https://doi.org/10.5194/bg-2020-266
Preprint. Discussion started: 10 August 2020

Biogeosciences Discussions Open Access EGU

Factors controlling *Carex brevicuspis* leaf litter decomposition and its contribution to surface soil organic carbon pool at different water levels

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https://doi.org/10.5194/bg-2020-266
Preprint. Discussion started: 10 August 2020

Biogeosciences Discussions

Abstract. Litter decomposition plays a vital role in wetland carbon cycling. However, the contribution of aboveground litter decomposition to the wetland soil organic carbon (SOC) pool has not yet been quantified. Here, we conducted a *Carex brevicuspis* leaf litter input experiment to clarify the intrinsic factors controlling litter decomposition and quantify it's contribution to SOC pool at different water levels. This species is ubiquitous to global freshwater wetlands. We sampled this plant leaf litter at -25, 0, and +25 cm relative to the soil surface over 280 days and analysed leaf litter decomposition and its contribution to the SOC pool. The mass loss and carbon release rates were the highest at +25 cm water level, followed by the 0 cm water level. The rates of these parameters were the lowest at -25 cm water level. Significant amounts of litter carbon, nitrogen, and phosphorus were released at all three water levels. Litter input significantly increased the soil microbial biomass and fungal density but had nonsignificant impacts on soil bacteria, actinomycetes, and fungal/bacterial concentrations at all three water levels. Compared with litter removal, litter application increased the SOC by 25.12%, 9.58%, and 4.98% at the +25 cm, 0 cm, and -25 cm water levels, respectively. Hence, higher water levels facilitate the release of organic carbon from leaf litter into the soil via water leaching. In this way, they strengthen the soil carbon pool. At lower water levels, soil carbon is lost as the slower litter decomposition rate and active microbial (actinomycete) respiration. Our results revealed that the water level in natural wetlands influences litter decomposition mainly by leaching and microbial activity, by extension, affects wetland surface carbon pool.

Key words: *Carex brevicuspis*; decomposition; leaf litter; soil surface organic carbon pool; water level

1 Introduction

Wetlands are important terrestrial carbon pools. They contain 1.5×10^3 Pg carbon (~35% of the global carbon supply) and 25–63% of the soil carbon distributed in the 0–30 cm topsoil layer (Whiting and Chanton, 2001; Means et al., 2016; Cao et al., 2017). The surface soil organic carbon (SOC) pool (S-SOCP) and its turnover are sensitive to climate, topography, and hydrological condition (Wang et al., 2016; Zhang et al., 2017;Pinto et al., 2018).

Leaf litter decomposition is a major biotic carbon input route from vegetation to S-SOCP in wetland ecosystems (Whiting and Chanton, 2001; Moriyama et al., 2013). However, the reported impacts of litter decomposition on the soil carbon pool are highly variable (Busse et al., 2009; Crow et al., 2009). Litter input destabilised carbon storage by stimulating soil mineralisation and increasing soil labile carbon fractions (microbial biomass carbon [MBC] and soil dissolved organic carbon [DOC]) and enzyme activity in the freshwater marshland of Northeast China (Song et al., 2014). It also promoted soil carbon loss via CO_2 emissions and microbial activity in alpine and coastal wetlands (Gao et al., 2016; Liu et al., 2017). In contrast, a study has recently found that litter decomposition increased soil active organic carbon and stabilised the soil carbon pool in the Jiaozhou Bay wetland (Sun et al., 2019).

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Litter decomposition is a physicochemical processes that reduces litter to its elemental chemical constituents (Aerts, 1997). Litter decomposition rates are determined mainly by environmental factors (climatic and soil conditions), litter quality (litter composition such as C, N, and lignin content) and decomposer organisms (microorganisms and invertebrates) (Aerts, 1997). A previous study showed that regional and global environmental conditions explain > 51% of the variation in litter decomposition rate (Zhang et al., 2019). In wetland ecosystems, the water level ecosystem processes as it determines soil aerobic and anaerobic conditions which, in turn, affect microbial decomposition of litter and SOC decomposition (Liu et al., 2017; Yan et al., 2018). An earlier study reported that high soil moisture content and long flooding periods facilitate litter decomposition by promoting leaching, fragmentation, and microbial activity (Zhang et al., 2019). The water level may contribute to soil physicochemical conditions which, in turn, regulate litter decomposition (Xie et al., 2016). Aboveground litter decomposition is the main source of SOC (Upton et al., 2018). However, the contribution of litter decomposition to the SOC pool has seldom been quantified.

