VIET NAM NATIONAL UNIVERSITY
UNIVERSITY OF ENGINEERING AND TECHNOLOGY

SANYA PRASEUTH

RESEARCH ON DEVELOPMENT OF DEDICATED DATA SYSTEM FOR URBAN MANAGEMENT IN LAOS

Major: Computer Science

ID: 9480101.01

SUMMARY OF DOCTOR THESIS
IN COMPUTER SCIENCE

Ha Noi – 2023

The project was completed at: University of Engineering and Technology, Vietnam National University

Supervisors:

Main supervisor: Associate Professor, Ph.D Nguyen Thi Nhat Thanh

Working unit: University of Engineering and Technology, Vietnam National University

Assistant supervisor: Ph.D Bui Quang Hung

Working unit: University of Engineering and Technology, Vietnam National University

Reviewer: .....

.....

Reviewer: .....

.....

Reviewer: .....

.....

1. The necessities of the dissertation

At present, the global socio-economic development has expanded widely by bringing the achievements of scientific research and technological development into the production promptly and leap forward to compete in business by using new technologies for creating innovative products such as information technology, biotechnology, renewable energy and materials, automation and other fields. As technology has evolved, we have come to study and incorporate technology into socio- economic development, with the theme "Research on Local Spatial Data Infrastructure of Urban Management in Vientiane, Laos".

Through the research on SDI, we have seen many issues related to the background of the development of such work, the organizational structure, responsibilities and coordination between the various parties are inevitable to make the development of such work even better. The better the coordination, the better the reduction of duplication works, a clear division of responsibilities, accurate information, information standard that can be shared among the stakeholders and sharing resources such as information effectively and efficiently. At present, the information is important and necessary, especially the location information on the earth should be accurate and up to date for the development of all sectors, especially in the economic, Socio-culture, liberation from least development, urban development, smart city, national defense, public security and environmental protection, green development, sustainability and so on are what human beings need to gradually improve their lives.

Research has helped us to discover many of the works that were developed in Laos, seeing the development of maps in the old days and after the liberation of the country. The Cooperation with strategic countries such as Vietnam, the former Soviet Union, China and other

countries and International Organizations have led to the development of mapping work, in particular the initiation and development of SDI in Laos during the government's World Bank assistance on the transformation of land as a basis asset for the development of the country, where land is important for development and land use should be managed properly in order to protect the environment, maintain 70% of the country's land area for forestry coverage, and the remaining 30% is used for agriculture, urbanization and so on.

The research found that, Prof. Dan Grant has ever proposed the SDI establishment for Lao PDR, but SDI development at that time was in its infancy, and many government agencies did not yet understand and see the importance of having SDI. Government agencies need to have an accurate information but do not know the importance of the concept of establishing SDI, so it is not considered by the government. Research shows that, now the need and readiness of Laos in establishment of SDI is necessary because based on government policies and legislation are ready and in the current era of the growth of Industry 4.0, the information work is growing faster, there is a need for coordination, the division of responsibilities in each part of the state clearly, not to repeat the work, there are standards for the exchange of information and for all parties, including the private sectors to be able access to information for further development in the country, and research has developed a specific model proposal for Lao government to consider, which is a very important issue.

This research has deepened the development of SDI for Vientiane Capital as a model because the Lao government has proposed to the National Assembly for adoption the third urban development of Vientiane Capital project, which was funded by the Japanese government and has studied the development of the city to 2030 and 2050 vision. The project has shown that the Vientiane Capital has

undergone rapid development, making it impossible for infrastructure to cope with growth, so it is necessary to reorganize the city in line with the party's policy on Enhancing Land Management and Development in new period, the National Land Allocation Master Plan, The National Socio-economic Development Plan and the Digital Economy Master Plan for 2021-2030. In the study, Vientiane Capital will be three times bigger area of the current area. In addition, the study project is being done to develop the city for modern living, a center for the economy, cultural, society and well-being for the country. Due to the location of the capital in the future, the transit goods from west to east and from south to the north will be more convenient. The research also highlights how the use of technology to serve the map development has reduced jobs, budgets, manpower significantly and improved the quality of work as well comparing with the old practical system by MAF, but, the important thing is that human resources must be developed to be more relevant and adequate to meet the needs of the works.

