Jurnal Manajemen Hutan Tropika, *28*(3), 221–231, December 2022
EISSN: 2089-2063
DOI: 10.7226/jtfm.28.3.221

Scientific Article
ISSN: 2087-0469

Modelling for Estimation Carbon Stocks in Land Cover Using A System Dynamic Approach (Case Study: Prabumulih City, South Sumatera, Indonesia)

Yuniar Pratiwi[1,2*], Amin Rejo[3], Armina Fariani[4], Muhammad Faizal[5]

[1]Postgraduate Program of Environmental Science, Universitas Sriwijaya, Jl. Padang Selasa, Palembang, Indonesia 30139
[2] Faculty of Engineering, Universitas Prabumulih, Jl. Patra, Prabumulih, Indonesia 31125
[3]Department of Agricultural Technology, Faculty of Agriculture, Universitas Sriwijaya, Jl. Padang Selasa, Palembang, Indonesia 30139
[4]Department of Animal Nutrition, Faculty of Agriculture, Universitas Sriwijaya, Jl. Padang Selasa, Palembang, Indonesia 30139
[5]Chemical Engineering Department, Faculty of Engineering, Universitas Sriwijaya, Jl. Padang Selasa, Palembang, Indonesia30139

Received April 6, 2022/Accepted October 21, 2022

Abstract

Human activities, which have interfered with the ecological system, have led to global warming. This has led to the release of carbon stocks into the atmosphere, thereby reducing the function of carbon sinks in places with vegetated land. With increased human activities, vegetated land will soon become non-vegetated. This is because the increased human activities have led to the absorption of higher amounts of carbon in the atmosphere than the required level. Therefore, this study aimed to estimate land cover on carbon stocks in Prabumulih City, South Sumatera Province, Indonesia. The study employed a random field survey using a dynamic system, with the results showing that land cover consisted of oil palm plantations, mixed plantations, grass, swamp shrubs, and rivers. However, the area was dominated by rubber plantations, and as a result, the carbon stocks continued to decline. For instance, in 2008, the level of carbon stock was 2,438.72 Gg and fell to 2,190.85 Gg in 2020, indicating a 4.8% decrease. It is projected that by 2030, the carbon stock in land cover will be 1,988.07 Gg.

Keywords: *global warming, emissions, simulation, environment*

**Correspondence author, email*: *ynr.pratiwi@yahoo.com*

Introduction

The main cause of global warming has been attributed to an increase in the concentration of various atmospheric greenhouse gases, including carbon dioxide (CO_2), methane (CH_4), nitrous oxide (NO), and chloro fluoro carbon (CFC), which are emitted directly to the environment (Prasad et al., 2017). Human activities disrupt this balance by producing an increase in CO_2 from fossil fuels such as coal, gas, petroleum products and combustion in power plants, transportation, and industry (Rahman & Hasan, 2017). In addition, according to Hairiah and Rahayu (2007), human activities such as burning forests and agricultural vegetation in protected areas have resulted in environmental damage. As a result, this affects the amount of carbon stock and causes climate change. The higher the level of GHG and carbon dioxide (CO_2) emission in the atmosphere, the greater the urgency in adopting carbon sequestration measures to mitigate the effects of climate change (Betts et al., 2016).

High demand for land to be used for infrastructure, settlement, and economic support facilities such as offices, roads, buying and selling centers, and industry has caused a decrease in the amount of vegetation cover, specifically in cities, as a result of the increasing urban population (Pratiwi et al., 2017). Further, rapid changes in land-use patterns have resulted in forest degradation negatively impacting the global climate due to the GHGs from terrestrial and aquatic systems (Kumar & Sharma, 2015). Emissions of carbon dioxide equivalent (CO_2eq) have continued to increase along with human activities such as land conversion, increased vehicle use, improper waste disposal, and other harmful activities (Pratiwi et al., 2021a).

Tropical forests in Indonesia have the most extensive natural and biological species in the world. However, most of them have been degraded and made distinct, thus, it is crucial to scrutinize the impact in relation to the role of storing carbon (Astiani et al., 2017). Sutaryo (2009) stated that one of the roles of tropical rain forests on the environment is their ability to absorb CO_2 due to the variety of plant species that grow in the area. Plants are naturally able to absorb CO_2 and convert it into oxygen through the process of photosynthesis. So tropical rain forests are the best carbon dioxide absorbers compared to other ecosystems. Changing vegetation land to non-vegetated land can cause the release of carbon stocks into the atmosphere, reducing the function of carbon sinks in places with vegetated land leading to increased CO_2 emissions. Each type of land cover has a different ability to

Jurnal Manajemen Hutan Tropika, *28*(3), 221–231, December 2022
EISSN: 2089-2063
DOI: 10.7226/jtfm.28.3.221
Scientific Article
ISSN: 2087-0469

absorb carbon, for instance, forests in the tropics serve as significant carbon sinks and store up to 40% carbon stocks compared to other ecosystems (Maxwell et al., 2019). The changes in carbon stocks occur due to natural processes in forests, indirect human influences, forest regeneration and harvesting, conversion of forests to agricultural land, wetlands, grasslands, settlements, and others (IPCC, 2003). Based on this, it is necessary to predict the carbon stock in land cover, which will likely decrease yearly, using a dynamic system approach.

System dynamics is a computerized approach to policy analysis and design used for dynamic problems that arise in complex social, managerial, economic, or ecological systems, literally any dynamic system characterized by interdependence, reciprocal interactions, information feedback. And circular causality. This approach starts with defining the problem dynamically, then carries out the mapping and modelling stage, to the steps to build confidence in the model and its policy implications. A system design based on a dynamic model approach was necessary to understand the behavior changes and perform a simple simulation in providing alternative control and management strategies that were more effective and integrated (Mandra, 2013). Modeling system is a simple method to describe the real situation in nature (Musi et al., 2017). Forrester (2016) states that after the modelling is complete, the logic and accuracy of the computer model simulation is determined by assumptions as input from the model.

Land cover in Indonesia is diverse, ranging from plantations to built-up land with the ability to absorb different types of carbon. Therefore, with these differences, it is necessary to calculate the stored carbon stock to determine changes in the land cover area on the existing carbon stock by utilizing a system dynamic approach. This study aimed at analyzing estimation land cover on carbon stocks in Prabumulih City, South Sumatera Province, Indonesia using a system dynamic approach.

