TRANSFORMATION OF LAND USE PATTERN IN PHNOM PENH CITY AT A WATERSHED SCALE

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ABSTRACT: Urban flooding and poor drainage system are considered as two serious problems exposed to Phnom Penh City urban development. Therefore, it is necessary to grasp the characteristics of land use pattern and its changing trends in order to meet the applicable land use planning. In this paper, threshold for watershed delineation in Phnom Penh City was demonstrated. Landsat TM in 2005 and Landsat 8 OLI in 2015 were used to detect land use in 2005&2015 using GIS. Land use analysis of planning in Phnom Penh City was conducted based on watershed. On the basis of findings, firstly, this paper showed the transformation of land use in 2005, 2015 and 2020 based on planning area in each watershed. The results showed that planning area is constantly urbanized. Secondly, the interaction of planning area and outside of planning area as part of watershed was analyzed. It indicates that from the viewpoint of watershed based planning perspective, more attention on interaction of planning and outside of planning area in watershed should be paid whenever the development is taken place in order to reduce the negative impact to the natural environment, mitigation of urban flooding and for a better future land use planning.

Keywords: urban flooding, poor drainage system, land use pattern, watershed delineation, land use detection, land use planning.

INTRODUCTION

Urbanization is considered to be the dominant form of land use change in term of increasing surface runoff, impervious cover, which then accompanied by water pollutant components and high peak discharge rate. Consequently, it led to the change of land use pattern, landscape, natural environment, increasing of non point source pollution (NPS) and can somehow provoking urban flooding (Bhaduri et al. 2000). These problems are even worse especially for the developing countries since the late industrialization that has concentrated urbanization process in the past half century (Miguez et al. 2015).

Issues of land use have been carried out by many researchers in watershed based land use analysis, a study concerned with the land use issues and their impact on watershed interests; it has been used as the physical, biological, social, economic and political unit for planning and implement of land use management (Erickson 1995).

Watershed delineation process and land use detection using remote sensing were considered as the fundamental tools to conduct the watershed based land use analysis.

Due to the advance in computer science in the early 1990s, many watershed geographical information system (GIS)- based applications have been developed, which simplified the watershed delineation process by using Digital Elevation Model (DEM) and input the threshold value to define the watershed (Strager et al. 2010). In evaluating the green space environment in small watershed based on the water cycle, threshold value was defined as trial and used natural topography as the reference (Yukiko et al. 2007). For the basic study of land use planning, threshold was defined by trial and comparing with the output average value of watershed and district average area (Junichiro et al. 2007). Threshold value was set equal to one percentage of the upper limit of the generated flow accumulation using Terrain Processing in ArcHydro, it was used to evaluate the urban spatial characteristics of traditional cities such as Japanese castle town based on watershed analysis (Luong and Yoh 2015).

Remote sensing images such as Landsat Thematic Mapper (TM) and Multispectral Scanner System (MSS) and GIS technique were used to carry out the dynamic of land use in the watershed and proved as an important technology for temporal analysis and qualification of spatial phenomenon, particularly as it allows for land use analysis with less time and low cost (Li et al. 2006, Hong et al. 2011, , Rawal et al. 2014, Kunihiko et al. 2015).

The objective of this paper is composed of three main contexts: (1) Watershed delineation for Phnom Penh City, (2) Land use detection using remote sensing images, (3) Analysis of land use planning in Phnom Penh City. This study is considered as the basic studies used to define a better future land use-planning method, which can be used to mitigate urban flooding exposed to Phnom Penh City urban development.

Description of study area

Cambodia is a one of the countries situated in Mekong River Basin while Phnom Penh City, a capital of Cambodia, is located at the intersection of Mekong, Tonle Sap and Basak River with district boundaries as shown in **FIG. 1**. Phnom Penh City is known as the city with urban development that is closely related to the water system. It is vulnerable to flood due to the fact that this city is located on the lowland, and it built on the high river embankments then continually expanded to the lower part from the river embankment, which is lower than the flooded elevation. These plains were prevented from flood by constructing several layers of dike lines (Molyvan 2004).

