Differences of soil enzyme activities and their influencing factors under different flooding conditions in Yili Valley

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Background. Wetland is a special ecosystem formed by the interaction between land and water. Water is an important component of wetland. The change of moisture content will greatly affect the function and structure of wetland internal system.

Method. This study takes *Phragmites australis* wetland (long-term flooding), *Calamagrostis epigeios* wetland (seasonal flooding) and Ditch millet wetland (rarely flooded) in Yili Valley of Xinjiang as research objects. The changes of microbial biomass carbon and soil physical and chemical properties in wetlands were compared, and the correlation between soil basic physical and chemical properties, microbial biomass carbon and the enzyme activity (soil sucrase, catalase, amylase and urease) were analyzed by the redundancy analysis. The differences of soil enzyme activities and its influencing factors under different flooding conditions in Yili Valley were studied.

Result. The results were as follows:(1) the activities of sucrase and amylase in rarely flooded wetlands and seasonally flooded wetlands were significantly higher than those in long-term flooded wetlands; there were no significant difference in catalase activities between rarely flooded wetlands and long-term flooded wetlands; and the catalase activities were highest in seasonal flooded wetlands. (2)The activities of sucrase in seasonally flooded wetlands were 4.91% lower than those in rarely flooded wetlands, and the activities of sucrase in long-term flooded wetlands were 46.04% lower than those in seasonally flooded wetlands; as far as catalase activities in 30-40 cm soil layer is concerned, the rarely flooded wetland was significantly reduced by 18.45% compared with the seasonal flooded wetland, and the seasonal flooding was significantly reduced by 33.20% compared with long-term flooding wetland.(3) Redundancy analysis showed that soil organic carbon, dissolved organic carbon, total phosphorus and soil microbial biomass carbon had significant effects on soil enzyme activity ($p < 0.05$), while ammonium nitrogen and easily oxidized organic carbon had no significant effects on soil enzyme activity; the correlation between soil organic carbon and the sucrase activity, total phosphorus and the catalase activity was the strongest; soil organic carbon was positively correlated with sucrase, urease and amylase activity, but had a slight influence on catalase activity; dissolved organic carbon had a positive correlation with four soil enzyme activities. It has been showed that different flooding conditions can affect the activity of soil enzymes in wetlands. Properly changing the degree of flooding will increase the content of soil fertility factors such as organic carbon and total phosphorus, and enhance the activity of enzymes.

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Abstract

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Keywords: Yili valley; wetland; flooding conditions; differences in enzyme activity; microbial biomass carbon.

Introduction

Wetlands are ecological systems with unique biological characteristics, soil and hydrology (Jenkinson DS., 1991). Its soil is immersed in water, and there are many different kinds of animals, plants and microorganisms with wetland characteristics. So wetland is not only a natural landscape with affluent ecological diversity in nature, but also an important environment for human survival (Lu Xiaoyi, 2004; Garken Jumaken ette et al., 2018). According to research, water is an important environmental factor, which plays an important role in maintaining the stability of structure and function in wetland ecosystem and affecting the biogeochemical cycle in wetland (Yu Xianmin, 1999). Therefore, in recent years, the effects of water on wetland soil factors and plant growth and reproduction have been widely studied. Studies have found that plants can adapt to the stress of different flooding environments by changing their height, the stem diameter, and population density (Tan Xuejie et al., 2006). Compared with natural exposed soil, the submerged environment promoted the growth and activity of soil microorganisms, and enhanced the activity of the soil enzyme (liu Yajun et al., 2017). It can be seen that different water conditions have a certain relationship with the growth and reproduction of wetland plants, and exert a profound influence.

The Yili Valley belongs to the arid inland river basin wetland, and its total wetland area is about 2.4×105 km2. There are many types and wide distribution of wetlands in the valley. Due to the natural environmental conditions and special geographical location, the Yili Valley has created a wetland landscape with abundant water resources and rich species, which is a key biodiversity area in China (Galkenjumaken Ett et al., 2014). In recent years, owing to human over-reclamation and the influence of natural factors, the degradation of most wetlands has become more and more serious, especially the fluctuation of water content. However, the change of water conditions will have a great impact on the process of soil carbon accumulation and decomposition (Wan Zhongmei, 2009). Besides, with the degradation of wetlands, the content of soil organic carbon decreased significantly, and the activity of soil enzymes also changed (Chen Yanxin, 2018). At present, there are few reports on this aspect in the Ili Valley. This study takes Yili valley wetland with different flooding degrees as the research object. It analyzes the change of soil enzyme activity of wetland under different flooding conditions, and it discusses the relationship between water and soil factors affecting the enzyme activity, which provided a theoretical basis for the study of the mechanism of soil water impact on Soil and wetland protection in Yili Valley.

Materials & Methods

Experimental site

Yili River Valley is located in the northwest direction of Tian shan Mountains in Xinjiang, surrounded by high mountains in the north, east and south, showing the natural geographical features of "three mountains with two valleys". It enjoys the reputation of "wet island in the western region" and "jiangnan beyond the Great Wall", and is the main transportation route of the ancient Silk Road. In addition, the Yili Valley is situated at 80°09′E—84°56′E in the east longitude and 42°14′N—44°50′N in the North latitude, with an altitude of 530—1000 m and an area of 56,400 km2. Because of the excellent natural environment and unique geographical position of the Yili Valley, the water resources and mineral resources are quite abundant, and there are various species in the valley. The climate is warm and humid, belonging to the temperate continental climate, with a great temperature difference between day and night. The annual average temperature is 10.4^{o}C, and the annual average sunshine hours are 2700—3000 hours. The annual average precipitation is about 417.6 mm, mainly concentrated in spring and summer, which is 60%~70% of the annual precipitation. With the increase of altitude, the precipitation can be as high as 600 mm in mountainous areas, and the annual average evaporation is about 1260~1900 mm. The Yili Valley is the wettest climate area in Xinjiang. Yili Valley mainly distributes forest, grassland, meadow and other vegetation types, among which the grassland soil type is mainly sierozem, the plant species are mostly perennial and cold-resistant gramineae. The forest soil is mainly grayish brown forest soil, and most of the tree species are Xinjiang spruce, Xueling spruce, Miye poplar et al. (Yang Yuhai et al., 2010).

Sampling point setting and field sample collection

The sampling sites were selected in Yili River floodplain wetland and Liberate Bridge National Wetland Park in Zhaosu County, as shown in figure 1. Firstly, three wetland soils with different flooding degrees were collected from Ditch millet wetland (DMW), Calamagrostis epigeios wetland (CEW) and Phragmites australis wetland (PAW). Among them, DMW belongs to rarely flooded habitat, CEW belongs to seasonal flooded habitat. The flooding period of one year is about 2-3 months, while PAW belongs to long-term flooded habitat, and the flooding period of one year is about 10 months.

