INNSPUB

Journal of Biodiversity and Environmental Sciences (JBES)
ISSN: 2220-6663 (Print) 2222-3045 (Online)
Vol. 10, No. 4, p. 103-113, 2017
http://www.innspub.net

RESEARCH PAPER OPEN ACCESS

Modeling the spatial pattern of carbon stock in Central Mindanao University using inVEST tool

Joseph C. Paquit*[1,2], Francis Niño W. Mindaña[1]

[1]*Department of Forest Biological Sciences, Central Mindanao University, Bukidnon, Philippines*

[2]*Center for Geomatics Research in Mindanao, Philippines*

Article published on April 30, 2017

Key words: InVEST tool, GIS modeling, Carbon stock, Central Mindanao University

Abstract

This study was primarily intented to model the spatial pattern of carbon stock in Central Mindanao University (CMU) campus. Thirty-three (33) land use/land cover (LULC) types were delineated in the study area. The carbon stored in each LULC type were determined using relevant secondary information generated from both local and international researches. The mapping of carbon across CMU's landscape was done using In Vest tool and ArcMap version 10.1. Results have shown that carbon stored varies within different LULC types. With a land area of 3,080.82 hectares, CMU currently stores an estimated 234,380 tonnes of carbon. The LULC type with rich vegetation had higher amount of carbon stored on a per hectare basis. Natural forest obtained the largest carbon stored with 41,455.10 tonnes (209 tonnes C/ha) which comprise 17.69% of the total carbon stock in the area. It was therefore identified as the potential area for the Reduction of Emission from Deforestation and Degradation Program (REDD+) and other related activities.

***Corresponding Author:** Joseph C. Paquit ✉ jcpaquit@cmu.edu.ph

Introduction

Climate change is of critical concern to the Philippines; it is one of the most climate change vulnerable areas in Southeast Asia (Yusuf and Francisco, 2009). The alarming increase of carbon dioxide (CO_2) in the atmosphere is largely influenced by human activities. These activities include burning fossil fuels, deforestation and degradation of valuable carbon sinks. Many activities are being done to address the issue. Currently, biotic carbon sequestration is being considered a workable option for mitigating CO_2 emission to the atmosphere (Tariyal, 2014).

Forestry and agriculture play an important role in biotic carbon sequestration and storage. The role of forests in sequestering carbon and helping to mitigate climate change was even recognized through the Kyoto Protocol. Forests operate both as vehicles for capturing additional carbon and as carbon reservoirs. Both young and old-growth forests are effective carbon sinks. A young forest can sequester relatively large volumes of carbon while an old-growth forest is more of a reservoir. An old forest may not be capturing any new carbon but can continue to hold large volumes of carbon as biomass over long periods of time (Kauppi and Sedjo, 2001). Although not the complete answer to the carbon problem, carbon sequestration through forestry does have the potential of stabilizing, or at least contributing to the stabilization of atmospheric carbon in the near term (20–50 years) and thereby, allowing time for the development of a more fundamental technological solution in the form of reduced carbon emission energy sources (Sedjo, 2001). Agriculture also serve as both sources and sinks for greenhouse gases. The emitted carbon from agricultural adds to the atmospheric CO_2, but with proper management practices involved, this trend can be changed up to some extent (Lal *et al.,* 1998). Agricultural lands could store substantial amounts of soil organic carbon (SOC). Soil carbon sequestration in agricultural ecosystems can prove to be a near-term option to mitigate the enhanced level of CO_2 concentration in the atmosphere. Agricultural practices that promote good stewardship of the land will reduce GHG emissions and maximize soil carbon sequestration. Sustainable agricultural practices such as conservation tillage, cover cropping, diverse crop rotations, and improved pasture management can limit soil erosion and increase soil organic carbon. (Greenhouse Gas Working Group, 2010).

This study employed InVEST 3.2.0 Carbon Storage and Sequestration Model together with ArcGIS 10.1 to know the spatial pattern of carbon stock in Central Mindanao University by using secondary information from credible sources. InVEST was designed to lead decision makers to informed conclusions of ecosystem trade-offs in terms of land development and land conservation (Finn *et al.,* 2011). In each LULC, carbon stock differs. It is therefore important to know the carbon stock to be able know the spatial trends of carbon in the area with the aid of GIS.

The resulting maps and database will contribute to the continuing climate change research in the area. This study can serve as basis for future similar researches especially those that will cover a larger geographic area. The patterns of carbon stock across a landscape could be very valuable in determining which areas to be devoted for conservation more so that most of the remaining forests in the area are under enormous anthropogenic threats. Likewise, the maps could also be used to identify priority reforestation areas to further enhance its capacity to sequester and store carbon.

