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A meta-analysis of the economic value of forest carbon stock

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Abstract

Global climate change has become a critical issue due to the global greenhouse gases (GHGs) emissions dominated by carbon dioxide (CO_2). Forest ecosystems are becoming increasingly essential in mitigating climate change by absorbing the atmospheric CO_2 and storing it in tree biomass, a process known as carbon sequestration. Decades of environmental valuation research show that forest carbon has a positive economic impact. Economic valuation of forest carbon provides mechanism for climate change mitigation policy instruments, compare rival forestry and environmental initiatives, and infuse public willingness to pay in forest conservation projects. It is also required for carbon trading, conservation, and management of the forests. However, carbon storage estimates in forest ecosystems throughout the world differ substantially. Thus, this study conducts a global meta-analysis to estimate the marginal economic value of forest carbon per hectare. A systematic review of scientific literature leads to the selection of 60 primary studies from 30 different countries published between 1990 to 2021. The meta-analysis identified wide variations in economic values of forest carbon across the globe. The outcome of the meta-analysis reveals that global economic value of forest carbon is USD2005 per hectare. This study provides an insight on the marginal economic value of global forest carbon which would be helpful to understand the necessity of avoiding deforestation and conserving more forested areas that ultimately helps to mitigate global climate change through emission reduction.

Keywords: Carbon sequestration, climate change, forest, economic valuation, meta-analysis, mitigation

Introduction

Global climate change induced by increased greenhouse gases (GHGs) emissions dominated by carbon dioxide (CO_2) has become a critical issue (Hu et al., 2012; Patton et al., 2015; Begum et al., 2020). Forest ecosystems are becoming more essential in the fight against climate change by absorbing the atmospheric CO_2 and storing it in tree biomass, which is called carbon sequestration

(Ismariah & Fadli, 2007; Guo et al., 2008; Keith et al., 2019; Hussainzad & Yusof, 2020; Naime et al., 2020; Suyadi et al., 2020). Up to 80% of all aboveground carbon and 40% of all belowground carbon (soils, litter, and roots) is stored in the world's forests (Dixon et al., 1994; Zohreh et al., 2017). Carbon sequestration is one of the most essential forest ecosystem services, as stated by global climate change estimates (Murray 2000; Huang et al., 2019; Kulshreshtha et al., 2020). Under the Kyoto Protocol, governments throughout the world are seeking worldwide commitment to decrease CO_2 emissions. It enables countries to sell carbon emissions by providing an economic process that assigns a value to not releasing CO_2. The Kyoto Protocol's Clean Development Mechanism (CDM) has a clause for developed nations to receive monitory benefits to finance specific forestry activities in poor countries, such as carbon sequestration through afforestation and reforestation (Nijnik, 2004; Singh, 2007; Derwisch et al., 2009; Kiyingi et al., 2019).

There is a growing concern of the impacts of climate change on the adaptability and integrity of the forests as a vital carbon reservoir (Raihan et al., 2018). However, deforestation and forest degradation are two important worldwide problems because they can diminish the carbon store and sequestration capability of forests (Matthew et al., 2018). Hence, understanding about the economic value of carbon stored in the forests can encourage countries to lower the rates of deforestation and improve the status of their natural carbon sinks (Yee 2010). The economic valuation of forest carbon helps the policymakers to take appropriate decisions for reducing deforestation and conserving biodiversity through the protection and conservation of the forest ecosystems (Verma, 2000; Bulte et al., 2002; Verma, 2009; Hugues, 2011; Malik et al., 2015). Economic valuation of forest carbon is also needed for forest resource accounting by optimizing forest products and environmental services forest ecosystem values (Ninan & Inoue, 2013). Economic valuation of forest carbon sequestration provides mechanism for climate change mitigation policy instruments, compare forestry and environmental projects, and infuse public willingness to pay into forest conservation projects (Cavatassi, 2004). Furthermore, quantifying the economic value of forest carbon is required for carbon trading (Deng et al., 2011) which has been identified as one of the most efficient methods for lowering carbon emissions (Hong et al., 2017).

Over the last two decades, the economic worth of forest carbon as a possibility to prevent global climate change has been evaluated by various studies in different countries around the world (Manoharan, 2000; Anielski & Wilson, 2003; Bush et al., 2004; Mates & Reyes, 2004; Olschewski & Benitez, 2005; Gutrich & Howarth, 2007; Brainard et al., 2009; Saner et al., 2012; Simpson et al., 2013; Ninan & Kontoleon, 2016; Suharti et al., 2016; Tilahun et al., 2016; Carver & Kerr, 2017; Ovando et al., 2017; Jahanifar et al., 2018; Mishra & Prasad, 2018; Nguyen et al., 2018; Danardono et al., 2019; Dhungana & Deshar, 2019; Medina et al., 2020; Başkent, 2021). Nevertheless, carbon storage estimates in the forest ecosystems and its economic value throughout the world differ substantially (Thuy et al., 2020). It is difficult to assume the global economic value of forest carbon based on the regional aspects. However, there is limited research on the economic value of forest carbon per hectare on the global perspective. Thus, assessing the global economic value of forest carbon is critical in determining the economic aspects of the global forest's climate change mitigation potential. Therefore, this study aims to fill up this research gap by performing a global meta-analysis to provide an insight on the marginal economic value of forest carbon per hectare. This study significantly contributes to the area of meta-analysis to estimate the economic value of forest carbon on a global perspective. The findings of this study would be helpful to understand the necessity of avoiding deforestation worldwide and conserving more forested area due to the economic benefits from forest carbon sequestration that ultimately helps to mitigate global climate change by reducing carbon emission.

