Steps towards the use of the compactness index to detect perforation and fragmentation in mangrove forests

Kemalasari Della[1], Arimatéa de Carvalho Ximenes[1,2], Farid Dahdouh-Guebas[1,2] and Nico Koedam[1]

[1] Laboratory of Plant Biology and Nature Management, Vrije Universiteit Brussel – VUB, Pleinlaan 2, B-1050 Brussels, Belgium
E-mail: dkemalas@vub.ac.be

[2] Laboratory of Systems Ecology and Resource Management, Université Libre de Bruxelles - ULB, Av. F.D. Roosevelt 50, B-1050 Brussels, Belgium

Mangroves are forests that grow in the intertidal zone of coastal areas and estuaries in the tropics and warm subtropics, with extensive roots well adapted to the saline water and anoxic/hypoxic soils. These highly productive forests can provide many ecosystem services, including carbon sequestration, coastal protection to wave action, storm surges, tsunamis, sea-level rise, a buffer to sedimentation loads, amongst others (Donato *et al.*, 2011; Dahdouh-Guebas *et al.*, 2005; Di Nitto *et al.*, 2008; Rajkaran and Adams, 2010). Mangroves consist of remarkably few species, and as ecosystems they are globally threatened as the rate of its deforestation is comparable to that of the terrestrial rainforests (Polidoro *et al.*, 2010; FAO, 2007; Duke *et al.*, 2007). If effective conservation does not take place at important locations, the world's mangrove formations would disappear in the next 100 years (Duke *et al.*, 2007). Currently, man-induced habitat fragmentation is a concern, a process through which contiguous forest stretches are broken down into several patches (Bogaert *et al.*, 2011). Each patch being more exposed to edge effects, this degrades the overall ecological quality of the forests (Ries *et al.*, 2004). The landscape transformation process that leads to habitat fragmentation is often preceded by perforation, which is marked by a distinct spatial pattern (Forman, 2001). Perforated forests will have more edge effects by the presence of inner holes, leading to further forest degradation. The methodology to quantify the process of forest fragmentation and perforation using landscape metrics has been widely applied in terrestrial ecosystems. However it is still understudied in mangrove ecosystems and complicated because of their naturally patchy pattern. After a methodological analysis related to scale effects of input data, we assess the magnitude, the extent and the location of perforated mangrove forests using Compactness Index on a 30-meter resolution global mangrove distribution map published by Giri *et al.* (2011). Here the emphasis lies on mangroves of the United States, Kenya, Sri Lanka and South Africa. The Compactness Index, which ranges from 0 to 1, measures the compactness of forests, with low values indicating perforated shapes and high values for compact shapes (Montero and Bribiesca, 2009). We found that this index detected highly porous patterns in the mangroves along the Sine Saloum delta in Senegal and the mangroves along the Gambia River, amongst many other locations in the world. We also found that this index is consistently detecting perforated patterns in the mangroves along the river.Therefore, this index is considered to be quite sensitive to measure the degree of perforation, if one considers the range of values obtained, to be further applied in diachronic analysis of forest fragmentation. We also indicated the scaling relation of this index on the mangroves of the United States, Kenya, Sri Lanka and South Africa, using 6 different scales (30, 60, 120, 240, 480, and 960 meter) and this index shows a consistent relation toward the coarser scales. Further study on multiscale analysis is needed to characterise the scaling relation of this index, so that conservation action can be directed at precise locations.

References

Bogaert J., Y.S.S. Barima, J. Ji, H. Jiang, I. Bamba, L.I.W. Mongo, A. Mama, E. Nyssen, F. Dahdouh-Guebas and N. Koedam. 2011. A methodological framework to quantify anthropogenic effects on landscape patterns. p.141-167. In: Hong S.-K *et al.* (Eds). Landscape Ecology in Asian Cultures, Ecol. Res. Monog.

Dahdouh-Guebas F., L.P. Jayatissa, D. Di Nitto, J.O. Bosire, D. Lo Seen and N. Koedam. 2005. How effective were mangroves as a defence against the recent tsunami? Curr. Biol.15(12):443-447.

Di Nitto D., F. Dahdouh-Guebas, J.G. Kairo, H. Decleir, N. Koedam. 2008. Digital terrain modelling to investigate the effects of sea level rise on mangrove propagule establishment. Mar. Ecol. Prog. Ser. 356:175–188.

Donato, D.C., J.B. Kauffman, D. Murdiyarso, S. Kurnianto, M. Stidham and M. Kanninen. 2011. Mangroves among the most carbon-rich forests in the tropics. Nature Geoscience 4:293-297.

Duke N.C., J.O. Meynecke, S. Dittmann, A.M. Ellison, K. Anger, U. Berger, S. Cannicci, K. Diele, K.C. Ewel, C.D. Field, N. Koedam, S.Y. Lee, C. Marchand, I. Nordhaus and F. Dahdouh-Guebas. 2007. A world without mangroves? Science 317:41-43.

FAO 2007. The world's mangroves 1980-2005. FAO Forestry Paper 153. Rome: FAO Forest Resources Division.
Forman R.J. 2001. Land mosaics: The ecology of landscapes and regions. Cambridge University Press, UK.
Giri C., E. Ochieng, L.L. Tieszen, Z. Zhu, A. Singh, T. Loveland, J. Masek and N. Duke. 2011. Status and distribution of mangrove forests of the world using earth observation satellite data. Glob. Ecol. Biogeogr. 20:154-159.
Montero R. and E. Bribiesca. 2009. State of the art of compactness and circularity measures. Int. Math. For.4(27):1305-1335.
Polidoro B.A., K.E. Carpenter, L. Collins, N.C. Duke, A.M. Ellison, J.C. Ellison, E.J. Farnsworth, E.S. Fernando, K. Kathiresan, N.E. Koedam, S.R. Livingstone, T. Miyagi, G.E. Moore, V.N. Nam, J.E. Ong, J.H. Primavera, S.G. Salmo III, J.C. Sanciangco, S. Sukardjo, Y. Wang and J.W.H. Yong. 2010. The loss of species: mangrove extinction risk and geographic areas of global concern. Plos ONE 5(4).
Rajkaran A. and J.B. Adams. 2010. The implications of harvesting on the population structure and sediment characteristics of the mangroves at Mngazana Estuary, Eastern Cape, South Africa. Wetl. Ecol. Manag.18:79–89.
Ries L., R.J. Fletcher, J. Battin and T.D. Sisk. 2004. Ecological responses to habitat edges: mechanisms, models, and variability explained. Annu. Rev. Ecol. Evol. Syst. 35:491-522.