Materials and methods

Study area

This study was conducted in Central Mindanao University (Fig. 1.) which lies between 125°03'03" E longitude and 7°51'34" N latitude. The area is situated 4.5 kilometers south of the city of Valencia. It has a total land area of 3,080.82 hectares with different LULC types such as natural forest, plantation forest, residential, and agricultural land.

The area has a mean elevation of 312 meters above sea level (MASL). The climate type falls under Type III based on the Modified Corona classification of PAGASA.

Type III climate is characterized as having a seasonal variability that is not very well pronounced, with dry season from November to April and wet during the remaining months of the year.

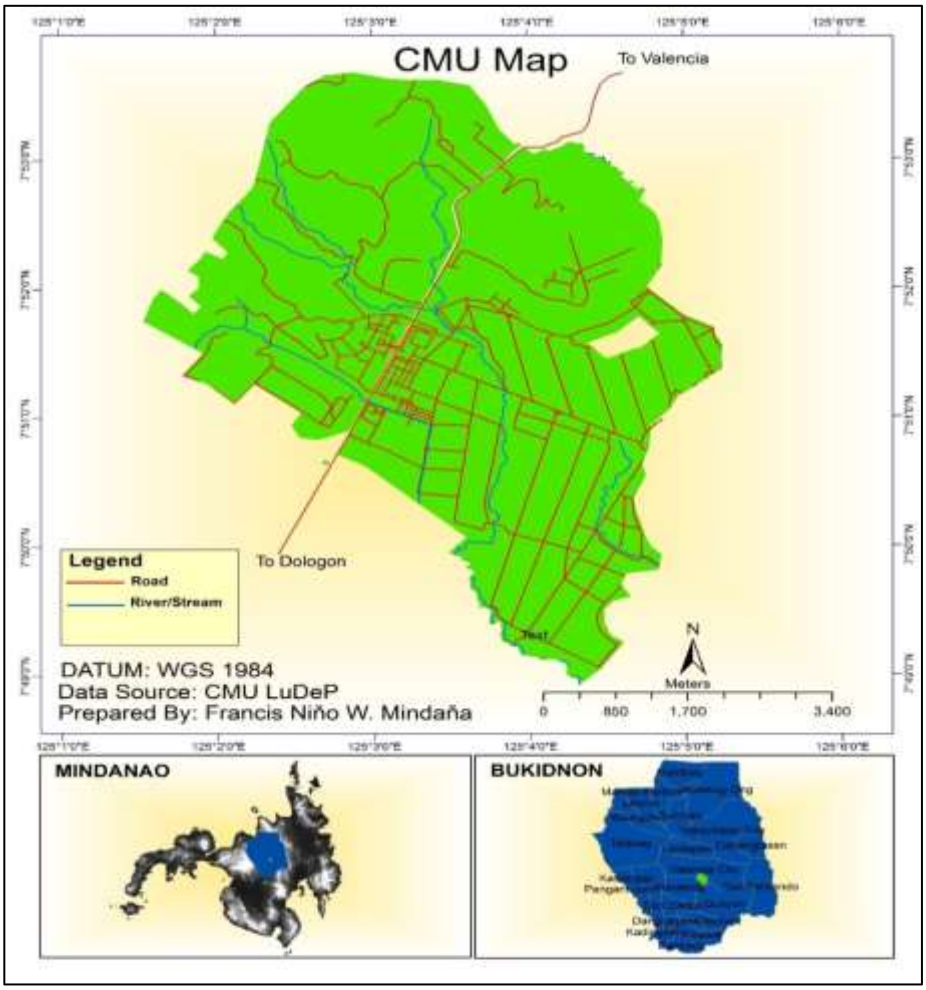

Fig. 1. Location map of Central Mindanao University.

Collection of carbon stock data

Secondary carbon stock data comprised the bulk of data used. The value of aboveground biomass of different LULC came from different sources. The value of below-ground carbon was estimated based on the 2006 IPCC report. There were different values on estimating the below-ground by using root-shoot ratio. The amount of root-shoot ratio used was 37% based on a global ecological zones report. Soil carbon data were also mined from different secondary sources. For the dead organic matter carbon pool, this study only included litter. Dead wood was not included since there was no enough literatures that provide pertinent information. Dead organic matter is a diverse carbon pool that is difficult to quantify in the field because of uncertainties about rates of transfer to litter, soil, or emissions to the atmosphere (IPCC, 2006).No data was found for the coconut and mullberry litter, thus the value assigned was zero (0).

Generation of carbon stock database

All carbon stock data were endoced in Microsoft Excel. The data include; land use code, land use/land cover name, amount of carbon above-ground biomass, amount of carbon below-ground biomass, amount of carbon in soil, and amount of dead organic matter. The LULC type was encoded in each row with a specific land use code (e.g., 1 for bare soil, 2 for built-up area). Each column contained different attributes of each LULC type except for built-up area, fishpond, residential, road (paved), road (unpaved) and river/streams which have zero (0) carbon stock in all carbon pools. Lastly, the excel file was saved in .csv format.

