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GEO-INFORMATION TECHNOLOGY APPLICATION FOR INVESTIGATING THE OLD LOPBURI RIVER AND THE ANCIENT CITY OF DVARAVATI PERIOD (6TH-8TH CENTURY AD) BASED ON THE RECORDS OF QUEEN CĀMADEVI'S WATERCOURSE TRAVELS IN THE CHAO PHRAYA RIVER BASIN

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ABSTRACT

At present, historical evidence has been discovered that the watercourse travels of Queen Cāmadevi and her group using the Lopburi River route is not the route that appears today. This research therefore searched for archaeological evidence from the Dvaravati period (6th-8th century AD), together with geo-information technology to find the old Lopburi River and the ancient city of Dvaravati, using Light Detection and Ranging (LiDAR) technology to analyze Least Cost Path (LCP) analysis, Visual image interpretation technique, Normalized difference Vegetation Index (NDVI), and Normalized difference built-up index (NDBI). The results of the study found that the old Lopburi River has now become 12 important canals. Results from the LCP can indicate that she traveled northwest through the ancient cities of Chan Sen, Utapao, and Bon (Khok Mai Den). As for the results of the study using the Visual Image Interpretation technique, it is possible to know the details of all 12 present-day canals, which are the Lopburi River in the Dvaravati period, and can also effectively detect the condition of the moats and embankments of ancient cities such as Lavapura, Chan Sen, Utapao, Bon, and Phra Bang. And the results from NDVI and NDBI can also clearly see the direction of urban expansion occurring within the ancient city and surrounding areas that has been affected archaeological sites. The impacts from building expansion should be protected as quickly as possible, and organize systematic planning to support spatial changes to be sustainable in the future.

KEYWORDS: Lopburi River, Dvaravati Period, Queen Cāmadevi, Chao Phraya Basin, Geo-information

1. INTRODUCTION

Dvaravati is a cultural group that appeared in the surrounding area of the Gulf of Thailand, especially indigenous people in Southeast Asia during the 6th-11th centuries AD (Mudar 1999; Murphy 2013; Carter 2023). Such culture is a result of the integration of the influence of Indian civilization that has come together to form a new cultural form and has a unique style that makes art, culture, antiques and archaeological sites have characteristics called Dvaravati art. In addition, Dvaravati is also the name of an ancient kingdom in Southeast Asia from evidence recorded during the Tang Dynasty of China. In 1923, Paul Pelliot, George Coedès, a French archaeologist, and Prince Tisavarakumarn, the Prince Damrong Rajanubhab, jointly conducted the first archaeological excavation, which has continued to be studied by historians until the present day (Peleggi 2013; Peleggi 2023). More and more evidence of antiquities, art objects, and archaeological sites have been discovered. Most of them were built according to the beliefs of Mahayana Buddhism, and some Hinduism, along with the discovery of archaeological sites, ancient sites and ancient cities scattered as many as 106 places, which 70 are in the Chao Phraya lowlands and eastern Thailand, another 30 in northeastern Thailand and 6 in northern Thailand. Therefore, it can be said that during the 6th-11th centuries AD was the era in which Dvaravati Civilization was very prosperous (Wales 1969; Welch 1998). It is an era of transition from prehistoric society entering the historical period in the Suvannabhumi area (the mainland part of Southeast Asia) as a result of Dvaravati having trade contacts and receiving culture from India during the Gupta Empire (Gupta Empire) (Kang 2013; Upadhyay 2023). Cities in this territory are proto-state, that is, each city is independent of the other. Their economic, social, cultural and religious beliefs are therefore similar.

According to historical evidence of Lanna (an ancient kingdom in northern Thailand) such as Mulasasana legends, Haripunjaya historical records, Chinna-kanmalipakon, Camadevivamsa or Chronicle of the Lineage of Cāmadevi, and Rishi Kaew legends, mention the destruction of cities in northern Thailand, caused by a strong earthquake that caused many people to die (Notton 1930; Ongsakul 2020; Swearer and Premchit 1998). As a result, Rishi Vasudeva, who was the spiritual center of the community at that time, conscripted people to build a new city named Haripunjaya (present-day Lamphun Province). The town's layout has a moat surrounding it, resembling a conch shell. Being an ascetic, unable to rule, he sent an ambassador named Gavaya (Tamil for Hanuman) to the city of Lava-pura or Lavo (present-day Lopburi province) to ask someone of royal

lineage and merit to rule Haripunjaya. Finally, Queen Chamadevi (or Cāmadevi), who had the status of being the daughter of King Jakawatti, the king of Lavapura, set out with Ri-shi Sukadanta and more than ten thousand soldiers traveling to the city (Swearer and Premchit 1998). Her travels had a great influence on the spread of Buddhism and Dvaravati culture. There was also the creation of new cities, and the expansion of communities in important cities, along the Lopburi, Chao Phraya and Ping rivers during the 7th century AD. Queen Camadevi's journey relied on the route of the Lopburi River, traveling upstream. It begins at Choeng Tha temple and goes up to the northwest passing important sites and ancient cities from the Dvaravati period as follows: Dhammika hill (Samo Khon Hill); Chan Sen; Utapao, respectively. Then take the Chao Phraya River route, passing Bon or Khok Mai Den, Phra Bang, respectively. Using the route into the Ping River, passing through Kanadi, Thep Buri, Pang Pol, Rak Siad, Rahaeng, Tak, Sam Ngao, Soi, Pla-Tao, Hot, Chom Thong, Wiang Tho, Wiang Koh Klang, respectively. Finally, it travelled to the Kuang river, where the city of Haripunjaya was located (Kanjanajuntorn *et al.* 2015), which is currently in the area of Lamphun province.

At present, historical evidence has been found that Queen Cāmadevi and her group used the Lopburi River route from Lavapura to U-Tapao, which is not the Lopburi River route that appears today. But it was found that the said journey was recorded through Dhammika hill (Samo Khon Hill), Ramapura and Chansen city, respectively. This location is not located along the current Lopburi River. Therefore, it is possible that the rivers and canals that appear today are the old Lopburi River that appeared during the Dvaravati period. The Lopburi River is a tributary of the Chao Phraya River, arising from stages of stream evolution until becoming a river entering the Old Age Stage, causing the river to have anabranching rivers patterns (Nanson and Knighton 1996; Shukla and Rhoads 2023; Nyberg *et al.* 2023). In addition, parts of the Lopburi River were dug again, especially the Bang Phutsa canal, for use in transportation in the 16th century during the reign of King Narai the Great (King of Ayutthaya Kingdom from 1656-1688) (Marcinkowski 2002; Ōhashi and Orchiston 2021). This caused the water system of the Lopburi River to change. Therefore, it is necessary to apply geo-information technology to study the development process of waterways in order to answer historical questions to reveal the truth about what river the Lopburi River was in the Dvaravati period.

Research related to Geo-information technology is applied in the field of archaeological prospection that shows the layout of the ancient city. Research by Chen *et al.* (2023) has brought such technology to study

characteristics and ideas of ancient city and land-use pattern of Chang'an City in the Sui and Tang Dynasties, revealing land-use composition, area value, and cultural significance in the functional area of Chang'an City of the Sui and Tang Dynasties. Cabrero-González et al. (2022) used Light Detection and Ranging (LiDAR) technology, a technique for detecting objects on the ground, to obtain land-cover data with high spatial resolution. The archaeological area in the Gor River, Spain, has been efficiently searched and has revealed the distribution of new burial mounds and megalithic graves, which date between the 4th and 3rd millennium BC. Davis et al. (2021) were able to find pedestrian survey, and micro-artifact approaches, the identification of hidden, permanent settlements and ephemeral artifact scatters in Pinckney Island, South Carolina, USA with LiDAR technology. Popović et al. (2021) performed spatial processing using airborne laser scanning (ALS or LiDAR) on the northern side of the Lim Bay, in the Municipality of Vrsar, Croatia. The study found remains of original Roman structures limit, with linear dry-stone features representing the territory of the centurias. The application of this technology has led to important archaeological excavations. Kaimaris (2022) used different sensors installed in an unmanned aerial vehicle (UAV) to locate buried ancient sites in two areas: North of ancient Amphipolis (Northern Greece) and Ancient city of Philippi. The research found that the multispectral scanner system is effective in finding traces of ancient architectural remains, especially in the near-infrared band, which can be used for the production of vegetation index maps, in order to obtain effective spatial information in excellent search for ancient ruins. Geo-information technology has developed functions for route analysis, especially LCP analysis, which appears in GIS programs, allowing Abou Diwan and Doumit (2017) to apply the principles of such analysis to find routes that have contact between the colony of Berytus, Northern Bekaa and the town of Heliopolis Baalbak. This analytical approach uses Digital Elevation Model (DEM), slope data, and connections from historical evidence and archaeological sites between the routes of the three cities. A suitable route between the major cities was discovered: the Berytus-Baalbak Heliopolis road. In addition, Aşınmaz and Özcan (2023) studied the Pamphylian archaeological evidence and examined the distribution patterns of settlements based on agricultural activities using spatial analysis and statistical principles in GIS, including nearest neighbor analysis and cost surface analysis, and relied on important data for this research, namely elevation, slope percentage, proximity to hydrologic units, ancient road network and major towns in the study area. The

