Land Use/Cover Change in the Central Luzon Plain and Its Surroundings in the Philippines since the 1950s

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フィリピン共和国中部ルソン平野および周辺地域の1950年代以降の土地利用変化
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要旨

SLUAS (基盤研究S「アジアにおける持続可能な土地利用の形成に向けて」、氷見山幸夫代表)の一環として、火山噴火や台風などの災害が多く、人口増加の著しいフィリピン共和国ルソン島の中部ルソン平野およびその周辺地域を対象に、1950年代以降の土地利用・土地被覆変化を明らかにし、その特徴と問題点を探った。中部ルソン平野は国の農業を支える重要な地域であり、人口増加の著しい地域でもある。また、テキサス大学オースティン校ベリー・カスタナダ図書館がウェブで公開しているフィリピン25万分1地形図を用いて、1950年代の土地利用図を作成した。次に、2013年9月に実施した現地調査の折に購入したNational Mapping and Resource Information Authorityのフィリピン5万分1地形図で2000年頃の土地利用図を、Google Mapの衛星画像と現地調査で得た情報から2010年頃の土地被覆図をそれぞれ作成した。これらの地図と現地調査で撮影した数千枚の位置情報付き写真を主な情報源として、研究を進めた。その結果、中部ルソン平野およびその周辺地域では1950年代以降、農業的土地利用および都市的土地利用が著しく拡大し、森林が減少していること、首都マニラでは急速に都市化が進んでいるが、環境衛生面の問題や貧富の格差が目立つこと、また、1991年にピナツボ火山が大噴火した際大量に流れ出た泥流の跡が現在も生々しく残り、避難生活を余儀なくされている人々がいることなどを確認した。

Keywords: the Philippines (フィリピン), Central Luzon Plain (中部ルソン平野), land use change (土地利用変化), land cover change (土地被覆変化), Global Land Project (GLP), Land Use/Cover Change Programme (LUCC)
1. Introduction

The present study is on the land use changes and the related issues in the Central Luzon Plain in Luzon Island, the Republic of the Philippines. The Philippines is one of the countries in South East Asia which became independent after World War II. It is a member of ASEAN, or the Association of South East Asia Nations. The Central Luzon Plain is the largest plain in Luzon Island, and is as large as 11,000 km². It is the main agricultural base of the country, and is undergoing rapid change of land use. The Philippines suffers from frequent natural disasters such as volcanic eruptions, earthquakes, and typhoons. They are often related with land use, and hence land use research should be of high priority. The present study is part of the SLUAS Project, or 'Towards Sustainable Land Use in Asia Project (2009-2014). The field survey was conducted in September 2013, and the main information sources of land use are i) 1:250,000 topographic maps of the 1950s supplied by Perry-Castaneda Library, the University of Texas at Austin; ii) 1:50,000 topographic maps of ca. 2000 provided by NAMRIA (=National Mapping and Resource Information Authority) of the Department of Environment and Natural Resources; iii) and the satellite images of ca. 2010 supplied by Google Map.

2. Study Area and Method

2.1 Study area

Fig.1 shows two different study areas, namely study areas S1 and S2. Study area S1 is the area covered by the land use maps of the 1950s and ca. 2010, while study area S2 is the area covered by the land use map of ca. 2000, which fits inside S1. Luzon is the largest island in the Philippines, and it occupies 104,688 km², or 35% of the country. In the north of Luzon is Cordillera Central, which is a massive mountain range situated in the northern central part of the island of Luzon, while in the west is the Zambales Mountains and in the east is the Sierra Madre Mountains. The Central Luzon Plain is as large as 11,000 km², and it is known as the largest rice production area of the country. It supplies rice and other agricultural products to Manila Metropolitan Area and the surrounding areas. The area of the Philippines is 299,404 km², i.e. about 80% of Japan, and the population is 96,707,000 (2012 National Census). Fig.2 shows the population trend of the country since 1950, while Fig.3 shows that of Manila. The study area includes the Central Luzon Plain and its surroundings. The field survey was conducted in September 2013 in order to get an extensive view of the study area. It includes Manila Metropolitan Area, Central Luzon District, Pangasinan State in Ilocos Region, Benguet State in Cordillera Administrative Region. The main cities are Manila, San Fernando, Angeles, Tarlac and Baguio. The first day was mainly for purchasing topographic maps at the NAMRIA map office. The second day was for a survey from Manila to Angeles and to the areas close to Mt. Pinatubo. The third day was for a long survey to Baguio. The fourth day was for the return journey to Manila.

