Original Article

A Simple Model To Estimate Carbon Stock Based On River Discharge: Supporting The Next Implementation Of Redd+ In Indonesia Under Paris Agreement Regime

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Abstract

Land covers is the main determinant of river discharge rate of a watershed. The land cover, on the other hand, also contain the carbon stock accumulated above ground over watershed. This relation is very useful in carbon stock monitoring to support Paris Agreement implementation especially for tropical countries where the MRV activities are commonly very expensive. In this research the ordinary least square models were employed at significant level of 95%. First model was the river discharge, [YD], as the function of rainfall [RAIN] (mm/year) and the acreage of land covers area (ha) namely the forest [FREST], shrub [SRHB], plantation [PLNT], up land crop [UPLND], mix farming [MIXFM], and settlement [SETL]. The second model was to express the carbon stock [YC] (ton/ha) as the function of the [YD]. Data series of [RAIN], [YD] and lands covers of 2011, 2014, 2017 covering 3 watershed (Way Pengubuan, Way Bulok, and Way Besai) lies at Lampung Province, Republic of Indonesia. We employed Minitab 16 for parameter model estimation. The simple models achieved for river discharge was [YD]i=13,612.00 +0.1192[RAIN]I -238,00[FREST]i-129,08[SRHB]i-107.46[PLNT]i-184.16[SETL]i-131.08[UPLND]i-30.97[MIXFM]i-127.01[PADY]i with P=0.000 and R.Sq (adjt) =96.6%; and the carbon stock expressed by [Yc]i=17.2237 - 0.0212 [YD]i with P=0.0006 and the Rsq(adjt)= 0.5283.

Index Terms— Land cover, carbon stock, MRV, REDD+.

INTRODUCTION

Global warming phenomenon has been confiscating attention for various groups in the world. The increasing emission of greenhouse gases in the atmosphere causes an imbalance of climate change, so that to deal with it requires actions that can be carried out simultaneously, namely mitigation and adaptation [1]. Land use and land change or what is known as Land Use, Land Use Change and Forestry (LULUCF) contributed 17-20% of the concentration of greenhouse gases (GHG) in the atmosphere which led to increased global climate change [2]. Increasing urban transportation also worsen the climate change effect on some various livelihood of human being respond to survive in adaptation [3].

In the context of adaptation and mitigation to climate change, Indonesia's commitment has been realized since the beginning of the Kyoto Protocol Scheme. Action plan for the implementation of climate change adaptation and mitigation in the land use, land use change and forestry (LULUCF) sectors Indonesia has prepared a supra structure known as the REDD (Reduction Emission from Deforestation and Land Degradation) institution which has been further developed into REDD+ [4]. Both the REDD and REDD+ mechanisms applied a sustainable forest management approach and increase the role of conservation and carbon stocks from forests. The REDD and REDD+ scheme were formed with the aim at reducing emissions from deforestation and land degradation, especially for developing countries that have forests and significantly address global climate change mitigation in efforts to protect and conserve protected areas as reported [5] and [6] Indonesia has very large tropical forests with 70% of its land area in the form of forests [7] so that it has become an important country related to REDD+ [8] as a form of national commitment (NDC: National Designated Contribution) under the Paris Agreement regime [9].

The next implementation of REDD+under the Paris Agreement regime, however, needs to supported the high costs of MRV costs. The high cost of MRV has made carbon prices in the international market very expensive. This is the main reason why carbon sequestration projects in the LULUCF sectors are so inefficient that they cannot be implemented in the carbon trading scheme under the past Kyoto Protocol regime. Most countries in Europe contribute emissions equivalent to 2 billion tons of carbon per year [10]. The largest MRV cost component is to carry out routine checks during the contract period between suppliers during the agreed period in REDD+ projects. For example, for carbon suppliers in the form of large institutions (including Forestry, Farmers, National Parks, and UPJL Carbon Absorption) [11].

To accommodate the highly cost of MRV, we have the imagination of a simple model developer that applies carbon stock measurement by utilizing relatively abundant river discharge data that routinely recorded in almost all watersheds in Indonesia. Until nowadays, there is no researcher who published his research about modeling of carbon stock as function of its river discharge accumulated on its watershed areas. This reasonhave stimulated us to do pioneer research in developingthis model. This model is very useful to accommodate the lack data of carbon stock for the bench marking in REDD+ projects and the routinely conducts MRV activities during the life cycle of the projects for the 30 years long or more.

