

ECOLOGICAL VALUATION TOOLS TO APPRAISE BIOMASS, NECROMASS AND SOIL ORGANIC MATTER IN A NATURAL FOREST ECOSYSTEM

Hari Sulistiyowati and Inocencio E. Buot Jr.

Received: 16.10.2015 / Accepted: 12.12.2015

Abstract: The need to devise the monetary value of the ecological contribution of carbon pools for the ecosystem increases as there is a limited baseline of immeasurable value of the natural ecosystem. This study has been undergone to develop ecological tools for assigning forest biomass, necromass, and soil organic matter to a natural forest ecosystem. Comprehensive analysis and review of many publications, and reports about ecological valuation, tree appraisals, and any appraisal methods were performed to determine the parameters of ecological contribution for the appraisal equation. Cost based approach and simple mathematical methods were used to propose the equations. Three equations for biomass, necromass, and soil organic matter (SOM) were developed as ecological valuation tools to assign their ecological values or ecovals (IC). This IC value was the sum of ecological structure (S) and function (F) values. S value was deducted from the ecological base value of structure (bS) and dimension (D). F value was derived from the ecological base value of F (bF) and carbon content weight, and additional parameter of existence factor (Ef) of species or decay class factor for necromass (d). The bS and bF prices or costs were taken from the national or international standard price/costs in USD currency. The equations are applicable to appraise the ecological values of any natural ecosystems. People may obtain information about the worth of the ecoval based on its carbon pool as a reflection of ecosystem structure and function. The information of ecoval can be used as database or ecological consideration to generate policy or make a decision for sustainable natural ecosystems.

Keywords: appraisal equation, cost based approach, ecological base value, ecological function value, ecological structure value, ecological valuation, ecological values

Introduction:

Hari Sulistiyowati:

Faculty of Mathematics and Natural Sciences
Biology Department
Jember University
Jl. Kalimantan no. 37 Kampus Tegal Boto
Jember, Indonesia
e-mail: sulistiyowati.hari@yahoo.com

Inocencio E. Buot Jr.:

Institute of Biological Sciences
College of Arts and Sciences
University of the Philippines Los Baños
Los Baños, Laguna, Philippines 4031
e-mail: ibuotjr@yahoo.com

Tropical forests are rich forests due to the rich tapestry of genes and species that define them and are very important natural resources for cultures, knowledge, human well-being, industries, building materials, or many valuable uses. How much is the value of these forests worth? How much is the ecoval of one big tree of *Santalum album* or two pieces of down woods reliant on their contributions to their natural habitat worth? Are there any ecological valuation tools to assign their ecovals? These are questions frequently asked in order to determine their ecological values especially for particular cases correlated to the destruction of natural

protected forest. In order to reach reasonable and feasible decisions or judgments there is an urgent need to investigate their ecovals for the provision of ecosystem services provided by forests such as carbon sequestration or stocks which become highly related to carbon trade or credit for removing CO₂ emission into the atmosphere.

However there are only limited appraisal methods to determine the ecological values for natural resources. Most appraisal methods are employed to determine compensatory values of trees in urban city or urban forest which are well-developed by the International Society of Arboriculture and some foresters and arboriculturists (Helliwell 1967; Franks and Reeves 1988; McGarry and Moore 1988; Nowak 1993; Cullen 2002; Thyer 2005; Hegedus et al. 2011), or compensation fee for forest rehabilitation or concession projects related to forest carbon offset commonly done by many institutions, Non-government or private organizations (Cacho et al. 2003; Bellassen and Gitz 2008; Wertz-Kanounnikoff 2008; Ginoga et al. 2011; Ndjondo et al. 2014). Other studies have determined the pricing of biodiversity and ecological services which quantify the worth of nature in economics terms (Cacho et al. 2003; Costanza et al. 1997; Costanza et al. 2014; de Groot et al. 2012), or value potential payment for ecosystem services (Naidoo et al. 2008; Strassburg et al. 2010).

Tropical forests have become a prominent feature in global climate regulation issues due to their huge carbon sink. There is a need to have baseline data for any resources, either intangible or tangible, of ecological structures within these tropical forests because if the forest loses these resources, there will be consequences to the ecological functions of the ecosystem (Franks and Reeves 1988; McGarry and Moore 1988; Sulistiyowati and Buot 2013). These baseline data can be used to set up a standard ecological valuation tool of biomass, necromass, or soil organic matter (SOM) that are needed to be appraised for decision makers or conservation management and policy purposes.

This study was done to develop ecological tools for assigning forest biomass, necromass, and soil organic matter ecovals in a natural ecosystem. The carbon pools were taken into account as sample ecological parameters because they are the starting points of any ecological processes and functions within the forest ecosystem. In addition, the tools were developed to adjust to any natural areas and not just to the forest ecosystem. The outputs of the study were three appraisal equations applicable for ecological values (ecovals) of biomass, necromass, and SOM determination.