2.2 Method

Land use of the three periods, namely that of the 1950s, ca. 2000 and ca. 2010, are reconstructed as follows:

1) Data files based on the 1:250,000 topographic maps of the Philippines, 1950s

1:250,000 topographic maps of the Philippines representing land use of the 1950s provided by Perry-
Fig.1  Survey route and study areas  
Source: Google Map, 2014

Fig.2  Population trend in the Philippines  

Fig.3  Population trend in Metro Manila  

Fig.4  1:250,000 topo map area, in the 1950s  
Source: University of Texas Perry Castaneda Library (2014)
Castaneda Library, the University of Texas at Austin, have been used to construct land use data files of the 1950s. This map series was made during ca. 1940-1960 by the U.S. Army Map Service (AMS) with the help of the Ordnance Survey of UK and other map agencies. The library has a rich archive of various maps in the world including topographic maps and census maps (Perry-Castaneda Library Map Collection, 2014). The topographic maps have been downloaded from the Library website, and are coloured directly on the computer display according to land use types by using Photoshop CS4. The topographic map has rich information on land use with detailed land use categories, and delineation of land use boundaries is fairly easy. The resultant map is regarded as a land use map of the 1950s. The area size of each land use type can be calculated by using the 'histogram' function of Photoshop (Himiyama & Abe, 2010). Fig.4 is the area covered by the 1:250,000 topographic maps, and the yellow maps are those used in the present study.

2) Data files based on the 1:50,000 topographic maps of NAMRIA, ca. 2000

The 24 sheets of 1:50,000 topographic maps covering the study area S2 were directly obtained at the NAMRIA map office in Manila. They were digitized as follows:

a. Each map sheet is .25 degree N-S and .25 degree E-W in size. It is divided into 24×24 grid squares. Each unit cell is approximately 1.1 km×1.15 km in size. (Fig.5)

b. Land use information is read and recorded for each grid cell according to the land use classification and the designated code numbers in Table 1.

c. The data files corresponding to each map sheet are put together in a single file with unified coordinates.

d. BASIC/98 is used to make various maps and to calculate areas of each land use type.

3) Data files based on the satellite image by Google Map, ca. 2010

The Japanese version of Google Map, which was started in 2007, has been used to reconstruct land use of ca. 2010. In order to cover the same area covered by the 1:250,000 NAMRIA topographic maps, 106 scenes of 15 km×26 km satellite images have been downloaded from Google Map and coloured on the computer display by using Adobe Photoshop CS4. The colour key is as follows:

- settlement ........... red
- agricultural land... yellow
- forest ............... green
- water ............... blue
- other ............... grey

Land use of each place is identified by enlarging the image on Google Map aided by Google Earth, and by comparing them with the numerous geo-referenced photographs taken on the field by using NIKON's View NX2 software. The process is schematically shown in Fig.6. The coloured 106 scenes are then put together to make a contiguous map of the study area S1. In this way, various maps have been produced by setting different conditions. The areas of each land use type have been calculated by using the histogram function of Adobe Photoshop (Himiyama & Abe, 2010; Himiyama, Kasai, Yabe, 2012).