MATERIAL AND METHODS

The Materials

The material used in this research includes paper, pencil, rope, and other stationaries. As for the equipments include GPS, compass, and clinometer apparatus

Model Approach

This study uses a modeling approach by utilizing the available data records based on watershed. Land cover data, river discharge records, and rainfall data. The Ordinary Least Square postulate is applied in the following 2 sequences modeling. Model I to formulate the river discharge as a function of monthly rainfall and land covers. Model II to formulate the relationship of carbon stock as a function of river discharge. However, before compositing the postulate Model I, it is necessary to first examine the types of land cover that exist in the 3 sub watersheds as research areas. From the work, it is known that there are 8 types of land covers, namely forest, shrub, plantation, upland cultivation, mix farming, paddy field, and settlement. The Model I and Model II are expressed respectively as the following:

$$[YD]i=\alpha 0+\alpha 1[RAIN]i+\alpha 2[FREST]i+\alpha 3[SRHB]i+\alpha 4[PLNT]i+\alpha 5[UPLND]i+\alpha 6[MIXFM]i+\alpha 7[PADY]i + \alpha 8[SETL]i+\xi i$$

Note:

[RAIN] = Monthly rainfall (mm)

[FREST] = Forest (ha)

[SRHB] = Shrub (ha)

[PLNT] = Plantation (ha)

[MIXFM] = Mix farming (ha)

[PADDY] = Paddy field (ha)

[SETL] = Settlement (ha)

Ξ = ErrorModel I

α0 - α8 = Parameter model

ith = Data series

The working hypothesis Model I is as the following:

H0: $\alpha 1= \alpha 2= \alpha 2=\alpha 3= \alpha 4=\alpha 5=\alpha 6= \alpha 7= \alpha 8=0$;

None of the predictor variable has significant effect on the river discharge [YD].

H1: $\alpha 1 \neq \alpha 2 \neq \alpha 2 \neq \alpha 3 \neq \alpha 4 \neq \alpha 5 \neq \alpha 6 \neq \alpha 7 \neq \alpha 8 \neq 0$,

At least there will be one predictor variable has significant effect on the river discharge [YD].

As for the Model II is expressed in the following:

$[YC]i=\beta 0+\beta 1[YD]i+£i$

Note:

[YC] = Carbon stock (tonnes/ha)

[YD] = River discharge (m3/year)

£ = Error Model II

$\beta 0$ and $\beta 1$ = Parameter model

ith = Data series

The working hypothesis Model II as the following:

H0: $\beta 1=0$, there will be no significant relationship between river discharge and the carbon stock.

H1: $\beta 1 \neq 0$, there will be significant relationship between river discharge and the carbon stock.

Data Analysis

Data input for modelling were collected from three watersheds lied in Lampung Province, namely Way Bulok, Way Besay, and Way Pengubuan (Figure 1). The management of the three watersheds are under control by Board of Way Seputih-Way Sekampung Watershed Managgement, the Ministerial of Environment and Forestry RI. The monthly rainfall data

One of the forest areas in Indonesia is located in Lampung Province, precisely in the forest area in the watershed area. Watershed areas in Lampung Province that have forest areas in it, such as the Way Sekampung watershed, the Way Tulang Bawang watershed and the Way Seputih watershed. The watershed area in Lampung Province has a different land cover classification for each land cover classification. The type of land cover in each watershed will affect the amount of river flow in the watershed [12]. The land cover classification into vegetated areas, non-vegetated areas and water areas [13]. Based on research conducted [12] stated that surface water runoff is strongly influenced by land cover in the vicinity, therefore it is important to know the effect of land cover and rainfall on river discharge in the sub-watershed area in Lampung Province.

Research on carbon stocks by utilizing river discharge data, especially in the Way Bulok, Way Besai and Way Pengubuan sub-watersheds, needs to be carried out because there is no research data regarding the calculation of estimation of carbon stocks using this method. Losing large amounts of carbine reserves in tropical regions can disrupt global climate change [14]. It is hoped that the resulting model from this research can be used to measure carbon stocks in the sub-watershed area, so that it can support Indonesia in REDD and REDD+ due to the lack of operation of the carbon trading mechanism due to the high transaction costs for Measurable, Reportable, and Verifiable (MRV) or measurement, reporting, and verification in calculating potential carbon stock. The REDD+ mechanism can convert carbon stocks in forest areas, therefore, against the background described, it is important to conduct research to determine carbon stocks using river discharge data [15].