results reveal settlement patterns consistent with agricultural areas near waterways and ancient roads. It has been a route for transporting agricultural products to important trading cities since the 18th century. Bachagha et al. (2022) used remote sensing and geographic information system (GIS) to analyze with unsupervised classification-based and statistical analysis-based methods in the Tunisian area. The results found that Military fortifications and troop routes associated with the Roman Empire can be detected. According to the research mentioned above, most are detecting archaeological sites, but to find connections between ancient cities, it is necessary to have a transportation route, especially the route of ancient rivers. As the research of Sarker et al. (2014) studied downstream of the Jamuna river, close to the Brahmaputra river in Bangladesh. It gives an understanding of morphological changes, especially important variables such as climate change, neo-tectonics, earthquakes, large-scale avulsions and engineering interventions. Such variables cause changes in the flow direction of the said river. This is consistent with historical evidence from 200 years ago when the Jamuna Channel showed signs of flowing through the western side of the current route. Magliulo et al. (2016) used a GIS and historical map showing the meandering stream of the Tammaro river, Italy from 1870 to 1955. The results of the study clearly show the development of the river. Vidya et al. (2023) analyzed morphotectonic analysis and structural controls on the geomorphic evolution of Shiriya river basin, Southern India. The research found that the bend and flow characteristics of the river in the meandering stream pattern directly affect the change in direction of water flow in the river, giving insight into the drainage system and river development. And, Arefin et al. (2023) applied Geo-information technology to study morphometric elements analysis to understand the development of the river flow system in the Bengal Basin in Bangladesh. From the research mentioned above, it is realized that Geo-information technology can help study archaeological prospection very well, if such technology is studied together with historical evidence such as chronicles, legends, archives, etc., it may make historical information clearer.

The objective of this research is to find the stream channel of the old Lopburi River and the ancient city of Dvaravati during the 6th-8th century AD according to the chronicles of Queen Camadevi's watercourse travels in the Chao Phraya River Basin, using geo-information technology combined with historical evidence. This is to pre-prepare spatial data of the old Lopburi River and the ancient city of Dvaravati along the said river during the 6th-8th century into a spatial database system. This will be useful information for historical studies to historians, archaeologists, related

agencies such as the Fine Arts Department of Thailand or related agencies, whether public or private, formulating policies for sustainable ancient conservation.

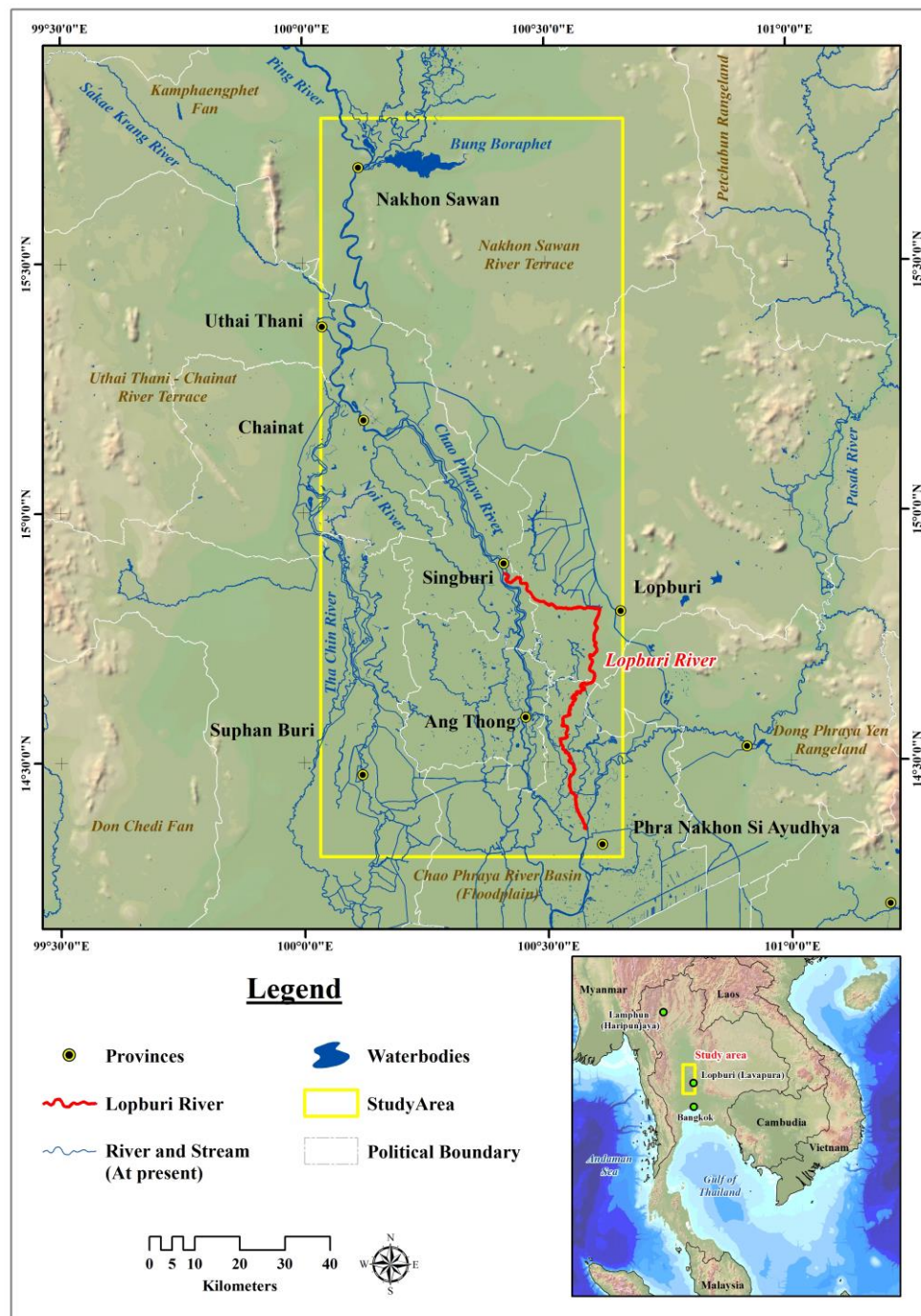


Figure 1. Location maps of the study area.

2. MATERIALS AND METHODS

2.1 Study area

The study area for this time is the Chao Phraya River Basin, where the water course of the Lopburi River will be studied mainly according to the records of Queen Cāmadevi's watercourse travels. The study area is located between latitudes 14°15' N to 15°45' N

and longitude 100° E to 100°45' E (Fig. 1). The topography is the floodplain of the Upper Chao Phraya River Basin, with the starting point of the Chao Phraya River being the area of Nakhon Sawan Province and Bung Boraphet Swamp. The Chao Phraya River flows in a meandering stream pattern in the upper part that is flanked by a terrace in the Quaternary era, namely Nakhon Sawan River Terrace on the east side, Kamphaengphet Fan, Uthai Thani-Chainat

River Terrace and Don Chedi Fan on the west side. The evolution of the Chao Phraya River Basin appears as a braided drainage pattern and anabranching drainage pattern starting in Chainat Province. This form resulted in the formation of an important river, namely the Tha Chin River in the west. Noi River and Chao Phraya River in the middle of the basin, and to the east is the Lopburi River. However, only the Noi River and the Lopburi River flow back into the Chao Phraya River in Phra Nakhon Si Ayudhya Province. These important rivers today flow through important cities, in order from north to south: Nakhon Sawan, Uthai Thani, Chainat, Singburi, Lopburi, Ang Thong, Suphan Buri, and Phra Nakhon Si Ayudhya. Some cities have developed since the Dvaravati period, and

some cities in the Dvaravati period appear to have been abandoned.

2.2 Data Preparation and Methodology

For preparing data for use in this research, secondary data from various sources were collected for analysis of the ancient waterways of the Lopburi River before being analyzed in the next process. Data for analysis includes Landsat satellite image, current rivers and streams, location of ancient city in the Dvaravati period, location of archaeological evidence, and Digital Elevation Model as shown in Table 1.

Table 1. Spatial data layers used in this research.