Methods

Research site The study was conducted in Prabumulih City, South Sumatera Province, Indonesia, which is between S3°20'09.01"–S3°34'24.7" latitude and E104°07'50.4"–E104°19'41.6" longitude with an average altitude of 5154 m above sea level. It covers 434.50 km^2 of land with over 60% of rubber plantations around it. However, due to the increasing urban population, the area is developing rapidly, with the city government committed to improving infrastructure for office facilities, entertainment, and modernized roads. This development has led to changes in land cover types, such as plantation patterns. In the long run, these changes are likely to affect the ecosystem in Prabumulih City negatively. The research site is shown in Figure 1.

Land cover data Land cover data were obtained from Pratiwi et al. (2021b) (Table 1), where the analysis was carried out using supervised classification from Landsat satellite imagery. They included area statistics of five different land cover types for 2008, 2014, and 2020. To analyze the type of land cover in the primary data, using a field survey by determining several sampling points that were carried out randomly representing each type of land cover according to the actual conditions using GPS (Table 2), which is used to confirm the results of Pratiwi et al. (2021b)

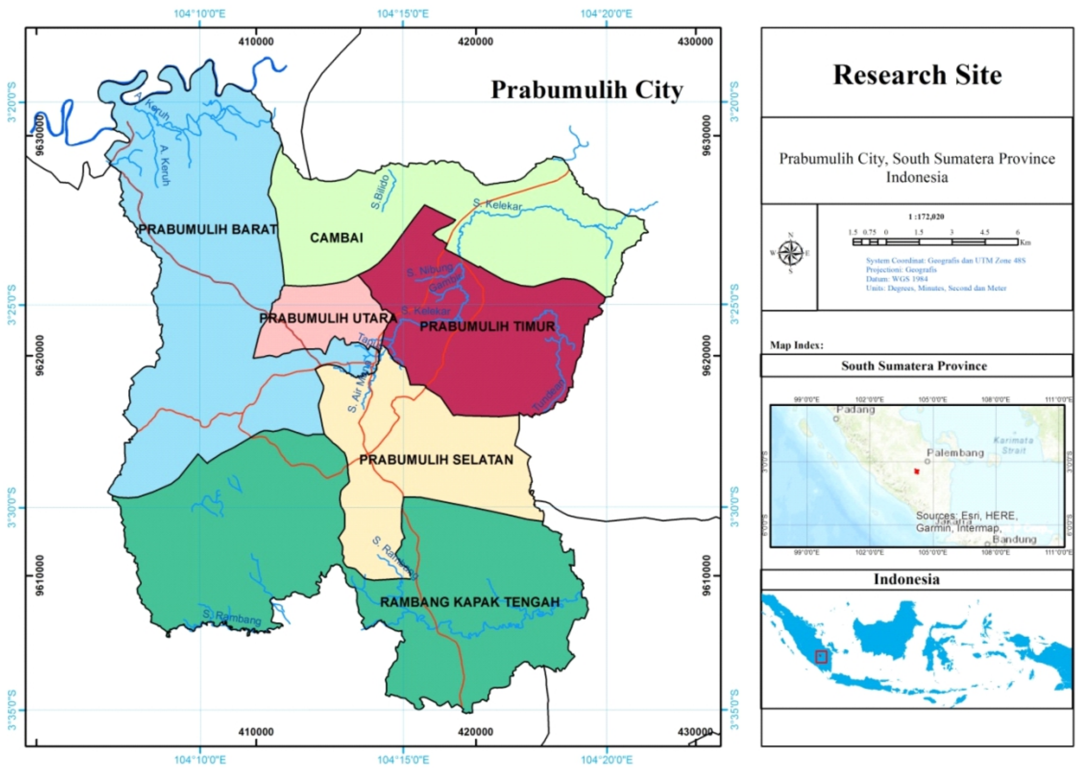

Figure 1 Map of research site, Prabumulih City, South Sumatera, Indonesia.

Jurnal Manajemen Hutan Tropika, *28*(3), 221–231, December 2022
EISSN: 2089-2063
DOI: 10.7226/jtfm.28.3.221
Scientific Article
ISSN: 2087-0469

Table 1 Land cover area Prabumulih City in 2008, 2014, and 2020

Land cover	2008		2014		2020	
	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)	Area (ha)	Proportion (%)
Cloud	37.8	0.08	496.11	1.08	786	1.71
No data	3.7	0.43	265.28	0.58	398.80	0.87
River	198.57	0.01	801.53	1.75	1,245.89	2.72
Swamp scrub	2,008.44	4.38	2,062.74	4.50	1,746.06	3.81
Built-up land	1,856.15	4.05	4,967.23	10.83	5,398.55	11.77
Open field	4,263.52	9.30	4,232.37	9.23	2,529.71	5.52
Mixed plantation	36,329.52	79.22	31,937.94	69.64	32,716.35	71.34
Palm plantations	1,135.33	2.48	852.80	1.86	764.12	1.67
Grass	25.62	0.06	244	0.53	274.46	0.60
Total	45,859	100	45,859	100	45,859	100

Source: Pratiwi et al. (2021a)

Table 2 Sampling points of land cover types in Prabumulih City

No	X coordinate	Y coordinate	Existing land cover
1	420,888	9,619,901	Open field
2	413,825	9,621,271	Open field
3	419,212	9,626,004	Open field
4	415,218	9,620,375	Built-up
5	415,960	9,622,216	Land built
6	421,525	9,626,691	Land built
7	417,658	9,623,354	Land built
8	423,101	9,619,308	Pineapple + rubber plantation
9	423,302	9,619,211	Pineapple + rubber plantation
10	423,099	9,619,287	Pineapple + rubber plantation
11	405,787	9,613,023	Palm plantation
12	405,439	9,612,646	Palm plantation
13	405,636	9,612,815	Palm plantation
14	408,165	9,614,875	Rubber plantation
15	409,501	9,613,326	Rubber plantation
16	407,828	9,609,873	Rubber plantation
17	425,670	9,626,147	Rubber plantation
18	415,935	9,621,237	Swamp scrub
19	409,513	9,613,176	Swamp scrub
20	412,796	9,620,302	Grass
21	419,342	9,622,181	River
22	418,513	9,621,404	River
23	419,433	9,622,876	River

listed in Table 1 and what types of land cover exist in Prabumulih City. Field survey data in the form of descriptions and documentation indicate the condition of land cover types in Prabumulih City.