Dongting Lake (28°30'–30°20' N, 111°40'–113°10' E) is the second largest freshwater lake in China. It is connected to the Yangtze River via tributaries. Dongting Lake wetlands are characterised by large seasonal fluctuations in water level (≤ 15 m) and are completely flooded during June–October and exposed during November–May (Chen et al., 2016). Peng et al. reported that the organic carbon density in Dongting Lake wetland soil at 1 m depth was 127.3 ± 36.1 t hm^{-2} and the carbon density in the 0–30 cm topsoil was 46.5 ± 19.7 t hm^{-2} (Peng et al., 2005). *Carex brevicuspis* is a dominant vegetation in the Dongting Lake wetland and has large carbon reserves (~6.5 × 10^6 t y^{-1}) (Kang et al., 2009). However, due to the dam construction in the upstream of Dongting Lake, the water regime varies remarkably (early water withdrawn and declining of groundwater in non-flood season) in recent years, leading a significant carbon loss in this floodplain wetland (Hu et al., 2018; Deng et al., 2018).

Here, we investigated *C. brevicuspis* litter decomposition and its contribution to the SOC pool at three water levels (-25 cm, 0 cm, and +25 cm relative to the soil surface) to find the factors controlling *C. brevicuspis* leaf litter decomposition and quantify the contribution of litter decomposition to the SOC pool. We tested the following hypotheses. First, the litter decomposition rate at the +25 cm water level is faster than that at the 0 and -25 cm water levels because of leaching, fragmentation, and microbial activity. Second, the rates of litter carbon, nitrogen and phosphorus release are the highest at the +25 cm water level, and the intrinsic litter decomposition controls differs among the three water levels because of

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the differences among them regarding water infiltration. Third, the S-SOCP is relatively higher at the +25-cm water level because of substantial carbon accumulation resulting from significant litter decomposition. In contrast, it is comparatively lower at the -25 cm water level owing to carbon loss because of slow litter decomposition.

2 Materials and methods

2.1 Soil core collection and leaf litter preparation

Soil cores (40 cm diameter × 50 cm length) and leaf litter were collected in May 2017 from an undisturbed *Carex brevicuspis* community at the sampling site (29°27'2.02" N, 112°47'32.28" E) of the Dongting Lake station for wetland ecosystem research. The litter was cleaned with distilled water, oven-dried at 60 °C to a constant weight, and cut into pieces 5–10 cm long. Preweighed litter samples (5 g; 10.73 ± 0.28 g kg^{-1} N, 0.89 ± 0.04 g kg^{-1} P, 40.23 ± 2.6% organic C, and 17.83±0.25% lignin) were placed into 10 cm × 15 cm 1mm mesh nylon bags. This mesh size excluded macroinvertebrates but permitted microbial colonisation and litter fragment leaching (Xie et al., 2016).

2.2 Experimental design

There were three water level treatments (-25 cm, 0 cm, and +25 cm relative to the soil surface) nested by two litter treatments (input vs. removal) and three replicates. The experiment was conducted in nine cement ponds (2 m × 2 m × 1 m) at the Dongting Lake station for wetland ecosystem research which is part of the China Ecosystem Research Network. For the -25 cm treatment, the water level was 25 cm below the soil surface. For the 0 cm treatment, the soil was fully wetted with belowground water but without surface pooling. For the +25 cm treatment, the water level was 25 cm above the soil surface. Water levels were adjusted weekly using belowground water (TOC: 3.44 mg L^{-1}; TN: 0.001 mg L^{-1}; TP: 0.018 mg L^{-1}). Three soil core sets were placed in each pond. One was designated the litter removal control (S), the second was distributed on the soil surface in 15 litter bags to observe the effects of leaf litter input on soil carbon pool (L), and the third was distributed on the soil surface in 15 litter bags to monitor the litter decomposition rate and process (D) (Fig. 1). The experiment started on 20 August 2017 and lasted 280 d. By that time, no further significant change in litter dry weight was observed. Before incubation, three litter and three soil samples were collected to determine their initial quality. Litter bags

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were randomly collected from treatment D after 20 d, 40 d, 60 d, 80 d, 100 d, 130 d, 160 d, 190 d, 220 d, 250 d, and 280 d. After collection, the litter samples were separated, cleaned with distilled water, and oven-dried at 60 °C to a constant weight (±0.01 g). All samples were pulverised and passed through a 0.5-mm mesh screen for litter quality analysis. At the end of incubation, the surface soil (0–5 cm, ~600 g FW) was collected to eliminate the influences of root decomposition on the soil organic pool. The soil samples were placed in aseptic sealed plastic bags and transported to the laboratory. The samples were sieved (< 2 mm), thoroughly mixed, and divided into three subsamples. The first subsample (~150 g) was stored at -20 °C and freeze-dried for phospholipid fatty acid (PLFA) analysis. The second one (~150 g) was stored at 4 °C for MBC and DOC measurements. The third subsample (~300 g) was air-dried for physicochemical analysis.

