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Short communication

# Reclamation of coastal salt marshes promoted carbon loss from previously-sequestered soil carbon pool

Nai-Shun Bu [a,b], Jun-Feng Qu [a], Gang Li [a], Bin Zhao [b,*], Rong-Juan Zhang [b], Chang-Ming Fang [b]

[a] *School of Environmental Science and Spatial Informatics, Low-carbon Energy Research Institute, China University of Mining and Technology, Xuzhou 221008, China*

[b] *Coastal Ecosystems Research Station of the Yangtze River Estuary, Ministry of Education Key Laboratory for Biodiversity Science and Ecological Engineering, The Institute of Biodiversity Science, Fudan University, 2005 Songhu Road, Shanghai 200438, China*

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ABSTRACT

Coastal salt marshes have recently been identified as important components of 'blue carbon' sinks, will continue to maintain C accumulation for millennia, but have been seriously lost or degraded worldwide mainly owing to land reclamation. Most work to date has concentrated on the effects of habitat conversion or destruction on C sequestration potential, while relatively less attention has been put on their impacts on large standing soil C pool (previously sequestered and stored soil C) associated with salt marshes. Here, we provide direct empirical evidence to determine reclamation effects on previously sequestered soil C pool in salt marshes after nine years following reclamation. Our results showed that soil moisture significantly decreased and soil microbial biomass significantly increased along with the transition from salt marshes to reclaimed lands. Meanwhile, soil respiration was three-folds higher in reclaimed lands than in salt marshes. Consequently, soil organic C pool in reclaimed lands declined to 60% (0–20 cm) and 79% (0–100 cm) of those in salt marshes after nine years. We may speculate that half-life of topsoil C pool of salt marshes after reclamation is approximately 10 years, and previously sequestered and stored soil C pool may decline to the minimum value within roughly 15 years. Our results suggest that a considerable proportion of previously sequestered soil C, once effectively 'locked up' in salt marshes mainly due to anaerobic conditions, is vulnerable to saltmarsh habitat loss and can be rapidly released into the atmosphere (as $CO_2$) contributing to global warming within a short period after reclamation.


## 1. Introduction

Vegetated coastal ecosystems (i.e., salt marshes, mangroves, and seagrasses) have recently been highlighted as one of the most powerful carbon (C) sinks of Earth's ecosystems and play crucial roles in mitigating global climate change (Chmura et al., 2003; Laffoley and Grimsditch, 2009). More specifically, coastal salt marshes buried C at a rate approximately 50 times higher than tropical rainforests, and their preliminary estimation of global C sequestration (up to 87 $Tg\,C\,yr^{-1}$) seems to exceed that of tropical rainforests (53 $Tg\,C\,yr^{-1}$) (McLeod et al., 2011). Furthermore, salt marshes can continue to maintain C accumulation for millennia (Macreadie et al., 2012). Although salt marshes provide a variety of ecological services including C sequestration as 'blue carbon' sinks, flood protection, nutrient filtration, and biodiversity preservation (e.g., flood protection, nutrient filtration, and biodiversity preservation) (Borsje et al., 2011; Hackney, 2000), about 50% of the world's salt marshes have been degraded or lost mainly due to land reclamation for farming and housing (Barbier et al., 2011). These habitat conversion or destruction can greatly alter hydrology conditions and redox environment of salt marshes because of constructing structures (such as dikes and floodgates) to impede tidal inundation in the process of reclamation (Dick and Osunkoya, 2000), thereby potentially affecting their intensity of C sinks and stability of large standing C pools (previously sequestered and stored C).

Previous studies have documented that habitat loss has substantial impacts on C cycling of salt marshes (Chmura et al., 2003; Duarte et al., 2005; Laffoley and Grimsditch, 2009). Most work to date has concentrated on the effects on C sequestration potential (Hopkinson et al., 2012; Macreadie et al., 2013 Macreadie et al., 2013), while relatively less attention has been put on the influence on large previously sequestered C pools associated with

* Corresponding author at: School of Life Science, Fudan University, 2005 Songhu Road, Shanghai 200438, China. Tel.: +86 21 51630688.
*E-mail address:* zhaobin@fudan.edu.cn (B. Zhao).

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salt marshes. A recent global estimation showed that habitat conversion causes roughly 0.15–1.02 Pg $yr^{-1}$ of $CO_2$ releasing from coastal ecosystems, being equivalent to 3–19% of that from global deforestation (Pendleton et al., 2012). These indicate that reclamation has the potential to greatly decrease previously sequestered and stored C pools of salt marshes. However, temporal dynamics of C loss following habitat loss was not considered in this evaluation. As massive coastal reclamation often implemented for agricultural land demand, several studies found that salt marshes conversion to croplands could significantly decline soil C pools on time scales of decades (Iost et al., 2007; Fernandez et al., 2010). But these work cannot distinguish the effects from reclamation or agricultural land use (e.g., crop cultivation, fertilization, and tillage practices) on soil C dynamics along with the conversion from salt marshes to croplands, because land use can significantly influence soil C dynamics (Bai et al., 2013). Thus, there are still rare direct empirical evidence of reclamation impacts on largely previously sequestered soil C pools of salt marshes. A study by Granek and Ruttenberg (2008) reported that half-life of surface sediments (0–5 cm) C pool was about 5–10 years following mangrove clearing, suggesting that previously sequestered soil C in coastal ecosystems has the potential to be rapidly lost after habitat conversion. Therefore, the temporal dynamics of previously-sequestered soil C following reclamation of salt marshes, especially within a short and specific length of time, are significant and pressing research need in the context of global climate change, because more serious reclamation are expected in the foreseeable future (Ma et al., 2014).

