Using an open-source spatial database and GIS to manage multi-scale land-use/ land-cover data in Laos PDR

2020

School of Science, Faculty of Health and Environment Science

A thesis submitted to Auckland University of Technology
in fulfilment of the requirements for the degree of Master of Science (Research)

By

Mr. Kongkeo Sivilay

Primary Supervisor: Dr. Bradley Case

Secondary Supervisor: Graham Hinchliffe

Abstract

Managing multi-level geospatial datasets, particularly the land-use and land cover data in highly changeable environments and social entities, such in Lao PDR is, always a challenging task for GIS specialists. They have to handle a variety of data types such as vector, raster, and non-spatial data from various data sources to fulfil the tasks. Over the years, GIS has developed rapidly and is considered one of the fastest growing industries; its market value was estimated at 10.8 billion USD in 2018 and continues to grow very strongly (Prescient & Strategic (P&S) Intelligence Private Limited, 2019). The commercial GIS enterprise provides complete package solutions for organisations; however, they have limitations and often come with a high cost and maintenance fee. This cost is a prohibitive factor for financial-constraint countries such as Lao PDR, and the package tends to lack flexibility for integrating with other applications as well as scalability.

In the open-source geospatial communities, developers have been collaborating to deliver commercial-grade products that are freely available to the public. For instance, under Open Source Geospatial Foundation (OSGeo) there are a number of powerful geospatial libraries such as GDAL, Orfeo Toolbox, PostGIS, QGIS, and MapServer. Taking advantage of this technology to fulfil the gap and fit the context of a financial-restricted environment is an approach worth investigating. This research examined the potentials of the open-source relational database PostgreSQL and its geographical extension PostGIS (hereafter referred to as PostGIS database) in concurrent use with desktop GIS application, QGIS by storing and managing multi-level land-use and land cover datasets with an aim for increased performance and efficiency over the existing workflows. The research was carried out at a governmental institution in Lao PDR where substantial proportion of land-use and land cover data were located.

The research findings indicated that the open-source spatial database resulted in 70 percent increase in performance and efficiency over the existing approach, as well as delivering opportunities for enhanced data security/integrity and accessibility. Additionally, the research findings supported the notion that the spatial database has greater flexibility for future integration and scalability, which were in line with the participant interview-based results.

Acknowledgement

I would like to express my sincere appreciation for my supervisors, Dr Bradley Case and Graham Hinchliffe, from the School of Science, Health and Environment Science Faculty of Auckland University of Technology for their supervision and guidance throughout my academic journey. It would have been impossible to complete this research without their assistance.

I would love to thank my families, loved ones, and friends back home who always supported me to overcome the difficulties and challenges throughout my studies, and life being away from home. Last, but not least, I would like to express my deepest gratitude for the New Zealand Ministry of Foreign Affairs (MFAT), the Government and the people of New Zealand for providing me this prestige scholarship to study here in New Zealand. It is truly a life-changing experience. I have really enjoyed the spectacular sceneries, hospitality and, of course, I have learned so much both academically and professionally. Now, it is time for me to go back to my home country to influence the positive change.

tēnā koutou!

Thank you!

Attestation of Authorship

To the best of my knowledge and belief, I here declare that this submission is the result of my original work and that it contains no material previously written and published by another person (except where explicitly defined in the acknowledgement) and where due reference is made. This thesis has not been previously submitted to meet requirements for an award of any degree or certificate of either this university or any other academic institution.

25th May 2020

__________________________________ ______________________________

Signature Date

Ethics Approval

This research was approved by the Auckland University of Technology Ethics Committee (AUTEC) at the meetings held on the 4th March 2019, subject to nine conditions and revisions. Then the revised ethical application and revisions were resubmitted, and the research's ethical application was approved by AUTEC on 2nd May 2019 and due to expire in three years on 2nd May 2022.

