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学 位 論 文 要 約
Dissertation Abstract

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論　文　名 : ANALYSIS OF THE ORGANIC CARBON STORAGE AND ORGANIC CARBON DYNAMICS OF MANGROVE FORESTS IN MEKONG DELTA, VIETNAM
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Mangrove forests are highly productive ecosystems in the coastlines of (sub) tropical regions. Mangrove forests provide various ecosystem services such as high carbon sequestration rate, nursery habitats for aquatic animals, filtering pollutants and reducing impacts of natural hazards, supporting fishery production and local communities. Mangrove forests have been recognized as the important organic carbon (OC) sources in the coastal zone, which export a large amount of OC to the ocean that supporting offshore ecosystems and fisheries. However, the OC storage and OC dynamics in mangrove forests have not yet been fully understood, particularly in regions with only a few information such as Vietnam and South East Asia. The lack of scientific information about OC storage and OC dynamics will lead to reducing the efficiency of management, conservation and restoration practices in mangrove forests. Therefore, the OC storage and OC dynamics in the mangrove forests should be examined to provide the knowledge for the improvement of conservation and restoration practices, sustainable development of mangrove forests and coastal area.

The present research focuses on the analysis of organic carbon storage and organic carbon dynamics in tropical mangrove forests in Mekong Delta (MKD), Vietnam. For analysis of these processes, the present research has adopted the TOC and sediment properties, and stable isotope ratios of carbon ($\delta^{13}C$) and nitrogen ($\delta^{15}N$) to explain the following questions: **(1)** What are the benefits of the mangrove restoration on the ecosystem C storage? and how will the ecosystem C storage change following the tropical typhoon disturbance?; **(2)** Which factors influence the $\delta^{13}C$ and $\delta^{15}N$ signatures of mangrove leaves and mangrove debris in the decomposition processes?; **(3)** Do mangroves sustain the benthic macro invertebrate‘s communities and what are the food sources which support benthic invertebrates in mangrove forests? **(4)** How will organic carbon dynamics change following the mangrove disturbance by the tropical typhoon?

As a result, the present study was summarized in four main points as listed in below paragraphs:

(1) Mangrove forests are large carbon sinks: The ecosystem C storage in the growing mangrove forests, a typhoon disturbed forest, and a mudflat in Can Gio Mangrove Forest Park (CGM), MKD, Vietnam was quantified by measuring the biomass of trees, roots, downed woody debris, and sediment organic C overall sediment depth. The mean above-ground C storage (mean ± SD) was 102 ± 24.7, 298.1 ± 14.1 and 243.6 ± 40.4 MgC ha^{-1} for the fringe, the transition, and the interior forests, respectively. The high above- and below-ground C stocks resulted in a large ecosystem C storage, ranging from 765 to 1026 MgC ha^{-1} with an overall mean of 910.7 ± 32.3 MgC ha^{-1} (mean ± SD). Moreover, the ecosystem C storage of the typhoon disturbed forest and mudflat were significantly lower than that of mangrove forests, being 573.5 MgC ha^{-1} and 619.8 ± 24.3 MgC ha^{-1} (mean ± SD), respectively. The ecosystem C storage (mean ± SD) in the CGM was significantly higher than that of natural mangrove forests in Ca Mau, Mekong Delta, Vietnam (762.2 ± 57.2 MgC ha^{-1}), indicating that the restoration practices have enhanced the C accumulation in mangrove forests. At the regional scale, the CGM can store up to 41.5 Tg C, which is equivalent to 152.3 Tg of carbon dioxide (CO_{2e}) Therefore, mangrove restoration and conservation are effective tools for increasing ecosystem C storage and offsetting C emissions at both regional and country levels.

(2) Factors influencing the variation of stable isotope signatures of mangrove leaves in the decomposition processes: The stable isotope signatures of leaves and debris of two mangrove species (*Avicennia alba* and *Rhizophora apiculata*) were measured for tracing the alteration of these isotopic signatures during the decomposition processes of mangrove leaves. The $\delta^{13}C$ signatures of mangrove leaves changed with seasons, species, and leaf status in the senescence process from green to brown (fresh fallen) leaves, but the $\delta^{15}N$ did not alter. On the forest floor, the leaching process of organic compounds and microbial activities potentially altered the $\delta^{13}C$ and $\delta^{15}N$ signatures in the decomposition processes from mangrove decomposed leaves to debris. Overall, the $\delta^{13}C$ signatures of mangrove leaves significantly increased during the decomposition processes, with values of approximately 2 and 4 ‰ from fresh to senescent leaves, and from fresh leaves to the fine debris, respectively. Additionally, the isotopic fractionations from fresh leaves to senescent leaves and fine debris may have important implications for OC dynamics and foodweb studies in the mangrove forests and coastal areas. The present results highlighted that the usage of fresh mangrove leaves as an isotopic end–member in the OC dynamics studies in mangrove ecosystems and coastal areas should be reconsidered.

