FLOODPLAIN DEVELOPMENT IN BUI RIVER DUE TO LAND-USE CHANGE FROM 2004 TO 2015

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SUMMARY

Floodplains are areas adjacent to rivers or lakes that are subject to recurring inundation. Notwithstanding floodplains play significant roles because of its multi-functions, it is impacted adversely by many factors. This study aims to focus on the floodplain development in Bui river belonging to Hoa Binh province and Hanoi capital regarding possible impacts due to land-use change from 2004 to 2015. The extent of floodplain was determined by using Hydrologic Engineering Centers River Analysis System (HEC-RAS) coupled with HEC-GeoRAS which is a useful tool in ArcGIS. Water surface profile data exported from HEC-RAS simulations were processed by HEC-GeoRAS for floodplain mapping. The result shows that during the study period, the total built-up area which are impervious surface including residential area, industrial zone, transportation system and many public areas increased by 2.89% while the unused land and agricultural land decreased by 5.66% and 3.62% respectively. Although the average rainfall of four selected flood events is nearly equivalent or even decreasing, the water surface elevation increased. The final result provides a quantitative analysis of the correlation between percentage of total impervious area and floodplain area in Bui river basin. This study is one of initial efforts that can be used by local administrations to develop contingency land-use plans in order to minimize the negative influences of flood disasters.

Keywords: Bui river, floodplain, inundation, land-use change, total impervious area.

I. INTRODUCTION

Vietnam has 2360 rivers and canals that add up to 220000 km in length. Only about 19% (41900 km) is considered navigable and 7% (15436 km) has been placed under management (Luis C. Blancas and M.Baher El-Hifnawi 2014). In terms of climate conditions, Vietnam has tropical monsoon climate that brings frequently much of rain. Therefore, floodplains play significant roles. Floodplains are areas adjacent to rivers, ponds, lakes, and oceans that are periodically flooded by lateral overflow at different points in time. Floodplains are hydrologically important, environmentally sensitive, and ecologically productive areas that perform many natural functions. Although flooding naturally occurs along every river and coastal area, floodplains are beneficial because of storage, conveyance and protection of water quality and recharge of groundwater. In addition to that, it provides a variety of habitats for fish and other animals.

The development of floodplain area may be a threat to the water quality, the level of storage, conveyance and could also destroy the habitat of many aquatic organisms. In the viewpoints of economists and sociologists, the dynamics of floodplain can enhance the risk of flood hazard, especially in flooding season. The unpredictable water level easily floods the low areas and consequently, floodplain development may cause severe economic disruption and loss of human life in densely populated region. However, floodplains are impacted adversely by many drivers. Some previous papers have identified the adverse impacts of land-use change to floodplain (Abolghasem Akbari et al., 2014; Jie Liu et al., 2014). The dynamics of land-use in river basin effects water cycle, flow conveyance and infiltration processes.

Bui river is a tributary of Day river. It is 91 kilometers in length and has 1249 km2 of basin area (Nguyen Thuy Duong, 2016). It originates from Lam Son commune (Luong Son district, Hoa Binh province) and flows to Phuc Lam commune (Chuong Mi district, Hanoi) before unifying with Day river.

Through a long time, Bui river catchment has experienced significant change in land use and land cover. As a consequence, flood regime and floodplain in Bui river also have been impacted. However, up to now, there are no studies on impacts of land use/cover change on hydrological condition and floodplain development in Bui river. Based on data from 2004 to 2015, this research aims to clarify possible impacts.

II. STUDY SITE AND METHODS

2.1. Study site

The study site includes Bui river and its basin, stretching from Lam Son commune (Luong Son district, Hoa Binh province) to Xuan Mai town (Chuong Mi district, Hanoi). In detail, it belongs to seven communes/towns including Lam Son, Tan Vinh, Nhuan Trach, Hoa Son, Luong Son, Xuan Mai and Thuy Xuan Tien (figure 2.1).

