LOW CARBON DEVELOPMENT STRATEGY FOR LAND USE SECTOR IN CILIWUNG MIDDLE-STREAM WATERSHED

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LOW CARBON DEVELOPMENT STRATEGY FOR LAND USE SECTOR IN CILIWUNG MIDDLE-STREAM WATERSHED. The second (2nd) and third (3rd) segment of Ciliwung middle-stream watershed land use have changed drastically over the past two decades. This paper analyses the land use change from 1989-2012 and its impact on decreasing carbon stock or increasing CO_2eq emission, as well as to establish projected Reference Level (RL) to 2020. Best RL projection was used to establish the Low Carbon Development Strategy (LCDS) in both segments. The land use changing from 1989-2012 indicated a reduction of green space area by 2,575.57 ha whereas the non-green space area increased by 2,575.57 ha. These changes decreases the carbon stock by 26,900 ton C and released CO_2eq emission by about 98,723 ton CO_2eq. Population growth, demand on land and land constraints were found to be the driving factors of land use changes in this area. Reference Level 2020 was established based on business as usual (BAU) and forward looking (FL) scenarios. The projection showed that FL was the best scenario which estimated carbon storage at 217,610 ton C in 2020. Low carbon development strategy directed to the area of green space added up to 20% carbon storage through the implementation of the strategy based on green space and non-green space which covered the areas from protection, supervision, extension or awareness and law enforcement.

Keywords: Carbon stock, Ciliwung watershed, land use, reference level

STRATEGI PEMBANGUNAN RENDAH KARBON UNTUK PENGGUNAAN LAHAN DI DAS CILIWUNG BAGIAN TENGAH. Segmen kedua dan ketiga yang merupakan bagian dari DAS Ciliwung bagian tengah mengalami perubahan penggunaan lahan yang cukup pesat selama dua dekade terakhir. Tulisan ini menganalisa trend perubahan penggunaan lahan dari 1989-2012 dan dampaknya terhadap penurunan stok karbon/peningkatan emisi CO_2*eq serta proyeksi Reference Level (RL) pada tahun 2020. Reference Level terbaik digunakan untuk membangun Strategi Pembangunan Rendah Karbon (Low Carbon Development Strategy-LCDS) di kedua segmen. Perubahan penggunaan lahan pada 1989-2012 memperlihatkan bahwa terjadi penurunan luasan ruang terbuka hijau (RTH) hingga 3.623,17 ha sedangkan non-RTH meningkat hingga 2.575,57 ha. Hal ini berdampak pada menurunnya stok karbon hingga 26.900 ton. C dan melepaskan emisi* CO_2*eq hingga 98.723 ton.* CO_2*eq. Penyebab perubahan penggunaan lahan yaitu pertambahan penduduk, kebutuhan lahan, dan keterbatasan lahan. Proyeksi RL hingga tahun 2020 dilakukan berdasarkan kondisi standar (BAU) dan rencana ke depan (FL). Hasil proyeksi memperlihatkan bahwa FL adalah skenario terbaik yang diestimasi menyimpan karbon hingga 217.610 ton C di tahun 2020. Strategi pembangunan rendah emisi karbon diarahkan pada penambahan luasan RTH hingga 20% melalui implementasi strategi didasarkan pada RTH dan non-RTH meliputi strategi perlindungan, pemantauan, penyuluhan, dan penegakan hukum.*

Kata kunci: Stok karbon, DAS Ciliwung, perubahan penggunaan lahan, reference level

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I. INTRODUCTION

Indonesia's Green House Gasses (GHG) data from 2000-2005 showed that GHG emissions from Land Use, Land Use Change and Forestry (LULUCF) sector was 48% of total national GHG emission, with emissions in 2004 amounting to 1,415 million Gg. CO_2e (Ministry of Environment [MOE], 2010). Based on 2000-2005 data, these emissions were mainly caused by forest cover and land use changes of the area amounted approximately to 1.1 million ha/year. Land use and land cover changes in the watershed especially occurred from green space (e.g. forests, plantations, etc.) to non-vegetation area (e.g. built up area, roads, etc.), which led to decrease of carbon stock in the watershed, as well as the ability to absorb carbon. One of the watersheds that have been affected by massive land use change is Ciliwung watershed.

Ciliwung watershed is an area with a main river and tributaries located adjacently to the DKI Jakarta Province and West Java Province. Total watershed area is approximately 337 km^2 having main river length of approximately 109.7 km (MOE, 2011). Based on administrative regions, Ciliwung watershed is divided into 6 segments, spanned from upstream (1st segments), middle-stream (2nd segment, 3rd segment, and 4th segment) to downstream (5th and 6th segment), with each segment managed by the local government whose land is crossed by the Ciliwung river. The segmentation covers from Bogor Regency (2nd and 3rd segments), Bogor City (2nd segment), Depok City (4th segment) and DKI Jakarta (5th and 6th segments).

First (1st) segment and third (3rd) segment is managed by the local government of Bogor Regency, with 1st segment covering the districts of Ciawi, Cisarua and Megamendung, while the 3rd segment covers the districts of Sukaraja, Babakan Madang, Bojonggede, and Cibinong. Second (2nd) segment is managed by the local government of Bogor City, which covers the districts of South Bogor, East Bogor, Center Bogor, and Tanah Sareal. Fourth (4th) segment is managed by the local government of Depok City, which covers the districts of Bejo, Limo, Cimanggis, Sukmajaya and Pancoran Mas. Fifth (5th) segment and sixth (6th) segment is managed by the local government of DKI Jakarta Province, with 5th segment covering the districts of Jagakarsa, Pasar Minggu, Mampang Prapatan, Pancoran, Tebet, Setia Budi, Kebayoran Baru, Pasar Rebo, Ciracas, Kramat Jati, and Jatinegara, while 6th segment is covering the districts of Pulo Gadung, Matraman, Menteng, Senen, Tanah Abang, Johar Baru, Cempaka Putih, Kemayoran, Sawah Besar, Gambir, Tambora, Taman Sari, Koja, Penjaringan, Tanjung Priok, and Kelapa Gading. Ciliwung watershed segmentation can be seen in Figure 1.