2.3 Litter quality analyses

Litter organic carbon content was analysed by the H_2SO_4-$K_2Cr_2O_7$ heat method. Litter nitrogen was extracted by Kjeldahl digestion and quantified with a flow injection analyser (AA3; Seal Analysisten GmbH, Langenselbold, Germany) (Xie et al., 2017). Litter phosphorus content was quantified by the molybdenum-antimony anti-spectrophotometric method. The lignin content was measured by hydrolysis (72% H_2SO_4) (Graça et al., 2005; Xie et al., 2017).

2.4 Soil quality analyses

2.4.1 Soil chemical analyses

SOC was determined by wet oxidation with KCr_2O_7 + H_2SO_4 and titration with $FeSO_4$ (Xie et al., 2017). Soil DOC was extracted with K_2SO_4 and measured with a TOC analyser (TOC-VWP; Shimadzu Corp., Kyoto, Japan). MBC was analysed by chloroform fumigation, K_2SO_4 extraction, and TOC analyser (TOC-VWP, Shimadzu Corp., Kyoto, Japan) (Tong et al., 2017).

2.4.2 Soil microbial composition

The total and specific microbial group biomass values and the microbial community structure were estimated by phospholipid fatty acid (PLFA) analysis. The PFLAs were extracted from 8 g of freeze-dried soil and analysed as previously described (Zhao et al., 2015). The concentrations of each PLFA was calculated relative to that of the methyl nonadecanoate (19:0) internal standard. The PLFAs

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for the following groups were determined: (a) bacterial biomass, sum of i15:0, a15:0, 15:0, i16:0, 16:1u7, i17:0, a17:0, 17:0, cy17:0, and cy19:0; actinomycete biomass, sum of 10 Me 16:0, 10 Me17:0, and 10 Me 18:0; and fungal biomass, 18:2 ω6 and 18:1ω9. The total microbial biomass was represented by the sum of the bacterial, fungal, and actinomycete biomass values. The ratios of fungal to bacterial lipids (F/B) were used to evaluate the microbial community structure ((Bossio and Scow, 1998; Wilkinson et al., 2002; Zhao et al., 2015).

2.5 Data processing

2.5.1 Litter decomposition rate

The percentage of litter dry weight loss was calculated as follows (Zhang et al., 2019):

$$L_t = \frac{M_0 - M_t}{M_0} \times 100\% \quad (1)$$

where L_t is the percentage litter dry weight loss at time t (%), M_t is the litter dry matter weight at the time t (g), and M_0 is the initial dry matter weight (g).

The instantaneous litter dry mass decay rate (k) was calculated using the Olson negative exponential attenuation model (Olson, 1963):

$$M_t = M_0 e^{-kt} \quad (2)$$

where M_t is the litter dry matter weight at time t (g), M_0 is the initial dry matter weight (g), k is the instantaneous litter decay rate at time t, and e is the natural base number. M_t increased with litter decomposition rate.

2.5.2 Relative release index

The relative release indices (RRIs) of C, N, and P from the plant litter were calculated as follows (Zhang et al., 2019):

$$RRI_t = \frac{M_0 \times C_0 - M_t \times C_t}{M_0 \times C_0} \times 100\% \quad (3)$$

where C_t is the concentration of an element in the litter at time t, C_0 is the initial concentration of an element in the litter, and M_t is the litter dry matter weight at time t (g). CRRI, NRRI, PRRI, and LRRI represent the carbon, nitrogen, phosphorus, and lignin RRIs, respectively. A positive RRI indicates a net release of the element during litter decomposition whilst a negative RRI indicates a net accumulation of the element during litter decomposition.

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164 **2.5.3 Contribution of litter-C input to the SOC pool**

165 The contribution of litter-C input to the SOC pool was calculated as follows (Lv and Wang, 2017):

166 $$LC = \frac{SOC_L - SOC_S}{SOC_i} \times 100\% \qquad (4)$$

167 where *LC* is the contribution of the litter-C input to SOC pool, SOC_L is the SOC concentration for the
168 litter input treatment, SOC_S is the SOC concentration for the treatment without litter input, and SOC_i is
169 the initial SOC content before the experimental treatments.