Materials and methods:

The ground base of these ecological valuation tools is fully analyzed comprehensively from many publications and reviews of ecological valuation, tree appraisals, landscape appraisals, and any appraisal methods. The equation of biomass, necromass, and SOM ecovals were developed by investigating a query in the Web of Science for articles with the words: appraisal methods, carbon trade, credit and offset, appraisal approaches, biomass, necromass, and soil valuations to set up the parameters used for the equations. It is very important to clarify the importance of these appraisals based on ecological concepts and principles. Compilation and investigation of recognized particular ecological values of the carbon pools were done to establish new tools so as to determine the basic values as initial methods of equation. The base monetary values of prices or costs used for both potential value and carbon content prices were taken from the standard rates set by Indonesia government or rates commonly used in Indonesia as sample cases for biomass, necromass, or SOM appraisals. However, the base value or basic price can be deducted from any standard rate of pricing used depending on the objective of the research study. The currency rate used is dependent on the time when the appraisal equations are applied.

Results and discussion:

Against the background of increasing valuations or appraisals being made for carbon stock, carbon sequestration, and carbon offset, the contribution of carbon pools in maintaining ecological cycles in a natural ecosystem becomes more obvious. There is a stringent need to approach ecological value appraisal in a reasonable way which is to enable us to take innovative action and enhance natural ecosystem conservation. We have inherited our natural ecosystems which serve ecological structure and functions within the system for centuries. The principles of natural ecosystem sustainability have led us to propose equations of ecological value appraisal. These equations were designed as ecological valuation tools for carbon pools' contribution.

Ecological Value of Carbon Pools Approach

Not all natural resources can be fully translated into economic terms (Christie et al. 2006; Christie 2012). The term ecological value or ecoval refers to the product of interactions between the internal and unpredictable external factor within the ecosystem (Sulistiyowati and Buot 2013). Thus, assessing the ecoval of resources, raw materials or functions within the natural ecosystem is impossible because there is no comparable price or cost for it. Some people believe that the ecoval for resources that do not have price on the market (intangible or non-market) is priceless. Many studies have developed methods and equations to put monetary value on these intangible ecovals. Foresters, ecologists, and arboriculturists proposed consider the dimension, condition, weight, character, and even contribution of the ecoval (Helliwell 1967; Wathern et al. 1986; Franks and Reeves 1988; McGarry and Moore 1988; Nowak 1993; Cullen 2002; Thyer 2005; Hegedus et al. 2011). On the other hand, economists used the revealed preference technique to get cost replacement or cost based approach for the value (Turner

et al. 2003; Chee 2004; Pak et al. 2010; Kiran and Malhi 2011; Diamini 2012). The destruction of forest ecosystem and increasing global warming encourage people to find ways in assessing this immeasurable ecoval.

The scarcity of carbon pools as source of energy flow and biogeochemical cycles has motivated people to assess the carbon stock, sequestration, and offset from the economic point of view. It is due to the fact that forest ecosystems withhold CO₂ release into the atmosphere so that the global warming and climate change are maintained. As a product of plant species and their environment, carbon pools contribute with their ecoval to the natural ecosystem. These conditions encourage many researches to investigate to what extent their existent ecological value in the ecosystem is beyond the potential values that can be easily quantified as many economists do through their neo-classical market-based economics approaches (Straton 2006).

There is a need to assess the carbon pools from an ecological perspective. To assess the ecological value of carbon pools, the ecological contributions (Franks and Reeves 1988; Straton 2006) or the functions (Helliwell 1967) of carbon pools for their ecosystems or environment have to be identified. It is difficult to assign monetary values on these contributions or functions because they are not available on the market. As suggested by Wathern et al. (1986), the ecovals are not estimated directly therefore surrogate parameters are required to appraise the values.

In this study, the cost based method has been employed to assign prices to the contribution of carbon pools. The contribution of carbon pools can be signalled according to their structure and functions. Regarding the structure, these carbon pools have the dimension of volume weight; as for function, these carbon pools hold carbon for long periods of time.

Ecological Structure Value

One of the prices that need to be appraised is the ecological structure value. The physical performance of living plants, dead plant materials, and soils as individual or landscape levels provide ecological structure as sources of energy and ecological cycles, protection, shading, and habitat for living organisms. All these carbon pools especially in the natural tropical forests are habitats for more than 50% of the threatened species in the world (Le Saout et al. 2013) and support multiple potential use for human well-being, particularly for local livelihoods (Duchelle et al. 2014). World forests also purvey 70% of the terrestrial gross primary production (Beer et al. 2010), and 80% of Earth's total plant biomass (Kindermann et al. 2008).

Each carbon pool has its dimension of structure as part of the forest ecosystem. Recognized wood structure parameters of living plants and woody debris such as trunk diameter, height/length, and/or weight and canopy width, length, and height are used to quantify their ecological structure values which are commonly employed in tree appraisals by foresters and arboriculturist (Helliwell 1967; Franks and Reeves 1988; McGarry and Moore 1988; Nowak 1993; Cullen 2002; Thyer 2005; Hegedus et al. 2011). Nutrient contents of SOM also provide ecological structure values of forest soils; therefore parameters of N, P, and K for this initial equation are used to quantify soil fertility.

