Italian Journal of Agrometeorology
Rivista Italiana di Agrometeorologia

Firenze University Press
www.fupress.com/ijam

Citation: A. Pescatore, D. Vergari, S. Orlandini, M. Napoli (2023) Agronomical management of detention basin. *Italian Journal of Agrometeorology* (1): 3-11. doi: 10.36253/ijam-2239

Received: March 15, 2023

Accepted: July 11, 2023

Published: August 03, 2023

Data Availability Statement: All relevant data are within the paper and its Supporting Information files.

Competing Interests: The Author(s) declare(s) no conflict of interest.

ORCID:
AP: 0000-0002-1678-4247
SO: 0000-0001-6290-9752
MN: 0000-0002-7454-9341

Agronomical management of detention basin

Antonio Pescatore[1,*], Daniele Vergari[2], Simone Orlandini[1], Marco Napoli[1]

[1] *Department of Agriculture, Food, Environment, and Forestry (DAGRI), University of Florence, Piazzale delle Cascine 18, 50144, Florence, Italy*
[2] *Consorzio di Bonifica 3 Medio Valdarno, Viale della Toscana, 21, 50127, Florence, Italy*
*Corresponding author. E-mail: antonio.pescatore@unifi.it

Abstract. The importance of effective stormwater management through detention basin arrangement has become increasingly evident due to recurring extreme events in recent years. Limitations of the traditional detention basin include a reduced ability of basins to infiltrate water due to compacted soil and the carbon cost associated with the Diesel-powered tractors with lawn shredders. This study aims to compare six different agronomical management approaches for detention basins to improve the water storage capacity and the carbon sequestration potential, including the cultivation of crimson clover, white clover, tillage radish, and two mono-dicotyledonous mixes, against the conventional stable lawn-based approach. The trial was conducted in the detention basin in Castelletti (Firenze, Italy) for one growing season (2020/2021) according to a randomized complete block design with 9 replicates. Soil physical and chemical properties, as well as soil water storage capacity, were assessed to determine the feasibility of agronomical management for detention basins. Results indicated that the different treatments significantly influenced aboveground biomass production, soil organic carbon (SOC) stock, carbon sequestration potential, and water storage capacity. Specifically, crimson clover exhibited the highest aboveground biomass of around 6 t ha^{-1} among the treatments, while tillage radish demonstrated the greatest carbon sequestration potential (4.58 t CO_2 ha^{-1}), stable carbon stock in soil (1.14 t S-SOC ha^{-1}), as well as the highest potential for improving the water storage volume (389 m^3 ha^{-1}) in the topsoil (0-20 cm) of the detention basin. The findings suggested also that the sowing of different mono-dicotyledonous plant mix were poorly effective in improving carbon sequestration potential and water storage volume compared to conventional basin management. To sum up, this experiment has demonstrated that alternative agronomical management practices can enhance the capacity of detention basins to store carbon and stormwater. These results provide valuable insights for improving the sustainability and functionality of detention basins.

Keywords: carbon sequestration potential, stable soil organic carbon, soil water storage, detention basin, drainable porosity.

INTRODUCTION

The recurring extreme events of the last years have highlighted the importance of appropriate stormwater management. Excessive stormwater usually poses problems for rural communities and their livelihoods. The rate of soil impermeabilization, as well as the loss in water storage capacity of agricultural soils, have dramatically soared the water stream flow, determining the increase in soil erosion (Adobati and Garda, 2020). Management plans have been formulated by the European Environment Agency (EEA) to keep the water cycle as sustainable as possible (EEA, 2016). Different strategies accounted for in the best management practices (BPM), have been developed to reduce flooding risk, improve water quality, and recharge groundwater, such as the construction of swales, infiltration basins, retention basins, and detention basins (Davis et al., 2017; Lam et al., 2011). Those basins had been commonly known since ancient times, but with the increase in flooding events, their construction has recently gained attention. Although those ponds' general aim is to reduce stormwater peak flow of torrents and rivers, some distinctions have to be made.

Swales are ditches designed to collect, store, and reduce water runoff both in urban and rural environments, while improving the rate of stormwater that flows toward the groundwater (Sañudo-Fontaneda et al., 2020). Infiltration basins are ponds whose primary function is to improve the amount of water that infiltrates into the soil, hence their design has to facilitate the water flow from the ground surface to the groundwater (Di Lena et al., 2023). Retention basins are the most commonly designed structures for the mitigation of flooding events involving a permanent pool made with landscaped banks and surroundings (Acheampong et al., 2023). Detention basins are designed to temporarily store stormwater, but most of the time of the year they are free from water (Sharior et al., 2019), therefore this lead to their putative use for agricultural purposes outside the rainy season.