Land cover types in carbon stock using system dynamic

Analysis of carbon stock on the land cover using dynamic systems approaches by Sterman (2002), as for the stage carried out such needs analysis, problem formulation,

Jurnal Manajemen Hutan Tropika, *28*(3), 221–231, December 2022
EISSN: 2089-2063
DOI: 10.7226/jtfm.28.3.221

ISSN: 2087-0469

system identification, model validation, and modeling. The initial step was needs analysis of model development with a dynamic systems approach that identified the demands of each stakeholder during the interviews. Additionally, the problem formulation stage was developed based on the needs of each stakeholder, where the identified differences prompted the problem of controlling CO_2eq emissions. The third stage involved system identification, which was carried out to provide an overview of the causal relationship represented by a positive (+) or negative (-) sign. The fourth stage was model validation, which ensured that the model described the actual system condition by statistical tests of absolute mean error (AME) and absolute variation error (AVE). According to Hartrisari (2007), AME was the difference between the average value of the simulation results and the actual value, while AVE was the deviation of the variation (variance) between the simulation value and the actual variation, while the acceptable deviation limit was between 110%. Finally, the Modeling stage was based on the model structure of the land cover diversity on carbon stocks. For the modeling stage, each land cover type has different carbon stocks (Table 3) absorption capacity of each type of land cover is described as follows in Equation *[1]*. The total carbon stock is obtained by multiplying the area of the land cover type by the carbon stock so that the total carbon stock is received.

$$C = L \times stock\ carbon\ (\text{ton C ha}^{-1}) \qquad [1]$$

note: C = stock carbon total (ton C); L = landcover area (ha). The dynamic system approach stages are mathematically defined in a computer language using Powersim 10 software.

Results and Discussion

Land cover type Based on the results of the field survey, several types of land cover were identified in Prabumulih City, such as rubber, pineapple, oil palm plantations, open land, built-up land, swamp scrub, grass, and rivers. Based on observations, Prabumulih City was dominated by rubber plantations, which are spread throughout the city, reaching 60% of the area because some people still use rubber farmers as a source of livelihood and most of the rubber plantations in Prabumulih City are smallholder rubber plantations. Prabumulih city has a characteristic called the "pineapple city" because pineapples have a delightful taste compared to other pineapples, and pineapple plants are mostly used as intercrops in rubber plantations. The area was centrally located with rubber plantations managed by the community as pictured in (Figure 2A, Figure 2B).

Results from the study indicated a lot of shifts in the land covers where oil palm plantations were being replaced with rubber plantations as shown in (Figures 3A, Figure 3B). The study area was considered an oil-producing city. Therefore, the available open land was due to conversion to residential land and oil wells (Figure 4A).

Prabumulih city is one of the national oil and gas barns and the operating base and mainstay of production where the natural gas network supplies almost 100% for households. The city was traversed by the Kelekar river, the Rambang river, and other small rivers (Figure 4B). Built-up land was centrally located in the city area (Figure 4C), with swamp shrubs that consisted of stagnant water (Figure 4D). Furthermore, grassland cover was in the form of football fields and golf courses (Figure 4E).

System dynamic model Analysis of land cover diversity on carbon stock analysis was carried out using a dynamic system approach with the aid of Powersim 10 software with the following stages discussed below:

Table 3 Carbon stocks by land cover type

Land cover type	Carbon stocks C (ton ha^{-1})	Source
Mixed plantation	63	Technical guidelines for calculating baseline greenhouse gas emissions and removals for the land-based sector, 2014
Palm plantations	63	
Shrubs	30	
Settlement/Built up	4	
Cloud	0	
Water body	0	
Open field	2.5	
Grass	4	

Figure 2 Rubber plantation land cover (2A), pineapple used as intercrops in rubber plantations (2B).

Jurnal Manajemen Hutan Tropika, *28*(3), 221–231, December 2022
EISSN: 2089-2063
DOI: 10.7226/jtfm.28.3.221

ISSN: 2087-0469

Figure 3 Oil palm (3A), oil palm plantations turned into rubber plantations (3B).