This study was focused on the 2nd segment managed by the Government of Bogor City and 3rd segment managed by the Government of Bogor Regency. Second segment and third segment in Ciliwung middle-stream watershed has been affected by the land use and land cover changes during the past two decades. Increasing population and their demand for land in a limited area had become the major causes of forest/land conversion, from forests and agriculture land into built up areas (MOE, 2011). Even though up to 73% of land use in Ciliwung middle-stream was dominated by farms and plantations while the residence area increased up to 71% (Kusmana, 2003). Land use and land cover change within a catchment has provided a bad impact on the increase of soil erosion, run-off, sedimentation, micro-climate change, as well as the increase in GHG emission (Wasis, Saharjo, Arifin & Prasetyo, 2012). Land use and land cover cause the increase of built-up area in Ciliwung middle-stream which affects the quality of the watershed, especially by lower water absorption capacity and increased carbon emission.

The decreasing of green space area impact on the decreased of carbon storage in both regions. Adinugroho (2012) stated that land use pattern largely determines its carbon sequestration ability. Changes in land use must be considered in the preparation of the Regional Spatial Plan in both regions. Based on the Regional Action Plan-GHG West Java Province, the potential GHG emission absorption can be enhanced

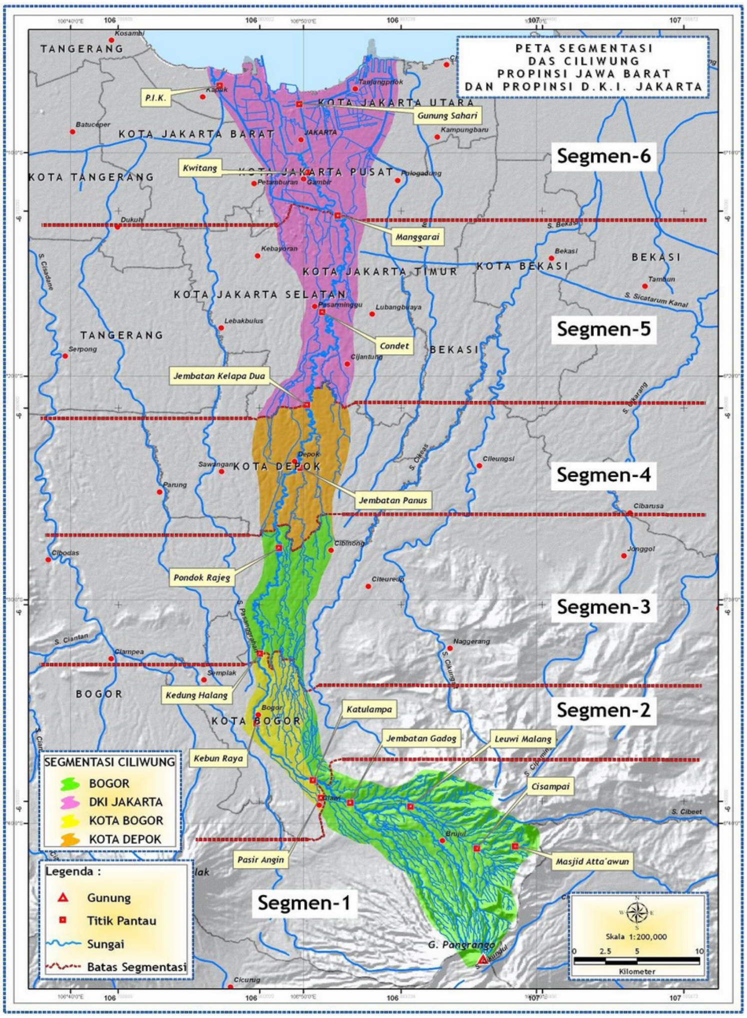

Figure 1. Ciliwung watershed segmentation map

Source : Ministry of Environment (2011)

through the increase of green space in urban areas by 30% which consists of: (1) 20% of public green space, and (2) 10% private green space located in residential areas. The creation of green space in urban areas will contribute to the national GHG emission reduction target by 2020. Government of Indonesia is targeting a national GHG emission reduction from BAU up to 26% with domestic resources and 41% with international assistance by 2020.

The objective of this study is to identify the contribution of spatial arrangement of land use and land cover on the preparation of climate change mitigation strategies for the land use sector in Ciliwung middle-stream watershed, focusing on 2^{nd} segment Bogor City and 3^{rd} segment Bogor Regency. The results of the study were expected to provide alternative plans that may support climate change mitigation strategies for the land use sectors in 2^{nd} segment and 3^{rd} segment of Ciliwung middle-stream watershed.

