Science of the Total Environment 706 (2020) 135416

Contents lists available at ScienceDirect

Science of the Total Environment

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

# The impacts of degradation, deforestation and restoration on mangrove ecosystem carbon stocks across Cambodia

Sahadev Sharma [a,1], Richard A. MacKenzie [b,*], Thida Tieng [c], Kim Soben [d], Natcha Tulyasuwan [e], Amomwan Resanond [e], Geoffrey Blate [f], Creighton M. Litton [a]

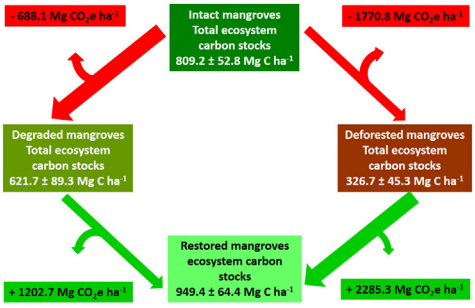
[a] Department of Natural Resources and Environmental Management, University of Hawaii at Manoa, 1910 East-West Rd., Honolulu, HI, USA
[b] USDA Forest Service, Institute of Pacific Islands Forestry, 60 Nowelo St., Hilo, HI, USA
[c] Asian Institute of Technology, Klong Luang, Pathumthani 12120, Bangkok, Thailand
[d] Royal University of Agriculture, Khan Dangkor, Phnom Penh, Cambodia
[e] USAID LEAD RDMA Program, 87 Wireless Road, Bangkok, Thailand
[f] USAID, 1300 Pennsylvania Ave. NW, Washington, DC, USA

## HIGHLIGHTS

- Deforestation reduced total ecosystem carbon (TEC) stocks of intact mangroves by 60%.
- TEC stocks from degraded mangroves forests did not differ from intact forests.
- TEC stocks from 25-year-old restored mangroves were similar to intact mangroves.
- A gridded sampling approach effectively captured TEC variability across an entire country.

## GRAPHICAL ABSTRACT

Our results concluded, that deforestation and degradation results in significant losses of TEC stocks from mangroves. While the prevention of deforestation and degradation is the most effective strategy for climate change mitigation and adaptation, it appears that restoration results in mangroves that can continue to combat climate change after 25–30 years.




## ARTICLE INFO

*Article history:*
Received 1 September 2019
Received in revised form 30 October 2019
Accepted 5 November 2019
Available online 23 November 2019

Editor: Jose Julio Ortega-Calvo

*Keywords:*
Blue carbon
Carbon inventory
*Rhizophora* plantation
Climate change mitigation

## ABSTRACT

Mangrove forest conservation can help reduce global C emissions. Despite this benefit to climate change mitigation and adaptation, mangrove forests are being deforested or degraded at an alarming rate, though restoration efforts may offset these losses. The impacts of deforestation to C stocks are relatively intuitive and result in significant decreases in C stocks. It remains unclear how degradation from selective harvesting of trees affects C stocks or how effective restoration efforts are at restoring C stocks. Furthermore, total ecosystem C (TEC) stocks of pristine mangroves can significantly vary spatially. To address these issues, we conducted an intensive, national assessment of mangrove forests across Cambodia using a grid approach to: 1) examine how land use land cover (i.e., pristine, deforested, degraded, and restored forests) impacts TEC stocks, and 2) how TEC stocks vary spatially across the country. TEC stocks from deforested mangroves were always lower than pristine forests, resulting in an overall loss of 60% C (480 Mg C $ha^{-1}$). However, TEC stocks from degraded and 25-year-old restored mangroves forests did not differ from pristine forests. Mean TEC in mangroves was 784.7 ± 30.1 Mg C $ha^{-1}$,

* Corresponding author.
*E-mail addresses:* ssharma@um.edu.my (S. Sharma), richard.mackenzie@usda.gov (R.A. MacKenzie), thidatiengclimate@gmail.com (T. Tieng), kimsoben@gmail.com (K. Soben), ntulyasuwan@pactworld.org (N. Tulyasuwan), amornwan.resanond@undp.org (A. Resanond), gblate@usaid.gov (G. Blate), litton@hawaii.edu (C.M. Litton).
[1] Present address: Institute of Ocean and Earth Sciences, University of Malaya, C308 Institute of Postgraduate Studies Building, Kuala Lumpur, Malaysia.

https://doi.org/10.1016/j.scitotenv.2019.135416
0048-9697/