Inorganic Carbon Sequestration in Tropical Karst Area (Case Study in Biduk-Biduk Karst Area, Kalimantan)

Danardono, EKO Haryono, M. Widyastuti, M. Iqbal Taufiqurrahman Sunariya

***Abstract:** Karst Area has a potential to absorb some of carbon derived from dissolution process called inorganic carbon sequestration. In the other hand, the potential of karst area on absorbing inorganic carbon was rarely studied especially in Indonesia. Studied about the potential of karst area to absorb inorganic carbon need to be done to know the role of karst area on reducing global carbon emissions. This research aims to 1) identify the potential value of inorganic carbon sequestration in the Biduk-Biduk Karst Region, and 2) analyze the potential value of the Biduk-Biduk Karst Region in supporting efforts to reduce carbon emissions in East Kalimantan Province and Indonesia Country. Inorganic carbon sequestration in Biduk-Biduk Karst Region was measured based on carbonate dissolution rate process using a standard limestone tablet method. The results showed that the total potential of Biduk-Biduk Karst Region to absorb inorganic carbon was 30.254 Mg/year-CO¬2. This potential value of inorganic carbon sequestration in Biduk-Biduk Karst Region can help to reduce carbon emissions in East Kalimantan Province of 0,07% every year and Indonesia Country of 0,008% every year.*

***Keywords:** Karst, Inorganic Carbon, Dissolution Process, Carbon Sequestration, Limestone Tablets*

I. INTRODUCTION

carbon especially carbon dioxide is one of the greenhouse gases that cause a phenomenon of global climate change. The proportion of carbon dioxide in the atmosphere has a big value compared to other greenhouse gases. Increased carbon dioxide produced by biosphere especially human activity causes increasing carbon dioxide concentration in atmosphere.

Increased concentration of carbon dioxide in the atmosphere has occurred a few decades ago. IPCC, 2013, states that increasing carbon dioxide concentration in the atmosphere has occurred since 1870 or during the industrial revolution in Europe. Increased carbon dioxide concentrations happen due to the increasing carbon dioxide emissions released by the biosphere into the atmosphere. Carbon dioxide emissions released into the atmosphere are dominated by anthropogenic activities through burning fossil fuels. International Energy Agency (2018) states that carbon dioxide emissions released by anthropogenic activities amount to 32 million tons per year with an average concentration of 397 ppm in 2013. This emission value is increasing by 1.5% until 2017.

Efforts to reduce carbon emissions have been researched and initiated by experts through calculation of global carbon balance (Pan et al. 2011, Cao et al. 2016; Khodashenas, 2015). Calculation of global carbon balance is intended to identify carbon dioxide sequestration potential that can balance the value of carbon dioxide emissions. Identification of carbon sequestration potential is carried out at all ecosystem layer in the earth to find both organic and inorganic carbon sequestration sources.

Karst is one landscape that has ability to absorb an amount of carbon dioxide (Jiang 2013, Cao et al. 2016 Song et al. 2017). Carbon absorbed in the karst landscape is known as inorganic carbon. Inorganic carbon is absorbed through the karst formation process called karstification (Yuan 1997, Ford and Williams 2007, Cao et al. 2016; Barjasteh et al, 2016). Karstification is a process of dissolving carbonate rocks by water with the help of carbon dioxide. The process of dissolving carbonate rocks has the chemical formula (see Formula 1).

$$CO_2 + H_2O + CaCO_3 \rightarrow Ca^{2+} + 2\ HCO3 \qquad 1$$

The interaction between carbon dioxide (CO_2), water (H_2O), and carbonate rock ($CaCO_3$) are known as the karst dynamic system (KDS). Carbon dioxide in karstification process comes from soil and or atmosphere. The process of taking atmospheric carbon dioxide for the karstification occurs when rainwater interact with atmosphere. Rainwater will interact chemically with carbon dioxide gas to form H_2CO_3 which can be used to dissolve carbonate rocks. The use of carbon dioxide for the carbonate rocks dissolution can reduce carbon dioxide emissions into the atmosphere.

