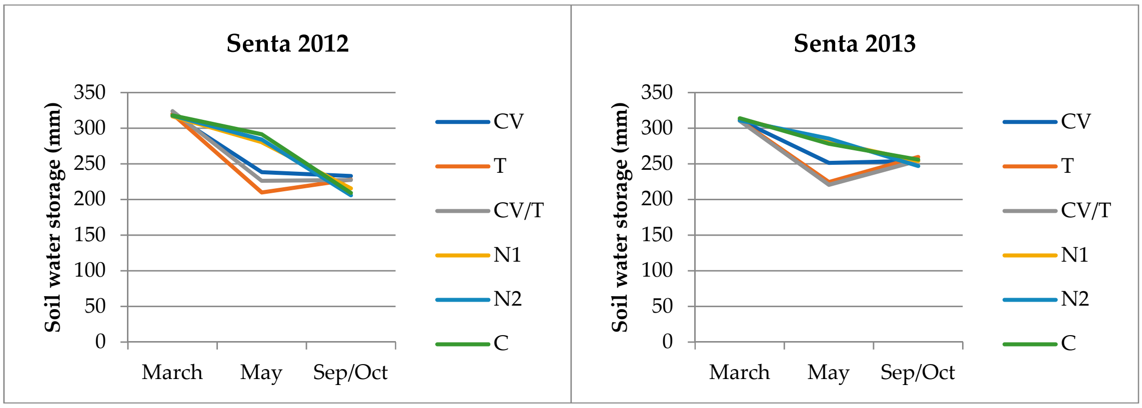

Figure 2. The effect of cover crops and nitrogen rate on soil water storage in the soil profile from 0 to 120 cm at the localities of Novi Sad-Rimski Šančevi, Sombor, and Senta in 2012 and 2013. CV: common vetch; T: triticale;CV/T: the mixture of common vetch and triticale; N1: 120 kg ha^{-1} mineral fertilizer; N2: 160 kg ha^{-1} mineral fertilizer; C: control.

In the period March–May in 2012, the lowest average changes in soil water storage in treatments with cover crops were in Sombor (193.2 mm), and the highest were in Novi Sad-Rimski Šančevi (244.1 mm) (Table 10). For the average changes in soil water storage, the smallest difference between cover crops and fallow treatments was recorded in Sombor (52.0 mm) and the highest in Novi Sad-Rimski Šančevi (88.2 mm). In 2013, the average changes in soil water storage in cover crop treatments ranged from 328.7 mm in Sombor to 367.8 mm in Senta and to 432.8 mm in Novi Sad-Rimski Šančevi. The smallest difference between cover crop and fallow treatments was recorded in Senta (81.3 mm) and the highest in Novi Sad-Rimski Šančevi (99.6 mm).

Table 10. The difference in changes in soil water storage (mm) between treatments with and without cover crops at the localities Novi Sad-Rimski Šančevi, Sombor, and Senta in 2012 and 2013.

Period	Location	2012			2013		
		Cover Crops	Fallow	CC-F	Cover Crops	Fallow	CC-F
March–May	Novi Sad-Rimski Šančevi	244.1	155.9	88.2	432.8	333.2	99.6
	Sombor	193.2	141.2	52.0	328.7	233.9	94.8
	Senta	215.1	150.7	64.4	367.8	286.4	81.3
	Average	217.5	149.3	68.2	376.4	284.5	91.9
May–September/October	Novi Sad-Rimski Šančevi	190.2	261.2	−71.0	335.9	404.6	−68.7
	Sombor	145.0	196.2	−51.2	373.7	482.3	−108.6
	Senta	114.8	194.4	−79.6	387.5	453.0	−65.5
	Average	150.0	217.3	−67.3	365.7	446.6	−80.9

CC-cover crops, F-fallow plots (with N fertilisation and the control).

In the second period in both years, the average changes in soil water storage were highest in the fallow treatments. In 2012, the lowest average changes in soil water storage were in Senta (114.8 mm in cover crop treatments, 194.4 mm in fallow treatments), whereas the highest were in Novi Sad-Rimski Šančevi (190.2 mm in cover crop treatments, 261.2 mm in fallow treatments). In 2013, the average changes in soil water storage in cover crop treatments ranged from 335.9 mm in Novi Sad-Rimski Šančevi to 387.5 mm in Senta, whereas in fallow treatments, the range was from 404.6 mm in Novi Sad-Rimski Šančevi to 482.3 mm in Sombor. In both years, the differences between cover crop and fallow treatments were negative, and the highest difference was calculated in Sombor in 2013 (−108.6 mm).