II. MATERIAL AND METHOD

This study was conducted in 2^{nd} and 3^{rd} segments of Ciliwung middle-stream watershed which is located at 60 27'07" – 60 40'47" South Latitude and 1060 47'36" – 1060 51' 01" East Longitude. Based on administrative region, 2^{nd} segment is located at 4 districts in Bogor City which are South Bogor, East Bogor, Center Bogor, and Tanah Sareal, while 3^{rd} segment is

Table 1. Carbon stock average in various land use types in Ciliwung watershed

No.	Type of land use	Carbon stock average (ton C ha^{-1})
1.	Natural forest	111.20
2.	Plantation forest	144.99
3.	Mixed plantation	29.77
4.	Shrub	4.94
5.	Paddy field	4.61
6.	Dry land agriculture	4.44
7.	Built up area	2.50

Source: Wasis et al. (2012)

located at 4 districts in Bogor Regency which are Sukaraja, Babakan Madang, Bojonggede, and Cibinong. Survey and collecting Ground Control Point (GCP) were carried out in July-August 2013 to help classify land use types and areas. Sampling data consisted of land use types, population, livelihoods, carbon stock change in every type of land use, and regulations and policies related to spatial plan and regional development plan. Land use and land cover types were categorized into 9 types namely: natural forests, plantation forests, mixed plantations, dry land agriculture, paddy fields, built up area, shrubs, barren lands and water bodies.

Research data consisted of: 1) Ground Control Point (GCP) from each type of land use based on survey; 2) Landsat satellite image path/row 122/065 in 1989, 2001, and 2012 from United States Geological Survey (USGS); 3) topographic maps with a scale of 1:25,000 from Faculty of Forestry, Bogor Agricultural University which originated from Geospatial Information Agency (*Badan Informasi Geospasial*, BIG); 4) carbon stock data in Ciliwung watershed from Wasis et al. (2012); 5) spatial plan (*Rencana Tata Ruang dan Wilayah*, RTRW) and regional development plan (*Rencana Pembangunan Jangka Panjang*, RPJP) in Bogor City and Bogor Regency; 6) regulations and policies related to the study from central government and local government; and 7) statistical report of population, livelihoods, education and health facilities in Potensi Desa 1990, 2001, and 2011 from Central Statistics Agency (*Badan Pusat Statistik*, BPS).

Data analysis in this study was done through five steps. First step was identifying the trend in land use changes by supervised classification method with maximum likelihood parametric rule of Landsat TM satellite images path/row 122/65 (date of acquisition: 9 September 1989; 29 June 2001, and 27 June 2012) using ERDAS 9.1 and ArcGIS 9.3. Each image was classified with GCP of each type of land use from the survey which produced classified time series images that contained area values (ha). This result was used for analyzing land use changes from 1989 to 2012.

Second step was determining the causes of land use changes from social-economic factors based on field survey and review of document Potensi Desa (PODES) obtained from BPS. Third step was estimating carbon stock and CO_2eq emission. Calculation of carbon stock was done by multiplying land use area with carbon stock value from Wasis et al. (2012). Calculation of CO_2eq emission was done by calculating the loss of carbon stock that was caused by land conversion. The deficit of carbon stock was multiplied by 3'67 (multiplying factor to transform carbon (C) into carbon dioxide (CO_2). Reference for carbon stock data in Ciliwung watershed is presented in Table 1.

Fourth step was projection of reference level (RL) with 3 scenarios. Reference level is the

$$\text{Historic C-stock rate } \left(\frac{ton.C}{year}\right) = \text{Land use change data } \left(\frac{ha}{year}\right) \text{ x C-stock factor} \left(\frac{ton.C}{ha}\right) \quad (1)$$

$$\text{RL (ton C)} = \text{Historic carbon stock rate } \left(t\,\frac{ton.C}{year}\right) + \text{Sub-national circumstances} \quad (2)$$

$$\text{MA} = \frac{\sum_{i=1}^{n} activitydata}{observation\ year\ (23\ years)} \quad (3)$$

$$\text{Land use change projection} = \text{land use area in year-i (ha)} + \text{MA land use in 1989-2012 } \left(\frac{ha}{year}\right) \quad (4)$$

$$\text{RL projection} = \text{RL in year-i (ha)} + \text{MA historic carbon stock in 1989-2012 } \left(\frac{ton.C}{year}\right) \quad (5)$$

baseline of carbon storage and CO_2eq emission in the land use sector in both segments. These projections were based on historical data for business as usual (BAU) RL projection and regional policies for forward looking (FL) RL projection. Regional policy data used for determining FL RL were spatial planning regarding green space and non-green space areas obtained from the spatial plan (RTRW) and the long-term regional development plan (RPJP) regarding compliance to fulfill green space area being 30% of the total area in both regions. Formula of RL was modified based on UN-REDD in Suryadi (2012) as mentioned in equations.

Three RL scenarios were as follow: 1) BAU RL based on historical data projection without considering future spatial and regional development plans; 2) FL1 RL based on combination of historical data projection and spatial and regional development plans in a pessimistic option (built up area increases by up to 20%); and 3) FL2 RL based on combination of historical data projection and spatial and regional development plans in an optimistic option (green space area increases by up to 20%). Land use change projection from 2013 to 2020 was conducted using forecasting method of Moving Average (MA) and validated by Mean Absolute Error (MAE). Formulas of forecasting, RL and land use change projections are as follow:

Fifth step was developing Low Carbon Development Strategies (LCDS) for the land use sector, which was conducted by analyzing the best RL scenario that can increase carbon storage or reducing carbon dioxide (CO_2) emission in both segments. This strategy was modified from Low Emission Development Strategy that was developed by Dewi, Ekadinata, Galudra and Johan (2011) by focusing on developing the strategies based only on the best RL scenario that increases carbon stock in both segments. Development of implementation strategies based on spatial analysis, best RL development that support reduced CO_2 emission/increased carbon stock, and problem-solving were related to the scenario target in site.

