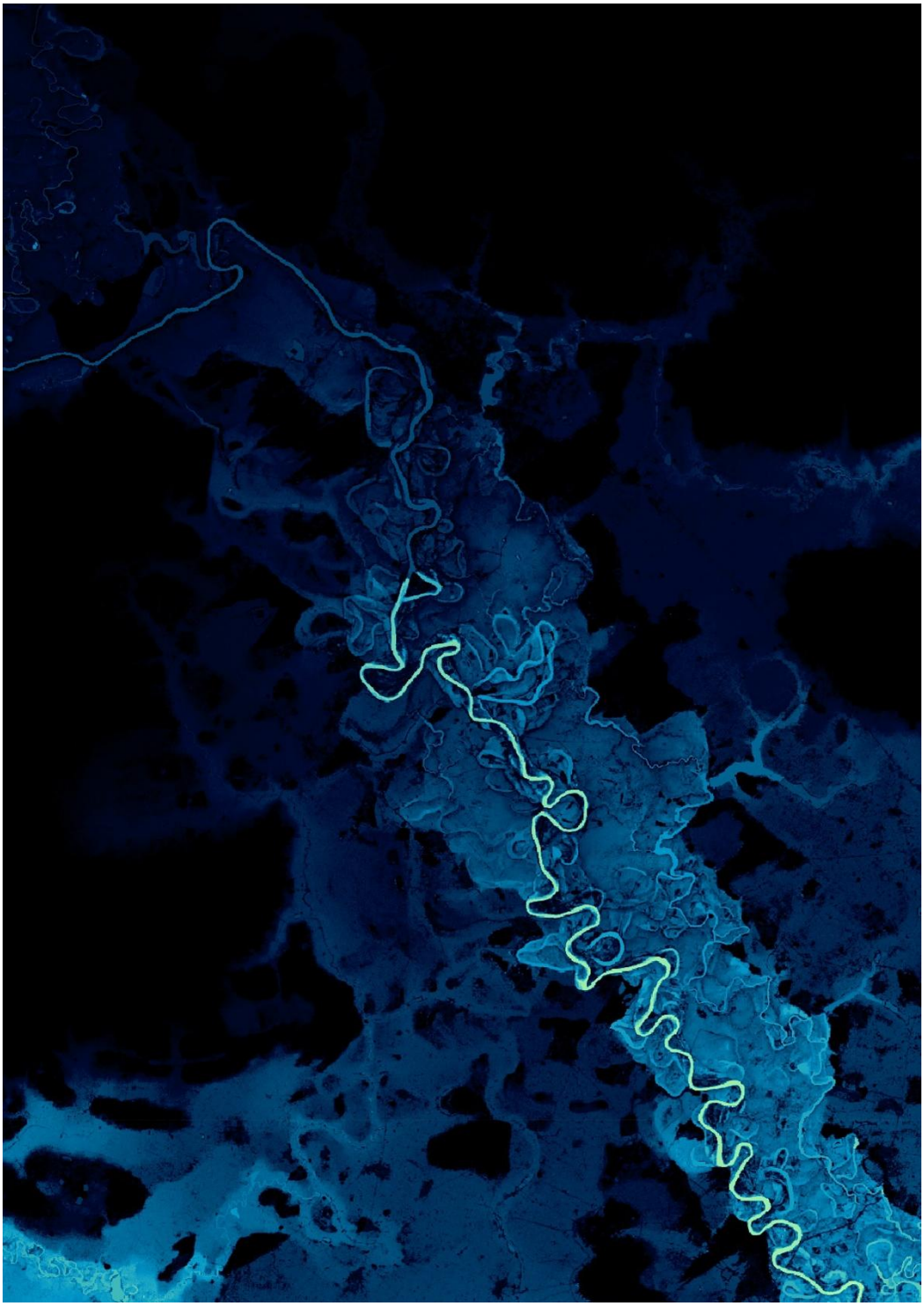

โครงสร้างภูมินิเวศ พลวัต และนิเวศบริการของแนวป่าชายน้ำ: กรณีศึกษาพื้นที่ตัวเมือง จังหวัดยโสธร

Landscape ecology, dynamics and ecosystem services of riparian forest corridor: the case study of Yasothorn, Thailand

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บทคัดย่อ

แนวป่าชายน้ำ เป็นกลุ่มพืชพันธุ์ที่เกิดขึ้นตามธรรมชาติบริเวณริมตลิ่ง เป็นส่วนหนึ่งของระบบนิเวศแม่น้ำและพื้นที่ราบลุ่มน้ำหลาก ทำหน้าที่เชื่อมต่อในแนวยาว แนวราบและแนวดิ่งของระบบนิเวศ กำเนิดผลผลิตเชิงนิเวศและนิเวศบริการ ยโสธร มีชุมชนชนบทขนาดเล็กที่ยังมีการดำรงชีวิตด้วยการเกษตรกรรม ประมงน้ำจืดและประโยชน์จากนิเวศบริการ งานวิจัยนี้จึงต้องการศึกษาโครงสร้าง พลวัตและนิเวศบริการของแนวป่าชายน้ำและประโยชน์ต่อชุมชนเกษตรกรรม รวมถึงการเปลี่ยนแปลงของแนวป่าชายน้ำด้วยวิธีวิจัย (1) ใช้เทคโนโลยีรับรู้ระยะไกลเพื่อระบุโครงสร้างภูมินิเวศ ขอบเขตการเกิดพลวัตน้ำหลากและการก่อตัวของแนวป่าชายน้ำ (2) สังเกตการณ์พื้นที่ ผลการศึกษาพบว่า แนวป่าชายน้ำพบมากในพื้นที่ราบลุ่มน้ำหลากซึ่งมีความกว้าง 3.00-8.00 กิโลเมตร การขยายและหดตัวของของพืชได้รับอิทธิพลโดยตรงจากพลวัตน้ำหลาก นิเวศบริการแนวป่าชายน้ำสำคัญมากต่อความมั่นคงทางอาหาร ความต่อเนื่องของวิถีชีวิตและระบบเศรษฐกิจหมู่บ้าน แนวป่าชายน้ำลดลงอย่างมากจากการเปลี่ยนการใช้ประโยชน์ที่ดินเพื่อเกษตรกรรม อ่างเก็บน้ำและการขยายตัวของเมือง ตามลำดับ รวมถึงการเปลี่ยนแปลงพลวัตน้ำหลากโดยเขื่อนและถนน จนนำไปสู่การลดลงของนิเวศบริการที่กระทบกับปริมาณอาหารและรายได้จากทรัพยากรธรรมชาติ