The study of karst potential on absorbing carbon dioxide from atmosphere is still rarely studied in Indonesia. Research on carbon calculation in Indonesia has been dominated by assessing carbon stocks from vegetation and soil (Rutishauser et al. 2013, Englhart et al. 2014; Göktaş et al, 2018). Carbon fluxes both from organic and inorganic carbon have not been widely practiced in Indonesia. Therefore, efforts to reduce carbon emissions in Indonesia are still based on carbon stocks potential from vegetation.

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On the other hand, Indonesia has a fairly wide karst landscape. The area of karst landscapes in Indonesia reaches 140,000 km^2 (Haryono 2011). Karst landscapes in Indonesia spread throughout the Indonesian archipelago. Distribution of karst landscapes in Indonesia can be seen in Figure 1.

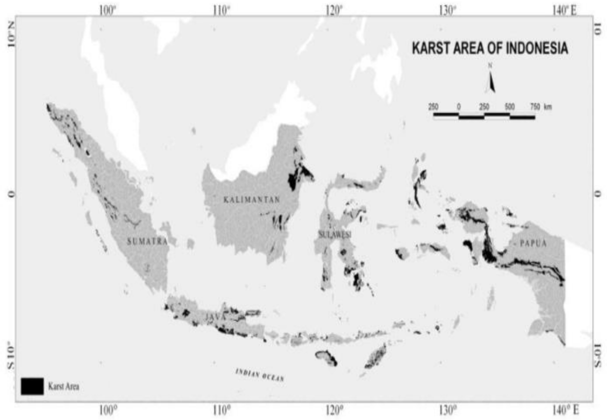

Figure 1. Karst Area in Indonesia

Source: Haryono, 2011

Karst landscapes in Indonesia have distinctive characteristics such as having high rainfall and covered by forest ecosystems (Haryono 2011). Rainfall in Indonesia has a value of 2000 - 3000 mm/year so it can accelerate the dissolution process in Indonesia Karst Landscapes. In addition, forest cover in karst landscapes can increase soil carbon dioxide that can produce more aggressive water to dissolve carbonate rock (Cao et al. 2016). The carbonate dissolution process is intensively running because of these two factors. Therefore, the potential of Indonesia Karst Landscape to absorb some of carbon dioxide from the atmosphere is also increasing.

The result of previous studies showed that the average rate of carbonate rocks dissolution in five Indonesian Karst landscapes were 82,9 m^3/km^2/year (Haryono 2011). Based on the dissolution rate, the total value of carbon dioxide sequestration in the entire Indonesian Karst Landscapes is 13,482 Gg CO_2/year (Haryono 2011). Carbon dioxide sequestration through the dissolution process in the Indonesian Karst Region has a great potential to support REDD+ program in Indonesia Country.

One of the karst area in Indonesia that has great potential to support the REDD+ program is Biduk-Biduk Karst Region. Biduk-Biduk Karst Region is a part of the Sangkulirang-Mangkalihat Karst Region located in Berau District, East Kalimantan Province. Biduk-Biduk Karst Region is included in the tropical karst area with high rainfall values and covered by forest ecosystem. The existence of two factors can optimize the dissolution of carbonate rocks and absorption process of carbon dioxide. The ability of the Biduk-Biduk Karst Region to absorb carbon dioxide can support carbon emission reduction programs in Berau District as contained in RAD-GRK.

This research aims 1) to identify the potential value of inorganic carbon sequestration in the Biduk-Biduk Karst Region; and 2) to analyze the potential value of the Biduk-Biduk Karst Region in supporting efforts to reduce carbon emissions in East Kalimantan Province and Indonesia Country.

