Tropical Agricultural Research Vol. 27 (2): 137– 146 (2016)

Above Ground Biomass Estimation of Mangroves Located in Negombo - Muthurajawela Wetland in Sri Lanka using ALOS PALSAR Images

A.R. Gunawardena[*], S.P. Nissanka[1], N.D.K. Dayawansa[2] and T.T. Fernando

Postgraduate Institute of Agriculture
University of Peradeniya
Sri Lanka

ABSTRACT: *In Sri Lanka, mangrove forests are scattered along the north-western, north eastern, Jaffna Peninsula and eastern coastal belt. The total estimated extent of mangroves in the country is about 87 km^2. Estimation of Above Ground Biomass (AGB) of mangroves is a challenging task due to field sampling difficulties. Use of satellite based remote sensing technologies is becoming popular for estimation of AGB for different vegetation types. To overcome the limitations during field sampling and to identify the possibility of using SAR data for AGB estimation, ALOS PALSAR satellite data were used to estimate AGB of mangroves and associated vegetation in Muthurajawela- Negombo wetland in Sri Lanka.*
Diameter at Breast Height (DBH) measurements over 5cm of eighteen (18) sampling plots (10x10 m) were collected and the relevant allometric equation was used to estimate the AGB. Backscatter coefficient values of HH and HV polarization of ALOS –PALSAR images were used to estimate the AGB of mangroves using a previously derived model. Finally, an AGB map of mangrove associated vegetation was developed for the study area using ALOS PALSAR data as a method of minimizing field work while saving time and cost.
According to the results, the average AGB is observed as 65t/ha from the field sampling method (28 -135 t/ha) while it was estimated as 76 t/ha (33-155 t/ha) using PALSAR which shows an overestimation by 17%. A significant overestimation by the remote sensing method is occurred when the tree height is more than 5 m. Though it shows an overestimation, the map developed using this approach is helpful to understand the distribution of AGB within mangrove associated vegetation systems where field sampling is a challenging task.

Keywords: *Remote Sensing, Biomass, Mangroves, Above Ground Biomass*

INTRODUCTION

All the living organisms above the soil is referred as the Above Ground Biomass (AGB). Natural ecosystems like forests store a massive quantity of biomass and the accurate quantification of it is a challenging task. The most accurate way of estimating forest biomass is the destructive sampling which consumes time and money. A far more efficient method, with well-established accuracy is to measure the above ground dimensions of trees to estimate weights (Brown *et al.,* 1989). The use of remote sensing technology has become a very effective approach to biomass estimation since it is non destructive and effective in terms of cost and time.

[1] Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.
[2] Department of Agricultural Engineering, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.
[*] Corresponding author: ajiththeja@gmail.com

Traditional inventory of forest parameters based on fieldworks is often difficult, costly and time consuming to conduct in large areas. Complexity of structure and inaccessible nature of many mangrove forests limits the feasibility of ground based inventory for biomass estimation. However, remote sensing is one of the feasible ways to acquire forest stand parameter information at a reasonable cost with an acceptable accuracy. Advanced new remote sensing techniques such as multi-sensor data fusion, increased spatial and spectral resolution and integration possibility with Geographical Information Systems (GIS) have made the remotely sensed data a primary source for many biomass estimation applications (Namayanga, 2002).

In Sri Lanka, mangrove forests are scattered mainly along the north-western, north eastern, Jaffna Peninsula and eastern coasts bordering lagoons and river estuaries. The area extent covered by the mangrove forests is estimated at only 87 km^2. Majority of the mangrove forest areas have been subjected to human interferences hence undisturbed mangrove forests are seldom found. In most areas, the mangrove forests are usually restricted to a narrow strip (Legg and Jewell, 1995).

Mangrove Forest of Sri Lanka

Two major types of mangrove forests, namely, low-saline and high-saline, could be distinguished by the floristic composition. Three other specialized high saline types, scrub, over wash, and basin, are also sometimes can be distinguished depending on the flooding characteristics and topography (Silva and Silva, 1998). Twenty three true mangrove species of trees and shrubs have been recorded in Sri Lanka, the common species being *Rhizophora mucronata, Avicennia marina, Excoecaria agallocha, Acanthus ilicifolius, Lumnitzera racemosa, Sonneratia caseolaris, Bruguiera gymnorhiza* and *Aegiceras corniculatum*. The rare species are *Ceriops decandra, Sonnera tiaapetala, Lumnitzera littorea, Scyphiphora hydrophyllacea and Cynome trairipa*, out of them the first three are endangered species in Sri Lanka (The National Red List of Sri Lanka, 2012).