Literature Review

Carbon sequestration has become one of the most important externality values of a forest due to concerns about climate change and the potential of forests to sequester 20 to 100 times more carbon per unit area than croplands (Cavatassi, 2004). However, the carbon sequestration benefits of forest can be estimated in a two-stage process. Firstly, the carbon sequestration and storage can be estimated through physical models of forest type and land use change (Derwisch et al., 2009). The amount of carbon sequestered is determined by the species mix, the organic matter content of the species, the age distribution of the stand, and soil and climate conditions. The net flux includes both aboveground and belowground biomass. Several methods are available to estimate the quantity of carbon stored in forests, such as extrapolation from experimental plots or modelling from inventory data (Zapfack et al., 2016; Hong et al., 2017; Zohreh et al., 2017; Ascioti et al., 2018; Matthew et al., 2018; Thuy et al., 2020; Suyadi et al., 2020). Forest inventory data can be used to estimate the above and below ground biomass of regional areas (Deng et al., 2011). Table 1 presents the average forest carbon density in different continents around the world. The average forest carbon density is highest in Oceania followed by Africa, Asia, South America, North America and Europe.

Table 1. The average forest carbon density in different continents.

Continent	Forested Area (Billion hectares)	Average forest carbon density Mean ± SD (Tons per hectare)
Global forests	4.19	140±12
Africa	0.71	198±19
Asia	0.57	173±33
Europe	1.08	69±9
North America	0.89	123±4
Oceania	0.12	217±18
South America	0.82	167±40

Source: Yingchun et al. (2012)

Furthermore, the second stage of the economic valuation of forest carbon is to assign a monetary value to this forest function in terms of global emission reduction (Adger et al. 1995). The most prevalent method of valuing forest carbon is the social cost of carbon (Suyadi et al., 2020). The social cost of carbon calculates the cost of continuing to pollute per unit of emissions. The social cost of carbon is frequently employed in the computation of the benefits of emission reduction initiatives (Brainard et al., 2009; Thorsen et al., 2014; Naime et al., 2020). The social cost of carbon is defined as the amount of carbon tax that must be imposed in order to attain the optimal level of emissions (Tanner et al., 2019). Furthermore, estimations of discounted costs and benefits of CO_2 emissions can be used to calculate the entire economic worth of carbon sequestration.

Moreover, because the future environmental impact of global warming and climate change is difficult to forecast, the social cost of carbon considered hypothetical. A minimal economic cost of USD5 per ton of carbon is recommended by Nordhaus (1992). Furthermore, Fankhauser (1995) attempted to account for inherent uncertainties in climate change consequences by incorporating random variables into critical variables such as damage functions and discount rates, and came up with a central estimate of USD20 per ton of carbon. The European Forest Institute (EFI) reviewed 237 studies and came up with a figure of €49 per ton of carbon dioxide equivalent (CO_2eq) as the average social cost of carbon (Thorsen et al., 2014). However, carbon valuation is a contentious topic, and many figures have been quoted and approximated. CDM market indicates a price per ton of carbon sequestered ranging from USD5 to USD15, with an average figure of USD10 per ton (Cavatassi 2004). The carbon offset market is rapidly growing, and associated pricing are roughly defined.

However, developing countries can benefit from the economic valuation of forest carbon and carbon trading service through the Clean Development Mechanism (CDM) or other similar mechanisms such as the Biocarbon Fund (BIOCF), Global Environment Facility (GEF), or private sector Joint Implementation (JI) schemes which operate under the principle that emission trading allows the achievement of a given mitigation target at the lowest cost while promoting sustainable development. Carbon offsets from reforestation and afforestation projects can be sold to those whose carbon emissions are constrained as a result of policy decisions to limit global carbon emissions. Rich countries can buy credits from poor countries for green political purposes, while poor countries gain in terms of project development, money and compensation for the limited access to forests for other land use (Cavatassi, 2004). Nevertheless, while the valuation process is site-specific, the value itself is completely interchangeable, since one atom of carbon stocked in the Amazon forest is exactly like one atom stored in a Malaysian forest (Cavatassi, 2004). Thus, the present study attempts to conduct a global meta-analysis to estimate a worldwide economic value of forest carbon.

Methodology

Document selection for meta-analysis

The word "meta-analysis" refers to the examination of data from a group of primary studies that address the same research issues. Meta-analysis provides robust data and is the highest level of evidence about a stated topic. Several studies with the result on the economic value of forest carbon per hectare were selected to conduct the present meta-analysis. A systematic review of the scientific literature leads to the selection of 60 primary studies from 30 different countries published in between 1990 to 2021. The documents are collected from Web of Science (WOS), Scopus and Google Scholar databases. Figure 1 presents the development of criteria for document selection to conduct the meta-analysis. Individual study data is compiled, then aggregated and computed to get an overall estimate of research outcomes. The studies with results of the economic value in local currency are converted to USD. Meta-analysis uses statistical techniques to provide an aggregate estimate of an effect, analysis between-study heterogeneity, and assess the influence of publication bias. The meta-analysis was carried out using Stata 16 software.