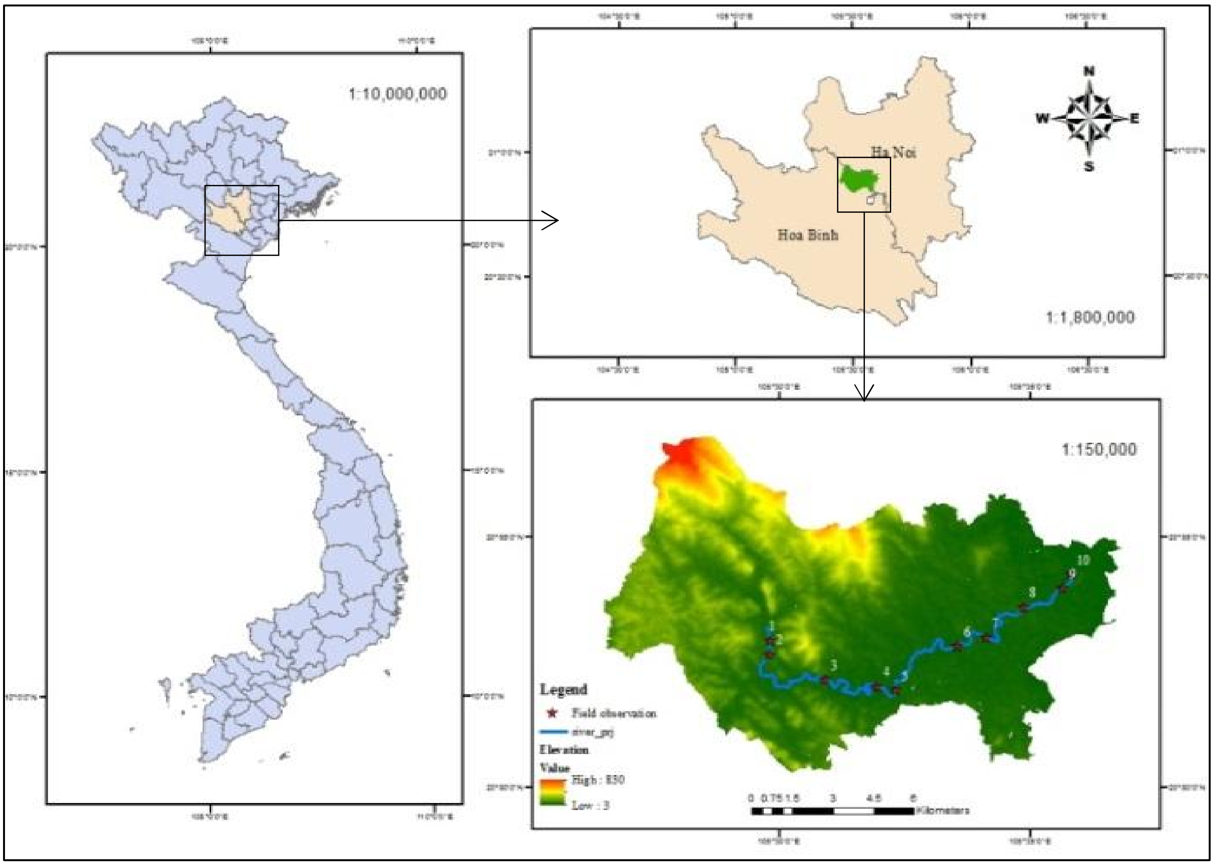

Figure 2.1. Map of study site

The study site belongs to a half-mountain half-plain area. It is characterized by low mountains and hills and represents a transition zone between delta and midland. Tropical monsoon dominate the climate of the Bui river basin. This area is known as abundant source for natural resources including: rock, mineral, forest…

2.2. Methods

2.2.1. Secondary data collection

Secondary data collection is the initial step before constructing a computational model. The required documents include: database of land use in the study area from 2004 to 2015 Digital Elevation Model (DEM) of Bui river; hydrometerologic data in Bui river (collected in Lam Son station located in Bui river upstream) and data of flow discharge and rainfall from 2004 to 2015.

2.2.2. Fieldworks

Aiming to assess the floodplain development, ten cross sections along Bui river have been chosen and investigated. The locations are illustrated in the diagram below:

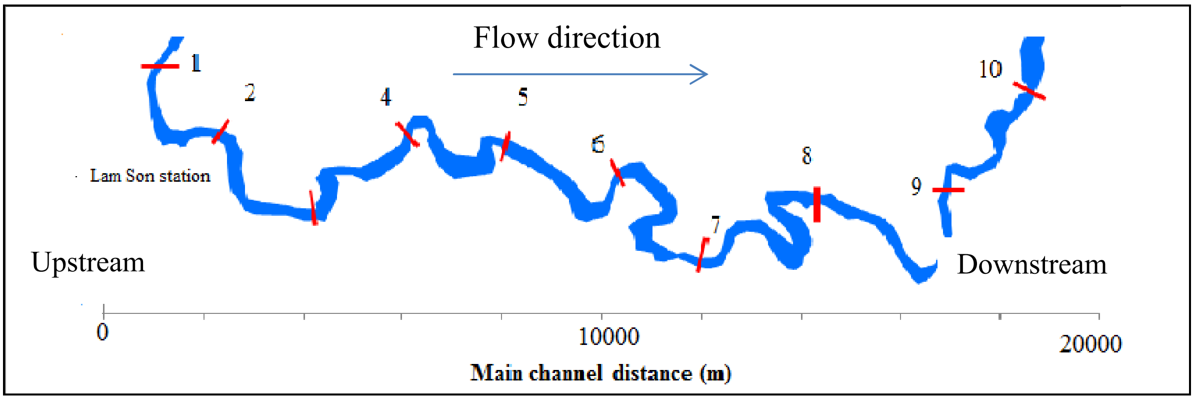

Figure 2.2. Sampling diagram

Water level and water surface elevation were measured in different locations in Bui River using transect and cross-sections.

2.2.3. Data processing

The land-use map of Bui river basin is extracted from land-use map of Chuong My and Luong Son districts after editing by using Map info. The process of floodplain mapping is described shortly in the following diagram:

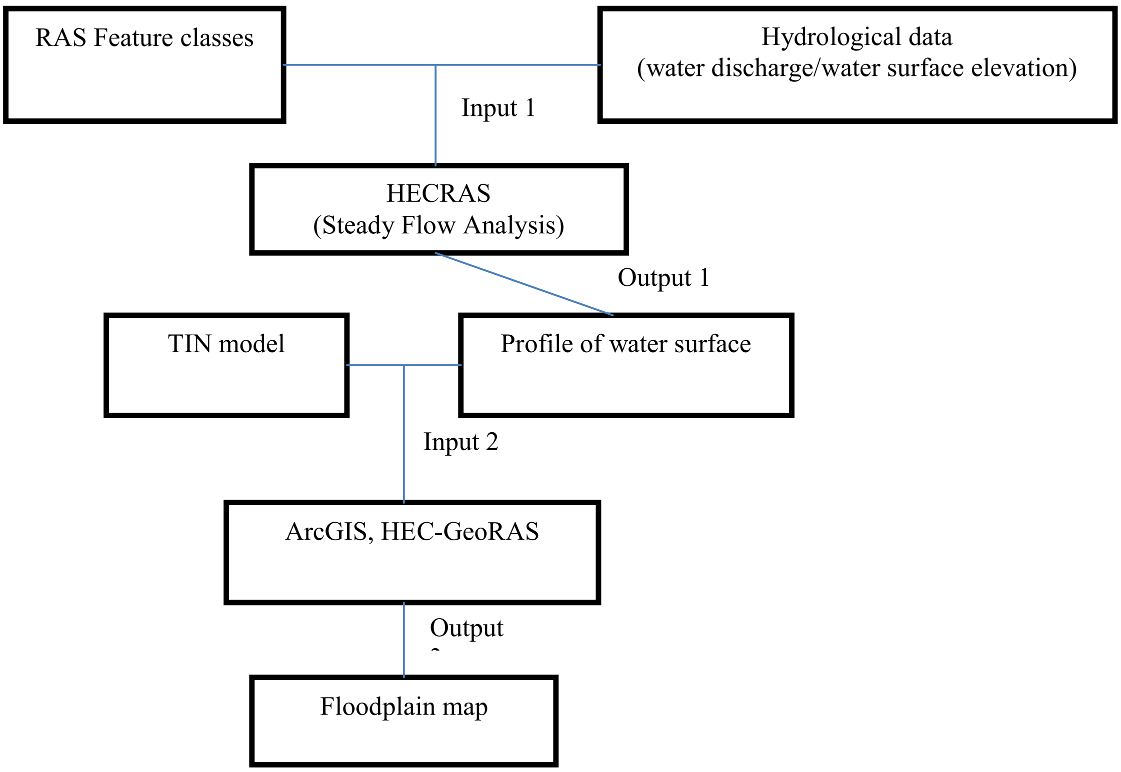

Figure 2.3. Diagram of floodplain mapping process

III. RESULTS AND DISCUSSION

3.1. Characteristics of hydrological conditions and land-use/cover change in Bui river basin

3.1.1. Characteristics of hydrological conditions in Bui river from 2004 to 2016

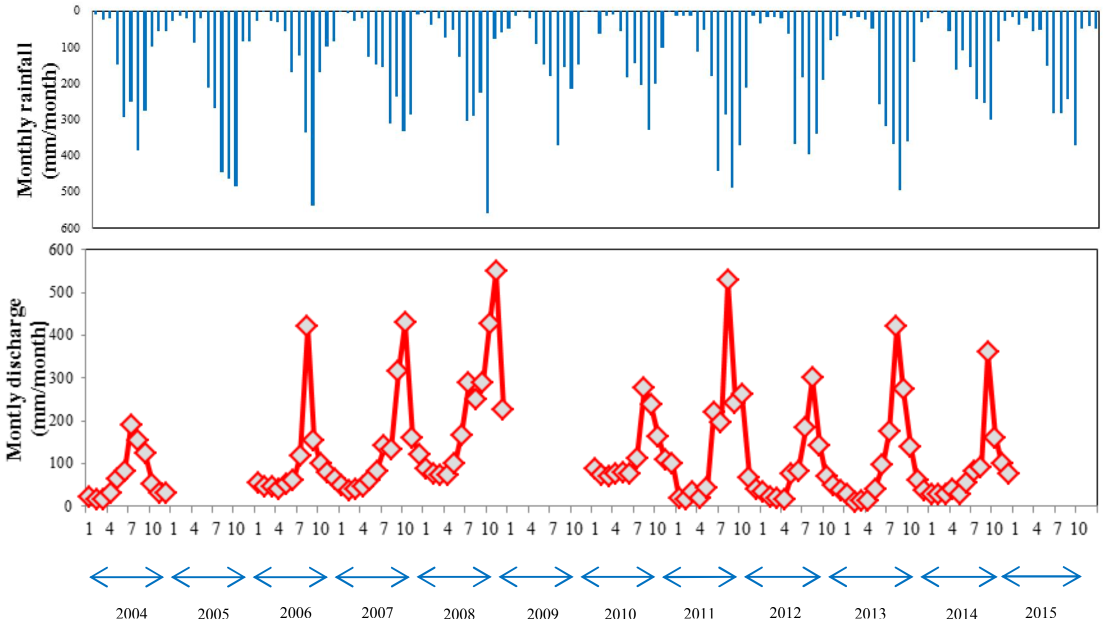

Figure 3.1. The response of monthly rainfall and monthly discharge from 2004 to 2015

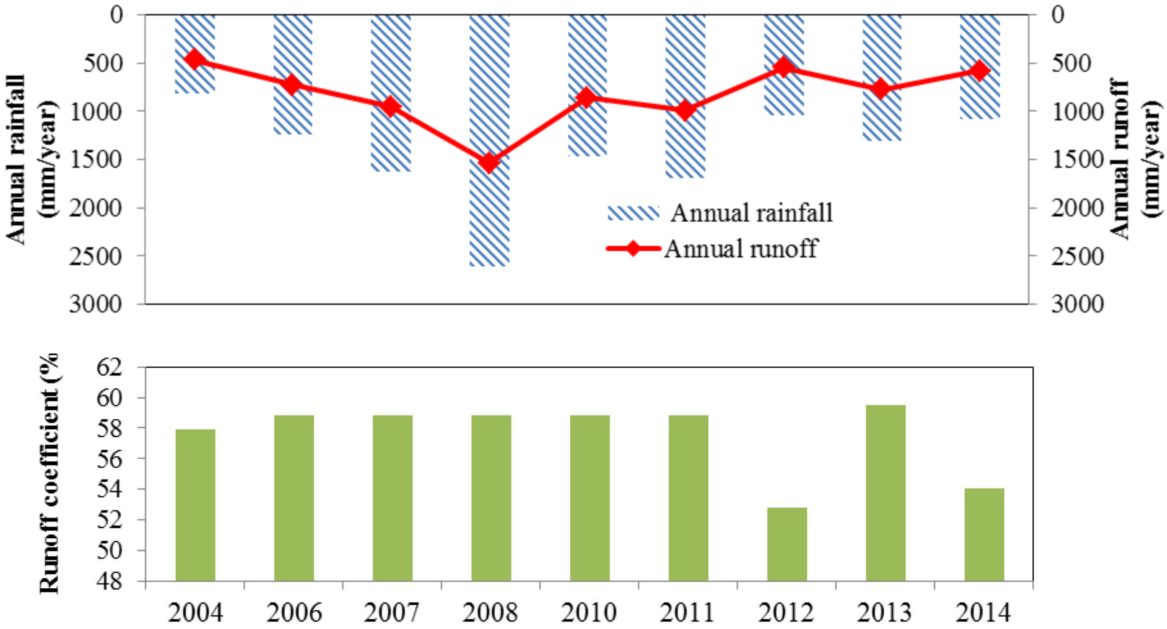

Figure 3.2. Relationship between annual rainfall and runoff in Bui river from 2004 to 2015

Flow regime in Bui river basin is divided clearly into two seasons: rainy season and dry season. The rainy season lasts from April to October and represents 78% (2007) to 89% (2004) of total annual rainfall. Dry season lasts from November to March . The evaluated databased shows a maximum reached monthly rainfall of 559.8 mm in September 2009. The minimum monthly rainfall was 0.5 mm in December 2009. Flooding season in Bui river is defined to last from May to October. The highest runoff is found in July, August and September. Total runoff in rainy season makes up 58.4% (2008) to 88.5% (2011) of total annual runoff during the evaluated period (figure 3.1). In the same period , the maximum annual rainfall reached 2608.1 mm recorded in 2008, while the minimum came to 810.72 mm recorded in 2004 (figure 3.2). The runoff coefficient within 2004 – 2015 changes from 54.0% to 57.9%. The relationship between annual rainfall and annual runoff is shown by the equation: y = 0.6093x – 42.176 (y is annual runoff and x is annual rainfall). The R2= 0.9948 ≈ 1 means that in reality 99.48% annual runoff follow this equation (figure 3.3).