The correlation analyses for 2012 showed that the relationship between the changes in soil water storage in the first period and silage maize yield was very strong and negative (Figure 3). The opposite was observed with a very strong and positive relationship between the changes in soil water storage in the second period and silage maize yield. Similar to 2012, in 2013, the correlation between the changes in soil water storage in the first period and silage maize yield was negative but with a different strength of the correlation among the locations. The correlation was very weak (r = −0.17) in Senta, moderate in Novi Sad-Rimski Šančevi (r = −0.59), and very strong in Sombor (r = −0.83). The relationship between the changes in soil water storage in the second period and silage maize yield was positive, with the highest value obtained in Sombor (r = 0.74).

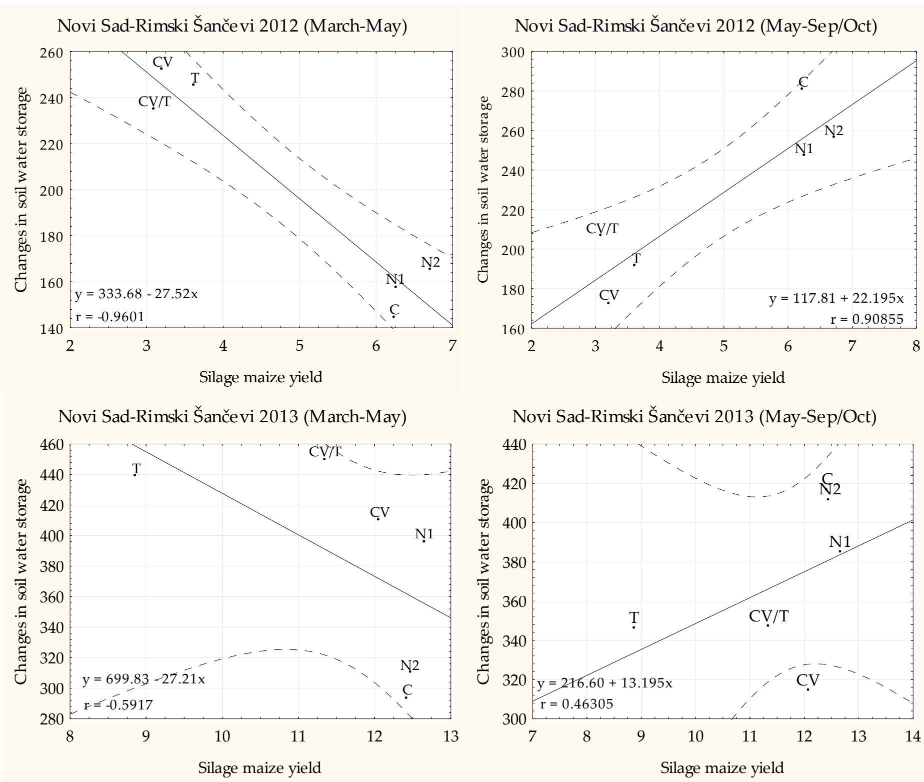

Figure 3. *Cont.*

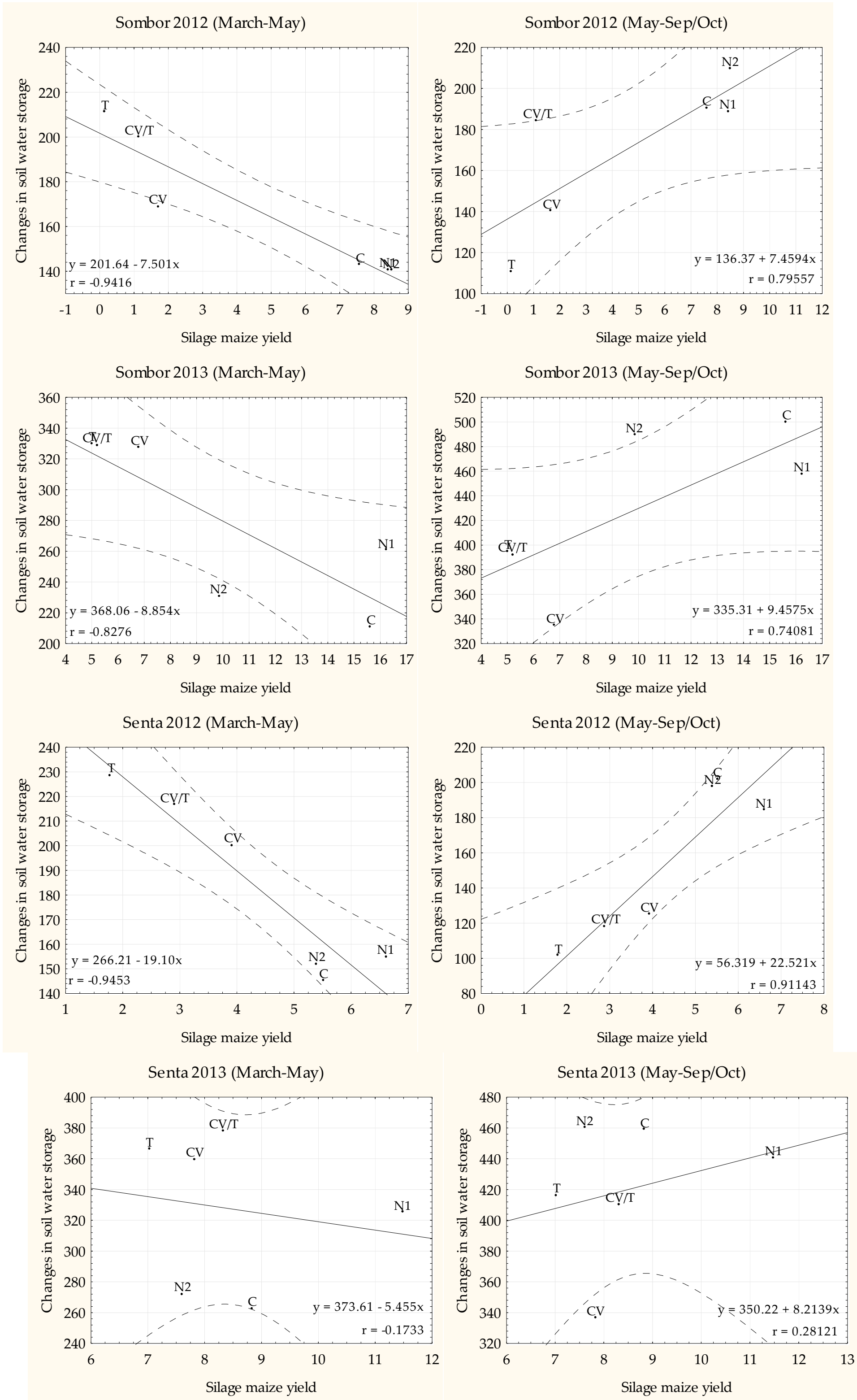

Figure 3. Correlations between the changes in soil water storage in the growing periods of cover crops (March–May) and silage maize (May–September/October) and silage maize yield in 2012 and 2013 (silage maize yield previously published by Cupina et al. [13]).

4. Discussion

In semiarid regions, the yield of cash crops such as maize or soybean is often unpredictable as a result of amount and timing of precipitation in the growing season [35]. Generally, reductions in yield of maize or any other warm-season cash crop are highly connected with the reduced precipitation and increased air temperatures during summer months [36]. According to SPI values, 2011 and 2012 were extremely dry years, and 2013 had moderately increased moisture, reaching normal values. The second warmest year in Serbia between 1951 and 2013 was 2012 [37]. This outcome confirms the statement of Stricevic et al. [38] that SPIs for Vojvodina reveal significant variations in drought intensity. Drought results from continued lack of precipitation and manifests when the amount of precipitation at a site is below usual levels during several months [39]. In the present study, the strongest drought effect was observed in November 2011 and in March and August 2012, because the amount of precipitation was less than 10 mm at all locations. These conditions significantly affected the water supply, and therefore the growth of both cover and cash crops.