Spatial Database	Date	Format	Sources
Landsat 1 MSS	7 Jan 1973	TIFF	US. Geological Survey (USGS)
Path/Row 139/49 and 139/50			
Landsat 9 OLI/TIRS	26 February 2023	TIFF	US. Geological Survey (USGS)
Path/Row 130/49 and 130/50			
Landsat 9 OLI/TIRS	27 February 2023	TIFF	US. Geological Survey (USGS)
Path/Row 129/49 and 129/50			
Digital Elevation Model (DEM) (LiDAR resolution 5 m.)	2023	GRID	Land Development Department, Thailand
Rivers and streams	2023	Shapefile	Department of Water Resource, Thailand
Ancient cities and Archaeological sites	2023	Shapefile	The Fine Arts Department of Thailand

2.3 Least Cost Path (LCP) analysis for Queen Cāmadevi's watercourse travels

LCP analysis allows users to establish cost parameters that take into account various factors influencing movement or human travel. It serves as a method to simulate theoretical movement across the terrain, determining the most efficient and cost-effective path between a source and destination (Cortegoso et al. 2016; Byrd et al. 2016; Gustas and Supernant 2019). This research used ArcGIS 10.4 software to perform LCP analysis. The first step was to collect the locations of ancient cities in the Dvaravati period (6th-8th century AD) that have historical evidence (Mulasasana legends, Haripunjaya historical records, Chinnakanmalipakon, Chronicle of the Lineage of Cāmadevi, and Rishi Kaew legends). The said position was analyzed together with DEM data obtained from a survey using the LiDAR technique with a high spatial resolution of up to 5 meters to generate a slope database for LCP analysis. The result is a travel route linking various ancient cities in the Dvaravati period.

A raster cost surface is a map that assigns different cost values to different locations in space. These values are determined by combining features of the landscape in a weighted manner. The costs associated with each landscape feature are measured using comparable units, often scaled to the same range for

weighting purposes. The cost value represents the time and resources required to traverse a location in path or space analysis (Etherington 2016).

When trying to determine the shortest path on a grid-based map, the main challenge is finding the minimum distance between two given points while accounting for obstacles and varied terrains. The commonly used algorithms to tackle this problem are Dijkstra's and A* algorithms.

To solve the least-cost path problem, it is necessary to adjust the cost function of the nodes based on the core principles of Dijkstra's algorithm (Tang and Dou 2023). Assuming a given path P on the cost surface f , the traditional expression for the least-cost path, $Min L_{sum}(P, f)$, can be expressed as follows:

$$Min \sum_{i,j \in P} \left[\left(\frac{f(i)+f(j)}{2} \right) \right] \cdot l(i,j) \quad (1)$$

Where, $f(i)$ denotes the value of grid i on the cost surface f , and $l(i,j)$ denotes the straight distance between grids i and j .

2.4 Analysis of investigating the old Lopburi River and the ancient city of Dvaravati. (6th-8th century AD)

In this step, Landsat satellite image data was used to detect the old Lopburi River, using the Visual image interpretation technique. The process of visual image interpretation involves the analyst or interpreter identifying the features observed in the images and effectively communicating the information gathered from these images to others, allowing for the evaluation of their significance (Wray 2009; Ciminale et al. 2009; Fan et al. 2019; Wagner et al. 2019). The search for this ancient stream was analyzed based on the study of historical evidence and the theory of Stages of stream evolution. Investigating traces of the ancient city that appear as evidenced by Queen Cāmadevi's watercourse travel in the old Lopburi River has used a spatial analysis process, to detect various land cover patterns around the ancient city with Normalized difference Vegetation Index (NDVI) and Normalized difference built-up index (NDBI) techniques. Both techniques are effective for analyzing urban, commercial, industrial, and agricultural areas (Li and Chen 2018; Waiyasusri 2021). The NDVI is useful for measuring the abundance of green vegetation. It takes into account the scattering of green leaves in Near Infrared wavelengths and the absorption of chlorophyll in red wavelengths. The Landsat 1 MSS satellite analyzes Band 4 with high reflectance in the Near Infrared (NIR) range and Band 2, which is in the Red range for density determination and natural vegetation classification. Landsat 9 OLI/TIRS, on the other hand, uses band 5 and band 4 as the NIR and red wavelengths, respectively (Markogianni and Dimitriou 2016; Ullah et al. 2023). NDVI can be analyzed as Equations 2 and 3.

$$\text{NDVI (Landsat 1 MSS)} = (\text{Band 4} - \text{Band 2}) / (\text{Band 4} + \text{Band 2})(2)$$

$$\text{NDVI (Landsat 9 OLI/TIRS)} = (\text{Band 5} - \text{Band 4}) / (\text{Band 5} + \text{Band 4})(3)$$

The NDVI has a value range from -1 to 1, where negative values (approaching -1) indicate the presence of water. Values close to zero (-0.1 to 0.1) generally indicate barren areas consisting of rock, sand, or snow. Low, positive values (around 0.2 to 0.4) correspond to shrub and grassland areas, while high values suggest the existence of temperate and tropical rainforests (approaching 1) (Singh et al. 2023; Al-Mulla et al. 2022).

The NDBI is indexes for the analysis of built-up area (Almadrones-Reyes and Dagamac 2023; Ismail et al. 2023). The build-up areas and bare soil reflections can be classified using the Short-wave Infrared (SWIR) wavelength together with the NIR wavelength (Guha et al. 2021). In this study, Landsat 9 OLI/TIRS was used to analyze the environmental traces of the ancient city. NDBI will use Band 6 which is SWIR1 (1.566-1.651 μm) to analyze together with Band 5 which is NIR spectrum in the study of NDBI (Guha et al. 2021; Kombate et al. 2022) as shown in equation 4 as follows:

$$\text{NDBI} = (\text{Band 6} - \text{Band 5}) / (\text{Band 6} + \text{Band 5})(4)$$

The analysis results will be NDBI values between -1 to +1. Negative value of NDBI represent water bodies whereas higher value represents build-up areas. NDBI value for vegetation is low (Singh et al. 2023). The NDBI analysis will be able to quickly and efficiently check the land cover, types of urban areas and buildings.

The entire research process, from data collection to analysis, uses geo-informatics technology to investigate for the old Lopburi River and the ancient city of Dvaravati (6th-8th century AD) according to the record of Queen Cāmadevi's watercourse travel in the Chao Phraya River Basin, shown as Fig. 2.

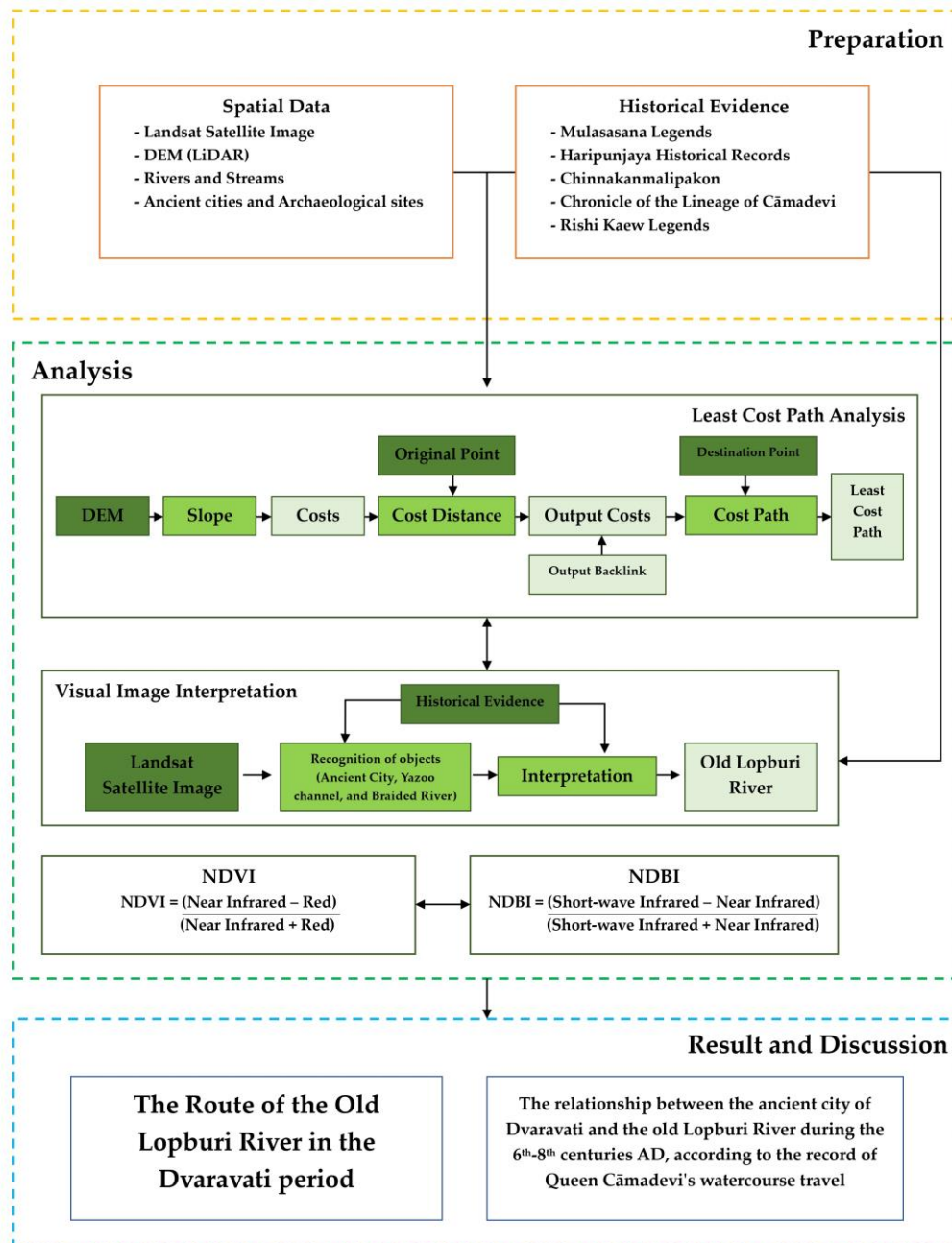


Figure 2. Flow chart of methodology.