Three 1 m×1 m plots were randomly set up in the selected sample plots. In each wetland type, plant and litter on the surface of the plot were removed with a shovel to obtain three random soil profiles, and then soil samples of 0-10, 10-20, 20-30, 30-40 cm were collected from bottom to top respectively. A total of 36 soil samples was collected from three wetland types. The samples were sealed and brought back to the laboratory in plastic bags, and then the samples were divided into two soil samples, one of which was stored in a sealed bag and stored in a refrigerator for the determination of soil microbial biomass carbon and soil enzyme activity, and the other soil sample was put into the bag for the determination of soil basic physical and chemical properties after air drying, grinding and 0.15 mm sieving.

Figure.1

Research method

(1) Soil basic physical and chemical properties

The content of soil organic carbon (SOC) can be calculated by heating and boiling with potassium dichromate and then titrated with ferrous sulfate solution. The soil samples were boiled with perchloric acid and sulfuric acid, and then the total phosphorus (TP) content in soil was determined by colorimetry (Lu Rukun, 2000); the content of easily oxidized organic carbon (EOC) in soil can be obtained by putting potassium permanganate solution into soil sample and then colorimetric method (Blair et al., 1995); the content of dissolved organic carbon (DOC) was determined by colorimetry (Zhan Xinhua et al., 2002). It is known that NH4+ in soil leaching solution reacts with hypochlorite and phenol in strong alkaline medium to form water-soluble dye indophenol blue. The content of ammonium nitrogen (NH4+-N) can be determined by colorimetry (Zhao Jie et al., 2011).

(2) Soil microbial biomass carbon

In the determination of microbial biomass carbon (MBC) content in wetland soil, firstly, the fumigated and unfumigated soils were extracted with potassium sulfate solution. Next, the content of organic carbon in the two extracts was determined by soluble carbon-nitrogen analyzer. Finally, soil microbial biomass carbon can be calculated by dividing the difference of carbon content by the conversion coefficient (Yu Shu et al., 2007).

(3) Soil enzyme activity

Because the enzymatic product ammonia reacts with phenol sodium hypochlorite to form blue indigo phenol, the activity of urease can be measured by colorimetry using urea as matrix (Ding Lei et al., 2011); adding hydrogen peroxide solution to the soil sample and titrating excess hydrogen peroxide with potassium permanganate solution can calculate the consumption of hydrogen peroxide solution and determine the activity of catalase (Guan Songyin, 1986). The reducing sugar produced by enzyme hydrolysis of sucrose and 3, 5-dinitrosalicylic acid will form orange solution, and the sucrase activity can be determined by colorimetry (Xiao Ye, 2015); the amylase activity was measured by colorimetry (Zhou Likai et al., 1980) , and soil amylase activity was determined by measuring the amount of glucose produced during hydrolysis.

Statistical analysis

Excel 2010, SPSS 19.0 and CANOCO 4.5 software were used to analyze the integrated data. One-way ANOVA method was used to analyze the differences of soil microbial biomass carbon, soil physical and chemical properties and soil enzyme activities in different flooding degrees, and Duncun table was used to analyze the significance of the existing data. Two-way ANOVA method was used to analyze the effects of flooding degree, the soil depth and their interaction on soil microbial biomass carbon, soil basic physical and chemical properties and soil enzyme activities.Using RDA sorting, the effects of soil physicochemical properties and microbial biomass carbon on soil enzyme activity were analyzed. It should be noted that the factors significantly related to soil enzyme activities need to be selected by Monte Carlo analysis before the redundancy analysis. The T-value double sequence diagram of CANOCO 4.5 can also be used to analyze the single environmental factor affecting soil enzyme activity.

Results

Soil basic physical and chemical properties under different flooding conditions

Under the same flooding conditions, the basic physical and chemical properties of different soil thickness are different (Table 1). Except for the PAW, the content of soil organic carbon in the DMW and CEW was obviously different among the three soil layers. The content of the SOC of the 0-10 cm soil layer of the CEW was significantly higher than that in 10-20cm,20-30cm and 30-40cm soil layers, while that in the 0-10cm and the 10-20cm soil layer of the DMW was significantly higher than that in the 20-30cm and 30-40cm soil layers. For total phosphorus (TP), there were no significant differences between the DMW and PAW in the three soil layers, and the TP content of the CEW decreased gradually with the increase of soil depth. In terms of easily oxidized organic carbon (EOC), there were no significant differences between the CEW and PAW in the three soil layers. The EOC content in 0-10 cm soil layer was the highest, while that in 30-40 cm soil layer was the lowest in the DMW. The content of DOC in wetlands under three flooding conditions showed a decreasing trend with the increase of soil depth.

Two-way ANOVA shows that except NH4+-N, different flooding conditions and soil layers have significant effects on the soil basic physical and chemical properties (Table 2). Among them, the effect of flooding conditions on the basic physical and chemical properties of soil was greater than that of soil depth. Only the *F* value of TP in different soil depths was higher than that of *F* value in different flooding conditions, indicating that different soil conditions had a stronger effect on TP content. At the same time, TP and SOC are also significantly affected by the interaction between different flooding conditions and the soil depth, but the interaction has no significant effect on EOC, DOC and NH4+-N. Different flooding conditions in the same soil layer have different effects on the soil basic physical and chemical properties (Table 1). By comparing the average values in (Table 1), it can be found that the contents of TP, DOC and NH4+-N in wetlands with different flooding conditions are PAW > CEW > DMW; the EOC content in wetlands with different flooding conditions is DMW > CEW > PAW. And the SOC content in the CEW and DMW was significantly higher than that in the PAW.

Table 1

Table 2

Soil microbial biomass carbon (MBC) under different flooding conditions

There were differences in soil microbial biomass carbon at different soil depths under the same flooding conditions (Fig. 2). The MBC content in 0-10 cm and 10-20 cm soil layers of the DMW and the CEW was significantly higher than that in 20-30 cm and 30-40 cm soil layers; the MBC content in 0-10 cm soil layers of the PAW was significantly higher than that in 30-40 cm soil layers. The MBC in wetlands under three flooding conditions showed a decreasing trend with the increase of soil depth.

The results of Two-way ANOVA showed that different flooding conditions and soil layers had significant effects on soil microbial biomass carbon, and the interaction between them also significantly affected soil microbial biomass carbon (Table 3). The content of MBC decreased gradually with the increase of flooding degree. The *F* value of MBC in different soil layers is far greater than that in different flooding conditions, which indicates that different soil depth has a deeper impact on the MBC than the flooding condition. The soil depth is indeed one of the important factors affecting the change of MBC content.

Figure.2

Table 3

Differences of soil enzyme activities in wetlands under different flooding conditions

The activities of enzymes in different soil layers are different (Table 4). For the sucrose, the sucrase activity of wetlands with three flooding degrees decreased significantly with the increase of soil depth. Among them, the sucrase activity of 0-10 cm and 10-20 cm soil layers in the DMW and CEW was significantly higher than that of 20-30 cm and 30-40 cm soil layers; the sucrase activity of 0-10 cm soil layers in the PAW was significantly higher than that of 10-20 cm, 20-30 cm and 30-40 cm soil layers. There was no significant difference in the catalase activity between the DMW and PAW, but the catalase activity decreased with the increase of soil depth in the CEW. The amylase activity of the different soil layers was not significantly different in the PAW; the amylase activity in the DMW decreased at first and then increased with the increase of soil depth; the amylase activity in the CEW decreased with the increase of soil depth, and the amylase activity in 0-10 cm soil layer was the strongest. There was no significant difference in the urease activity among the three wetlands of flooding conditions.