คำสำคัญ: ป่าชายน้ำ ภูมินิเวศ นิเวศบริการ ความมั่นคงทางอาหาร ยโสธร

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Abstract

Riparian forest (RF) distributes along riverbanks, considered part of the river-floodplain system, provides longitudinal, lateral and vertical connectivity, as well as numerous ecological functions and ecosystem services (ES). In Yasothorn, many communities sustain their livelihoods through agriculture, freshwater fishing, and benefits derived from ES. This study aims to identify the structure and dynamics of RF, ES benefits to agrarian communities, and monitor changes using two main methods: (1) classifying landscape structures, detecting FPD extents, and riparian coverage through remote sensing, and (2) conducting field observation. The results indicate that RF predominantly located within an extensive floodplain ranging from 3.00-8.00 kilometers. The expansion and contraction of RF coverage are directly correlated with the occurrence of FPD. Ecosystem services from RF are essential for food security, the continuation of livelihoods, and household economy. The Loss of RF is primarily caused by land cover change for farmlands, reservoirs, and urban development, as well as FPD alteration due to dams and roads. These changes have significantly impacted the availability of natural foods sources and benefits derived from natural capital.

Keywords: riparian forest, landscape ecology, ecosystem services, food security, Yasothorn

Introduction

Riparian vegetation are plant communities that occupied riverbanks which influenced by the riverine dynamics. The Riparian forest (RF) distributes at the transition between terrestrial and aquatic ecosystems (Griggs, 2009) therefore, developed the ability to avoid and withstanding floods (Junk et al, 1989; Kaewthumrong, 2018; Poopat et al, 2018). RF plays an important role in providing numerous ecosystem services (ES), maintaining biodiversity including protecting and mitigating floods. For human society, The ES provided by river and riparian ecosystem are the essential to daily basis and agricultural practices (Murye et al.,2023).

There are researches highlighted the ecological and biochemical process of RF including species composition and habitats (Johnson & Buffler, 2008; Mariem & Pérez-Pérez, 2020; Poopat et al., 2018). Also, for landscape architecture planning approach, RF is recognized as an intervention for blue-green infrastructure promoting urban ecology, mitigating urban floods and providing public recreation spaces (Haase, 2017). However, this study aims to capture the interplay between human livelihoods and RF ecosystem services for agrarian society in rural context of Thailand by (1) investigating landscape structure, dynamics, ES of RF and (2) identifying significant benefits of RF to human well-being.

Literature review

1. Riparian forest (RF) and flood adaptation

The RF is known as riparian zones, comprise with biotic communities distributed along riverbanks between the lowest to the highest flood level including areas under the influence of groundwater levels and flood pulse dynamics (FPD). (Naiman & Décamps, 1997).

According to Naiman & Décamps (1997), RF distribution and species composition are determined by landscape structure, hydrological characteristics of river corridor and fluvial process e.g. flow, biogeochemical cycles and river morphology. RF with high biodiversity usually found the large river-floodplain systems, like in the northeastern region, with continuously hydrological process like FPD, lateral channel migration, oxbow lake formation processes, and moisture retention soil.

Riparian plants can thriving with FPD, pioneer species rapidly grow and withstand flood environment for 2-3 months (Poopat et al., 2018). Characterized by level of woodiness and local soil moisture, two major types of riparian found in Thailand are riparian wetland and wet forest (see Figure 1) (Riis et al., 2020). Riparian wetland could thrives in seasonal inundation and waterlogging area with stagnant water or gentle water flow. Therefore, the vegetation are mostly aquatic plants. In constrast, wet forest is typically found in high fertile soil of the transitional zone and natural levees. Wet forest distributes by diverse evergreen

plant community including tree, shrub, climbing shrub, and vine that could tolerate submerging for 1-3 months during inundation (Poopat et al., 2018) .

RF adapt its morphological, physical character and seed dispersal mechanisms tackle 2 main survival constraints: (1) flooding conditions and (2) reproductive issues (Naiman & Décamps, 1997). The vegetations adapt its root system that is able to transport oxygen from above-water and capture oxygen from anaerobic process. Plant stems developed high flexible stems and branches to withstand shear stress from flood and abrasion. Some species adapt to toxic conditions by releasing oxygen into the surrounding soil, stimulating reaction of oxygen processes. However different plant species has different adaptation mechanisms to survive. Another adaptation strategy shows that riparian species start the reproduction phase after flood recede to guarantee a higher survival rate (Naiman & Décamps, 1997).