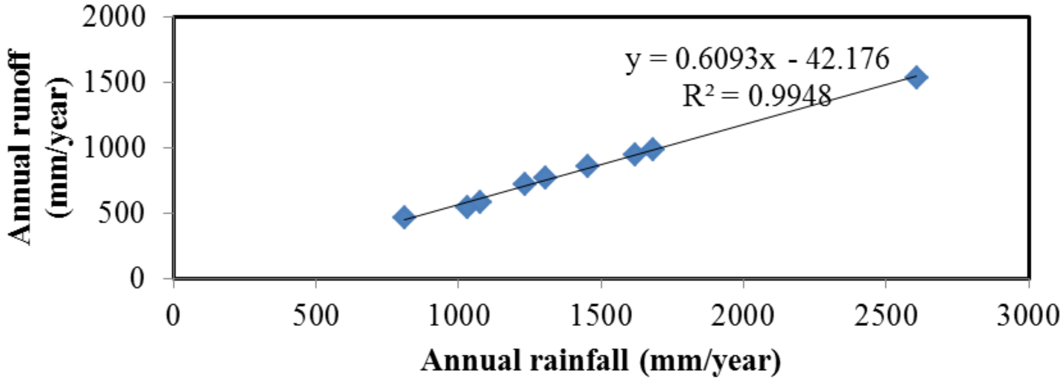

Figure 3.3. Relationship between annual rainfall and runoff in Bui river from 2004 to 2015

