Applied Geo-Informatics Technology to Urban Green Space Management on Role of Stormwater Runoff Reducing and Increasing of Subsurface Water

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ABSTRACT

This study aimed to determine spatially geographical locations for managing urban green space based on the relationships between urban greenness, storm water runoff reduction and subsurface water increase in the past 11 years (2006-2016) in the Nakhonratchasima Municipality (NM). The SWAT model and GIS was used in this study. As results, 6 sub-sites of NM were totally analyzed for classifying into 2 levels: priority (higher runoff and lower infiltration into subsurface or more requirement of the urban green space management) and minority (lower runoff and higher infiltration into subsurface or less requirement of the management). The level of priority was in the middle part of NM (urban and built-up land, recreation area, and golf course) and the northern NM (urban and built-up land, recreation area, vegetable crop behind the mall department store), while other sites were manipulated on monitoring level. The results also indicated the most significant factors affecting higher runoff and lower infiltration into subsurface are elevation and land use (urban green space). However, these mentioned areas are not fully understood yet, particularly at spatial and temporal scales relevant to managing urban green area. As such, a reliable land use of urban greenness for storm water and subsurface water control depends on improved understanding of how and to what extent urban greenness (plant species) interact with storm water and subsurface water, and the context-specific consideration of optimal arboriculture practices and NM frameworks to maximize the storm water and subsurface water benefits trees should provide.

Keywords- Geo-Informatics, Urban Green Space, Stormwater Runoff, Subsurface Water

1. INTRODUCTION

Increasing urban population has affected to expansion of urbanization especially built-up land such as buildings, residents, roads, etc. Green-dominated land covers are being converted to built-up areas. In fact, some areas in urban still have green land covers, but some areas have no green sites. It depends on planning of the urban management. Moreover, development of urban society still has to be inescapably prepared for growing of ASEAN Economic Community (AEC), it consists of growth of buildings and public utilities. In the past of Thailand, an dramatically economic development had an impact on directionless urban land use patterns [4] as well as, in the present, it still faces problem of urban land use changes especially green areas where have become more built-up areas [10]. Consequently, stormwater runoff occurs severer and oftener a rapid flooding (flash flood) in low-lying areas such as a case of flooding in Nakhon Ratchasima and Bangkok in year 2010 and 2011. Furthermore, these flooding also most likely can cause water pollution in urban areas, particularly sites without green spaces and planting, according to the study of ,[1], [2], [7], and [15].

Geo-informatics has not only become very important technology to decision-makers across a wide range of disciplines, industries, commercial sectors, environmental agencies, local and national government, research, and academia national survey and mapping organizations, etc. but also geospatial-temporal data has become infused into many aspects of our daily life and the major driver of today's information society [11] and [12]. Basically, geo-informatics technology focuses on 3 fields: remote sensing (RS), geographical information system (GIS), and global position system (GPS). The examples of benefits of geo-informatics application includes cost saving with greater efficiency, better decision making, improved communication, better geographic information recordkeeping and managing geographically, have been evidenced by relevant papers such as [5], [3], and [8]. In addition, the geo-informatics also can be an efficiently techniques for analyzing input data into the Soil and Water Assessment (SWAT) tool, or called 'ArcSWAT' for use with ArcGIS in order to evaluate and plan water management in a watershed The ArcSWAT and SWAT model have been applied in many studies of water management. An example of studies include [6], [9], [13] and [14].

As mentioned above, this article mainly aimed to determine spatially geographical locations for the urban green management by considering on the relationships between urban greenness, storm water runoff reduction and increasing subsurface water for 11 years (2006-2016) in the Nakhonratchasima Municipality (NM). Due to the 2010 flash flooding in NM, NM authorities have attempted to find the best and most suitable policies and practices in the sustainable protection of flooding in NM. Development of urban green spaces (UGSs) is a potential approach that is created in 3-year continuous plan with periods of 2016-2018, 2017-2019 and 2018-2020. Therefore, this paper will be a guideline for the UGSs management in NM and also will be utilization for the management in other urban areas of Thailand.