The most recent reclamation in the east of Chongming Island in the Yangtze River estuary of China, conducted in 1998, provides an ideal area to quantify the dynamics of previously-sequestered soil C after reclamation within a specific time. The island is the largest estuarine alluvial island in the world, and half of its present area was obtained by reclamation of salt marshes and was almost all used as agricultural land before 1998 (He and Gu, 2003). The most recent dike was implemented in 1998 to impede tidal inundation (Wu et al., 2005). Since then, large areas in the middle of the reclaimed lands nearby the dike were no longer used as cropland or aquaculture ponds, and were also not subjected to other disturbances. Therefore, the differences in soil C dynamics between this 'undisturbed' reclaimed area and adjacent salt marshes were mainly caused by reclamation effects. Our study, conducted from November 2007 to October 2008, was to quantify the dynamics of previously sequestered soil C after reclamation within nine years (from 1998 to 2007). More specifically, the aims of our work are to evaluate soil C dynamics following reclamation by comparing the differences in soil respiration, soil microbial biomass and SOC between 'undisturbed' area of reclaimed land in 1998 and adjacent salt marshes in the east of Chongming Island.

## 2. Materials and methods

### 2.1. Study site and experimental design

Our study area was in the east of Chongming Island in the Yangtze Estuary, China (31°25′–31°38′N, 121°50′–122°05′E). The island is located in the northern subtropical marine climate zone, with a mean annual precipitation of 1022 mm and temperature of 15.3 °C (Xu and Zhao, 2005). Due to a huge amount of sediments brought by the Yangtze River, the eastern salt marshes of Chongming Island retain an expansion rate of 150–200 m in distance or 4.06 $km^2$ in area per year toward the East China Sea (Yang et al., 2001).

Reclamation was performed as frequent as nearly once every 2–3 years in Chongming Island owing to increasing agricultural land use since the 1950s, and almost all the reclaimed lands before 1998 was used as croplands (He and Gu, 2003). The most recent reclamation was conducted in 1998. As the wetland in the east of Chongming Island (i.e., Chongming Dongtan wetland) was recognized as an International Importance Wetland by the *Ramsar Wetlands Convention* in 2002, and accepted as a National Nature Reserve in 2005 (Xu and Zhao, 2005), there was no more reclamation occurred from 1998 to the present. Prior to diking in 1998, dominant species of inside and outside the dike was *Phragmites australis*, and dominant species of large areas in the middle of the reclaimed lands in 1998 and present adjacent salt marshes was also *P. australis* (Li et al., 2009). Considering that this area is adjacent to the Chongming Dongtan National Nature Reserve for birds, and that *P. australis* stands can provide habitats and foods for a variety of shorebirds, the area is left there and has not been used as agricultural land as well as subjected to other disturbances by local authorities until 2010. Since then, this area is restored as an artificial wetland park.

In November 2007, we set up three plots, ca. 30 × 30 $m^2$ in area and 100 m apart, in 'undisturbed' area of reclaimed land in 1998 and adjacent salt marshes, respectively (Fig. 1). All plots were in *P. australis* stands and three replicates were randomly selected in each plot when in situ measurements and soil sampling. The

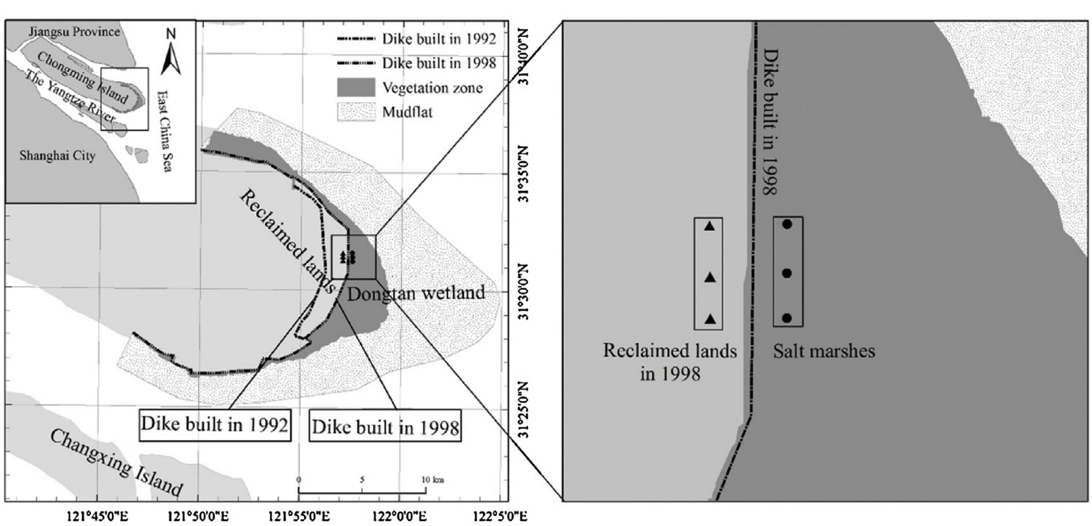


**Fig. 1.** Locations of sampling plots in reclaimed lands and adjacent salt marshes in the east of Chongming Island in the Yangtze River estuary.