In conclusion, the research shows that the possibility of establishing and developing SDI work in Laos is highly prepared. This research will help the government to consider in developing SDI for the country by assigning responsibilities to each party according to the roles and responsibilities. But the important thing is coordination and cooperation, there should have a mechanism for a regular consultation, the establishment of SDI should be in line with the policies in each period to improve the quality of work. If we have a SDI in-house, it will make basic information accurately and help the country to develop faster, which is in line with the national strategy that the government has put in place, creating and developing information for sustainable socio-economic development for the country.

2. Research objectives of the thesis

The general goal of this thesis is to research and propose a roadmap and technological solutions to build a spatial data infrastructure for the capital Vientiane.

Specific goals include:

- *Research the current status of spatial data in the capital Vientiane*.

- *Proposing technological solutions to build spatial data infrastructure for the capital Vientiane*.

- *Proposing a roadmap to build spatial data infrastructure for the capital Vientiane*.

3. Scope of the thesis

The thesis focuses on research and propose a roadmap and technological solutions to build a spatial data infrastructure for the capital Vientiane, Laos.

4. The main contribution of the Dissertation

The Dissertation has three main contributions:

- *Research the current status of spatial data in the capital Vientiane*: The challenges in Lao PDR are related to the unplanned use of natural resources and related environmental degradation. Most of the ministries have already laid a good legislation to improve the situation, but actual implementation is delayed because of two reasons related to geospatial data.

- *Proposing technological solutions to build spatial data infrastructure for the capital Vientiane*: With the new technology, the data can be classified in detail in real time, after producing the thematic map, the field trip it is absolute necessary for the having the map with high quality. More over with the new technology, there are a lot of series of information from the previous years up to date time

(depending on the satellite), the analysis of the event can be seen the whole evolution and helped to identify the problems visually.

- *Proposing a roadmap to build spatial data infra structure for the capital Vientiane*: The establishment of the NSDI for the country will begin with the existing data information first, in which for the time being the land information is available across the country and the collaboration among the government agencies have started the discussion together with the proposal of the interoperability mechanism for better use of spatial data.

5. Research methodology

The research methodology of the Dissertation comes from surveying scientific document to state the problem, studying related works and research situation, proposing and improving the models, evaluating the models by several experiments and analyzing the results as well as the model errors.

6. The thesis outline

The thesis outline contains Preface, seven Chapters. The related publications are marked to their corresponding Chapter.

- Chapter 1: Introduction to Spatial Data Infrastructure
- Chapter 2: The concept of SDI
- Chapter 3: Spatial Data in the Lao PDR
- Chapter 4: Proposed SDI for Lao PDR
- Chapter 5: Urban Management and Development of Vientiane Capital
- Chapter 6: Legal Framework of the Lao PDR Related to Socio-Economic Development
- Chapter 7: Map Development in Vientiane Capital (Case study)
- Results and Conclusion.

CHAPTER 1: INTRODUCTION TO SPATIAL DATA INFRASTRUCTURE

I. Introduction

Now a day, a rapid booming of Information Communication Technology (ICT) has changed the habit of human life in deeper manner. We are describing the experience of the coordination of geographic information in the United States because of the technology in the spatial data of this country is more advance than the others following by the European experience. The Office of Management Budget (OMB) Circular A-16 was the backboned legal document of the coordination within the agencies in geospatial area. This chapter will examine the historical evolution of Circular A-16.

II. Background

The two executive orders in 1890 and 1919 show that the U.S. Government has almost 100 years been interested in coordinating surveying and mapping activities to avoid duplication of effort, to have standardized maps, to have information about maps readily available regardless of its source and to engage non-government sector in the coordination process.

III. Circular A-16

In 1953, the Bureau of Budget (now OMB) issued the first Circular A-16 to Federal agencies (OMB, 1953). Its simple goal was to ensure that surveying and mapping needs of the Federal State and general public were met.

Circular A-16 has been revised twice since it was first issued, first in 1967 and again in 1990 (OMB: 1967, 1990). In the 1967 revision one of the significant changes was that agencies were given more responsibility for the coordination of related activities.

In 2002, OMB issued its third revision to Circular A-16.

In 2010, OMB Circular A-16 provides for improvements in the coordination and use of spatial data and describes effective and economical use and management of spatial data assets in the digital environment.

IV. Federal Geographic Data Committee (FGDC)

The Initiative of the FGDC comprises of following items:

- NSDI Strategic Plan
- Geospatial Platform
- NGDA Management Plan
- Open Water Data Initiative
- National Address Database
- Geopathways

V. Conclusion

Since, 19 Century, the geospatial information in the United States has started, where many Federal Agencies have collected, processed and distributed by their owned ways which cause a duplication, non-standardize information, low quality products and limited use. The coordination in the area of geographic data is important and the coordination should be well established in order to have the efficiency and efficacity products in geospatial data information.