2. OBJECTIVES

This study aims to determine spatially geographical locations for managing urban green spaces by considering on the relationships between urban greenness, storm water runoff reduction and increasing subsurface water for 11 years (2006-2016) in the Nakhonratchasima Municipality (NM). The objectives of this research are as the following:

(1) To estimate UGSs based on remote sensing,

(2) To apply the ArcSWAT model for estimating stormwater runoff and subsurface water recharge based on changes of estimated UGSs,

(3) To study the relation of stormwater runoff, subsurface water and UGSs,

(4) To determine identification of specific areas for improving and restoring UGSs

3. METHODOLOGY

3.1 Study site

The study area is Nakhonratchasima Municipality or shortly, “NM” as shown Fig. 1. NM site is located in Muang district of Nakhon Ratchsiam province at 14’ to 16’N and 101’ to 103’E and occupies a total area of 37.5 km^2 (4.96 and 0.18 percent of Muang district and Nakhon Ratchasima province) with sea level 174-206 m. NM is far from Bangkok by vehicles about 255 km., by rails about 264 km. NM topography is characterized by most plain, a little slope in eastern direction, low land in the NM north and high land in the southern west. Most of soils are loamy sand. The main river is Lum Ta Klong (the major of Mun river) where flows through the NM north with length about 12 km. Authority of NM comprises of the north adjacent to 3-subdistrict administrative organization (SAO): Muen Wai, Nongkratum and Bankoh, the south adjoining 2-subdistrict municipality and 1 SAO: Nong Phailom, Pho Klang and Nong chabok, the east close to Hau THale subdistrict municipality, and the west next to 2- SAO and 1 subdistrict municipality: Ban Mai, Suranari and Pru Yai.

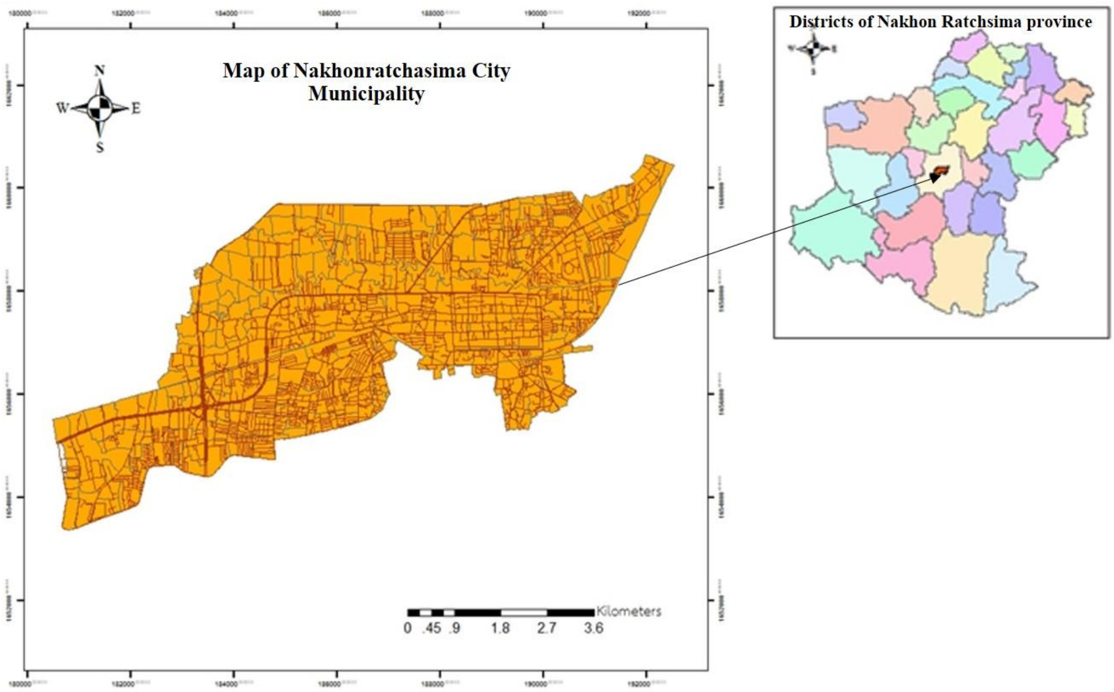


Fig.1 Area of Nakhonratchasima Municipality

3.2 Study procedure

3.2.1 Data collection

In this study, we collected data during 2006 to 2016 from many sources including:

(1) Remotely sensed data is in form of aerial photos and satellite images from Land Development Department (LDD), Geo-Informatics and Space Technology Development Agency (Public Organization) (GISTDA), U.S. Geological Survey (USGS) and Google Inc.