II. METHODOLOGY

2.1. Study Area

This research was conducted in the Biduk-Biduk Karst Region. Biduk-Biduk Karst Region is part of Sangkulirang-Mangkalihat Karst Region which is located in Berau District, East Kalimantan Province, Indonesia. Biduk-Biduk Karst Region is nearly close to the equator line so this area has a tropical climate zone. Annual rainfall in the Biduk-Biduk Karst Region is 2521 mm/year with the absence of a dry month for a year (rainfall under 100 mm/month). The average air temperature in the study area is 26,4 – 27,4oC. Based on the Koppen climate classification, the study area is included in the Af climate with the absence of dry months for a year and relatively warm air temperatures each year.

Biduk-Biduk Karst Region was developed in the area with lithology of coral limestones and crystalline limestones in the Domaring Formation (Tmpd); bioclastic limestones with interlude of breccia in the Lebak Formation (Toml); and bioclastic limestones with coral limestone inserts in the Karangan Formation (Teok) (Djamal et al. 1995). Three lithologies were deposited in a shallow-neritic depositional environment in Tertiary times. Each lithology in the Biduk-Biduk Karst Region will form different geomorphological units.

Geomorphological units in the study area were controlled by three main processes, namely dissolution, marine, and structural. These processes form three geomorphological units in the Biduk-Biduk Karst Region. Geomorphological units that can be identified are karst plain, terrace marine solutional 1, and terrace marine solutional 2. The distribution of geomorphological units in the study area can be seen in Figure 2.

The Karst Plain has a wavy morphology with a slope ranging from 0–13%. Lithology in the Karst Plain is coral limestones and crystalline limestones in the Domaring Formation (Tmpd). Terrace Marine Solutional 1 has hilly morphology with a slope ranging from 8–80%. Lithology in the Terrace Marine Solutional 1 is bioclastic limestone with interlude of coral limestone in the Karangan Formation (Teok). Karst features that can be found in this geomorphological unit are “ceruk”, ponors, and limestone pavement. Terrace Marine Solutional 2 was exposed after Terrace Marine Solutional 1. Terrace Marine Solutional 2 has hilly morphology with a slope of 8–55%. Lithology of Terrace Marine Solutional 2 is the intersection of bioclastic limestone with breccia in the Lebak Formation (Toml). Karst features that can be found in this geomorphological unit are clustered conical hills and cockpits.

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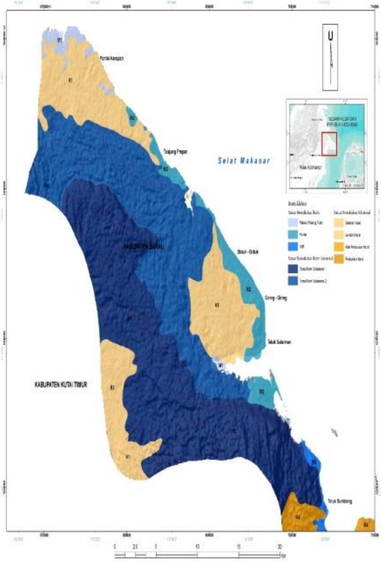

Figure 2. Geomorphology Map of Biduk-Biduk Karst Region

Source: Danardono et al., 2019

III. METHODS

3.1. Data Collection

Data needed in this research consist of primary and secondary data. The primary data was the rate of dissolution of carbonate rocks. The value of dissolution rate was used to determine the inorganic carbon sequestration in the karst region. The Limestone tablets method was used to calculate the value of dissolution rate. Limestone tablets were planted for 1 year from October 2015 to November 2016 at three depths which were 1 meter above ground, 30 cm and 60 cm below the soil surface. Limestone tablets were planted in three different geomorphological units assuming the differences of the dissolution rate value in the Karst Plain, Terrace Marine Solutional 1, and Terrace Marine Solutional 2.

The secondary data that were needed in this study area were carbon emissions in East Kalimantan Province and Indonesia Country. Carbon emissions data in East Kalimantan Province and Indonesia Country were obtained from INCAS-Indonesia. Carbon emissions were used to determine the ability of Biduk-Biduk Karst Region on reducing carbon emissions at regional and national scales.