Biomass estimation using SAR data

The ALOS (Advanced Land Observing Satellite) PALSAR (Phased Array type L-band Synthetic Aperture Radar) in 2006 has increased the potential of utilizing radar to measure biomass, as this is the first long-wavelength (L-band, 23-cm wavelength) SAR satellite sensor to have the capability of collecting single, dual, full and Scan-SAR mode with cross-polarized (HV, horizontal-transmit, vertical receive) and co-polarized (HH, horizontal-transmit, horizontal receive; VV, vertical-transmit, vertical receive) data. The HV polarization is useful because it interacts with trees and produces a strong response (Avtar *et al.,* 2013). Various studies have analyzed the retrieval of Above Ground Biomass (AGB) using radar data in tropical regions (Mitchard *et al.,* 2009). These methods are mostly based on empirical or semi-empirical relationships between radar backscatter and ground based data.

There are many studies (Ranasinghe, 1998, 2001; Amarasinghe and Liyanage, 1996) conducted to describe the ecology and biology of mangroves in Sri Lanka. However, there are no specific studies on biomass estimations of mangroves in the country.

It is not possible to find literature on estimation of AGB using SAR data in Sri Lanka though some studies have been carried out on the use of optical and infrared data (Gunawardena *et al*., 2006; 2009; 2013 and 2014). This study attempted to identify the possibility of using

SAR data to estimate the AGB of mangrove forest and associated vegetation in Negombo – Muthurajawela area of Sri Lanka using ALOS PALSAR data.

METHODOLOGY

Study site

The selected mangrove area can be found in Muthurajawela - Negombo Lagoon which is a large estuarine located in the western coast of Sri Lanka (Figure 1). The lagoon is fed by a number of small tributaries and major rivers namely; Dandugan Oya and Hamilton Canal. The estuary is linked to the sea by a narrow channel. The lagoon has extensive mangrove swamps rich in biodiversity. The three islets which are famous for the mangroves are in northern end namely; Kakaduwa, Mandagasalamba and Kadolnallala. Fourteen (14) mangrove species have been found in these islets. Sedimentation has accelerated between the islets and form mud flats which supports the primary generation of mangroves (Pinto, 1982).