III. RESULT AND DISCUSSION

A. Land Use Change at 2nd Segment and 3rd Segment of Ciliwung Middle-stream Watershed during 1989-2012

Based on the processed land use maps of 1989, 2001, and 2012, green space areas were identified as natural forests, plantation forests, mixed plantations, dry land agriculture, paddy fields, and shrubs, whereas non-green space areas were identified as built up areas, barren lands, and water bodies. Natural forest in both segments was mostly found along the river banks which was dominated by jackfruit (*Artocarpus heterophyllus*), gandaria (*Bouea macrophylla*) and bamboo (*Asparagus* sp., *Gigantochloa* sp., *Bambusa* sp. and *Dendrocalamus* sp.). The forest crown covered approximately 40%-70% with canopy stratification range from A to E (from emergent trees to herbs and litters). Natural forest area was largely fragmented because of land clearing and death of trees. Plantation forest in both segments was mostly found near mixed plantation, dryland agriculture and settlement. Plantation forest is dominated by teak (*Tectona grandis*) and white albizia (*Falcataria mollucana*) owned by individuals and communities as

Table 2. Land use changes in 2nd and 3rd segments of Ciliwung middle-stream watershed from 1989-2012

Type of Land Use	1989 (ha)	2001 (ha)	2012 (ha)	Land use change from 1989-2001 (ha)	Land use change from 2001-2012 (ha)
Natural forests	1,035.09	487.71	404.73	-547.38	-82.98
Plantation forests	243.72	356.4	754.65	112.68	398.25
Mixed plantations	1,493.97	622.44	452.34	-871.53	-170.1
Dry land agriculture	3,249.07	2,672.83	1,297.62	-576.24	-1,375.21
Paddy fields	82.53	207.54	259.38	125.01	51.84
Built up areas	2,786.45	3,642.22	5,264.82	855.77	1622.6
Shrubs	527.40	1,458.7	887.49	931.30	-571.21
Barren lands	2.25	0.09	152.1	-2.16	152.01
Water bodies	162.63	135.18	109.98	-27.45	-25.2
TOTAL	9,583.11	9,583.11	9,583.11		

community forest (Hutan Rakyat-HR). Most of the plantation forests were planted with spacing from 1 m x 1 m to 3 m x 3 m, but they were also interspersed with fruit trees. Mixed plantations in both segments were dominated by banana (*Musa* sp.), coconut (*Cocos nucifera*), and mango (*Mangifera indica*) which was located near dryland agriculture, forest plantation, and river banks. Dryland agricultures in both segments were dominated by cassava (*Manihot utilissima*) and chili (*Capsicum annum*) which located near settlements and roads to facilitate the transportation of the crops. Paddy fields in both segments were dominated by rice but it turned to planted crops during fallow period.

Built up area in both segments consisted of settlements from medium to compact residential, schools, offices, factories, commercial and recreational areas that were often found near river banks. Compact residential area was mostly found in 2nd segment whereas in 3rd segment it varied relatively ranging from compact residential area near the commuter train track in Bojonggede and Cibinong to elite settlement in Cibenon. Schools, offices, factories, commercial and recreational areas were mostly found in downtown. Shrubs in both segments consisted of grassland, bushes and border highways. The widest area of shrubs was located in Sukaraja. Shrubs were dominated by reed, bulrush, and Bermuda grass.

Barren land in both segments was found near new settlement and construction areas of factories and stadiums. The largest barren land was located in Cibinong which was caused by land clearing to build Bogor Stadium. Water bodies consist of streams, lake, dam, and reservoir. Most of the green space area around lakes and reservoirs are turned into tourist sites, such as in Situ Cilodong. Cumulatively, land use change in both segments from 1989-2012 indicated a reduction of the green space area by 2,575.57 ha, whereas non-green space increased by 2,575.57 ha. Each land use area was obtained from the processing of Landsat images from 1989, 2001 and 2012 with overall classification accuracy of 80%, 80% and 95.04%, respectively. Table 2 shows land use changes in 2nd and 3rd segments of Ciliwung middle-stream watershed from 1989-2012.

From 1989-2001, the land use area has increased for shrubs, built up areas, paddy fields and plantation forests, whereas it has decreased for mixed plantations, dryland agriculture, natural forests, water bodies and barren lands. Increased area of shrubs was caused by construction of golf course and the fallow period of paddy and crops. Reduction of mixed plantation areas mostly occurred in Bojonggede district and Cibinong district, Bogor regency, caused by the changes in land use from plantation into crops and expansion of residential areas.

From 2001-2012, the increase in area has occurred for built up areas, natural forests, barren lands, and paddy fields, whereas it has decreased for dryland agriculture, shrubs, mixed plantations, natural forests and water bodies. Increase of built up areas drastically occurred in Bojonggede District and Cibinong District, Bogor Regency. Decreased dry land agriculture was caused by land conversion into built up areas and plantation forests. Bogor City and Bogor Regency was the main centre of tapioca starch production in Bogor District, which resulted in dry land farms in both segments which was dominated by cassava crops. The decrease in the dry land agriculture area was the main reason for the decline in production due to shortages of tapioca raw materials.

Residential, commercial, and supporting infrastructures were the causes of rural-urban linkages (Rustiadi, Saefulhakim & Panuju, 2009). Rural-urban linkages in both segments were highly affected by the mobility of the people working in the Jakarta-Bogor-Depok-Tangerang-Bekasi (Jabodetabek) area and living in Bogor City and Bogor Regency. Development of satellite towns which become a buffer area of Jakarta and Bogor has resulted in rapid increase of residential, commercial, industrial areas, and infrastructure. Improved road access and public transportation led to the development of suburban areas into urban areas, especially in Bojonggede, Cibinong, Northern Bogor, and Sareal Land. Demand for land for the development of the region in both segments led to the conversion of green space area to non-green space area. Figure 2 shows land use in 2nd and 3rd segments of Ciliwung middle-stream watershed.