(3) Carbon sources supporting benthic macroinvertebrates in mangrove forests: The dual stable isotope signatures ($\delta^{13}C$ and $\delta^{15}N$) of potential food sources and benthic invertebrates significantly varied among habitats such as the fringe, the transition, the interior, the cleared and the adjacent cleared forests in the tropical mangrove ecosystems of the Can Gio Mangrove Biosphere Reserve (CGMBR). The analysis of food sources proportion by mixing model indicated that the macroinvertebrates in the CGMBR depended on various kinds of food sources from mangrove leaves, sediment organic matter (SOM), particulate organic matter (POM), and benthic microalgae (BMA). The benthic invertebrates in the fringe and the cleared (typhoon disturbed) forest mainly consumed algal sources (POM and BMA), whereas the food sources of invertebrates from the transition, the interior, and the adjacent cleared forests were based on the SOM and mangrove-derived OC sources. The large variations of stable isotope compositions of benthic invertebrates demonstrated that their diets were greatly heterogeneous in the CGMBR. These findings also indicated that the scale of carbon movement and assimilation by benthic invertebrates was less than 100m in the CGMBR. Furthermore, the variation of

invertebrate's diets could have effects on the food sources of predators at higher trophic levels, highlighting the question of ecological linkage between invertebrates of different microhabitats and predators in the tidal creeks and estuaries.

(4) Changes in organic carbon dynamics following typhoon disturbance in mangrove ecosystems: The environmental conditions (such as salinity, temperature, redox potential, and Chlorophyll a), sediment properties, and stable isotopes compositions of benthic invertebrates were measured for tracing organic carbon dynamics in the typhoon disturbed and the adjacent growing forests of the CGMBR. The results of the present study demonstrated that the environmental conditions, the dynamics of sedimentary organic carbon and the carbon food sources assimilated by the benthic invertebrates were significantly changed by typhoon disturbance. The loss of above-ground biomass and tidal turbulences were the main factors which influenced the changes of environmental conditions and OC sources in surficial sediment layers. The main food sources of the benthic invertebrates in the growing mangrove forests were SOM, POM, and mangroves, whereas the algal sources (BMA, POM) significantly contributed to the diet of benthic invertebrates in the typhoon disturbed forests. The decomposition of mangrove dead roots was the main reason causing the increase of TOC from sediment cores of 20-70cm in depth, whereas the oxidation, sediment re-deposition, and tidal turbulences were main factors causing the loss of TOC in the surface sediments (0-20cm in depth) of the typhoon disturbed forests. However, the sedimentary C storage was not significantly changed in the typhoon disturbed forests. The present results were inconsistent with the recent studies about the impacts of anthropogenic disturbances (such as land-use change) on mangrove forests, which frequently showed a significant loss of C storage after forest disturbance. Therefore, the present results will provide the valuable information on management, conservation and monitoring the recovery of mangrove forest in Vietnam and Asia-Pacific region.

5) Recommendation for future studies: In the present study, organic carbon dynamics and organic carbon storage in the mangrove forests were examined. The impacts of typhoon disturbance on environmental conditions, sedimentary organic carbon dynamics and carbon food sources assimilated by benthic macroinvertebrates were also determined in mangrove forests in the CGMBR. However, the impacts of anthropogenic factors such as deforestation and land conversion on organic carbon dynamics and the ecological connectivity between mangrove forests and adjacent coastal ecosystems have not yet been presented in the present study. Additionally, the signs of forest regeneration have been observed in the typhoon disturbed forest, such as high density of seedlings in the growing/typhoon disturbed forest boundaries. The regeneration process plays important roles in the recovery of mangrove forest in the coastal area, enhancing C storage and coastal stabilization, and climate change adaptation. Thus, the future studies should be focused on these processes to fill the gaps in the ecological functions of mangrove ecosystems and the consequences of anthropogenic disturbances in mangrove forests.