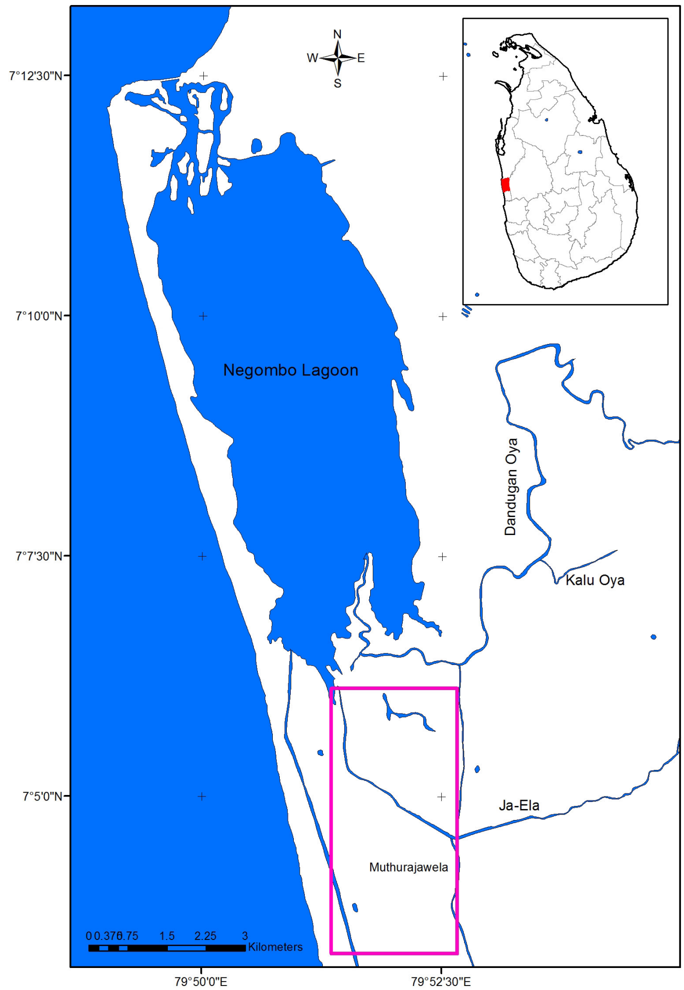

Fig. 1. Study area - Negombo - Muthurajawela wetland of Sri Lanka

Many important aspects have made the Negombo Lagoon and its associated wetland ecosystem very significant. It provides a source for natural products of peat, timber, flowers, vegetable, fruit, grasses for livestock, corals, fish, shrimp, sand and shells, reeds for thatch, salt and clay (CEA, 1994). Fishing and shrimp farming are the main income generation of the people in the surrounding. According to the studies carried out by Panditharatne (1981) shrimp farming was spreading at an alarming rate around the lagoon and currently majority of the farms are abandoned (Wimalasena and De Mel, 2009). Because of the importance of mangroves in this unique eco system of Negombo Lagoon, this study was carried out to find out the biomass association which supports the carbon sink of the environment. Brush-pile fisheries (use of mangrove branches as fish aggregating devices) has been noted in Negombo lagoon, where mangrove branches are piled in the lagoon to act as fish aggregating devices which cause to biomass reduction (Amarasinghe *et al.,* 2011)

Data, materials and software

- ALOS PALSAR images of Duel Polarizations (HH, HV) ALOS –PALSAR were used (LED-ALPSRP125690120-H1.5_UA). Processing level was 1.5 and the Pixel Spacing was 12.5 m. Date of image acquisition was 03 May, 2008. This image was originally projected to UTM, WGS 84.
- Landsat 8 OLI (Date of image acquisition 30 August 2014)
- High Resolution imageries (IKONOS and Quick Bird) and Google Earth.
- GPS locations of field sampling plots and different land uses and land cover.
- ERDAS, PolsarPro, Nest, Remote 10 and ArcMap software were used for image analysis and map generation.

Boundary demarcation of mangroves and associated vegetation

Initial field survey was conducted to collect GPS locations of the study area representing all land use and land cover types. Collected ground truth data were used to carry out an unsupervised classification of Landsat 08 OLI (2014) data which ultimately derived the updated land use/cover map of the area. High resolution IKONOS, Quick Bird and Google Earth images were used to validate the developed land use/cover map. Mangrove and associated vegetation were extracted from the land use/cover maps and a separate thematic layer was created. It was overlaid on PALSAR image to delineate the study area boundary.

Field based biomass estimation

Diameter at Breast Height (DBH) measurements over 5 cm of eighteen (18) sampling plots (10x10 m) have been collected and allometric equation developed by Ong *et al.* (2004) was applied (Equation 1) to estimate AGB. Field measurement collection was conducted during year 2011 - 2012. Canopy cover percentage was also estimated by visual interpretation of high resolution satellite imageries.

$$\text{Log } 10\ (AGB) = 2.420 * \log 10\ (DBH) - 1.832 \quad \text{(Equation 1)}$$

(Ong *et al.*,2004)

Conversion of DN of PALSAR image into backscattering coefficient

In this study, ALOS –PALSAR images with HH and HV duel polarization were used to calculate the biomass. The DN (Digital Number) of the HH and HV polarized images were converted into backscattering coefficient using Equation 2 (Shimada *et al.*, 2009). L-band microwaves (wavelength approximating 25 cm) emitted by the ALOS PALSAR penetrate through the foliage and interact primarily with the woody components of vegetation. Horizontally transmitted waves are either depolarized through volume scattering by branches in the canopy, with a proportion of vertically polarized microwaves returning to the sensor, or penetrate through the canopy and interact with the trunks, returning primarily through double bounce scattering, as a horizontally polarized wave (Lucas *et al.*, 1998).

$\sigma^0 = 10*\log10\,(DN2)-83.0$ (Equation 2)
σ^0 = Backscattering Coefficient

Biomass estimation using backscatter coefficient

Biomass estimation model developed for ALOS PALSAR imageries has been applied to estimate the carbon in Cambodian mangroves and other ecosystems and has obtained significant results (Avtar *et al.*, 2013). The same model was used in this study to estimate the AGB in the mangroves and associated vegetation. The model is presented in Equation 3.