170 **2.6 Statistical analyses**

171 The percentage litter dry weight losses and the instantaneous decomposition rates were compared among
172 the three water levels by repeated ANOVA. Water level was the main factor and time was the repeated
173 factor. The surface soil chemical components and the microbial community structure were compared by
174 two-way ANOVA. Treatment (with or without litter input) and water level were the main factors. The
175 percentage differences in litter dry weight loss, the instantaneous decomposition rates, the soil chemical
176 components, and the microbial community structure were evaluated by LSD at the 0.05 significance
177 level. The data were expressed as means ± standard error. All statistical analyses were performed in
178 SPSS 21 (IBM Corp., Armonk, NY, USA).

179 **3 Results**

180 **3.1 litter decomposition process**

181 The percentage litter dry weight loss was the highest for the +25 cm water level treatment through the
182 entire litter decomposition period followed by the 0 cm water level treatment. The percentage litter dry
183 weight loss was the lowest for the -25 cm water level treatment ($P < 0.01$; Fig. 2A). After 280 d
184 decomposition, the percentage litter dry weight loss values under the +25 cm, 0 cm, and -25 cm water
185 level treatments were 61.8%, 49.8% and 32.4%, respectively.
186 The instantaneous decomposition rate at each measurement time point was calculated using the Olson
187 negative exponential decay model. The instantaneous litter dry weight decomposition rate rapidly
188 increased and then slowly decreased and stabilised for all three water levels. The maximum
189 decomposition rates for the -25 cm, 0 cm, and +25 cm water levels were 0.0069631 d^{-1}, 0.008990 d^{-1}, and
190 0.012954 d^{-1}, respectively (Fig. 2B).

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3.2 Intrinsic litter decomposition rate-limiting factor

During the entire decomposition process, CRRI, NRRI, PRRI, and LRRI significantly increased with water level. Litter carbon and lignin were always released at all three water levels whilst at -25 cm, nitrogen and phosphorus enrichment appeared in the middle stage (Fig. 3A–3D). At the start of the experiment, neither the C/N nor the lignin/N ratio significantly differed at the three water levels. At the middle stage, however, both the C/N and lignin/N ratios were significantly lower at the -25-cm water level than they were at the 0 cm and -25 cm water levels (Fig. 3E–3F).

The multiple regression model of the instantaneous litter decomposition rate and the litter properties showed that at the -25 cm and 0 cm water levels, the main decomposition rate-limiting factor was the lignin concentration whilst at the +25 cm water level, the main litter decomposition rate-limiting factor was the lignin/N ratio (Table 1).

3.3 Soil surface microbial community structure

Under both litter input and litter removal conditions, the bacterial, fungal, and microbial biomass levels were the highest under the 0 cm water level treatment; however, these parameters showed nonsignificant differences between 25 cm above and below water level treatments ($P > 0.05$; Fig. 4A, 4B, and 4F). The actinomycete biomass was the highest under the -25 cm water level treatment, followed by that under the 0 cm water level treatment. It was the lowest under the +25 cm water level treatment (Fig. 4C). Litter input significantly stimulated fungal and microbial biomass at all three water levels but only significantly stimulated bacterial and actinomycete biomass at the -25 cm water level ($P < 0.05$; Fig. 4A–4C and 4E). Under litter input conditions, the fungal/bacteria ratio was the highest at the 0 cm water level, followed by the +25 cm water level. It was the lowest under the -25 cm water level treatment. Under litter removal conditions, however, the fungal/bacteria ratio was significantly higher under the -25 cm water level treatment than it was under the 0 cm and +25 cm water level treatments ($P < 0.05$; Fig. 4D).

3.4 Contribution of leaf decomposition to the soil surface carbon pool

The SOC, MBC, and DOC concentrations were significantly affected by the water level. SOC and MBC were the highest at the 0 cm water level and the lowest at the -25 cm water level ($P < 0.01$; Fig. 5A and 5B). DOC was the highest at the -25 cm water level and the lowest at the +25 cm water level ($P < 0.01$; Fig. 5C).

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Compared with the litter removal group, the SOC concentrations were significantly higher for the litter input group at the +25 cm and 0 cm water levels. Relative to the litter removal group, the DOC concentrations were significantly higher for the litter input group at the 0 cm- and -25 cm water levels ($P < 0.001$; Fig. 5A and 5C). The contribution of the litter-C input to the S-SOCP was the highest for the +25 cm water level treatment (13.75%), intermediate for the 0 cm water level treatment (4.73%), and the lowest for the -25 cm water level treatment (2.51%) ($P < 0.001$; Fig. 5D).