CHAPTER 2: THE CONCEPT OF SDI

I. Introduction

Spatial Data Infrastructure (SDI) is the infrastructure that facilitates the discovery, access, management, distribution, reuse, and preservation of digital geospatial resources. These resources may include maps, data, geospatial services, and tools. As cyber infrastructures, SDIs are similar to other infrastructures, such as water supplies and transportation networks, since they play fundamental roles in many aspects of the society.

II. Spatial Data

Spatial Data are items of information which can be related to a location on the Earth, particularly information on natural phenomena, cultural and human resources such as topography including geographic features, place names, height data, land cover, hydrography; cadastre (property-boundary information); administrative boundaries; resources and environment; socio-economic including demographic; etc…

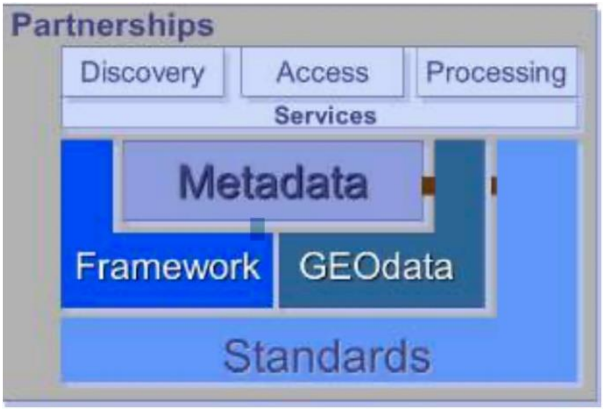
The importance of spatial data and information to the economy goes far beyond the potential development of the industry itself. It has the potential to impact widely on society, due to its ability to represent a host of important characteristics spatially.

III. Spatial Data Infrastructure

Spatial Data Infrastructure is a data digital implementing a framework of geographic data, metadata, users and tools that are interactively connected in order to use spatial data in an efficient and flexible way.

1. Component of Spatial Data Infrastructure

The components of the Spatial data Infrastructure can be defined as bellow (Douglas, 2009)



2. Open Standard for spatial data infrastructure

OGC is a not-for-profit international voluntary consensus standards organization. OGC's open standards:

- Data models/encodings
- Sensor Web enablement standards for collecting data from sensors
- Discovery Services
- Access Services
- Processing services

3. Server architecture models for the National Spatial Data Infrastructure and Geospatial One-Stop portal

This section presents an analysis of the current disparate server architectures of the National Spatial Data Infrastructure (NSDI) and the Geospatial One-Stop (GOS) portal:

- GOS portal architecture
- Standards for GOS portal architecture
- Taxonomy of geospatial server architecture
- Three reference architectures for server architecture model

IV. North American Experience on SDI

An SDI must include the following (GeoConnections, 2005): Network Protocol Interoperability; Standard Interface Specifications; Data Transport Interoperability; Semantic Interoperability

The primary components of an SDI can be briefly described as follows: Institutional Arrangements, Framework Data, Policies, Standards, Technologies.

V. European Experience on SDI

Directive 2007/2/EC of the European Parliament and of the Council of 14 March 2007 establishing an Infrastructure for Spatial Information int eh European Community (INSPIRE).

To ensure that the spatial data infrastructures of the Member States were compatible and usable in a Community and transboundary

context, the INSPIRE Directive required that common Implementing Rules (IR) were adopted in a number of specific areas : Monitoring and Reporting, Metadata, Network Services, Data and Service Sharing

VI. Conclusion

The SDI is like other infrastructure that the government should undertake, monitor, improve it from time to time to meet according to the need of the socio-economic development of the country and to be used by others government agencies. After revising the experience of the high technology of other countries, almost every countries have the same concept structure and understanding the important of SDI and the need to better collaboration and coordination between the government and private sector for maximizing the used of the SDI for their daily business work, but the different of each countries is the scale of organizations, duties and responsibilities and the legal framework to compact with the need development of the every countries.

CHAPTER 3: SPATIAL DATA IN THE LAO PDR

I. Introduction

Lao PDR is a land locked country that covers 236,800km2 , it is the second smallest country between Cambodia (181,000 Km2) and Vietnam (330,400 Km2). The topography of Laos is largely mountainous with elevation above 500 meters typically characterized by steep terrain, narrow river valleys, and low agricultural potential.