3. RESULTS

3.1. Old Lopburi River using Geo-information Technology

From historical evidence (Mulasasana legends, Haripunjaya historical records, Chinnakanmalipakon, Chronicle of the Lineage of Cāmadevi, and Rishi Kaew legends) that mentioned Queen Cāmadevi's waterway journey from Lavapura to Haripunjaya using the Lopburi and Chao Phraya River routes, traveling upstream towards North, especially the Chao Phraya Basin area where very little evidence of her travels has been found. It only mentions that it traveled using the Lopburi and Chao Phraya rivers,

passing through cities and important places including Dhammika Hill (Samo Khon Hill), Ramapura, Chan Sen, Utapao, and Bon (Khok Mai Den) respectively. Since the position was still under the authority of Lavapura, it was not carefully recorded during the journey. This has caused historical debate as to whether she really traveled by the Lopburi River or not, whether it was consistent with the recorded historical evidence or not. Because the current route of the Lopburi River begins at Sing Buri, Lavapura (Lopburi), and ends at Phra Nakhon Si Ayudhya, it is necessary to use GIS to analyze using the LCP analysis principle. The results of the study found that generating travel routes from Lavapura to various

ancient cities surrounding the northwestern region are connected, especially the cities that Queen Cāmadevi traveled through including Chan Sen, Utapao, and Bon (Khok Mai Den). The results of the LCP study show that it is likely that she used the route shown, and this is consistent with records of her travels along the river. The results of this study can track the route from the starting point, Lavapura, to the final point of the journey. The distance from Lavapura to Chan Sen is 42.45 km., the distance from Lavapura to Utapao is 71.65 km., and the distance from Lavapura to Bon (Khok Mai Den) is 87.46 km. (Fig. 3a)

From the LCP analysis study, which discovered the route of Queen Cāmadevi's journey, it may not be the actual route. But with Geo-information Technology that uses Landsat satellite images and high spatial resolution LiDAR-DEM data to trace the route, using Visual image interpretation techniques, together with historical evidence of Lanna in all 5 stories, it gives more clarity to the results of the study, and provides an actual and historical journey. Queen Cāmadevi's water travel route is clearly evident, especially her journey along the old Lopburi River from Lavapura (present-day Lopburi) to Utapao (Fig. 3b).

The old Lopburi River that appears from the travel records of Queen Cāmadevi began its journey at Wat Choeng Tha, Tha Hin Subdistrict, Mueang Lopburi District, traveling north past Dhammika Hill (Samo Khon Hill), where Rishi Vasudeva and his disciples practiced Dhamma, and was a source of study for the upper classes in the Dvaravati period. The area is close to Ramapura, which is the second most important city after Lavapura because the sons of King Lavapura ruled this city. (At present, it is found as the

remains of the base of a building in the area of Bang Phueng temple, Mahason sub-district, Lopburi). Traveling north through the important ancient city of the Dvaradi period is Chan Sen (currently in the area of Nakhon Sawan Province). The city was a trading city with contacts between India, Dvaravati and the Funan Kingdom. Between Chan Sen and Utapao, it was found that the Queen's travel route along the old Lopburi River may have had two routes. The results of the interpretation of Landsat satellite images combined with LiDAR-DEM have revealed the first tracks, showing ancient river channels formed by Stages of stream evolution. The upper water route is along the Yazoo channels, formed by the main river branching off into branches, which appear in the floodplain area. The channel will have a curve running parallel to the main river, and near the boundary between floodplain of Chao Phraya River Basin and Nakhon Sawan River Terrace. In the study area, there appears to be a long channel showing the direction of flow from northwest to southeast, from the area of the ancient city of U-Tapao to the ancient city of Chan Sen. The second route is a channel in the form of braided river channels, formed by the criss-crossing flow of the Chao Phraya River, showing a stream flowing parallel to the Chao Phraya River at a short distance. Both routes flow to meet the waterways of the old Chao Phraya River where Utapao is located. After that, she used the route of the Chao Phraya River to travel through the city of Bon and build a new city, Phra Bang (current city of Nakhon Sawan), before evidence from the Lanna chronicles appears that there is a fairly clear record of settlement and development of cities along the Ping River, continuing from Phra Bang to Haripunjaya.

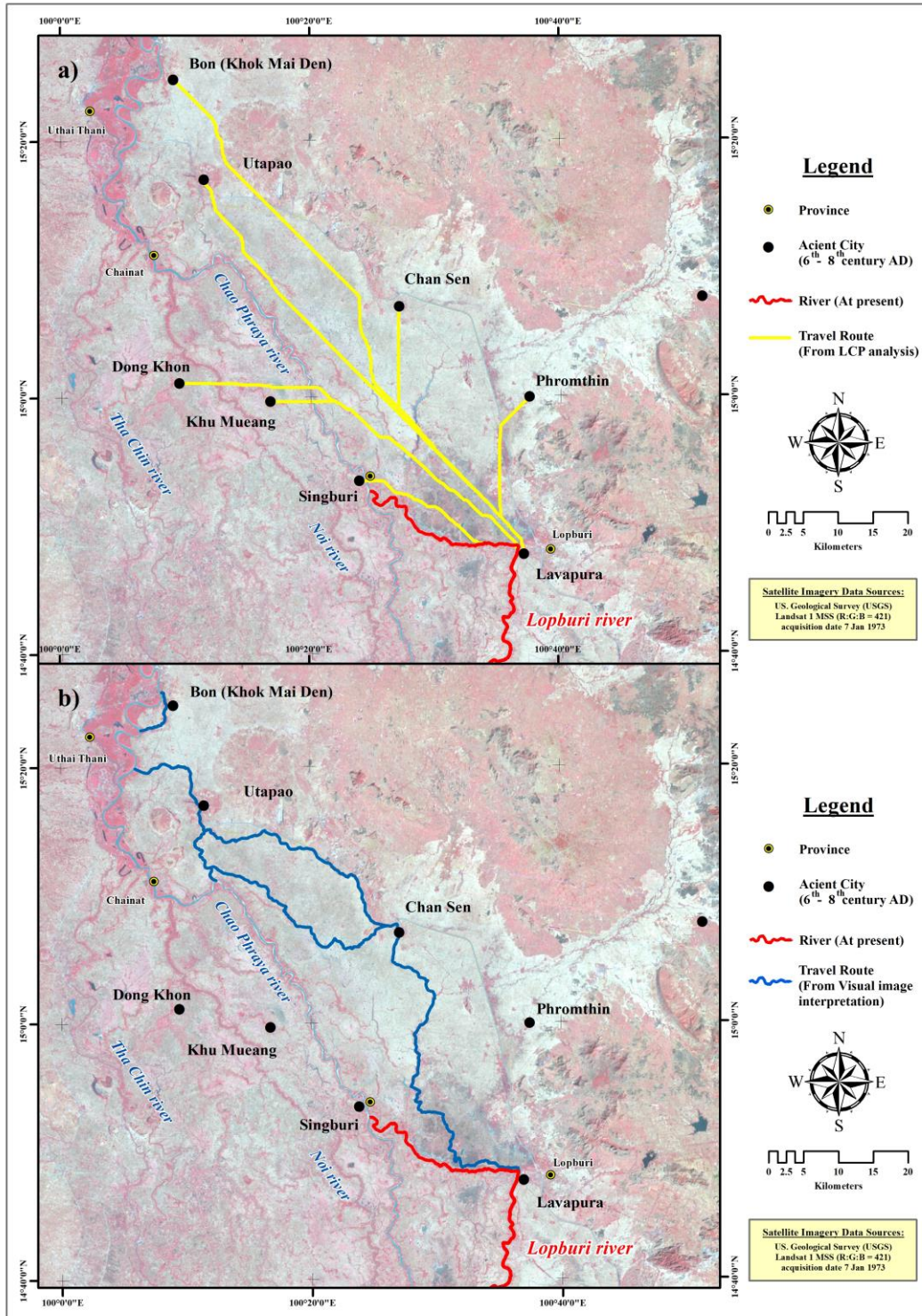


Figure 3. Old Lopburi River from LCP analysis (a) and Visual image interpretation (b).