4 Discussion

4.1 Environmental control of litter decomposition

Water level significant influenced *C. brevicuspis* leaf litters decomposition ($P < 0.001$). The *K*-values were the highest for the +25 cm water level treatment, intermediate for the 0 cm water level treatment, and the lowest for the -25 cm water level treatment (Fig. 2B). Hence, the percentage litter dry weight loss and the decomposition rate increased with water level. These results supported our first hypothesis. The wetland water level strongly affect litter leaching and microbial decomposition (Peltoniemi et al., 2012). Compared with the terrestrial environment, water promotes litter leaching and microbial metabolism, thereby accelerating litter decomposition. Moreover, water infiltration into litter also increases relative leaching loss (Molles et al., 1995). Here, the high litter decomposition rate measured for the +25 cm water level treatment may be explained primarily by litter leaching. This finding was consistent with those reported for *Carex cinerascens* litter decomposition in Poyang Lake (Zhang et al., 2019) and *Calamagrostis angustifolia* litter decomposition on the Sanjiang Plain (Sun et al., 2012).

The high soil total microbial, bacterial and fungal biomass levels at the 0 cm water level could account for the rapid litter decomposition observed there. Certain microorganisms are vital to the decomposition process (Yarwood, 2018). Fungi are primary litter decomposers as they fragment dead plant tissues by breaking down lignin and cellulose. Bacteria are secondary decomposers that utilise the simpler compounds generated by fungal activity (de Boer et al., 2005; Bani et al., 2019). Microbial decomposers generally flourish in humid environments. At the 0-cm water level, microbial activity explains most of the litter decomposition. At the -25-cm water level, the soil surface is dry, there are comparatively few microbial decomposers, and decomposition is very slow.

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246 **4.2 Intrinsic factors controlling litter decomposition**

247 Decomposition rapidly increased to reach a maximum by 20 d. Thereafter, it slowly decreased and then
248 stabilised (Fig. 2B). Water-soluble components and non-lignin carbohydrates are preferentially and
249 quickly decomposed at the onset of decomposition (Davis et al., 2003). Here, a multiple regression model
250 of the instantaneous litter decomposition rate and litter properties showed that the internal limiting
251 factors affecting the rate of *C. brevicuspis* leaf litter decomposition varied with water level. The lignin
252 concentration determined the litter decomposition rate for the -25 cm and 0 cm water level treatments
253 whilst the lignin/N ratio regulated the litter decomposition rate for the +25 cm water level treatment. This
254 discovery upheld our second hypothesis and was consistent with the findings of Zhang et al. who
255 reported that wetland ecosystems decomposed *Carex cinerascens* lignin much earlier faster than did
256 terrestrial ecosystems (Zhang et al., 2019). Here, we found that the lignin content was the major internal
257 limiting factor of the *C. brevicuspis* leaf litter decomposition rate. At the +25 cm water level, N is rapidly
258 lost and the L/N ratio significantly increases. Thus, L/N is the main internal limiting factor at the +25 cm
259 water level. A few studies showed that the lignin content is a key factor limiting terrestrial plant and
260 hygrophyte litter decomposition (Yue et al., 2016; Zhang et al., 2018). Therefore, the amount of carbon
261 that the litter can return to the ecosystem is closely associated with the plant lignin content. The lignin
262 content of *C. brevicuspis* leaf litters is ~10% less than that of other wetland plants such as *Miscanthus*
263 *sacchariflorus* (~30%) (Xie et al., 2016), *Spartina alterniflor* (~40%) (Yan et al., 2019), and terrestrial
264 plants such as willow (~25%), larch (~38%), and cypress (~28%) (Yue et al., 2016). Furthermore, *C.*
265 *brevicuspis* covers a large area (~23,950 hm^2) and generates abundant litter (~36,547 t) (Kang et al.,
266 2009). Thus, *C. brevicuspis* litter may potentially return large amounts of carbon to the soil.

267 **4.3 Contribution of leaf decomposition to the soil surface carbon pool**

268 Litter decomposition is the main pathway by which nutrients are transferred from the plants to the soil.
269 Litter affects SOC whose stabilisation affects other soil properties such as sorption, nutrient availability,
270 pH, and water holding capacity (Brady and Weil, 2008). The results of this study showed that litter
271 addition increases SOC in a manner that varies with water level. The contribution of litter-C input to the
272 S-SOCP was the highest under the +25 cm water level treatment (13.75%), intermediate under the 0 cm
273 water level treatment (4.73%), and the lowest under the -25 -cm water level treatment (2.51%). For this
274 reason, flooding conditions are conducive to litter carbon input into the soil. These findings corroborated

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our third hypothesis. In addition, litter input had a similar effect on soil DOC at the 0 cm and -25 cm water levels. Therefore, litter decomposition contributes mainly soluble carbon to the soil (Zhou et al., 2015). However, this DOC is also readily lost and decomposed (Sokol and Bradford, 2019;Gomez-Casanovas et al., 2020). This fact accounts for the significantly lower relative DOC under the +25 cm water level treatment here. Wetlands have comparatively larger but also more unstable S-SOCPs than terrestrial environments. In wetlands, water level fluctuations could readily cause carbon loss (Gao et al., 2016; Chen et al., 2018). Nevertheless, we considered mainly aboveground litters in this experiment. Hence, the influences of underground litter (root) decomposition on the SOC pool should be investigated in future research (Sokol and Bradford, 2019; Lyu et al., 2019).