According to Two-way ANOVA of flooding conditions and soil depth on soil enzyme activity (Table 5), except the sucrase, the soil depth had no significant effect on other soil enzyme activities. Different flooding conditions have significant effects on the activities of the sucrase and amylase. The *F* values of sucrase, amylase and urease activities in different flooding conditions were higher than those in different soil depths, which indicated that the effects of different flooding conditions on soil enzyme activities were greater than those at different soil depths, and flooding conditions were one of the important factors affecting soil enzyme activities.

According to the average comparison of table 4), the activities of sucrase and urease decreased gradually with the increase of flooding degree. Among them, the activities of sucrase in the CEW significantly decreased by 4.91% compared with the DMW, and the activities of sucrase in the PAW significantly decreased by 46.04% compared with the CEW. Although the flooding conditions had no significant effect on the catalase activity in 0-10 cm, 10-20 cm and 20-30 cm soil layers, the effects of different flooding conditions were extremely significant on the catalase activity in 30-40 cm soil layers. As far as the catalase activity in 30-40 cm soil layers was concerned, the DMW was significantly reduced by 18.45% compared with the CEW, and the CEW was significantly reduced by 33.20% compared with the PAW. The activities of sucrase and amylase in the DMW and CEW were significantly higher than those in the PAW, while the catalase activity was the highest in the CEW.

Table 4

Table 5

Correlation analysis of soil physical and chemical factors, microbial biomass carbon and soil enzyme activity

Redundancy analysis (RDA) was used to analyze the relationship between soil physical and chemical factors, microbial biomass carbon and soil enzyme activities in wetlands under different flooding conditions (Fig. 3). The results showed that the first two sorting axis together explained 52.6% of the change of soil enzyme activity, of which the contribution rate of the first sorting axis (RDA 1) was 47.6% and that of the second sorting axis (RDA 2) was 5%. This indicated that most of the information between soil physical and chemical factors, microbial biomass carbon and soil enzyme activities could be reflected by these two axes, and was mainly determined by the first sorting axis. According to the redundancy analysis (Fig. 3), the arrow lines of SOC, DOC and TP are the longest, which together with the importance sorting results of Table 6 shows that SOC, DOC, TP and MBC can explain the changes of soil enzyme activities very well. The angles are small and the directions are the same between SOC and the sucrose, TP and catalase, which indicates that there are significant positive effects between SOC and the sucrase activity, TP and the catalase activity. SOC may be the dominant factor affecting the sucrase activity in Yili Valley, and TP is an important factor affecting the catalase activity.

A single environmental factor analysis was carried out for the environmental factors affecting soil enzyme activity by using the T-value double-sequence diagram of CANOCO 4.5 (Fig. 4). As shown in (Fig. 4A), the arrows of sucrase, urease and amylase all fall on the solid line circle of SOC, indicating that SOC has a significant positive correlation with the sucrase, urease and amylase activities, that is to say, the activities of sucrase, urease and amylase increase with the increase of SOC content. The arrow of catalase passes through the solid line circle of SOC, which shows that there is a positive correlation between SOC and CAT. (Fig. 4B) shows that four soil enzymes pass through the solid line circle of DOC, which indicates that there are a positive correlation between DOC and the activities of the four soil enzymes. (Fig. 4C) shows that most of the four soil enzymes fall outside the solid line circle and dotted line circle of NH4+-N, indicating that there was no significant relationship between NH4+-N and the activities of the four soil enzymes.

Different environmental factors have different effects on soil enzyme activity (Table 6). The effects of different environmental factors on soil enzyme activities were SOC > DOC > TP > MBC > NH4+-N > EOC. Among them, the effects of SOC, DOC, TP and MBC were significant on soil enzyme activity, especially the effect of SOC on soil enzyme activity was extremely significant. And SOC had the greatest effect on soil enzyme activity, accounting for 45% of the total explanations ($F = 27.82$, $p < 0.01$). The effects of NH4+-N and EOC were not significant on soil enzyme activity ($p > 0.05$).

Figure.3

Table 6

Figure.4

Discussion

Effects of different flooding conditions on soil enzyme activities

Soil enzyme is a kind of proteins with special catalytic ability, which mainly comes from the decomposition of soil microorganisms, animal and plant secretions and residues (Guan Songyin, 1986). Soil moisture has a significant correlation with soil microbial activity and type, and different water conditions will directly affect the existence and activity of soil enzyme activity (Wan Zhongmei, 2005). This indicates that the degree of flooding did significantly affect the activity of soil enzymes. The results showed that the activities of sucrase and amylase were closely related to the degree of flooding, and decreased gradually with the increase of flooding degree (Wan Zhongmei, 2008; Zhou Xiaoming, 2018), which was consistent with the effect of flooding degree on sucrase and amylase activities, and the activities of sucrase and amylase in the rarely flooded and seasonal flooded wetlands were significantly higher than those in the long-term flooded wetlands. This phenomenon may be due to the increase of soil moisture, which leads to the decrease of soil permeability, restricts the growth of soil microorganisms, greatly slows down the decomposition of soil humus, and thus reduces the activity of soil enzymes. It is also possible that increasing soil water will affect the availability of oxygen in an environment with abundant substrates and wet soils, then affecting the growth of soil microorganisms and plant roots, resulting in a decrease in enzyme activity (Guenet et al., 2012).

In this study, although the correlation between sucrase and urease activity and flooding conditions was not significant, the urease activity of rarely flooded wetlands was much higher than that of long-term flooded wetlands as a whole, which was similar to the results of other researchers (Xu Jingjing, 2017). However, except that the sucrase activity of 30~40 soil layer decreased significantly with the increase of water content, the sucrase activity in other soil layers did not change significantly with the increase of water content, which was consistent with that the catalase activity did not change significantly with the water gradient in non-rhizosphere soil(Tian Youhua, 2012). This phenomenon may be that the deeper the soil layer and the less water it contains, the more beneficial it is to increase the content of soil organic matter, the survival of soil microorganisms and the activity of enzymes.

Effects of microbial biomass carbon and soil physical and chemical properties on soil enzyme activities

Soil microbial biomass is an essential indicator for detecting soil quality. On the one hand, it can indicate the number of microorganisms involved in energy flow, the material cycle and organic matter transformation in soil (Powlson D S, Brookes P C Christensen B T., 1987). On the other hand, it reflects the process of nutrient transfer and transport and the energy cycle in soil (Doran JW., 1994). Previous studies have shown that the carbon contents of soil microbial biomass and soil enzyme activities in the treatment of underwater are higher than those in the treatment of natural bareness (Liu Yajun et al., 2017). (Table 6) shows that soil microbial biomass carbon is significantly correlated with soil enzyme activity, which is closely related to soil microbial biomass carbon and soil enzyme activity obtained by the predecessors. With the change of water gradient, soil enzyme activity is positively correlated with microbial biomass carbon (Wan Zhongmei et al., 2008).