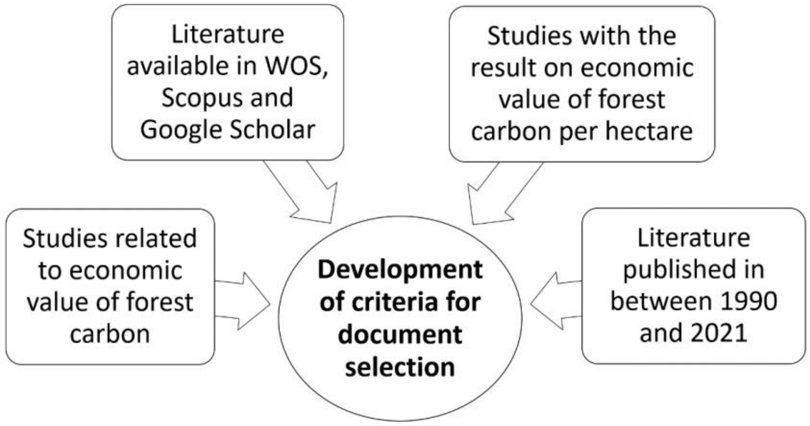

Figure 1. The development of criteria for scientific literature selection.

Effect size and meta-analysis model

The effect sizes for the present meta-analysis are the economic values of forest carbon per hectare reported by the primary studies. The overall effect size is calculated as a weighted average of study-specific effect sizes, with greater weights for more accurate (larger) research. The precision of a study determines how much weight it receives. The degree of precision of a study is determined by a variety of methodological parameters. It's not only the study's total size that matters. However, as the random effects model implies that the study effect sizes are diverse, this study employed a random effects meta-analysis methodology (Raihan & Said, 2021). A random-effects meta-analysis model assumes the observed estimates of treatment effect can vary across studies because of real differences in the treatment effect in each study as well as sampling variability. Thus, even if all studies had an infinitely large sample size, the observed study effects would still vary because of the real differences in treatment effects. Different effect sizes underlying different studies are because of the sample size, methodology, forest type, type of biomass, discounting rate, and carbon price. The random-effects model is defined by the fact that real effect sizes of forest carbon stock per hectare are distributed, and the current research seeks to determine the mean of this distribution, which would be generalized by the examples from different countries.

Meta-analysis forest plot

The meta-analysis findings are summarized on a forest plot, which includes study-specific effect sizes and confidence intervals, as well as a pooled estimate of the effect size and its confidence interval. A forest plot additionally displays information regarding study heterogeneity and the significance of the overall impact magnitude. This graph makes it easy to compare study impact sizes, which can be any summary estimates from primary research. Furthermore, in subgroup meta-analysis, studies from the 60 main studies are categorized depending on the research region (continent and nation), and an overall effect-size estimate is calculated for each group. The purpose of the subgroup meta-analysis is to compare the economic value of forest carbon among the countries and the continents.

Contour-enhanced funnel plot

The meta-analysis contour-enhanced funnel plot is frequently utilized to see if the meta-analysis outcome is publication bias on positive instead of non-significant or negative outcomes (Raihan & Said, 2021). A funnel plot in meta-analysis is a scatterplot with effect magnitude and standard error on the two axes. The areas of statistical significance are displayed using a contour-enhanced funnel plot. In a funnel plot, there are contour lines denoting traditional indicators in statistical significance levels (e.g., <0.01, <0.05, <0.1). The funnel plot is easier to comprehend with this contour overlay. If main studies appear to be absent in regions of statistical non-significance, for example, likelihood that imbalance is attributable to publication bias increases. Absence of research in statistical significance regions, on the other hand, imply that the observed imbalance is more likely attributable to reasons other than publication bias based on statistical significance (e.g., variable study quality).

Results and discussion

The meta-analysis conducted by the present study is based on the results about the economic value of forest carbon per hectare from 60 primary studies from 30 different countries published in between 1990 to 2021. Parameters used to convert biomass to carbon and the carbon price differ across the studies. Table 2 presents the primary studies with author's names, publication year, study area, and carbon price used to calculate the economic value of forest carbon per hectare in USD.

Table 2. Economic value of forest carbon per hectare by different studies in different countries.

