Science AAAS

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Science **314**, 1417 (2006);
DOI: 10.1126/science.1130168

Old-Growth Forests Can Accumulate Carbon in Soils

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Old-growth forests have traditionally been considered negligible as carbon sinks because carbon uptake has been thought to be balanced by respiration (*1*). We show that soils in the top 20-cm soil layer in preserved old-growth forests in southern China accumulated atmospheric carbon at an unexpectedly high rate from 1979 to 2003. This phenomenon indicates the need for future research on the complex responses and adaptation of belowground processes to global environmental change.

Understanding the locations and driving forces of carbon sources and sinks at plot-to-global scales is critical for the prediction and management of the global carbon cycle and ultimately the behavior of the Earth's climate system (*2*). Major uncertainties remain in the geospatial distribution of terrestrial carbon sources and sinks and the mechanisms that drive the distribution and its change. Research efforts have largely been focused on the investigation and quantification of the impacts of climate variability and land use activities on the carbon cycle at various spatial and temporal scales. The soil carbon balance of old-growth forests has received little attention. It is generally accepted that soil organic carbon (SOC) levels in old-growth forests are in a steady state (*1*). To our knowledge, the long-term dynamics of SOC in old-growth forests and the validity of the above perception have not been tested.

We conducted a study to measure the long-term dynamics (1979 to 2003) of SOC stock in old-growth forests [age > 400 years (*3*)] at the Dinghushan Biosphere Reserve (23°09′21″N to 23°11′30″N and 112°30′39″E to 112°33′41″E) in Guangdong Province, China. The estimation of SOC stock change requires a series of measurements of SOC concentration, bulk density, and soil thickness taken at different points in time (*4*, *5*). In this study, we observed long-term changes in SOC concentration and bulk density but did not measure changes in soil thickness in the old-growth forests. Although soil thickness dynamics were not monitored, their possible contribution to the uncertainty in the results was analyzed and quantified by using upper and lower bounds of possible SOC change (Materials and Methods).

Results show that SOC concentration in the top 20-cm soil layer increased between 1979 and 2003 from about 1.4% to 2.35% at an average rate of 0.035% each year, which was significantly different from 0 at $\alpha = 0.05$. At the same time, the mean bulk density of the top 20-cm soil layer decreased significantly ($\alpha = 0.05$), with an average rate of 0.0032 g cm^{-3} $year^{-1}$. Measurements on a total of 230 composite soil samples collected between 1979 and 2003 suggested that SOC stock in the top 20-cm soil layer increased significantly during that time ($P < 0.0001$), with an average rate of 0.61 Mg C ha^{-1} $year^{-1}$ (Fig. 1). The lower and upper bounds of this average rate were 0.54 and 0.68 Mg C ha^{-1} $year^{-1}$, after considering the uncertainty introduced by the lack of thickness-change monitoring. We took more than enough samples to detect the observed SOC change. In fact, statistical analysis shows that 20 samples taken every 8 to 10 years of sampling interval (or 100 samples every 5 years) would be sufficient to detect the observed SOC change rate in these forests at a 95% confidence level. More samples would be required at shorter sampling intervals to detect the observed change, given the observed spatial variability of SOC concentration and bulk density.

The driving forces for this observed high rate of SOC increase in the old-growth forests are not clear at present and deserve further study. This study suggests that the carbon cycle processes in the belowground system of these forests are changing in response to the changing environment. This result directly challenges the prevailing belief in ecosystem ecology regarding carbon budget in old-growth forests (*1*) and supports the establishment of a new, non-equilibrium conceptual framework to study soil carbon dynamics. Our study further highlights the need to focus on the complexity of the belowground processes, as advocated in previous research (*6*, *7*), and the importance of establishing long-term observation studies on the responses of belowground processes to global change.

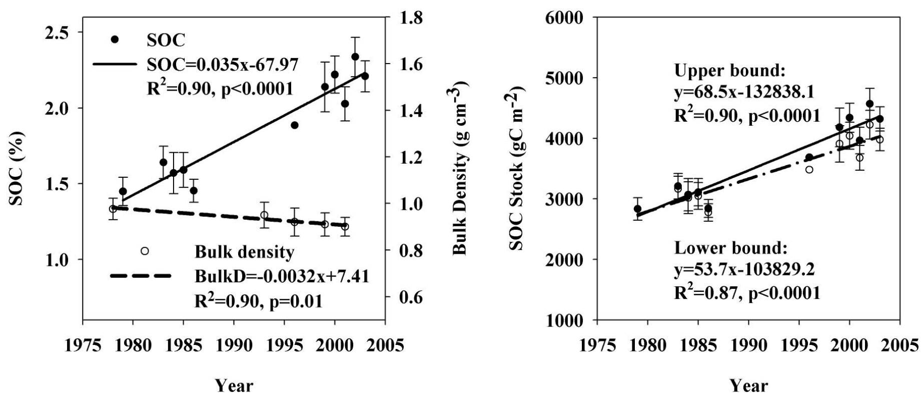

Fig. 1. Temporal changes of (**left**) soil organic carbon concentration, bulk density, and (**right**) soil organic carbon stock in the top 20-cm soil layer in broadleaved old-growth forests in Dinghushan Nature Reserve. Upper and lower bounds contain the uncertainty introduced by the lack of monitoring of soil thickness during the study period. Error bars indicate standard deviation.

References and Notes

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8. G.Z. acknowledges support from the Chinese Ecosystem Research Network (CERN), the Chinese Academy of Science (project KSCX2-SW-120), and the Natural Science Foundation of China (project 30470306). S.L.'s work was supported by the USGS Geographic Analysis and Monitoring Program and the Earth Surface Dynamics Program. Work was performed under USGS contract 03CRCN0001.

Supporting Online Material

www.sciencemag.org/cgi/content/full/314/5804/1417/DC1
Materials and Methods
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18 May 2006; accepted 13 September 2006
10.1126/science.1130168

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