Science of the Total Environment 592 (2017) 527–534

Contents lists available at ScienceDirect

Science of the Total Environment

journal homepage: www.elsevier.com/locate/scitotenv

Plant soaking decomposition as well as nitrogen and phosphorous release in the water-level fluctuation zone of the Three Gorges Reservoir

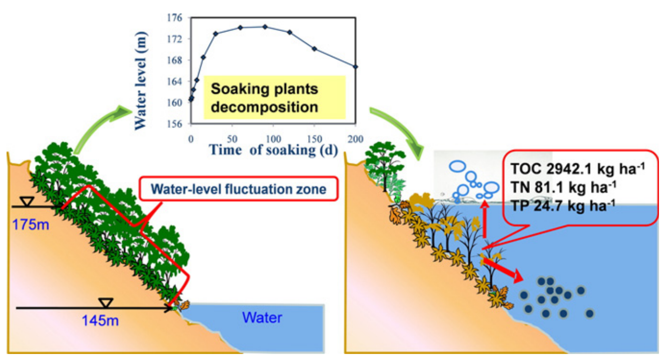
Liwei Xiao [a,b,c], Bo Zhu [a,b,*], Mathieu Nsenga Kumwimba [a,b,c], Shiwei Jiang [a,b]

[a] Key Laboratory of Mountain Surface Processes and Ecological Regulation, Chinese Academy of Sciences, 610041 Chengdu, China
[b] Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, 610041 Chengdu, China
[c] University of Chinese Academy of Sciences, Beijing 100049, China

HIGHLIGHTS

- Soaking plant decomposition rates was related to initial C/N ratios positively or negatively at "breakpoint" of 50.
- Total nitrogen and phosphorus released by decomposition was related to C/N and C/P.
- Large quantities of nutrient loadings resulted from soaking decomposition.
- Soaking plant decomposition may lead to eutrophication in the Three Gorges Reservoir.

GRAPHICAL ABSTRACT



ARTICLE INFO

Article history:
Received 16 December 2016
Received in revised form 24 February 2017
Accepted 10 March 2017
Available online 18 March 2017

Editor: D. Barcelo

Keywords:
Plant species
Litter-bag decomposition
Nutrient cycling
Eutrophication
Riparian zone
Three Gorges Reservoir

ABSTRACT

The operating scheme of the Three Gorges Reservoir results in a summer drought in the water-level fluctuation zone during which plants grow vigorously. In the winter inundation season, soaking plants may decompose and release nutrients resulting in water quality deterioration. This study quantifies the contributions of the underwater decomposition of nine dominant plant species in the water-level fluctuation zone to nutrient release. The in-situ litterbag technique was used to study for soaking decomposition over 200 days. All soaking plant species decomposed rapidly at an average rate of $1.99 \pm 0.33\%\ d^{-1}$ in the early stage of soaking (0 to 30 days) and at an average rate of only $0.07 \pm 0.04\%\ d^{-1}$ in the later stage (30 to 200 days). After 200 days of soaking, the nine plant species released an average of 312.40 ± 39.97 g kg^{-1} organic carbon, 6.71 ± 4.29 g kg^{-1} of nitrogen and 2.25 ± 1.25 g kg^{-1} of phosphorus. A positive relationship was found between soaking plant decomposition rates and initial C/N ratios of 25 to 50, and a negative relationship where the C/N ratios were between 50 and 100. The amounts of total nitrogen or total phosphorus released were significantly negatively correlated with the initial C/N or C/P ratios of the plants. Among the studied plant species, *Xanthium sibiricum Patr ex Widder* showed high level of nutrient release via soaking decomposition. In contrast, *Cynodon dactylon* (*Linn.*) *Pers.* and *Polygonum hydropiper* exhibited low levels of nutrient release and are recommended as suitable species for the ecological restoration of the water-level fluctuation zone. Our results demonstrate that after 200 days of soaking plant decomposition, the loadings of total organic carbon, nitrogen, and phosphorus in the water-level fluctuation zone of the Three Gorges Reservoir were 2942.1, 81.1, and 24.7 kg ha^{-1}, respectively and therefore could potentially damage the aquatic environment of the reservoir.