3. Land Use/Cover, General

The land use maps of the three time periods, namely the 1950s, ca. 2000 and ca. 2010, are now compared
Table 1  Land use classification of 1:50,000 maps

<table>
<thead>
<tr>
<th>Map symbol</th>
<th>Land use</th>
<th>Code number</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy field</td>
<td></td>
<td>10</td>
<td>Yellow</td>
</tr>
<tr>
<td>Dry field</td>
<td></td>
<td>11</td>
<td>Orange</td>
</tr>
<tr>
<td>Orchard</td>
<td></td>
<td>13</td>
<td>Pink</td>
</tr>
<tr>
<td>Forests</td>
<td></td>
<td>20</td>
<td>Green</td>
</tr>
<tr>
<td>Mangrove</td>
<td></td>
<td>23</td>
<td>Gold</td>
</tr>
<tr>
<td>Tropical grass</td>
<td></td>
<td>25</td>
<td>Light green</td>
</tr>
<tr>
<td>Settlement</td>
<td></td>
<td>30</td>
<td>Red</td>
</tr>
<tr>
<td>Road</td>
<td></td>
<td>40</td>
<td>Red</td>
</tr>
<tr>
<td>Sand</td>
<td></td>
<td>61</td>
<td>Purple</td>
</tr>
<tr>
<td>Lahar</td>
<td></td>
<td>62</td>
<td>Brown</td>
</tr>
<tr>
<td>River</td>
<td></td>
<td>63</td>
<td>Blue</td>
</tr>
<tr>
<td>Swamp</td>
<td></td>
<td>64</td>
<td>Light blue</td>
</tr>
<tr>
<td>Pond</td>
<td></td>
<td>65</td>
<td>Blue</td>
</tr>
</tbody>
</table>

Fig. 5  1:50,000 topo map (ca. 2000)
Source: NAMRIA

Fig. 6  Process of producing land use map from Google satellite image (ca. 2010)
(a) Satellite image before painting
(North part of Laguna De Bay)
(b) On larger scale
(c) Satellite image after painting
and land use changes examined with the help of thousands of photographs taken in the field survey. The study area S1 is the whole area covered in the present study, while the study area S2 is the area covered by the 1:50,000 NAMRIA map which occupies part of the area S1 (Fig.1). The area S1 is 33,118 km², and the area S2 is 17,487 km² according to the area measuring tool of Google Earth.

3.1 Land use in the 1950s

Table 2 and Fig.7 show land use in the study area S1 located in the Central Luzon Plain and its vicinity in the 1950s. The plain area is dominated by 'rice paddy', and is sandwiched by the mountain ranges covered largely by forest. Forest occupies 59% of the area in the 1950s. Agricultural land occupies 34.6% of the area S1, and much of the agricultural land in the Central Luzon Plain is paddy field. Settlement occupied only 1.3%, indicating the region’s then predominant rural character. In the 1950s sizable urban areas were quite limited, and even such major cities as Tarlac, Angeles, San Fernando, Cabanatuan, and Baguio were still quite small.

The population of the Philippines in 1945, i.e. at the end of the Second World War, was about 18 million (Fig.2), and about 150,000 km², i.e. half of the country total, was covered by forest (Dugan, 2000). The country largely belongs to tropical monsoon climate, and the vegetation in the lowland is mainly tropical deciduous forest, while the highland is mountain evergreen forest. Fig.7 shows 'mangrove' and 'nipa' on the Manila Bay coast. Forest occupied some 170,000 km² in 1934 and 157,000 km² in 1945, i.e. more than half of the country, but it declined rapidly, particularly from the 1960s, due to large scale felling, mining, and slash-and-burn agriculture (Forest Partnership, 2014).

3.2 Land use in ca. 2000

Fig.8 is the general land use map of ca. 2000, which shows the largest land use type in each grid square. The topographic map series fails short of covering the whole area of S1, so that the area covered by the available 24 map is named study area S2. The figure shows widespread 'rice paddy', 'cultivated land' and 'orchard' in the Central Luzon Plain. Settlement is dominant in the National Capital Region and in the whole plains area. The population of the country in ca. 2000 was 77.6 million (Fig.2), and about 25% of it lived in area S2 in ca. 2000, with half of it in the National Capital Region (National Statistics Office, 2014).