II. Status of Spatial Data

1. Assistance from Japan (JICA)

The first objective is to generate the digital base map data for the Mekong River Basin in Laos at a scale of 1:100,000 and to create a database “the Mekong GIS Database” in cooperation with NGD. The

second objective is to transfer the technology of GIS data generating, updating and data base management to NGD.

2. Assistance from the World Bank

The concept on the land Title program was “to develop and implement its national land titling program and thereby establish a system of clear and enforceable land transfer, occupancy and use rights supported by an effective land administration and valuation system so as to promote, inter alia, the long-term development of efficient land markets and facilitate domestic resource mobilization throughout its territory”. The summary of the development project composed of 6 main components after the completion of the Land Titling Program.

3. Assistance from the Finland

Strengthening National Geographic Services in Lao PDR is a four years programme started in August 2010. The programme is bilateral technical co-operation between the Government of Lao PDR and the Government of the Republic of Finland. The programme is continuation to extensive support from Finland to Laos, particularly focused on land sector.

III. Conclusion

The challenges in the country are related to the unplanned use of natural resources and related environmental degradation. Most of the ministries have already laid a good legislation to improve the situation, but actual implementation is delayed because of two reasons related to geospatial data. The first one is the lack of accurate and up-to-date data. The second is nonexisting co-operation between different organizations.

CHAPTER 4: Proposed SDI for Lao PDR

I. Introduction

Spatial Data Infrastructure has been layout as the fundamental element already because of the Donors Communities, Financial Institutions and Bilateral Agreement have established the ground work in the various areas of the government by using the spatial data. However, there still have a lot of work need to be done in order to successfully and efficiently used of these data for the socio-development of the country.

II. Lao Spatial Data Infrastructure

1. The Vision and Objectives for the use, provision, acquisition, security and management of land information

In this section, the article states 21 sections for the vision and Objectives for the use, provision, acquisition, security and management of land information.

2. Minimum standards for public access to land information and service delivery by local land offices

Minimum standards for public access to land information and service delivery by local land offices in Lao PDR is needed for the improvement. Principles, such as those adopted of service delivery is referred to as the nine "Principles of Public Service Delivery".

3. National Spatial Information System Road Map

The establishment of the NSDI for the country will begin with the existing data information first. The proposal for the National Spatial Information System Project Road Map is described in detail in the thesis.

4. Establish the National Objectives for ICT, e-governance and spatial information

The project entitled "ICT for Development in the Lao PDR" which started in September 2014. The project consisted of two main objectives:

- Developing a policy framework

- Enabling digital standardization for the Lao information exchange to implement this government strategy in term of ICT

5. Consensus on the Land Information

The coordination of land information goes well beyond the LTPII objectives. However, there seems to be general consensus as to the need for a coordinating mechanism and discussions at the Workshops would indicate that the NLMA was the preferred agency to fulfill this role. The LTPII objectives could be considered as focused on land administration information which is a part of the land information set.

6. Role of all stakeholders in the coordination of land information

Stakeholders can be divided generally into producers, users, value added resellers, suppliers and academia. They all have a role which is often overlapping or twofold in that the same agency or private firm could be a producer and a user or value-adder.

7. Defined the scope and responsibilities of the National Land Information Center

The detailed mandates, responsibilities rights and duties of the National Land Information Center, now called the Centre for Research and Information of Land and Natural Resources (CRILMR) includes 10 things.

III. National Framework datasets and outline the agencies to be responsible for maintaining these datasets

Lao PDR does not have the time to create the traditional institutional arrangements, invest in the equipment and train the people to acquire, analyze, monitor and distribute the spatial information to safeguard the natural resources and improve the livelihood of the people. It would seem that the only way that the situation can be addressed is by a national urgent and rapid acquisition of land related information by the use of the private sector.

To maintain the momentum of such a national project it could be augmented by a regional initiative and/or pilot projects to trial some of the ideas and develop appropriate systems whilst the national information sets are identified and compiled and the institutional arrangements are put in place. Such an approach is outlined in the Road Map

IV. Conclusion

To attempt a serious and comprehensive analysis and design leading to an action plan for the progressive computerization of all relevant national agencies and to identify the staff development needs of the country with respect to computerization, including training and education is a formidable task . It is also one that requires considerable preparatory work.