Author's names and publication year	Study area (Continent and Country)	Carbon price (USD)	Economic value (USD ha^{-1})
	Southeast Asia		
Danardono et al. (2019)	East Kalimantan, Indonesia	5	412-1255
Hazandy et al. (2015)	Perak, Malaysia	15.09	1963-2518
Hong et al. (2017)	Malaysia	6	3314-5389
Hussainzad & Yusof (2020)	Pahang, Malaysia	4.51	2594
Ismariah & Fadli (2007)	Puchong, Malaysia	4.23, 5.63	1654-2080
Malik et al. (2015)	South Sulawesi, Indonesia	5.5	550-1100
Matthew et al. (2018)	Johor, Malaysia	7	1967
Nguyen et al. (2018)	Vietnam	14	1565-1613
Rumahorbo et al. (2019)	Jayapura, Indonesia	5.5	825
Saner et al. (2012)	Sabah, Malaysia	3.82	2891-5431
Suharti et al. (2016)	South Sulawesi, Indonesia	3.67	1604-2580
Thuy et al. (2020)	Thai Binh provinc, Vietnam	3	1588
	East Asia		
Deng et al. (2011)	Tiantai, Zhejiang, China	32.73	327-3397
Guo et al. (2008)	Pine forests, China	32.73	4336
Hu et al. (2012)	China	32.73	4298-7206
Huang et al. (2019)	Pangu Forest Farm, China	20	867-1005
Li et al. (2006)	Qinba mountains, China	37.14	1405
Ninan & Inoue (2013)	Japan	5.45	1182
Xie et al. (2010)	Beijing, China	-	1014
	South Asia		
Dhungana & Deshar (2019)	Dhading, Nepal	11.73	3988

Manoharan (2001)	India	-	479-2857
Mishra & Prasad (2018)	Jharkhand, India	20	4100
Ninan & Kontoleon (2016)	Karnataka, India	10	790
Singh (2007)	Uttarakhand, India	13	2967
Verma (2000)	Himachal, India	10	2674
Verma (2009)	Uttarakhand, India	10	1639
	Middle East		
Başkent (2021)	Eregli and Yesilkusak, Turkey	20	1410-1629
Jahanifar et al. (2018)	Mazandaran, Iran	10	1196
Zohreh et al. (2017)	Asalem forest, Iran	7.6	2618
	Europe		
Ascioti et al. (2018)	Reggio Calabria, Italy	4.71	1024
Borys et al. (2015)	Thuringia, Germany	21.43	3819
Brainard et al. (2009)	Great Britain	1.00, 10.00	720-853
Kazak et al. (2016)	Tuczno, Poland	7	3153-3718
Moore et al. (2011)	Georgia	21	998
Nijnik (2004)	Wooded Steppe, Ukraine	15	783-1325
Ovando et al. (2017)	Andalusia, Spain	-	1196
	North America		
Adger et al. (1995)	Mexico	20	650-3400
Anielski & Wilson (2003)	Boreal forest, Canada	17.50, 16.25	744
Gutrich & Howarth (2007)	New Hampshire, US	6.82, 20.45	1027-1805
Kulshreshtha et al. (2000)	Canadian National Parks	16.25	2967
Mates & Reyes (2004)	New Jersey, US	29, 54, 77	1001-3312
Murray (2000)	Douglas fir, US	10, 50	600-1900
Naime et al. (2020)	La Huerta Jalisco, Mexico	11.45	541-1749
Patton et al. (2015)	National Wildlife Refuge, US	13	2800
Simpson et al. (2013)	Texas, US	6	1831
	Central America		
Bulte et al. (2002)	Atlantic zone of Costa Rica	15	1500
Derwisch et al. (2019)	San Lorenzo, Panama	4.1	461-564
	South America		
Medina et al. (2020)	Puna Seca, Peru	6.39	4086
Olschewski & Benitez (2005)	Ecuador	-	1730
Pavani et al. (2018)	São Paulo, Brazil	7.4	2082-3131
Tanner et al. (2019)	Galapagos, Ecuador	13.93	2940
	Africa		
Bush et al. (2004)	Uganda	20	1625-2730
Hugues (2011)	Protected Areas, Congo	12.5	1568
Kiyingi et al. (2016)	Rubirizi and Mitooma, Uganda	4.15	424-997
Tilahun et al. (2016)	Ghana	5.9	3544
Zapfack et al. (2016)	Lobéké, Cameroon	17.6	1796
	Oceania		
Carver & Kerr (2017)	Native forest, New Zealand	17.5	562-3244
Gaylard et al. (2020)	Temperate forests, Australia	-	3237
Keith et al. (2019)	Victoria, Australia	12.25	1789
Suyadi et al. (2020)	Auckland, New Zealand	17	1834

The forest plot of meta-analysis outcome is depicted in Figure 2. The study findings are based on the economic value of forest carbon stock per hectare in USD. The list of studies represented by the first author for every specific main research, as well as the year of publication, can be found in column on left side of the forest plot. The blue square boxes in the forest plot are the outcomes of averaged effect sizes measure for the economic value of forest carbon per hectare by individual studies. This box also represents the size of individual study. The wider the box, the larger study area used for estimating the economic value of forest carbon. The 90 % confidence intervals (CI) of the research result are shown by horizontal lines running through the boxes, with each end of the line denoting the CI's limits. The study results become less trustworthy as the lines lengthen and the CI widen. In addition, the column on right side of forest plot gives numerical results for each study (95% CI). The weight (in %) indicates the influence of an individual study on the overall outcomes of the meta-analysis. The sample size of a study and precision of research results reported as a CI define the study's effect or "weight" on overall outcomes.