5 Conclusion

The water level in natural wetlands influences litter decomposition mainly by leaching and microbial activity, by extension, affects wetland surface carbon pool. Higher water levels facilitate the release of organic carbon from leaf litter into the soil via water leaching, and thus strengthened soil carbon pool. At lower water levels, wetland soil carbon is lost as the litter decomposition is lower, but active microbial (actinomycete) respiration rates is comparatively higher. The groundwater decline which was caused by the climate change and human disturbance in Dongting Lake floodplain would slowdown the return rate of organic carbon from leaf litter to soil, and facilitate the S-SOCP loss. Therefore, in wetland management and restoration practices, the construction of microhabitat with prolonged flooding period and relatively higher water level are essential ways to improve the carbon sequestration potential.

Data availability

The data used in this paper are stored in the open-access online database Figshare and can be accessed using the following link: https://doi.org/10.6084/m9.figshare.12758387.v1 (Zhu et al. 2020).

Conflict of interest

The authors declare that they have no conflict of interest.

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299 **Author contributions**

300 Lianlian Zhu designed experiments, collected samples, acquired, analyzed, interpreted data, and wrote
301 the manuscript. Zhengmiao Deng designed experiments, interpreted data and revised the manuscript.
302 Yonghong Xie designed experiments and revised the manuscript. Xu Li, Feng Li, Xinsheng Chen and
303 Yeai Zou collected samples and revised the manuscript. Chengyi Zhang and Wei Wang interpreted data
304 and revised the manuscript.

305 **Acknowledgement**

306 We are immensely thankful to teachers in Dongting Lake Station and Key Laboratory of Agro-ecological
307 Processes in Subtropical Region for their help in soil sample collection and chemical analysis. We would
308 like to thank Editage [www.editage.cn] for English language editing. The data used in this paper are
309 available in the supplement material.

310 **Financial support**

311 This study was financial supported by the Hunan innovative province construction projection (Hunan
312 Key Research and Development Project, 2019NK2011), the National Natural Science Foundation of
313 China (41401290), Changsha Natural Science Funds for Distinguished Young Scholar (2020), the
314 Natural Science Foundation of Hunan province(2018JJ3580).

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456 **Table 1: Multiple regression model of instantaneous litter decomposition rate and litter properties**

Water level (cm)	Multiple regression model	*F*	R^2	*P*
-25	$R = -\mathbf{0.861L} - 0.404C + 0.239CN + 2.586$	27.264	0.887	< 0.001
0	$R = -\mathbf{1.131L} - 0.390P - 0.218LN + 2.124$	48.330	0.934	< 0.001
+25	$R = -\mathbf{0.739LN} - 0.636N + 4.162$	19.465	0.787	< 0.001

457 **where *R* is the litter instantaneous decomposition rate, L is the lignin concentration, C is the carbon**
458 **concentration, N is the nitrogen concentration, P is the phosphorus concentration, CN is the**
459 **carbon-to-nitrogen ratio (C/N, g g^{-1}), and LN is the lignin-to-nitrogen ratio (lignin/N, g g^{-1}).**

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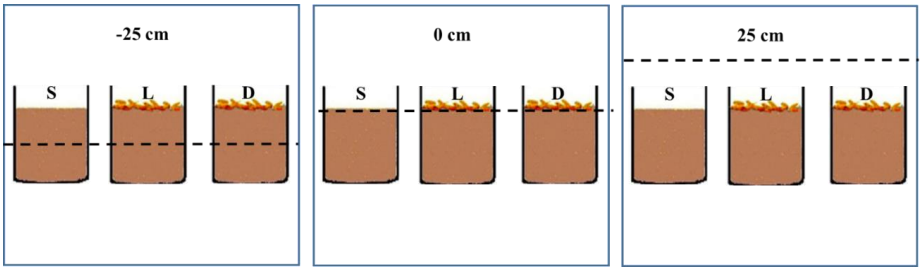

Figure 1: Schematic diagram of the experimental setup. The dotted line represents the water level.