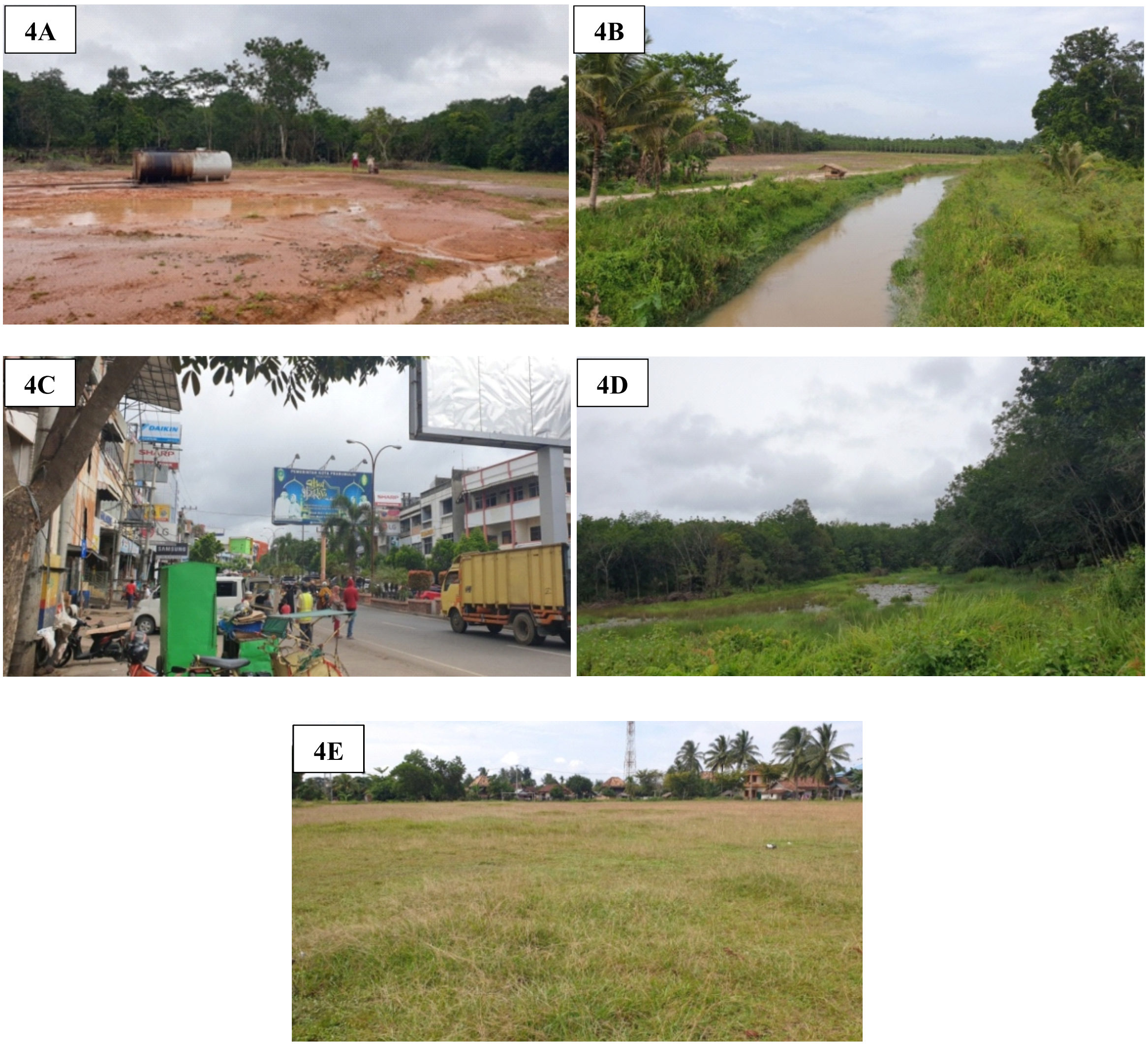

Figure 4 Open land in the form of oil wells (4A), river (4B), built-up land (4C), swamp shrubs (4D), land cover type of grass used as a football field (4E).

Need analysis The interview results showed the need for the government, academics, and the community to analyze carbon stocks since each stakeholder had different needs as illustrated in Table 4. In general, stakeholders want a healthy and pollution-free environment.

Identified problems The following needs were identified from each stakeholder interviewed. First, lack of public awareness on the importance of vegetated land cover and carbon stocks. Second, lack of government socialization to the community to maintain the existing plants in the home

Jurnal Manajemen Hutan Tropika, *28*(3), 221–231, December 2022
EISSN: 2089-2063
DOI: 10.7226/jtfm.28.3.221
Scientific Article
ISSN: 2087-0469

Table 4 Analysis of stakeholders needs

Stakeholders	Identified needs
Government	1. Increasing the area of green open space 2. The environment is not polluted 3. Environmental quality meets environmental quality standards 4. Controlled carbon stock 5. Reducing the amount of CO_2 emissions 6. Eco-friendly city development
Public	1. Cool and healthy air quality 2. Environmental quality improvement 3. Pollution-free city
Academics	1. Stable carbon stock 2. CO_2 emission reduction 3. Air quality improvement

environment. Finally, the conversion of vegetated land into built-up land, which affected the ecosystem.

Developed system The system identification described a causal relationship with positive (+) and negative (-) polarities where the vegetated land area was influenced by oil palm plantations, mixed plantations, grass, and swamp shrubs, increasing the carbon stock. Furthermore, the available open land that had risen due to the developments in the city reduced the carbon stocks. With increasing carbon stocks, the absorption of carbon dioxide increases shown in Figure 5. The increase and decrease in the growth rate of each type of land cover influenced the amount of carbon stock where the higher the growth rate of vegetated land cover, the higher the carbon stock. Conversely, if the growth rate of vegetated land cover decreases, the carbon stock will also decrease.

Model validity The test was carried out by comparing the actual data with the simulation data. The study found that the AVE and AME values of each type of land cover were below 10%. Therefore, based on this validation test, the model built was valid and acceptable. The results of the validation were used to project the land cover area as shown in Table 5.

Carbon stock model Based on the structure of the carbon stock estimation model, which consisted of vegetated land cover types, the causal loop diagram showed the relationship between variables in each sub-model with mathematically defined computer language using Powersim 10 software. The area was described by an auxiliary consisting of the built-up land, mixed plantations, oil palm plantations, open land, swamp shrubs, and grasses using existing data in 2008, 2014, and 2020, where interpolation was used to estimate the area of vacant land cover as described in (Figure 6). Land cover in Prabumulih City, according to Pratiwi et al. (2021b), consist of built-up land, mixed plantations, oil palm plantations, open land, swamp scrub and grass (Table 1).

The study found out that the total area of vegetated land cover in Prabumulih City continued to decline. Based on the findings in the field, the decline in vegetated land is caused by land clearing for plots and national housing. This was contributed by the changes in land cover from vegetated to non-vegetated, leading to loss of biodiversity, thereby affecting carbon stocks and CO_2 emissions. For instance, in 2008, it was 45,619 ha, and in 2020, it was 43,433 ha indicating a 4.8% decrease (Table 1). In 2030, it is estimated that vegetated land cover will continue to decline to 39,167 ha showing an alarming trend that needs intervention. According to Feng et al. (2020), land-use change was attributed to the rapid urban expansion and loss of forests and grasslands, causing substantial carbon emissions that contributed to greenhouse warming as indicated in Figure 7.

The study also indicated that human and climatic factors contributed to land use/cover changes, where decisions were based on short-term economic factors such as globalization, policy, and technological innovation (USGCRP, 2018). For vegetated land (forest), the risk of conversion to other land uses was related to environmental, social, cultural, economic, and political factors (Puhlick et al., 2017; USGCRP, 2018). Several other factors led to land conversions, such as urban expansion (Shifley et al., 2014), demographic variables(Woodall et al., 2015), and distance to the nearest road (Puhlick et al., 2017). Therefore, it was feared that these factors affected vegetated areas and threatened carbon stocks and CO_2 emissions.

The graph in Figure 8 shows the projected carbon stock in Prabumulih City for 20082030, which is above ground carbon stock. Carbon stocks in 2008 were 2,438.72 Gg, and there was a decrease in carbon stocks in 2020 to 2,190.85 Gg. In 2030 it is predicted that the carbon stock in land cover will be 1,988.07 Gg.

Table 6 shows the trend of carbon stocks from each land cover type that tends to decrease, such as mixed plantations, oil palm plantations, swamp shrubs and open land. Meanwhile, those that have increased are built-up land and grass. The increase in carbon stocks in built-up land is due to an increase in built-up land area, where the assumption is that the built-up land still contributes 4 ton ha^{-1} of carbon stocks from home yards or private green open spaces. Compared to other land cover types, carbon stocks from open land are smaller than different types of land cover, especially woody land cover.