IV. DATA ANALYSIS

Data from limestone tablets measurement were used to calculate the dissolution rate of carbonate rocks in the study area. The dissolution rate of carbonate rocks was calculated using formula 2.

$$DR = \frac{(w1-w2)}{A} \text{ x } 1000 \text{ x } \frac{T}{365} \quad \ldots\ldots 2$$

(Daoxian 1988)

Where DR = dissolution rate of Limestone Tablets (mg/cm^2/year); w1–w2 = weight difference of Limestone Tablets between before and after planted (gr); A = surface area of Limestone Tablets (cm^2); T = planted time scale (days). Furthermore, the dissolution rate value was used to calculate the inorganic carbon sequestration using formula 3.

$$F = E \text{ x } S \text{ x } R \text{ x } 0{,}44 \quad \ldots\ldots 3$$

(Zhongcheng 1999)

Where F = CO_2 fluxes consumption from dissolution process (gr-CO_2/ year); E = dissolution rate of Limestone Tablets (gr/cm^2/year); S = karst area (cm^2); R = carbonate concentration on the Limestone Tablets (~90%). The potential value of carbon dioxide sequestration was calculated in each geomorphological unit. Furthermore, the value of inorganic carbon sequestration in each landform was summed to determine the total value of potential carbon sequestration in the Biduk-Biduk Karst Region.

The ability of Biduk-Biduk Karst to support reducing carbon emissions was calculated by comparing the value of total carbon sequestration with the value of carbon emissions. The results of this comparison can produce the percentage of the contribution of Biduk-Biduk Karst Region to reduce atmospheric carbon emissions. Comparisons were made to carbon emissions in East Kalimantan Province and Indonesia Country.

V. RESULTS

5.1. Dissolution Rate of Carbonate Rocks

The dissolution rate of carbonate rocks in the Biduk-Biduk Karst Region was calculated by considering the weight difference of Limestone Tablets before and after planting. The dissolution rate of carbonate rocks can be calculated in absolute and relative values. Relative values were showed the percentage of Limestone Tablets reduction, while absolute values were obtained using a formula developed by Daoxian, 1988. The calculation results show that there are variations vertically in each soil depth and spatially in each geomorphological unit. The percentage rate of carbonate rocks dissolution in the Biduk-Biduk Karst Region can be seen in Table 1.

Table 1. Percentage of Dissolution Rate in Biduk-Biduk Karst Region

No	Landform	Soil Depths (cm)	Percentage of Denudation Rate (%)
1	Solusional Marine Terrace 2	40	3,5
2	Solusional Marine Terrace 2	-30	0,7
3	Solusional Marine Terrace 2	-60	1,2
4	Solusional Marine Terrace 1	-30	2,3
5	Solusional Marine Terrace 1	-60	3,1
6	Karst Plain	40	11,8
7	Karst Plain	-30	3,3
8	Karst Plain	-60	6,3

Source:Limestone Tablets Analysis, 2018

Based on Table 1, it can be seen that the rate of carbonate rocks dissolution in the study area varies in each

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geomorphological unit. The geomorphology unit with the highest dissolution rate was Karst Plain of 4,8%. Meanwhile, the smallest value of dissolution rate was found in the Terrace Marine Solutional 2 of 0,95%. This condition indicates that there are differences in the development of karst in the three geomorphological units. Karst Plain with a high dissolution rate has more intensive potential of karst development.

The dissolution rate of carbonate rocks in the study area also has a vertical variation. The vertical variation occurs in different soil depths. The highest value was found at above ground, while the smallest value was at a depth of 30 cm from the soil surface. Vertically variation of the dissolution rate in each geomorphological unit is similar. The value of dissolution rate in the above-ground is relatively high and decreasing at a depth of 30 cm. This value will increase again at a depth of 60 cm. This condition indicates that the dissolution rate of carbonate rocks tends to be intensive at the depth which soil close to the limestone bedrock.