B. Driving Factors of Land Use and Land Cover Changes in 2nd and 3rd Segments of Ciliwung Middle-stream Watershed

Land use and land cover changes were caused by three main driving factors namely: population growth, demand for land, and land constraint. These driving factors were interrelated. Population growth implies increased demand for land to meet basic needs. But increased demand for land was not followed by land use area expansion due to land constrain. This has

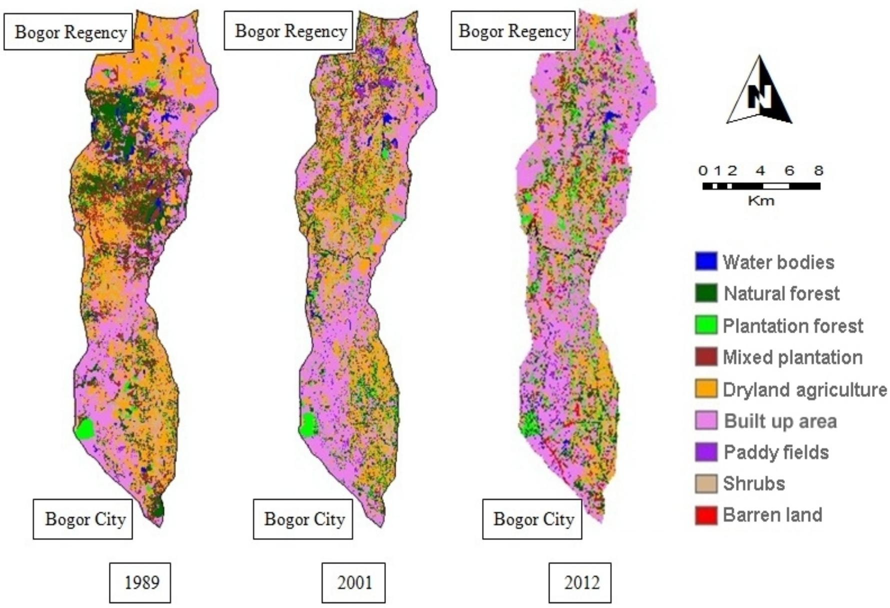

Figure 2. Land use in 2nd and 3rd segments of Ciliwung middlestream watershed

resulted in the conversion of green space area to accommodate the needs of non-green space areas, mainly to expand the built up area.

The first driving factor was population growth from 1990-2011. The population of 3rd segment increased from 246,200 people in 1990 to 371,934 people in 2012 whereas the population of 2nd segment from 205,505 people in 1990 to 466,870 in 2012. The total number of population in both segments has increased by 7.77% or 76,106 people from 1990-2001 but from 2001-2011 the population increased four times (31.75 % or 310,003 people). This matched with the West Java Province census data from 2010 (BPS West Java Province, 2010) that Bogor Regency had higher rate of population increase than Bogor City which was 3.15% compared to 2.40%. The rise of population growth led to increase of demand for land especially for residential-commercial-industrial areas and for infrastructures. Thuo (2013) stated that increased population in rural-urban fringe open new income opportunity in the service sector such as construction sector due to people's need for settlement especially for housing. .

Moniaga (2011) stated that one of the factors influencing population pressure on land was the people's livelihood structure. Employment changes of people occurred in both segments which were from jobs that required land such as agriculture and mining into jobs that required higher skills and education. It has indirectly affected people's activities in each land use. In 1990, agriculture and trade was still dominated in both segments that affected the expansion of the agricultural area of paddy fields and dry land agriculture because of the trade of food crops. People livelihood in 3rd segment mainly shifted from agriculture sector (37% of population) in 1990 to trade sector (30.43%) in 2012. People livelihood in 2nd segment mainly shifted from trade sector (64%) in 1990 to service sector (44%) in 2012. Livelihoods changes from 2001-2011 in agriculture and trade shifted to industry and services (banking and construction). The emergence of trade and service sectors caused land conversion from agriculture land use to build up area. Gyawali et al. (2013) stated that balancing rural-urban growth by establishing rural-urban business linkages was important so the urbanization effect like land conversion for urban sprawl can be reduced. Urban sprawl in both segments was caused by increased population and shifting livelihoods caused the expansion of built up areas for residential, commercial, and industrial purposes. The land conversion that occurred from 1989-2012, from green space area to built up areas amounted to 1,382.76 ha.

The second driving factor was increased demand for land along with the population growth in both segments. Based on the Regulation of the Minister of Environment No. 17/2009 on Guidelines for Determining Environmental Carrying Capacity in Regional Spatial Planning, land requirement calculation was based on the results of the calculation of land requirements for a decent life multiplied by the number of population. Area of land required for the necessities of life per person for decent living was divided by local rice productivities. Productivity of rice in Bogor Regency was 5,923 ton ha^{-1} $year^{-1}$, while in Bogor City it was 5,852 ton ha^{-1} $year^{-1}$. Decent living per people was assumed to be equivalent to 1 ton of rice/capita/year (stated assumption from MoE regulation No.17/2009). In 2011, demand for land in 3rd segment was 78,823.23 ha which was higher than in the 2nd segment where it was 63,556.73 ha. This was caused by the increased number of population who required land for basic needs, especially in the border areas between Depok City and Bogor City. Overshoot demand for land in both segments were 7 times from the actual area.