CHAPTER 5: LEGAL FRAMEWORK OF THE LAO PDR RELATED TO SOCIO-ECONOMIC DEVELOPMENT

I. Introduction

In this chapter, we will describe in summary the content of the relevant legal framework which has support the implementation of the NSDI of the country, the important is to apply the Laws, Strategy, the combination of the technology and the coordination mechanism among the government agencies to deeply implement their daily works for achieving the target of the socio-economic development of the country.

II. The Enhancement of Land Management and Development in new period

1. Overall Situation regarding the Land Management in the Past

In practice up to today it appears that the land management has created several complicated issues especially land conversion not strictly in compliance with laws; development of the master plan for

land allocation and plans for land use by sector authorities have not been completed, resulting in the wasting use of land, illegal possession of public land-forest, unlawful granting of land use rights over state land to individuals is widespreading.

2. Guidance view regarding land management and development in new period

Land must be adequately allocated and used according to its required purpose efficiently ensuring short and long-term benefits, protecting environment, meeting demand for national development for green growth and sustainability, increasing land quality and ensuring land for agriculture for guaranteeing food security.

3. Main direction for enhancing land development and management in new period

The focus of land management and development must be as follows:

- Regarding ownership and land use rights
- Land allocation and use planning
- Land management
- Limitation of land areas for use by individuals
- Regarding the retaking of land use rights
- Conversion of land into capital, development to land market and financial policy regarding land
- Concession and lease of land
- Resolution of land-related disputes
- Monitoring and inspection
- Strengthening of state management-governance of land-related issues

III. Conclusion

The NLAMP is a strategy which give us the direction to all manage the land use in proper manner in order to use the land for long lasting,

efficiently and effectively for at least preserve the three type of forest to be sustainable for the contribution to the socio-economic development plan of the country.

The 9th NSDP (2021-2025) defined 6 goals that the government has to take into consideration for implementing such measures in order to strengthen the economy by insuring the applied the digital in the economy.

CHAPTER 6: URBAN MANAGEMENT AND DEVELOPMENT OF VIENTIANE CAPITAL

I. Introduction

In this chapter we will present the overview of Vientiane Capital which includes the summary history on the creation of Vientiane capital, how it is built and provide the information on the socio-economic development of each district. The information will reflect on the potential strength and weakness on the development of the Vientiane Capital.

II. Vientiane Capital

Vientiane is the capital and largest city of Lao PDR, on the bank of Mekong River near the border of Thailand. Vientiane was the administrative capital during the French rule and due to economic growth in recent times, is now economic center of the country.

III. The Constraints of Vientiane Capital

There are some constraints in the Urban development of Vientiane Capital about:

- Urban Landscape
- Land Use
- Urbanization
- Population and Density
- Population Distribution Pattern
- Increase of Traffic Volume
- Wastewater/Sewerage
- Generation of Solid Waste

- Volume of Solid Waste Disposal
- Overview of Parks

IV. The Expansion of Vientiane Capital

The third master plan of Vientiane Capital has set out the contents of the city development plan with a total area of 61,600 hectares, an increase of 40,950 hectares or about 3 times compared to the area according to the second urban plan of Vientiane Capital which was promulgated in 2002.

V. Conclusion

- The development of the Vientiane Capital in the future composes of two zones as following:
    - Core Urban Zone of Vientiane Capital
    - Urban Cluster Zone
- Priority projects: In order to implement this master plan, priority programs and projects have been introduced till 2030 with a focus and set a development plan for each period of 5 years and 10 years.
- Through the research of the third urban plan of Vientiane Capital, there are still challenges to pay attention.

CHAPTER 7: MAP DEVELOPMENT IN VIENTIANE CAPITAL (CASE STUDY)

I. Introduction

In this section, the study area will focus into Vientiane Capital as a model for applying the technology and applications on Spatial data for producing better quality map, more accuracy then it will help to improve the planning of the used and exploitation of the land.

II. Defining and Compiling the maps

The steps in mapping agricultural and forestry land include six steps:

1. Preparation
2. Analysis to identify primary agricultural and forestry areas
3. Enter the field to collect various geographical and socioeconomic information
4. Compile information, prioritize and analyze the suitability of agricultural and forestry
5. The steps in defining area for Agriculture and Forestry
6. The Result from the current technology

III. The new technology of creating the map for Agriculture and Forestry Land

1. Study Area and Data
    - Study Area: Vientiane capital
    - Data: Landsat 8 Surface Reflectance (Landsat 8 SR)
2. Methodology

The land-cover classification method is presented in our previous study. The method, described bellow, includes 4 parts: (1) generation of cloud-free composite images for each classification year, (2) image stacking and feature extraction, (3) classification using XGBoost classifier, (4) validation of the classifier.

a. Generation of composite images

To create composite images, the total score of each pixel is used. The total score is calculated by adding up the year score, DOY score, distance to cloud/cloud shadow score and opacity score. The candidate pixel with the highest total score will be selected as a replacement in the target image.

b. Features extraction

To extract features, five composite images of the classification year were created and stacked together into a single image. The features will be extracted from this stacked image.

c. Land-cover classification method

To separate land use categories, this study used XGBoost classifier for classification.