3.2 The route of the old Lopburi River that appears the present

From the analysis of Landsat satellite image data and visual interpretation techniques of satellite images, the study found that traces of the old Lopburi

River that appear today have been turned into irrigation canals for agriculture, some of which have back swamp and oxbow lake topography, and some parts were covered with sediment until it was difficult to see traces of waterways. The details are shown in Table 2 and Fig. 4.

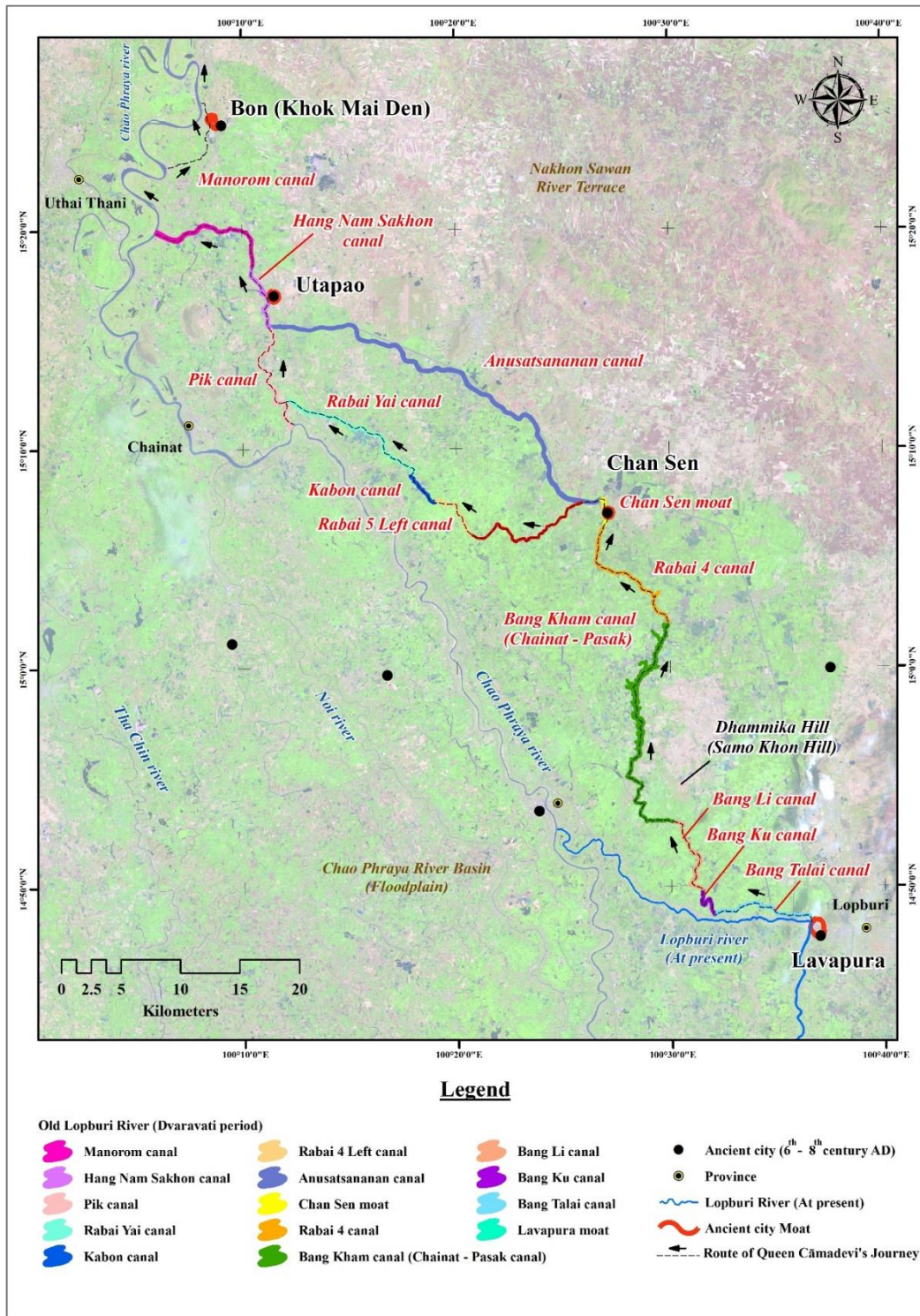


Figure 4. The route of Queen Cāmadevi's Journey in the old Lopburi River, which is now a canal.

Period 1: Bang Talai canal, from Lopburi Province - Pak Khlong Temple, the topography of the old Lopburi River has now become a small canal running parallel to the east-west, starting at Mani Chon Khan Temple, which is located. To the northwest of the Lavapura moat (now Lopburi Province), this canal ends at Pak Khlong Temple, with a distance of 9.4 km.

Period 2: Bang Ku canal, from Pak Khlong Temple - Village No.8 (Moo 8), Bang Li Subdistrict Administrative Organization (SAO). It has the characteristics of a narrow canal with a distance of 3.8 km.

Period 3: Bang Li canal, from Village No.8 (Moo 8), Bang Li SAO. - Muchalin Temple, the topography of the old Lopburi River in this area has a bank more than 100 meters wide. The canal is with a distance of

8.4 km, flowing through important places including Bang Li Temple and Bang Li SAO.

Period 4: Bang Kham canal, from Muchalin Temple - Mahason Sub-district, Ban Mi District, Lopburi. The topography is quite pronounced, causing the width of the river to be as much as 200 meters at the Bang Kham Temple pier. This Bang Kham River has a distance of 22.9 km, considered to be the longest distance of this old Lopburi River. Bang Kham canal has many historical sites and relics from the Dvaravati period appearing along this waterfront include Dhammika Hill (Samo Khon hill), Lai Temple, Tha Khong Temple, Tha Chang Temple, and Bang Phueng Temple.

Period 5: Rabai 4 canal, Mahason Sub-district, Ban Mi District, Lopburi - Chan Sen the Ancient city, with

a distance of 11.9 km. Near the ancient city of Chan Sen on the south side, the waterway is carried by fluvial sediment, covering up traces of the ancient waterway, hardly visible.

Period 6: the Moat of Chan Sen, Chan Sen the Ancient City appears as a moat and embankment surrounding the ancient city of Chan Sen, which was an ancient city from the Dvaravati period between the 6th and 8th centuries. Currently, only a rectangular basin of water can be found on the eastern side of the Moat of Chan Sen. The moat surrounding the city of Chan Sen was found only on an earthen embankment showing the moat surrounding the city.

Table 2. The route of the old Lopburi River that become a canal.

Present Canal	Initiation	Termination	Distance (km.)
Lopburi river	Choeng Tha Temple Tha Hin, Mueang Lop Buri District, Lopburi	Mani Chon Khan Temple Phrommat, Mueang Lop Buri District, Lopburi	0.7
Bang Talai canal	Mani Chon Khan Temple Phrommat, Mueang Lop Buri District, Lopburi	Pak Khlong Temple Bang Khu, Tha Wung District, Lopburi	9.4
Bang Ku canal	Pak Khlong Temple Bang Khu, Tha Wung District, Lopburi	Village No.8 (Moo 8), Bang Li Subdistrict Administrative Organization (SAO)	3.8
Bang Li canal	Village No.8 (Moo 8), Bang Li Subdistrict Administrative Organization (SAO)	Muchalin Temple Tha Wung District, Lopburi	8.4
Bang Kham canal	Muchalin Temple Tha Wung District, Lopburi	Mahason Sub-district, Ban Mi District, Lopburi	22.9
Rabai 4 canal	Mahason Sub-district, Ban Mi District, Lopburi	Moat of Chan Sen Takhli District, Nakhon Sawan	11.9
Moat of Chan Sen, the Ancient city	Around the Chan Sen, the Ancient city	Around the Chan Sen, the Ancient city	2.7
Anusatsananan canal	Moat of Chan Sen Takhli District, Nakhon Sawan	Tha U Temple U Taphao, Manorom District, Chai Nat	37.2
Rabai 5 Left canal	Chiang Rak Temple Thong En, In Buri, Sing Buri	Ban Nom Tho Tai Khao Kaeo, Sapphaya District, Chai Nat	4.6
Kabon canal	Ban Nom Tho Tai Khao Kaeo, Sapphaya District, Chai Nat	Ban Nom Tho Nuae, Khao Kaeo, Sapphaya District, Chai Nat	3.3
Rabai canal	Ban Nom Tho Nuae, Khao Kaeo, Sapphaya District, Chai Nat	Ban Nong Temple Taluk, Sapphaya District, Chai Nat	14.1
Pik canal	Ban Nong Temple Taluk, Sapphaya District, Chai Nat	Ban Tha U U Taphao, Manorom District, Chai Nat	11.7
Hang Nam Sakhon canal	U Taphao, Manorom District, Chai Nat	Ban Khlong Klang Wat Khok, Manorom District, Chai Nat	5.9
Manorom canal	Ban Khlong Klang Wat Khok, Manorom District, Chai Nat	Manorom Operation and Maintenance Project	11.5
Manorom canal	Ban Khlong Klang Wat Khok, Manorom District, Chai Nat	Manorom Operation and Maintenance Project	11.5

From data analysis using geo-informatics technology and all 5 historical evidences, the results of the study found that from the ancient city of Chan Sen onwards, it is possible that the old Lopburi River line, as evidenced by Queen Cāmadevi's water travel records, has two assumptions that are expected to be the old Lopburi River.