Generally, detention basins allow the handling of a higher water volume than that of the usual riverbed; when the river flow is lowered, the basin-stocked water flows back to the river (Emerson et al., 2005). They could be used for managing and treating surface water runoff from impermeable surfaces such as roads (Griffiths, 2017). The conventional management of (dry) detention ponds consists of a soil bed where native plant species capable of tolerating periodic inundation are left to grow up and periodically mowed (Emmerling-DiNovo, 1995). Limitations of the traditional detention basin include a reduced ability of basins to infiltrate water due to compacted soil. One cause of this is that the soil at the bottom of these basins may become overly compacted during construction. Further, these basins are typically planted with turf grass that is shredded and mowed regularly 1-2 times a year to control the growth of aboveground biomass and the formation of shrubs. However, tractor traffic on lawns can have a significant impact on reducing the maximum root number and air-filled porosity in the upper 5 cm of soil, thereby decreasing the soil infiltration rate (Sveistrup and Haraldsen, 1997). Thus, a significant volume of water passes through these basins without the opportunity to infiltrate into the basin soil. Infiltration of precipitation and runoff water is an important green infrastructure goal, since infiltration recharges groundwater, decreases total runoff, and helps remove pollutants from the runoff water. Further, while lawns can function as "carbon sinks," their benefit is often outweighed by the carbon cost associated with their maintenance, specifically Diesel-powered tractors with lawn shredders.

The soil properties of detention basins can be improved by adopting alternative agronomical management while providing environmental and ecosystem services. For example, lawn management can be substituted by the cultivation of a specific crop that might enhance the soil water storing capacity. In this context, the soil in detention basins can be periodically tilled using a chisel plough and harrow to facilitate water accumulation but also to avoid the excessive soil compaction, that compromises detention basin functionality. In addition, the putative crop should produce both high aboveground and root biomass to increase carbon sequestration; previous properties could be satisfied with the sowing of different clover species, which usually occur in frequently flooded habitats (Huber et al., 2009).

However, few studies have been realized on the effect of tillage management on the soil properties of detention basins. Moreover, during the water storage, detention basins represent also a humid area, where some ecosystem functions could be achieved, such as wastewater treatment and the creation of wildlife habitats (Sharma et al., 2023).

The agronomical management of a detention basin could take into account that it is a periodically flooded soil; hence, some soil properties alterations should be observed. According to Schroer et al., (2018), the sediments transported by the water flow toward the detention basins are capable of increasing the carbon, nitrogen, and phosphorus concentration in soil. Accordingly, the basin could also support plant growth and reduce the carbon concentration in the atmosphere. In terms of nutrient load, the analyses of the water inflow revealed a significant amount of phosphorus and nitrogen that could be useful for plant growth (Wissler et al., 2020). In the same study, it was demonstrated that unmaintained detention basins were able to sequester higher amounts of carbon concerning maintained ones over 20 years; however, the maintenance they considered was only the turf grass mowing. Other authors reported an increase in soil particulate organic carbon (POM-C) concentration in a detention basin as a consequence of runoff water flow (Stanley, 1996). On the other hand, no significant changes in organic matter (OM), carbon, and nitrogen concentration were observed in turf-grassed detention basins for the 0-5 and 15-20 soil layers (McPhillips et al., 2018).

Consequently, this work aimed to compare six different management of the detention basin to improve its capacity to stock carbon and store stormwater. Specifically, the sowing of different species of clover, the sowing of tillage radish, and the sowing of two crop mixes made of graminaceous and leguminous plants termed Fascia Tampone and Rustico Dicotiledoni were compared to the conventional management of the detention basin, consisting in the growth of a stable lawn, which is periodically mowed. Some soil physical and chemical properties and soil water properties were measured for the different treatments to assess the feasible agronomical management of the detention basins, which are commonly considered marginal areas.

MATERIALS AND METHODS

Experimental setup

The trial was carried out at the detention basin of Castelletti (Signa, Florence, Italy, 43° 47’ 49” N, 11° 4’ 51” E) that are managed by the local land requirement consortium (Consorzio di Bonifica 3 Medio Valdarno; CB3MV) , from October 2020 to September 2021. The test site consisted of a surface of 4.2 ha that was subdivided into 15 adjacent watersheds around 2500 m^2 in size. The area was recovered with some projects that aim to restore traditional lowland agricultural hydraulic arrangement patterns and establish areas to promote biodiversity. The experimental design was a randomized completely block design, consisting of 15 blocks identified with the different treatments (3 blocks for treatment); for each block, 3 replicates were considered, hence a total of 9 replicates for treatment were obtained. According to the initial characterization, the soil was silt loam textured as the percentage of sand, silt, and clay were 21.7%, 53.8%, and 24.2%, respectively. The soil pH of the detention basin was neutral (7.19) with an average bulk density of 1.45 t m^{-3}.

Before the arrangement of the trial, the detention basin was managed with a stable lawn, and the soil was periodically tilled with a plough and harrow; before the sowing of different plants, the soil of the detention basin was ploughed and harrowed using moldboard plough and disk harrow, respectively. Six different management of the detention basin were compared: the stable lawn (SL) was considered the control as it was the conventional management before the arrangement of the trial; crimson clover (CC; *Trifolium incarnatum* L.); white clover (WC; *Trifolium repens* L.); tillage radish (TR; *Raphanus sativus* L. var. Longipinnatus); a mono-dicotyledonous mix called OP-Rustico dicotiledoni (RD), a mono-dicotyledonous mix called OP-Fascia tampone (FT). The species description for each treatment is reported in Table 1. No fertilizers and pesticides were applied over the entire field. CC, FT, RD, TR, and WC were sowed at a seeding rate of 25, 35, 55, 18, and 25 kg seeds ha^{-1}, respectively. The TR root system is mainly composed of a taproot with only some fibrous lateral roots. RC and WC have both fibrous lateral roots and a taproot. SL is mainly composed of graminaceous species with fibrous roots, while FT and RD are mixtures comprising both graminaceous species with fibrous roots and leguminous species with both fibrous lateral roots and a taproot. The biomass collection for each treatment was carried out on May 21’. A sampler of 25 cm*25 cm was used to collect the aboveground biomass of the different treatments. The dry weight of the plant biomass was measured after oven drying at 70°C, until reaching constant weight.