$AGB = 752.95 + (44.4*\sigma^0 HV)-(8.73*\sigma^0 HH/HV)$ (Equation 03)
Avtar *et al.* (2013)

HH = Horizontal – Horizontal Backscattering coefficient of PALSAR
HV = Horizontal – Vertical Backscattering coefficient of PALSAR

The accuracy of estimated AGB was assessed by comparing with field sampled AGB using statistical analysis by t- test. Finally, the AGB map of mangrove and associated vegetation was developed using ALOS PALSAR imagery. The methodology followed in estimation of biomass is presented in Figure 2.

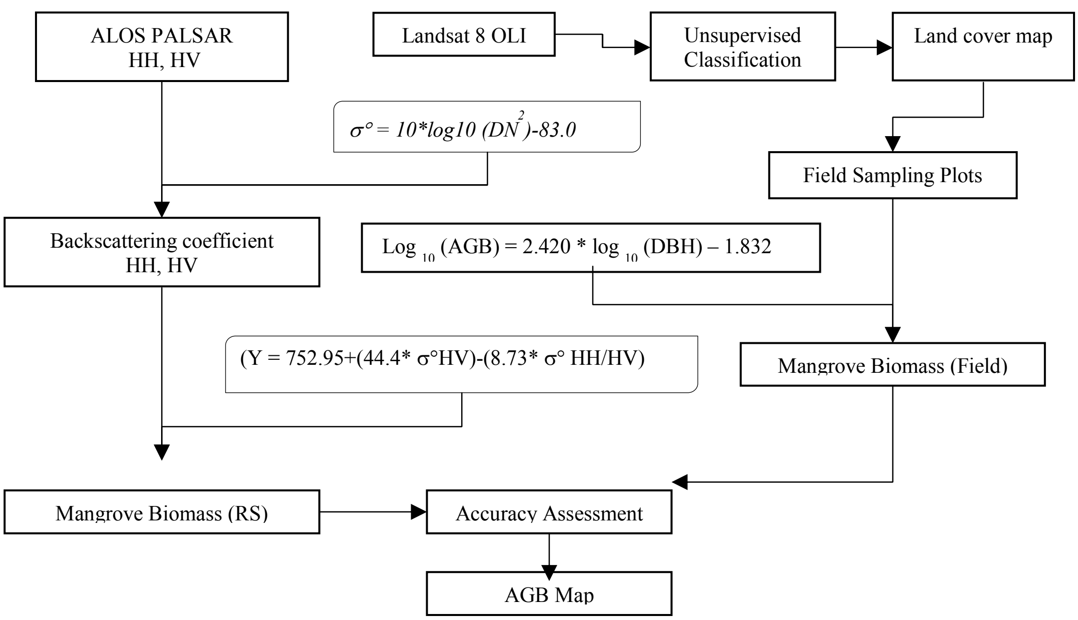

Fig. 2. Flow diagram of the methodology

RESULTS AND DISCUSSION

Demarcation of mangrove and associated vegetation using Landsat OLI

Unsupervised classification of Landsat 8 OLI image (2014) which was used to develop the land use/cover map with accuracy checking using Google Earth images and GPS based ground truth information is shown in Figure 3. There are 8 major land use/cover classes derived for the study area and mangrove with associated vegetation were extracted for field biomass estimation.