(2) Land use/land cover data of Muang Nakhonratchasima district, Nakhon Ratchasima province is in form of polygon-based vector layer from Land Development Department (LDD)

(3) Climate data is in form of attribute of rainfall data from Nakhon Ratchsima Meteorological Observation Station and The Thai Meteorological Department

(4) Subsurface water data is in form of attribute of groundwater wells and volume and point-vector layer of wells from Bureau of Groundwater Conservation and Restoration, Department of Groundwater Resources and Office of Groundwater Resource Area 5

(5) Boundary and land use of Nakhonratchasima municipality is in form of polygon-vector layer from Office of Nakhonratchasima City Municipality

3.2.2 Application of ArcSWAT model for determining specific areas and managing urban green spaces

In this section, we applied the ArcSWAT model to estimate stormwater runoff and subsurface water recharge and investigated the relationship with urban greenness during 2006 to 2016 in NM. The steps of method are described as the following:

(1) Defining site boundary with direction of water flow in the study area.

(2) Classifying sites for estimating stormwater runoff and subsurface water recharge.

(3) Ranking index for UGSs management on role of stromwater runoff reducing and increasing of subsurface water.

(4) Evaluating the accuracy of modeling by using calibration and validation.

4. RESULTS

4.1 Directions of water flow

Based on the ArcSWAT model, site boundary with water flow directions was defined and evaluated from considering DEM and land use as shown in Fig. 2. We found that water flows from the western part (higher elevation) to eastern part (lower elevation) of the study area and the southern (higher) to northern (lower) of NM area.

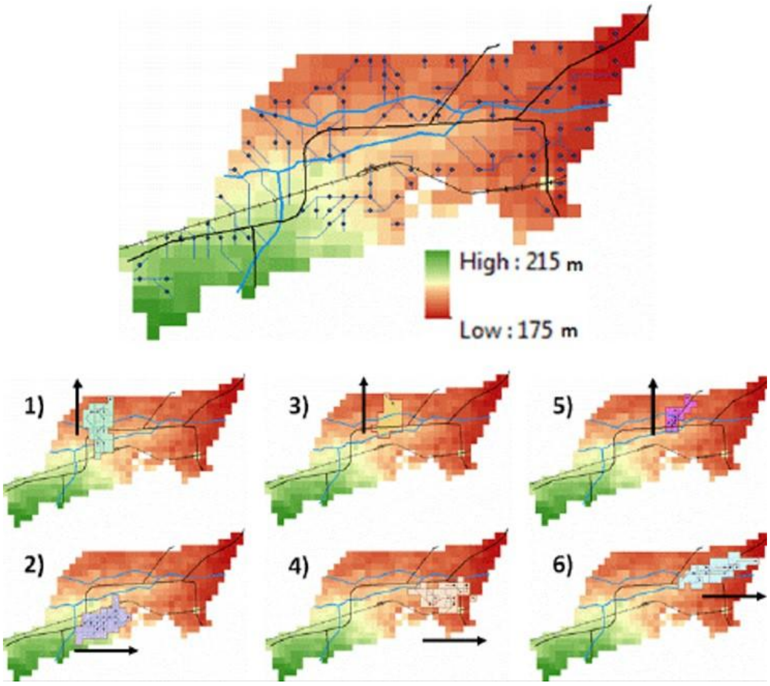


Fig. 2 Output of site boundary and direction of water flow in the study area

4.2 Sites with stromwater runoff

Stormwater runoff in NM was estimated based on land use, soil characteristics, and rainfall data in the ArcSWAT model. This model elaborately classified the study area into 6 sub-sites based on water flow directions (Fig. 3) as described in the following:

Site no.1: community of Ban Kham Thuat, low land and agricultural land, with the direction of stormwater runoff towards the north.

Site no.2: area of city, town and commercial, recreation area and golf course with the direction of stormwater runoff towards the east.

Site no.3: area of city, town and commercial, recreation area, agricultural area (such as vegetation and truck crops behind the mall department store) and low land with the direction of stormwater runoff towards the northern west.

Site no.4: area of city, town and commercial, recreation area and low land with the direction of stormwater runoff towards the southern east.

Site no.5: area of city, town and commercial and water body with the direction of stormwater runoff towards the north.