In recent year, urban land use has become a major driving force for land cover and land use change due to the constantly increasing of population and has been transformed into the city that led to the increasing demand for housing and city infrastructure. More and more satellite cities have been built in order to meet the demand. However, this development not only leads to the increasing of impervious cover, but also decreasing the capability of natural reservoir. Natural reservoirs are gradually being reclaimed brought about intensified flow velocity from the upstream

to downstream. Besides, inefficiency of drainage management and land reclamation without long-term consideration has caused so far many negative effects to the environment and social aspects.

On the other hand, as one of the developing countries, Cambodia, land use data is found lacking. In this respect, detecting land use data using remote sensing image is expected to significantly improve the land use planning.

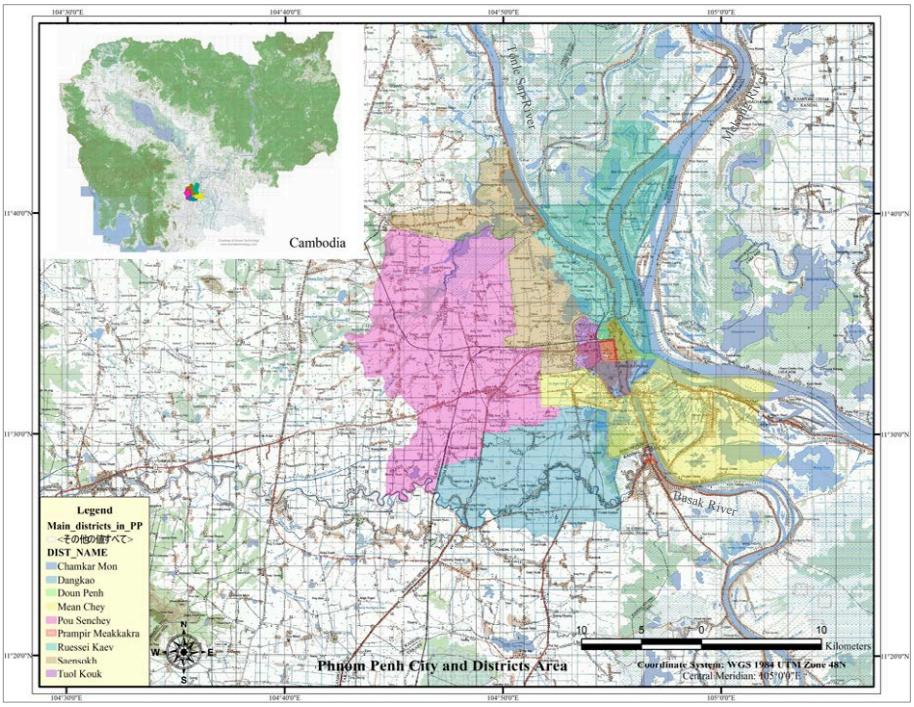

FIG.1. Phnom Penh City and Districts Area

METHODOLOGY

Firstly, watershed delineation of Phnom Penh City was determined. Watershed delineation processes and defining threshold value of Phnom Penh City using Terrain Processing of ArcHydro tool in GIS were illustrated.

Secondly, detection of land use using remote sensing images was demonstrated. Landsat TM in 2005 and Landsat 8 Operational Land Imager (OLI) in 2015 were used to detect land use in 2005 and 2015 based on watershed by using GIS.

Thirdly land use analysis of planning in Phnom Penh City was discussed. Transformation of land use in 2005, 2015 and 2020, and grasping the interaction of areas in watershed were analyzed.

Data Source and Processing

The spatial databases for Phnom Penh City were collected and complied with various data source with different scales and resolutions (**Table 1**).

For watershed delineation process, the data was prepared into three steps using ArcMap. Firstly, GeoTiffs were combined into single Digital Elevation Model (DEM). Secondly, the spatial reference of DEM was projected with coordination

system WGS_1984_UTM_Zone_48N with 90 m cell size for Phnom Penh City. Finally, districts layer of Phnom Penh city were created with districts shape file.