Table of Contents

List of Figures

List of Tables

List of Appendices

Abbreviations

3FC	Three national forest categories
ADB	Asian Development Bank
ASEAN	Association of Southeast Asian Nations
AEC	ASEAN Economic Community
API	Application Programming Interface
A.msl	Above mean sea level
AUT	Auckland University of Technology
AUTEC	Auckland University of Technology Ethics Committee
CRS	Coordinate reference system
CSO	Civil society organisation
CSV	Comma-separated values
CIFOR	Centre for International Forestry Research
DALaM	Department of Agricultural Land Management and Development
DoF	Department of Forestry
FOSS	Free and open-source software
GIS	Geographical Information System
GoL	Government of Laos PDR
GUI	Graphical User Interface
GNI	Gross national income
IDE	Integrated Development Environment
INGO	International Non-Governmental Organisation
LULC	Land-use and land cover data
LUPLA	Land-use planning and land allocation
Lao PDR	Lao People’s Democratic Republic
LDC	Least Developed Countries

MAF	Ministry of Agriculture and Forestry of Laos
MoU	Memorandum of Understanding
MoNRE	Ministry of Natural Resources and Environment
MoH	Ministry of Health
MoES	Ministry of Education and Sports
NAFRI	National Agriculture and Forestry Research Institute
NAS	Network-Attached Storage
NGO	Non-governmental organisation
NGD	National Geographic Department
NPA	National Protected Area (or national conservation forest)
NTFP	Non-timber forest products
NUOL	National University of Laos
ODA	Official Development Assistance
OSGeo	Open Source Geospatial Foundation
OODBMS	Objected-oriented database management system
OGC	Open Geospatial Consortium
OSM	Open Street Map
PC	Personal computer
PLUP	Participatory Land-use Planning
PFALUPAM	Participatory land-use planning, allocation and management
QGIS	Quantum GIS
RS	Remote Sensing
RDBMS	Relational Database Management System
SDG	Sustainable Development Goal
SQL	Structured Query Language
TB	Terabyte
VF	Village forestry

Glossary of terms

Agro-biodiversity /Forestry	Agro-biodiversity/forestry refers to a form of land-use management system, particularly cultivation practice where crops are grown within the forest ecosystem to minimize environmental impact while maximizing the yield.
Conservation forest	Conservation forest is protected forestry ecosystems whose functions are to conserve the nature, fauna and flora as well as forestry and biodiversity ecosystems.
Geospatial data	Geospatial data describes the data and information that are embedded with geographical information such as location, boundaries, coordinate systems, which can be used to refer to a location on the earth's surface. Geospatial data are typically in the forms of point, lines, polygon, raster-based, or 3-D.
LU/LC	LU/LC refers to the land-use and land cover data. The data are typically extracted from semi or fully automatic classification using remotely sensed data with random field checks and digitisation. This type of data is generally used to represent land-use and land cover at a bigger scale such as provincial or country level.
Non-spatial data	The data that do not have geographical information. However, they can be linked to GIS data or as standalone data. Often, they are in the form of tables, statistics, or figures.
NPA	NPA is the national protected area and a broader term for any given forestry and biodiversity protected area within the 3FC. Since the (national) Conservation Forest is well-managed when compared to the other 2 FC, people usually refer the term NPA to conservation forest.
NTFP	Non-timber forest/wood product are materials and resources obtained from the forest outside timber. It includes vegetables, fish, honey, mushroom, medicinal plants, resins, bamboo, rattan. NTFPs sustain lives of the local communities as well as generating cash incomes.
Raster	Raster data refers to the dataset consisting of pixels organised into rows and columns whose values represent some kind of information such as digital number (DN). Raster datasets include aerial photographs, satellite or drone imagery, digital elevation model, hill shade-relief.
Relational database	A relational database is one of the many database types; it is based on the relational model of data. Data are often stored in tabular form of columns and rows. SQL is the standard language used to query for information within the database.