Moreover, the maroon-colored diamonds reflect each continent's total effect size, while the green diamond at bottom of the forest plot is the outcome of combining and averaging all 60 original research. The graph's bottom axis depicts the range of forest carbon economic value per hectare. The number for overall effect estimate is in the center of the diamonds, and the width of the diamonds represents the breadth of the overall CI. Overall estimate of the meta-analysis reveals that global economic value of forest carbon is USD2005 per hectare with a range of USD1732 to USD2279. The outcomes from the subgroup meta-analysis indicate that among the ten continents, forests South America in hold the averaged maximum economic value of forest carbon per hectare (USD2854) followed by South Asia (USD2609), Oceania (USD2191), East Asia (USD2138), Africa (USD1968), North America (USD1837), Southeast Asia (USD1793), Middle East (1780), Europe (USD1644) and Central America (USD1008). The level of heterogeneity is shown by the I^2 at the bottom of the forest plot, which relates to the variation in research results between the primary studies. The extreme amount of heterogeneity (I^2 =100%) justifies the use of a random-effects model for meta-analysis, however the low value of heterogeneity implies that a fixed-effects model would be more suited. The P-value for the total impact is 0.00, indicating that the finding is very significant.

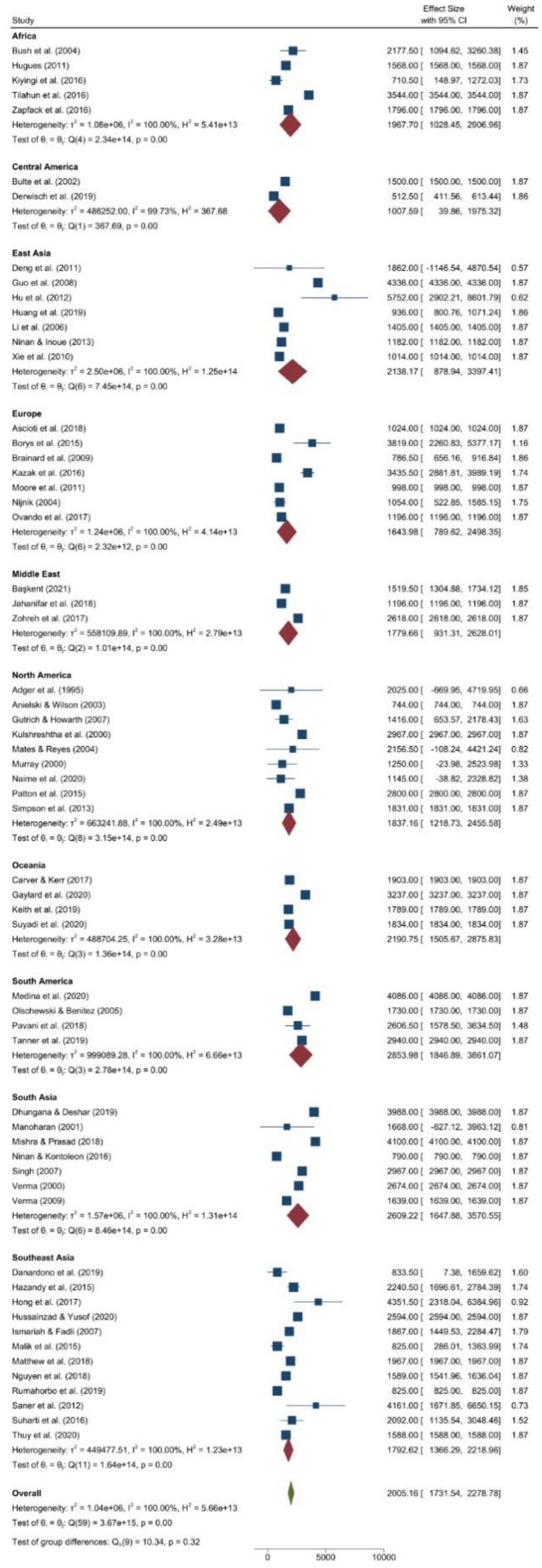

Figure 2. Meta-analysis forest plot on the economic value of forest carbon per hectare.

The level of economic valuation of forest carbon can help to determine whether or not forest conservation is the best option. However, outcomes of subgroup meta-analysis by countries are presented in Figure 3. Based on the selected primary studies for the meta-analysis, Peru shows the highest economic value of forest carbon per hectare (USD4086) followed by Nepal (USD3988), Germany (USD3819), Ghana (USD3544), Poland (3436), Brazil (USD2607), Australia (USD2513), India (USD2363), China (USD2352), Ecuador (USD2335) and Malaysia (USD2293). In addition, Panama shows the lowest economic value (USD513) of forest carbon among the 30 countries. The economic value of forest carbon per hectare differs among the countries due to the variations in forest type (hill forest, mangrove forest, peat swamp forest, plantation forest), forest conditions (degraded, protected, reforested) climatic factors (temperature, humidity, rainfall), soil type, suitability of tree species, sample size, type of forest carbon pool (aboveground biomass, belowground biomass, soil carbon), models used to estimate forest biomass, carbon price and discounting rate considered to calculate the economic value by the primary studies. Figure 4 presents the global map of economic value of forest carbon per hectare based on the outcome of subgroup meta-analysis by countries.