3.1.2. Situation of Land-use in Bui river basin from 2004 to 2016

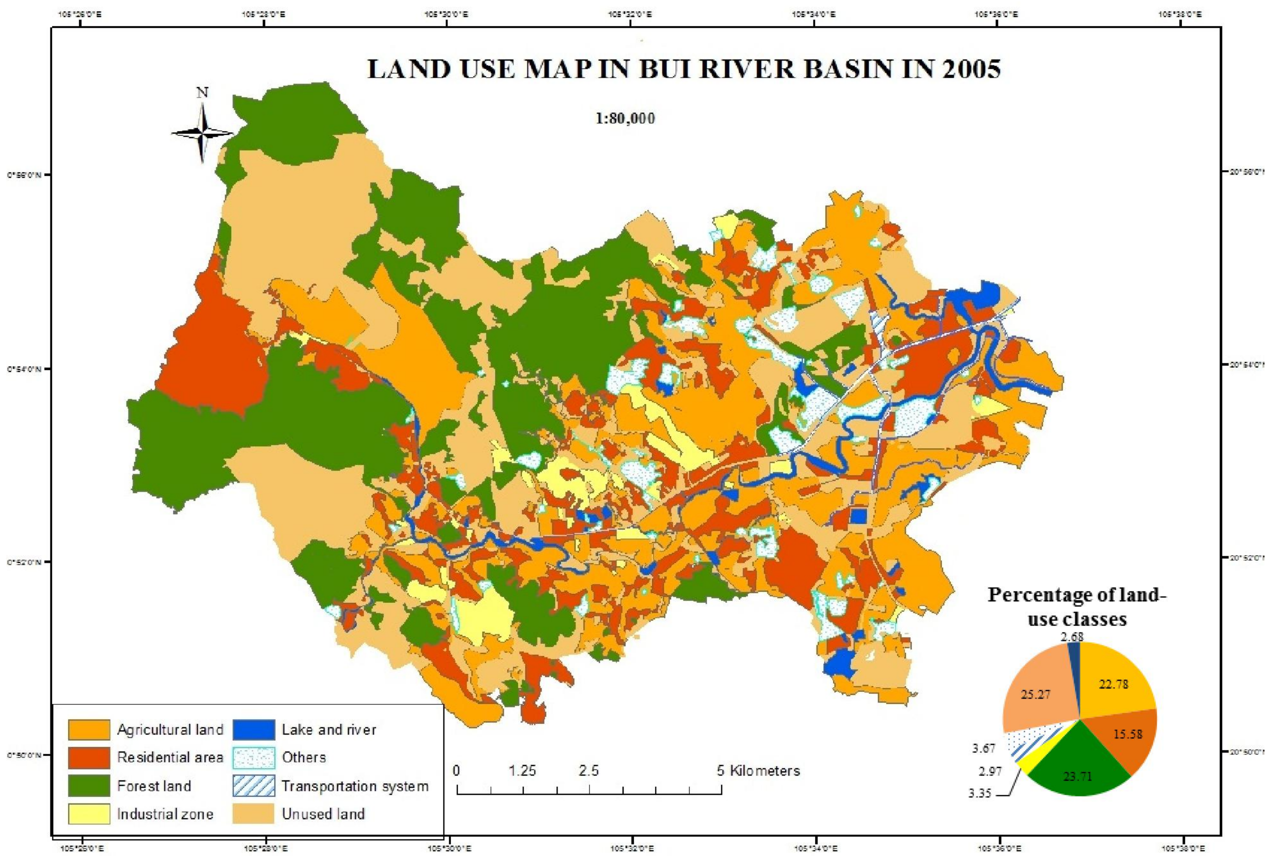

Figure 3.4. Land-use map in Bui river in 2005

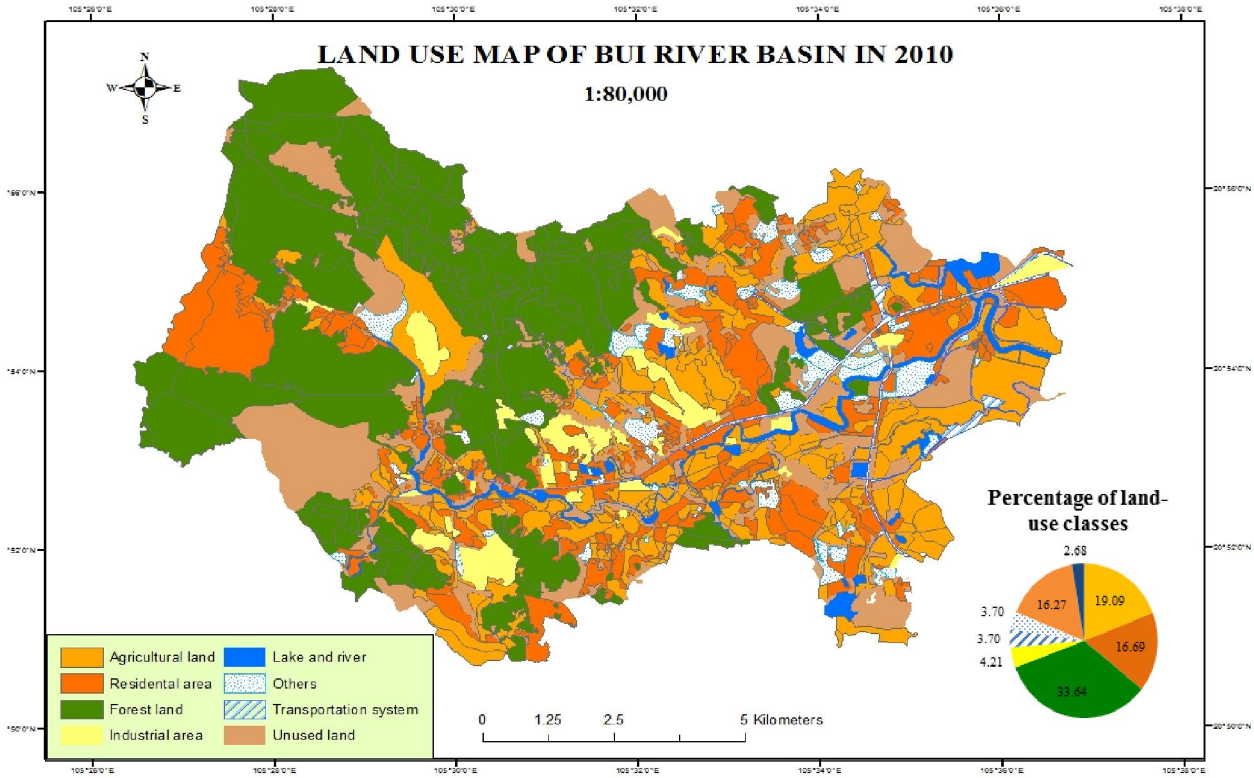

Figure 3.5. Land-use map in Bui river in 2010

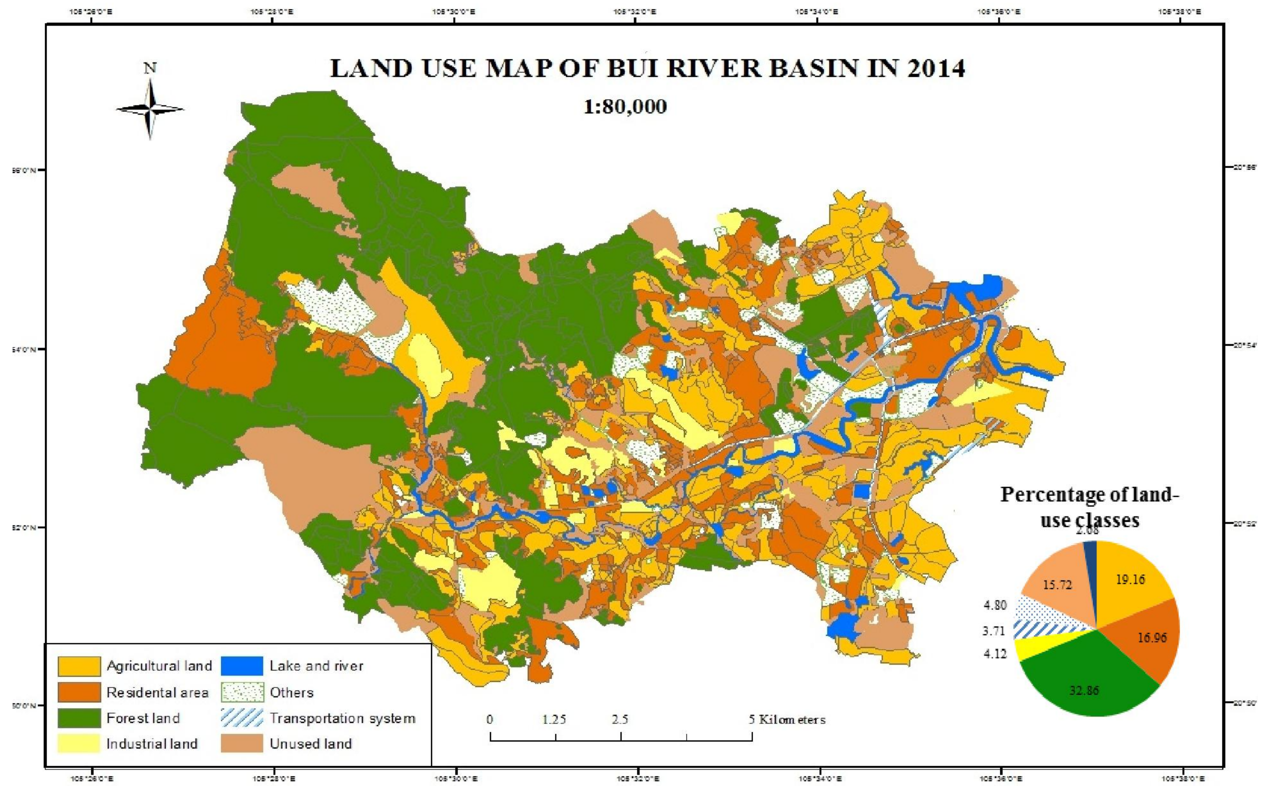

Figure 3.6. Land-use map in Bui river in 2014

The fluctuation of land-use classes during 2005 - 2014 is depicted more clearly in the following chart:

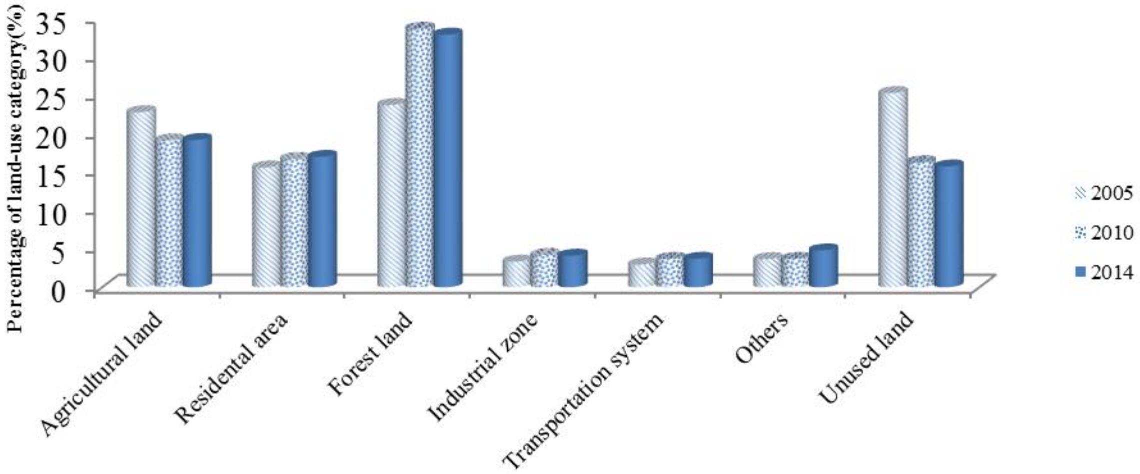

Figure 3.7. Fluctuation of land use classes in Bui river basin in 2005, 2010, 2014

According to the changes of land-use/cover, the built-up areas which represent impervious surface have been enlarged towards the main channel of Bui river. Total impervious area comprises many classes: residential areas, industrial zone, transportation system and others (cemeteries, defending areas, educational areas, public services areas). According to land-use maps of Bui river in 2005, 2010 and 2014, the percentage of total impervious area (%TIA) in Bui basin were 25.57%, 28.21% and 29.59%. It is evidently to state that the total impervious area increased during the evaluated period.

3.2. Floodplain characteristics in Bui river for different flood events

Four individual flood events were selected which all show equivalent amounts of rainfall. ArcGIS, HECRAS and HEC-GeoRAS are supportive softwares and tools to model floodplain successfully.

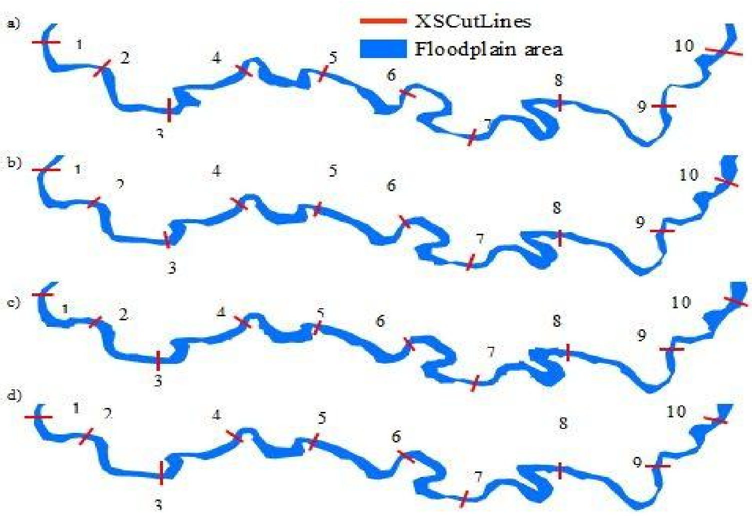

Figure 3.8. Model of floodplain in Bui river in different flood events:
a) July 11th 2006, b) June 21st 2010, c) August 23rd 2012, d) September 25th 2013

The correlation of rainfall, floodplain and water surface elevation in Lam Son station and total impervious area over time is summarized in the table below:

Table 3.1. Correlation of rainfall, water surface elevation, floodplain areas

Year	2006	2010	2012	2013
Rainfall (mm)	42.7	42.8	42.0	41.6
Water surface elevation (m)	19.9	20.0	20.1	20.1
Floodplain area (ha)	135.3	150.9	153.7	153.8

The second, third and fourth cross sections are used to evaluate the change of floodplain during the four different flood events.

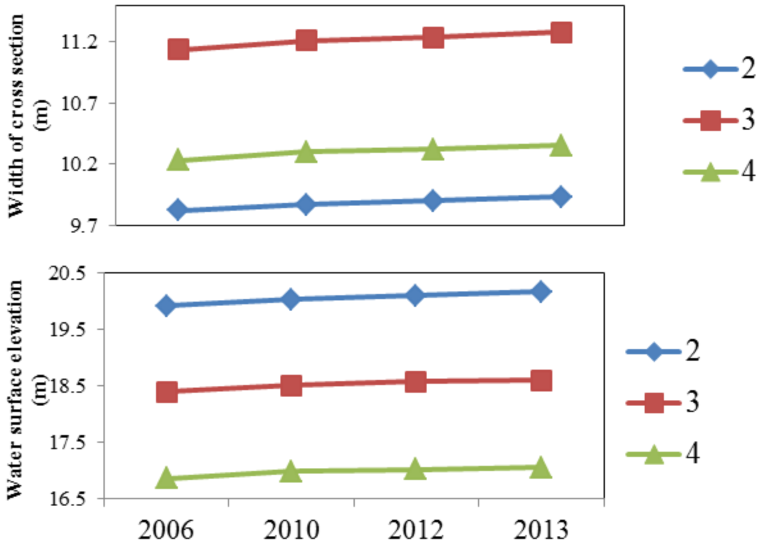

Figure 3.9. Fluctuation of width and water surface elevation in cross section 2,3,4 in four flood events

The accuracy assessment of modeling floodplain is quite necessary. Therefore, experimentally measured- and simulated widths of ten cross sections are compared. The relationship between measured widths and simulated widths is shown by the equation y = x (x is experimental width, y is simulated width). R^2 = 0.8879 means that the accuracy of this model is 88.79%.