Mixed plantations have the highest carbon stocks from year to year compared to other land covers, followed by swamp shrubs, mixed plantations, built-up land, open land

Jurnal Manajemen Hutan Tropika, *28*(3), 221–231, December 2022
EISSN: 2089-2063
DOI: 10.7226/jtfm.28.3.221

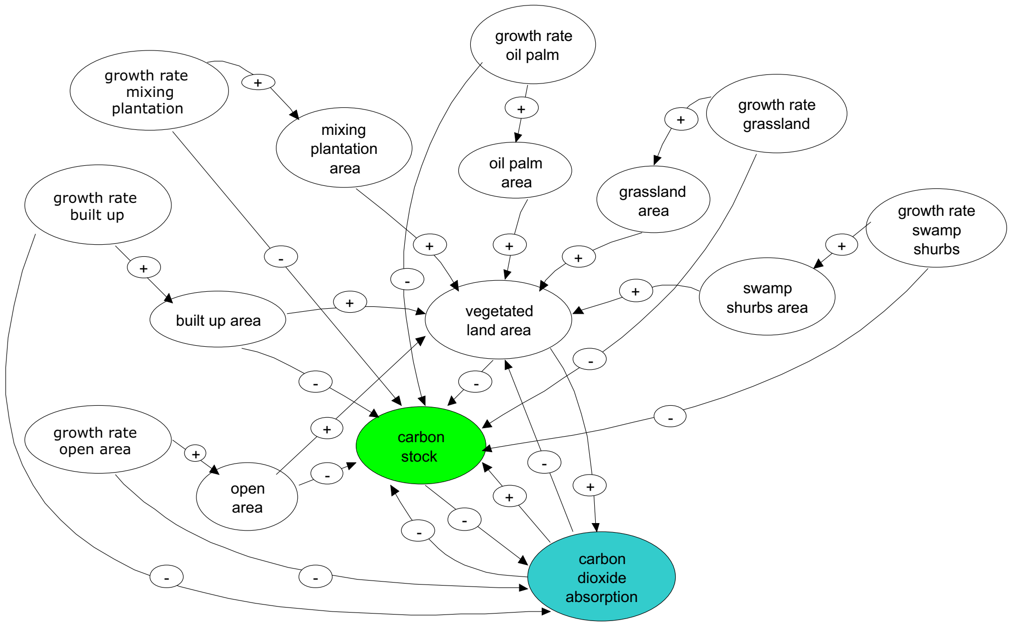

Figure 5 Causal loop diagram of area and carbon stock in Prabumulih.

Table 5 Validation of AME and AVE values

Year	Mixed plantation		Oil palm		Open land		Built-up land		Swamp shrubs		Grassland	
	A (ha)	S (ha)	A (ha)	S (ha)	A (ha)	S (ha)	A (ha)	S (ha)	A (ha)	S (ha)	A (ha)	S (ha)
2008	36,329.52	36,329.52	1,135.33	1,135.33	4,263.52	4,263.52	1,856.15	1,856.15	2,008.44	2,008.44	25.62	25.62
2014	31,937.94	31,939.92	852.8	852.79	4,232.37	4,232.91	4,967.23	4,967.30	2,062.74	2,062.67	244	243.99
2020	32,716.35	32,719.23	764.12	764.12	2,529.71	2,530.21	5,398.55	5,399.44	1,746.06	1,745.951	274.46	274.45
Average	33,661.27	33,662.89	917.42	917.12	3,675.2	3,675.55	4,073.98	4,074.30	1,939.08	1,939.02	181.36	181.35
AME	0.005		0.00039		0.0108		0.006		0.0032		0.0026	
AVE	0.111		0.0017		0.0276		0.033		0.0432		0.0084	
Status	Valid		Valid		Valid		Valid		Valid		Valid	

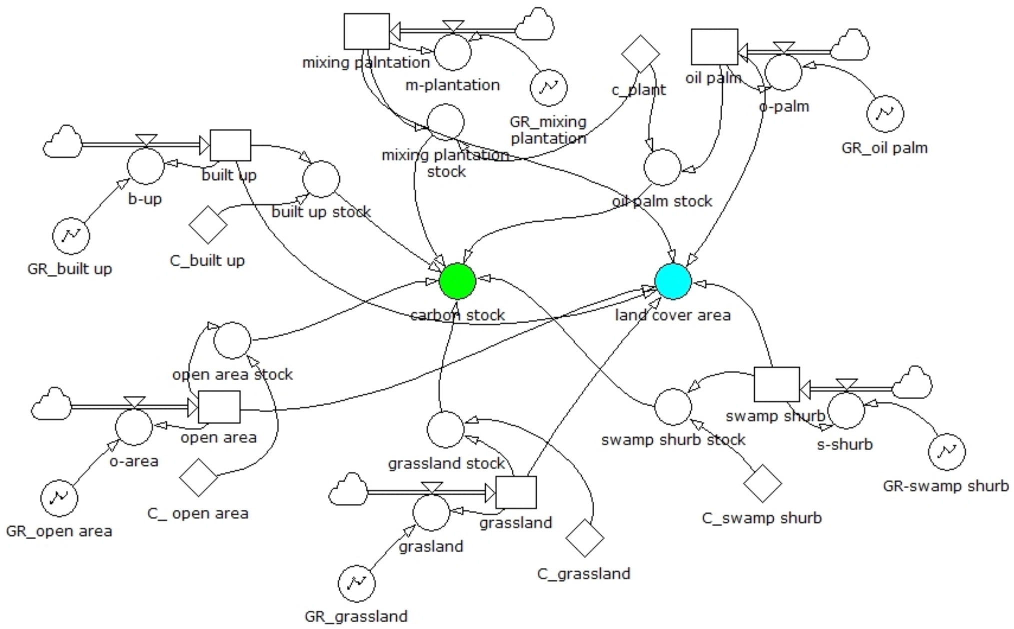

Figure 6 Land cover area and carbon stock sub model.

Jurnal Manajemen Hutan Tropika, *28*(3), 221–231, December 2022
EISSN: 2089-2063
DOI: 10.7226/jtfm.28.3.221

ISSN: 2087-0469

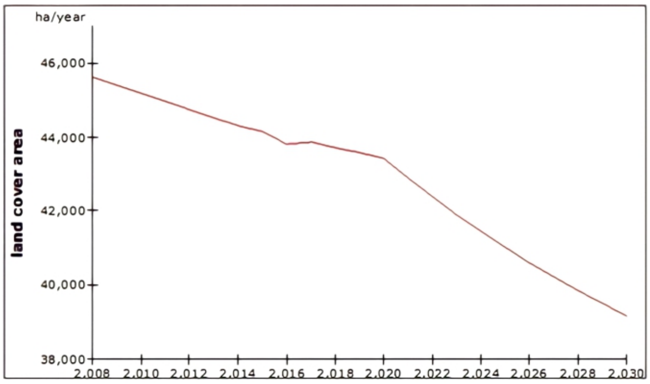

Figure 7 Projected land cover area.