<table>
<thead>
<tr>
<th>Land use/cover</th>
<th>1950s</th>
<th>ca.2010</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>km²</td>
<td>%</td>
</tr>
<tr>
<td>Water</td>
<td>968.5</td>
<td>3.0</td>
</tr>
<tr>
<td>Urban</td>
<td>480.5</td>
<td>1.3</td>
</tr>
<tr>
<td>Forest</td>
<td>19539.6</td>
<td>59.0</td>
</tr>
<tr>
<td>Mangrove</td>
<td>17188.1</td>
<td>51.9</td>
</tr>
<tr>
<td>Tropical grass</td>
<td>662.3</td>
<td>2.0</td>
</tr>
<tr>
<td>Agricultural</td>
<td>11458.8</td>
<td>34.6</td>
</tr>
<tr>
<td>Paddy field</td>
<td>9471.6</td>
<td>28.6</td>
</tr>
<tr>
<td>Other</td>
<td>685.4</td>
<td>2.1</td>
</tr>
<tr>
<td>Total</td>
<td>33117.8</td>
<td>100.0</td>
</tr>
</tbody>
</table>
Rivers and lakes are found in the north of the Manila Bay and Laguna de Bay to the south-east of the NCR. The water surface along the Manila Bay and Lingayen Gulf are mostly "fish pond" according to the map.

In study area S2 agricultural land occupies 48.3%, and 80% of it is paddy field (Table 3). Since the 1950s agricultural land increased 1.6% from 46.8%, and settlement also increased for 6.8%. On the other hand, forest decreased from 39.7% (1950s) to 32.1% (ca. 2000), giving way mainly to settlement and agricultural land.

### 3.3 Land cover in ca. 2010

Fig. 9 shows land cover of the Central Luzon Plain and its vicinity in ca. 2010. There is by far the largest concentration of settlement, i.e. red colour, at the National Capital Region. It is around 50 km long north-south. Other sizable concentration of settlement includes San Fernando, Angeles, and Tarlac in the Central Luzon Plain, and Baguio in Cordillera Administrative Region. Settlement occupies 1,490 km² (4.5%) in S1 (Table 2), of which 638 km² belongs to the National Capital Region (National Statistics Office, 2014). Agricultural field in the Central Luzon Plain is quite large. Apart from it there are smaller but none-the-less important agricultural areas, such as the western coast of Zambales Mountains, the coast of Lingayen Gulf, and mountain areas in the north-east region. Agricultural area occupies 13,313 km² (40.2%) of study area S1.

Forest is losing its ground to settlement and agricultural land, but it still occupies 16,658 km² (50.3%) of area S1, and is the largest type of land cover. It is predominant in the Zambales Mountains in the west, Cordillera Central in the north, Sierra Madre Mountains in the east. Water surface is mainly seen on the coastal area of Manila Bay. Many of them are located to the north of the Bay, and are mainly used as 'fish pond'. Other land includes rough land, rocky land, sandy land, and mud flow called 'Lahar'.

Study area S2 is now used to compare three time periods, namely the 1950s, ca. 2000 and ca. 2010 (Table 3). Agricultural land shows constant increase, but the increase of 577 km² since ca. 2000 is notable. Forest decreased for more than 10% in area S2 during the 1950s - 2010 (Table 3). The decrease of forest is evident in the east, particularly to the east of 121°E in Nueva Vizcaya State (Fig.7, Fig.8, Fig.9). On the other hand, agricultural land increased for 840 km² and settlement increased for 1,311 km² in area S2.
Fig. 7  Land use in the Central Luzon Plain and Its Surroundings in the 1950s
(Based on 250,000 topographic maps)

Fig. 8  Land use in the Central Luzon Plain and Its Surroundings in ca. 2000
(Based on 50,000 topographic maps)

Fig. 9  Land use in the Central Luzon Plain and Its Surroundings in ca. 2010
(Based on Google satellite images)
The population of Study area S1 in 2010 was about 25,300,000, which was 26% of the total population (National Statistics Office, 2014). Settlement is predominant in the National Capital Region in 2010. The population of Metro Manila is about 11.5 million (Fig.3). The population of the National Capital Region increased for 2 million during 2000 - 2010. There are many tall buildings and construction sites of motorways and underground, and they are changing the townscape of Manila. However, old and congested areas are still prevalent, and some areas have poorer environment which may be classed as slum.