Site no.6: area of city, town and commercial, recreation area and low land with the direction of stormwater runoff towards the east.

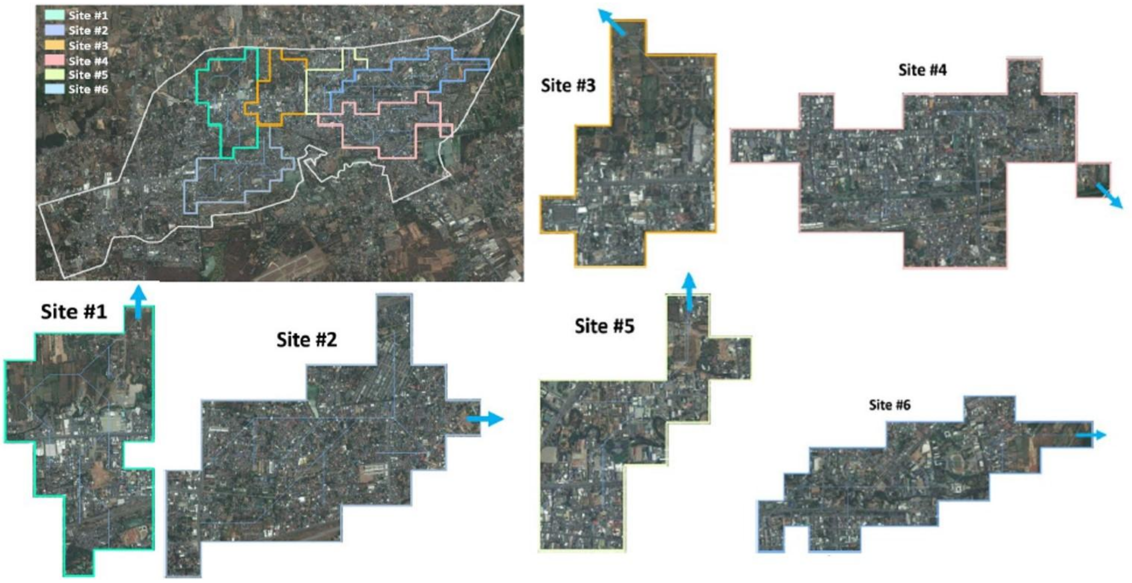
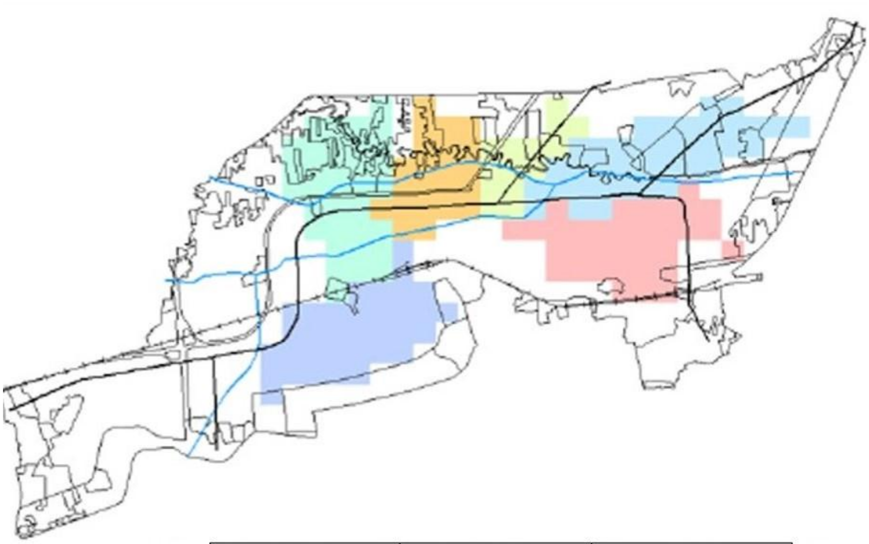


Fig. 3 Sites for estimating stromwater runoff and subsurface water recharge

4.3 Ranking index

The indices of stormwater runoff and subsurface water recharge in 6 sub-sites were executed in ranking at risk of a stormwater runoff is in high level and a subsurface water recharge is in low level. Fig. 4 presents the indices of stormwater runoff and percolation (subsurface water) for 6 sub-sites.