The tools and materials used in this study consist of hardware, software and stationery. The hardware used includes notebooks, Global Positioning System (GPS) and digital cameras or cellphone cameras. The software used in this study included geographic information system software, applications for statistical tests (Minitab 16) and Microsoft Office.This research was conducted using secondary data.

The stages in the research carried out were preparing data, analyzing digital maps, analyzing data on monthly rainfall data and monthly discharge and regression analysis. This research was conducted in December 2019-November 2020 at the Central Postgraduate Geographic Information System (GIS) Laboratory of the University of Lampung. The study area in this research is in the watershed area, precisely in the Way Bulok Sub-watershed, which is a tributary of the Way Sekampung watershed and administratively included in the Pringsewu Regency area, Way Besai Sub-watershed, which is a tributary of the Way Tulang watershed. Onions and administratively included in the West Lampung Regency area, as well as the Way Pengubuan Sub-watershed which is a tributary of the Way Seputih watershed and administratively included in the Central Lampung Regency area. The map of the location used as the object of research can be seen in Fig 1

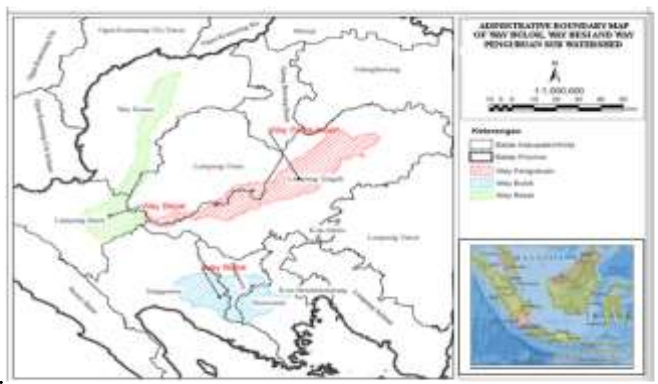

Fig 1. Research location.

The carbon stock data in this study uses data from research conducted [16] which can be seen in Table I.

Tabel I. Carbon stocks per hectare based on land cover type

Land Cover Type	Carbon Stock (ton C/ ha)
Primary dryland forest	132.99
Secondary dryland forest	98.84
Primary mangrove forest	183.30
Primary swamp forest	96.5
Plantation forest	98.38
Shrubs	30.00
Plantation	63.00
Settlement	4.00
Open land	2.50
Cloud	0.00
Grass	4.00
Body of water	0.00
Secondary mangrove forest	94.07
Secondary swamp forest	79.67
Swamp scrub	30.00
Dryland farming	10.00
Mixed dryland farming	30.00
Rice fields	2.00
Pond	0.00
Airport / port	0.00
Transmigration	10.00
Mining	0.00

Land Cover Type	Carbon Stock (ton C/ ha)
Swamp	0.00

Source: Tosiani et al (2014)

Then perform an analysis to see the effect of land cover on river discharge using a linear regression equation. This study conducted a regression test to determine the effect between variables [17]. Linear regression is a statistical technique used to test the effect of two or more predictor variables on the respond variable [18]. In general, the model used in this study refers to Hosmer and Lemeshow [19].

Model parameters optimization

The goodness fits of the models were tested by employing F statistic test and followed by T statistic test to examine the role of each predictor variable at significantlevelof 95%. For optimizing parameters models we used Minitab 16.

Result and Discussion

Firstly we needs to display the data series of monthly rainfall, land cover, carbon stock, and river discharge of the three watersheds of 2011, 2014, and 2017, then analyzed their characteristics in relation to the main purposes of this research.

Monthly rainfall

Rainfall is the amount of water that falls on the ground during a certain period if there is no removal by the evaporation, drainage and infiltration processes, which is measured in units of height [20]. Rainfall in the Way Bulok, Way Besai and Way Pengubuan sub-watersheds is calculated using the arithmetic method [21] to determine the distribution of rainfall at the observed research location. Rainfall data was obtained from the Way Mesuji-Sekampung River Basin Center (BBWS-MS) which was then processed as research data. The purpose of measuring rainfall is to determine the thickness of the water that falls to the surface during the occurrence of rain in a certain time intensity.

Table II also explains that of the three sub-watershed areas observed as research objects, it is known that the maximum rainfall occurs in the periode of November-March, while the minimum rainfall values occur in the range of June-September during 2011-2017. The rainy season occurs in October-March and the dry season occurs in April-September [22]. Based on the rainfall data in the three sub-watersheds that were the object of research that was observed and analyzed, Lampung Province experienced the rainy season and dry season in the same month as the research .