Absolute value of dissolution rate needs to be calculated to know the value of inorganic carbon sequestration. The vertical value of dissolution rate in the Biduk-Biduk Karst Region can be seen in Figure 3.

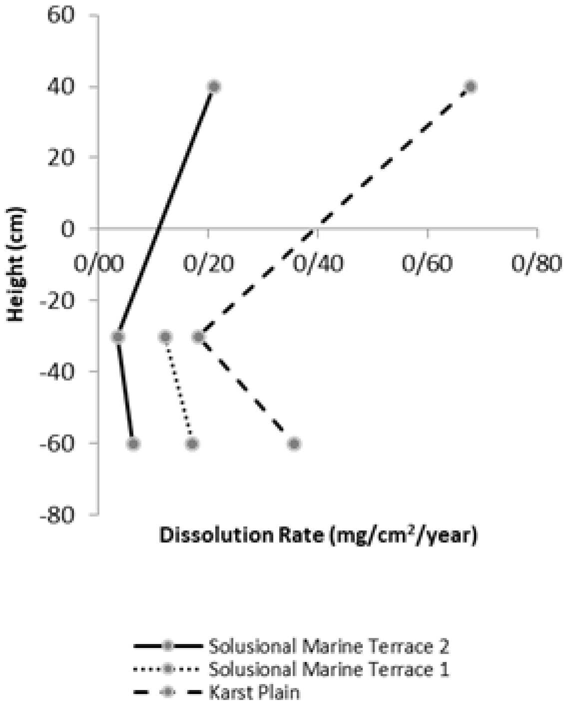

Figure 3. Dissolution Rate Value in Biduk-Biduk Karst Region

Source: Limestone Tablets Analysis 2018

Based on Figure 3, it can be seen that the highest average of dissolution rate was found in the Karst Plain of 0,269 mg/cm^2/year. In vertical condition, the largest value of dissolution rate was found in the topsoil of 0,677 mg/cm^2/year, followed by soil layer at a depth of 60 cm of 0,357 mg/cm^2/year. The smallest value of dissolution rate was in the Terrace Marine Solutional 2 at a depth of 30 cm of 0,108 mg/cm^2/year.

5.2.Inorganic Carbon Sequestration

Inorganic carbon sequestration was calculated by utilizing the results of calculating dissolution rates. Inorganic carbon sequestration in the Biduk-Biduk Karst Region shows vertically and spatially variations. Spatially, the value of inorganic carbon sequestration varies in three geomorphological units. While vertically, the value of inorganic carbon sequestration varies in three depths. The calculation result of inorganic carbon sequestration in the study area can be seen in Figure 4.

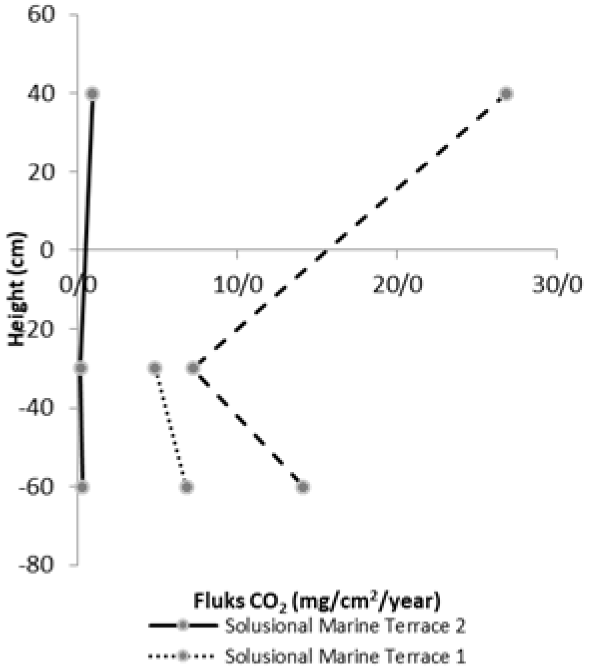

Figure 4. Potential of Inorganic Carbon Sequestration in Biduk-Biduk Karst Region