Spatial	Spatial is the characteristic that is related to space and contains geographical features.
Spatial database	Spatial database refers to the relational database that is optimised to handle geographical data and information, which may include geometric objects, 3-D, topographic, raster data, etc.
Upland farming	Upland cultivation is a common practice of crop cultivation, particularly rice in the mountainous regions where the crop is being grown based on fallow cycle rotation for an extended period.
Vector data	Vector data is a data structure which is used to store geographical objects. Geospatial vector is represented in the form of point, polyline, or polygon, comprising one or more coordinates of any given point in space. They are determined by a beginning and end points.
Village forestry	Village forestry, excluding from the 3FC, usually refers to the forest that is managed by the local village level. In recent years, the government has made a lot of efforts to improve the management and conservation of village forestry in order to leverage the benefits upon the local communities.
WCS	Web coverage service is the fundamental requirement of Open Geospatial Consortium (OGC) in order to display raster dataset on the web map.
WFS	Web feature service is OGC's requirements for the web map to display data as vector or features.
WMS	Web map service is the OGC's requirements to display maps as image or tile on the web.

Chapter 1 Introduction to the study

1.1 Introduction

Lao's People Democratic Republic (Lao PDR) is a landlocked country located in Southeast Asia; bordering China to the north, Vietnam to the east, Cambodia to the south, and Kingdom of Thailand and the Republic of the Union of Myanmar to the west (Figure 1). North, central, and the south make up the three administrative regions, comprising 18 provinces. Vientiane is the capital and largest city; major cities include Luang Prabang, Savannakhet, and Pakse. The total land area is approximately 236,800 square kilometres.

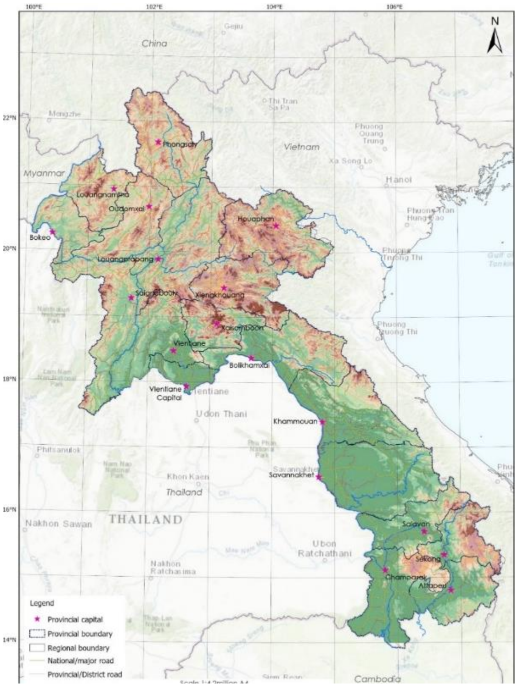


Figure 1. Map of Lao PDR with regional context.

Geographical information system (GIS) and geospatial data play an important role in managing datasets from various development sectors in the country; specifically, planning and decision making. Lao PDR has rich natural resources of natural forest, hydropower, and minerals. GIS has been increasingly utilised to assist the development in those areas. Additionally, GIS is also helping to guide social-economic and sustainable development of the country. By using the power of GIS, people have access to spatial characteristics information such as geographical location and spatial correlation/distribution. Particularly, GIS has been a pivotal tool for land-use planning activities. Land-use planning is a key component supporting socio-economic development as well as customary land registration/titling. Nevertheless, geospatial datasets resulting from land-use planning activities often encounter mismanagement and generally lack standardisation. Storing datasets within a relational database is still perceived as new and untested. Consequently, datasets are not consolidated and stored as individual shapefiles. Often, these land-use planning shapefiles cannot be consolidated to form meaningful landscape perspectives, and eventually pose risks to data being corrupted and lost.

This research aims to examine the viability of the open-source relational database PostgreSQL and its geographical extender PostGIS, in concurrent use with QGIS, for managing multi-level vector land-use and land cover (LULC) of Lao PDR. The study addresses the spatial data management needs for small to medium-sized organisations typically found in governmental institutions. Open-source technologies, fulfilling the context of the resource constraint economies, are being continually developed and widely used amongst the global geospatial communities. Additionally, the research invites participants to take part in the study and the evaluations in order to obtain their perspectives of the introduced system.

1.2 Research background

Several historical topographic, administrative, and geological maps were produced during French colonisation to assist the administration and development; for instance, 1:50K topographic map (Figure 2) and 1:1 million geological maps (Figure 3). Many of these maps still exist and are being used today. They were converted into digital format by geo-referencing in the GIS system.