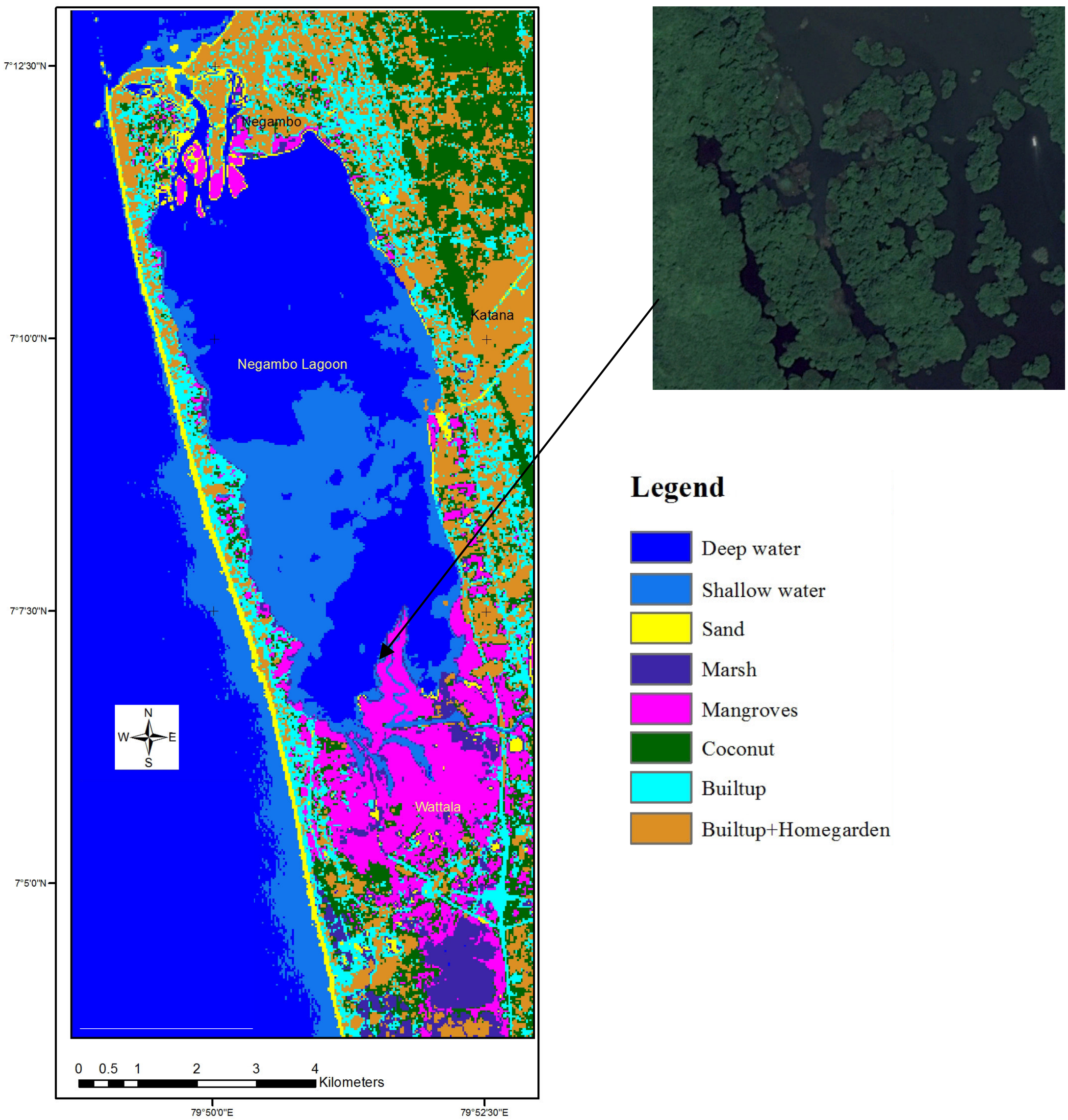

Fig. 3. Land use/cover map of study area derived from Landsat OLI image (2014) using unsupervised classification

Comparison of PALSAR estimated AGB with estimations made by field sampling

During field observations, 10 species of mangrove were identified in the study area. Among the mangrove species, *Acrostichum aureum, Barringtonia racemose, Rhizophora apiculata, Rhizophora mucronata, Excoecaria agallocha, Acanthus ilicifolius, Lumnitzera racemosa, Sonneratia caseolaris,* and *Bruguiera gymnorhiza* are commonly found in the study area.

According to the field AGB observation, an average of 65 t/ha of AGB was estimated which was ranging from 28 t/ha to 135 t/ha within the plots. Some plots which were dominated with *Bruguiera, Rhizophora* and *Sonneratia spp* show high biomass content. Figure 4 presents the AGB estimated using PALSAR data and the field measurements. Accordingly, comparatively high estimation of biomass compared to field estimations can be seen in majority of plots except in plots 2, 6, 13, and 14. According to field observations, these plots consisted with more exposed soil and root which are represented by lower backscatter coefficient. On average, an overestimation of 17.7% of AGB can be identified using PALSAR data. Lucas *et al.* (2007) also observed lower backscatter in HH polarization in mangroves having extensive prop root systems. Analysis of field collected data revealed that a significant overestimation (plot no 7 and 15) is occurred when the average tree height of the plot is more than 5 meters with higher stem densities and more inundated water which produce high backscattering.