Source:Dissolution Rate Analysis 2018

The largest inorganic carbon sequestration was found in the Karst Plain of 16,060 mg/cm^2/year. Whereas, the lowest value was found in the Terrace Marine Solutional 2 of 4,425 mg/cm^2/year. Variation value of inorganic carbon sequestration in each geomorphological unit is due to topographic and slope factors condition. In vertical conditions, the largest inorganic carbon sequestration was found in the above-ground of 26,839 mg/cm^2/year. While the lowest value is at a depth of 30 cm below the ground of 1,440 mg/cm^2/year. The difference value at each depth is due to the variation of contact times between water and Limestone Tablets. The faster contact of water with Limestone Tablets will be followed by increasing of inorganic carbon sequestration.

VI. DISCUSSION

The value of inorganic carbon sequestration can be calculated based on the rate of carbonate rocks dissolution. The potential of inorganic carbon sequestration has a similar trend value with the value of dissolution rate. The higher carbonate dissolution rate will be followed by an increasing inorganic carbon sequestration value.

Dissolution rate in the tropical karst region (Biduk-Biduk Karst) varies in each geomorphological unit and soil depth. The difference value of dissolution rate in geomorphological units (Terrace Marine Solutional 1, Karst Plain, and Terrace Marine Solutional 2) shows variation based on slopesequence. The dissolution rate in the study area has a high value in relatively flat slope. The largest dissolution rate was found in the karst plain with a slope of 0 - 4%. Meanwhile, the lowest dissolution rate was found in the Terrace Marine Solutional 2 with a slope of 15-45%. Variations of carbonate dissolution rate based on slopesequence at Biduk-Biduk Karst Region are presented in Figure 5.

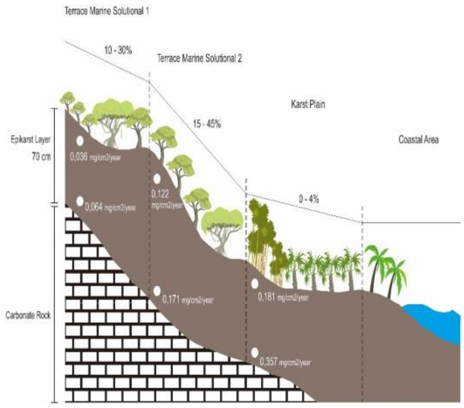

Figure 5. Dissolution Rate Value in Morphological Variation in Biduk-Biduk Karst Region

Source: Danardono et al. 2019

Variation value of dissolution rate based on slopesequence also occurs in other karst regions such as Gunungsewu Karst, Indonesia (Haryono et al. 2016), Guilin, China (Liu et al. 2000), and Austrian Alps (Plan 2005); and Akiyoshi-da'i, Japan (Akiyama et al. 2015). The result in three karst regions showed that the highest value of dissolution rate is found in geomorphological unit with low or flat slope. An amount of water infiltration into the epikarst layer through infiltration and percolation process is factors causing the intensity of the carbonate dissolution rate (Plan 2005, Gabrovsek 2009, Akiyama et al. 2015). In areas with low or flat slope, water retention has a long time compared to areas with high or hilly slope. Increasing amount of water that carries carbon dioxide into the epikarst layer makes the carbonate dissolution process more intensive. However, the infiltration and percolation rate values were not calculated in this study so the influence of infiltration and percolation rates on the carbonate dissolution rate in the study area couldn’t be certainty known.