The first channel line is the Anusatsananan canal line, with a distance of 37.2 km. At present, it is a canal that was dug to drain water from the Chao Phraya River to the farmlands of Lopburi Province. The canal is dug along the Yazoo Channel, a channel formed by a main river with branching branches, which appears in the floodplain. The channel is curved and runs parallel to the main river and near the boundary between

floodplain of Chao Phraya River Basin and Nakhon Sawan River Terrace.

The second channel is the southern side of the Anusatsananan canal, which has a direction of flow from northwest to southeast. It consists of 3 important canals: Rabai 5 Left canal, Kabon canal, and Rabai canal. The three rivers have a distance of 4.6 km, 3.3 km, and 14.1 km respectively. The channels are in the form of braided river channels formed by the back-and-forth flow of the Chao Phraya River. Along this second channel, ancient sites and antiquities from the Dvaravati period were found at Nom Tho temple and Khok Bot temple.

The two canals meet with the old Chao Phraya River, which is now the Pik canal, Hang nam Sakhon canal, and Manorom canal. The three canals have a distance of 11.7 km, 5.9 km, 11.5 km, respectively, especially along the Hang nam Sakhon canal, appears important places like Utopao the Ancient city, which is also an important ancient city from the Dvaravati period from the 6th to 8th centuries AD.

3.3 The relationship between the ancient city of Dvaravati and the old Lopburi River during the 6th-8th centuries AD, according to the record of Queen Chamadevi's water travel

From LCP analysis, Visual image interpretation technique, and 5 historical evidences, the study results reveal that all 5 ancient cities in the Chao Phraya Basin were located along important rivers. The towns of Lavapura and Chan Sen are located along the old Lopburi River. Utopao is located along the old Chao Phraya River. Bon and Phra Bang are located along the current Chao Phraya River. The structural characteristics of the ancient riverside city are as follows:

Lavapura (present-day Lopburi Province) has been a capital since the Dvaravati period. The city is located on the left bank of the Lopburi River (Fig. 5a). The town is surrounded by a moat, similar to an oval, 2 km wide, 2.2 km long, with a topographic elevation of 5-16 msl. There are important historical sites remaining from the Dvaravati period, including Phra Prang Sam Yot, Nakorn Kosa Temple, and Phrasi Rattana Mahathat Temple. Phra Prang Sam Yot is a Khmer castle with Bayon arts. The structure is made of laterite decorated with stucco and has three pointed peaks. Nakorn Kosa Temple is a religious place from the Dvaravati period, with a stupa in the Lawo style, and with a stucco Buddha image in the U

Thong style. Phrasi Rattana Mahathat Temple is a large historical site in Lopburi, consisting of a royal temple with a large Khmer-style stupa made of laterite. This stupa originally contained a large number of famous Buddha images from the Lopburi period, such as Phra Hu Yan and Phra Ruang, which have been unearthed in large numbers. At present the environment and topography have completely changed, due to urban expansion the interior of the Lavapura moat has become a commercial area and many buildings can be seen. The results of the study with NDVI found values between 0.1-0.15 that detected many urban areas and expanded buildings in the interior of the ancient moat, and high levels were found in the middle of the ancient moat, which is the commercial area. The results of the study with NDBI revealed the density of buildings, clearly showing the characteristics of the dense built-up land area distributed in the interior of the ancient moat of Lavapura, with high NDBI values of 0.8-0.9. The surrounding dense built-up land area appears as medium and low built-up land area.

Chan Sen was a trading city during the Dvaravati period. It is currently located in Chan Sen Sub-district, Takhli District, Nakhon Sawan Province (Fig. 5b). The city currently has an Alluvial plain topography with an elevation of 10-16 msl. The city plan is surrounded by a moat, width 700 m., length 800 m. The status of Chan Sen city in the Dvaravati period was a city with complex development and technology, knowing about irrigation and drainage into the city, raising animals and agriculture, having the ability to make pottery, knowing about metal smelting, and there is transportation and trade in contact with other communities and cities in the same period. It is considered to be the earliest community in Suvannabhumi to have contact with India at the same time as U Thong, where fragments of decorative vessels often found in the same style as those found in India and the Funan Kingdom. At present the area has been completely transformed, especially within the Chan Sen moat where many buildings have been built. The results of the study found that NDVI levels found to detect village and sparse vegetation, which are areas where gardening is common in rural homes. High levels of NDBI were found in the central part of the moat, where buildings were scattered in Chan Sen village, and in the east outside the moat where the Chan Sen temple and museum are located.

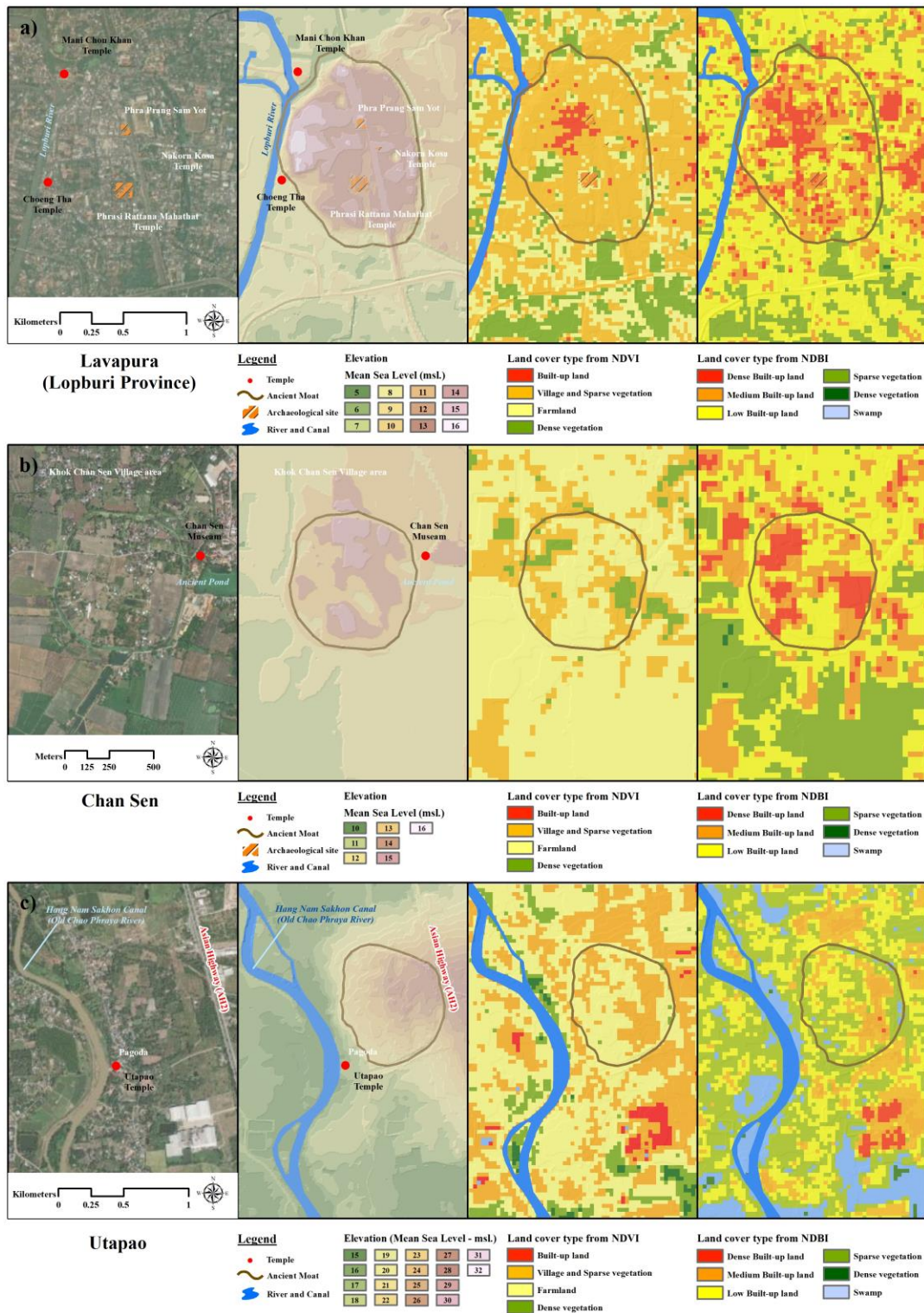


Figure 5. The ancient city of Dvaravati in the 6th-8th century AD according to the water travel records of Queen Cāmadevi (a) Lavapura, (b) Chan Sen, and (c) Utapao.