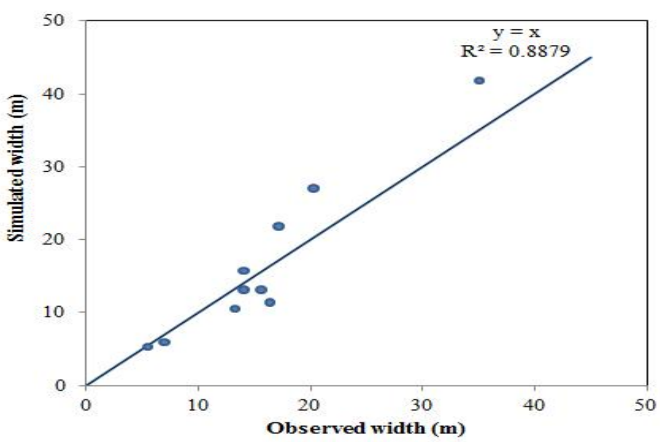

Figure 3.10. The relationship between experimental width and simulated width in 2016

3.3. Evaluation of the interactions between changes in land-use/cover, hydrological conditions and floodplain

In order to assess the impacts of land-use change on floodplain, this study campares four flood events that have equivalent rainfall. The chosen flood events took place at July 11th 2006, June 21st 2010, August 23rd 2012, September 25th 2013. Therefore, it is compulsory to have land-use data of Bui river basin in 2006, 2010, 2012 and 2013. However, due to the lack of database, this study suggests a hypothesis based on the fluctuation trend of land-use planning.

$\%TIA_{2006} \approx \%TIA_{2005} = 25.57$

$\%TIA_{2013} \approx \%TIA_{2014} = 29.59$

$\%TIA_{2010} < \%TIA_{2012} \approx 29.00 < \%TIA_{2013}$

(%TIA: Percentage of Total Impervious Area)

This hypothesis will be used to analyze the influences of land-use change on floodplain.

Changes in land-use can be categorized into two types: modification and conversion. Modification is the change of condition within a cover type, for example, forest can become more scattered because of selective thinning. In contrast, conversion is a change from one type of land-use into another, for example, large area of farmland gets converted to residential area. Within Bui river basin from 2004 up to now, the most significant changes observed are the conversion of agricultural land and unused land into built-up area and the expansion of forest land at the upstream area. The total impervious area (residential area, industrial zone, transportation system, cemeteries, defending areas, educational areas, public services areas) in Bui river basin has increased significantly from 25.57% to 29.59% from 2005 to 2014. This change directly impacts the runoff surface because of decreased infiltration capacity. The decrease of water storing agricultural land intensifies the increase of water level in the main channel.

Although the average amount of rainfall during the four selected flood events were nearly equivalent or even decreasing, the mentioned reasons lead to increasing water surface elevation in Lam Son station as well as a growth of floodplain area (figure 3.11).

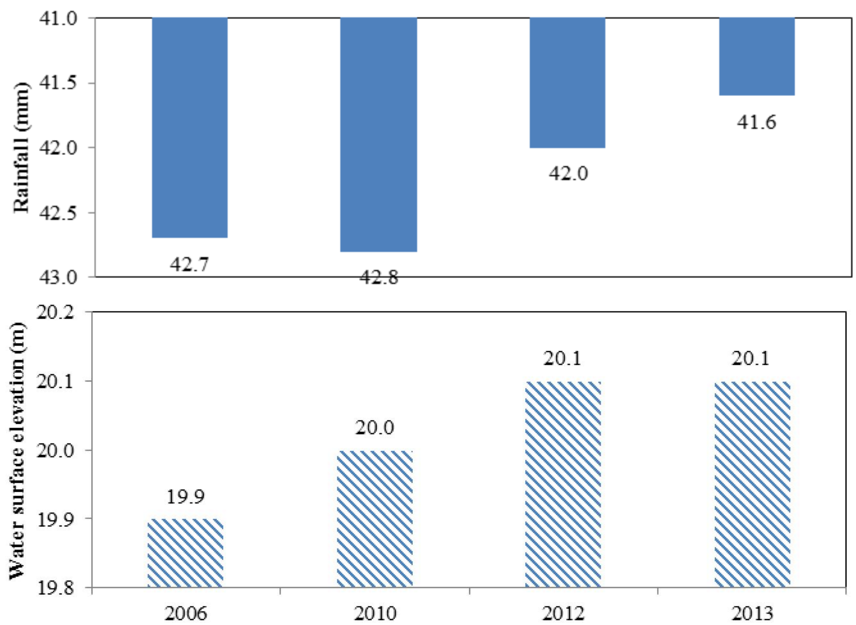

Figure 3.11. The response of rainfall and water surface level in Lam Son station

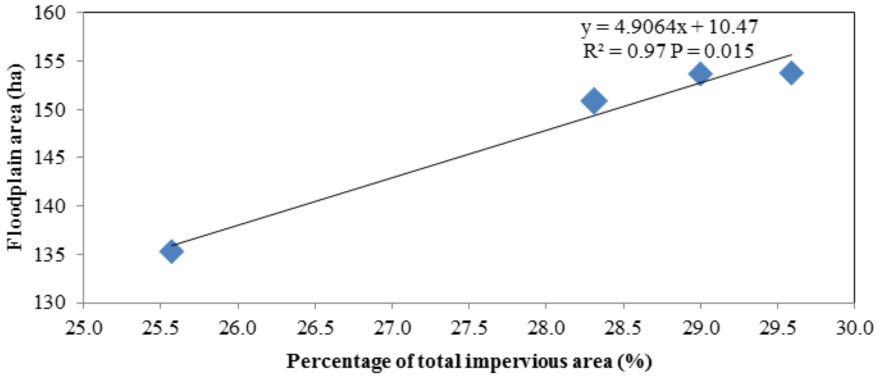

Figure 3.12. The relationship between percentage of total impervious area and floodplain area in Bui river

P-value was 0.015 and smaller than 0.05 so it had great deal in statistics. R2 is nearly 1 then the hypothesis is acceptable. From figure 3.12, it proves that the total impervious area strongly impacts the floodplain area. In other words, the land-use change plays significant role in floodplain development.

3.4. Possible solutions to enhance corridor management for sustainable development

Aiming to reduce negative impacts of flood events in Bui river basin, this study also provides some possible solutions to enhance floodplain management for sustainable development.