The third driving factor was land constraint. Increased demand for land from 1990-2011 exceeded the actual area in both segments. While land area in both segments from 1989-2012 was still the same which was 9.583,11 ha, but the demand in 2011 has reached 78.823,23 ha. So there was a deficit area of 69.240,12 ha. It can be concluded that both segments were

Table 3. Carbon stock and total CO_2eq emissions in each land use type at 2nd and 3rd segments of Ciliwung middle-stream watershed in 1989, 2001 and 2012

No.	Type of land use	1989	2001	2012
1.	Natural forests	115,102.01	54,233.35	45,005.98
2.	Plantations forests	35,336.96	51,674.44	109,416.70
3.	Mixed plantations	44,475.49	18,530.04	13,466.16
4.	Dry land agriculture	14,425.87	11,867.37	5,761.43
5.	Paddy fields	380.46	956.76	1.195.74
6.	Built up areas	6,966.13	9,105.55	13,162.05
7.	Shrubs	2,605.36	7,205.98	4,384.20
	Total ton C	219,292.27	153,573.48	192,392.27
	Total ton CO_2eq	804,802.64	563,614.67	706,079.62

dependent on the surrounding areas to meet the needs of the population living, mainly for food. Food supply in both segments was supported by the region of Ciliwung upstream or cross-regency such as Cianjur, Indramayu, Karawang and Subang. Those regencies were the biggest contributors of rice production in West Java.

C. Carbon Stock and CO_2eq Emissions in 2nd and 3rd Segments of Ciliwung Middle-stream Watershed

Carbon stock and CO_2eq emissions in 2nd and 3rd segments of Ciliwung middlestream watershed changed during 1989-2012. Both segments stored carbon up to 219,292.27 ton C in 1989, 153,573.48 ton C in 2001, and 192,392,27 in 2012. Despite enhancement of carbon stock from 2001-2012, the decline from 1989-2001 was still higher, cumulatively from 1989-2012 the carbon stock was reduced by 15,106 ton C. Table 3 shows carbon stock and total CO_2eq emissions in each type of land use at both segments of Ciliwung middle stream watershed in 1989, 2001 and 2012.

From 1989-2001, carbon stock reduction occurred in natural forests, mixed plantations, and dryland agriculture, whereas carbon stock increment occurred in plantation forests, paddy fields, built up areas, and shrubs. Reduction of natural forest's carbon stock in this period mostly happened in Bogor Regency. The increase in plantation forest's carbon stock was caused by the development of community forests in both segments. Plantation forest in both segments was mainly planted with fast-growing species white albizia (*Falcataria mollucana*) that influenced the increase of carbon stock in plantation forests.

Carbon stock increase in plantation forests was caused by the expansion of community forests. In this period, community forests in Bogor Regency and Bogor City expanded greatly due to its profitable market share. White albizia and teak became two dominant species in community forests in West Java including Bogor because of its ability to grow fast, easy access and wide open marketing (Rachman, Mile & Achmad, 2007). White albizia had a wide market share for raw materials for plywood, pulp and paper while teak had a market share for furniture and handicraft. In common community forest plantation was established by combining timber with crops or horticulture in the form of agroforestry (Hakim, Indartik & Suryandari, 2009). Timber species was planted without intersperse with crops or horticulture in community forests in both segments. In community forests in Cibinong, Bogor Regency, and Sareal Land, Bogor City, white albizia and teak was planted at a spacing of 3 m x 3 m and 4 m x 4 m with an average diameter ranging from 15-20 cm. Therefore, community forest's carbon stock in plantation forest was the highest carbon storage compared with other land uses.

Loss of 1 ton of carbon (ton C) equivalent to the release of 3.67 ton CO_2eq (Von

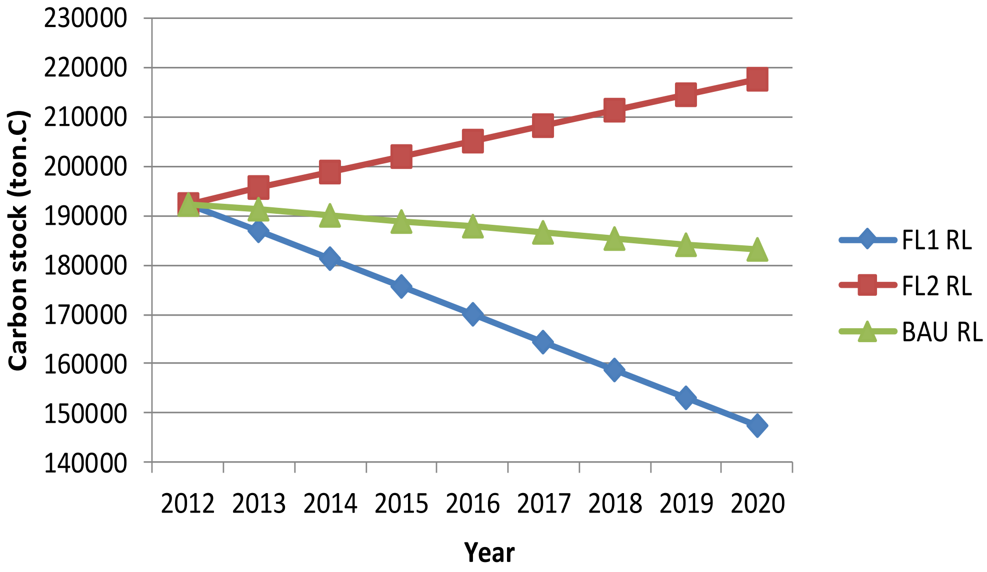

Figure 3. Reference Level projections in three Scenarios (BAU RL, FL1 RL, and FL2 RL) in 2nd and 3rd segments of Ciliwung middle-stream watershed

Mirbach, 2000). Accumulatively, from 1989-2001 the release of CO_2 emissions amounted to 241,188 ton CO_2eq which was caused by the loss of carbon stock in natural forests, mixed plantations, and dryland agriculture. Cumulatively from 1989-2012 the release of CO_2 emissions amounted to 98,723 ton CO_2eq. Whereas from 2001-2012 absorption of carbon amounted to 142,465 ton CO_2eq as a result of carbon stock enhancement in plantation forests, built up areas and paddy fields.