4. Agricultural Land Use

4.1 Agricultural land use in the 1950s

Fig.10 shows the distribution of agricultural use of land in the 1950s based on the 1:250,000 topographic map. The Central Luzon Plain was already a major agricultural area. Nearly 90% of agricultural land was paddy field. Agricultural area was also found in and around National Central Region and the present Manila Metropolitan Area on the eastern coast of Manila Bay was still largely agricultural. 34.6% of study area S1 is agricultural (Table 2). The yellow part of Fig.10 is largely the plain area, and it was dominated by paddy field. The Green Revolution of rice came to the Philippines in the middle of the 1970s, and in the late 1970s self-sufficiency of rice was achieved. The Philippines briefly became an exporter of rice around 1980, but since the middle of the 1980s it became an importer of rice again mainly because of rapid population growth (Umehara, 1994).

4.2 Agricultural land use in ca. 2000

Fig.11 is the dominant-existent map of agricultural land which includes paddy field, dry field and orchard in ca. 2000. The dominant cells are numerous and wide spread, while existent cells are limited and around urbanized areas and in the mountainous areas surrounding the Central Luzon Plain. Most of the agricultural land is still ‘rice paddy’ (79%) dry field and orchard are gradually increasing (Table 2).

Comparing Fig.11 with Fig.10, which shows the situation of the 1950s, the increase of agricultural land is remarkable. It is particularly obvious in the area east to 121°E. However, some decrease is seen in and around National Central Region due to urbanization.

Agricultural land covers 48.3% of study area S2, and it means 262 km² increase since the 1950s (Table 3). The crop production in the Philippines was 5,176,370 t in 1961 and 16,900,660 t in 2000, i.e. tripled (World Data Atlas, 2014). It coincides with the sharp increase of agricultural land in the Central Luzon Plain.

Table 4 Agricultural land use in Central Luzon in 2010

<table>
<thead>
<tr>
<th>Cultivated land</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Paddy field</td>
<td>82.72</td>
</tr>
<tr>
<td>Dry field</td>
<td>10.56</td>
</tr>
<tr>
<td>Orchard</td>
<td>4.77</td>
</tr>
<tr>
<td>Other</td>
<td>2.01</td>
</tr>
<tr>
<td>Total</td>
<td>100.00</td>
</tr>
</tbody>
</table>

Source: Philippines Bureau of Agricultural Statistics (2014)
4.3 Agricultural land cover in ca. 2010

Fig.12 shows the distribution of 'agricultural land' in ca. 2010. The increase of 'agricultural land' in the Central Luzon Plain and the surrounding areas, such as in the coastal areas to the west of the Zambales Mountains, the coastal areas of Lingayen Gulf, and the mountainous areas in the north-east. 40.2% of study area S1 is covered by agricultural land, occupying 13,313 km² (Table 2). According to Table 4, 'paddy field' occupied 82.72%, dry field 10.5%, and orchard 4.77%. Main crops of dry field are corn and sugar cane, and main fruits are bananas, pineapples, and mangos. Photo. 1 is paddy field in the Central Luzon Plain, Photo. 2 shows sugarcane field, and Photo. 3 shows bananas and paddy field in the Central Luzon Plain.

In study area S2, agricultural land occupies over 50% in ca. 2010, showing the increase of 577 km² since ca. 2000. This is a big increase. Agriculture is common not only in the plains area but also mountain areas. Photo.4 is paddy field in Cordillera Central. The Philippines is the largest importer of rice, and the government is keen on increasing rice production by the Rice Self-sufficiency Plan (JETRO, 2013).