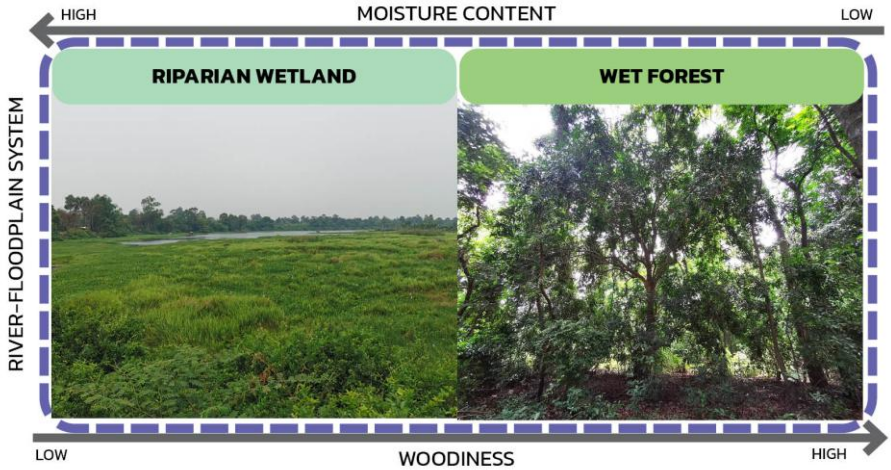

Figure 1 Riparian character predominantly founded in Yasothorn are riparian wetland and wet forest
Source: adapted from Riis et al. (2020)

2. River corridor and flood pulse dynamics

River-floodplain is a co-existing system characterized by seasonal fluctuation with diverse timing, magnitude, and duration (Correa et al., 2022). The fluvial process including FPD contributes to the formation of RF and landscape features e.g. riverbanks, mounds, swamps, and low-lying areas. The FPD occurs when water volume exceeds river capacity and inundates into interconnected floodplain, transforming the terrestrial ecosystem to aquatic ecosystem (Nilapornkun & Thaitakoo, 2018). According to Junk et al. (1989), the FPD regulates (1) life cycle in unseasonal floodplain by indicating the annual migration and reproduction phase for aquatic species, (2) producing ecological productivity by stimulating detritus decomposition enrich aquatic ecosystem and support the rising biota populations, (3) enhance habitats from numerous habitat heterogeneity allow the colonization and increasing

populations, and (4) influence plants distribution and species combination from habitats regulation.

Floodplain and RF provide a wide range of ES which directly harvested and consumed by human. Indirect benefits, riparian helps regulating and supporting the continuation of ecological process and landscape integrity, significant to climate mitigation and climate resilience (Riis et al., 2020; Schindler et al., 2014).

3. Ecosystem services (ES)

ES provide life-supporting system and contributes to human well-being including alleviate quality of life by safeguarding the continuous environmental processes (Singh & Dudley, 2010). For information service, beautiful landscape inspiries the creation of arts. RF offers wide range of ES important to livelihoods especially regulating and supporting service (Keleş Özgenç, 2024). Human utilizing ES for agriculture, fishing including tourism (Murye et Al., 2023). The relationship between human and RF is represented by livelihoods, culture, and belief (Nilaponkun & Thaitakoo, 2018).

4. Household economy

ES is the foundation of household economy development, because ES generates revenues from market values (Hussain et al., 2010). The existence of ecosystem and services generates economic value, which can be monetarized for either its present or value for future possibility.

For rural community, primary products are important to household for daily consumption, including household economy where household income mostly earns from agricultural products, fisheries and natural resources harvesting. Therefore, the availability of ES is significant maintainance of household economy and maintains their well-being (Adger et al., 2018).

Site Description

Yasothorn (YT) province is located in the northeastern region of Thailand with area in total of 4,161 square kilometers. Chi river is the main feature on prevalent flat topography with slope towards the east, and the elevation ranges from 120 to 160 meters above sea level. There are diverse landscape features exist in large lowland areas and floodplain of Chi river, which allow the remote sensing analysis (see Figure 2). Also, there are some primary studies and the royal irrigation department telemetry stations providing literature and open source data facilitating the study.

According to Department of Public Works and Town & Country Planning (2012), Yasothorn is promoted as organic agricultural product hub and local heritage preservation. To conserve rural and agricultural areas, building height in downtown, rural zone and

agricultural zone should not exceed 15, 9, and 6 meters, respectively. Set back from water bodies is rough address with minimum of 6 meters.

In Yasothorn, there are RF visible and left intact along the riverbanks and wetlands, which easily observable from ground observation and can be analyzed by remote sensing method. Moreover, along Chi river in Yasothorn, located the early settlement typology where local people has been developed in tandem with landscape and natural dynamics wisely. Currently, local livelihoods is prevalently connected to ES. Agriculture and fisheries contribute to economic growth with GPP value approximately 28,000 million baht in 2019 (Yasothon Provincial Administrative Organization, 2019).