In detecting land use, Landsat 4-5 TM of band 2 (green), band 3 (red) and band (near infrared) at 30 m resolution in 2005 (Rawal et al. 2014) and band 3 (green), band 4 (red) and band 5 (near infrared) of Landsat 8 OLI at 30 m resolution in 2015 were used to detect the land use with max cloud equals to 0% (Senevirathne et al. 2010). In this paper, the first level of the classification system for use with remote sensing was adopted (Anderson 1976). According to topographic map in 2002 and Google earth with time slider moving to 2005, five types of land use including urban or built up, agricultural land, forest land, water and wetland were prominently determined, the general description of each land use was shown as in **Table 2**.

In the process of analyzing land use planning in Phnom Penh city, two steps were implemented. Firstly the obtained JPEG image of master plan in 2020 was georeferenced in ArcMap with the Landsat data. Secondly, manually tracing the land use according to the master plan.

Table 1. Data Sources and Scales for Phnom Penh City

Data	Source	Scale / Other
Shuttle Radar Topography Mission (SRTM) with 4 GeoTiffs	http:// srtm.csi.cgiar.org	90 m
Landsat 4-5 TM (01/03/2005) Landsat 8 OLI (01/15/2015) (Max cloud=0%)	http:// glovis.usgs.gov	30 m
Topographic Map 2002	http://www.arunatechnology.com	1:100,000
Base Maps (Districts, National road, Provinces and Water Bodies)	http://www.opendevelopmentcambodia.net/	Shape files
Master Plan in 2020	DATUC-BAU, 06-2009 (Municipality of Phnom Penh)	JPEG Image

Table 2 Land use classification system

Level I	Description of each land use
Urban or Built Up	Residential, commercial or service, industrial, transportation, communication, utilities and other urban land such as garden, waste dumps etc.
Agricultural Land	Cropland, pasture, orchards and other agricultural land, etc.
Forest Land	Deciduous, evergreen forest land and mixed forest land
Water	Stream, canal, lake, reservoir, bay and estuary
Wetland	Forest wetland and nonforest wetland

Watershed delineation of Phnom Penh City

In this study, watershed delineation of Phnom Penh City was analyzed using Terrain Processing of ArcHydro Tool in ArcGIS with the main steps with main steps including Fill sinks, Flow Direction, Flow Accumulation, Stream Definition,

Catchment Grid Delineation, Catchment Polygon Processing, Drainage Line Processing. However, the stream definition, in which required inputting threshold value is the most important factor to identify the size of the catchment, equals to the product of number of cell in flow accumulation and square cell size.

Threshold value used for identifying watershed for Phnom Penh City was identified on the basis of comparing the output average value of watershed and district average area of Phnom Penh city, obtained from the division of total district area and number of districts. 20 threshold values were trialed then choosing the two most approach values to the output average value of districts area (**Table 3**). By conducting linear interpolation, threshold value was defined. This method is similar to the existing study (Junichiro et al. 2007). The average districts area is 7603.76 ha, interval of threshold value between 4000-5000 ha; by using linear interpolation, the threshold value for watershed delineation in Phnom Penh City was determined 4447 ha. Finally obtained watershed was as shown in **FIG.2.**

Table 3. Results of threshold value

Case	Threshold value (ha)	Number of cell	Average area of catchment (ha)
1	25	30.86	49.82
2	50	61.73	95.39
3	100	123.46	183.38
13	**4000**	**4938.27**	**6875.97**
14	**5000**	**6172.84**	**8506.02**
20	11000	13580.25	18969.64