Ecological Function Value

Another important parameter to look into as regards developing ecological value tool is the ecological function value. All living plants, dead materials, and SOM have opportunities to contribute as ecological function values of Carbon stock in the system for long periods of time. Removing these carbon pools from their ecosystem can remove their opportunities to play roles in the forest ecosystem's sustainability, therefore parameters of carbon contents are

used as ecological function values (Cacho et al. 2003; Bellassen and Gitz 2008; Wertz-Kanounnikoff 2008; Ginoga et al. 2011; Ndjondo et al. 2014).

Among these carbon pools, plant species not only act as predominant carbon stock but also provide nectar, pollen, fruit, or other body parts which are needed by other living organisms. These plant species such as endemic or non-endemic, and rare or common species play important roles as keystone species for ecological function in the forest ecosystem because they may have many links and interactions (Duffy 2009; Jordan 2009). Loosing rare or local endemic species from their sites can decrease the existence of other species that highly depend on their life. Their existence in the ecosystem may be in high risk because of low abundances and small geographic extension or distribution (Pimm et al. 1988; Smith and Knapp 2003).

Conservation plan and action focusing on the existence of species in their ecosystem have to be undergone to acquire more information about these species which play important roles in ecological functions. Taking into account the existence of species' parameters of certain ecosystems is important, so people will be more aware of how important these species are for functioning ecological cycles (Cardinale et al. 2006; Bracken et al. 2012).

Cost Based Approach

Cost based approach is used to put a price or cost on ecological base value for structure and function of biomass, necromass, and SOM. It is also widely used among economic assessment appraisals. The cost of a measure is employed to maintain or replace forest goods and services in the valuation methods that have been discussed in many studies (Turner et al. 2003; Chee 2004; Pak et al. 2010; Kiran and Malhi 2011; Diamini 2012).

All the parameters of both ecological structure and function values were utilized to propose three appraisal equations for three

types of carbon pools such as living plants (biomass), dead plant materials (necromass), and soil organic matter (SOM) because they have different dimension or weight parameters as ecological valuation tools. The equations were developed using a simple mathematical method which is applicable for natural ecosystems and converted into ecoval (IE) using the proposed equation as follows:

(1) Equation of Biomass Ecoval Appraisal:

$$\begin{aligned} IE_{\text{biom}} &= S + F; \\ &= \{bS*D\} + \{bF*3.667W*Ef\}; \\ &= \{(bS_t*V_t)+(bS_{tl}*V_{tl})+(bS_u*V_u)\} \\ &\quad + \{(c+o)*3.667W*Ef\} \end{aligned}$$

(2) Equation of necromass ecoval appraisal:

$$\begin{aligned} IE_{\text{nec}} &= S + F \\ &= \{bS*D*d\} + \{bF*3.667W*d\} \\ &= \{(bS_{wd}*V_{wd}*d)+(bS_t*V_t)\} \\ &\quad + \{(c+o)*3.667W*d\} \end{aligned}$$

(3) Equation of SOM ecoval appraisal:

$$\begin{aligned} IE_{\text{SOM}} &= S + F \\ &= (bS*E) + (bF*3.667W) \\ &= \{(bSN*N)+(bSP*P)+(bSK*K)\} \\ &\quad + \{(c+o)*3.667W\} \end{aligned}$$

where:

IE = Ecological value or ecoval. This ecological value is representative of the total ecoval of measured plant species biomass (IE_{biom}), necromass (IE_{nec}), or SOM (IE_{SOM}) in USD currency as equivalent value for particular ecoval structure (S) and functions (F) values. The symbol of IE is taken from the notified Cyrillic capital letter E. Because each species has its own structure, the IE_{biom} is deducted per individual plant species. The IE_t is used for plants in >1cm height (the term t indicates tree), IE_{tl} for tree 'like' species (palm or bamboo), IE_u for plants species < 1m tall (small trees and shrubs, seedlings, or herbs). The IE_{nec} is representative of the total ecoval of the measured woody debris ($_{wd}$) and litterfall ($_l$). The IE_{SOM} is the total ecoval of all SOM

element content (i.e. C-organic, N, P, and K as study cases) per hectare within a certain assigned natural ecosystem.

S = Ecological structure value. This ecological structure value refers to the basic replacement price in USD currency of plant species, woody debris and litterfall, or SOM structures as the product of its ecological base value of structure (bS), size (D, for biomass and necromass) or element (E, for SOM), or decay class (d, additional multiplier for necromass).