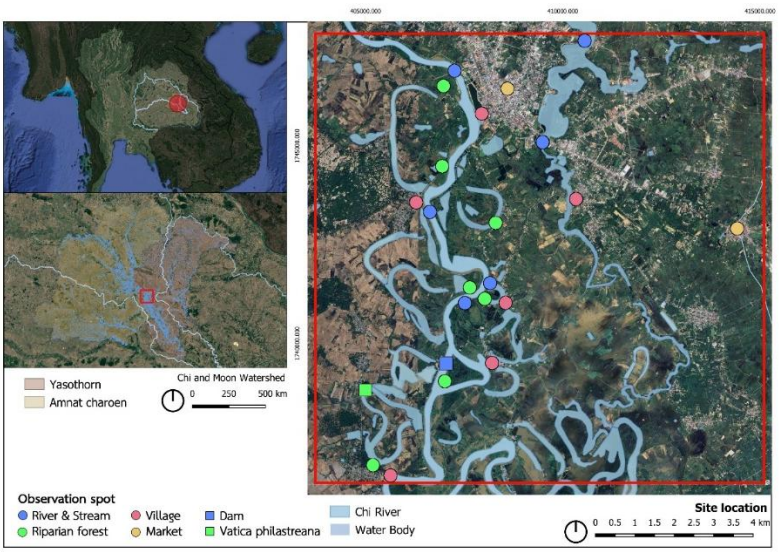

Figure 2 Study area and location of ground observation spots in Yasothorn.
Source: Author

Methodology

The study employs two major methods: (1) remote sensing analysis and (2) field observation. Remote sensing dataset provides a record of spatio-temporal events, allowing spatial calculation and monitoring changes. The utilization of ES was documented from field observation including other quanlitative aspects.

1. Remote sensing

The analysis aims to re-construct landscape structure and detect spatial correlation to natural dynamics by compiling multiple materials. Due to the data availability, the oldest aerial photography and L7018 topography map are selected to study land cover change. The most recent elevation model is selected, and satellite images are representing temporal FPD

change, inundation (2017), drought (2015) and average year (2009). These following are the spatial data for the study:

1.1 Digital Elevation Model (DEM), resolution 30 meters (European Space Agency, 2021)

1.2 Landsat 7ETM+ and Landsat 8OLI satellite imagery (U.S. Geological Survey, 2022)

1.3 Aerial photography of Yasothorn, 1954 AD. (Royal Thai Survey Department, 1954)

1.4 Topography map series L7018 (Royal Thai Survey Department, 2013)

2. Analysis

Topographic classification method is applied. DEM data has been classified using the classification function in QGIS and multiples topography profiles are generated to study Yasothorn topography and elevation. These profiles define floodplain boundary and the correlation to other landscape context.

The normalized difference water index (NDWI) is employed to analyse annual FPD by extracting water bodies expansion and diminishing between wet and dry deason. The three sets of Landsat 7ETM+ satellite imagery that represent inundation (2017), drought (2015) and average year (2009) are selected and have been used for the calculation:

$$NDWI = (GREEN - NIR)/(GREEN + NIR)$$

RF change is detected and utilized. The same set of satellite imagery represent, the onset of maximum, minimum and normal FPD. The enhanced vegetation index (EVI) is employed due to the advantages of high sensitivity and atmospheric corrections to obtain accurate information in dense vegetation area:

$$EVI = G * \big((NIR - R)/(NIR + C_1 * R - C_2 * B + L)\big)$$

3. Field observation

Field observation are conducted three times in wet (November), dry (April) and rainy seaon (June), including 23 observation spots in 6 villages (Yasothorn town, Tha-Yiam, Kutkong, Nonghoi, Talad, Kaset-somboon), 2 markets, 6 oxbow lakes, 1 river, 1 stream and 1 dam with drone and ground survey. The researcher observed the locals with varied age groups and careers to identify the interplay between direct riparian ES and livelihoods e.g. natural foods, recreation, fishing. The indirect services are analysed using information from the literature review including the assessment of their importance to rural livelihoods.

Result

Research results are categoried into 3 parts: (1) riparian landscape and dynamics, (2) identification of riparian ecosystem services and, (3) riparian forest changes.

1. Riparian landscape and dynamics

Yasothorn town center is situated on a high mound named ‘Ban Sing Tha’, on the edge of Chi riverbank (see Figure 3). The location represents the understanding of landscape

context that city footprint was settled on highland above flood level. Flooplains are enclosed in between elevated terrains parallel to Chi river corridor. The floodplains are largely expansive, ranging from 3.00 to 8.00 kilometers wide from east to west where oxbow lakes, swamps and wetlands can be found all over the area. Majority of the floodplains were modified into rice paddies and farmlands (see Figure 4).

The highlands rise 5.00 to 15.00 meters higher than floodplains, and many villages are commonly located on mounds. In constrast, fishing communities are found in the middle of floodplains where inundation and numerous water bodies occure. It indicates the different settlement criteria and adaptation stategy by taking the benefits from floods to facilitate fishing practices.

Within Chi river-floodplain system, riparian vegetation can be detected ranging from Chi riverbank to the edge of mounds alternated with rice paddies. There are two major types of RF founded which are riparian wetland and wet forest.