Increasing the resilience of river communities

As a consequence of being dependent to water supplies, fertile soils and flat landscape, the amount of people living in floodplains is predicted to increase. In order to improve the resilience of river communities, mitigation of actual risk should be solved through structural solutions such as levees and flood storages. Non-structural solutions such as flood warning systems and regulatory measures should also be considered.

Ecohydrology planning

The development of a long term action plan for floodplain management requires an appreciation of the potential of natural floodplain ecosystems. However, it is necessary to define strategies which aim to reduce the chance of flood events and improving water quality. For examples:

- A growth in the mosaic character within the catchment/basin

- Extension of ecotone buffer zones that slow down the water run-off from a basin to river ecosystems and further restrict the transfer of pollutants.

- A successful application of high-qualified technologies to increase the permeability of river basin's surface and to reduce its ability to retain water over large areas (for example: the use of partial permeable materials to water for the construction of houses, building, etc.)

- Increasing the water retention capacity by carrying out forestation.

- Defining a restrictive limit for residential and economic development in river floodplains.

Increasing societal awareness and exchanging knowledge

By exchanging knowledge and experience among scientists, public officials and representatives of industry, business, agriculture awareness of sustainable floodplain management can be created. This is such an important solution to restrain encroachment actions that can become endanger for future floodplain.

IV. CONCLUSION

Including research results about effectiveness of policies on coastal mangroves management, the following conclusions can be drawn: The flow regime of Bui river is divided into two seasons, the runoff coefficient fluctuated from 54.0% to 57.9% during the period of 2004 – 2015 and the relationship between annual runoff and annual rainfall follows the equation $y = 0.6093x – 42.176$ (x is annual rainfall, y is annual runoff) with R2 = 0.9948. The total impervious area in Bui river basin increased according to land-use planning from 25.57% to 29.59% while the agricultural land and unused land decreased by 3.62% and 5.55%. Although the amount of rainfall was equivalent, the width and the water surface elevation increased. One could also observe that the relationship between total impervious area and floodplain area followed the equation $y = 4.9064x + 10.47$ (y is floodplain area and x is percentage of total impervious area) with R2 = 0.97. In summary, this study is a successul quantitative analysis about the impacts of land-use change to floodplain development.

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REFERENCES

1. Albolghasem Akbari, Golamali Mozafari, Mohsen Fanodi, Maliheh Sadat Demmesy, 2014. Impact of Landuse Change on river floodplain using public domain hydraulic model. **8**, 80-86.

2. A. Beckers, B. Dewals. S. Erpicum, S. Dujardin, S. Detrembleur, J. Teller, M. Pirotton, P. Arcchambeau, 2013. Contributions of land use changes to future flood damage along the river Meuse in the Walloon region. **13**, 2301-2318.

3. Bui Anh, 2016. Phu Tho: Building house on stilts in the floodplain.

4. Bui Duy Tan, Pham Van Lac, 2012. Applying MIKE model in flooding calculation of downstream of the Cude river basin, Da Nang city.

5. Duong Dang Minh Phuoc, 2014. Inundation illustration in downstream of DakBla river by application of HEC-RAS model and HEC-GeoRAS tool.

6. Dimitrios Alexakis, M.G. Gryllakis, Aristeidis Koutroulis, Diofantos G. Hadjimitsis, 2013. GIS and remote sensing techniques for the assessment of land use change impact on flood hydrology: The case study in Yialias basin in Cyprus. **16** (5), 671-680.

7. James Kriz, Don Huggins, Craig Freeman, Jude Kastens, 2007. Assessment of Floodplain Wetlands of the Lower Missouri River Using a Reference-based Study Approach. *Open-file Report No.142. Kanses Biological Survey, Lawrence*, KS. 63pp.

8. Jie Liu, Shao-yu Wang, Dong-mei Li, 2014. The Analysis of the Impact of Land-use Changes on Flood Exposure of Wuhan in Yangtze River Basin, China. **28**, 2507-2522.

ẢNH HƯỞNG CỦA THAY ĐỔI SỬ DỤNG ĐẤT TỚI HÀNH LANG THOÁT LŨ SÔNG BÙI GIAI ĐOẠN 2004 – 2015

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TÓM TẮT

Hành lang thoát lũ là những khu vực tiếp giáp với sông hồ và thường bị ngập lụt. Mặc dù hành lang thoát lũ đóng vai trò quan trọng, nó vẫn bị ảnh hưởng tiêu cực do nhiều nguyên nhân. Nghiên cứu này nhằm mục đích tập trung vào sự phát triển hành lang thoát lũ trên sông Bùi thuộc tỉnh Hòa Bình và thành phố Hà Nội dưới tác động của thay đổi sử dụng đất từ năm 2004 đến năm 2015. Sự phát triển của hành lang thoát lũ được đánh giá bằng mô hình HEC-RAS cùng với công cụ HEC-GeoRAS. Dữ liệu độ cao mặt nước xuất ra nhờ việc mô phỏng trong HEC-RAS được xử lý bằng HEC-GeoRAS để thiết lập bản đồ ngập lụt. Kết quả chỉ ra rằng trong giai đoạn nghiên cứu, tổng diện tích đất xây dựng là bề mặt không thấm nước bao gồm đất ở, khu công nghiệp, hệ thống giao thông và các khu vực công cộng tăng 2.89%, trong đó diện tích đất chưa sử dụng và đất nông nghiệp giảm lần lượt 5.66% và 3.62%. Mặc dù lượng mưa trong bốn trận lũ được lựa chọn là tương đương nhau hoặc có xu hướng giảm, độ cao mặt nước có xu hướng tăng lên. Nghiên cứu đã cung cấp một phân tích định lượng về mối tương quan giữa tỷ lệ phần trăm của tổng diện tích không thấm nước và diện tích hành lang thoát lũ ở lưu vực sông Bùi. Nghiên cứu này là một trong những nỗ lực ban đầu giúp chính quyền địa phương xây dựng kế hoạch sử dụng đất dự phòng để giảm thiểu tối đa những ảnh hưởng tiêu cực của thiên tai lũ lụt.

Từ khóa: Lũ, lụt, sông Bùi, thay đổi sử dụng đất, tổng diện tích không thấm nước.

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