In this study, the average biomass content was estimated as 90.5 t/ha in Muthurajawela – Negombo mangrove wetlands. Study conducted by Eskil *et al.* (2012) observed the biomass carbon in mangroves in Northwestern coastal zone of Sri Lanka as 35 –149 t/ha using inventory data. Similar study conducted by Lucas *et al.* (1998) in Southeast Asia and Northern Australia have obtained 100 -120 t/ha of AGB. The results of this study are compatible with the results obtained in the above research. Figure 5 presents the AGB map prepared for the study area. According to the map, AGB density distribution of mangrove and associated vegetation are dominated in lower part (Southern) of the Negombo Lagoon and along Dandugam Oya. There is a sparce distribution of mangroves in the Eastern and Western borders of the lagoon and most of the mangrove vegetation are situated as a thin belt less than 5m in width which is difficult to visualize in the map.

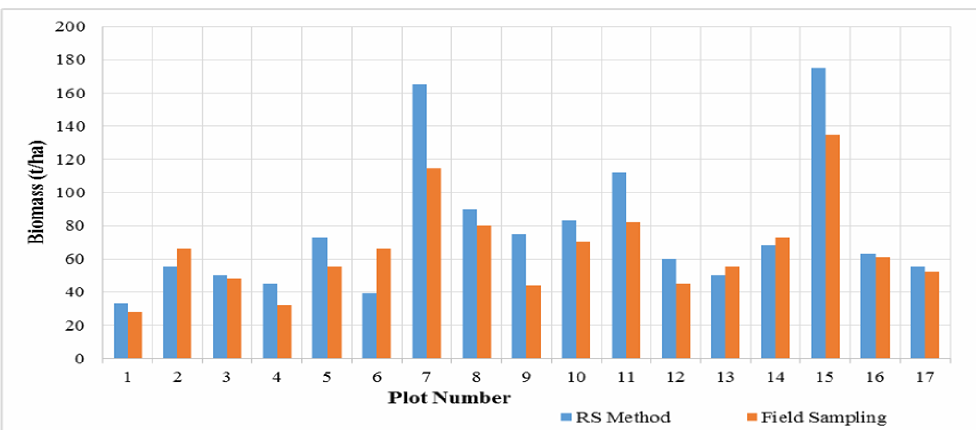

Fig. 4. Comparison of estimated AGB of mangroves associated vegetation by field sampling with PALSAR data