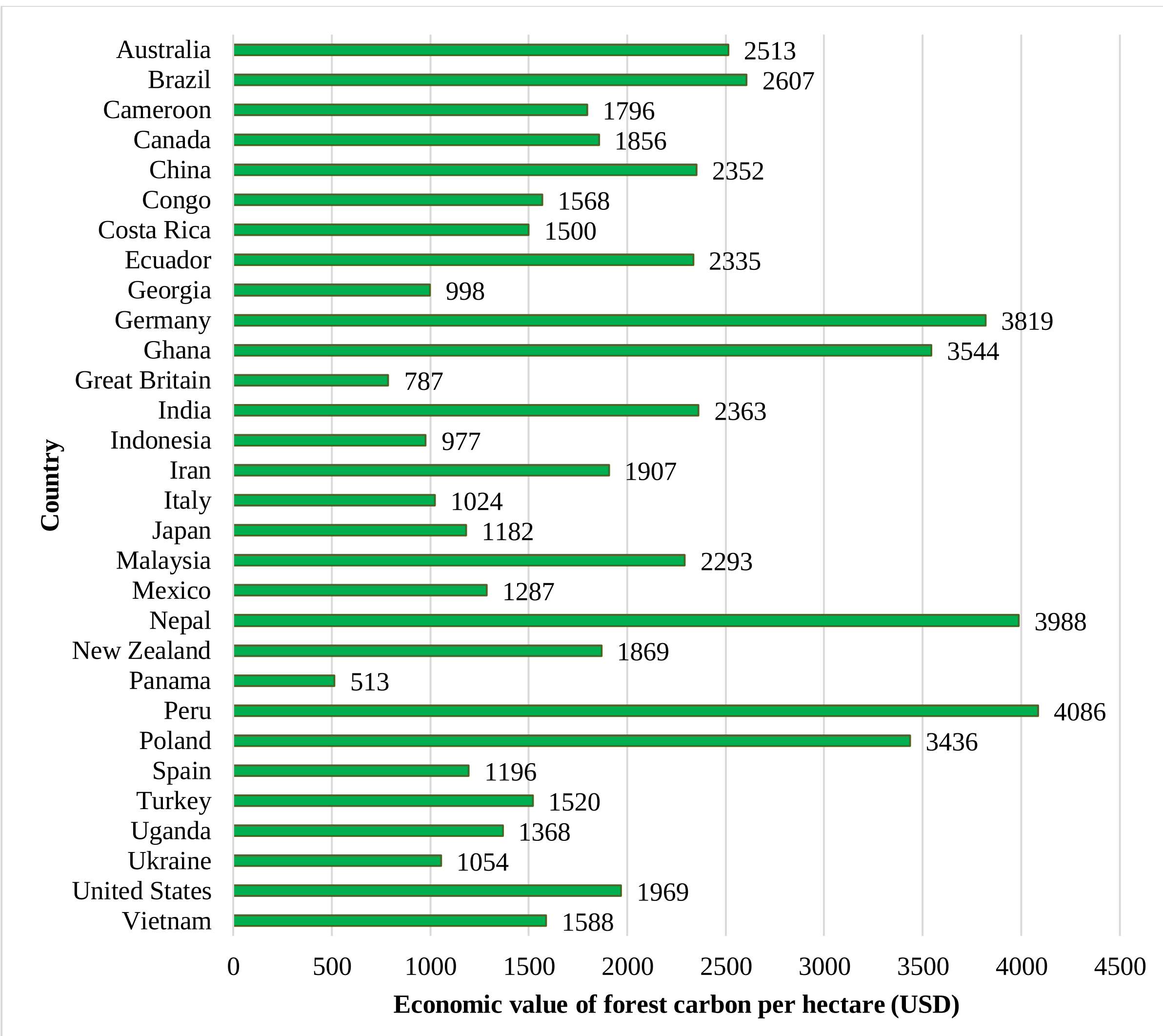

Figure 3. Outcomes of subgroup meta-analysis on economic value of forest carbon by countries.