Preparation of Land use/land cover (LULC)

A 2008 land use map of the study area served as baseline data in preparing the current LULC map.

Google Earth (GE) was used to determine the actual extent of vegetation in a land use and was supplemented with field validation to determine the actual land cover. GIS analysis techniques used included buffer, erase, union, and dissolve. The buffer tool was used to create a 5 meter buffer of roads and river/streams to create polygons.

The updated LULC map was then converted from shape file to geodatabase format to detect and current errors caused by gaps and overlaps. This process enhanced the quality of the LULC data. The rectified LULC was then converted to raster to generate the final LULC raster ready for modeling.

Model Building

Each LULC was assigned with carbon stock values. The carbon stock values used were based on the 2006 IPCC Guidelines for National Greenhouse Gas Inventories (Vol. 4) for agriculture, forestry and other land use and other credible sources.

A 5x5 meter raster dataset with LULC code for each cell was then prepared. The InVEST Carbon Storage and Sequestration Model required current LULC in raster format and the csv file previously prepared. These data were required to run the model and produce the carbon storage map.

Data Analysis

The resulting carbon storage map was further refined in ArcMap ver. 10.1 where the final maps were produced.

Carbon stored per hectare and the total carbon stored in each LULC was then analyzed using the same software.

Results and discussion

Detailed Land Use/Land Cover (LULC) of Central Mindanao University campus

Out of the 33 LULC types (Fig. 2)., rice plantation had the largest area covering 32.45% (999.6 ha) of the area. It was followed by Gmelina plantation comprising 11.29% (347.9 ha) while the LULC with least area was mullbery with only 0.51 ha (0.02%). The type of LULC could easily provide hints on the quantity of carbon stored in an area. Carbon sequestration and storage potential of agricultural lands is often overlooked and maybe underestimated. Since crops are harvested, carbon sequestration is offset during harvest. However, agricultural lands contribute much by storing soil organic carbon (SOC). Houghton (2013) cited that most changes in land use affect the vegetation and soil of an ecosystem. This could change the amount of carbon held per hectare of land. The changes may be large, for example, with the conversion of forest to cropland. When forests are cleared, or agricultural areas burned after harvest, large amounts of CO_2 is released to the atmosphere. While we highlight the significance of agricultural lands in the context of carbon sequestration and storage, forest ecosystems are still the prime carbon sinks. Forests can capture and retain large volumes of carbon over long periods. CMU's forests are therefore important to be conserved including its other areas with high carbon storage capacity.

Table 1. Area of each Land Use/Land Cover (LULC) in CMU campus.

Land Use/Land Cover (LULC)	Area (ha)	%	Land Use/Land Cover (LULC)	Area (ha)	%
Rice	999.64	32.45	Coconut	12.74	0.41
Gmelina	347.92	11.29	Coffee and Cacao	10.22	0.33
Grassland	274.6	8.91	Mangium	9.65	0.31
Mixed forest	222.48	7.22	Santol	9.01	0.29
Natural forest	198.35	6.44	Mango	8.96	0.29
Sugarcane	193.12	6.27	Baresoil	4.69	0.15
Pasture	190.08	6.17	Golden shower	2.8	0.09
Rubber	127.97	4.15	Thailand acacia	2.7	0.09
Road (Unpaved)	88.1	2.86	Vermi farm	1.76	0.06
Built-up Area	86.86	2.82	Narra	1.67	0.05

Mixed crops	85.91	2.79	Fishpond	1.5	0.05
Mahogany	41.54	1.35	White Lauan	0.98	0.03
Rambutan	27.77	0.9	Carribean Pine	0.75	0.02
Pave	25.7	0.83	Mulberry	0.51	0.02
River/Streams	23.8	0.77			
Residential	23.7	0.77			
Corn	21.43	0.7			
Road (Paved)	19.5	0.63			
Teak	14.41	0.47			
Total				3080.82	