Utapao was an ancient Dvaravati city in trade and manufacturing, especially iron smelting. Currently, the ancient city is located in the area of U-Taphao Sub-district, Manorom District, Chai Nat Province (Fig. 5c). It is a city located along the Hang Nam Sakhon Canal (the old Chao Phraya River in the Dvaravati period). The city has an Alluvial plain topography with

an elevation of 23-29 msl. The city's structure is characterized by a moat and earthworks surrounding the city in a trapezoidal shape. Within the ancient city of U-Tapao, antiquities from the Dvaravati culture were discovered, many metal smelting furnaces were found within the city and antiques such as earthenware lamps, silver coins bearing the conch symbol,

Srivatsa, and fragments of the Dhamma Chakra Sila, octagonal pillar with Pallava and Pali script inscribed. Today, the condition of the ancient city has been transformed into a wasteland. When NDVI and NDBI analyzed, it was found that the distribution of sparse

vegetation in the ancient moat and low built-up land appeared on the east and west outside the ancient moat. The ancient city is located along the Asian Highway (AH2).

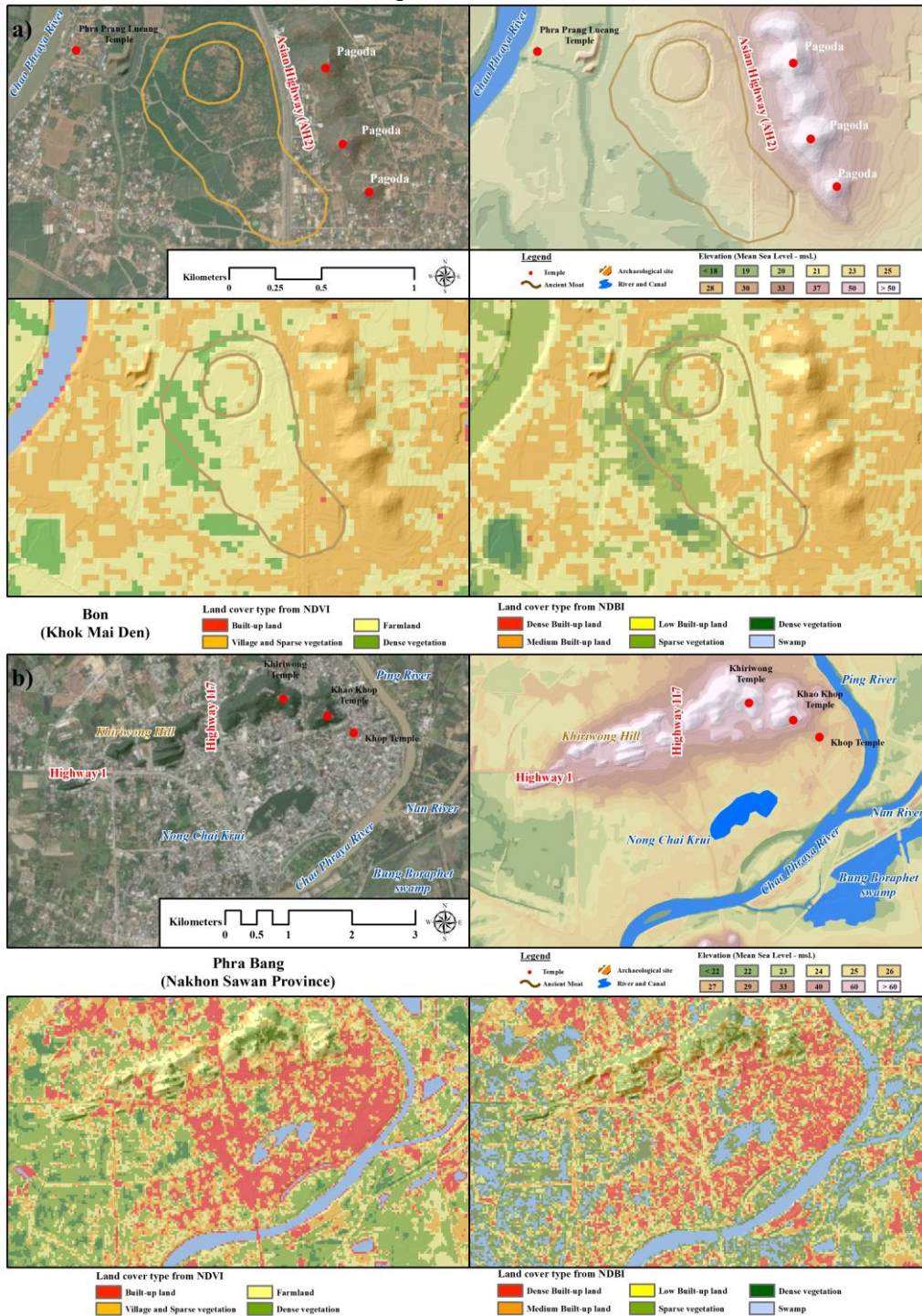


Figure 6. The ancient city of Dvaravati in the 6th-8th century AD according to the water travel records of Queen Cāmadevi (a) Bon (Khok Mai Den), (b) Phra Bang.

Bon (Khok Mai Den) is an ancient Dvaravati city, currently located in Tha Nam Oi Sub-district, Phayuha Khiri District, Nakhon Sawan Province (Fig. 6a). The geography is located along the current Chao

Phraya River. The city has an Alluvial fan topography with an elevation of 20-30 msl. On the eastern side, it is flanked by the Maiden Mountains with a height of 112 msl. The structure of the city is oval shaped like a

conch shell, approximately 250 meters long and 600 meters wide. This ancient city is surrounded by 3 levels of moats and earthen embankments. In the current state, some parts of the city's moat and outer wall were partially covered by the Asian road. On the outskirts of the city on the eastern side, there are also a group of ancient sites, most of which are the bases of pagodas, and on various mountain peaks that have been surveyed, totaling 16 sites. Various antiques such as the Phaya Chattan elephant statue from the Dvaravati period was also discovered. At present, the condition of the ancient city has been affected by urban expansion. The study results from NDVI and NDBI found that the inside of the ancient city's moat and embankment has been transformed into farmland, appearing on the western side of the area. In the east, buildings were found, the community area expanded, because the condition of the ancient city was cut through by the Asian Road, which greatly affected the ancient city. Large ancient sites that appear often found around the moat and embankment of Mueang Bon, include Phra Prang Lueang on the northwest side of the ancient city and Pagoda on the top of Mai Den Mountain on the east side of Mueang Bon.

Phra Bang (present-day Nakhon Sawan Province) was an ancient Dvaravati city built by Queen Cāmadevi, and was the northern outpost of the Lavapura Kingdom. The city had the status of a commercial and agricultural city. The geography is located at the outlet of two rivers, the Chao Phraya River and the Nan River. The city has floodplain terrain on the east side of the river. The city itself is a plain with high banks flanked by a large mountain range in the north, Khiriwong Hill, with a topographic elevation of 26-172 msl. (Fig. 6b). In the central area, there are two swamp-like water sources: Nong Chai Krui on the right bank of the Chao Phraya River, and Bung Boraphet swamp on the left bank of the Chao Phraya River. In the current state of the ancient city, no traces of the ancient moat have been found, because it has been completely replaced by an urban community. The results of the study from NDVI and NDBI were able to detect built-up land cover, with NDVI finding index values between 0.05-0.15, and NDBI levels clearly reaching 0.6-0.9 in the right bank area of the

Chao Phraya River. Currently, ancient sites found as evidenced in history are Khiriwong Temple, Khao Khop Temple, and Khop Temple, which are temples located on the top of Khiriwong Hill.

The results of the study of the five ancient cities in the Chao Phraya River Basin show the land cover that appears today in the form of satellite image data, spatial data from NDVI and NDBI interpretations and topography from LiDAR data, showing details as shown in the Fig. 5 and 6.