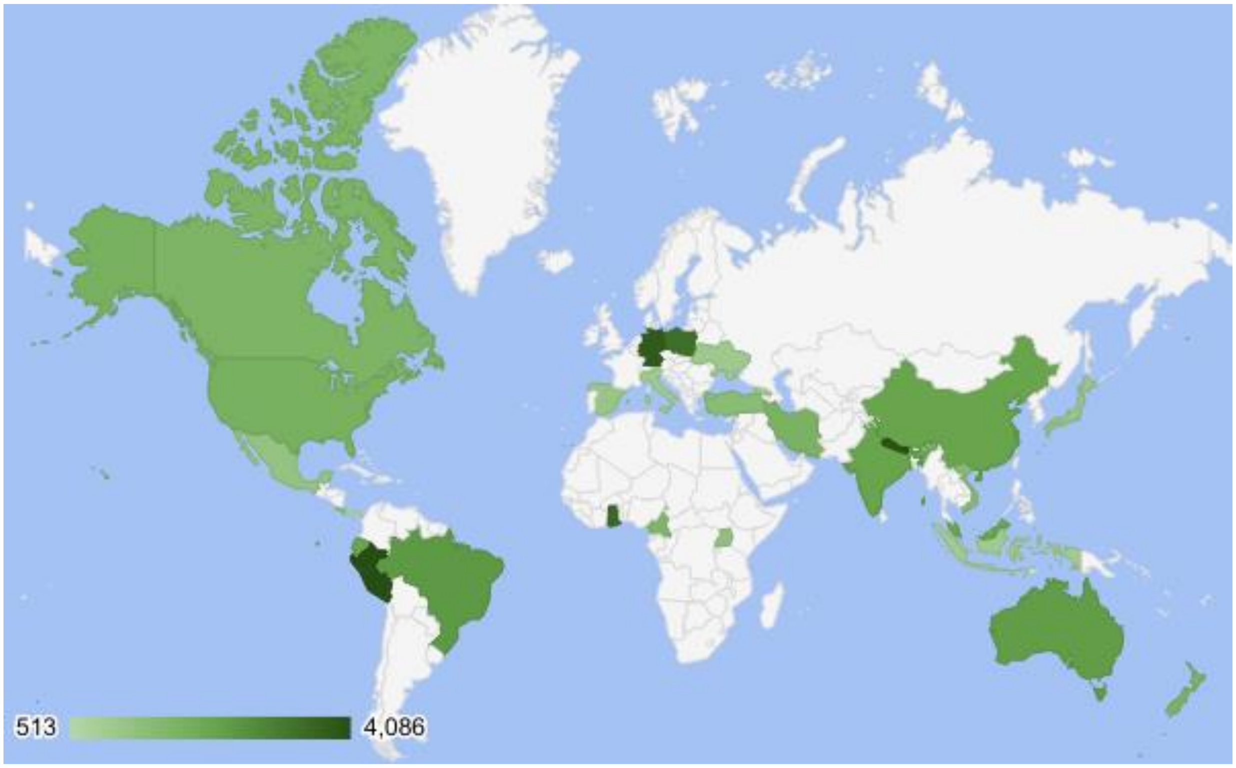

Figure 4. Global map of economic value of forest carbon per hectare.

Furthermore, meta-analysis contour-enhanced funnel plot to assess publication bias is depicted in Figure 5. A contour-enhanced funnel plot gives a complete overall estimate that improves precision by integrating the data from primary research. It indicates that an overall substantial impact that was not detected in any of the individual studies may be seen. Asymmetry in the funnel plot is indicated by a statistically significant effect. The points or dots at the peak of the graph represent research with larger sample size or highest accuracy, whereas research with smaller sample sizes or lower accuracy (higher standard error) spread out at the bottom side. For studies located in white region, the null hypothesis of no effect can be rejected at 1% level of significance. For example, the significance tests for these findings would have p-values less than 0.01 or 1% significance level. For the studies located in light-grey region, p-values would be between 1% and 5% significance level (0.01-0.05). For studies located in darker-grey region, p-values would be between 5% and 10% significance level (0.05-0.1). Additionally, for studies located in darkest-grey region, p-values would be larger than 10% significance level (>0.1).

The contour-enhanced funnel plot demonstrates that most of the studies report a statistically significant result, supporting the treatment, except eight studies in non-significant region. The eight non-significant studies include six countries which are China (two studies), Malaysia (two studies), India, Mexico, Germany and United States. However, studies published in peer-reviewed journals are far more likely to produce statistically significant results than research that report a nonsignificant conclusion, especially for smaller (less precise) studies. Among the eight non-significant studies, one studies in 1% significance level four studies in 5% significance level and three studies in 10% level of significance. The contour-enhanced funnel plot suggests that the result from meta-analysis is not publication bias on significant rather than non-significant or negative outcomes.