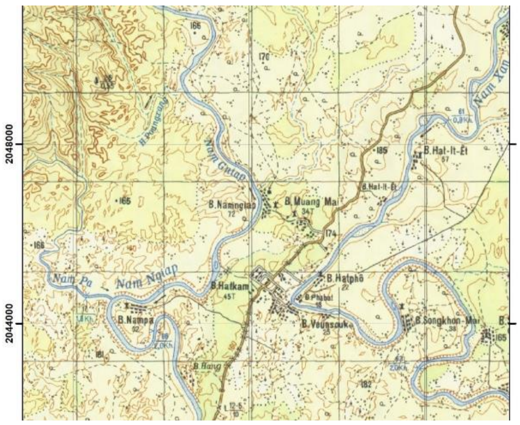


Figure 2. An extraction of 50k-scale topographic map, scanned and georeferenced.

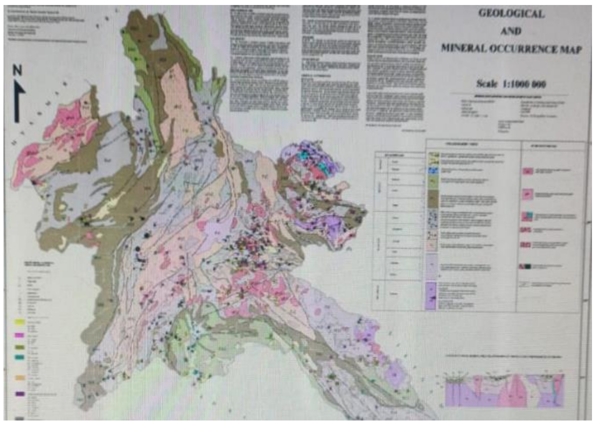


Figure 3. Geological and mineral occurrence in Lao PDR (Keohavong, 2009).

GIS-based technology was introduced into Lao PDR in the early 1990s to support the building of geospatial databases, aerial photography, and cadastral survey with the support from the Finnish International Development Agency (FINNIDA) project for the National Geographic Department (NGD). The first GIS software was the ArcMap from the Environmental Systems Research Institute (ESRI) and it was used to store, handle, and geo-process geospatial datasets such as raster-based aerial imagery, digital elevation model (DEM), topographical, administrative, and other related digital maps.

In the 1990s, only a few people had access to the GIS due to various reasons; one reason being the licenses. Thus, GIS was not widely used, and applications were limited. Since late 2000s, more GIS software options (e.g., Global Mapper, MapInfo Professional, QGIS (formerly Quantum GIS), SAGA GIS) have become available. Access to the software has become easier, especially open-source GIS software, more people have had a chance to use the software and integrate it into various applications, and new datasets have been constantly generated and updated. As shown in Table 1 below, the geospatial community in Lao PDR has grown considerably. There are over 3,800 people taking part in the geospatial community both professionally and academically.

Table 1. Approximate number of GIS users in Laos.

User group	Number of active users	Facebook page	Number of followers
QGIS user in Laos	74	Lao Geomatic Groups	1,462
Lao GIS	610	Information exchange on GIS and cartography (in Lao language)	1,190
		GIS and GPS training course at National University of Laos	472

Information obtained from Facebook as of 16th December 2019.

A user survey about the GIS software currently being adopted by the organisation in Laos revealed the software of choice varies, depending on specific needs, usability, and associated software costs. The survey further suggested that ESRI's ArcGIS and QGIS are the most frequently-used GIS software packages, as shown in Table 2 below.

Table 2. Primary GIS software package used by organisations in Laos.