* Corresponding author at: Institute of Mountain Hazards and Environment, Chinese Academy of Sciences, 610041 Chengdu, China.
E-mail address: bzhu@imde.ac.cn (B. Zhu).

http://dx.doi.org/10.1016/j.scitotenv.2017.03.104

1. Introduction

In the Three Gorges Reservoir (TGR), periodic fluctuations of the water level, ranging from 145 m to 175 m, form a water-level fluctuation zone (WLFZ) with a total area of 349 km^2 (Yuan et al., 2013). Water quality degradation in the TGR is currently a major issue. Algal blooms have frequently occurred in the TGR and have been attributed to the accumulation of nutrients triggered by changes in the water level (Hu and Cai, 2006; Ye et al., 2014). Thus, the eco-environment, especially aquatic environment of the WLFZ is vulnerable to disturbance by flow regulation. Meanwhile, plants in the WLFZ are important for nutrient cycling within the TGR, because they may regulate the nutrient availability for plant growth, soil absorption and water environments (Gregory et al., 1991).

Studies have shown that soaking macrophytes plays an important role in the restoration of shallow eutrophic lakes (Kelley and Jack, 2002; Liu et al., 2016; Wantzen et al., 2008). From May to September, luxuriant plants grow in the WLFZ, accumulating nutrients from both the overlying water and sediments. When the water level then gradually rises by up to 175 m, soaking plants may decompose and release large amounts of organic matter and nutrients (Asaeda et al., 2000; Kröger et al., 2007; Yang et al., 2010). The large amounts of nitrogen and phosphorus released by plant decomposition may lead to deterioration of the water quality in the TGR and have a significant influence on the TGR ecosystem (Ye et al., 2014; Yuan et al., 2013; Zhang and Lou, 2011). However, the decomposition process and nutrient release from plants in the WLFZ are not yet well understood. There is no doubt that a preliminary estimate of nutrient release from soaking plants will have a great influence on prediction of water quality deterioration in the TGR (Wang et al., 2012).

Plant species in the WLFZ of the TGR differ widely in their relative biomass during growth, which may influence the way they decompose after soaking (Willison et al., 2013; Zhang and Lou, 2011). Different plant community composition or vegetation types would affect the decomposition rate and amounts of nutrients released (Hooper, 1998; Kalburtji et al., 1999; Koukoura et al., 2003). Interspecific variation in plant species induces marked difference to decomposition rates and nutrient availability (Koukoura et al., 2003; Trogisch et al., 2016).

Nine plant species representative of those in the WLFZ of the TGR were chosen for this study. The objectives of this study were to: (1) investigate the soaking decomposition processes and rates for the dominant plant species in the WLFZ; (2) evaluate nutrients release from the nine species and identify suitable plants for ecological reconstruction; and (3) obtain loadings of TOC, TN and TP released by soaking plant decomposition in the WLFZ and thus provide a scientific basis for subsequent environmental risk assessment in the TGR.

2. Materials and methods

2.1. Study sites

The study was conducted at the TGR, whose longitude and latitude range from 105°44′ to 111°39′ E and from 28°32′ to 31°44′ N, respectively. The TGR spans a total area of 58,000 km^2. This subtropical monsoon region experiences a humid (60% to 80% humidity) and continental climate with a mean annual temperature of 17.0 ± 1.4 °C. The water-level fluctuation zone of the reservoir includes 21 counties and a total area of 349 km^2 (Yuan et al., 2013). Land use in the region is characterized by agricultural development, including croplands, dairy operations and confined animal farm operations. After several drying-rewetting cycles, the predominant natural vegetation consisted of secondary herbaceous plants (Lu et al., 2010; Wang et al., 2012). In-situ field soaking experiments were conducted in the WLFZ near E108°06′47.65″ and N30°23′53.62″ at Pingshan Bridge, Zhongxian Chongqing (Fig. 1).