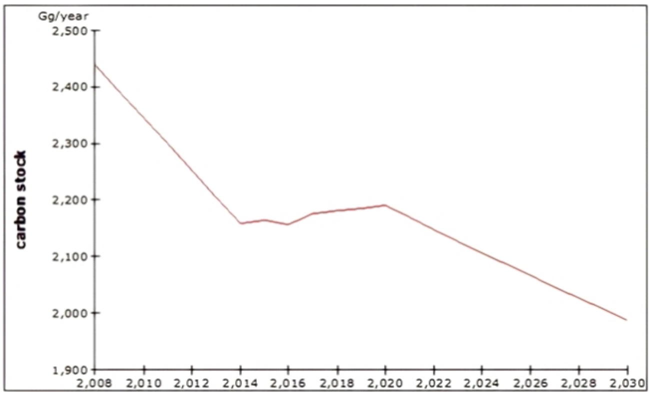

Figure 8 Projected land cover carbon stocks.

Table 6 Carbon stock for each type of land cover

Land cover	Carbon stock (Gg ha^{-1})			
	2008	2014	2020	2030
Mixing plantation	2,288.76	2,012.09	2,061.13	1,872.74
Oil palm	71.53	53.73	48.14	37.60
Swamp shrub	60.25	61.88	52.38	52.89
Bulit-up	7.42	19.87	21.59	31.9
Open land	10.66	10.58	6.32	5.68
Grassland	0.10	0.98	1.1	1.32
Total	2,438.73	2,159.13	2,190.67	1,988.07

and grass (Table 6). Carbon stock in 2008 mixed plantations was 2,288.76 Gg and then decreased to 2012.09 Gg in 2014. In 2020 it increased slightly to 2,061.13 Gg, and it is predicted that in 2030 mixed plantations will experience a decrease in carbon stock to 1,872.74 Gg. The amount of carbon stock is influenced by the type of land cover where the area of mixed plantations in Prabumulih City reaches 70%.

When viewed from the type of land cover in Prabumulih City, this city only has vegetated land in the form of plantations. There are no more forests, both primary and secondary, which have the most significant carbon stock of 112,377 ton ha^{-1}, so the carbon stock in Prabumulih City, seen from the land cover classification, is classified as not diverse. According to Sukarna et al. (2021), low carbon stocks above the surface are related to ecosystem stability.

The figure illustrates that vegetated land in this area is decreasing in terms of the environment (Figure 9), so it is necessary to consider managing it as a potential carbon stock that helps absorb greenhouse gas emissions.

Biomass carbon concentration has been highly influenced by land use. The biomass carbon stock was, on average, five times higher in the dense forest than in open forest and twenty times higher than in grassland (Solomon et al., 2018). Carbon sequestration through planting fruit trees can be a cost-effective option to reduce global warming and, at the same time, increase farmers' incomes. However, the amount of wood biomass absorbed by C depends on plant age, stem density, site conditions, management practices, and climatic conditions (Fischer et al., 2013).

Vegetated land cover that continues to experience a reduction in the area will affect the stored carbon stock. According to Dewa & Sejati (2019), the reduction in carbon stock is caused by a decrease in canopied forests land cover, which is turned into other types of land cover, such as settlements. Therefore, carbon emissions are released as the ability to store carbon stocks decreases, impacting environmental sustainability.

Each type of land cover that turns into other land covers, especially non-vegetated land covers, can release different amounts of carbon. Carbon sequestration can even occur if there is a change in land cover with low to high carbon absorption, so a scenario is needed to maintain or increase carbon stocks to absorb CO_2. According to "(Murdiyarso et al., 2010; Sugiri & Buchori, 2016), reported that reduced forest and increased settlements have a significant impact on carbon emissions so that efforts to control land-use change are needed.

The scenario used is land cover, where 20% of the open land is mixed plantation land/vegetated land. The figure shows the results of the scenario applied to increase carbon stocks due to the increased area of vegetated land in 2024. The resulting carbon stock is 2,126.50 Gg, whereas the carbon stock before the scenario was 2,106.49 Gg.

Maintaining and adding vegetated land in Prabumulih City supports the government's commitment to handling climate change through Low Carbon Development Planning. President Joko Widodo's commitment at COP 21 in Paris, December 2015, is to reduce emissions by 29% (Fair scenario/using own capabilities) and 41% (ambitious scenario/if international support). One of the efforts to realize this policy is to maintain and optimize green open space. According to Gómez-Baggethun et al. (2013) and Elmqvist et al. (2015), climate regulation is one of the primary regulatory services provided by urban green space.

The development of green open spaces requires efforts from various substances such as researchers, local governments, communities and other stakeholders because green open spaces are a form of climate change mitigation that supports CO_2 emission reduction. According to Helen et al. (2019), green infrastructure consisting of green open spaces has many benefits for urban residents. It contributes to current national policy goals related to urban sustainability and the transition to a green economy. Vegetation in urban green spaces absorbs and stores carbon by converting CO_2 into biomass both above-ground and below-ground, such as in stems, branches, leaves, and roots through photosynthesis (Nowak & Crane, 2002).

Jurnal Manajemen Hutan Tropika, *28*(3), 221–231, December 2022
EISSN: 2089-2063
DOI: 10.7226/jtfm.28.3.221