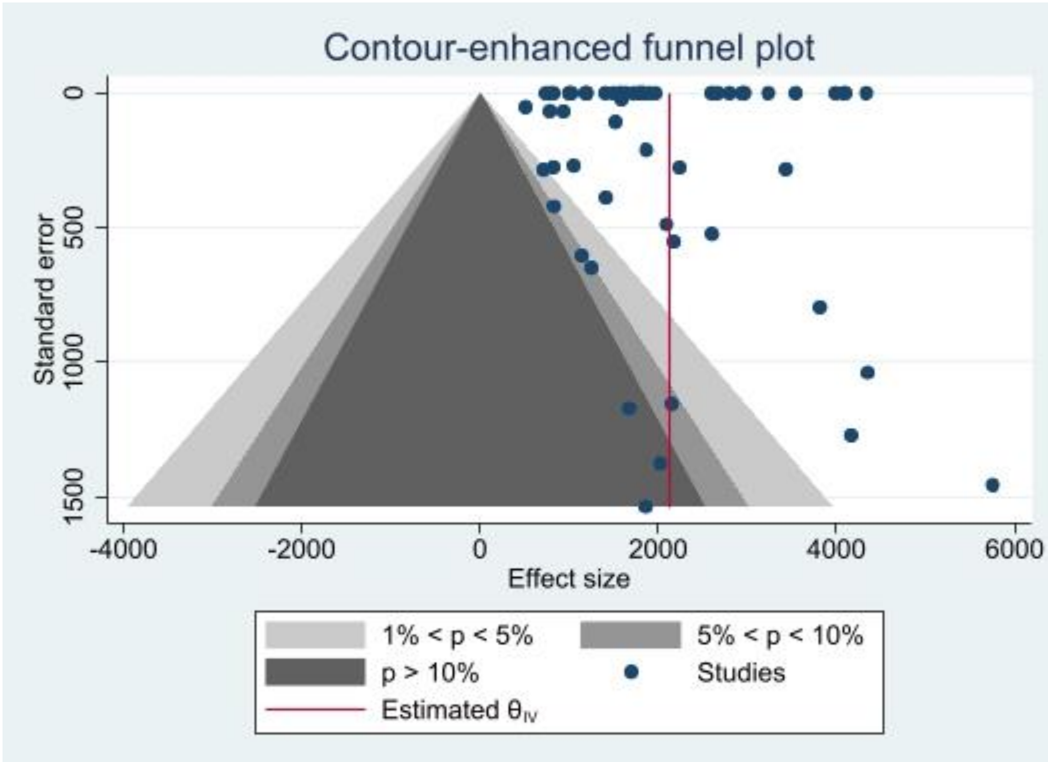

Figure 5. Meta-analysis contour-enhanced funnel plot for economic valuation of forest carbon.

However, forests can mitigate climate change in both developed and developing countries through a variety of activities (Raihan et al., 2019). Forest carbon sequestration is as least as cost-effective as increasing energy efficiency, switching to renewable energy, switching fuels, and collecting and storing CO_2 (Pan et al., 2011). Nevertheless, many nations and areas consider forest management to improve carbon storage or reduce carbon emissions to be effective strategies to combat climate change (Raihan et al., 2019). Reducing Emissions from Deforestation and Degradation (REDD), Improved Forest Management (IFM), and Afforestation/Reforestation (A/R) are the three types of actions most referred to collectively as "forest carbon activities," each of which, when designed properly, can produce real, measurable, and verifiable carbon benefits. These actions can be utilized individually in single projects or in combination to help reduce climate change on a broader scale.

The present study findings reveal that developing countries such as, Peru, Nepal, Ghana, Brazil, India, Ecuador and Malaysia have a mesmerizing potential to emission reduction through forest carbon sequestration due to the high economic value of forest carbon per hectare. Contrastingly, some of the developing countries such as, Great Britain, Italy, Japan, Spain and Turkey shows low economic value of forest carbon per hectare. However, extensive implementation of different mitigation measures, such as, afforestation, reforestation, forest conservation, sustainable forest management, enhanced natural regeneration and REDD+ initiatives can increase the carbon sink as well as the economic value of forest carbon (Raihan et al., 2018).

Moreover, carbon finance can be used to fund forest conservation and protection. Carbon credits are one of the ways to generate financing to protect nature and enhance its ability to regulate the climate. Developing countries that cut their emissions or remove carbon from the atmosphere, for example through tree planting or forest conservation, may sell or trade unused credits to the developed countries seeking to complement their internal emission reductions and to further decrease their carbon footprints. The proceeds from the carbon trading go to the developing countries and communities, offering alternative livelihoods for those who had previously relied on deforestation. This money also helps to fund new jobs, wildlife conservation, education, clean water, and other activities aimed at shifting the local economy away from reliance on the forest. Hence, the developing countries with more forested area can be financially rewarded for keeping carbon stored in their natural forests. The present study encourages the developing nations to estimate the economic value of their forest carbon which may help to enhance forest carbon sink by reducing deforestation, along with their economic development through emissions trading system.

Conclusion

A global meta-analysis has been employed to estimate the marginal economic value of forest carbon per hectare. A systematic review of scientific literature leads to the selection of 60 primary studies from 30 different countries published in between 1990 to 2021. The outcome of the meta-analysis reveals that global economic value of forest carbon is USD2005 per hectare. The results from the subgroup meta-analysis show that forests in South America hold the averaged maximum economic value of forest carbon per hectare followed by South Asia, Oceania, East Asia, Africa, North America, Southeast Asia, Middle East, Europe and Central America. The meta-analysis identified wide variations in economic values of carbon stock across the globe. The study findings indicate that due to the high economic value of forest carbon per hectare, developing countries such as Peru, Nepal, Ghana, Brazil, India, Ecuador, and Malaysia have a tremendous potential for emission reduction through forest carbon sequestration. In addition, developed countries such as the United Kingdom, Italy, Japan, Spain, and Turkey have a low economic value of forest carbon per hectare. This study implies that developing countries can be financially benefited by keeping carbon stored in the forests and sell the carbon to the developed countries seeking emission reduction through carbon trading system. Moreover, the contour-enhanced funnel plot shows that there is no publication bias on positive outcomes in meta-analysis. This study provides an insight on the marginal economic value of global forest carbon per hectare. The findings of this study would be helpful to understand the necessity of avoiding deforestation worldwide and conserving more forested area due to the economic benefits from forest carbon sequestration that ultimately helps to mitigate global climate change by reducing carbon emission.

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