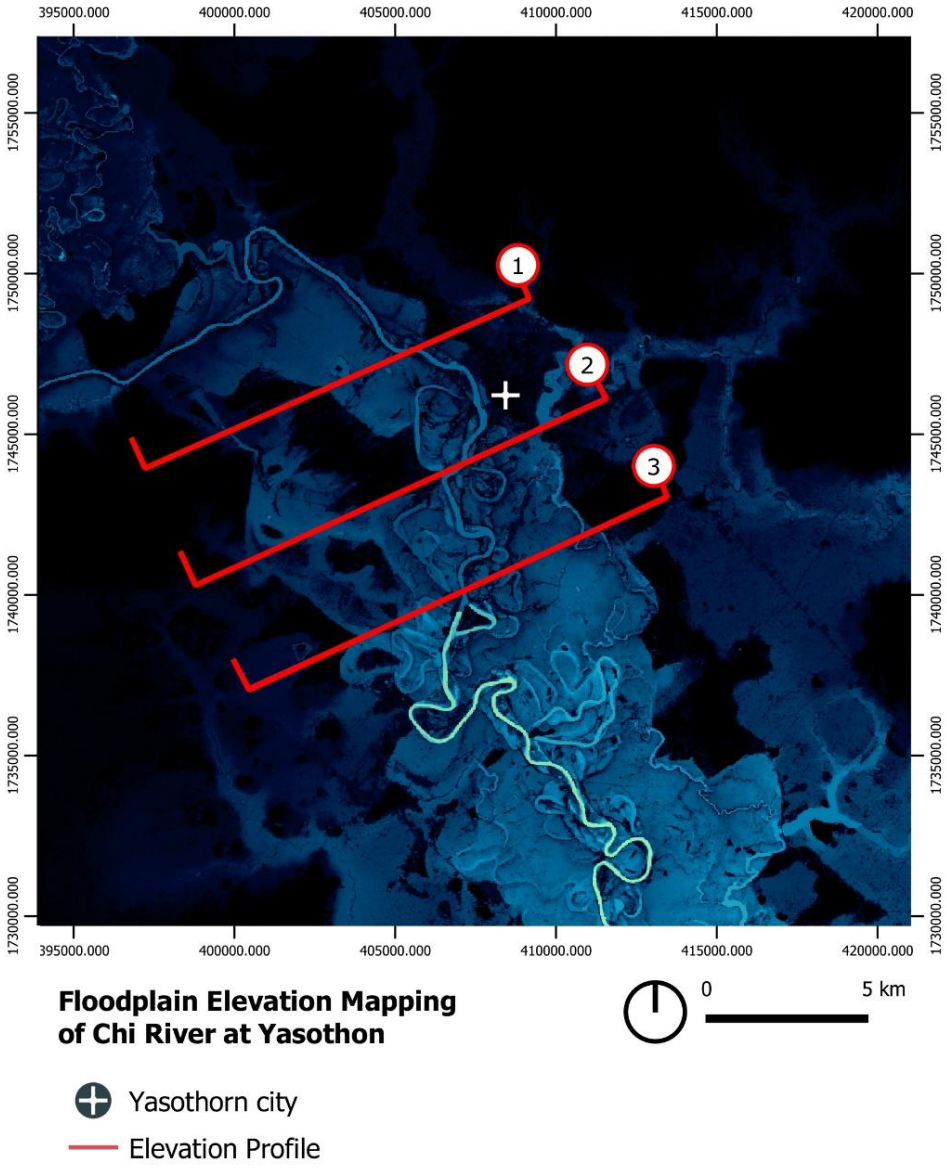

Figure 3 Topography of Yasothorn: color enhancement reveals extents of highlands (black) and floodplains (blue).

Source: Author

The existence of RF is in fluenced by two major factors which are natural factors and land use. Riparian wetland predominantly distributed where permanent water bodies were found in the large area where oxbow lakes and swamps exists. Human utilization of farmlands offer suitable habitats for wetland plants since water bodies are preserved to ensure water for consumption and agriculture. In contrast to wet forest where trees are predominated,

scattered on mounds. Due to land utilization, wet forest remains only in undisturbed area close to oxbow lakes, lavees and protected sites like temples. Common species are *Crateva adansonii, Depterocarpus alatus*, *Alibzia procera, Combretum quadrangulare,* etc. In protected sites, *Vatica philastreana,* an index specie of riparian plant community is found. This species is hardly detected nowdays due to floodplain habitats loss (see Figure 2).