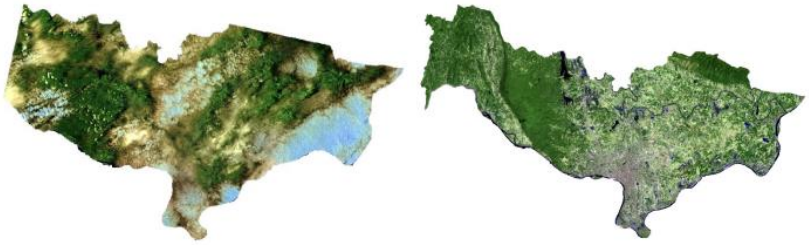
d. Validation Step

This study uses overall accuracy (OA), precision, recall and F1 score (F1) as evaluation metrics. Class-specific evaluation metrics are also computed.

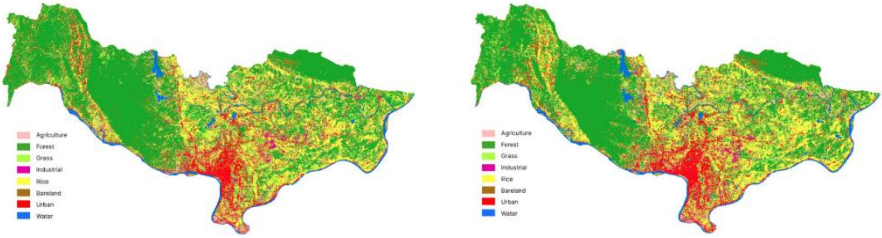
3. Results

a. Cloud-free composite images

Over the course of the research period that lasted from 2013 to 2023, a total of six images with clouds removed were captured each year. In figure bellow, original image (left) and cloud-free composite image (right)



b. Classification analysis



During the research period spanning from 2013 to 2023, the XGBoost classification method was employed to generate 10 land cover maps of the Vientiane area. The macro average (0.63) and the weighted average (0.67) are acceptable for the XGBoost classifier.

IV. Conclusion

The researchers have used the method of image composite to remove clouds and overlay monitoring to limit the loss and fragmentation of data. This has greatly increased the accuracy of the classification model. The XGBoost classification model used in this research is a powerful classifier that can work well on sparse data and has high reliability. With the application of research and new technologies, the classification of coatings has been greatly improved in terms of speed and accuracy. This improvement has contributed to optimizing the cost of land monitoring for the Lao government.

RESULTS AND CONCLUSION

The thesis has three main contributions:

- Research the current status of spatial data in the capital Vientiane.
- Proposing technological solutions to build spatial data infrastructure for the capital Vientiane.
- Proposing a roadmap to build spatial data infrastructure for the capital Vientiane.

LIST OF THE AUTHOR'S SCIENTIFIC WORKS RELATED TO THE THESIS

1. Spatial Data Infrastructure, Sanya Praseuth, Quang Hung Bui, Quang Thang Luu, Duc Van Ha, Tuan Dung Pham, Dominique Laffly, Book Chapter, TORUS 2– Toward an Open Resource Using Services: Cloud Computing for Environmental Data, 2020 (published).

2. Mapping land cover types in Vientiane, Laos using multi-temporal composite Landsat 8 images, Sanya Praseuth, Dung Pham Tuan, Chuc Man Duc, Hung Bui Quang, Thanh Nguyen Thi Nhat, 6th NAFOSTED Conference on Information and Computer Science (NICS), 2019 (published)

3. Annual land cover changes (2013-2023) in Vientiane, Lao PDR using time-series composite Landsat 8 images, Sanya Praseuth, Dao Le Quang, Dung Pham Tuan, Hung Luu Viet, Chuc Man Duc, Hung Bui Quang, Son Pham Bao, 2023 RIVF International Conference on Computing and Communication Technologies (RIVF), 2023 (published)