F = Ecological function value. This ecological function value is calculated as the product of its ecological base value of function (bF), ecoval of carbon content weight (W), existence factor of species (Ef, additional multiplier for biomass), or decay class (d, additional multiplier for necromass).

bS = Ecological base value of S. The ecological base value of structure refers to the basic replacement price in USD currency of each plant species, woody debris and litterfall, and SOM structure. Sample case in Indonesia: the price of biomass and necromass structures may be taken from the list stated in Policy of Trading Ministry Number: 22/M-DAG/PER/4/2012 about Fixed Auction Price Limit of Timber and Non-Timber; the terms t is for plant species ≥ 1 m tall, tl is for tree like, u is for understory or plant species < 1 m tall); the NPK standard prices can be taken from the Regulation of the Minister of Agriculture of the Republic of Indonesia No. 130/Permentan/SR.130/11/2014 (MOAGRI 2014). The rated price in both regulations are in IDR converted into USD at currency rate of calculation.

bF = Ecological base value of F. The ecological base value of function represents two types of basic price taken from carbon trade or credit and basic cost from resource offset in USD currency of each plant species. The c symbol is representative of carbon credit, while o is ecological resource offset. Sample case in Indonesia: the standard price of carbon credit which is in the range of 7-20USD tCO_2 was taken from the Consolidation Report: Reducing Emissions

from Deforestation and Forest Degradation in Indonesia published by FORDA Indonesia (MOFOR 2008); whilst the resource offset was taken from the standard commonly used to ratify transaction cost of forest offset which is in the range of 4-15USD tCO₂ prices (Wertz-Kanounnikoff 2008).

D = Dimension of plant or woody debris trunk and/or canopy or piles of litterfall. The dimension of biomass is representative of its ecoval size in the form of height, length, width, diameter, and percent cover depending on the habitus of plant species. Its ecovals converted into volume (m³) for tree species (V_t). The dimension of tree like (u) such as Palm species is rated in consonance with volume (V_{ti}), Bamboo species is ranked according to the number of stem or culm, or Rattan species is in accordance with the stem length. Furthermore for understory species the dimension is representative of cubic meter or stapel meter (Vu). The dimension of woody debris (D_{wd}) is representative of its ecoval size in the form of height and diameter ecovals converted into volume (m³), while that of litterfall (D_l) is in percent cover ecovals converted into stapel meter (Sm). The V (volume) is representative of D, so V_{wd} is for volume of woody debris and V_l is for volume of litterfall.

d = Decay class factor. Specifically for woody debris, the decay class factor is taken into account because they are found in different degrees of decomposition and so are the decay classes (Tab. 1). The determination of this factor which lies within the range of 0 to 1 was derived from the decay classes modified from Carleton and Gordon (1992) used during woody debris fieldwork sampling. For logs, all classes were used (0.12-1.00), while for both snags and stumps the decay classes 1-3 were used (0.61-1.00) for the decay classes of 4 and 5 were assumed falling as logs during their decomposition processes.

Table no. 1 Decay class factor of woody debris

Class	% of decomposition	Decay class factor
1	<1% decomposed or fresh deadwood	1.00
2	1-25% decomposed	0.87
3	26-50% decomposed	0.61
4	51-75% decomposed	0.37
5	76-100% decomposed	0.12

E = Nutrient content. The nutrient content of SOM is representative of N, P, and K in kg or Mg metric value.

W = Weight of Carbon content. Total dry weight of each tree species (biomass), necromass, or SOM in ton C/ha is the weight of carbon content. This ecoval of carbon content was deducted from 50% of its biomass. The 3.667 (or 44/12) was used to convert Carbon to Carbon dioxide because both price and cost were referred to USD per tCO₂.

Ef = Species existence factor. The existence factor of species is representative of distribution of plant species in its ecosystem. This value is representative of three categories which are frequency (Fr), conservation status (Cs), and geographic extension or distribution (Gd) of species (Tabs. 2, 3, 4 and 5). The Fr value is calculated from the percentage of number occurrence of plant species in its ecosystem (relative frequency of species); this value is then converted into Fr status (level of frequency, see Table 2). The Cs status is ranked on five levels using the modification ranks of RED-LIST of The International Union for the Conservation of Nature (IUCN) 2013 modified in May 2014 (Tab. 3). On the other hand, the Gd status is rated based on its geographic (area) distribution as seen at Table 4.

Table no. 2 The frequency status rank (Fr)

Percentage	Fr status
81-100	1
61-80	2
41-60	3
21-40	4
0-20	5

Table no. 3 The conservation status rank (Cs)

Cs value	Cs status
CR = Critically Endangered*	5
EN = Endangered	4
VU = Vulnerable	3
NT = Near Threatened	2
LC = Least Concern**	1

Note: * The EW (extinct in the wild), PE (probably extinct), and PEW (probably extinct in the wild) are included; ** The DD (data deficient) and NE (not evaluated) are included.

Table no. 4 The Geographic (area) distribution status rank (Gd)

Geographic (area) distribution	Gd status
Distributed in certain local area (dl)	5
Distributed in region/island within country (dr)	4
Distributed in Indonesia country (di)	3
Distributed in continental Asia (da)	2
Distributed throughout the world (dw)	1

Table no. 5 The existence factor of species (Ef)

Ex (%)	Ef
81-100	5
61-80	4
41-60	3
21-40	2
0-20	1

The existence factor (Ex) of species is calculated based on the three values of Fr

status, Cs status, and Gd status modifier ranks using the equation:

$$Ex = [Fr\ status + Cs\ status + Gd\ status / 3 \times 5] \times 100$$

The percentage of Ex was rated and converted into species' existence factor (Ef) as seen at Table 5.