Fuel consumption for the different management

The data of diesel fuel consumption (L ha^{-1}) for the specific agricultural operations were provided by CB3MV. The main fuel-consuming activity was ploughing at 30 cm depth because of the high energy requirement for moving a huge amount of soil (Table 2). Also, the preparation of the seedbed for the cultivation of CC, WC, FT, and RD represented a highly energy-consuming activity. The following activity that requires high-energy consumption was the soil disk harrowing, which was null for the conventional management of the detention basin. As regards the management of the aboveground biomass, all the treatments required two grass shredding per year, except the TR which requires only one per year.

Soil sampling and analyses

The collection of soil samples was carried out according to the core sampling method; specifically, three samples for the plot were collected and mixed for 3 different soil depths (0-5, 5-10, 10-20 cm) both as disturbed and undisturbed samples. Disturbed samples were collected to determine some soil chemical properties, while soil

Table 1. Description of the species for the different treatments (SL: stable lawn; CC: crimson clover; WC: white clover; TR: tillage radish, FT: OP-Fascia tampone; and RD: OP-Rustico dicotiledoni).

Herbaceous species in the different treatments					
SL	CC	WC	TR	FT	RD
Bellis perennis L.	*Trifolium incarnatum* L.	*Trifolium repens* L.	*Raphanus sativus* Var.Longpinnatus L.H.Bailey	*Achillea millefolium* L.	*Achillea millefolium* L.
Bromus hordeaceus L.				*Dactylis glomerata* L.	*Leucanthemum vulgare* Lam.
Cynodon dactylon L.				*Festuca rubra* L.	*Lotus corniculatus* L.
Lolium perenne L.				*Lolium arundinaceum* L.	*Medicago sativa* L.
Holcus lanatus L.				*Lolium perenne* L.	*Onobrychis viciifolia* Scop.
Hordeum murinum L.				*Lotus corniculatus* L.	*Phacelia tanacetifolia* Benth.
Plantago Media L.				*Onobrychis viciifolia* Scop.	*Plantago lanceolata* L.
Cichorium intybus L.				*Phacelia tanacetifolia* Benth.	*Salvia pratensis* L.
				Poa pratensis L.	*Silene vulgaris* Moench.
				Trifolium pratense L.	*Trifolium pratense* L.
				Trifolium repens L.	*Trifolium repens* L.

Table 2. Diesel fuel consumption (L ha^{-1}) of the different management of detention basin (SL: stable lawn; CC: crimson clover; WC: white clover; TR: tillage radish, FT: OP-Fascia tampone; and RD: OP-Rustico dicotiledoni) for the different agronomical practices (ploughing, disk harrowing, sowing, first and second shredding operations).

	Diesel fuel consumption per treatment (L ha^{-1})					
	SL	CC	WC	TR	FT	RD
Ploughing (30 cm)		60	60		60	60
Disk Harrowing		33	33	33	33	33
Sowing		6	6	6	6	6
Shredding 1st time	25	25	25	25	25	25
Shredding 2nd time	25	25	25		25	25
Total fuel consumption	50	149	149	64	149	149

physical properties were measured on undisturbed samples. The first soil sampling was carried out in August 2020 for the initial characterization of the soil, and after the soil tillage, the second sampling was performed (October ’20); in September ’21 after the first growing season, the subsequent soil samples were collected.

The collected samples were air-dried and filtered by a 2-mm sieve. Soil Organic Carbon (SOC; g C kg^{-1}) was measured on disturbed soil samples using the CHNS elemental analyzer (Thermo Fisher Scientific, Waltham, MA, USA). Starting from the SOC it is possible to determine the amount of stable organic C by subtracting the Labile organic C from the SOC; labile organic C is obtained through the addition of particulate-organic carbon (POM-C; g C kg^{-1}) and Permanganate-Oxidable Carbon (POX-C; g C kg^{-1}). The determination of both POM-C and POX-C in soil was assessed through the methods proposed by Cambardella and Elliott, (1992) and Blair et al., (1995). Briefly, POM-C was measured by dissolving 10 g of soil into 30 mL of sodium hexametaphosphate (5 g L^{-1}). The dispersion was left for 15 h on a reciprocal shaker; then the dispersion was filtered through a 53-μm sieve. After various water rinsing, it was dried overnight at 50°C. The resulting dried sample was ground using a mortar and pestle and then subjected to the CHNS elemental analyzer. Regarding POX-C, a solution of $KMnO_4$ (52.625 g L^{-1}) was used for the oxidation of the soil sample. The soil containing 15 mg of SOC was dissolved in 25 mL of the $KMnO_4$ solution and left shaking for 1 h. Afterward, the tubes were centrifugated at 3500 rpm for 5 minutes and the resulting supernatants were diluted to 1:500. The absorbance of the sample was measured at 565 nm using a spectrophotometer. The bulk density (BD; t m^{-3}) of the detention basin for the different treatments was measured on undisturbed soil samples using cylinders of known volume. The SOC stock, the POM-C stock, and the POX-C stock of the 20 cm layer for the different treatments were calculated according to the following formulas:

$$\text{SOC}_{\text{Stock}} = \frac{(\text{SOC}_{\text{Sept'21}} *\text{BD}*0.2)-(\text{SOC}_{\text{Oct'20}} *\text{BD} *0.2)}{100000} \quad (1)$$

$$\text{POM-C}_{\text{Stock}} = \frac{(\text{POM}-\text{C}_{\text{Sept'21}} *\text{BD}*0.2)-\ (POM-C_{\text{Oct'20}} *\text{BD}*0.2\ )}{100000} \quad (2)$$

$$\text{POX-C}_{\text{Stock}} = \frac{(\text{POX}-\text{C}_{\text{Sept'21}} *\text{BD}*0.2)-\ (\text{POX}-\text{C}_{\text{Oct'20}} *\text{BD}*0.2)}{100000} \quad (3)$$

Where $\text{SOC}_{\text{Sept'21}}$ is the amount of organic C measured in September '21, is the bulk density measured in October '20, $\text{SOC}_{\text{Oct'20}}$ is the amount of organic C measured in October '20, $\text{POM-C}_{\text{Septs'21}}$ is the POM-C measured in September '21, $\text{POM-C}_{\text{Oct'20}}$ is the POM-C measured in October '20, $\text{POX-C}_{\text{Septs'21}}$ is the POX-C measured in September '21, $\text{POX-C}_{\text{Oct'20}}$ is the POX-C measured in October '20 and is the bulk density measured in October '20. The previous parameters were used to calculate the stable SOC stock (S-SOC; t ha^{-1}) as follows:

$$\text{S-SOC}_{\text{stock}} = \text{SOC}_{\text{stock}} - (\text{POM-C}_{\text{stock}} + \text{POX-C}_{\text{stock}}) \quad (4)$$

The calculation of the drainable porosity (%) for the determination of the water storage volume (WSV; $\text{m}^3\ \text{ha}^{-1}$) for the different treatments was assessed through the soil water retention curve. Specifically, the water percentage at field capacity was measured through the water retention curve using Richard's plate apparatus (Richards and Fireman, 1943). The estimation of the total porosity was calculated as follows:

$$\text{Total porosity [\%]} = \left[1 - \left(\frac{BD[t\ ha^{-1}]}{2.65\ [t\ ha^{-1}]}\right)\right] * 100 \quad (5)$$

Where BD is the bulk density measured, and 2.65 is the estimated real density. Accordingly, the drainable porosity was calculated as the difference between the total soil porosity and the water percentage in the soil at field capacity. Lastly, the WSV was calculated as the amount of drainable porosity in the topsoil (20 cm).

Statistical analysis

The comparison among the means of different treatments for each variable was assessed according to the one-way ANOVA. The parameters which resulted significantly were compared through a post-hoc Tukey's Test.

RESULTS AND DISCUSSION

Weather description

The climate of the area is Mediterranean with an average annual rainfall and a mean annual temperature of 872 mm and 15.25°C, respectively (Figure 1). No significant differences were observed in the annual rainfall amount between the long-term average (2001-2020) and the 2020/2021 growing season. However, by comparing the monthly data, it was observed that rainfall that occurred during the 2020/2021 growing season exceeded the long-term average in October, December, and January, leading to the flooding of the detention basin for 4 days in December and January. On the other hand, the area experienced a low rainfall amount concerning the long-term average in November 2020 and March 2021. The temperature pattern of the 2020/2021 growing season was quite similar to the long-term trend of temperature, except for the spring months when the average monthly temperature of the 2020/2021 growing season was lower than those reported for the long-term.

Aboveground Biomass yield

The different treatments significantly affected the amount of aboveground biomass (AG-y) produced over the detention basin (Figure 2). The AG-y produced by the different treatments ranged between 2.71 and 6.04 t ha^{-1} of DW. Specifically, CC highlighted the best performance, accounting for 6.04 t ha^{-1} of AG-y. Indeed, Knight, (1985) reported that CC can successfully and

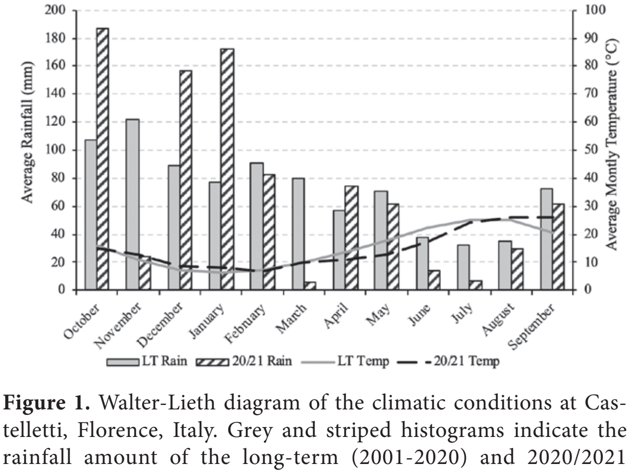

Figure 1. Walter-Lieth diagram of the climatic conditions at Castelletti, Florence, Italy. Grey and striped histograms indicate the rainfall amount of the long-term (2001-2020) and 2020/2021 growing season, respectively; gray and dashed lines show the temperature trend of the Long-Term and 2020/2021 growing season, respectively.