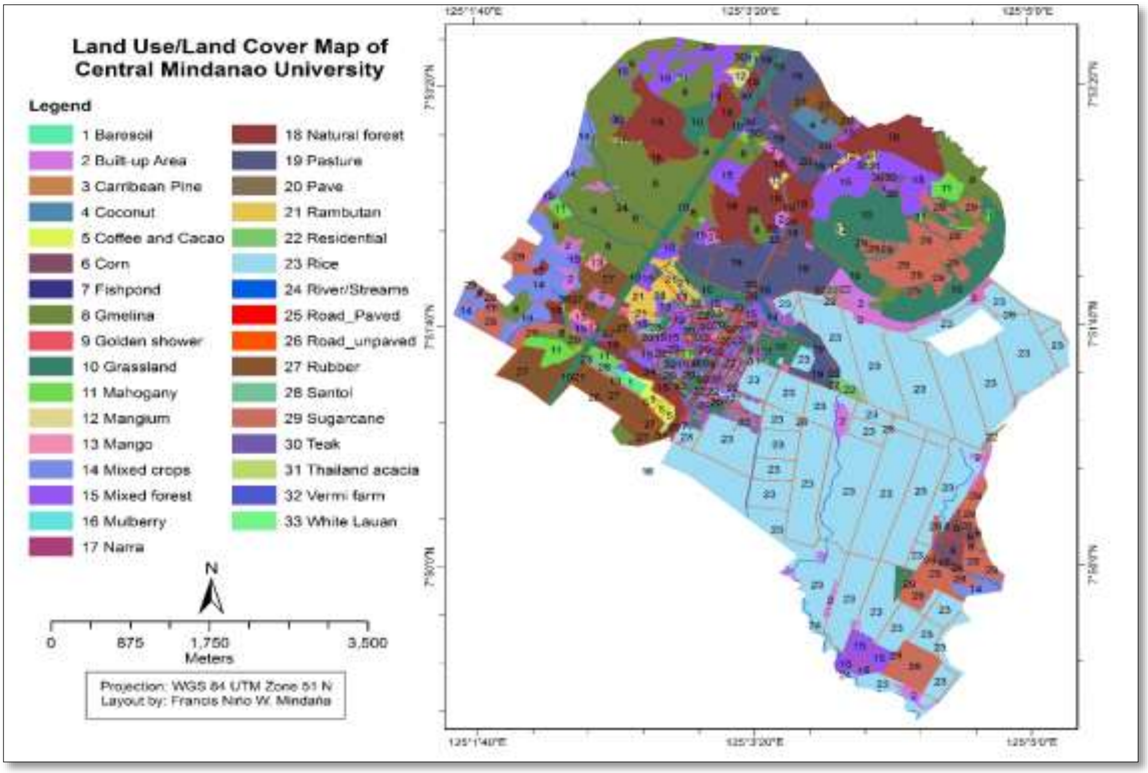

Fig. 2. Land use/ land cover map of CMU.

Table 2. LULC included in each carbon stock range.

Tonnes of C/ha	Land Use/Land Cover
0	Built-up Area, Fishpond, Pave, Residential, River/Streams, Road_Paved, and Road_Unpaved
1-47	Baresoil, Coffee and Cacao, Corn, Mulberry, Rice, Sugarcane and Vermi farm
48-61	Grassland, Mixed Crops, and Pasture
62-123	Gmelina, Mango, and Rambutan
124-151	Mangium and Mixed forest
152-186	Carribean Pine, Coconut, Mahohany, Narra, and Rubber
187-218	Golden Shower and Thailand acacia, Natural forest, Santol, and Teak
353	White Lauan

Spatial Pattern of Carbon Stock in Central Mindanao University

The amount of carbon stored vary with in LULC type (Fig. 3). The carbon stock in CMU ranges from 0-353 tonnes of carbon per hectare. The estimated total amount of carbon stock of CMU is 234,380.11 tonnes.

Rice plantation with an area of 999.64 hectares managed to contribute 39985.6 tonnes C which comprise 17.06% of the total carbon stock in the area. Even with its lesser land area (198.35 ha), natural forest still obtained the greatest carbon stock with 41,455.1 tonnes C (17.69%).

According to Hairiah *et al.* (2011), aboveground carbon storage in natural forest is higher than that of any other vegetation. Another study from Lasco and Pulhin (2009), stated that, even if the species used for plantation development are fast growing, C stored in the natural forests is observed to be far higher than the C contained in tree plantations. Teak and white lauan were the only LULC types that had higher amount of carbon stock per hectare than the natural forest, with 218 and 353 C/ha, respectively. White lauan has the largest amount of carbon stored with 353 tonnes C/ha. Moreover, teak which is a plantation species was higher with 218 C/ha compared to the Natural forest with only 209 C/ha.

It was also the highest among all the plantation species due to the high amount of carbon stored in the soil. Santol plantation had a high carbon stored at 203 C/ha (Janiola, 2013) because of its age at 32 years. Typically, LULC which have tree species store higher amounts of carbon because they can continually capture carbon over a growth cycle of many decades (Sedjo, 2001). According to Lunsayan (2008), older trees undergone photosynthetic activity, with much longer time compared to young trees consequently, they are absorbing and storing more carbon. This implies that large amounts of carbon can be sequestered and stored by a landscape with smaller area if devoted for forest purposes.