D. Reference Level Projections in 2nd and 3rd Segments of Ciliwung Middle-stream Watershed

Reference Level (RL) projections were determined by considering the changes in land use also carbon stock and CO_2eq emissions at both segments. Historical trends of land use were identified in the span of 8 years or until 2020. The projections focused on carbon stock changes caused by land use change activities from green space area into non-green space area and vice versa. Sub-national conditions were referenced from: 1) 20 year's spatial plan i.e. RTRW Bogor Regency 2005-2025 and RTRW Bogor City 2011-2031; 2) 20 year's regional plan i.e. RPJPD Bogor Regency 2005-2025 and RPJPD Bogor City 2005-2025. Based on these documents, Bogor Regency and Bogor City planned to meet the compulsory allocation of green space area of up to 30% of total area until 2025. Both regions have a green space area of about 10% of the total regional area. Therefore, for this analysis it was assumed that at sub-national (Bogor Regency and City) level planning the green space area should be increased by 20%.

In 2020, it will be evaluated how much of the achievement of GHG emission reduction on BAU conditions and how far the target of the 26% emission reduction of RAN GRK has been achieved. From the projections of land uses in 2020, the types of land use areas that reduced will be: natural forests (185.47 ha), mixed plantations (90.03 ha), dry land agriculture (618.85 ha), and water bodies (91.95 ha). Whereas the types of land uses that increase will be: plantation forests (932.36 ha), paddy fields (320.89 ha), built up areas (6,126.86 ha), shrubs (1,012.17 ha) and barren lands (204.37 ha).

Reference level projections were done by using three scenarios namely: BAU RL, FL1RL, and FL2 RL. Those scenarios were developed from projecting historical data of carbon stock and land use changes during 1989-2012, and has been projected 8 years forward or until 2020. The MAE error rate of historical data was 0.0267. It could be concluded that the forecast accuracy of the historical data was 97.33%. Figure 3 shows RL projections based on three scenarios, namely BAU RL, FL1 RL, and FL2 RL until 2020 in both segments.

In BAU RL scenario, carbon stock and CO2eq emissions until 2020 remained the same as the carbon stock history from 1989-2012 without considering spatial plan and regional plan in both segments. The BAU RL projection results showed a decrease in carbon stock by 1,169.57 ton C/year. So the BAU condition in both segments indicated that the total carbon stock stored was estimated at 183,035.7 ton C in 2020 or 9,356.57 ton C deficit from 2012. Carbon storage reduction in the BAU scenarios is also stated in Wohl, Dwire, Sutfin, Polvi and Bazan (2012) that historical changes in riverine complexity have likely reduced carbon storage in mountain's headwater rivers in Rocky Mountain National Park, USA.

In FL1 RL scenario, the assumption used in 2020 was an increase in the built up areas up 20% from 2012. Based on the documents of the spatial plan and regional plan, regional development strategies such as residential areas and infrastructure will be improved to develop new regional growth centers in remote areas. Pessimistic scenarios development was that the development in Bogor City and Bogor Regency will result in the decrease of green space in both regions. In FL1 RL projection, a decrease of green space area resulted in carbon stock reduction by 5,626.52 ton C year^{-1}. If this occurred, in 2020 both segments will store 147,380.10 ton C or 45,012.17 ton C deficit from 2012.

In FL2 RL scenario, the assumption used in 2020 was an increase in green space area up to 20%. Both regions considered to implement policy of allocating up to 30% of green space areas of the total regional area. Four basic strategies used for FL2 RL scenario, that is both regions were capable to optimize the utilization of vertical space, developing green space areas of up to 30%, limiting the development of the built up areas in urban centres by reducing the area by 5%, and maintain the function of the surrounding rural areas. In FL2 RL scenario it was estimated that there will be an increase in green space area that results in the increase of carbon stock by 3,152 ton C year^{-1}. If this occurs, in 2020 both segments were estimated to store 217,610 ton C carbon or a surplus by 25,218 ton C from 2012. From the three scenarios it can be concluded that FL2 RL is the best option for developing LCDS.

E. Low Carbon Development Strategies for Land Use Sector in 2nd Segment and 3rd Segment of Ciliwung Middle-stream Watershed

Low carbon development strategies (LCDS) for land use sector of Ciliwung middlestream watershed was developed based on analysis of policies and regulations related to existing conditions and the best RL scenario that can increase carbon stock. Forward looking optimistic scenario (FL2 RL), was the best projection that can significantly reduce carbon emission by increasing the green space area to 20%. In accordance with the authorities of the regency/city to support national program for reduction of GHG emissions, both governments of Bogor Regency and Bogor City are responsible for the implementation of GHG emission reduction, application of relevant policies, stakeholder consultations, and also have policies in place to support the plan to increase green space and control the utilization of Ciliwung watershed area. Policy analysis for the reduction of carbon emissions in 2nd and 3rd segments of Ciliwung middle-stream watershed is presented in Table 4.