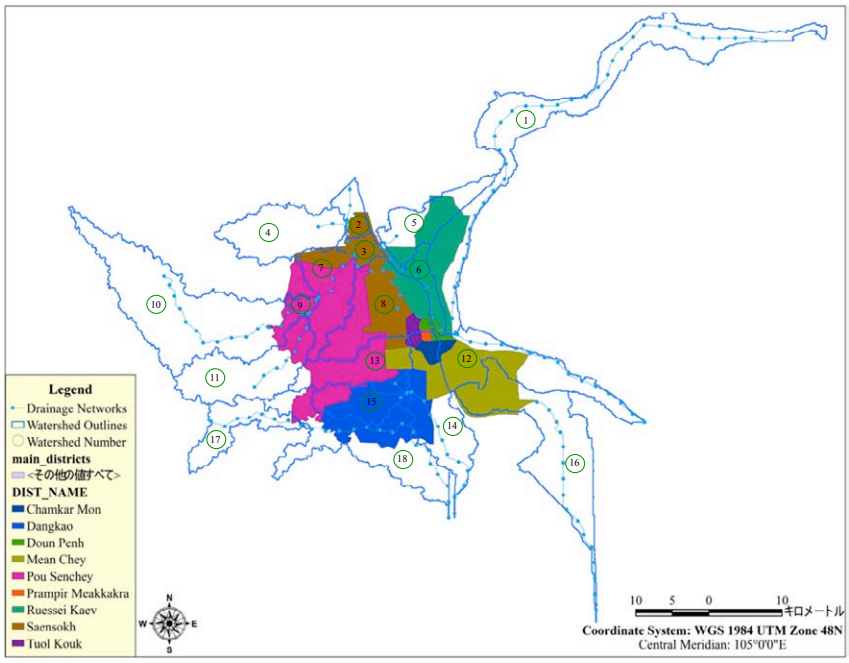

FIG. 2. Districts and Watershed Outlines of Phnom Penh City

Detection of land use in 2005 and 2015 using remote sensing and mapping in GIS

In this paper, the dynamic of land use during 2005-2015 of Phnom Penh City with its watersheds was analyzed using Landsat data with the aid of ArcGIS 10.2 with fourth main steps (Tammy et al. 2013). Firstly, the bands of each Landsat data were composited and clipped based on the defined watershed for the study area using Image Analysis. Secondly, manually drawing the training samples, a total of 186 training samples for five types of land use were drawn. To achieve high accuracy, the training samples were drawn based on the information from Google earth in 2005 and Topographic map in 2002. Thirdly, Maximum Likelihood Algorithm of Supervised Classification was used for pixel clustering. Five types of land use were classified (1) Urban or Built Up, (2) Agricultural Land, (3) Forest Land, (4) Water and (5) Wetland. Finally, accuracy assessment of Landsat data was conducted, 190 random points were created for verifying the defined land use and actual land use based on Google earth in 2005 and 2015; However in 2005, only 157 points could be found while the other 33 points were located in the uncompleted maps. Error matrix and product matrix for each land use data were calculated based on the points and used for defining the overall accuracy and Kappa coefficient (Congalton 1991). As the results, the overall accuracy and Kappa coefficient of land use in 2005 and 2015 were 70.39% with K= 60.05% and 74% with K= 67% respectively. Land use in 2005 and 2015 of Phnom Penh City with its watersheds was as shown in **FIG.3.**