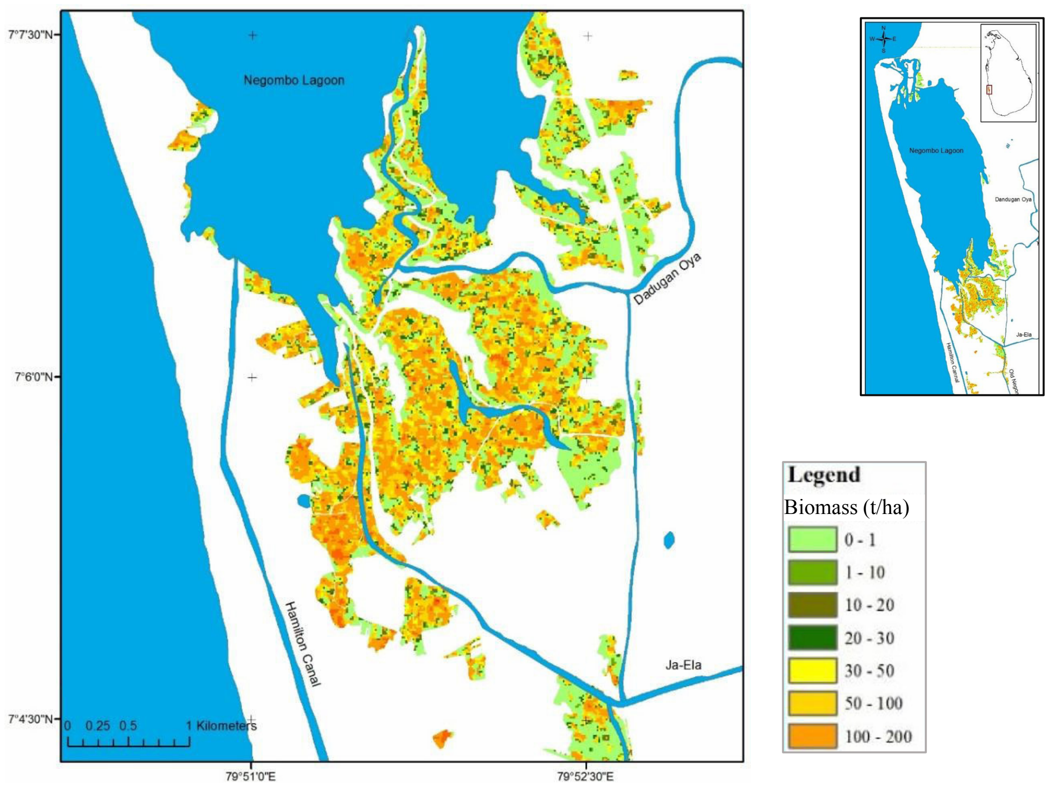

Fig. 5. Estimated AGB map derived from ALOS PALSAR imagery

CONCLUSIONS

The study identified that the AGB estimated using the model developed by Avtar *et al.* (2013) using backscattering coefficient derived from HH, and HV polarized PALSAR data overestimate the AGB of mangroves compared to the field sampled data. On average, this overestimation is 17.7% for this study.

According to the PALSAR data, the average biomass content of the mangrove forests of the study area is 90.5 t/ha which gives 17% overestimation than the field sampled estimation. Many reasons can be attributed to the deviation of estimated AGB. Among them, biophysical parameters of the mangrove vegetation, inundated water levels, soil exposure levels and associated plants are directly affected to backscatter coefficient of the PALSAR image. In addition, the AGB estimation was carried out with a model derived elsewhere hence it is important to identify its suitability to local mangrove species and their distribution. Further studies with the same SAR data will be helpful to derive a suitable model for the local conditions to asses AGB of Sri Lankan mangroves.

REFERENCES

Amarasinghe, M.D. and Liyanage, S. (1996). Contribution of mangrove resources to the socio-economic status of adjacent human communities along the West and Southern coasts of Sri Lanka, IUCN-Forest Department, Sri Lanka.

Amarasinghe, O. and Bavinck, J.M. (2011). Social capital and the reduction of vulnerability: The role of fisheries cooperatives in southern Sri Lanka. In: Poverty mosaics, realities and prospects in small scale fisheries, ed., Jentoft, S. Arne, Aide.Dordrecht: Springer.

Avtar, R., Suzuki R., Takeuchi, W. and Sawada, H. (2013). PALSAR 50 m Mosaic Data Based National Level Biomass Estimation in Cambodia for Implementation of REDD+ Mechanism. PLoS ONE 8(10): e74807. doi:10.1371/journal.pone.0074807.

Brown, S., Gillespie, A.J.R. and Lugo, A.E., (1989). Biomass estimation methods for tropical forests with applications to forest inventory data. Forest Science, vol. 35, pp. 881 - 902.

CEA/Euroconsult (Netherlands) (1994). Muthurajawela Marsh and Negombo Lagoon Wetland site report, Central Environmental Authority, Sri Lanka.

Eskil, M., Persson, U.M., Ostwald, M., Nissanka, S.P. (2012). REDD plus readiness implications for Sri Lanka in terms of reducing deforestation, Journal of Environmental Management, Vol.100, pp. 29 - 40.

Gunawardena A.R, Nissanka S.P., and Dayawansa N.D.K. (2006). Relationship between above Ground Live Biomass and Satellite Image Spectral Responses (Landsat ETM+) of Pinus caribaea at Lower Hantana Region in Sri Lanka. Tropical Agricultural Research vol. 18. pp. 334 – 345.

Gunawardena A.R, Nissanka S.P., and Dayawansa N.D.K. (2009). Development of Merchantable Timber Volume Estimation of Pinus caribaea Plantations using Multi-Spectral Satellite Images ENGINEER - Vol. XXXXI, No. 05, pp. 68 - 73.

Gunawardena, A.R, Nissanka, S.P, and Dayawansa, N.D.K. (2013). Estimation of above ground live biomass of *Tectona grandis* (teak) plantation in low country dry zone region in Sri Lanka using IRS LISS III (2008) data. Proceedings of the First Symposium of geo-informatics, International Water management Institute, Colombo.