The dissolution rate in the study area has a high range of values in each soil depth. The highest dissolution rate value is found at 1 meter above the soil surface. At a depth of 20 cm, value of carbonate dissolution rate will decrease and rises again at a depth of 60 cm. Variations of dissolution rates value in each soil depth also occur in other karst regions both tropical and non-tropical karst such as Guilin Karst, China (Liu et al. 2000, Shengyou et al. 2002), Nongla, Guangxi and Jinfo, Chongqing, China (Cheng 2011). This condition happens because of two factors both water contact with carbonate rocks and carbon dioxide availability (Liu et al. 2000, Shengyou et al. 2002, Cheng 2011). At the top of the soil surface, carbonate dissolution rate has a high value compared with dissolution rate value at below of soil surface. This condition happens because water that carries carbon dioxide can directly contact with carbonate rock without barriers. While, at the below of soil surface, water that carries carbon dioxide will interact with the epikarst layer before corroding the carbonate rock at the bottom of this layer. When water interacts with epikarst layer, an amount of carbon dioxide will be buried in this layer.

Variation value of carbonate dissolution rate in each soil depth is caused due to differences in soil carbon dioxide concentration. This condition is similar to previous study in other karst regions (Liu et al. 2000, Shengyou et al. 2002, Haryono et al. 2016). However, because the value of soil carbon dioxide was not measured in this study, the effect of soil carbon dioxide concentration on carbonate dissolution rate values couldn’t be proven. Based on theory, the value of soil carbon dioxide in the lower soil layer has a high value compared with the upper soil layer (Urushibara et al. 1998, Shengyou et al. 2002) so the ability of water to corrode carbonate rocks will also increase (Krklec 2016). The other source of carbon dioxide from soil can be used to corrode carbonate rocks, especially when there is no input carbon dioxide from rainwater infiltration in a dry season.

The potential value of inorganic carbon sequestration can be calculated using the dissolution rate value. The value of inorganic carbon sequestration shows the value of carbon dioxide that needs to dissolve carbonate rocks taken from the atmosphere and or soil. Inorganic carbon sequestration in the study area has an average value of 8,770 mg/cm2/year. This value is different with previous study both in other tropical karst regions such as Gunungsewu Karst, Indonesia (Haryono et al. 2016), Nongla, Guangxi and Jinfo, Chongqing, China (Cheng 2011), Guilin, China (Liu et al. 2000) and non-tropical karst such as high mountain karst area in Huanglong, China, semi-karst area in Beijing, China, temperate karst humid area in Taizihe (Liu et al. 2000) which has lower inorganic carbon uptake values. Comparison of the inorganic carbon sequestration value in the study area with other karst regions is presented in Table 2. One of the factors that influence the difference of inorganic carbon sequestration value is rainfall. Annual rainfall in the study area that has a high value compared than rainfall in other tropical and non-tropical karst areas makes a high value of carbonate dissolution rate in the study area. A high intensity of rainfall in tropical karst areas can accelerate and increase the intensity of carbon dioxide sequestration from the atmosphere. The monthly rainfall pattern also needs to be assessed to determine the pattern of differences on

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carbonate dissolution rate in each season.

Table 2. Comparing inorganic carbon sequestration in the study area and other karst regions

Location	Karst Type	Annual Precipitation (mm)	Inorganic Carbon Sequestration ($mg/cm^2/year$)
Biduk-Biduk Karst, Indonesia	Tropical Karst	2521	8,770
Gunungsewu Karst, Indonesia	Tropical Karst	1500 – 2986	5,600
Nongla, Guanxi, China	Tropical Karst	1750	0,632
Guilin, China	Tropical Karst	1000 – 1850	2,926
Jinfo, Chongqing, China	High Mountain Karst	1436	1,239
Huanglong, China	High Mountain Karst	300 – 800	1,495
Beijing, China	Semiarid Karst	400 – 600	0,271
Taizihe, China	Humid Temperate Karst	800 – 1000	0,081

Source: Liu et al. 2000, Cheng 2011, Haryono et al. 2016

The value of inorganic carbon sequestration from the carbonate dissolution process in the study area can contribute to reduce atmospheric carbon emissions. Contributions of inorganic carbon sequestration can help to realize carbon emission reduction programs at the regional scale (East Kalimantan Province) and national scale (Indonesia). Regional and national carbon emission reduction programs were contained in RAD-GRK and RAN-GRK that aim to reduce carbon emissions of 26%.