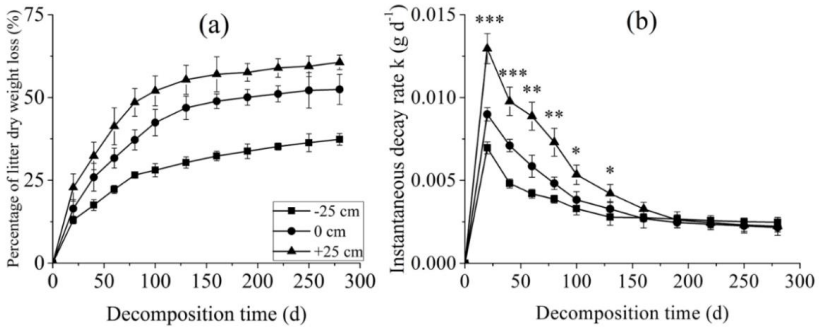

Figure 2: Percentage litter dry weight loss and decomposition rate during *C. brevicuspis* decomposition at three water levels (-25 cm, 0 cm, and +25 cm). *, **, and * represent significant differences of the litter instantaneous decay rate among the three water levels at the 0.05, 0.01, and 0.001 significance levels, respectively.**

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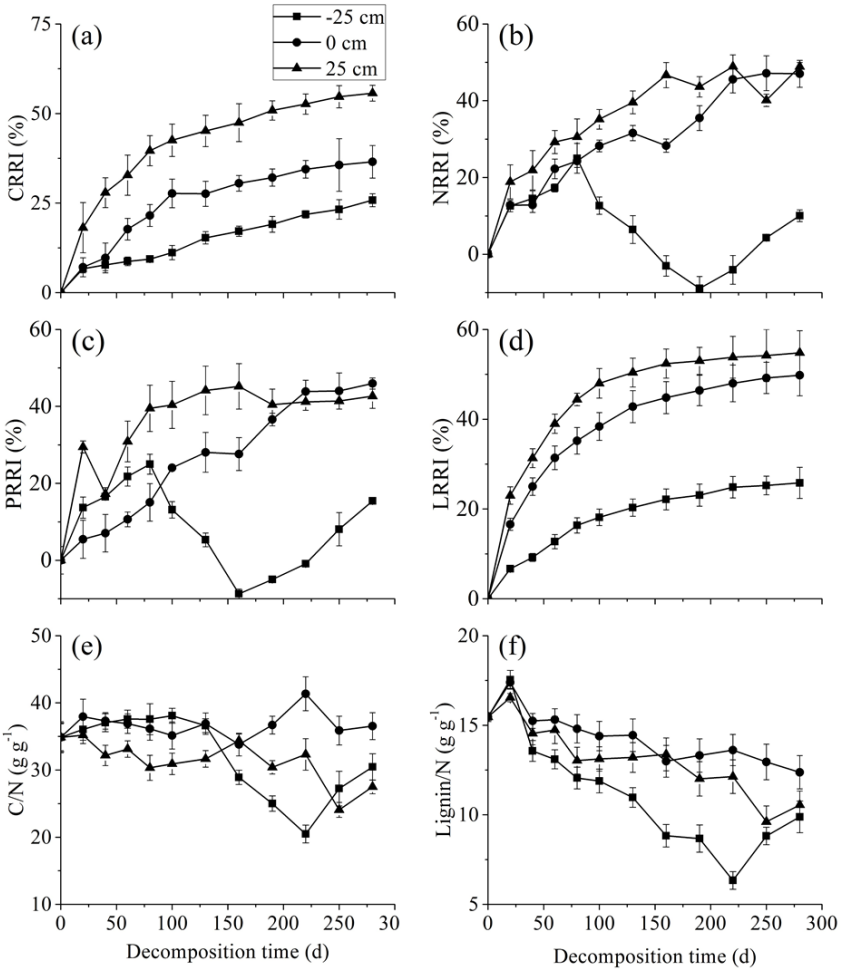

Figure 3: Percentage (mean ± SE) of carbon relative release index (CRRI), nitrogen relative release index (NRRI), phosphorus relative release index (PRRI), lignin relative release index (LRRI), C/N ratio, and lignin/N ratio at three water levels (-25 cm, 0 cm, and +25 cm).