The height of Ef indicates the great risk of plant species in its ecosystem. This basic equation is employed to calculate each individual plant species. The total IC is the sum of all ecological values of all plant species' biomass found in the study site.

The estimated range of prices for carbon credit and offset was applied to adjust the variability for the prices used by many studies of forest carbon offset, while for fertilizers it was used to adjust the subsidized and normal prices stated by the regional and national policy of fertilizer trading.

The comparable costs or prices are used to replace the contributions of carbon pools to the system assigned based on each parameter of ecological structure (S) and function (F) values in their ecosystems with the price or cost that has already rated in the market. The price and cost standard rate can be taken from national or international regulation that has already been applied in the country. Ecological Base Value (b) is the basic replacement price or cost commonly using USD currency. This currency refers to the price or cost per kg, per ton, per m³ or other metric units. This parameter is very important to deduce the value of ecological structure (bS) and function (bF).

Ecological Base Value for Ecological Structure (bS)

The ecological base value for ecological structure is used to assign particular uses or structures of carbon pools such as woods, nutrient contents, or others. The prices depend on the quantity or quality of the carbon pools' structures such as strong texture, big -or small- size diameter, or other acknowledged structural parameters. As an

example, for *Shorea* sp. with a diameter of 45 cm, its wood price ranges from 39.33-54.63 USD per cubic meter on market trade or auction based on the Ministry of Forestry, Republic of Indonesia regulation.

For woody debris with a diameter of 25 cm, the estimation is based on the identified dead plant materials. If we can identify the dead plant species, we can use the similar wood trunk plant species on the pricing standard list of current regulation. However, if we cannot identify the scientific denomination of the woody debris species we can use the price of jungle mixed wood which is worth at a range of 19.12-26.53 USD per cubic meter on market trade or auction based on the Ministry of Forestry, Republic of Indonesia regulation.

In both cases, the prices of wood trunk *Shorea* sp. and woody debris are named as ecological base values (b) that will be used in the appraisal equation to acquire the ecological structure values (S) of *Shorea* sp. and woody debris. The range of price was used to overhaul the low and high prices of the wood on the Indonesian market depending on the provincial areas. This range may be used also to obtain the range of base values. This b value can be representative of nutrients, canopy, barks, branches, leaves, or other forest structures depending on the kinds of estimated objects or carbon pools. This study focused on the structure of wood and canopy of plant species, wood of woody debris, and nutrient (N, P, K) content of SOM.

The ecological base values of SOM elements N, P, and K are determined relying on the national standard market price as functions of fertilizer N, P, and K. The fertilizer grade is an expression used in extension and the fertilizer trade refers to the legal guarantee of the available plant nutrients expressed as a percentage by weight in a fertilizer. For example 16-16-16 NPK fertilizer which is always written in the sequence, N, P₂O₅ and K₂O, indicates the presence of 16 percent nitrogen (N), 16 percent phosphorous pentoxide (P₂O₅) and 16 percent potash (K₂O) in it. For this study,

the replacement cost approach of N, P, and K was derived from the NPK price of Indonesia's Ministry of Agriculture Policy (MOAGRI 2014) for fertilizer trading as equivalent ecological base values of those elements within forest soils.

Ecological Base Value for Ecological Function (bF)

The ecological base value for ecological function is used to appraise the opportunity value of the carbon pools in the natural ecosystem. It is very common that the carbon pools store carbon naturally for a long period of time; therefore in this ecoval appraisal equation this function is referred to as ecological function value (F). This is due to the fact that carbon is the main source of biogeochemical (or ecological) cycles that support ecological processes and functions of a sustainable forest ecosystem (Daily et al. 2000; Farber et al. 2002; Straton 2006).

To achieve this value, we need to calculate the carbon credit (price) which stems from carbon trade and ecological resources offset cost being rated from its transaction cost. The ratification of both price and cost can be reached depending upon the basic standard of estimation undergone by any well-known projects or extracted from REDD project programs in any countries.

However, the price varies among countries as influenced by their standard ratifications of the carbon price. Each country displays its own standard which arrays from 1 USD (Mexico) to 168 USD (Sweden) as reported by World Bank (2014). As for Indonesia, the carbon credits are used in the range of 7-20 USD per tCO₂ as stated in MOFOR (2008). The transaction costs of 4-15 USD per tCO₂ prices (Wertz-Kanounnikoff 2008) commonly applied by many studies can be used for the cost of resources offset.

All the parameters used in the ecological valuation appraisal are representative of the potential values of carbon pools (biomass, necromass, and SOM) of a particular natural

ecosystem. The higher the ecological value, the bigger is ecoval structure and/or carbon stocks deposited in that ecosystem and vice versa. It means that there is high diversity of plant species, woody debris and litterfall, and other elements of the ecosystem where various living organisms depend on them (including human well-being).