The results of FL2 RL projection which support the reduction of CO_2 emissions and increase carbon stock were consistent with the result of the policy analysis. Implementation strategy was based on the development options

Table 4. Policy analysis for the reduction of carbon emissions in 2nd and 3rd segments of Ciliwung middle-stream watershed

RL scenario	Supportive existing policy options	Non-supportive existing policy options	Strategies/policies needed	Follow-up plan
Additional green space area up to 20%	1. Green space area allocation up to 30% at regency/city in UU No. 26/2007 about Spatial Planning. 2. Article 40 about land use control in catchment area in PP No. 37/2012 about Watershed Management. 3. Bogor as a water catchment area in Keppres No. 114/1999 about Regional Spatial Planning in Bogor-Puncak-Cianjur. 4. Government affairs division between government, provincial government, and local government about PP No. 38/2007. 5. Guidelines for provision and utilization of green space in urban areas about PermenPU No. 05/PRT/M/2008. 6. Green space area allocation and land use control in Perda Kabupaten Bogor No. 19/2008 about Bogor Regency Spatial Planning; Perda Kota Bogor No. 8/2011about Bogor City Spatial Planning; Perda Kabupaten Bogor No. 27/2008 about Bogor Regency RPJPD 2005-2025; Perda Kota Bogor No. 7/2009 about Bogor City RPJPD 2005-2025. 7. Guidelines for construction of private green space in residential areas and procurement of land acquisition and supporting components for public green space area in the document resume of West Java Regional Action Plan for GHG Reduction.	1. Inconsistency in the application of spatial planning in the field in Bogor Regency and Bogor City, especially for the control of built up areas development on river banks. 2. Violations of building permits about establishment of spatial planning policy in Bogor Regency and Bogor City. 3. Green space area addition had not been implemented in Bogor Regency and Bogor City.	1. Harmonization of the implementation of regency/city spatial plans on the ground. 2. Legal prosecution for violators of site plan and building permit in the regency and city, especially built up areas on river banks. 3. Relocation of settlements that are located at river banks. 4. The realization of additional green space area.	1. Control of land use to restore it according to its function (in green space area and non-green space area). 2. Accelerate the realization of additional green space areas as planned by local governments in both regions.

of the green space area and non-green space area. Low carbon development strategy aimed at adding green space area up to 20% through implementation of strategies based on type of green space area and non-green space area.

Implementation strategies of green space area consist of: protection, control, extension/awareness rising, and enforcement. Protection strategies will be implemented through conservation of the remaining natural forests in Ciliwung middlestream watershed, preserving existing public green space, and optimization of green space by planting tree species with higher carbon sequestration. Control strategies will be implemented by strengthening monitoring and evaluation of land use and land use changes. Extension/awareness rising strategies will be implemented by awareness rising and providing

Table 5. Low carbon development strategy for land use sector in 2nd and 3rd segments of Ciliwung middle-stream watershed

Type of land use	Scenario options	Problems	Implementation strategy
1. Green space area (consisting of natural forests, plantation forests, mixed plantations, dry land agriculture, and paddy fields)	1. Limiting the land conversion from green space area to non-green space area 2. Adding public and private green space area 3. Supporting the development of community forests and agroforestry 4. Planting species of tree with higher carbon sinks especially in public green space area (ex: *Samanea* sp. and *Cassia* sp.)	1. Population growth 2. Land constraint 3. Increased demand for land for built up areas The area of the existing green space is only 10% from the minimum target of 30%	1. Suggest to conserving the remaining natural forest area in Ciliwung middlestream watershed and maintain existing public green space. 2. Optimize existing public green space by planting species of trees with higher carbon sinks. 3. Strengthen monitoring and evaluation of land use control and land use change. 4. Improve socialization and incentives from local governments and the private sector to the public to support addiing of public/private green space. 5. Support community agroforestry and community forests through incentives. 6. Law enforcement
1. Non-green space (built up areas, barren lands, and water bodies)	1. Encouraging for residential green clusters 2. Limiting the land conversion of potential lands for green space area 3. Confirming that developers will build or have built for providing green space area 4. Legal action against violations of spatial rules, especially hoarding or narrowing the river to build residential-commercial-industrial areas	1. Land conversion to built up areas 2. The lack of monitoring and control of the spatial plan in the field 3. Frequent flooding and landslides in the river banks settlements	1. Engage social communities and community leaders in the socialization of Ciliwung watershed management. 2. Submit a proposal to build a public green space such as parks in dense and/or moderate settlements. 3. Provide relocation of residents from land acquisition, especially for people living on river banks. 4. Law enforcement for violators of spatial rules and building permits.

incentives for people to add public/private green space areas, and development of agroforestry and plantation forests. Enforcement strategies will be implemented by strict action against violations of the spatial law through letters of reprimand to the prosecution.

Implementation strategies on non-green space area consist of: extension/awareness raising, incentives, and enforcement. Extension/awareness raising strategies will be implemented by inclusion of social community and community leaders in socialization and management of both segments. Incentives strategies will be implemented by providing budget for adding green space area in new locations, relocation of residents whose lands have been redeemed for green space development and supporting infrastructures. Enforcement strategies will be implemented by strict action against violations of the spatial law through letters of reprimand to the prosecution. Low carbon development strategies on land use sector in both segments are summarized in Table 5.

IV. CONCLUSION

Land use change in 2nd and 3rd segments of Ciliwung middle-stream watershed from 1989-2012 indicated that reduction of green space area was caused by the increased population and land demand. The reduction of green space area from 1989-2012 accumulatively resulted in the reduction of carbon stock by 15,106 ton C. But the increase of green space area and carbon stock enhancement from 2001-2012 resulted in increased community forest and public green space areas in both segments which have the potential to support mitigation strategies for spatial arrangements especially in catchment areas.

By projecting the Reference Level of both segments with three options, namely: BAU, FL1 RL (forward looking, pesimistic scenario) and FL2 RL (forward looking, optimistic scenario), it was concluded that the best RL projection was the forward looking, optimistic scenario option by adding green space area up to 20% with an estimated carbon storing of 217,610 ton C or a surplus of 25,218 ton C from 2012. The best projection was used to develop LCDS in both segments. The LCDS aimed at adding green space up to 20% through the implementation of the strategies based on the type of green space area and non-green space area. Implementation strategies of green space area consist of protection, control, extension/awareness rising, and enforcement. Implementation strategies of non-green space area consist of extension/awareness raising, incentives, and enforcement.

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