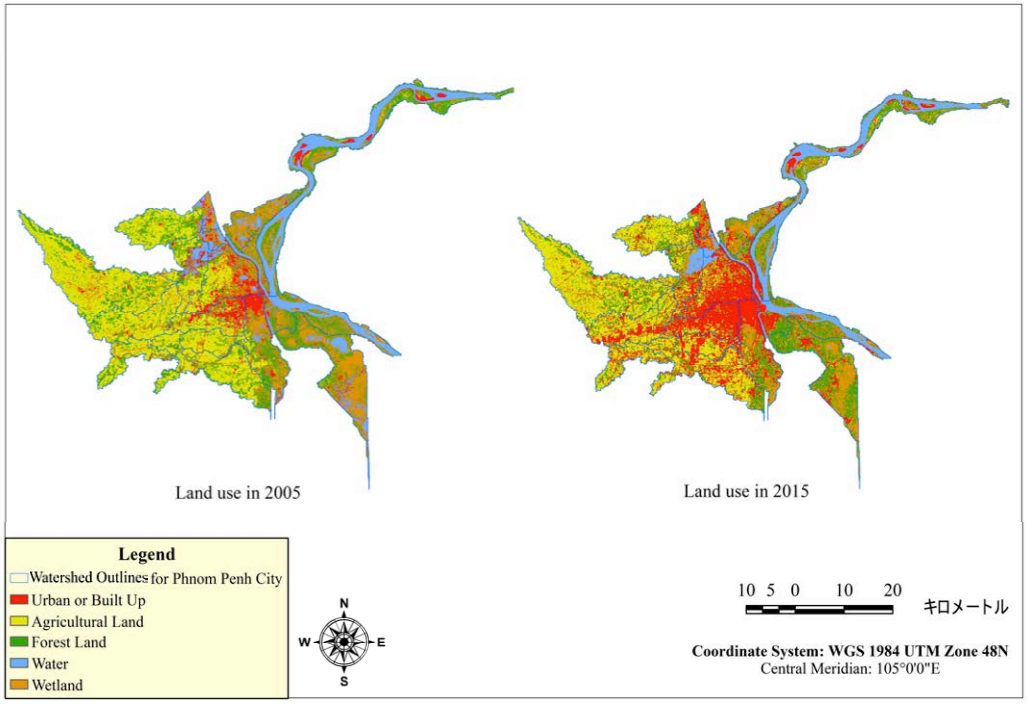

FIG. 3. Land use detection in 2005 and 2015

LAND USE ANALYSIS OF PLANNING IN PHNOM PENH CITY

In this section, transformation of land use in 2005, 2015 and 2020 based on watershed, and grasping the interaction of the areas in watershed were identified as two important factors to discuss land use planning in Phnom Penh City.

To achieve these two factors, it is essential to be focused on Phnom Penh City district area and master plan in 2020. However, the boundary of Phnom Penh City districts and master plan in 2020 were not completely overlapped due to the fact that some areas of districts were not yet developed according to master plan in 2020. In this respect, common area was picked and called planning area. Master plan in 2020 was overlaid with watershed outlines and drainage networks as shown in **FIG. 4.**

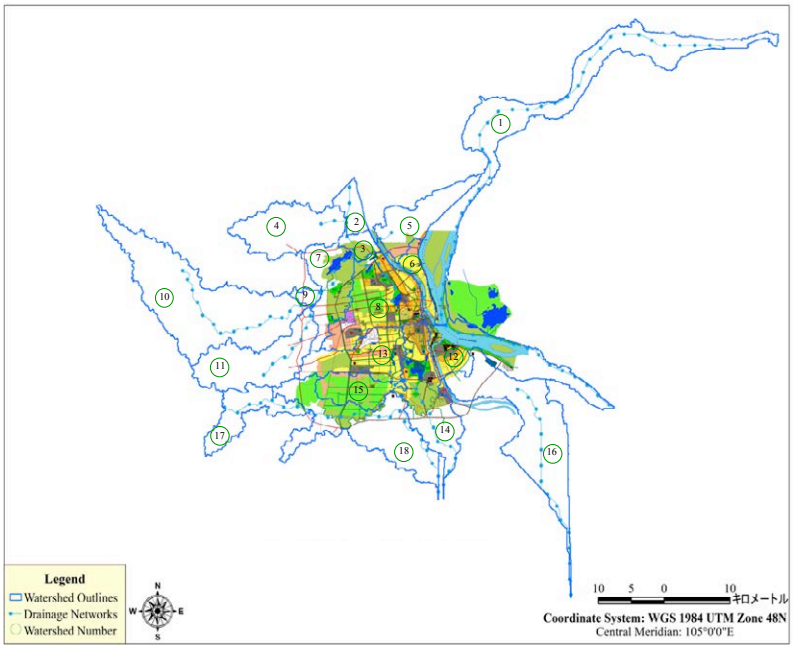

FIG. 4. Overlaying Maps of watershed outlines, drainage networks and master plan in 2020

Transformation of land use in 2005, 2015 and 2020 based on planning area in each watershed

Area of land use in 2005, 2015 and 2020 in planning area was computed and analyzed based on the located watershed by using ArcMap (**FIG.5.**). The results indicated that urban land use of planning area in each watershed constantly increased among the three periods (**FIG.6.**). This result implies that planning area is urbanized.