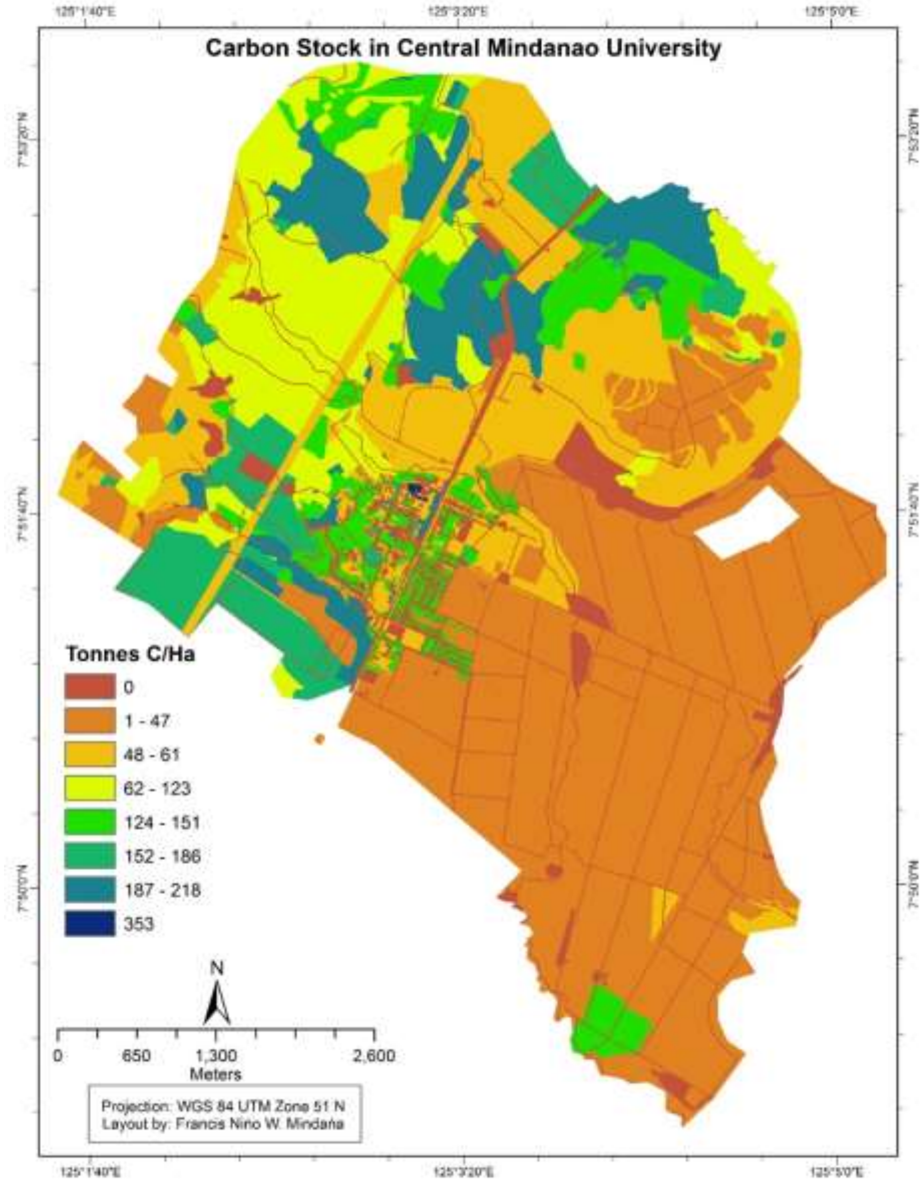

Fig. 3. Carbon stock map CMU (2015).

Table 3. Carbon stock of each LULC (in tonnes).

Land Use/Land Cover (LULC)	Area(ha)	Carbon Stored/ha	Total Carbon Stored	Percentage
Natural forest	198.35	209	41455.1	17.69
Rice	999.64	40	39985.6	17.06
Gmelina	347.92	105	36531.6	15.59
Mixed forest	222.48	143	31817.5	13.58
Rubber	127.97	159	20347.2	8.68
Grassland	274.6	59	16201.40	6.91
Pasture	190.08	61	11594.80	4.95
Sugarcane	193.12	42	8111.04	3.46
Mahogany	41.54	180	7477.20	3.19
Mixed crops	85.91	59	5068.69	2.16
Teak	14.41	218	3141.38	1.34
Rambutan	27.77	112	3110.24	1.33
Coconut	12.74	156	1987.44	0.85
Santol	9.01	203	1829.03	0.78
Mangium	9.65	151	1457.15	0.62
Mango	8.96	123	1102.08	0.47
Golden shower and Thailand acacia	5.5	200	1100.00	0.47
Corn	21.43	27	578.61	0.25
Coffee and Cacao	10.22	44	449.68	0.19
White Lauan	0.98	353	345.94	0.15
Narra	1.67	156	260.52	0.11
Baresoil	4.69	44	206.36	0.09
Carribean Pine	0.75	186	139.50	0.06
Vermi farm	1.76	33	58.08	0.02
Mulberry	0.51	47	23.97	0.01
Built-up Area, Fishpond Pave, Residential, River/Streams, Road_Paved, and Road_Unpaved	269.16	0	0	0
Total	3,080.82		234,380	100