Table II. Rinfall at the Way Bulok, Way Besai and Way Pengubuan sub-watershed areas

Month	Way Bulok			Way Besai			Way Pengubuan		
	2011	2014	2017	2011	2014	2017	2011	2014	2017
January	262.00	237.67	133.00	139.60	310.15	51.63	320.25	385.38	371.25
February	124.00	128.67	309.33	235.20	354.25	262.18	246.63	347.25	300.13
March	122.17	167.17	164.50	180.28	285.75	235.35	359.25	247.85	372.93
April	123.50	75.67	150.17	209.55	165.23	211.73	332.38	226.75	360.50
May	92.00	108.00	154.50	193.73	313.35	215.50	187.63	161.00	234.50
June	34.17	43.67	61.17	56.18	238.75	76.05	138.13	60.38	191.88
July	66.00	35.67	120.00	49.88	209.60	99.75	76.25	85.63	87.13
August	76.80	49.33	53.33	12.47	257.68	46.43	1.50	188.68	114.70
September	68.60	16.00	105.20	57.75	13.03	119.65	21.00	0.50	119.88
October	141.50	39.67	209.50	330.85	87.00	186.00	79.00	79.15	168.38

November	151.67	85.83	152.83	500.78	249.43	296.95	319.00	142.05	217.38
December	182.33	263.67	224.17	431.90	262.60	192.93	331.88	378.74	377.88
Amount	1444.73	1251	183.70	2398.15	2746.80	1994.12	241.,88	230.39	2916.5
Max	262	263.67	309.33	500.78	354.25	296.95	359.25	385.38	377.88
Min	34.17	16	53.33	12.47	13.02	46.43	1.50	0.50	87.13
Average	120.39	104.25	153.14	199.85	228.90	166.18	201.07	191.94	243.04

Source: Board of Way Seputih-Sekampung Watershed, Ministerial of Environmental and Forestry RI (2020; processed by authors).

River Discharge

Discharge is the rate of water flow (in the form of water volume) passing through a cross section of the river per unit time [23]. This data is valuable information for planning a water resource management activity in a watershed area [24]. As for describing the physical performance of water quality as discharge, in Fig 2, Fig 3 dan Fig 4. presents photos of water flow from 3 sub-watersheds. The severest in sediment contend is at Way Pengubuan river, the lowest is in Way Bulok River. It seem correlated with its forested covering each sub-watershed namely 2.12% (Table 4), 4.84% (Table 5) , and 0.83% (Table 6) for Way Besai, Way Bulok, and Way Pengubuan respectively. Table 3 depicts the average of river discharge at the three sub-watershed.

Fig 2. The river physical water quality performance of Way

Bulok

Fig 3. The river physical water quality performance of Way Besai.

Fig 4. The river physical water quality performance of Way Pengubuan.

Table III. River discharge average of the Way Bulok, Way Besai and Way Pengubuan sub-watersheds

Month	River Discharge (m^3/s)								
	Way Bulok			Way Besai			Way Pengubuan		
	2011	2014	2017	2011	2014	2017	2011	2014	2017
January	13.19	46.40	10.37	48.31	90.70	57.06	17.44	67.75	41.86
February	15.18	34.64	29.89	184.86	70.63	60.54	26.90	54.68	42.45
March	11.39	25.93	26.32	223.30	72.86	74.28	47.95	38.47	58.95
April	7.93	9.85	36.37	244.50	69.94	58.14	44.24	26.37	32.34
May	2.69	5.26	10.32	90.14	64.02	77.88	21.89	12.25	18.70
June	2.98	4.60	6.68	60.84	50.07	26.04	10.17	6.31	5.72
July	1.18	2.52	5.49	11.33	30.18	17.94	5.64	3.60	5.59
August	5.39	5.04	2.82	9.45	24.55	12.74	2.80	6.71	3.68
September	4.34	0.49	5.87	9.34	21.45	11.44	2.46	2.06	3.34
October	0.30	2.09	9.97	9.36	19.79	27.88	2.34	1.14	4.37
November	2.18	4.03	18.31	12.13	29.73	45.60	4.48	3.91	6.86
December	9.60	24.93	16.38	13.90	58.90	36.34	11.16	39.03	14.87
Max	15.18	46.40	36.37	244.50	90.70	77.88	47.95	67.75	58.95
Min	0.30	0.49	2.82	9.34	19.79	11.44	2.34	1.14	3.34
Average	6.36	13.82	14.90	76.46	50.24	42.16	16.46	21.86	19.89

Source: Board of Way Seputih-Sekampung Watershed, Ministerial of Environmental and Forestry.