Software package	Organisation	Domain /functionality
ArcGIS, QGIS, Erdas, eCognition	Ministry of Agriculture and Forestry	Agriculture/forest and resources planning, analysis, classification/segmentation
ArcGIS, Global Mapper	National Geographic Department of Laos	Providing satellite/aerial images and GIS data, inventory, and cartographic service
QGIS, PostGIS	Ministry of Natural Resources and Environment	Environment and social management, monitoring, and evaluation
ArcGIS, QGIS	Ministry of Labour and Social Welfare	Disaster/emergency preparedness, risk reduction, and response. Hazard and vulnerability mapping
Autodesk Land, LaoLandReg, ArcGIS/QGIS	Land Registration Division	Cadastral survey, land surveying, land titling/certificates, and urban planning
ArcGIS, QGIS, MapInfo	National University of Laos	Academic and research
SMART GIS, QGIS, Erdas, eCognition	Wildlife conservation units (various)	Wildlife conservation/patrolling and reporting
ArcGIS, Survey123 (mobile data collection tool)	The National Regulatory Authority for UXO/Mine Action Sector (NRA)	Spatial planning for UXO clearance, UXO incident recording

Above information is as of 01-11-2019 and may be subject to change.

1.3 Research rationale

Storing and managing geospatial data on personal-level computers poses several limitations since a single vector shapefile does not consist of a single file but multiple auxiliary files forming one shapefile. Improper handling or file-missing may cause the shapefile to become invalid. Multiple users working on the same datasets may result in the data being obsolete and redundant due to the lack of frequent updates. Additionally, shapefiles lack standardisation and are unable to conform to the geometry integrity rule, making data maintenance across the workflow a challenging task. Currently, there is limited access to the relational database that stores, manages, and handles geospatial datasets while providing spatial functionality. Consequently, this has resulted in:

- Low efficiency and performance when querying and data management
- Data integrity and security inconsistency
- Limited access to the datasets for wider users in the team
- Inability to join multiple datasets and non-spatial tables

Notably, from Table 2 above, relational database or spatial database at enterprise level has not been adopted nor have there been attempts to develop one. Enterprise-level database has several advantages when it comes to managing geospatial datasets including, but not limited to:

- The ability to be accessed by multiple users simultaneously
- Relationships between tables enhance data manipulation and analysis
- Improving data integrity, standardisation, and prevention of data corruption/lost
- Making changes and updating table is easier; the data is more secure due to frequent or scheduled backup

This research adopts the PostGIS database since it is an open-source technology, versatile, highly flexible, and has numerous advantages compared to other relational databases. Most importantly, it is suitable for small to medium-sized organisations, has sufficient performance and adequate spatial capabilities, while providing all around database management needs (Bartoszewski et al., 2019a; Chaudhry & Yousaf, 2019). Moreover, since open-source relational database source codes are not closed, it offers flexibility for future improvement and scalability (Bocetta, 2019; Dudoit et al., 2003; Omni Sci, 2019; Swain et al., 2015). Figure 4 demonstrates the evaluation framework of this study.

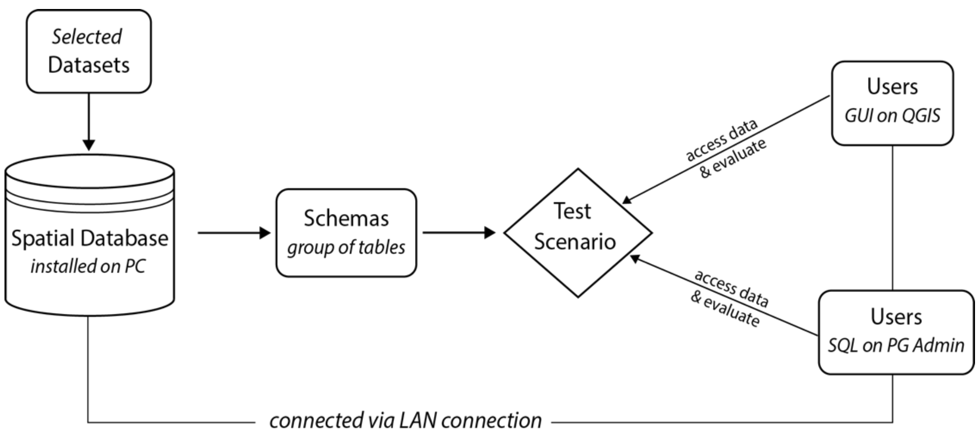


Figure 4. Spatial database infrastructure deployed for this study.