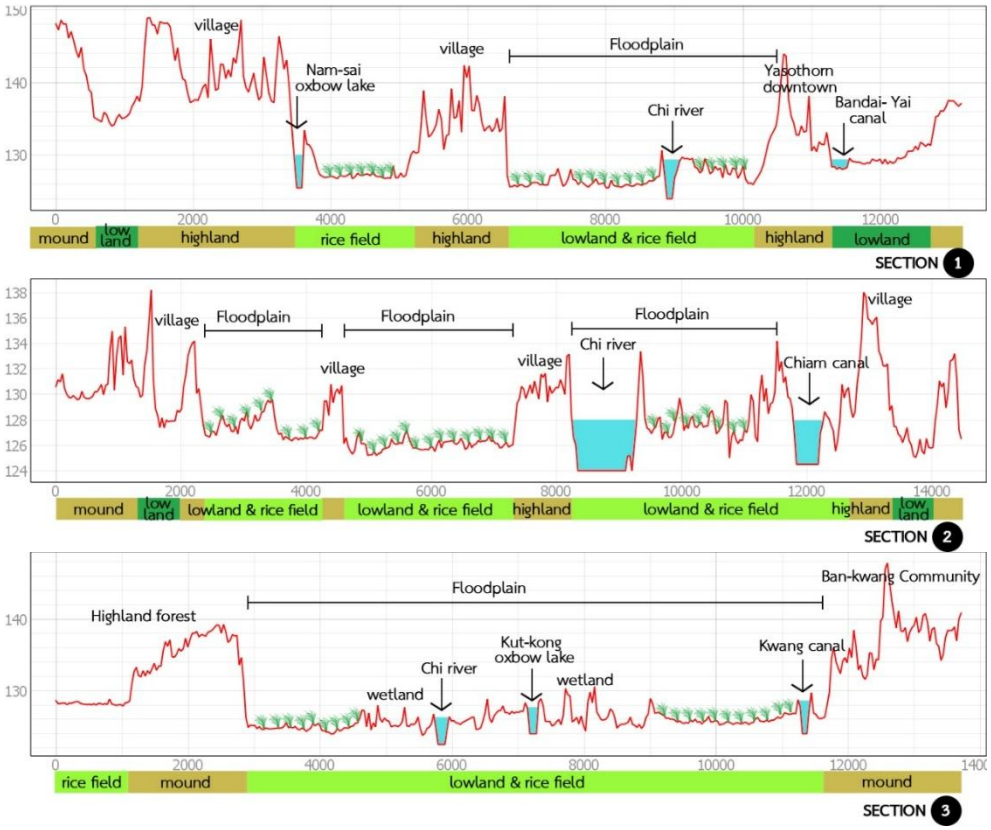

Figure 4 Section profiles shows landscape structure of Yasothorn highlands and floodplains

Source: Author

RF are under the influence of FPD. In wet season, NDWI detects 15.80 sq.km. of water surfaces while water extent is significantly reduced to 2.96 sq.km. in dry season. The EVI detects area of a broad expansion of RF cover over 46 sq.km. in wet season while vegetation decreased to 41 sq.km. during drought. This detection indicates that the reduction in vegetation coverage is correlated with flood recession (see Figure 5). According to literature review, RF distributed in close proximity to permanent water bodies has a higher chance of surviving drought.

2. Riparian ecosystem services

RF contributes to 4 types of ES essential to the agrarian society in rural context (see Table 1). In Yasothorn, many settlements are located in a close proximity to wet forest. The vegetation stands promote multiple benefits for instance, provision of wind shields protecting villages and crops from strong wind, water and air quality, increasing livability, including climate regulation.

RF is considered an important habitat therefore, there are variety of plants and wildlifes colonization. Fishes, shellfishs, amphibians, and diverse insects are harvested for daily consumption and trading. Wet forests are primary source for vegetable and herbs which are used as ingredients in locals cuisines e.g. mushrooms, ant larvae. The diversity of natural foods and its high quality in nutrition are keys in maintaining food security. While accessibility to natural foods generate income for a household from exchanging by its market values.

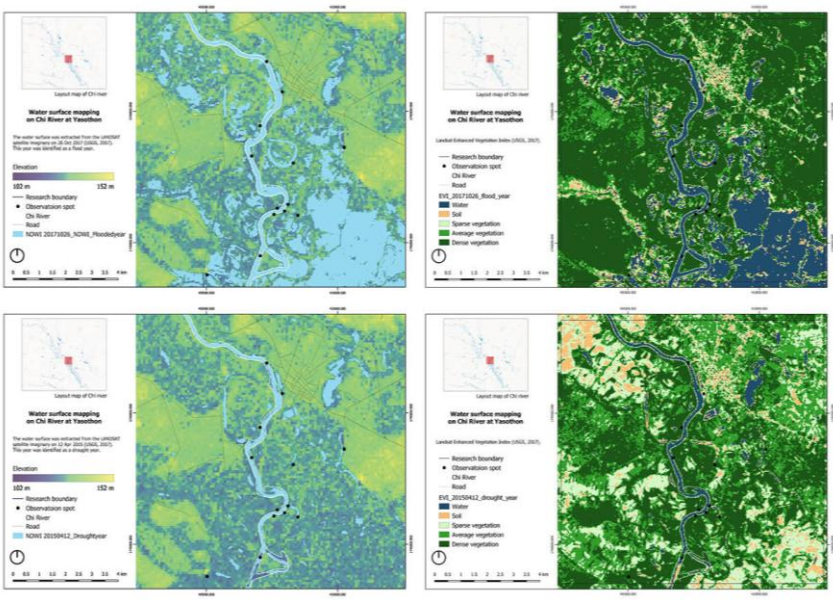

Figure 5 The correlation of water extent and vegetation coverage in wet (top) and dry seaon (bottom)
Source: Author

Regulating and supporting service have a crucial role in maintaining the continuation of livelihoods and certain way of life. Thses services maintaining landscape normalcy resulting in soil fertility, climate consistency and resiliency with long term facilitatation for human settlements, agricultural practices and livelihoods.

Isan cuisine, recognized as food identity, is one of the evidence of regulating and supporting service that maintain the long-term practices by continuously provide sufficient natural capital. For instance, fishes and fermented fish have been consumed since the

prehistoric time up to the recent date. It clearly shows prolong provisioning service supporting the forming culinary culture.

Cultural service is easily perceived through practices of arts, tradition, local architecture, including tourism. In YT, the most popular festival is rain making ritual where a large celebration was held in the town center where all villages handcrafted their rain rockets to join the celebration. It represents a strong belief in the role of natural dynamics that provide natural capital for agricultural communities.

Table 1 The identification of ES and the degree of importance derived from riparian forest.