2.2. Dominant plant species

Species selected for the study were *Vetiveria zizanioides* (*Linn.*) *Vach*, *Cynodon dactylon* (*Linn.*) *Pers*., *Bidens bipinnata Linn*., *Polygonum hydropiper*, *Digitaria sanguinalis* (*Linn.*) *Scop*., *Echinochloa crusgali* (*Linn.*) *Beauv*., *Xanthium sibiricum Patr ex Widder*, *Hemarthria altissima* (*Poir.*) *Stapfet C. E. Hubb*., and *Salicaceae*. These plant species are common in the study area and have accumulated many nutrients. Plant samples were collected on September 10, 2015 from the WLFZ. For easy reference, we abbreviate the above nine plant species as follows (in order): *Ve*, *Cy*, *Bi*, *Po*, *Di*, *Ec*, *Xa*, *He*, and *Sa*.

2.3. Soaking experiments

Soaking experiments were conducted for 200 days to assess nutrient loadings from plant decomposition in the WLFZ of the TGR during the flood period. The plant samples for each species were gathered from fields, and stems and leaves were uniformly mixed. For each species, 50 g of the mixed sample was placed in nylon gauze litterbag (mesh size: 1 × 1 mm), and a total of 450 litterbags (9 plant species × 5 replications × 10 sampling dates) were placed over the soil within the WLFZ near to E108°06′47.65″ and N30°23′53.62″. All the litterbags were soaked from September 18, 2015 to April 5, 2016 to simulate a 200-day flood inundation. After periods of 1, 3, 7, 15, 30, 60, 120, and 200 days, the litterbags were extracted, and the dry weight, total organic carbon content (TOC), total nitrogen content (TN) and total phosphorous content (TP) of each sample were measured.

TOC, TN and TP were all determined by standard analytical methods (Lu, 1999). TOC content was analyzed by the wet combustion method (170–180 °C oil-heating for 5 min with potassium dichromate and sulfuric acid oxidation) and then titrated with 0.3 mol L^{-1} $FeSO_4$. TN content was determined by an Auto Kjeldahl Analyzer (FOSS Kjeltec 8200 Auto Distillation, Sweden) after heat digestion with concentrated sulfuric acid and titration with 0.05 mol L^{-1} HCl. TP content was measured by the ammonium molybdate spectrophotometric method after heat digestion with a nitric acid and perchloric acid mixture.

The loss process of dry weight was modeled by the amendatory Olson (1963) exponential decomposition model:

$$X_t = a \times X_0 \times e^{-k \times t} \quad (1)$$

where X_t is the remaining weight, TOC, TN, and TP of the undecomposed plant samples after soaking for t days (g), X_0 is the initial sample weight (g), t is the soaking time (d), a is the correction factor, and k is the decomposition coefficient (d^{-1}).

The cumulative release of nutrients from the experimental samples was calculated as follows:

$$T_t = N_0 - N_{wt} \quad (2)$$

where T_t is the mass of nutrient released at t time (g kg^{-1}), N_{wt} is the nutrient content per dry mass at day t (g kg^{-1}) and N_0 is the initial nutrient content (g kg^{-1}).

The organic carbon and nutrient loading from soaking plants was calculated as follows:

$$A = 0.01 \times B \times T_i \times IV_i \quad (3)$$

where A is the load of TOC, TN or TP (kg ha^{-1}), B is the average biomass of the WLFZ in the TGR (g m^{-2}), T_i is the mass of TOC, TN or TP released from each plant species by soaking decomposition (g kg^{-1}) and IV_i (importance value) is a weighting specific to each plant species. The importance values of species in the WLFZ were calculated from relative cover (RC) and relative height ($IV = (RC + RH) / 2$) (Pielou, 1975; Wang et al., 2012).