Data limitation on the carbon stock of white lauan was a factor in this study. The data used was generated from a study of dipterocarps and not specifically for white lauan. The carbon stock data which is 353 tonnes C/ha was from Lasco and Pulhin (2013).It is higher compared to the study of Racelis *et al.* (2008) where dipterocarp forests has a total of 347.07 tonnes C/ha. Although considered as one the richest terrestrial biodiversity resource of the country, there is limited data available on the carbon stocks of these forests. Primarily because most of them are located in highly inaccessible areas. In addition, it is sometimes difficult to distinguish between primary and secondary forests since historical records are not always available.

Potential Areas Suited for REDD+ or Carbon Trading

Using the United States Environmental Protection Agency's Greenhouse Gas Equivalencies Calculator, the total carbon stored in CMU is equal to CO_2 emissions from 87,726,887 gallons of gasoline consumed, 837,410,149 pounds of coal burned, greenhouse gas emissions from 164,132 passenger vehicles driven for one year, greenhouse gas emissions from 279,437 tonnes of waste sent to the landfill, and carbon sequestered by 19,990,483 tree seedlings grown for 10 years. Since Natural forests in CMU is the LULC type that has the highest amount of carbon stored (Fig. 4), cutting/logging may be strictly prohibited. This LULC, in the context of climate change mitigation, is the most important area not only for REDD+ or Carbon Trading but for other ecosystem services as well. Its implication could include the basis for decision making in terms of the management for conservation and protection of these areas considering its ability to minimize the emission of CO_2. According to Sharp *et al.* (2015), the Chicago Climate Exchange (CCX) and the European Climate Exchange (ECX) provide values $24 and $153 per metric ton of C sequestered on May 14, 2008, respectively. The average of these prices for sequestered C would be $88.50. The currency exchange used was 1$ = ₱ 46.91. Tulod *et al.* (2015) also underlined that second-growth forests which take so much time to develop have an average carbon sequestration rate of 4.8 tonnes C/ha/yr. In this study, the natural forest which is a second-growth forest could have an estimated value of ₱ 19,927.37/ha and with a total of ₱ 3,952,593.44 in 198.35ha total area for the amount of carbon it can sequestered.

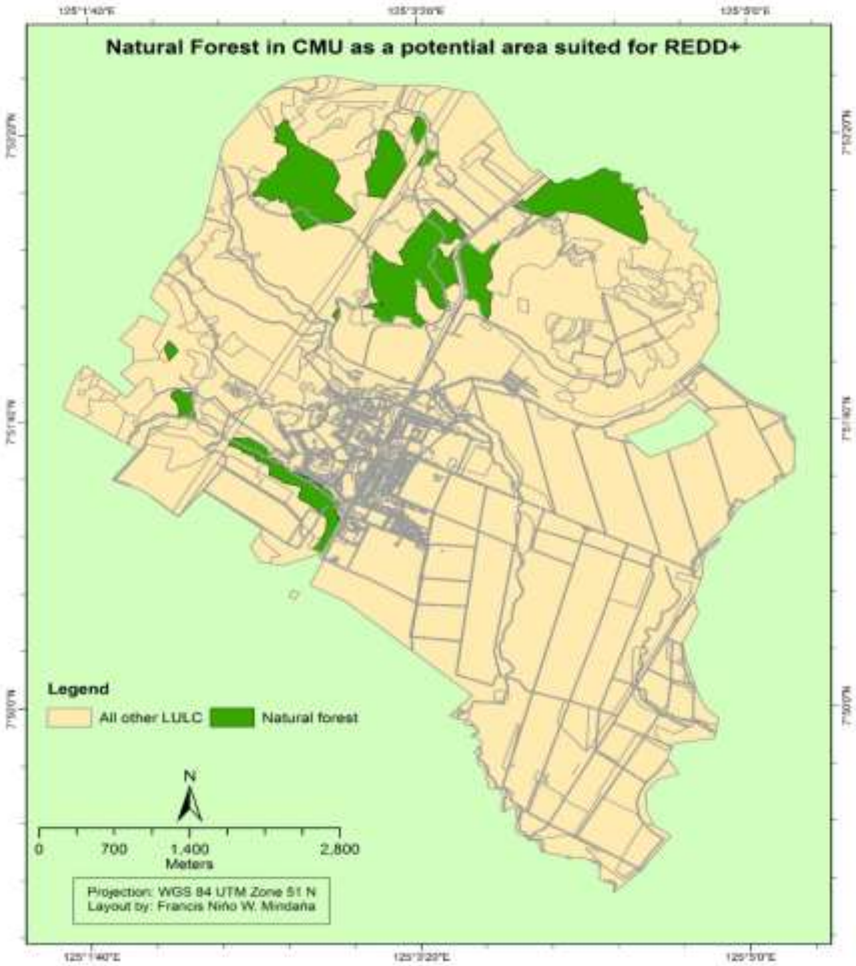

Fig. 4. Natural forest in CMU as a potential area suited for REDD+.