4. DISCUSSION

The Chao Phraya River basin area during the 6th-11th centuries was a period when the Dvaravati civilization was very prosperous. This period is a transition period from the prehistoric period to the historical period in this area of the Chao Phraya River Basin. From archaeological surveys, it has been found that almost every ancient city had a proto-state form of government. Each city has the power to govern itself, so the economic system, society, culture and religious beliefs will have an influence on the daughter cities surrounding that administrative center, especially Lavapura is considered to be the center city of the Dvaravati period at that time, equivalent to U-Thong, Nakhon Pathom, Sri Thep. Sima, and Khu Bua are contemporary ancient cities (Quaritch Wales 1966). The economic and social conditions at that time were based on agriculture, and trade between cities, causing religious influence to enter the city as well. This can be seen from the art and sculptures in the Dvaravati community that express the Theravada Buddhist beliefs, along with Brahminism or Hinduism, both Shaivism and Vaishnavism (Indrawoorth). In addition to the trading travels that show historical evidence in the form of antiques, the record of Queen Cāmadevi's water travel is another important piece of evidence that has been recorded in the Mulasasana legends, Haripunjaya historical records, Chinna-kammalipakon, Camadevivamsa or Chronicle of the Lineage of Cāmadevi, and Rishi Kaew legends (Notton 1930; Swearer and Premchit 1998) give a clearer picture of the historical context of the Dvaravati period.



Figure 7. Location of ancient sites and antiques discovered along the old Lopburi River

The research results from LCP analysis make it possible to more clearly simulate the route of Queen Cāmadevi's journey in the Chao Phraya River Basin.

It can be seen that Her Majesty and the traveling group that followed her for more than ten thousand lives traveled in the northwest, which is consistent

with the 5 historical evidences that she traveled along the old Lopburi River from Lavapura, Dhammika hill (Samo Khon Hill), Chan Sen, Utapao, respectively, before exiting into the Chao Phraya River, passing The towns of Bon and Phra Bang then enter the Ping River north to Haripunjaya. LCP analysis using LiDAR dem, slope, and stream route data results in travel direction is well supported with historical evidence, which is consistent with the study guidelines of Khamsiri et al. (Khamsiri et al. 2023) who used LCP analysis to find the Angkor-Phimai route. There are also things to support the route of her journey along the old Lopburi River with archaeological evidence such as pagodas, ruins, abandoned temples, building foundations in the basement, paintings and sculptures carved on cave walls, etc., and antiques such as Buddha statues, idols, Buddha images, pottery, ancient beads, and ancient agricultural tools, etc. (Table 3). Especially at Tham Tako Temple, located in the area of Dhammika hill, it is considered to be the Taksila school of Dvaravati where the ruling class had to come to study and gain knowledge from the rishis who practiced Dhamma here. At the present temple, Buddha images carved on the limestone walls, reclining Buddha images, and many laterite Buddha images have been discovered. Next to the west side of Dhammika hill is the ancient city of Ramapura. But at present, the area of the ancient city no longer appears. Since the 11th century, King Suryavarman I, King of Yashodharapura (Khmer Empire), attacked the city of Lavapura and surrounding cities until they became deserted cities and forests (Briggs 1950). This leaves no trace of the city of Ramapura, leaving only archaeological evidence at Lai Temple such as pottery and ancient objects dating from the Dvaravati period. But there is still an assumption that the city of Ramapura is located in the area of Bang Phueng Temple because the remains of ancient bricks, beads, gold, and terracotta statues from the Dvaravati period have been discovered. The ancient city of Chan Sen is a trading city from the Dvaravati period, also located along the old Lopburi River (now located between Anusatsananan canal and Rabai 4 canal) Important antiques such as clay dolls in the shape of a person leading a monkey, Kachalakshmi figures, ancient clay takhan have been discovered, etc. On the route between the ancient city of Chan Sen and the ancient city of U-Tapao, ancient remains such as a carved reclining Buddha were discovered inside the limestone cave of Nom Tho Temple, which is on the edge of the old Lopburi River (present Kabon canal). Khok Bot Temple is an ancient Dvaravati period site located along the old Chao

Phraya River (now Pik Canal). Ancient stone inscriptions from the Dvaravati period, and fragments of pottery utensils, along with an old brick wall found underground, were discovered. In the area of the ancient city of U-Tapao, graves with skeletons, earthen lamps, silver coins bearing the conch symbol, Rising Sun Coin, and fragments of the Dhamma Chakra Sila, octagonal pillars with Pallava inscriptions, and traces of iron ore obtained from smelting scattered all over the area of the ancient city, were found. It can be seen that the various locations that Queen Cāmadevi traveled through show traces of archaeological evidence from the Dvaravati period. Details of the locations of ancient sites and antiquities discovered along the old Lopburi River are shown in Table 3 and Fig. 7.

The results of interpreting satellite images using visual image interpretation, LCP analysis, NDVI, and NDBI, which are all Geo-information technology. It allows us to obtain spatial information of the old Lopburi River based on historical reference evidence clearly visible. However, the results from the interpretation of land cover using NDVI and NDBI techniques make the changes that occurred within the moat of the ancient city and the surrounding area clearly visible. It can be seen from the cities of Lavapura and Phra Bang that studies have empirically shown that urban expansion has completely expanded within the ancient moat and surrounding areas into commercial and residential areas. It causes some ancient sites to be directly affected by the environment, which may cause damage to the ancient sites. This is different from the research of Li et al. (2017) who applied GPS Tracking to collect historic site data in Gulangyu, China to create a spatial database, overlay with information in community areas to build community understanding so as not to encroach on historic sites, as Gulangyu is undergoing rapid urbanization and is about to be developed as a historical preservation site for sustainable tourism as well (Li and Chen 2018; Li et al. 2016). As for the ancient city of U-Tapao, the Thai government agency, the Fine Arts Department of Thailand, has prepared to protect the area in a timely manner, so that the ancient city has not yet been encroached upon by residents. As can be seen from the results of the study, at the NDVI and NDBI levels, no index values were found to detect buildings. But on the other hand, the ancient cities of Muang Bon and Chan Sen found NDVI and NDBI levels that detected buildings that had encroached on the ancient cities. This may have an environmental impact on the two ancient cities, because it may cause damage to the archaeological sites. These two ancient cities are of great concern.

Table 3. Location of ancient sites and antiques discovered along the old Lopburi River.

No.	Location	Longitude	Latitude	Historical Evidence
1	Lavapura, the Ancient city	100° 36' 50"	14° 48' 10"	Phra Prang Sam Yot
2	Mani Chon Khan Temple	100° 36' 35"	14° 48' 23"	Chedi (Dvaravati Period)
3	Tham Tako Temple	100° 29' 45"	14° 54' 48"	Mini sandstone buddha and Antiquities Limestone buddha in cavern
4	Khao Samo Khon Temple	100° 29' 33"	14° 55' 4"	
5	Lai Temple	100° 27' 50"	14° 54' 46"	Carved images on the temple walls Ancient pottery and Antiquities
6	Bang Phueng Temple	100° 29' 17"	15° 0' 41"	Ancient pottery and Antiquities
7	Chan Sen Museum	100° 27' 23"	15° 7' 11"	A clay offering doll depicting a human leading a monkey, Pediment Carved of Gajalakshmi, and Antiquities
8	Nom Tho Temple	100° 18' 5"	15° 8' 38"	Reclining Buddha (Dvaravati Period)
9	Khok Bot Temple	100° 11' 44"	15° 12' 39"	Inscription stone, Ancient city wall (Dvaravati Period), and Ancient pottery
10	U Tapao Temple	100° 11' 17"	15° 16' 42"	Dharmacakra, Pallava inscription stone, Rising Sun coins, Silver conch shell coins, and Antiquities

It can be seen that the integration of Remote Sensing, Digital photogrammetry, Laser Scan, GPS, GIS, etc. has also been studied to find important ancient sites (Green et al. 2019). Therefore, Geo-information technology is essential for accurate and efficient survey of ancient sites that will be developed into historical and cultural conservation areas in the future

5. CONCLUSIONS

The Dvaravati civilization that occurred between the 6th and 11th centuries has archaeological evidence scattered throughout many areas in the Chao Phraya Basin, together with historical evidence that mentions various ancient cities, especially Lanna historical evidence such as the Mulasasana legends, Haripunjaya historical records, Chinnakanmalipakon, Camadevi-vamsa or Chronicle of the Lineage of Cāmadevi, and Rishi Kaew legends, important evidence that describes Queen Cāmadevi's journey from Lavapura to

Haripunjaya. Along the way, she built various cities along the Chao Phraya Basin and the Ping River Basin. However, in order to see the historical context, technology must be used, so Geo-information techniques were brought into this research. Therefore, a travel route appears that is consistent with historical evidence in the form of legends, chronicles, ancient sites, antiques, and a travel route through the ancient city of Dvaravati period has evidence that is consistent in the same direction. It is even more evident, which is considered a highlight in this research. The spatial database obtained from this research study is beneficial to historians, archaeologists, and related government and private agencies that are studying and searching for ancient sites and antiquities in the area of ancient civilizations, including framing policies to prevent and reduce the damage of the surrounding area of the ancient site, by creating a database as a spatial model for systematic land use planning to support sustainable change in the future.

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