There was a certain relationship between soil organic carbon and soil enzyme activity (Wan Zhongmei et al., 2009). It can be seen form Figure. 3 that soil organic carbon was significantly positively correlated with sucrase, urease and amylase activities, and the correlation was strongest with the sucrase activity. There was a positive correlation between soil easily oxidized organic carbon and the activities of sucrase, urease, catalase and amylase, which was consistent with previous research results (Xiao Ye et al., 2015). In addition, total phosphorus had significant positive effects on four soil enzymes, and had the strongest correlation with the catalase activity, which could better explain the change of catalase activity, indicating that total phosphorus was the main factor affecting urease, catalase and sucrase activity through direct or indirect effects (Liu Guangshen et al., 2003).

Conclusions

The results of the experiment showed that most of the wetland soil enzymes in Yili Valley decreased with the increase of flooding degree under different flooding conditions. The activities of sucrase and urease in the three flooded wetlands were as follows : rarely flooded wetlands > seasonal flooded wetlands > long-term flooded wetlands; the activities of sucrase and amylase in rarely flooded wetlands and seasonal flooded wetlands were significantly higher than those in long-term flooded wetlands; while the activities of catalase were the highest in seasonal flooded wetlands. It can be seen that flooded condition is indeed one of the important factors affecting the enzyme activity.

Soil organic carbon (SOC), dissolved organic carbon (DOC) and total phosphorus (TP) had significant effects on soil enzyme activity in wetland, while ammonium nitrogen (NH4+-N), easily oxidized organic carbon (EOC) and microbial biomass carbon (MBC) had no significant effects on soil enzyme activity. Among them, the correlation between soil organic carbon and the sucrase activity, total phosphorus and the catalase activity were the strongest; soil organic carbon had a significant positive correlation with sucrase, urease and amylase activity, but had a slight influence on catalase activity; dissolved organic carbon had a positive correlation with four soil enzyme activities. It can be seen that the activity of soil enzyme in wetland is closely related to soil organic carbon and dissolved organic carbon. Appropriate increase of soil organic carbon content can enhance the activity of soil enzyme.

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Figure Interpretation

Figure.1

Diagram of wetland sampling point in Yili Valley.

DMW: Ditch millet wetland; CEW: Calamagrostis epigeios wetland; PAW: Phragmites australis wetland

Figure.2

Soil microbial biomass carbon content in wetland soil of different layers under different flooding conditions.

Figure.3

Redundancy analysis of soil physical and chemical indexes, microbial biomass carbon and soil enzyme activity.

The quadrant of arrow in the figure represents the positive and negative correlation between different factors and the sorting axis, the hollow arrow represents several soil enzymes, the solid arrow represents environmental variables, and the cosine value of corresponding angle represents the correlation between environmental variables and soil enzymes. With the smaller the cosine value, the greater the correlation. Solid line represents the factors significantly related to the soil enzyme activity ($p < 0.05$).

Figure.4

The T-value for a single factor influencing varied of soil enzyme activities in wetland.

The quadrant of the arrow in the figure represents the positive and negative correlation between different factors and the sorting axis. The arrow represents several soil enzymes, and the solid triangle represents environmental variables.

Table 1 (on next page)

Soilbasic physical and chemical properties of different soil thickness underdifferent flooding conditions.

The values are average (standard error). The different letters of the same column data represent significant differences among different soil layers of the same wetland ($p < 0.05$). Table 4 is the same.

Table 1

Soil basic physical and chemical properties of different soil thickness under different flooding conditions.

Wetland Type	Soil Layer (cm)	SOC ($g\bullet kg^{-1}$)	TP ($g\bullet kg^{-1}$)	EOC ($mg \bullet kg^{-1}$)	DOC ($mg \bullet kg^{-1}$)	NH_4^+-N ($mg \bullet kg^{-1}$)
DMW	0-10	27.17 a (7.02)	8.15 a (0.57)	7.39 a (0.95)	219.30 a (3.53)	6.99 a (0.25)
	10-20	16.43 ab (6.42)	7.35 a (0.50)	4.11 b (0.85)	199.72 ab (5.87)	6.68 a (0.34)
	20-30	6.57 b (2.29)	6.61 a (0.67)	4.63 b (0.38)	173.28 b (6.42)	6.59 a (0.31)
	30-40	5.79 b (1.98)	6.29 a (0.50)	3.48 b (0.04)	145.87 c (11.29)	6.48 a (0.29)
CEW	0-10	31.37 a (11.01)	8.30 a (0.06)	6.15 a (1.68)	241.81 a (4.27)	7.20 a (0.20)
	10-20	15.06 ab (6.89)	7.85 ab (0.36)	4.09 a (0.20)	214.40 ab (2.94)	6.95 a (0.10)
	20-30	11.18 ab (7.50)	7.23 b (0.42)	4.52 a (0.56)	181.11 b (6.42)	6.78 a (0.08)
	30-40	3.32 b (0.29)	7.20 b (0.23)	3.25 a (1.33)	140.00 c (20.51)	6.76 a (0.08)
PAW	0-10	11.66 a (5.21)	8.72 a (0.64)	5.07 a (3.00)	256.50 a (36.38)	7.22 a (0.25)
	10-20	4.49 a (2.26)	8.39 a (0.56)	3.68 a (0.55)	237.90 a (38.33)	7.02 a (0.15)
	20-30	1.66 a (0.49)	7.88 a (0.88)	3.15 a (0.79)	206.57 a (33.46)	6.97 a (0.24)
	30-40	1.67 a (0.88)	7.82 a (0.47)	3.02 a (2.07)	158.60 a (22.17)	6.84 a (0.32)

The values are average (standard error). The different letters of the same column data represent significant differences among different soil layers of the same wetland ($p < 0.05$). Table 4 is the same.

Table 2(on next page)

A two-way ANOVA for theeffects of different flooding conditions and soil layers on soil basicphysicochemical properties .

Table 2

A two-way ANOVA for the effects of different flooding conditions and soil layers on soil basic physicochemical properties.

Influence Factor		SOC ($g \bullet kg^{-1}$)	TP ($g \bullet kg^{-1}$)	EOC ($mg \bullet kg^{-1}$)	DOC ($mg \bullet kg^{-1}$)	NH_4^+-N ($mg \bullet kg^{-1}$)
Soil Layer	*F*	4.29	4.40	0.50	2.02	1.30
	P	0.03	0.00	0.00	0.00	0.29
Flooding Conditions	*F*	7.70	3.38	1.72	10.87	3.06
	P	0.00	0.02	0.01	0.00	0.05
Interaction	*F*	0.55	0.34	0.45	0.13	0.28
	P	0.03	0.02	0.84	0.99	0.94

Table 3(on next page)

A two-way ANOVA for theeffects of different flooding conditions and different soil layers on soilmicrobial biomass carbon .

Table 3

A two-way ANOVA for the effects of different flooding conditions and different soil layers on soil microbial biomass carbon.