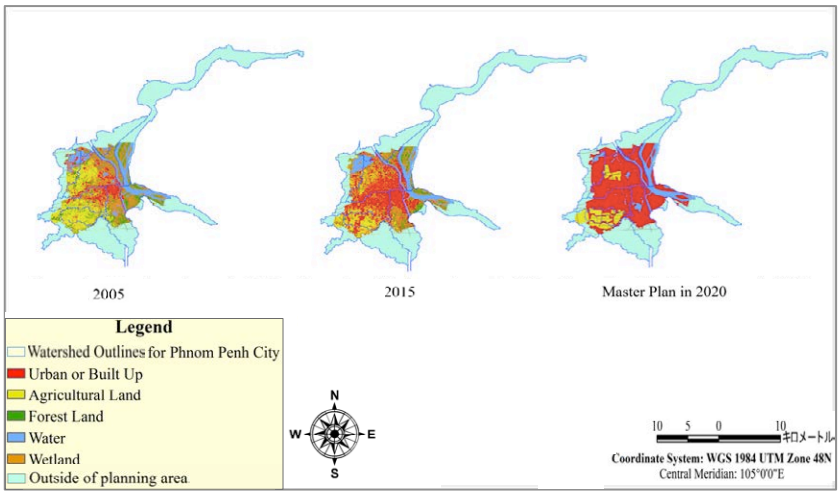

FIG.5. Transformation of land use in 2005, 2015 and 2020 based on planning area in each watershed

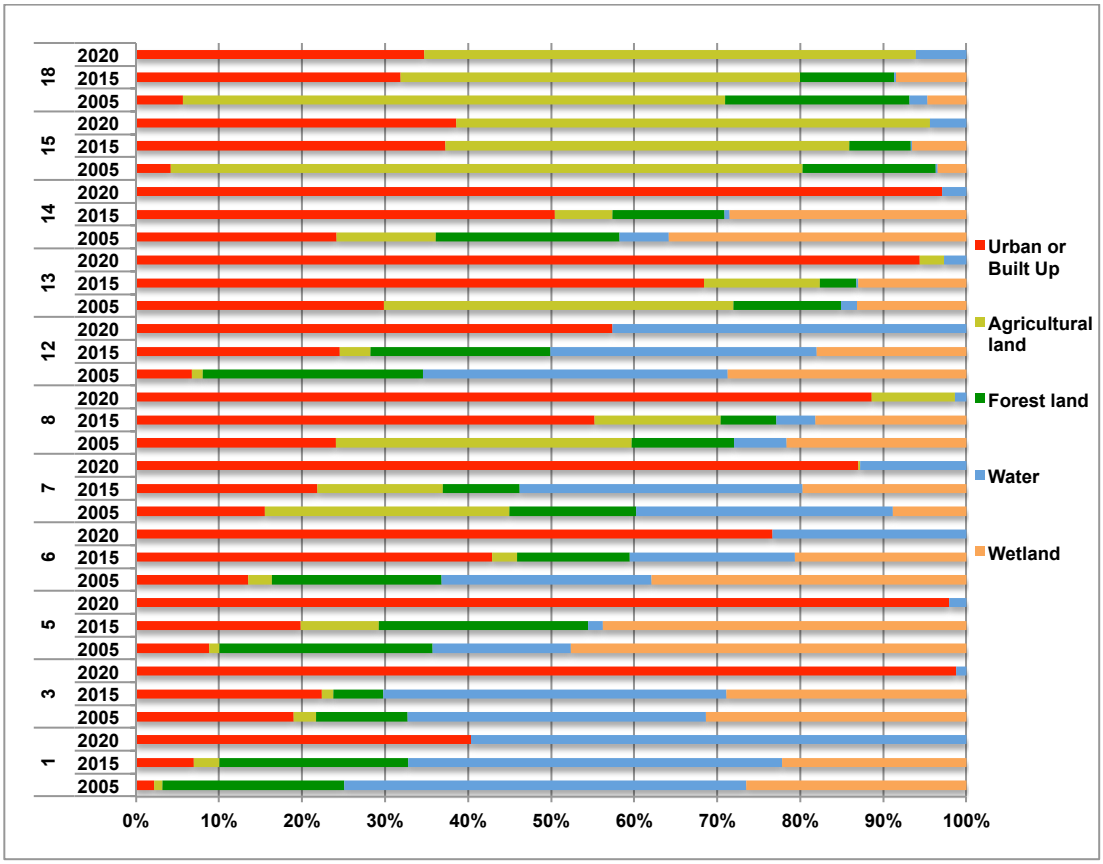

FIG.6. Results of land use transformation in 2005, 2015 and 2020 based on planning area in each watershed