ISSN: 2087-0469

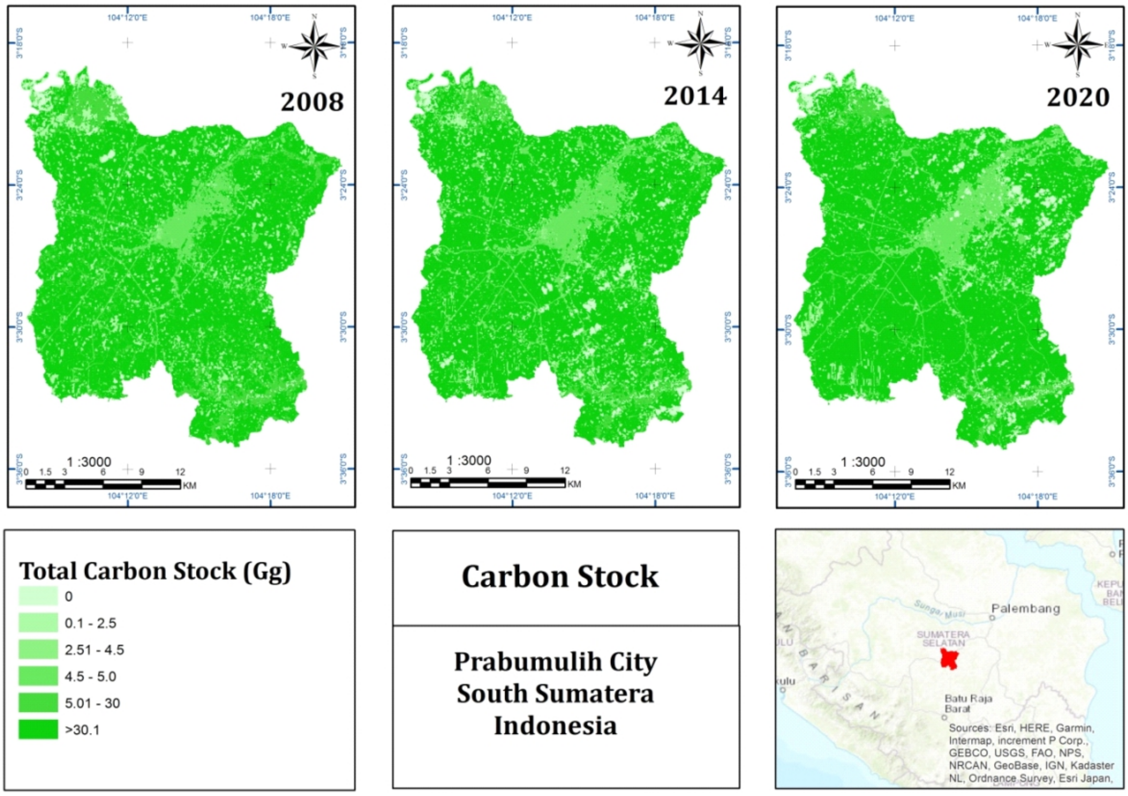

Figure 9 Changes in the distributin of carbon stock.

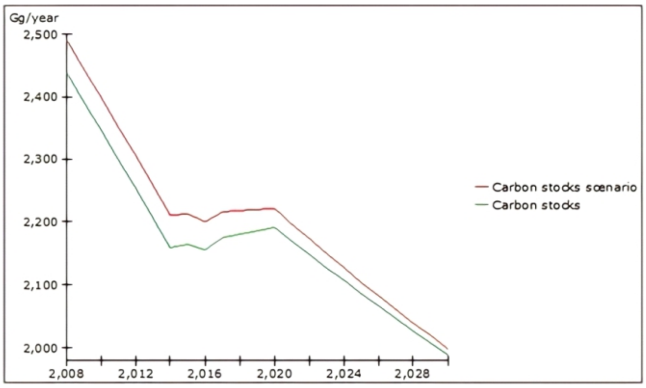

Figure 10 Scenario of adding 20% vegetated land area.

Conclusion

In conclusion, the diversity of land cover types consisted of oil palm plantations, mixed plantations, grass, swamp shrubs, and rivers. In 2008, carbon stocks in this region reached 2,438.72 Gg, while in 2020, they amounted to 2,190.85 Gg. However, there are projections that by 2030, the carbon stock in land cover will be in excess of 1,988.07 Gg. Vegetated land cover that continues to experience a reduction in the area will affect the stored carbon stock. Adding vegetated land is carried out, whereas much as 20% of open land is used as vegetated land. There is an increase in carbon stock due to the vegetated land area, which was originally 2106.49 Gg to 2,126.50 Gg in 2024.

References

Astiani, D., Mujiman, & Rafiastanto, A. (2017). Forest type diversity on carbon stocks: Cases of recent land cover conditions of tropical lowland, swamp, and peatland forests in West Kalimantan, Indonesia. *Biodiversitas*, *18*(1), 137–144. https://doi.org/10.13057/biodiv/d180119

Betts, R. A., Jones, C. D., Knight, J. R., Keeling, R. F., & Kennedy, J. J. (2016). El Nino and a record CO_2 rise. *Nature Climate Change*, *6*, 806–810. https://doi.org/10.1038/nclimate3063

Dewa, D. D., & Sejati, A. W. (2019). Pengaruh perubahan tutupan lahan terhadap emisi GRK pada wilayah cepat tumbuh di Kota Semarang. *Jurnal Penginderaan Jauh Indonesia, 1*(1), 24–31.

Elmqvist, T., Setala, H., Handel, S. N., Ploeg, S. V. D., Aronson, J., Blignaut, J. N., ..., & Groot, R. D. (2015). Benefits of restoring ecosystem services in urban areas. *Current Opinion in Environmental Sustainability*, *14*, 101–108. https://doi.org/10.1016/j.cosust.2015.05.001

Feng, Y., Chen, S., Tong, X., Lei, Z., Gai, C., & Wang, J. (2020). Modeling changes in China's 2000–2030 carbon stock caused by land use change. *Journal of Cleaner Production*, *252*, 119659. https://doi.org/10.1016/j.jclepro.2019.119659

Fischer, G., Almanza-Merchán, P. J., & Ramírez, F. (2013). Source-sink relationships in fruit species: A review. *Revista Colombiana de Ciencias Hortícolas*, *6*(2), 238–253. https://doi.org/10.17584/rcch.2012v6i2.1980

Forrester, J. W. (2016). Learning through system dynamics as preparation for the 21st century. *System Dynamics Review*, *32*(3–4), 187–203. https://doi.org/10.1002/sdr.1571

Gómez-Baggethun, E., Gren, A., Barton, D. N., Langemeyer, J., McPhearson, T., O'Farrell, P., ..., & Kremer, P. (2013). Urbani ecosystem services. In T. Elmqvist, M. Fragkias, J. Goodness, B. Güneralp, P. J. Marcotullio, R. I. McDonald, …, & C. Wilkinson (Eds.), *Urbanization, biodiversity and ecosystem services: Challenges and opportunities* (pp. 175251). Springer, Dordrecht. https://doi.org/10.1007/978-94-007-7088-1

Hairiah, K., & Rahayu, S. (2007). *Pengukuran karbon tersimpan di berbagai macam penggunaan lahan*. Bogor: World Agroforestry Centre.