Influence Factor		MBC
Soil Layer	*F*	2192.83
	P	0.00
Flooding Conditions	*F*	465.36
	P	0.00
Interaction	*F*	75.75
	P	0.00

Table 4(on next page)

Soi lenzyme activities of different soil thickness under different floodingconditions .

Table 4

Soil enzyme activities of different soil thickness under different flooding conditions.

Wetland Type	Soil Layer (cm)	Sucrase (mg·(g·24h)-1)	Catalase (mg/g)	Amylase (mgC6H12O6/(g*h))	Urease (mg/g)
DMW	0-10	1.57 a (0.27)	1.72 a (0.51)	14.52 a (0.22)	23.91 a (10.63)
	10-20	1.43 a (0.31)	1.90 a (0.30)	6.60 b (0.23)	13.74 a (7.38)
	20-30	0.93 ab (0.16)	1.91 a (0.26)	5.75 b (0.51)	12.01 a (7.01)
	30-40	0.47 b (0.08)	2.16 a (0.05)	6.47 b (0.53)	5.86 a (2.62)
CEW	0-10	2.19 a (0.24)	2.10 a (0.02)	13.29 a (3.41)	20.04 a (12.13)
	10-20	1.16 b (0.36)	2.03 a (0.06)	8.76 ab (2.53)	12.98 a (7.36)
	20-30	0.44 c (0.03)	1.96 a (0.05)	5.84 b (0.24)	7.96 a (2.61)
	30-40	0.40 c (0.03)	1.76 b (0.04)	5.83 b (0.59)	7.23 a (2.43)
PAW	0-10	1.21 a (0.38)	1.97 a (0.24)	10.45 a (3.27)	7.81 a (2.62)
	10-20	0.39 b (0.03)	1.92 a (0.25)	6.17 a (0.81)	6.10 a (2.28)
	20-30	0.34 b (0.02)	1.72 a (0.30)	6.21 a (0.26)	4.74 a (2.41)
	30-40	0.32 b (0.02)	1.17 a (0.40)	5.92 a (0.68)	6.86 a (3.10)

Table 5(on next page)

Atwo-way ANOVA for the effects of different flooding conditions and soil layerson soil enzyme activities.

Table 5

A two-way ANOVA for the effects of different flooding conditions and soil layers on soil enzyme activities.

Influence Factor		Sucrase	Catalase	Amylase	Urease
Soil Layer	*F*	7.78	1.25	0.74	1.58
	P	0.03	0.30	0.49	0.23
Flooding Conditions	*F*	21.08	0.60	12.13	1.69
	P	0.00	0.62	0.00	0.20
Interaction	*F*	2.18	1.11	0.59	0.35
	P	0.04	0.38	0.74	0.90

Table 6 (on next page)

Significance rank andsignificance test of soil physicochemical factors and microbial biomass carbonin explanation .

Table 6

Significance rank and significance test of soil physicochemical factors and microbial biomass carbon in explanation.

environmental Factor	Sorting of Importance	Degree of Interpretation (%)	Importance (*F* value)	Significance (*P* value)
SOC	1	45	27.824	0.002
DOC	2	13.3	5.209	0.012
TP	3	8.9	3.337	0.032
MBC	4	5.1	2.728	0.050
NH_4^+-N	5	8.5	3.139	0.114
EOC	6	4.7	1.284	0.296

Figure 1

Diagram of wetland samplingpoint in Yili Valley.

DMW: Ditch millet wetland; CEW: Calamagrostis epigeios wetland; PAW: Phragmites australis wetland

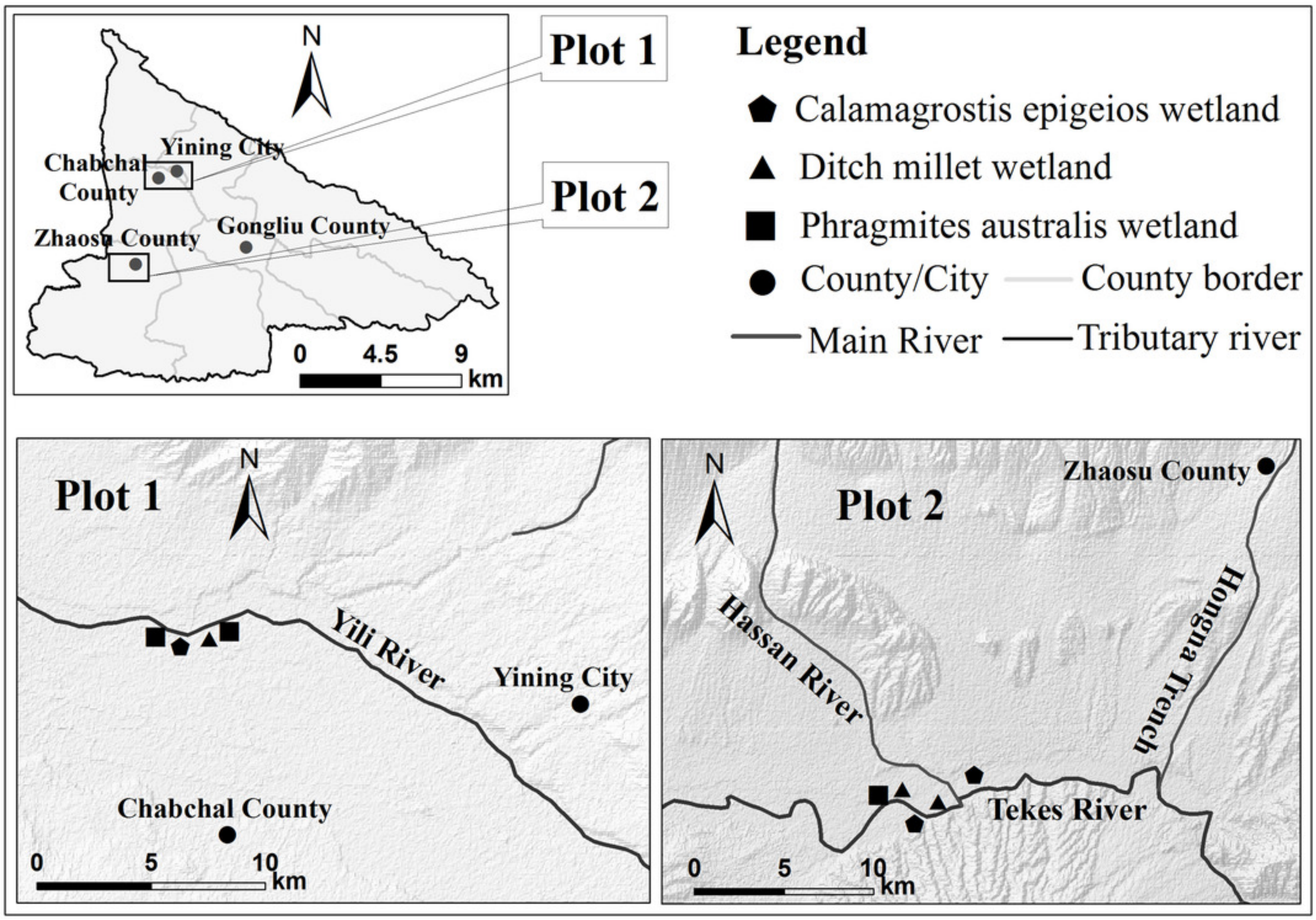

Figure 2

Soil microbial biomasscarbon content in wetland soil of different layers under different floodingconditions.