Interaction of planning area and outside of planning area in each watershed

From the viewpoint of watershed, the interaction between upstream and downstream is very important and critical issues to discuss in planning perspective, in particular, planning for flooding mitigation. In this sense, the influence of the development in planning area was discussed by focusing on the planning area and outside of planning area as part of watershed. A total of 11 watersheds (**FIG.5.**) with an exception of watershed 6, whole area was planning area, were analyzed by comparing land use change ratios from 2005 to 2015 in both planning area and outside of planning area in each watershed.

Change ratio of urban land use was considered as contributing the negative effects, which could lead to cause urban flooding due to fact that increasing of impervious cover, to the urbanized area. Therefore, the change ratios for urban land use from 2005 to 2015 of both planning and outside of planning areas in each watershed were compared. More attention would be paid, in particular, outside of planning area, which had high tendency of change ratio compared to the planning areas in each watershed.

Change ratio of urban land use in outside of planning area located in upstream is greater than planning area located in downstream of one watershed, it indicated that planning area in downstream maybe suffer large influence of water flow. So the development should paid more attention on the influence of upstream area. Whereas

change ratios of urban land use in outside of planning area located in downstream is greater than planning area located in upstream of one watershed, the development should be considered of its influence to the downstream area.

The results showed that 5 outside of planning areas in watershed 1, 3, 5, 7 and 18, having higher change ratios of urban land use from 2005 to 2015 compared to planning areas. Urban land use of outside of planning areas in watershed 1, 5, and 7 are mainly located in the upstream while watershed 3 and 18 are located in the downstream (**Table 4**).

Table 4 Change ratios of urban land use in Planning and outside of planning area from 2005 to 2015 in each watershed

Outside of planning areas area are located *: in upstream /**: in downstream

Watershed	Change Ratio of planning area from 2005 to 2015 (%)	Change Ratio of outside of planning area from 2005 to 2015 (%)
1	0.42 to 1.32	**6.57 to 8.92***
3	9.53 to 11.23	**7.55 to 15.53****
5	1.25 to 2.81	**4.78 to 12.82***
7	8.19 to 11.53	**3.75 to 10.49***
8	23.59 to 54.08	0.04 to 1.08*
12	3.85 to 12.40	1.25 to 2.80**
13	26.08 to 59.71	1.26 to 5.85*
14	14.01 to 29.24	3.52 to 8.29**
15	4.21 to 37.09	0.00 to 0.02*
18	1.22 to 6.88	**2.24 to 17.48****

CONCLUSION

This study showed threshold-defining method to delineate watershed in Phnom Penh City using Terrain Processing of ArcHydro Tool in GIS. Detection of land use in 2005 and 2015 by remote sensing image with the aid of ArcGIS and analysis of land use planning in Phnom Penh City were illustrated.

On the basis of the findings, two conclusions can be made.

Firstly, this paper showed the transformation of land use in Phnom Penh City in 2005, 2015 and 2020 based on the planning area in each watershed. The results demonstrated that all urban land use of planning area in each watershed is increasing and the master plan also intending to accelerate the trends. In this respect, it can be concluded that planning area is urbanized.

Secondly, the interaction of planning area and outside of planning area as part of watershed was analyzed. It was found out that 5 outside of planning areas, having higher change ratios of urban land use from 2005 to 2015 compared to planning area. These areas occurred in watershed 1, 3, 5, 7 and 18. 3 of 5 outside of planning areas are located in upstream while 2 of 5 are located in downstream of its watersheds. It indicates that high attention should be paid when the development is taken place in these watersheds. It can be mentioned that the interaction between planning and

outside of planning area in each watershed should be considered whenever the development is taken place.

Therefore, from the viewpoint of watershed and flooding mitigation for urbanized city, Phnom Penh, controlling land use change in upstream and downstream should be implemented by introducing some methods to increase the rain water retention capability in the development. By doing this, it may lead to reduce the negative impact to the natural environment, mitigation of urban flooding as well as for a better future land use planning.

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