5. Forests

5.1 Forests in the 1950s

Fig.13 shows the distribution of forest in the 1950s based on the 1:250,000 topographic map. 59.0% (19,539 km²) of study area S1 is forest (Table 2). Even in the 1950s, the Central Luzon Plain and National Capital Region had only very few forests, and forest was mostly found in the mountains such as Zambales Mountains, Cordillera Central and Sierra Madre Mountains surrounding the Central Luzon Plain. According to Dugan (2000), some 50% of the Philippines was covered by forest.

5.2 Forests in ca. 2000

Fig.14 shows the distribution of forest in ca. 2000, with dominant cells in green and existent cells in yellow. Forest surrounds the Central Luzon Plain and at the volcanic area surrounded by the Plain. Forest occupies 32.1% (5,613 km²) in area S2, which is next to agricultural land (Table 3).

However, forest in S2 decreased from 39.7% in the 1950s to 32.1% in ca. 2000, i.e. 1,323 km² decrease by giving way to agricultural development or urbanization (Fig.7, Fig.8). The population of the Philippines in 1945 was about 18,000,000 (Fig.2) and about 50% (150,000 km²) of the country was covered by forest. The population increased to 75,000,000 by 2000, while forest cover decreased to 57,000 km². In other words, the country's population increased for 400%, while forest decreased for 65% (Dugan, 2000). Decline in forest since the 1950s has been very fast, indeed.

5.3 Forests in ca. 2010

Fig.15 is the forest map produced by colouring Google Map satellite image. Forest is declining due to enlargement of agricultural land and expansion of settlements, but it still dominates the mountains surrounding the Central Luzon Plain. It occupies 50.3% (16,658 km²) of study area S1 (Table 2). Photo.5 is the forest in Cordillera Central, where small scale agricultural lands and rural settlements and towns were found among the mountains as high as 1,500m.

In study area S2, 27.6% (4,826 km²) is forest in ca. 2010, meaning decline since the 1950s (Table 3). The decline since ca. 2000 was 786 km², which is considerably large. Comparison of Fig.15 with Fig.13 also
Photo. 1 Paddy field in the Central Luzon Plain
14° 56'N  120° 46'E

Photo. 2 Sugarcane field in the Central Luzon Plain
15° 41'N  120° 34'E

Photo. 3 Banana and paddy near Mt. Pinatubo
15° 21'N  120° 30'E

Photo. 4 Paddy field in Cordillera Central
16° 17'N  120° 28'E

Photo. 5 Forests in Cordillera Central
16° 22'N  120° 33'E

Photo. 6 Manila City
14° 33'N  121° 1'E
Photo 7 Building under construction, Manila City
14° 34' N  121° 02'E

Photo 8 Working by the road side, Manila
14° 32' N  121° 01'E

Photo 9 Cleaning at the coast of Manila Bay
14° 34' N  120° 58'E

Photo 10 Suburb of Baguio City
16° 23' N  120° 34'E

Photo 11 Fish pond in the north of Manila
15° 00' N  120° 44'E

Photo 12 Mud flow called 'Lahar' near Mt.Pinatubo
15° 16' N  120° 36'E
Fig. 13  Forests in the 1950s
(Based on 250,000 topographic maps)

Fig. 14  Forests in ca. 2000
(Based on 50,000 topographic maps)

Fig. 15  Forests in ca. 2010
(Based on Google satellite images)
suggests the decrease of forest in the mountain areas. The decrease is particularly visible in the area east to 121° E. In addition to the agricultural development and urban expansion, large scale felling starting in the 1960s, mining, shifting cultivation and commercial forest development are considered to be responsible for the reduction of forest (Forest Partnership, 2014).

6. Settlement

6.1 Settlement in the 1950s

Fig.16 shows the distribution of settlement in the 1950s. Manila is seen near the south-east corner of the map. It was only about 5 km wide in the 1950s. Other major cities such as Angeles, Tarlac and Baguio were also quite small, but never the less they were recognizable. Some 26 towns are identifiable on the map. Only 1.3% (430 km²) of study area S1 was settlement.