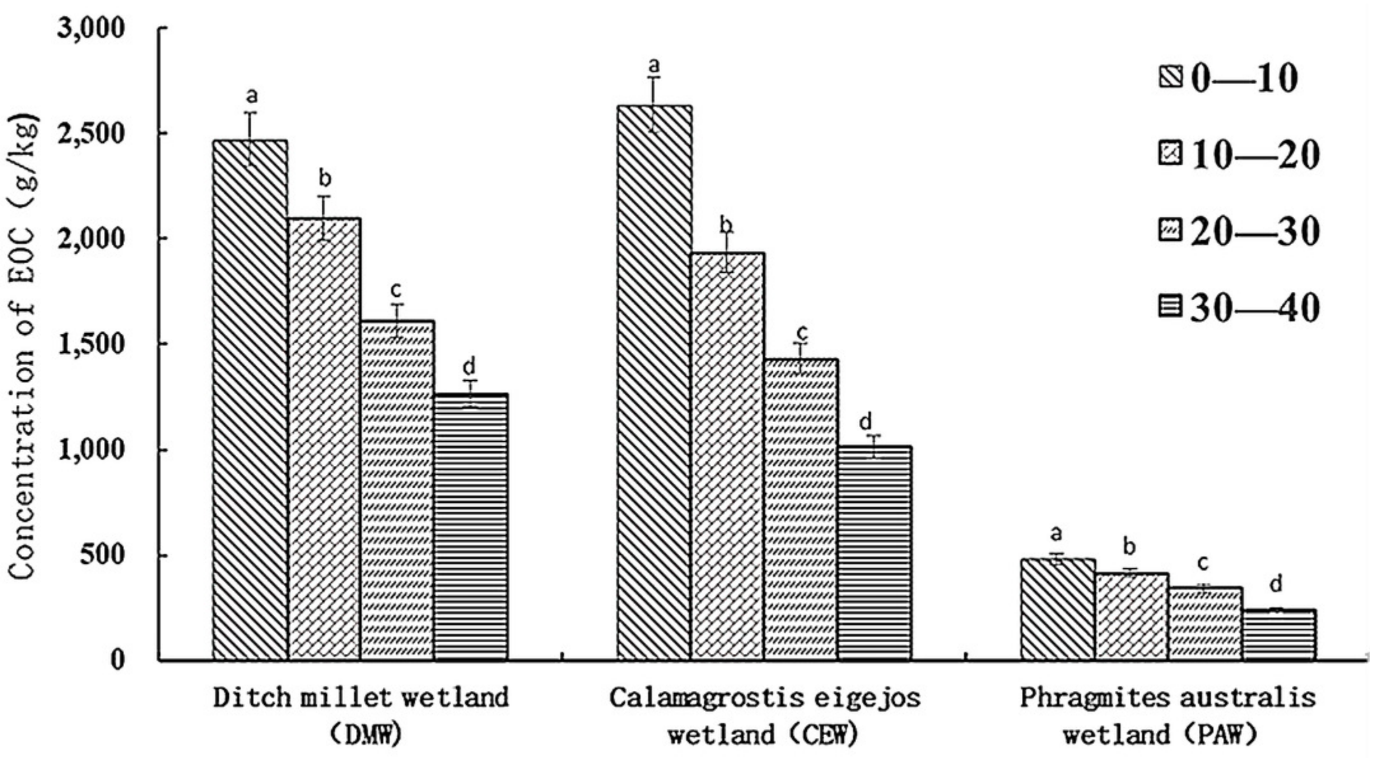

Figure 3

Redundancy analysis ofsoil physical and chemical indexes, microbial biomass carbon and soil enzymeactivity.

The quadrant of arrow in the figure represents the positive and negative correlation between different factors and the sorting axis, the hollow arrow represents several soil enzymes, the solid arrow represents environmental variables, and the cosine value of corresponding angle represents the correlation between environmental variables and soil enzymes. With the smaller the cosine value, the greater the correlation. Solid line represents the factors significantly related to the soil enzyme activity ($p < 0.05$).

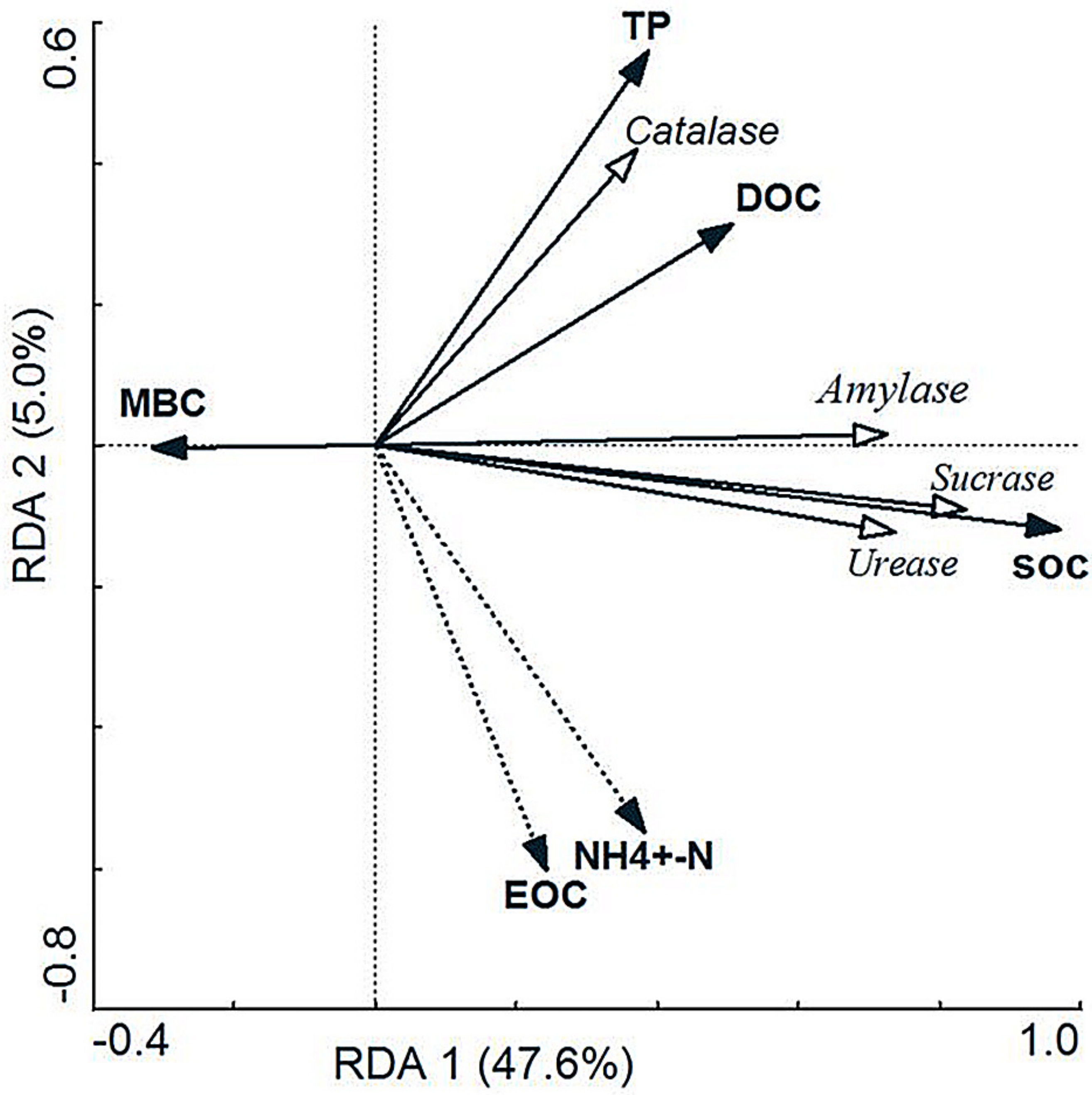
TP
Catalase
DOC
Amylase
MBC
Sucrase
Urease
SOC
NH4+-N
EOC
0.6
-0.8
RDA 2 (5.0%)
-0.4
1.0
RDA 1 (47.6%)