1.4 Research scope and location

The scope of this research only applies to small to medium-sized Laotian institutions, the typical scale encountered in the government and private sectors. This scope allows the researcher sufficient time to cover critical aspects and gain in-depth understanding of this mainstream user-group. The research study incorporates performance evaluations of the spatial database and user survey data from the participating institutions of the Ministry of Agriculture and Forestry of Laos, in the Vientiane, Lao PDR.

1.5 Research question

To understand the PostGIS database and be able to quantitatively assess performance, the research replicates practical geospatial tasks in an experimental situation by installing and assessing the spatial database, together with research participants as users. The participants are to test the following question: Can a developed PostGIS solution in concurrence with QGIS be a viable tool to manage multi-level LULC data, with measurable increase in performance in the context of Lao PDR? The overarching question can be broken down into specific questions as follows:

- Q1. Does the introduced solution allow for spatial querying with a measurable increase in performance over existing platform?
- Q2. Does such solution offer capabilities which were previously unavailable? Such as (1) processing complex geospatial dataset, (2) querying between GIS data and non-spatial tables?
- Q3. What is the overall participant satisfaction towards the introduced solution?
- Q4. What are the current limitations of the solution, and the unexplored potentials which are worth studying in the future?

1.6 Research framework

The study consists of three main phases. Phase one, carried out in New Zealand, gathered and organised selected LULC datasets to be stored in the database; and mainly involved data handling, structuring, and migrating into the spatial database. Phase two, once the PostGIS database has been installed with selected spatial datasets, involved written structured query language (SQL) functions to perform initial testing. Finally, in Phase three, the researcher worked with the participants at the participating institutions in Laos to conduct the assessment of the introduced solution as well as obtaining interview survey data. Finally, the researcher compiled and consolidated the findings and results and wrote the thesis. The overall research framework is displayed in the diagram below (Figure 5).

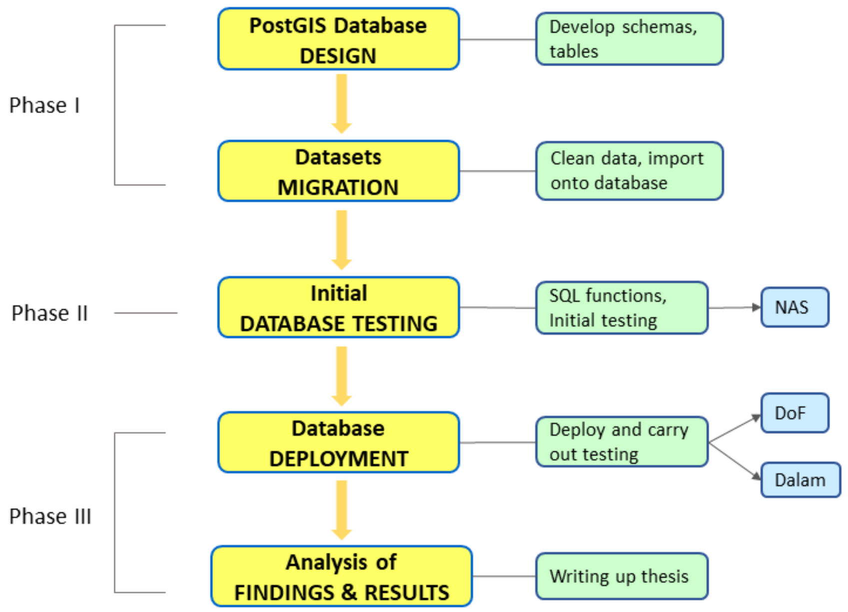


Figure 5. Research framework.

Chapter 2 Literature review

2.1 Origins of spatial database

PostgreSQL relational database inherited the primary architectures from the Ingres Project, developed in the early 1970s by the University of California, Berkeley, USA. The first version which was released in 1986 subsequently went through several updates. The Postgres database version 4.2 ended in 1994 due to overwhelming maintenance demands and finance burden. In 1996, after replacing Query language (QUEL) with structured query language (SQL) as scripting language which were used to interact with the datasets, the project was subsequently renamed as PostgreSQL and made publicly available in January 1997 under version 6.0. Since then, PostgreSQL has gained popularity as the open-source relational database for users around the world (PostgreSQL.org, 2019).