		2006-2010		2011-2015		2016-2020	
		Runoff Index	Percolation Index	Runoff Index	Percolation Index	Runoff Index	Percolation Index
	Site no.1	6	2	5	3	5	1
	Site no.2	1	3	1	5	2	3
	Site no.3	2	4	2	4	1	6
	Site no.4	4	1	3	2	4	2
	Site no.5	5	6	4	6	6	4
	Site no.6	3	5	6	1	3	5

Note: - Index no.1 defines the highest level for stormwater runoff reducing or percolation increasing
- Index no.2 defines the high level for stormwater runoff reducing or percolation increasing
- Index no.3 defines the moderate for stormwater runoff reducing or percolation increasing
- Index no.4 defines the lower moderate for stormwater runoff reducing or percolation increasing
- Index no.5 defines the low for stormwater runoff reducing or percolation increasing
- Index no.6 defines the lowest for stormwater runoff reducing or percolation increasing

Fig. 4 Index of stromwater runoff reducing and Percolation

4.4 Calibrating and Validating Model

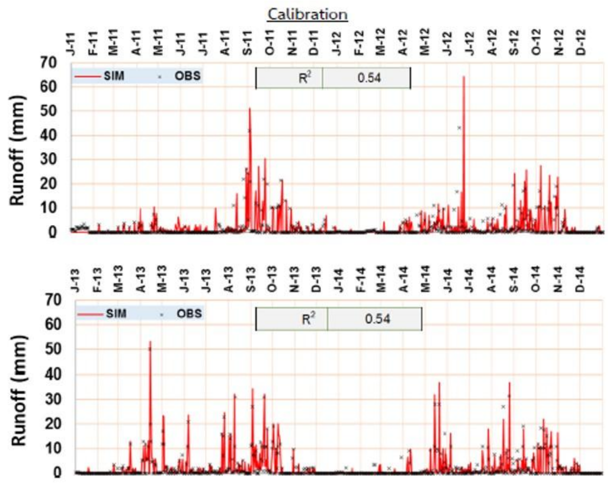
For evaluating the model, observed water discharge at the Assumption College station (Fig. 5a) was used to estimate statistically error of modeling. Basically, the evaluation of a model consists of 2 steps: calibration and validation. Fig. 5b and Fig. 5c show the result of calibration during 2001 to 2014 with 0.54 of R^2 and the result of validation from 2015 to 2016 with 0.79 of R^2, respectively.

5. CONCLUSION AND DISCUSSION

This study analyzed spatially geographical locations for managing urban green space based on the relationships between urban greenness, storm water runoff reduction and subsurface water increase in the past 11 years (2006-2016) in the Nakhonratchasima Municipality (NM). The SWAT model and GIS was used in this study. Consequently, there were 6 sites of NM were obtained and analyzed for classifying into 2 levels: priority (higher runoff and lower infiltration into subsurface or more requirement of the urban green space management) and minority (lower runoff and higher infiltration into subsurface or less requirement of the management). The level of priority was in the middle part of NM (urban and built-up land, recreation area, and golf course) and the northern NM (urban and built-up land, recreation area, vegetable crop behind the mall department store), while other sites were manipulated on monitoring level. The results also indicated the most significant factors affecting higher runoff and lower infiltration into subsurface are elevation and land use (urban green space).

(5a)

(5b)



(5c)

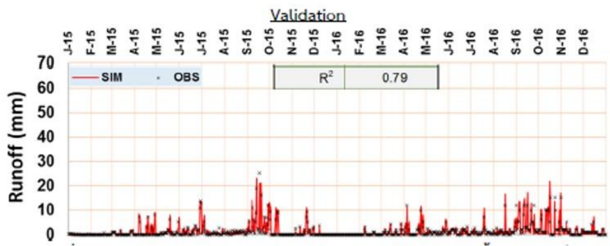


Fig.5 Gauging station, Calibration and Validation

6. RECOMMENDATION

The prior and minor areas were mentioned above should be not fully understood yet, particularly at spatial and temporal scales relevant to managing urban green area. As such, a reliable land use of urban greenness for stormwater and subsurface water control depends on improved understanding of how and to what extent urban greenness (plant species) interact with storm water and subsurface water, and the context-specific consideration of optimal arboriculture practices and NM frameworks to maximize the storm water and subsurface water benefits trees should provide.

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