Table III depicts that the average river discharge value in the Way Bulok and Way Pengubuan sub-watersheds has increased, while in the Way Besai sub-watershed area it has decreased. This condition is the same as the rainfall that occurs in each observed sub-watershed area. The results of this analysis indicate that rainfall in a watershed area will affect river discharge in the watershed [21]. The flow rate describes the response of the watershed system to the overall rainfall input [25]. River discharge is not only influenced by rainfall, but is also influenced by soil conditions, the area of vegetation cover, and the topography of the landscape.

Land Cover

that the maximum average river discharge value occurs between December-April in the three sub-watershed areas. The amount of maximum discharge that occurs is caused by high rainfall in that month [25]. A large river discharge value is influenced by the physical characteristics of a watershed, such as rainfall and land cover [26]. Population growth will affect river water quality which can lead to ecosystem degradation, decreased water quality, and loss of biodiversity [27] ; [28]. Land cover is the appearance of physical material on the face of the earth which is one unit interrelated between social and natural processes [29]. The results of the research analyzed in this study were in three sub-watershed areas based on the results of the interpretation of Landsat 8 imagery for the period 2011-2017. The following is the result of image interpretation for the existing land cover in each watershed area.

Table IV. Land cover at the Way Bulok Sub-watershed area

Way Bulok Land Cover	2011		2014		2017	
	ha	%	ha	%	ha	%
Forest	1,376	1.57	1,867.61	2.13	1,861.23	2.12
Shrub	4,653	5.31	4,554.33	5.20	1,925.51	2.20
Plantation	2,322	2.65	2,322.08	2.65	1,815.67	2.08
Settlement	5,994	6.84	5,994.18	6.84	7,380.91	8.42
Dry land farming	6,067	6.92	5,485.46	6.26	1,191.66	1.36
Mixed Dry Land Farming	57,442	65.52	57,519.20	65.61	51,041.59	58.22
Rice fields	9,816	11.20	9,927	11.32	22,453.43	25.61
Total	87,670		87,670		87,670	

Source: Board of Way Seputih-Sekampung Watershed, Ministerial of Environmental and Forestry RI (2020; processed by authors).

Table IV depicts that the percentage of mixed dry land is the largest area of land cover, while the area of forest cover is the lowest. The area of forest land cover in the Way Bulok Sub-watershed area is always below 2000 ha each year. Forests have an important role in the hydrological process because of their ability to control water systems. Forests can also play a role in absorbing and storing water during the rainy season and releasing it in the dry season [30], but the forest area in the Way Bulok Sub-watershed area is relatively small so that it affects relatively small river discharge in the area. Plantation land cover has decreased from 2,322 ha in 2011 and to 1,815.67 ha in 2017. [31], in his research said that plantation land has a role in maintaining erosion and flooding, but the area of plantations in the Way Bulok Sub-watershed tends to low. Plantation land cover also plays an important role in protecting fragile ecological environments [32], therefore plantations have an important role in protecting the environment.

Table V. Land cover at the Way Besai Sub-watershed area

Way Besai Land Cover	2011		2014		2017	
	ha	%	ha	%	ha	%
Forest	4,722.00	4.84	4,651.01	4.76	4,724.66	4.84
Shrub	25,535.18	26.14	25,535.18	26.14	11,987.22	12.27
Plantation	2,490.89	2.55	2,490.89	2.55	8,004.62	8.20
Settlement	1,687.82	1.73	1,687.82	1.73	3,909.39	4.00
Dryland farming	12,323.42	12.62	12,323.42	12.62	7,908.75	8.10
Mixed Dry Land Farming	50,182.26	51.38	50,253.25	51.45	58,279.59	59.67
Rice fields	730.35	0.75	730.35	0.75	2,857.69	2.93
Total	97,671.92		97,671.92		97,671.92	

Source: Board of Way Seputih-Sekampung Watershed, Ministerial of Environmental and Forestry RI (2020; processed by authors).