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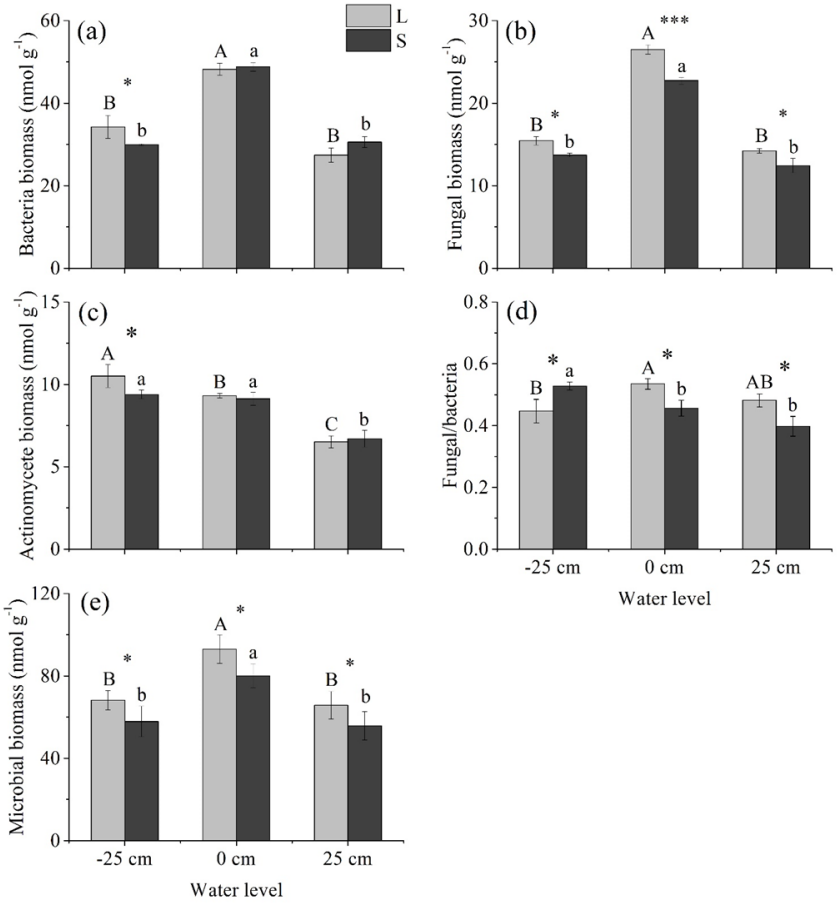

Figure 4: Microbial community structure under litter input and litter removal at three water levels. Different uppercase letters among vertical bars indicate significant differences among the three water levels in the litter input (L) group. Different lowercase letters indicate significant differences among the three water levels in the litter removal (S) group. The significance level is α = 0.05. *, **, and * represent significant differences between the litter input (L) and litter removal (S) groups at the three water levels at the 0.05, 0.01, and 0.001 significance levels, respectively.**

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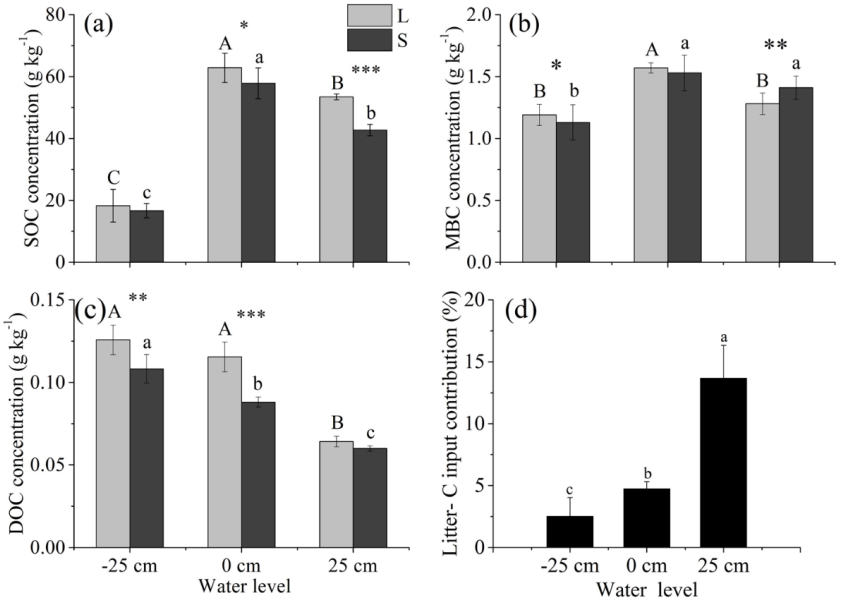

Figure 5: Concentrations of SOC (A), MBC (B), DOC (C) between the litter input (L) and litter removal (S) groups and the litter-C input contribution (D) under three water levels at the end of the experiment. Different uppercase letters among vertical bars indicate significant differences among the three water levels in the litter input (L) group. Different lowercase letters indicate significant differences among the three water levels in the litter removal (S) group. The significance level is α = 0.05. *, **, and * represent significant differences between the litter input (L) and litter removal (S) groups at the three water levels at the 0.05, 0.01, and 0.001 significance levels, respectively.**