6.2 Settlement in ca. 2000

Fig.17 shows the distribution of settlement in ca. 2000, with dominant cells in red and existent cells in yellow-green. Expansion of main cities such as Manila, Angeles and Tarlac is particularly rapid (Fig.3). It is also noted that settlement is distributed extensively all over the plain and co-exist with agricultural land side by side. Settlement occupies 10.3% (2,273 km²) of study area S2 (Table 3). Settlement in area S2 increased for 1,661 km² since the 1950s, mainly due to the expansion of the National Capital Region and other large cities in the Central Luzon Plain.

6.3 Settlement in ca. 2010

Fig.18 shows the distribution of settlement in ca. 2010. Settlement shown in red is large and clear in the National Capital Region. It is scattered, but numerous in the Central Luzon Plain, and there are linear stretches connecting red nodes which correspond to regional nodal cities. Baguio located in Cordillera Central is easy to identify in the map. Settlement occupies 4.5% of study area S1 (Table 2).

Manila has over 10 million residents (Fig.3). There are many high rise buildings and still more are under construction (Photo.6, Photo.7). On the other hand, there are many shanty areas along the rivers or elsewhere. There are people selling many sorts of things on the streets (Photo.8). There are beaches on the coast of Manila Bay, but they and the sea water are both badly polluted with garbage and other pollutants (Photo.9).

Angeles is the largest city in the area hit by the eruption of Mt. Pinatubo in 1991. The United States of America used to have a huge military base in Angeles, but the eruption terminated its existence. The area now has a large commercial zone, and is called 'Clark Special Economic Zone' (Diamond-Big Co.: Philippines, 2012).

Baguio is a highland city with elevation of 1,500m and population of about 300,000. It is called the summer capital, as governmental departments move to Baguio during summer time. Baguio is also an important nodal city of transport, and it is an academic city as well. There are numerous houses and other buildings on the mountain slopes of the suburbs of Baguio (Photo.10).

Settlement covered 3.5% (612 km²) of study area S2 in the 1950s, and it covered 11.0% (1,923 km²) of study area S2 in ca. 2010 (Table 3). The red colony of settlement area in the National Capital Region
increased nine times as large from the 1950s to ca. 2010. (by using the 'histogram' function of Photoshop, Himiyama & Abe, 2010). It continues to increase since ca. 2000, and the population of study area S2 changed from 19,21 million in ca. 2000 to 23,12 million in ca. 2010, i.e. 4 million

7. Others

7.1 Water

The field survey revealed the existence of many rivers and ponds. Photo.11 shows fish ponds in the north of Manila. Water surface covers 4.0% of study area S1 in ca. 2010. It is an increase since the 1950s, which reflects the increase of fish ponds in the marshy areas along the northern coastline of Manila Bay.

7.2 Lahar

One of the characteristic land use/cover in the study area is 'Lahar', or mud flow. Volcanic mud flow is caused when the volcanic ashes are mixed with large quantities of water and flow down the mountain slopes. In June 1991 Mt. Pinatubo erupted and the volcanic ash caused enormous damage to extensive area. The damage was so huge that the disaster was known as one of the severest disasters in the 20th century. Photo.12, which was taken in 2013 in the suburbs of Angeles, is a reminder of that mega disaster caused by the eruption of Mt. Pinatubo.

8. Conclusion

Land use change of the Central Luzon Plain has been studied by using two different series of topographic maps representing two different time periods, and the latest information of land use/cover obtained through satellite images and the field survey. It has been found that agricultural land and settlement increased drastically in the Central Luzon Plain with forest in the Plain and the surrounding areas diminishing, and that the eruption of Mt. Pinatubo in 1991 still leaves scars both on the ground and in the society. It is also noted that the rapid urbanization has been causing serious problems of environmental pollution and malfunctions in and around cities. This study is sponsored by JSPS Basic Research (S) No.21222003. The authors wish to express their thanks to those who help the project.

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(J): in Japanese