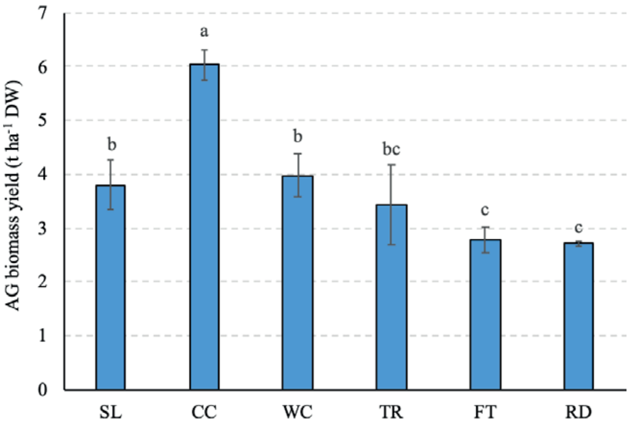

Figure 2. Aboveground biomass yield (AG-y; t ha^{-1} Dry weight) for the different management of detention basin (SL: stable lawn; CC: crimson clover; WC: white clover; TR: tillage radish, FT: OP-Fascia tampone; and RD: OP-Rustico dicotiledoni). Error bars represent the standard deviation (n=9). The letters indicate significant differences between the treatments according to the post-hoc Tukey's test.

rapidly grow in a wide range of climatic and soil conditions. The observed yield of CC was similar to that reported in SARE Outreach, (2007), indicating that crimson clover can reach 7 t ha^{-1} DW in good growing conditions. The AG-y of WC was significantly lower than that of CC, resulting in 34.2% lighter than WC; in fact, WC AG-y was more negatively affected by soil flooding than CC was. The WC susceptibility to flooding was also been described by Huber et al., (2009). The AG-y in SL was significantly lower than that measured in WC but not significantly different from CC and TR. The AG-y in SL, mainly composed of graminaceous plants including common ryegrass, was consistent with the average annual AG-y value of approximately 5 t ha^{-1} reported by several authors for common ryegrass (Vinther, 2006). The AG-y value measured in TR was 3.43 t ha^{-1} and was consistent with that reported by Cottney et al., (2022) for the tillage radish sowed in September. The aboveground biomass of the two herbaceous mixes, FT and RD, were significantly lower compared to the other treatments.

Carbon Stocking capacity

After 1 year, the SOC stock ranged between -0.08 t ha^{-1} in FT to 1.25 t ha^{-1} in TR (Table 2). The TR treatment produce the highest significant increase in SOCstock, followed by CC and WC. The SOCstock variation in SL was not significant, and a not significant negative variation was observed in FT and RD. The labile C stock ranged between -0.08 t ha^{-1} in FT to 0.12 t ha^{-1} in WC. However, no significant differences in labile C stock were detected between the six treatments. The S-SOC stock ranged between -0.05 t ha^{-1} in FT to 1.14 t ha^{-1} in TR. The TR treatment produce the highest significant increase in S-SOC stock, followed in decreasing order by CC and then WC. Further, the S-SOC stock variation in SL, FT, and RD was not significant. These values are consistent with Franzluebbers et al., (2012) who observed that after the conversion of an arable cropping system into perennial grassland the rate of C accumulation down to a depth of 20 cm has an initial value of 0.8 t ha^{-1} y^{-1}. Probably for mixes containing grasses as in FT and RD, the time required to recover the oxidized carbon through soil tillage is longer than a single year of cultivation. As reported by Li et al., (2020) and Liu et al., (2015) the tap-root system may have a higher impact on increasing SOCstock in soil than the fibrous roots. Therefore, the differences between the treatments can be attributable to the different root systems of the plant species in the six treatments.

Table 3. Changes in SOC stock, Labile C stock, and Stable C stock (S-SOC) for the different treatments (SL: stable lawn; CC: crimson clover; WC: white clover; TR: tillage radish, FT: OP-Fascia tampone; and RD: OP-Rustico dicotiledoni). Standard deviation values are reported in brackets (n=9). The letters indicate significant differences among the treatments according to Tukey's test (p<0.05).