Category		Importance	Major ES	Minor / Indirect ES
Provisioning	Space	Significant	Settlement, human space	
			Open spaces	Mitigate urban density and promoting quality of life
			Natural & cultural tourism	Promoting economic growth
			Habitats and urban sanctuary	Recreation and learning spaces
		Medium	Agriculture, livestock, raw material for manufacturing	Cultural landscape
		Minimum	Accommodates urban expansion and infrastructure	
	Material	Significant	Natural food and herbs, insects, fishes, shellfishes	Reduce household expenses, food security, income
			Organic matter and nutrients	Reduce farming cost
			Clean water for consumption	Reduce household expenses
			Medicinal and pharmaceutical material	Wisdom in treatment and reduce expenses
		Medium	Wood for construction and handicraft	Reducing expenses and maintaining craftsmanship identity.
			Water for agriculture	Reduce farming cost
		Minimum	Soil material and fertilizer	Reduce farming cost
			Fresh air	Increase living quality
Regulating	Climate regulation	Significant	Surface temperature control through vegetation coverage	Increase livability
			Windbreaker and dust filter	Reduce climate impacts
			Water quality regulation	Increase living quality

			Promote decomposition, filtrate runoff, pollutions removal and absorbance	Increase living quality
	Fluvial process	Significant	Riverbank stabilization and induce sedimentation	Reduce flood risks and property damage
			River corricor stabilization	Reduce property damage
			Regulate water temperature	Promote habitats
	Natural cycles	Significant	Carbon sequestration	Enhance climate stability
			Maintain carrying capacity	The continuation of agrarian livelihoodss, farming practices
			Pest and disease control	Improve product yields, quality and saleability
Supporting	Space	Significant	Maintain habitats heterogeneity and biodiversity	Maintain natural capital, food security
			Wildlife migration and shelter	Maintain biodiversity, food security
		Minimum	Support urban expansion and infrastructure	
	Nutrient cycles	Significant	Organic matters decomposition cycles	Promote farming yields, reduce farming cost
			Maintain genetic diversity and the dispersal	Maintain natural capital, food security,
			Pollination	Maintain biodiversity, reduce farming cost
		Medium	Maintain soil fertility	Promote farming yields, reduce farming cost
	Well-being	Significant	High quality nutrition	Food security, physical strength
		Medium	Increase livability	Promote mental health
	Livelihoodss	Significant	Prolong availability of natural capital	Continuation of household economy, fishing and farming practices
Cultural	Vernacular wisdom	Medium	Settlement typology and criteria	
	Cultural identity	Minimum	Rainmaking rituals, rain rocket festival, god of rain parade	Torism and economic value

	Spiritual and belief	Significant	Local belief in guardian of forest promote the conservation of RF as protected site	Biodiversity sanctuary, food security, natural capital protection
	Aesthetic	Significant	Aesthetic scenery	Livability, tourism
			Recreation	Enhance quality of life
	Information & knowledge	Medium	Education, outdoor classrooms, research ground	

Source: Author

3. Riparian forest change

Floodplains have experienced land cover change the most where RF was removed, according to two major factors which are (1) land cover changes and (2) FPD changes. Land cover changes were induced by human acitivities from (a) the extensive expansion of agriculture, (b) the increasing of reservoirs for water supply, and (c) urban expansion. Land cover comparison between 1954 and 2013 show that RF, had extended across 40.48 sq.km., was replaced by agricultural farmlands and significantly decreased to 11.75 sq.km. (see Figure 6). Recently, RF became fragmented and scattered on wetland edges or remained in undeveloped sites.

In contrast, farmlands and reservoirs have been increased. Rice fields, originally covered 60.94 sq.km. in 1954, have expanded to 71.36 sq.km. while reservoirs which naturally covered the area of 4.50 sq.km., have been excavated and significantly increased to 13.50 sq.km. The results indicated population growth raising demands of consumption resources.

Urban expansion was clearly detected in YT downtown where footprint has enlarged. Built and impervious surfaces were increased in area from 2.99 sq.km. to 13.07 sq.km. Maps show the direction of expansion toward the undeveloped highlands in the north of YT downtown and on highlands eastward. The increasing of road infrastructure is another important factor facilitating urban expansion.

The second factor contributed RF loss is FPD change due to water retention and FPD alteration. Started from the construction of Yasothon-Phanom Phrai Dam which obstructs river profile and longitudinally disconnects Chi river corridor. Futhermore, after the reservoirs' dredging, the Royal Irrigation Department (RID) installed sluice gates to manage the water flows for irrigation and utilization purpose. The dam retains 80% of water within river corridor upstream followed by drastic different of water level between upstream and downstream. By comparing hydrograph between Yasothon dam station and Maha Chana-Chai station (Hydrology Irrigation Center for Upper Northeastern Region, 2024, n.d.) indicates

different maintain level where upstream water level is at 125 msl. while downstream is at 116 msl. There are 9 meters difference in water level under normal conditions.

FPD was alterated according to RID water management pratices. The annual prolong inundation, originally last 7 months, was altered into unpredictable short-term floods of 2-3 months. The shortened and delayed cycles impacts riparian ecosystem because the alteration of flood duration, timing, and magnitude are not aligned with the biota reproductive cycles and becoming threats to their survival. The alternate wet and dry cycles is key factor of RF survivial. Retained, stagnant and disconnected rivers are deteriorating RF health. According to site observation, upstream RF exposes to excessive moisture, stagnant and inadequate alternate cycles which plants communities hardly thrive. River impediments disconnect river corridor and obstruct plants dispersal route including aquatic species migratory route. In long term, the entire RF ecosystem tends to degrade followed by the decline of ES. From field observation, locals harvest wild vegetables, catch and trade fishes, process food products, utilize RF for recreation and preserve as spiritual place. The reduction of life-support resources inevitably reduce human well-being and increase the difficulty to access to living necessities. For agrarian society, the lacking of provisioning service impacts their food security, livelihoodss and culinary practices. The absent of natural capital de-escalate, financial stability, because it increases living expenses as household has to spend for the resources needed for living which resulting in the disruption of household economy.