Table V depicts that the land cover in the Way Besai sub-watershed area is dominated by mixed dry land agriculture. The percentage of land cover always increases every year. The percentage of agricultural land cover for mixed dry land in 2011, 2014 and 2017 is 51.38%, 51.45% and 59.67% respectively, while the land cover for forest areas in Way Besai Sub-watershed is quite good compared to that in Way Bulok Sub-watershed area and Way Pengubuan Sub-watershed area. The increasing area of agricultural land cover is in accordance with the research conducted in Najran ota, Saudi Arabia [33]. The percentage or area of forest land cover in the Way Besai sub-watershed is above the cover of plantations, settlements, and rice fields, which indicates that the ecosystem is still maintained in the forest area in the Way Besai Sub-watershed. The sharp increase in the area of plantation land cover is in line with the research [34], where in the results of his research the area of plantation and agricultural land cover increased in the mangrove ecosystem area in South Sumatra Province.

Table VI. Land cover in the Way Pengubuan Sub-watershed area

Land Cover Way Pengubuan	2011		2014		2017	
	ha	%	ha	%	ha	%
Forest	1,195.89	0.93	1,195.89	0.93	1,070.46	0.83
Scrub	9,185.72	7.15	9,131.96	7.11	6,156.59	4.79
Plantation	7,513.82	5.85	7,490.07	5.83	12,346.46	9.61
Settlement	13,573.52	10.56	13,597.27	10.58	16,483.98	1.83
Dryland farming	83,024.71	64.60	76,301.46	64.66	44,996.84	35.01
Mixed Dry Land Farming	13,308.29	10.35	20,085.34	10.35	42,960.18	33.43
Rice fields	726.51	0.57	726.51	0.57	4,513.95	3.51
Total	128,528.5		128,528.4		128,528.5	

Source: Board of Way Seputih-Sekampung Watershed, Ministerial of Environmental and Forestry RI (2020; processed by authors).

Table VI can be seen that there has been an increase in residential land cover in the Way Pengubuan Sub-watershed area. The area of residential land cover in 2011 was 13,573.52 ha and increased to 16,483.98 ha in 2017. The increase in population causes the need for land for housing to increase [25], resulting in increased residential land cover as well. The decrease in the area of forest and scrub areas is in line with research in the Rontu watershed area of West Nusa Tenggara Province Indonesia [35]. The results of this study were a decrease in forest area of 28.68% and shrubs decreased by 10.74% of the total area. The increase in residential land cover was due to an increase in population which caused people to convert forest land cover [36].

Estimated Carbon Stock

The following is the change in land cover in the watershed area which was used as the object of research in 2011, 2014 and 2017 based on the results of the interpretation of images that have been analyzed

Table VII. Estimated carbon stock in Way Bulok Sub-watershed

Way Bulok land cover	2011		2014		2017	
	ha	ton	ha	ton	ha	ton
Forest	1,376	182,994.24	1,867.61	248,373.45	1,861.23	247,524.98
Scrub	4,653	139,590	4,554.33	136,629.9	1,925.51	57,765.3
Plantation	2,322	146,286	2,322.08	146,291.04	1,815.67	114,387.21
Settlement	5,994	23,976	5,994.18	23,976.72	7,380.91	29,523.64
Dryland farming	6,067	60,670	5,485.46	54,854.60	1,191.66	11,910.66
Mixed Dry Land Farming	57,442	1,723,260	57,519.20	1,725,576	51,041.59	1,531,247.70
Rice fields	9,816	19,632	9,927.15	19,854.30	22,453.43	44,906.86
Total	87,670	2,296,408.24	87,670	2,355,556.01	87,670	2,037,266.35
Max		1,723,260		1,725,576		1,531,247.70
Min		19,632		19,854.30		11,910.66
Average (tonnes / ha)		26.19		26.87		23.24

Source: Board of Way Seputih-Sekampung Watershed, Ministerial of Environmental and Forestry RI (2020; processed by authors).

Table VII depicts that the largest estimated carbon stock is the land cover classification in mixed dry land agriculture. The results of this study are in line with research [16], which states that the largest carbon stock is in the classification of plantation land cover, shrubs / shrubs and in mixed dry land agricultural systems. The smallest amount of carbon reserves in the Way Bulok Sub-watershed area is the classification of paddy land, this is because rice field cover stores more methane gas than stores carbon reserves. Paddy soil is a contributor to methane gas, around 10-15% [37]. Methane is produced as the end result of anaerobic microbial decomposition of organic matter by methanogenic bacteria. Methane emissions are determined by water management, tillage, variety and climate.