Figure 4

The T-value for a singlefactor influencing varied of soil enzyme activities in wetland.

The quadrant of the arrow in the figure represents the positive and negative correlation between different factors and the sorting axis. The arrow represents several soil enzymes, and the solid triangle represents environmental variables.

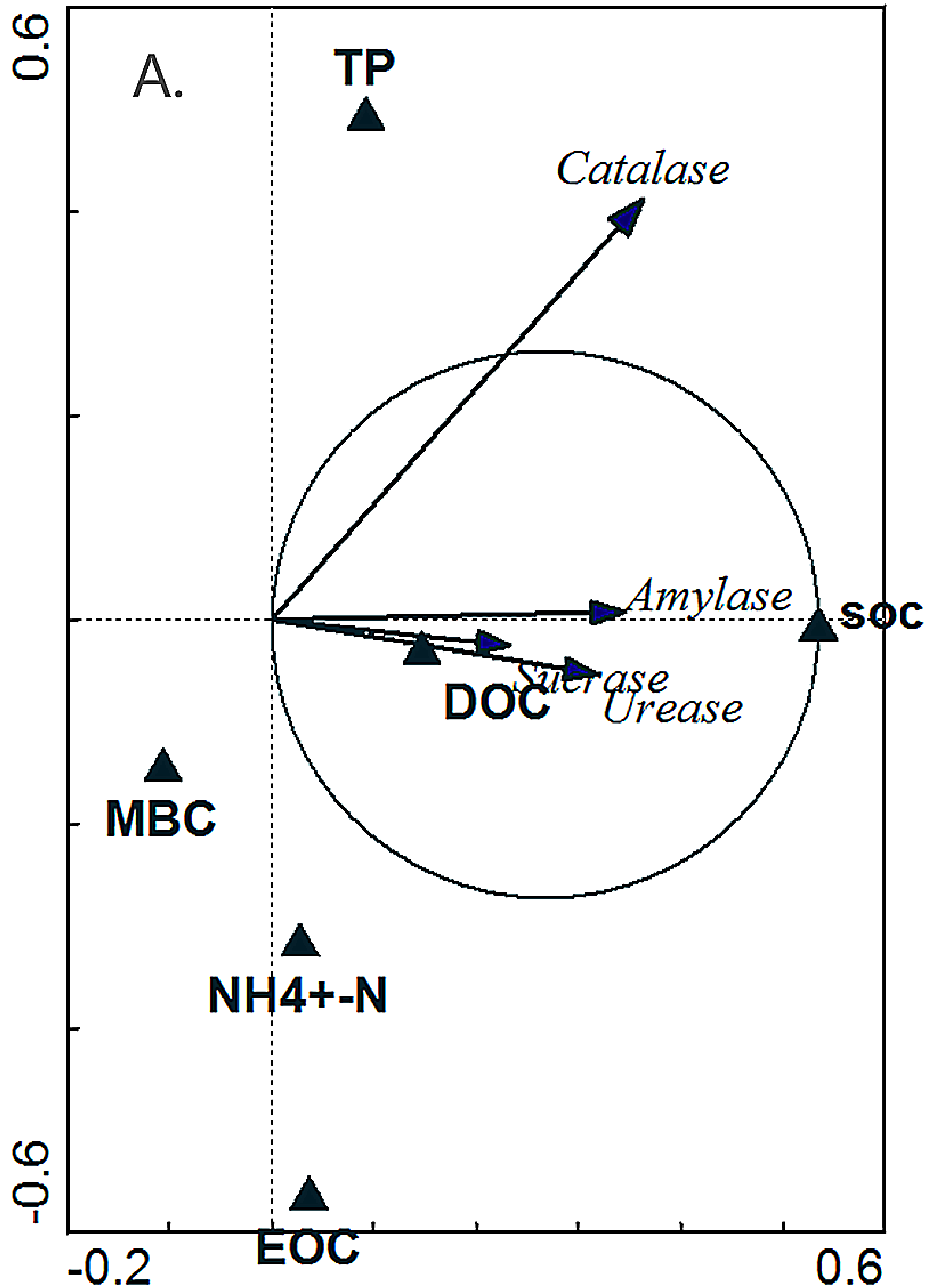
A.
TP
Catalase
Amylase
SOC
Sucrase
DOC
Urease
MBC
NH4+-N
EOC
0.6
-0.6
-0.2
0.6