Therefore, the output of the calculation can be used as indicator to acquire information on the health of the ecosystem, the true condition of the ecosystem's components, where the ecoval is at risk or other purposes correlated to conservation management and policy. By appraising the ecoval of carbon pools the comparable monetary value can be obtained by the reasonable judgment used in law enforcement, developing regulation or policy, or standardized payment environmental service (PES) of CO₂ emission or carbon trading.

Conclusions:

All these ecological valuation tools are proposed to appraise the contribution of carbon pools on the level of living plants, woody debris and litterfall, and soil organic matter from an ecologist's point of view. The contributions or potential uses of each carbon pool are used as reasonable and feasible ecological consideration parameters valued in the ecoval appraisals. To convert these parameters of structure and function into ecological value, a cost-based approach was employed to rate the price and cost using a simple mathematical method. Hence, these three equations for biomass, necromass, and SOM may finally ensure immeasurable ecoval which once was impossible to access.

The equations that were developed from this study need to be evaluated and enhanced further for a complete and valid assessment in protecting the ecosystem, especially carbon pools. A limited baseline is the constraint in assessing the potential lifespan

of all carbon pools especially for ecological resource offset purposes.

The monetary value can be used as information to assess the ecoval of any natural ecosystem assigned. The high and low of the ecological value are tasks for decision makers to be more concerned with the natural resources' values in their managed natural ecosystem. The higher value means a high ecoval diversity of carbon stocks and should therefore be preserved and monitored. On the other hand, the low value indicates there is scarcity of ecoval diversity of carbon stocks so there should be designed a conservation management plan and actions to investigate the problem and to improve the ecoval.

These tools can be applied in any types of ecosystem. However the standard price and costs can be derived relying on its area regulation. Perhaps ecologists across the world set up a standard price or cost for the ecological structure and function values to have a valid standard for ecological valuation.

Rezumat:

INSTRUMENTE DE EVALUARE ECOLOGICĂ PENTRU ESTIMAREA BIOMASEI, NECROMASEI ȘI MATERIEI ORGANICE DIN SOL ÎNTR-UN ECOSISTEM NATURAL DE PĂDURE

Nevoia de a proiecta valoarea monetară a contribuției ecologice a rezervelor de carbon pentru ecosistem este din ce în ce mai actuală, deoarece există o bază limitată a valorii incalculabile a ecosistemului natural. Acest studiu s-a realizat pentru a dezvolta instrumente ecologice pentru evaluarea biomasei din pădure, necromasa și materia organică dintr-un ecosistem natural de pădure. Analize exhaustive și recenzia a numeroase publicații și rapoarte despre evaluarea ecologică, estimarea arborilor și alte metode de estimare au fost realizate spre a determina parametrii contribuției ecologice în ecuația de estimare. Abordarea bazată pe

costuri și metodele matematice simple au fost folosite pentru a propune ecuațiile. Trei ecuații pentru biomasă, necromasă și materia organică din sol (SOM) au fost dezvoltate ca instrumente de valoare ecologică pentru a atribui valorile lor ecologice sau ecovalorile (IC). Această valoare IC reprezintă suma dintre structura ecologică (S) și valoarea funcției (F). Valoarea S a fost dedusă din valoarea ecologică de bază a structurii (bS) și dimensiunii (D). Valoarea F a fost derivată din valoarea ecologică de bază a lui F (bF) și a greutateii conținutului de carbon, iar parametrul adițional al factorului de existență (Ef) al speciilor sau factorul clasei de descompunere pentru necromasa (d). Prețurile sau costurile pentru bS și bF au fost preluate de la prețurile/costurile standard naționale sau internaționale în moneda de schimb USD. Ecuațiile se pot aplica pentru a evalua valorile ecologice ale oricărui ecosistem. Oamenii pot obține informații despre ecovaloare pe baza rezervelor de carbon, ca o reflecție a structurii și funcției ecosistemului. Informația despre ecovalori poate fi utilizată ca bază de date sau ca apreciere ecologică pentru a genera politici de mediu sau a lua decizii pentru ecosistemele naturale durabile.

Acknowledgments:

This study was made possible through the financial and logistic support of the Directorate General of Higher Education (DGHE) of Indonesia Scholarship and SEARCA (the Southeast Asian Regional Center for Graduate Study and Research in Agriculture) Research Grant.

References:

- BEER C., REICHSTEIN M., TOMELLERI E., CIAIS P., JUNG M., CARVALHAIS N., RÖDENBECK C., ARAIN M.A., BALDOCCHI D., BONAN G.B., BONDEAU A., CESCATTI A., LASSLOP G., LINDROTH A., LOMAS M., LUYSSAERT S., MARGOLIS H., OLESON K., ROUPSARD O., VEENENDAAL E., VIOVY N., WILLIAMS C., WOODWARD F.I., PAPAIE D. (2010), Terrestrial gross carbon dioxide uptake: global distribution and covariation with climate, *Science*, 329:834–838.
- BELLASSEN V., GITZ V. (2008), Reducing Emissions from deforestation and degradation in Cameroon—Assessing costs and benefits, *Ecological Economics*, Volume 68, Issues 1–2: 336–344. doi:10.1016/j.ecolecon.2008.03.015
- BRACKEN M.E.S., LOW N.H.N. (2012), Realistic losses of rare species disproportionately impact higher trophic levels, *Ecol. Lett.*, 15:461–467.
- CACHO O.J., HEAN R.L., WISE R.M. (2003), Carbon-accounting methods and reforestation incentives, *The Australian Journal of Agricultural and Resource Economics*, 47:2: 153-179.
- CARDINALE B.J., SRIVASTAVA D.S., DUFFY J.E., WRIGHT J.P., DOWNING A.L., SANKARAN M., JOUSEAU C. (2006), Effects of biodiversity on the functioning of trophic groups and ecosystems, *Nature*, 443:989–992.
- CHEE Y.E. (2004), An ecological perspective on the valuation of ecosystem services, *Biological Conservation*, 120: 549–565.
- CHRISTIE M., HANLEY N., WARREN J., MURPHY K., WRIGHT R., HYDE T. (2006), Valuing the diversity of biodiversity, *Ecological Economics*, 58:304-317.
- CHRISTIE M. (2012), An Evaluation of Monetary and Non-monetary techniques for assessing the importance of biodiversity and Ecosystem services to people in countries with developing Economies, *Ecological Economics*, 83: 67-78.
- COSTANZA R.D., D'ARGE R., De GROOT R., FARBERK S., GRASSO M., HANNON B., LIMBURG K., NAEEM S., O'NEILL R.V., PARUELO J., RASKIN R.G., SUTTONK P., Van Den BELT M. (1997), The value of the world's ecosystem services and natural capital, *Nature* 387, 15 May 1997: 253-260.
- COSTANZA R., De GROOT R., SUTTON P., Van Der PLOEG S., ANDERSON S.J., KUBISZEWSKI I., FARBER S., TURNER R.K. (2014), Changes in the global value of ecosystem services, *Global Environmental Change*, 26: 152-158.

- CULLEN S. (2002), Tree appraisal: Can depreciation factors be rated greater than 100%? *Journal of Arboriculture*, 28: 153-158.
- DAILY G.C., SÖDERQVIST T., ANIYAR S., ARROW K., DASGUPTA P., EHRLICH P.R., FOLKE C., JANSSON A., JANSSON B., KAUTSKY N., LEVIN S., LUBCHENCO J., MÄLER K.G., SIMPSON D., STARRETT D., TILMAN D., WALKER B. (2000), Ecology: The value of nature and the nature of value, *Science*, July, 289: 395-396.
- De GROOT R., BRANDER L., Van Der PLOEG S., COSTANZA R., BERNARD F., BRAAT L., CHRISTIE M., CROSSMAN N., GHERMANDI A., LARS HEIN, KUMAR P., McVITTIE A., PORTELA R., RODRIGUEZ L.C., HUSSAIN S., TEN BRINK P., Van BEUKERING P. (2012), Global estimates of the value of ecosystems and their services in monetary units, *Ecosystem Services*, 1: 50-61.
- DIAMINI C.S. (2012), Types of values and valuation methods for environmental resources: Highlights of key aspects, concepts and approaches in the economic valuation of forest goods and services, *Journal of Horticulture and Forestry*, Vol. 4: 181-189. <http://www.academicjournals.org/JHF>. DOI: 10.5897/JHF12.011 (online)
- DUCHELLE A.E., CROMBERG M., GEBARA M.F., GUERRA R., MELO T., LARSON A., CRONKLETON P., BÖRNER J., SILLS E., WUNDER S., BAUCH S., MAY P., SELAYA G., SUNDERLIN W.D. (2014), Linking forest tenure reform, environmental compliance, and incentives: lessons from REDD+ initiatives in the Brazilian Amazon, *World Development*, 55:53-67. <http://dx.doi.org/10.1016/j.worlddev.2013.01.014>
- DUFFY J.E. (2009), Why biodiversity is important to the functioning of real-world ecosystems, *Front. Ecol. Environ.*, 7:437-444.
- FRANKS E.C., REEVES J.W. (1988), A formula for assessing the ecological value of trees, *Journal of Arboriculture*, 14: 255-259.
- GINOGA K., DJAENUDIN D., EKOWAN E. (2011), Penilaian kelayakan ekonomi Reducing Emission from Deforestation and Forest Degradation (REDD+). (Economic feasibility of Reducing Emission from Deforestation and Forest Degradation (REDD+)), *Jurnal Penelitian Sosial dan Ekonomi Kehutanan*, 8: 276-287.
- HEGEDÜS A., GAÁL M., BÉRCES R. (2011), Tree appraisal methods and their application – first results in one of Budapest's districts, *Applied Ecology And Environmental Research*, 9: 411-423 (online).
- HELLIWELL D.R. (1967), The Amenity Value of Trees and Woodlands, *Scottish Forestry*, 21:109-112.
- JORDAN F. (2009), Keystone species and food webs, *Phil. Trans. R. Soc. B*, 364: 1733–1741 DOI:10.1098/rstb.2008.0335.
- KINDERMANN G.E., McCALLUM I., FRITZ S., OBERSTEINER M. (2008), A global forest growing stock, biomass and carbon map based on FAO statistics, *Silva Fennica*, 42:387–96.
- KIRAN G.S., MALHI R.K.M. (2011), Economic valuation of forest soils, *Current Science*, 100: 396-399.
- Le SAOUT S., HOFFMANN M., SHI Y., HUGHES A., BERNARD C., BROOKS T.M., BERTZKY B., BUTCHART S.H.M., STUART S.N., BADMAN T., RODRIGUES A.S.L. (2013), Protected areas and effective biodiversity conservation, *Science*, 342:803-805. <http://dx.doi.org/10.1126/science.1239268> (online)
- McGARRY P.J., MOORE G.M. (1988), The Burnley Method of Amenity Tree Evaluation, *Australian Journal of Arboriculture*, 1: 19-26.
- MOAGRI (Minister of Agriculture of the Republic of Indonesia) (2014), Peraturan Menteri Pertanian Republik Indonesia Nomor 130/Permentan/SR.130/11/2014 Tentang Kebutuhan dan Harga Eceran Tertinggi (HET) Pupuk Bersubsidi untuk Sektor Pertanian Tahun Anggaran 2015. Menteri Pertanian Republik Indonesia. Jakarta-Indonesia. 50pp. (Regulation of the Minister of Agriculture of the Republic of Indonesia No. 130/Permentan/SR.130/11/2014 On Demand and Retail Price (MRP) Subsidized Fertilizer for Agriculture Sector Fiscal Year 2015. Ministry of Agriculture of The Republic Indonesia).
- MOFOR (MINISTRY OF FORESTRY) (2008), Peraturan Menteri Kehutanan No: P.47/Menhut-II/2008 tentang Penetapan Harga Limit lelang Hasil Hutan Kayu dan bukan Kayu (Policy of Forestry Minister Number: P.47/Menhut-II/2008 about Fixed Auction Price Limit of Timber and Non-Timber), Jakarta, Indonesia.