Table VIII. Estimated carbon stock in Way Besai Sub-watershed

Way Besai land cover	2011		2014		2017	
	ha	ton	ha	ton	ha	ton
Forest	4,722.00	627,978.78	4,651.01	618,537.82	4,724.66	628,332.53
Scrub	25,535.18	766,055.40	25,535.18	766,055.40	11,987.22	359,616.60
Plantation	2,490.89	156,926.07	2,490.89	156,926.07	8,004.62	50,4291.06
Settlement	1,687.82	6,751.28	1,687.82	6,751.28	3,909.39	15,637.56
Dryland farming	12,323.42	123,234.20	12,323.42	123,234.20	7,908.75	79,080.75
Mixed Dry Land Farming	50,182.26	1,505,467.80	50,253.25	1,507,597.50	58,279.59	1,748,387.70
Rice fields	730.35	1,460.70	730.35	1,460.70	2,857.69	5,715.38
Total	97,671.92	3,187,874.23	97,671.92	3,180,562.97	97,671.92	3,341,061.58
Max		1,505,467.8		1,507,597.5		1,748,387.7
Min		1,460.7		1,460.7		5,715.38
Average (tones / ha)		32.64		32.56		34.21

Source: Board of Way Seputih-Sekampung Watershed, Ministerial of Environmental and Forestry RI (2020; processed by authors).

In table VIII it can be seen that the largest estimated carbon stock is in the land cover type of mixed dryland agriculture The stored carbon reserves in the Way Besai sub-watershed area is said to be better when compared to similar research in the Pancoran Mas Depok Raya Forest Park which produces stored carbon reserves of only 33.92 tons / ha [38]. The value of carbon stocks in the Way Besai Sub-watershed area is lower when compared to research conducted in the Way Khilau Sub-watershed area, Bayas Jaya Village, Way Khilau District, Pesawaran Regency, Lampung Province which produces stored carbon reserves of 57.20 tons /ha [39].

Table IX. The acreage of land covers and estimated carbon stock in Way Pengubuan Sub-watershed

Land Cover Way Pengubuan	**2011**		**2014**		**2017**	
	ha	Ton	ha	ton	ha	ton
Forest	1,195.89	159,041.41	1,195.89	159,041.41	1,070.46	142,360.48
Scrub	9,185.72	275,571.60	9,131.96	273,958.80	6,156.59	184,697.70
Plantation	7,513.82	473,370.66	7,490.07	471,874.41	12,346.46	777,826.98
Settlement	13,573.52	54,294.08	13,597.27	54,389.08	16,483.98	67,375.92
Dryland farming	83,024.71	830,240.71	76,301.46	763,014.60	44,996.84	449,960.84
Mixed Dry Land Farming	13,308.29	399,248.70	20,085.34	602,560.20	42,960.18	1,288,805.40
Rice fields	726.51	1,453.02	726.51	1,453.02	4,513.95	9,027.90
Total	128,528.50	2,193,220.18	128,528.40	2,326,291.52	128,528.50	2,920,055.22
Max		830,240.71		763,014.60		1,288,805.40
Min		1,453.02		1,453.02		9,027.90
Average (tonnes / ha)		17.06		18.10		22.72

Source: Board of Way Seputih-Sekampung Watershed, Ministerial of Environmental and Forestry RI (2020; processed by authors).

Table IX shows that the largest carbon stock in the Pengubuan watershed is found in dry land agricultural land cover. The value of carbon stocks in the Way Pengubuan Sub-watershed area is better when compared to the value of carbon stocks in the Ciliwung watershed area which has a carbon stock value of 1,091,666.15 tonnes in 2011 [40], while the amount of stored carbon in the Way Pengubuan Sub-watershed area in 2011 amounting to 2,193,220.18 tons.

The average value of carbon stocks in the Way Pengubuan Sub-watershed area has increased from 17.06 tonnes / ha in 2011 to 22.72 tonnes / ha in 2017, but these results are not better than the research in the area of Register 39 KPHL Batutegi, Tanggamus Regency which has carbon reserves of 178.24 tonnes/ha [41].

Regression of River Discharge on Rainfall and Land Cover

The results of the regression test to determine the effect of river discharge on rainfall and land cover in the observed watershed area can be seen in Table X and Table XI.

Table X. Analysis of variance the river discharge as the function of rainfall and land cover

Source	Degree of Freedom	Sum Square	Mean Square	F	P
Regression	8	17,016.7	2,127.1	116.10	0.00
Residual Error	55	1,007.7	18.3		
Total	63	18,024.3			

Table X depicts that the F-value in this study is 116.0Based on the results of the F test, it can be seen that overall the independent variables have a significant effect on the dependent variable. The results of the T-test regression can be seen in Table XI.