Treatments	SOC stock t ha^{-1}	Labile C stock t ha^{-1}	S-SOC stock t ha^{-1}
SL	0.08 (0.18) c	0.07 (0.1)	0.01 (0.13) d
CC	0.59 (0.12) b	0.05 (0.12)	0.54 (0.14) b
WC	0.47 (0.04) b	0.12 (0.06)	0.35 (0.08) c
TR	1.25 (0.56) a	0.11 (0.26)	1.14 (0.21) a
FT	-0.08 (0.03) c	-0.08 (0.1)	0 (0.09) d
RD	-0.01 (0.02) c	0.04 (0.07)	-0.05 (0.08) d

Carbon sequestration

The annual amount of fixed CO_2 ranged between -0.29 and 4.58 t ha^{-1}, respectively in FT and TR, when considering the whole SOC_{stock} (Figure 3). According to our results, TR was the best treatment in terms of annual carbon sequestration potential, resulting in significantly higher carbon sequestration of 53.65% and 62.43% concerning CC and WC, respectively. The annual carbon sequestration rate SL (0.30 t CO_2 ha^{-1}y^{-1}) was significantly lower than that calculated for CC and WC. Lastly, negative values of carbon sequestration were calculated for RD and FT, indicating that the carbon that was released into the atmosphere by these treatments was higher than that incorporated in the soil. Specifical-

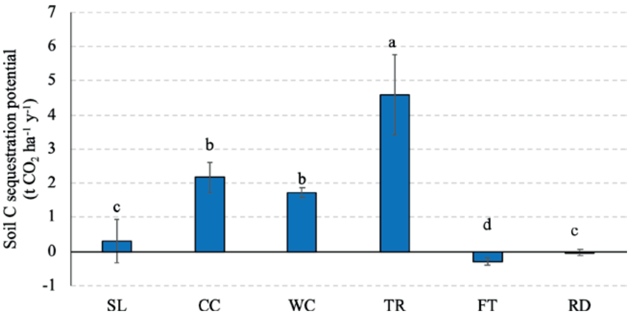

Figure 3. Annual Carbon sequestration rate (t CO_2 $ha^{-1}y^{-1}$) for the different management of detention basin (SL: stable lawn; CC: crimson clover; WC: white clover; TR: tillage radish, FT: OP-Fascia tampone; and RD: OP-Rustico dicotiledoni). Error bars represent the standard deviation (n=9). The letters indicate significant differences between the treatments according to Tukey's test ($p<0.05$).

ly, FT showed a significantly lower carbon sequestration potential than RD. The amount of annual CO_2 sequestered by SL was in agreement with that reported by Yang et al. (2019) for topsoil (20 cm) with 8 species making up the grassland system. However, the potential carbon sequestration of the same author for a single species system was lower than we have observed. On the other hand, our results were not consistent with the estimation of carbon balance for Western Europe by Dondini et al. (2023) for an unimproved grassland system of about 4.40 t CO_2 ha^{-1} y^{-1}. However, the value of carbon balance these authors estimated for unimproved grassland was quite similar to the value of the carbon sequestration potential of TR.

Water Storage Volume

The correct management of the detention basin was also assessed through the calculation of its capacity to store water (Figure 4). Our results highlighted significant differences in the WSV among the different treatments, ranging from 258 to 389 m^3 ha^{-1} for RD and TR, respectively. In particular, the highest WSV value was detected in TR, which was significantly higher than CC and WC by 6% and 8% respectively; the average WSV value of CC (364 m^3 ha^{-1}) was significantly higher than that of WC (356 m^3 ha^{-1}). Lastly, the lowest average WSV values were detected in RD, which were not significantly different from that detected in SL and RT, indicating that the behavior of FT and RD in determining the WSV was very similar to that of SL. The WSV values of the latter were quite similar to those reported by Zhu et al. (2022) for the topsoil (20 cm) of mountain grassland. Similarly, the WSV values observed by Otremba et al., (2021) were around 280 m^3 ha^{-1} considering the 0-35 soil layer after one year of alfalfa and orchard grass cultivation. On the other hand, similar results for clover WSV values were obtained by Fang et al., (2023). The good performance in terms of WSV obtained by TR could be determined by the wide holes that taproot leaves in the soil (White and Weil, 2011).

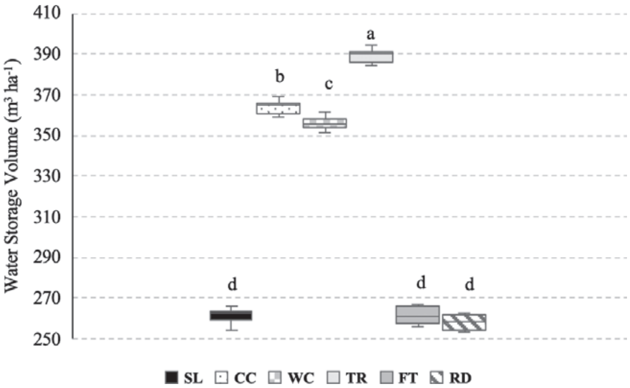

Figure 4. Soil Water Storage Volume (m^3 ha^{-1}) for the different management of detention basin (SL: stable lawn; CC: crimson clover; WC: white clover; TR: tillage radish, FT: OP-Fascia tampone; and RD: OP-Rustico dicotiledoni). The letters indicate significant differences between the treatments according to Tukey's test ($p<0.05$).

CONCLUSIONS

The different plants in the agronomic treatments were rapidly adapted to the detention basin conditions, especially the crimson clover that produced the highest aboveground biomass yield. Regarding the increase of soil organic carbon, the best performance was obtained by the tillage radish, which could represent a good strategy for increasing soil stable organic carbon. Likewise, tillage radish was also enormously effective in increasing the water storage capacity of the detention basin, followed by the crimson clover and white clover. In summary, the results emphasize the importance of plant selection for the effective management of detention basins. Crimson clover and tillage radish emerged as promising options for maximizing aboveground biomass production, improving soil organic carbon stock, enhancing carbon sequestration potential, and increasing water storage capacity. The findings provided valuable insights for the design and implementation of sustainable and efficient detention basin management strategies, highlighting the role of specific plant species in achieving desired outcomes. Further research and long-term monitoring are needed to fully understand the dynamics and long-term effects of these treatments on the detention basin dynamics.