Hartrisari. (2007). *Sistem dinamik: Konsep sistem dan pemodelan untuk industri dan lingkungan*. Bogor: SEAMEO BIOTROP.

Helen, Jarzebski, M. P., & Gasparatos, A. (2019). Land use change, carbon stocks and tree species diversity in green spaces of a secondary city in Myanmar, Pyin Oo Lwin. *PLoS ONE*, *14*(11), e0225331. https://doi.org/10.1371/journal.pone.0225331

[IPCC] Intergovernmental Panel on Climate Change. (2003). *Good practice guidance for land use, land-use change and forestry*. Kanagawa: Institute for Global Environment Strategies (IGES).

Kumar, A., & Sharma, M. P. (2015). Assessment of carbon stocks in forest and its implications on global climate changes. *Journal of Materials and Environmental Science*, *6*(12), 3548–3563.

Mandra, M. A. S. (2013). Model dinamik pengendalian emisi kendaraan bermotor di Kota Makassar [dissertation]. Bogor: IPB University.

Maxwell, S. L., Evans, T., Watson, J. E. M., Morel, A., Grantham, H., Duncan, A., ..., & Malhi, Y. (2019). Degradation and forgone removals increase the carbon impact of intact forest loss by 626%. *Science Advances*, *5*(10). https://doi.org/10.1126/sciadv.aax2546

Murdiyarso, D., Hergoualc'h, K., & Verchot, L. V. (2010, November 16). Opportunities for reducing greenhouse gas emissions in tropical peatlands. *Proceedings of the National Academy of Sciences of the United States of America*, *107*(46), 19655–19660. https://doi.org/10.1073/pnas.0911966107

Musi, C., Anggoro, S., & Sunarsih. (2017). System dynamic modelling and simulation for cultivation of forest land: Case study Perum Perhutani, Central Java, Indonesia. *Journal of Ecological Engineering*, *18*(4), 25–34. https://doi.org/10.12911/22998993/74307

Nowak, D. J., & Crane, D. E. (2002). Carbon storage and sequestration by urban trees in the USA. *Environmental Pollution*, *116*(3), 381–389. https://doi.org/10.1016/S0269-7491(01)00214-7

Prasad, P. V. V., Thomas, J. M. G., & Narayanan, S. (2017). Global warming effects. In B. Thomas, B. G. Murray, & D. J. Murphy (Eds.), *Encyclopedia of applied plant sciences* (2nd ed.) (pp. 289–299). Academic Press. https://doi.org/10.1016/B978-0-12-394807-6.00013-7

Pratiwi, Y., Rejo, A., Fariani, A., & Faizal, M. (2021a). Source of carbon dioxide emissions equivalent to plant-based control concept with dynamic system in Prabumulih City, South Sumatra Province. *IOP Conference Series: Earth and Environmental Science, 810*, 012051. https://doi.org/10.1088/1755-1315/810/1/012051

Pratiwi, Y., Rejo, A., Fariani, A., & Faizal, M. (2021b). Monitoring and prediction land cover in Prabumulih City, South Sumatera Province, Indonesia using land change modeler and multi-temporal satellite data. *Ecology, Environment and Conservation Paper*, *27*, 334–340.

Pratiwi, Y., Dachlan, E. N., & Prasetyo, L. B. (2017, October 1920). *Simulasi emisi CO_2 dari penduduk dan areal persawahan menggunakan sistem dinamik* [Conference presentation]. Seminar Nasional Lahan Suboptimal, Palembang, Indonesia.

Puhlick, J., Woodall, C., & Weiskittel, A. (2017). Implications of land-use change on forest carbon stocks in the eastern United States. *Environmental Research Letters*, *12*(2), 024011. https://doi.org/10.1088/1748-9326/aa597f

Rahman, A., & Hasan, M. (2017). Modeling and forecasting of carbon dioxide emissions in Bangladesh using autoregressive integrated moving average (ARIMA) models. *Open Journal of Statistics*, *7*, 560–566. https://doi.org/10.4236/ojs.2017.74038

Shifley, S. R., Moser, W. K., Nowak, D. J., Miles, P. D., Butler, B. J., Aguilar, F. X., ..., & Greenfield, E. J. (2014). Five anthropogenic factors that will radically alter forest conditions and management needs in the Northern United States. *Forest Science*, *60*(5), 914–925. https://doi.org/10.5849/forsci.13-153

Solomon, N., Pabi, O., Annang, T., Asante, I. K., & Birhane, E. (2018). The effects of land cover change on carbon stock dynamics in a dry Afromontane forest in northern Ethiopia. *Carbon Balance and Management*, *13*, 14 (2018). https://doi.org/10.1186/s13021-018-0103-7

Sterman, J. (2002). *System dynamics*: *System thinking and modeling for a complex world*. Working paper Series ESD-WP-01.13-ESD Internal Symposium. United States: Cambridge.

Sugiri, A., & Buchori, I. (2016). Towards low emission development: Prospects of applying MBIs in the industrial sector of Central Java, Indonesia. *American Journal of Environmental Sciences*, *12*(3), 225–236. https://doi.org/10.3844/ajessp.2016.225.236

Sukarna, R. M., Birawa, C., & Junaedi, A. (2021). Mapping above-ground carbon stock of secondary peat swamp forest using forest canopy density model Landsat 8 OLI-TIRS: A case study in Central Kalimantan Indonesia. *Environment and Natural Resources Journal*, *19*(2), 165–175. https://doi.org/10.32526/ennrj/19/2020209

Sutaryo, D. (2009). *Penghitungan biomassa sebuah pengantar untuk studi karbon dan perdagangan karbon*. Bogor: Wetlands International Indonesia Programme.

[USGCRP] U.S. Global Change Research Program. (2018). *Impacts, risks, and adaptation in the United Statesa: Fourth National Climate Assessment, Volume II* [D. R. Reidmiller, C. W. Avery, D. R. Easterling, K. E. Kunkel, K. L. M. Lewis, T. K. Maycock, & B. C. Stewart (Eds.)]. *Washington DC: U.S. Global Change Research Program.* https://nca2018.globalchange.gov/

Woodall, C. W., Walters, B. F., Coulston, J. W., D'Amato, A. W., Domke, G. M., Russell, M. B., & Sowers, P. A. (2015). Monitoring network confirms land use change is a substantial component of the forest carbon sink in the eastern United States. *Scientific Reports*, *5*, 17028 (2015). https://doi.org/10.1038/srep17028