The REDD concept is, at its core, a proposal to provide financial incentives to help developing countries voluntarily reduce national deforestation rates and associated carbon emissions below a baseline (based either on a historical reference case or future projection). Countries that demonstrate emissions reductions may be able to sell those carbon credits on the international carbon market or elsewhere. These emissions reductions could simultaneously combat climate change, conserve biodiversity and protect other ecosystem goods and services (Gibbs *et al.*, 2007).

Despite relatively limited remaining natural forest cover, REDD-plus presents considerable opportunities for forestry sector initiatives in the Philippines. Initial estimates suggest that the Philippines has a total emissions mitigation potential of approximately 38,540,000 tons of CO_2 between 2011- 2030. According to Philippine National REDD Plus Strategy (PNRPS) (2011), potential REDD pilot areas include forests in Northern Leyte's Anonang-Lobi mountains, the Philippine Eagle's known habitats in Samar, Panay and the Caraga region in Mindanao.

Payments for REDD+ are very important considering the fact that most people and organization are more inclined to Agriculture, mostly unsustainable, over forestry. This would financially reward forest owners for reversing their planned deforesting and thinning actions (Sedjo & Sohngen, 2000). Central Mindanao University having Natural forest could be one of the recipient of the incentives provided by REDD+. The University has extensive hectares of natural and plantation forest that are of big potential for the for REDD+. This is one of the emerging carbon trading mechnisms that has not been tapped by many institutions in the Philippines.

Conclusions

The total land area of Central Mindanao University is 3,080.82 ha consisting of thirty-three LULC. Rice plantation contained the largest area with 999.64 ha (32.45%) of the total area. However, it is only second in terms of carbon stock having 39985.6 tonnes C compared to Natural forest having 41455.1 tonnes C (17.69%) of the total carbon stock in CMU with just 198.35 ha. The total carbon stock in CMU is 234380.11 tonnes C. The total carbon stock generated by InVEST greatly depends on the amount of carbon in each pool used. This study might have underestimated/overestimated the amount of carbon in the sense that the dead wood was not included as part of dead organic matter. The soil beneath the pave/roads were also not included. A probable overestimation is also possible since some of the carbon stock values used were not the actual amount of carbon in each LULC in CMU. This study highlighted the importance of natural forests and tree bases LULC types for carbon sequestration and storage. The natural forest of CMU could be the potential area for REDD+ and other related activities geared at climate change mitigation and adaptation.

References

Canadell JG, Raupach MR. 2008. Managing Forests for Climate Change Mitigation. Science **320**(5882), 1456-1457.

Edmondson J, Davies Z, McCormack S, Gaston K, Leake J. 2014. Land-cover effects on soil organic carbon stocks in a European city. Science of the Total Environment **472,** 444-453.

Finn S, Keiffer S, Koroncai B, Koroncai B. 2011. Assessment of In VEST 2.1 Beta: Ecosystem Service Valuation Software. http://webspace.ship.edu/cajant/ documents/white_ papers/finnetal_ invest_ 2011.pdf.

Food and Agriculture Organization of the United Nations. 2008. The carbon sequestration potential in agricultural soils.

Gibbs H, Brown SO, niels J, Foley J. 2007. Monitoring and estimating tropical forest carbon stocks: making REDD a reality. Environ. Res. Lett **2**, 15. http://dx.doi.org/10.1088/1748-9326/2/4/045023.

Gnanavelrajah N, Shrestha RP, Schmidt-Vogt D, Samarakoon L. 2008. Carbon Stock Assessment and Soil Carbon Management in Agricultural Land-uses in Thailand. Land Degradation & Development **19,** 242-256. http://dx.doi.org/10.1002/ ldr.838.

Greenhouse Gas Working Group. 2010. Agriculture's role in greenhouse gas emissions & capture. Greenhouse Gas Working Group Rep. ASA, CSSA, and SSSA, Madison, WI.

Guo LB, Gifford RM. 2002. Soil carbon stocks and land use change: a meta-analysis, Global Change Biology **8,**345–360. http://dx.doi.org/10.1046/j.1354-1013. 2002.00486.x.

Hairiah K, Dewi S, Agus F, Velarde S, Ekadinata A, Rahayu S, Noordwijk M. 2011. Measuring Carbon Stocks Across Land Use Systems: A Manual. Bogor, Indonesia. World Agroforestry Centre (ICRAF), SEA Regional Office, 154 pages.