ACKNOWLEDGMENTS

The authors wish to thank Consorzio di Bonifica 3 Medio Valdarno for supporting this research.

The authors gratefully extend their heartfelt appreciation to Dr. Iacopo Manetti, the General Manager of Consorzio di Bonifica 3 Medio Valdarno, and Mr. Marco Bottino, the President of the same organization, for their support in facilitating access to resources and providing the necessary approvals.

BIBLIOGRAPHY

Acheampong, J.N., Gyamfi, C., Arthur, E., 2023. Impacts of retention basins on downstream flood peak attenuation in the Odaw River basin, Ghana. J. Hydrol. Reg. Stud. 47, 101364. https://doi.org/10.1016/J.EJRH.2023.101364

Adobati, F., Garda, E., 2020. Soil releasing as key to rethink water spaces in urban planning. City, Territ. Archit. 7, 1–16. https://doi.org/10.1186/S40410-020-00117-8/FIGURES/4

Blair, G.J., Lefroy, R.D., Lisle, L., 1995. Soil carbon fractions based on their degree of oxidation, and the development of a carbon management index for agricultural systems. Aust. J. Agric. Res. 46, 1459–1466. https://doi.org/10.1071/AR9951459

Cambardella, C.A., Elliott, E.T., 1992. Particulate Soil Organic-Matter Changes across a Grassland Cultivation Sequence. Soil Sci. Soc. Am. J. 56, 777–783. https://doi.org/10.2136/SSSAJ1992.03615995005600030017X

Cottney, P., Black, L., Williams, P., White, E., 2022. How Cover Crop Sowing Date Impacts upon Their Growth, Nutrient Assimilation and the Yield of the Subsequent Commercial Crop. Agronomy 12. https://doi.org/10.3390/AGRONOMY12020369

Davis, Mckenna, Naumann, S., Davis, M, Naumann, • S, 2017. Making the Case for Sustainable Urban Drainage Systems as a Nature-Based Solution to Urban Flooding. Theory Pract. Urban Sustain. Transitions 123–137. https://doi.org/10.1007/978-3-319-56091-5_8

Di Lena, F., Berardi, M., Masciale, R., Portoghese, I., 2023. Network dynamics for modelling artificial groundwater recharge by a cluster of infiltration basins. Hydrol. Process. 37, e14876. https://doi.org/10.1002/HYP.14876

Dondini, M., Martin, M., De Camillis, C., Uwizeye, A., Soussana, J.-F., Robinson, T., Steinfeld, H., 2023. Global assessment of soil carbon in grasslands – From current stock estimates to sequestration potential. Rome. https://doi.org/https://doi.org/10.4060/cc3981en

EEA, 2016. European water policies and human health — Combining reported environmental information. Luxembourg. https://doi.org/10.2800/821091

Emerson, C.H., Welty, C., Traver, R.G., 2005. Watershed-Scale Evaluation of a System of Storm Water Detention Basins. J. Hydrol. Eng. 10, 237–242. https://doi.org/10.1061/(ASCE)1084-0699(2005)10:3(237)/ASSET/3B60F889-4B60-4EFA-A8FA-5AE08ED-1A7EC/ASSETS/IMAGES/3.JPG

Emmerling-DiNovo, C., 1995. Stormwater Detention Basins and Residential Locational Decisions. JAWRA J. Am. Water Resour. Assoc. 31, 515–521. https://doi.org/10.1111/J.1752-1688.1995.TB04038.X

Fang, C., Song, X., Ye, J.S., Yuan, Z.Q., Agathokleous, E., Feng, Z., Li, F.M., 2023. Enhanced soil water recovery and crop yield following conversion of 9-year-old leguminous pastures into croplands. Agric. Water Manag. 279, 108189. https://doi.org/10.1016/J.AGWAT.2023.108189

Franzluebbers, A.J., Paine, L.K., Winsten, J.R., Krome, M., Sanderson, M.A., Ogles, K., Thompson, D., 2012. Well-managed grazing systems: A forgotten hero of conservation. J. Soil Water Conserv. 67, 100A-104A. https://doi.org/10.2489/JSWC.67.4.100A

Griffiths, J.A., 2017. Sustainable Urban Drainage, in: Encyclopedia of Sustainable Technologies. Elsevier, pp. 403–413. https://doi.org/10.1016/B978-0-12-409548-9.10203-9

Huber, H., Jacobs, E., Visser, E.J.W., 2009. Variation in flooding-induced morphological traits in natural populations of white clover (Trifolium repens) and their effects on plant performance during soil flooding. Ann. Bot. 103, 377. https://doi.org/10.1093/AOB/MCN149

Knight, W.E., 1985. Crimson Clover, in: Clover Science and Technology. John Wiley & Sons, Ltd, pp. 491–502. https://doi.org/10.2134/AGRONMONOGR25.C21