The total value of inorganic carbon sequestration in Biduk-Biduk Karst Region can be calculated to determine the contribution of the study area on supporting carbon reduction policies in Indonesia. The contribution of the study area can be calculated by comparing the total potential of inorganic carbon sequestration in the study area with the total annual emissions in the East Kalimantan Province and Indonesia Country. The total value of inorganic carbon sequestration in the study area is 30.254 Mg/year (see Table 3). While, the annual value of carbon dioxide emissions in East Kalimantan Province is 39.835.354 Mg/year (INCAS, 2017) and in the Indonesia Country is 347.000.000 Mg/year. These emission values present the average annual value of carbon dioxide emissions from 2009 to 2012. The total potential of inorganic carbon sequestration in Biduk-Biduk Karst Region can help to reduce carbon dioxide emissions in East Kalimantan Province of 0,07% every year and Indonesia Country of 0,008% every year.

Table 3. Potential of total carbon inorganic sequestration in Biduk-Biduk Karst Region

No	Landform	Dissolution Rate ($mg/cm^2/year$)	CO_2 Flux ($mg/cm^2/year$)	Area (hectares)	Inorganic Carbon Sequestration (Mg/year)
1	Solusional Marine Terrace 2	0.050	4.425	13772.00	6094.15
2	Solusional Marine Terrace 1	0.147	5.826	8834.04	5146.81
3	Karst Plain	0.269	16.060	11838.99	19013.42
Total				34445.03	30254.38

Source: Dissolution Rate Data Analysis, 2018

The percentage value of karst contribution in reducing carbon emissions shows that the karst region is very potential to be used on supporting carbon emission reduction program. The area of Biduk-Biduk Karst Region which is only 0,180% of the total area in Indonesia Country can help to reduce 0,008% of carbon dioxide emissions. In fact, the area of karst landscapes in Indonesia Country is 7,31%. If all of karst landscapes in Indonesia are calculated for their carbon absorption potential, carbon emissions in the Indonesia Country can reduce until 4% per year. Therefore, it is necessary to integrate the potential of karst landscapes on absorbing carbon into carbon emission reduction programs, one of which is REDD+.

VII. CONCLUSION

The average value of inorganic carbon sequestration in the Biduk-Biduk Karst is 8,770 $mg/cm^2/year$. This value varies in each geomorphological unit and the depth of the soil. The geomorphology unit which has the highest value was the Karst Plain of 16,060 $mg/cm^2/year$. Whereas the lowest value was found in the Terrace Marion Solutional of 2 of 4,425 $mg/cm^2/year$. Differences values in geomorphological units are caused by variation in slope value. Inorganic carbon sequestration calculated based on the dissolution rate of carbonate rocks is strongly influenced by the slope. Flat slope in the Karst Plain causes the inorganic carbon dissolution and sequestration rate values to be greater. The effect of slope on the dissolution rate of carbonate rocks can be further investigated by adding infiltration and percolation calculations that occur in the epikarst layer.

Inorganic carbon sequestration also varies in each soil depth. The highest value of inorganic carbon sequestration was at above ground, followed at a depth of 60 cm, and the lowest is at a depth of 20 cm. The direct contact between water and carbonate rocks above the ground makes the inorganic carbon sequestration rate greater. While the cause of differences value of inorganic carbon sequestration below the soil surface is carbon dioxide content in each soil depth. The effect of carbon dioxide content on the dissolution rate and inorganic carbon sequestration can be further investigated by measuring soil carbon dioxide in different depths and comparing it with the value of the dissolution rate.

The total inorganic carbon sequestration in the Biduk-Biduk Karst Region is 30254 Mg/year. Based on these values, Biduk-Biduk Karst Region can contribute to the reduction of carbon emissions in the regional scale (East Kalimantan Province) and national scale (Indonesia Country). Biduk-Biduk Karst Region can contribute to reducing carbon emissions in East Kalimantan Province of 0,07% every year and in Indonesia of 0,008% every year.

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