Conclusion

This study concludes that (1) Yasothorn landscape topography comprises with expansive floodplains and high mounds. The floodplains are ranged from 3.00-8.00 kilometers wide where riparian is vegetation distributed from the Chi riverbank to the edge of mounds. Riparian wetland predominantly founded in riverbanks, oxbow lakes, and swamps while wet forest scattered on mounds in undisturbed area.

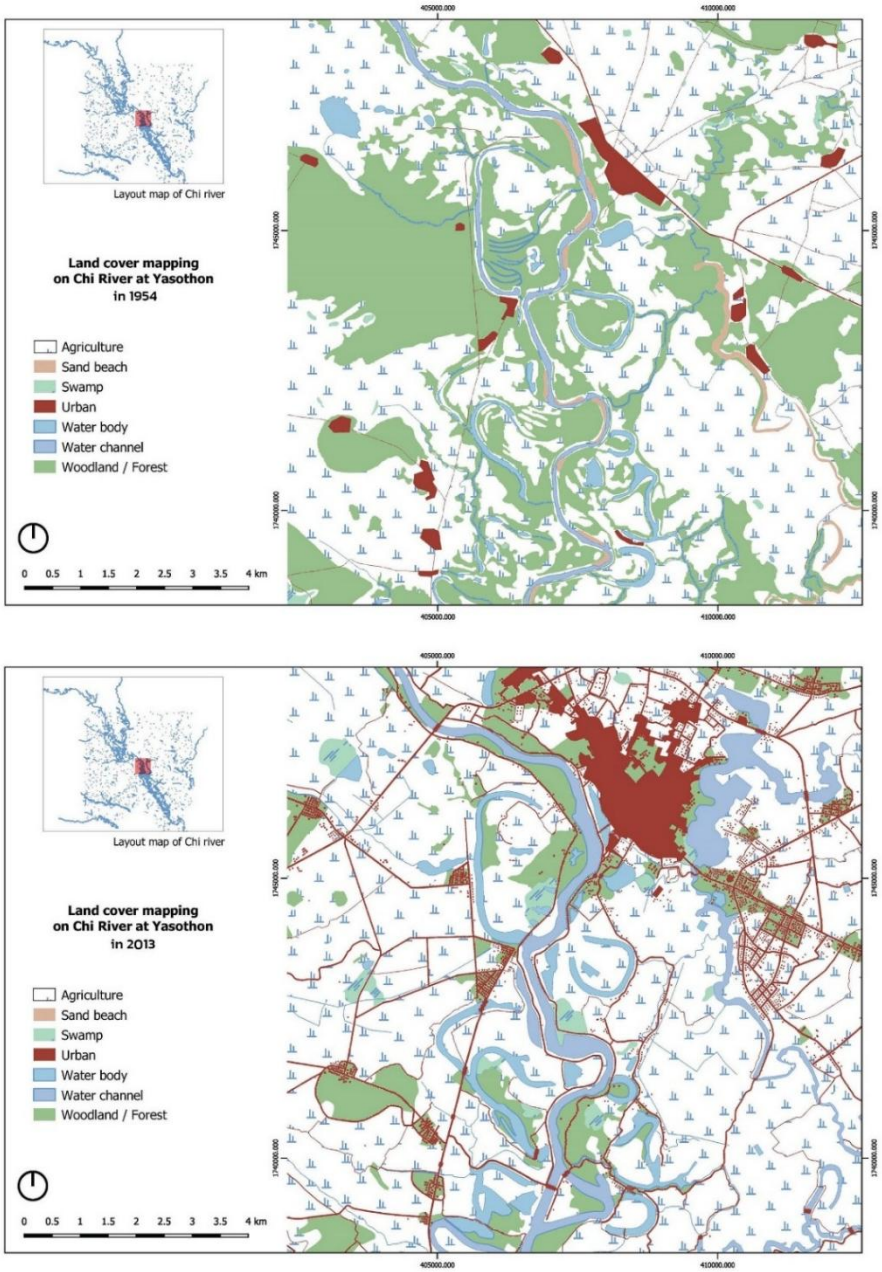

Figure 6 Classified maps indicated land cover change in Yasothorn between 1954 (top) and 2013 (bottom).
Source: Author

FPD has major influence over RF spatio-temporal fluctuations that during inundation, vegetation coverage is broadly expanded across floodplain and shrinking in area during drought condition. (2) RF provides four major ES. For agrarian society in rural context, the most important service sustaining livelihoods are maintaining food security and continuation

of certain way of life including financial stability. (3) RF drastic loss is due to the expansion of farmlands, reservoirs, and urban footprints including FPD alteration induced by river impediments and road networks. The results of change are followed by the absent of ES and natural capitals which impact human well-being, food security and household economy.

The findings should be contributed to policy recommendations and spatial management in protecting and enhancing urban-rural riparian corridors for mutual conservation benefits. The policy recommendations must adopt a proactive, which includes: (1) incorporating all permanent structures like floodwall, retaining wall and fence under the building control act to ensure appropriate setbacks from watercourses and conserve existing RF, (2) prohibiting all activities to encroach on natural and unstable riverbanks and, (3) establish tax incentive to promote RF preservation. Spatial management must focus on: (1) restoration of river corridor and enhancing of river-floodplain connectivity, and (2) implementing sustainable land use management by supporting and protecting land use that align with natural condition or promotion of natural processes and biodiversity within river-floodplain zone.

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