Figure 5

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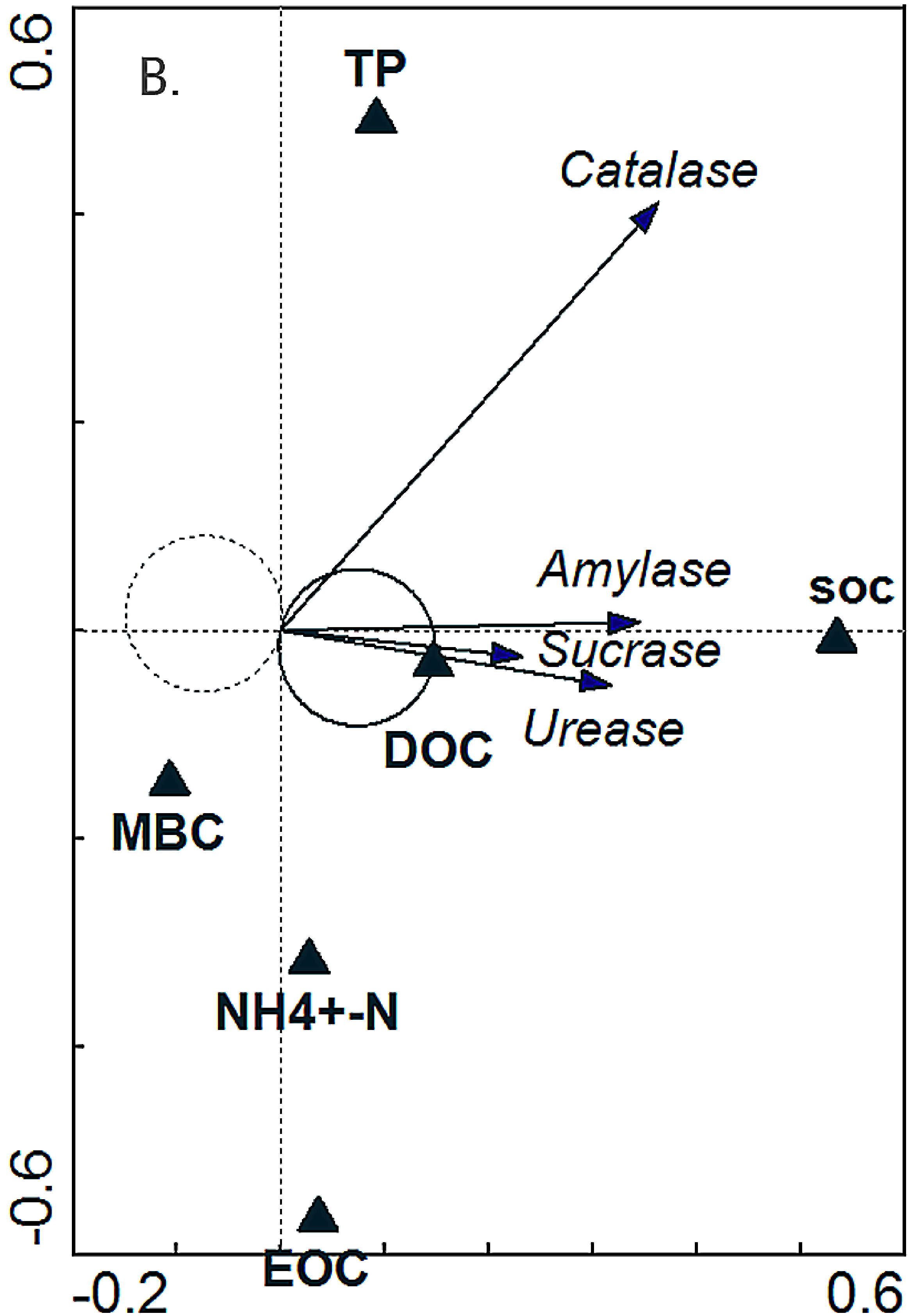
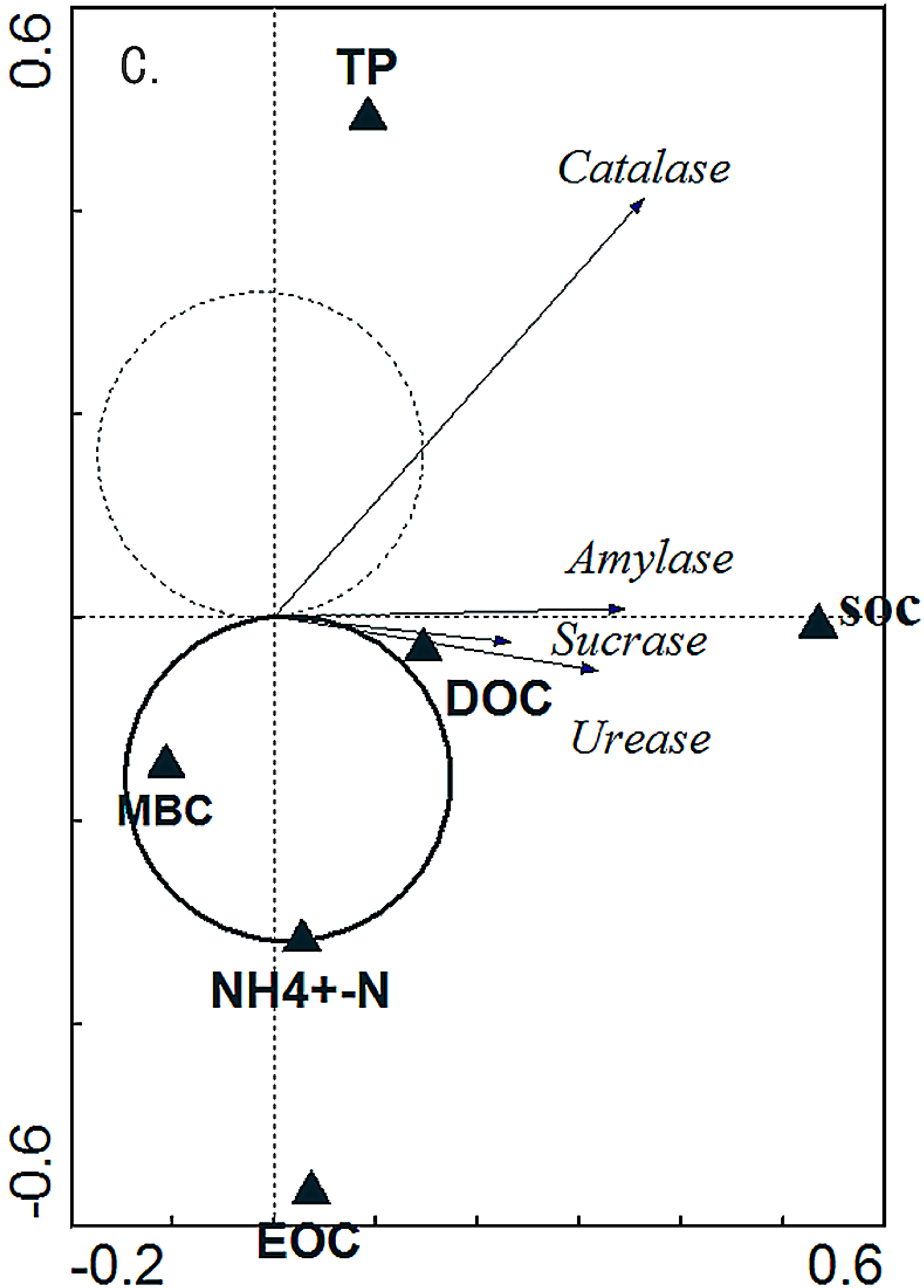

B.
TP
Catalase
Amylase
SOC
Sucrase
Urease
DOC
MBC
NH4+-N
EOC
0.6
-0.6
-0.2
0.6

Figure 6

The T-value for a singlefactor influencing varied of soil enzyme activities in wetland.

The quadrant of the arrow in the figure represents the positive and negative correlation between different factors and the sorting axis. The arrow represents several soil enzymes, and the solid triangle represents environmental variables.


C.
TP
Catalase
Amylase
SOC
Sucrase
DOC
Urease
MBC
NH4+-N
EOC
0.6
-0.6
-0.2
0.6