Table XI. The T-test of river discharge as the function of rainfall and land cover

Variable	Coefficient	Std. Error	T	P
Constant	13,612	6,537	2.08	0.042
Rainfall [RAIN]	0.1192	0.0059	20.06	0.000
Forest [FORS]	-238.00	120.20	-1.98	0.053
Scrub [SRHB]	-129.08	62.02	-2.08	0.042
Plantation [PLNT]	-107.46	50.12	-2.14	0.036
Settlements [SETL]	-184.16	89.99	-2.05	0.045
Dry Land Agriculture [UPLND]	-131.08	62.76	-2.09	0.041
Mixed Dry Land Farming [MIXFM]	-130.97	62.64	-2.09	0.041
Rice fields [PADY]	-127.01	60.60	-2.10	0.041
S = 4.28039	R.Sq= 94.4%		R.Sq (adj)= 93.6%	

Table XI depicts the effect of land cover and rainfall on the river discharge [YD]i. As connoted by its R-Sq obtained, the variance of the seven land cover and rainfall contributed asa much as 964.4%. This model achieved, therefore, can be utilized as the tool for predicting the rivers discharge based on the seven land cover and the rainfall data. The model equation can be expressed as follow.

$[Y_D]_i$=13,612.00 +0.1192$[RAIN]_i$-238,00$[FORS]_i$-129,08 $[SRHB]_i$-107.46$[PLNT]_i$-184.16$[SETL]_i$131.08$[UPLND]_i$-130.97$[MIXFM]_i$-127.01$[PADY]_i$

The Model of Carbon Stock based on River Discharger

The effect of carbon stocks on river discharge is carried out by performing simple linear regression. The regression used is the F test to determine the effect of river discharge on the estimated carbon stock, while the T-test is carried out to determine whether the predictor variable (river discharge) has a significant effect on the respond variable (carbon stock). The regression results to determine the effect of river discharge on carbon stocks in the watershed area can be seen in Table XII below.

Table XII. Analysis of variance carbon stocks as the function of river discharge

Source	Degree of Freedom	Sum Square	Mean Square	F	P

Regression	1	265.38	265.38	9.96	0.016
Residual Error	7	186.52	26.64		
Total	8	451.90			

Table XII depicts that the results of the F test that have been carried out show that the p-value is 0.0160 with the calculated F value of 9.96. The results of the p-value obtained can be concluded that the predictor variable is able to explain and significantly influence the respond variable. This is because the p-value based on the F test regression that has been carried out has a false probability value of only 1.6%.

Table XIII. The T-test of carbon stocks as the function of river discharge

Source	Coefficient	Std. Error	T	P
Constant	17.2237	2.9089	5.9211	0.0006
$[Y_D]$	0.0212	0.0067	3.1559	0.0160
S = 5.1620 R-Sq= 0.5872		R-Sq (adj)=0.5283		

Based on Table XIII the results of the T-test regression that has been carried out, it can be seen that the relationship between the respond variable (Y) and the predictor variable (X) has a value of 0.5283. This value means that the river discharge variable is able to explain the estimated carbon stock in the sub-watershed area which is used as a research location as much as 52.83%. The value of 47.17% of the remainder is explained by other variables that are not included and explained in the estimation model. The equation model obtained based on the results of the research that has been done is as follows:

[YC]i=17.2237 - 0.0212 [YD]i

Based on the equation model obtained from the regression results, the equation can be used to calculate the estimated carbon stock by using river discharge data in a watershed area that is used as a research location, so that in this equation it can support Indonesia in implementing REDD and REDD+ due to lack of the operation of the carbon trading mechanism due to the high transaction costs for Measurable, Reportable and Verifiable (MRV) or measurement, reporting, and verification in calculating the potential for stored carbon stocks.

conclusions

This study proves that river discharge can be modeled based on monthly rainfall variables together with land cover area with R-sq = 93.6% (P=0.000). Furthermore, river discharge can be modeled to predict carbon content in a watershed with R-sq= 0.5872 (P=0.016). The equation obtained based on the regression results is [YC]i=17.2237 - 0.0212 [YD]i where [YC]i is the estimated carbon stock and [YD]i is the river discharge data in a watershed area.

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Disclaimer

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