Houghton RA, Hackler JL. 2006. Emissions of carbon from land use change in sub Saharan Africa, Jour. Geophys. Res **111,** G02003, http://dx.doi.org: doi/10.1029/2005JG000076.

Houghton RA. 1991. Tropical deforestation and atmospheric carbon dioxide. Climate Change **9,** 99-118. http://dx.doi.org/10.1007/BF00142217.

Houghton RA. 2013. Effects of Land-Use Change on the Carbon Balance of Terrestrial Ecosystems. Ecosystems and Land Use Change Geophysical Monograph Series **153,** http://dx.doi.org:doi/10. 1029/153GM08.

Intergovernmental Panel on Climate Change (IPCC). 2006. Guidelines for National Greenhouse Gas Inventories. Agriculture, Forestry and Other Land Use V 4.

Janiola MD. 2013. Carbon Sequestration of Three Fruit Crop Plantations in CMU, Musuan, Maramag Bukidnon. Undergraduate thesis (unpublished). Central Mindanao University, Philippines 40-55.

Kar R, Bose PC, Majumder SK, Ghosh A. 2012. An account of soil organic carbon reserve under long-term fertilizer experiment in mulberry [*Morus alba* L.]. Journal of Crop and Weed **8(1),** 57-59.

Kauppi P, Sedjo R. 2001. Technical and Economic Potential of Options to Enhance, Maintain and Manage Biological Carbon reservoirs and Geo-engineering. TAR Working Group III, Chapter **4,** 242.

Lal R, Kimble JM, Follett RE, Cole CV. 1998. The Potential of U.S. Cropland to Sequester Carbon and Mitigate the Greenhouse Effect. Chelsea, MI: Sleeping Bear Press 128.

Lasco R, Pulhin F. 2003. Philippine Forest Ecosystems and Climate Change: Carbon stocks, Rate of Sequestration and the Kyoto Protocol. Annals of Tropical Research **25(2),** 37-51.

Lunsayan D. 2008. Carbon Sequestration Potential of Carribean Pine (*Pinus carribea*) Plantation in Malaybalay City, Bukidnon. Undergraduate thesis (unpublished). Central Mindanao University, Philippines 54-70.

Norgrove L, Hauser S. 2013. Carbon stocks in shaded *Theobroma cacao* farms and adjacent secondary forests of similar age in Cameroon. Tropical Ecology **54(1),** 15-22.

Patricio JH. 2014. How much soil organic carbon is there in agricultural lands? A case study of a prime agricultural province in Southern Philippines. AES Bioflux 6(3) www.aes.bioflux.com.

Potvin C, Whidden E, Moore T. 2004. A Case Study of Carbon Pools Under Three Different Land uses in Panama. Kluwer Academic Publishers. Climatic Change 67(2), 291-307 http://dx.doi.org: doi/10.1007/s10584-004-0079-z.

Racelis E. 2008. Assessing the Carbon Budgets of Large Leaf Mahogany (*Swietenia macrophylla* King) and Dipterocarp Plantations in the Mt. Makiling Forest Reserve, Philippines, Journal of Environmental Science and Management **11(1),** 40-55.

Romaniuk R, Giuffre L, Romero R. 2011. A Soil Quality Index to Evaluate the Vermicompost Amendments Effects on Soil Properites. Journal of Environmental Protection **2**, 502-510 http://dx.doi. org:doi/10.4236/jep.2011.25058.

Sedjo R, Sohngen B. 2000. Carbon Credits for Avoided Deforestation. Washington, DC: RFF Discussion Paper DP 00-34. Washington, D.C: Resources for the Future.

Sedjo R. 2001. Forest Carbon Sequestration: Some Issues for Forest Investments. RFF Discussion Paper Washington, D.C: Resources for the Future.

Tariyal K. 2014. Total Carbon Stock in Agricultural System having Crop Rotation in Tarai Region of Northern India. Oct. Jour. Env. Res **2(2),** 127-138.

Tulod A, Patricio JH, Paquit J. 2015. Carbon Stocks of Second Growth Forest and Common Tree Plantations in Bukidnon. Unpublished research. Central Mindanao University, Philippines 12-13.

United States Environmental Protection Agency. 2014. Greenhouse Gas Equivalencies Calculator. http://www.epa.gov/energy/greenhouse-gas-equivalencies-calculator.

Villamor GB. 2010. Rapid Carbon Stock Appraisal: Kalahan, Nueva Vizcaya, Philippines. Working paper 106. Bogor, Indonesia: World Agroforestry Centre (ICRAF) Southeast Asia Program 87p.

Yusuf AA, Francisco HA. 2009. Climate change vulnerability mapping for Southeast Asia. Economy and Environment Program for Southeast Asia, Singapore. Available online at: www.idrc.ca/uploads/userS/12324196651 Mapping_Report.pdf.