Gunawardena, A.R, Nissanka, S.P, and Dayawansa, N.D.K. (2014). Assessment of the spatial distribution and biomass estimation of Prosopis juliflora in Puttlam to Mannar Region of Sri Lanka Using Multi-Temporal Satellite Images. Tropical Agricultural Research Vol. 25, pp. 228 - 239.

Legg, C. and Jewell, N. (1995). A 1:50 000 scale forest map of Sri Lanka, the basis for the National Forest Geographic Information System. Special Issue: Remote Sensing Sri Lanka. Forester, Vol. 3, p. 24.

Lucas, R.M., Curran, P.J., Honzak, M., Foody, G.M., Do Amaral, I. and Amaral, S. (1998). The contribution of remotely sensed data in the assessment of the floristic composition, total biomass and structure of Amazonian tropical secondary forests. In: Regenerac¸ao˜ Florestal: Pesquisasna Amazonia, C. Gascon and P. Moutinho (Eds), Manaus, INPA Press, pp. 61 - 82.

Lucas R.M, Mitchell A.L, Rosenqvist A, Proisy C, Melius A, et al. (2007) The potential of L-band SAR for quantifying mangrove characteristics and change: Case studies from the tropics. Aquatic Conservation - Marine and Fresh Water Ecosystems Vol.17: 245 - 264.

Mitchard, E.T.A., Saatchi, S.S., Woodhouse, I.H., Nangendo, G. and Ribeiro, N.S. (2009). Using satellite radar backscatter to predict above-ground woody biomass: PALSAR Based Cambodian Forest Biomass. A consistent relationship across four different African landscapes. Geophysical Research Letters, Vol. 36, pp. 1 - 6.

Namayanga, L.N. (2002). Estimating terrestrial carbon sequestered in above ground woody biomass from remotely sensed data. International Institute for Geo-information Science and Earth Observation, Netherlands. MSc Thesis pp. 10 - 12 .

Ong, J.E., Gong, W.K. and Wong, C.H. (2004). Allometry and partitioning of the mangrove, *Rhizophora apiculata*. J. Forest Ecology Management, Vol.188, pp. 395 - 408. DOI: 10.1016/j.foreco.2003.08.002 .

Panditharatne, S. (1981). Impacts of technology and institutional changes on the fishing community of Negombo 1950 - 1980. NARESA Final Report RGB/81/5/3.

Pinto, M.L. (1982). Distribution and zonation of mangroves in the Northern Part of the Negombo Lagoon. Sri Lanka, Journal of National Science Council, Sri Lanka, pp. 245 - 255.

Ranasinghe, D.M.S.H.K. (1998) Mangroves of Sri Lanka; a losing resource. In: MPT News Vol. 7, No. 2, 1998, Multi- Purpose Tree Species Network, Faculty of Agriculture, University of Peradeniya, Sri Lanka.

Ranasinghe, D.M.S.H.K. (2001) Conservation of mangroves in Muthurajawela Marsh and Negombo/ Chilaw Lagoon, Proceedings of the workshop on Effective Management for Biodiversity Conservation in Sri Lanka Coastal Wetlands (ed Farmer, N), Centre for Economics and Management of Aquatic Resources, University of Portsmouth, U.K.

Shimada, M., Isoguchi, O., Tadono, T. and Isono, K. (2009). PALSAR polarimetric calibration and geometric calibration. IEEE, Transactions on Geoscience and Remote Sensing, Vol.47 (12), pp. 3915 - 3932.

Silva, D.M. and Silva, P.K., (1998). Status, diversity and conservation of the mangrove forests of Sri Lanka. J. South Asian nat. Hist., ISSN 1022 - 0828. January, 1998. Vol.3 (1), pp. 79 - 102.

The National Red List 2012 of Sri Lanka (2012). Conservation Status of the Fauna and Flora. Weerakoon, D.K. & S. Wijesundara Eds., Ministry of Environment, Colombo, Sri Lanka.

Wimalasena, H.D. and de Mel, W.D.M. (2009). Shrimp Farming in Sri Lanka: Risks and Returns. Sri Lankan Journal of Humanities and Social Sciences Vol.1 (2).