As emphasised previously, cover crop contribution to the crop rotation depends on species, soil and weather conditions. All three effects can be analysed individually, but also through mutual interactions. For example, the soil water storage was lowest in all treatments with cover crops, but the deficiency was more intensive in extremely dry 2012. Similar results were obtained by Basche et al. [15] who concluded that ten days before cover crop termination and main crop sowing, soil water storage was significantly lower in the cover crop treatments than that in the treatment without cover crops. Furthermore, they concluded that in years with adequate precipitation distribution, the soil water deficit is replenished after cover crop growth. Regardless of the weather conditions, the changes in soil water storage in the two observed periods showed increased water use in the cover crop as a result of evapotranspiration, leaching, and plant water uptake, whereas the water loses in fallow treatments were only by evaporation and leaching. Thus, the use of cover crops is often confronted with the problem of soil water conservation [40]. Before sowing of silage maize, the highest water loss was registered in cover crop treatments, indicating that less water was available for maize requirements, which results in much more difficult starting conditions for the silage maize plants. Generally, more water was used by triticale because of the well-developed cereal root system. Namely, small grain cover crops are known as so-called catch crops with an increased ability for soil water uptake. Thus, these cover crops are used for water conservation and to prevent nitrogen leaching [41]. As a result of different root morphology and development, the highest water consumption was also recorded in the mixture. Additionally, in the mixture, more nitrogen was available for the cereal, which demonstrated complementarities of the cereal-legume mixture and intensive use of water and nutrients. These conditions of reduced soil water availability for a subsequent crop are aggravated further in areas with dry weather terms, irregular precipitation or on soils with a low water capacity [42]. The timely spring termination of a cover crop avoids the negative effects of opposite water conditions: excess residue holding in too much moisture for planting in wet years, or living plants drawing too much moisture from the soil in dry years [43]. In 2013, in the spring and early summer, the experimental sites received more water than average, which compensated for the moisture deficit after cover crops and mitigated their negative effect on the growth and yield of silage corn. Thus, in a region and years with no water limitation, cover crops are highly beneficial and applicable, which is in accordance with Cupina et al. [13] who stated that in the average year when the amount and timing of precipitation are consistent with the long-term average, cover crops have a positive effect on the changes in soil water storage. By contrast, in the first year of the study with water supplies used by cover crops and extremely dry and warm conditions, the silage maize yield was very low, or the crop completely failed in some localities. However, in the temperate region, such specific years with a negative effect of cover crops on the subsequent crop occur once in 5 to 10 years [44,45]. In the second year, silage maize use of water was intensive, and the yield obtained was similar between cover crop treatments and treatments with fertilisation. Among the cover crops, the lowest silage maize yield in both years was obtained in the treatment with triticale, as a result of high water consumption, whereas the highest yield in both years was after the common vetch because of less water consumption and better moisture conditions for the main crop. The correlations between the changes in soil water storage and silage maize yield confirmed that the silage maize yield is highly connected with the water storage after cover crop incorporation, considering that cover crops reduce available water for a subsequent crop. However, if the water limitation is continuous, as it was in 2012, then the negative effect is prolonged to the entire growing period.

Climate change and the extreme variation in precipitation distribution during the growing period in temperate regions have brought and will bring many challenges in crop production. One of the ways to respond to these differences is to maintain or to obtain fertile and well-structured soils, by manure application, growing cover crops or with some other measure. In the region of Vojvodina Province, livestock production is low, and therefore, the reduced availability of organic fertilisers justifies the importance of cover cropping [41]. The variations in weather conditions raise the question of whether to include cover crops in crop rotations. Moreover, the question is whether the benefits of cover crops can occur in areas with different precipitation and temperature values during a growing period, such as occur in temperate and semiarid regions, or only in a region that is generally not water limited. The use of cover crops has numerous positive effects but with short-term and long-term benefits. Soil water availability, additional nitrogen by legumes, and erosion reduction are some of the short-term effects, which vary significantly and are strongly dependent on the water supply. However, the improvement in soil properties such as infiltration, structure, and organic matter content by root residues or biomass incorporation of cover crops requires several years, which in that case, leads to better soil conditions for overcoming temperature and precipitation variations [13]. In the present research, the winter covers were ploughed-in in the late spring, which directly affected the silage maize development, because the period for water recharge was short. As a precaution, Joyce et al. [40] suggest cutting and incorporation of winter cover crops at the beginning of spring to avoid any negative effects on the following main crop by excessive evapotranspiration and other water losses. Cover cropping is an intensive system in which some operations (cutting, incorporation, soil preparation, sowing) must be performed within one or a few days [17]. Alternatively, Lyon et al. [46] propose harvesting cover crops in the fall to leave sufficient time for water accumulation. In semiarid regions such as Vojvodina Province, these approaches could be options that include cover cropped systems but reduce the possibility of cover crop disadvantages. Based on our results from Sombor and Senta, when the precipitation amount and water supply were adequate during the summer months, the soil water storage was the highest after main crop termination in the fall in the treatments with cover crops. Providing support for this outcome, the results of Basche et al. [15] indicate that because of cover crop effects on soil properties, the capacity for soil water storage increases, and therefore, the soil water content can remain high during summer months. The continuous decrease in water storage in the control variant in both years was notable. Simultaneously, in the nitrogen treatments, because of intensive water uptake by maize, soil water storage also decreased. Therefore, farmers suspicious of whether they should use cover crops should consider the importance of maintaining soil properties and investment in long-term production.

5. Conclusions

Generally, cover crops can be efficiently used for soil water conservation and yield improvement of the subsequent cash crop, with the following conclusions:

- Cover crop benefits were more weather-specific than site-specific,
- The soil water storage was reduced during the cover crop growing season compared to control variant and variants with nitrogen fertilisation,
- Before the cash crop growing season, cover crops temporarily decreased the soil water storage,
- When precipitation decreased or was not properly distributed, the water reduction after cover crops had a negative effect on the cash crop growth and yield,

- When the precipitation amount and water supply was adequate during the cash crop growing season, the soil water storage was the highest after main crop termination in the fall in the treatments with cover crops,
- Common vetch and the mixture of common vetch and triticale had a greater positive effect on the changes in soil water storage after ploughing-in than that of triticale as sole crop.

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