Lam, Q.D., Schmalz, B., Fohrer, N., 2011. The impact of agricultural Best Management Practices on water quality in a North German lowland catchment. Environ. Monit. Assess. 183, 351–379. https://doi.org/10.1007/S10661-011-1926-9/METRICS

Li, J., Yuan, X., Ge, L., Li, Q., Li, Z., Wang, L., Liu, Y., 2020. Rhizosphere effects promote soil aggregate stability and associated organic carbon sequestration in rocky areas of desertification. Agric. Ecosyst. Environ. 304, 107126. https://doi.org/10.1016/J.AGEE.2020.107126

Liu, B., Xie, G., Zhang, X., Zhao, Y., Yin, X., Cheng, C., 2015. Vegetation root system, soil erosion and eco-hydrology system: A review 271–279. https://doi.org/10.2991/IFEESM-15.2015.52

McPhillips, L., Goodale, C., Walter, M.T., 2018. Nutrient Leaching and Greenhouse Gas Emissions in Grassed Detention and Bioretention Stormwater Basins. J. Sustain. Water Built Environ. 4. https://doi.org/10.1061/JSWBAY.0000837

Otremba, K., Kozłowski, M., Tatuśko-Krygier, N., Pająk, M., Kołodziej, B., Bryk, M., 2021. Impact of alfalfa and NPK fertilization in agricultural reclamation on the transformation of Technosols in an area following lignite mining. L. Degrad. Dev. 32, 1179–1191. https://doi.org/10.1002/LDR.3781

Richards, L.A., Fireman, M., 1943. Pressure-plate Apparatus for Measuring Moisture Sorption and Transmission by Soils. Soil Sci. 56, 395–404. https://doi.org/10.1097/00010694-194312000-00001

Sañudo-Fontaneda, L.A., Roces-García, J., Coupe, S.J., Barrios-Crespo, E., Rey-Mahía, C., Álvarez-Rabanal, F.P., Lashford, C., 2020. Descriptive Analysis of the Performance of a Vegetated Swale through Long-Term Hydrological Monitoring: A Case Study from Coventry, UK. Water 2020, Vol. 12, Page 2781 12, 2781. https://doi.org/10.3390/W12102781

SARE Outreach, 2007. Managing Cover Crops Profitably, 3rd Edition - SARE [WWW Document]. URL https://www.sare.org/resources/managing-cover-crops-profitably-3rd-edition/ (accessed 7.6.23).

Schroer, W.F., Benitez-Nelson, C.R., Smith, E.M., Ziolkowski, L.A., 2018. Drivers of Sediment Accumulation and Nutrient Burial in Coastal Stormwater Detention Ponds, South Carolina, USA. Ecosystems 21, 1118–1138. https://doi.org/10.1007/S10021-017-0207-Z/TABLES/6

Sharior, S., McDonald, W., Parolari, A.J., 2019. Improved reliability of stormwater detention basin performance through water quality data-informed real-time control. J. Hydrol. 573, 422–431. https://doi.org/10.1016/J.JHYDROL.2019.03.012

Sharma, S., Kumar, S., Singh, A., 2023. Assessment of Green Infrastructure for sustainable urban water management. Environ. Dev. Sustain. https://doi.org/10.1007/S10668-023-03411-W

Stanley, D.W., 1996. Pollutant removal by a stormwater dry detention pond. Water Environ. Res. 68, 1076–1083. https://doi.org/10.2175/106143096X128072

Sveistrup, T.E., Haraldsen, T.K., 1997. Effects of soil compaction on root development of perennial grass leys in northern Norway. Grass Forage Sci. 52, 381–387. https://doi.org/10.1111/J.1365-2494.1997.TB02370.X

Vinther, F.P., 2006. Effects of cutting frequency on plant production, N-uptake and N2 fixation in above- and below-ground plant biomass of perennial ryegrass–white clover swards. Grass Forage Sci. 61, 154–163. https://doi.org/10.1111/J.1365-2494.2006.00519.X

White, C.M., Weil, R.R., 2011. Forage Radish Cover Crops Increase Soil Test Phosphorus Surrounding Radish Taproot Holes. Soil Sci. Soc. Am. J. 75, 121–130. https://doi.org/10.2136/SSSAJ2010.0095

Wissler, A.D., Hunt, W.F., McLaughlin, R.A., 2020. Hydrologic and water quality performance of two aging and unmaintained dry detention basins receiving highway stormwater runoff. J. Environ. Manage. 255, 109853. https://doi.org/10.1016/J.JENVMAN.2019.109853

Yang, Y., Tilman, D., Furey, G., Lehman, C., 2019. Soil carbon sequestration accelerated by restoration of grassland biodiversity. Nat. Commun. 2019 101 10, 1–7. https://doi.org/10.1038/s41467-019-08636-w

Zhu, G., Yong, L., Zhao, X., Liu, Y., Zhang, Z., Xu, Y., Sun, Z., Sang, L., Wang, L., 2022. Evaporation, infiltration and storage of soil water in different vegetation zones in the Qilian Mountains: a stable isotope perspective. Hydrol. Earth Syst. Sci. 26, 3771–3784. https://doi.org/10.5194/HESS-26-3771-2022