- NAIDOO R., BALMFORD A., COSTANZA R., FISHER B., GREEN R.E., LEHNER B., MALCOLM T.R., RICKETTS T.H. (2008), Global mapping of ecosystem services and conservation priorities, *Proc.Natl.Acad.Sci., USA*, 105:9495-9500.
- NDJONDO M., GOURLET-FLEURY S., MANLAY R.J., OBIANG N.L.E., NGOMANDA A., ROMERO C., CLAEYS F., PICARD N. (2014), Opportunity costs of carbon sequestration in a forest concession in central Africa, *Carbon Balance and Management*, 9:4.
<http://www.cbmjournal.com/content/9/1/4> (online)
- NOWAK D.J. (1993), Compensatory value of an urban forest: An application of the tree-value formula, *Journal of Arboriculture*, 19: 173-177.
- PAK M., TÜRKER M.F., ÖZTÜRK A. (2010), Total economic value of forest resources in Turkey, *African Journal of Agricultural Research*, 5: 1908-1916.
- PIMM S., JONES H., DIAMON J. (1988), On the risk of extinction, *Am. Nat.*, 132:757-785.
- SMITH M.D., KNAPP A.K. (2003), Dominant species maintain ecosystem function with non-random species loss, *Ecol. Lett.*, 6:509-517.
- STRASSBURG B.B.N., KELLY A., BALMFORD A., DAVIES R.G., GIBBS H.K., LOVETT A., MILES L., ORME C.D.L., PRICE J., TURNER R.K. (2010), Global congruence of carbon storage and biodiversity in terrestrial ecosystems, *Conservation Letter*, 3: 98-105.
- STRATON A. (2006), A complex systems approach to the value of ecological resources, *Ecological Economics*, 56:402-411. DOI:10.1016/j.ecolecon.2005.09.017
- SULISTIYOWATI H., BUOT I. Jr. (2013), Integrated Biodiversity Valuation Framework: Ecological Approach, *J. Wetlands Biodiversity*, 3:7-16. www.muzeulbrailei.ro/vol3-2013-01HariSulistiyowati (online)
- THYER P.R. (2005), *The Thyer Tree Valuation Method*, retrieved from <http://peterthyer.com/Thyer%20Tree%20Valuation%20introduction%20Jan%202002.pdf> on 22 February 2015
- TURNER R.K., PAAVOLA J., JESSAMY V., COOPER P., GEORGIOU S., FARBER S. (2003), Valuing nature: lessons learned and future research directions, *Ecological Economics*, 46: 493-510.
- WATHERN P., YOUNG S.N., BROWN I.W., ROBERTS D.A. (1986), Ecological evaluation techniques, *Landscape Plann.*, 12:403-420.
- WERTZ-KANOUNNIKOFF S. (2008), *Estimating the costs of reducing forest emissions. A review of methods*, Working Paper No. 42, Center for International Forestry Research (CIFOR), Bogor, Indonesia, 22 p.
- WORLD BANK (2014), *State and Trends of Carbon Pricing 2014*, Washington, DC: World Bank, 140 p. DOI: 10.1596/978-1-4648-0268-3.