Geographical extension for PostgreSQL relational database PostGIS was first invented in 2001 by the Refraction Research in British Columbia, Canada (Refraction Research, 2019). The first version 0.1, releasing in May 2001, was able to store and retrieve data but lacked analysis capability. Thereafter, PostGIS functions were constantly improved and added. In PostGIS version 1.4, efficiency and performance of geometry processing such as intersects, contains, aggregates were significantly improved. As of June 2019, the stable version of PostGIS, version 2.5, was the latest update and fully compatible with PostgreSQL version 9.4 and later. PostGIS has become the most trusted spatial extender for relational database amongst the open-source communities (Open Geo, 2019; Refraction Research, 2019).

2.2 Key benefits of PostGIS database

Geospatial datasets residing in a relational database have superior power to return queries more efficiently thanks to its highly structured manner and indexing scheme, which helps speed up data search, geoprocessing tasks, and data analysis (Cimpianu, 2017; Miller, 2017; Sveen, 2019). PostGIS handles geospatial objects in two major data formats, the GIS objects (geometry) and the Geography data type. The geometry type, the most common data type, supports two types of spatial objects - the well-known text (WKT) and the well-Known binary (WKB). PostGIS data types are fully compliant with Open Geospatial Consortium (OGC) and based on the commonly used SQL for interacting with spatial objects, making it convenient for users as well as maintaining data standards (PostGIS.net). In PostGIS database, users can perform data manipulation directly via SQL statements such as update, insert, delete records, and analysis in any supported integrated development environment (IDE) provided that it is connected to the spatial database (Marx, 2019; Tjukanov, 2018)

Another benefit of PostGIS is its built-in indexing schemes, the primary indexes include generalised search trees (GiST), block range index (BRIN), and space-partitioned generalised search tree (SP-GiST). GiST is the most common indexing algorithm; it speeds up the irregular data formation using the geometry field by breaking data into three different tree mechanisms for the most efficient processing (PostGIS.net). Meanwhile, another key component of any enterprise database, which PostGIS possesses, is the security and user authentication. There are several security mechanisms; one is file protection which restricts file reading and writing only to the superuser. Client connection could be limited by IP address/username and authenticated via certified external package. By default, users will not have write access unless they create their own database, and require username/password upon log-in. The user authentication process in PostGIS ensures only genuine users have access to the database by checking against the information in the pg_user class and further verified by the user shell and the network. If any attempt fails to meet the required authentication, access permission will be rejected (PostGIS.net; PostGIS.org). The ability control access to prevent potential risk by allocating appropriate access rights to each user is another security mechanism. Other security measures include trigger and transaction functions which are built-in the PostGIS database (Miller, 2017). The benefits of PostGIS are the variety of supported extenders that further enhance the capability of PostGIS. For example, PGRouting extender enhances PostGIS database for building navigation applications which leverages the popular shortest path algorithm Dijkstra (Pastewski, 2017; pgRouting, 2020), and web map applications which work seamlessly with the two popular web-map servers, GeoServer and MapServer (Obe & Hsu, 2011; PostGIS.net; Zouagui et al., 2017).

2.3 Types of spatial analysis enabled by native PostGIS functionality

PostGIS database comes with rich spatial functionalities. It is regarded as one of the most potent spatial analytical tools built-in a relational database currently available on the market (Bartoszewski et al., 2019b; Shukla et al., 2016). One project exploiting PostGIS's analytical tool was estimate shoreline movement and changes overtime in Poland (Kostecki, 2018). Various functions were used in the estimation but primarily comprise st_makeline, st_segmentize, st_closet, and st_dwithin. These tools were ready-to-use in PostGIS, making it convenient for the researcher to conduct the study. The statistical results and output geometries resulting from the study were visualised in R and QGIS, respectively, once connected to the spatial database (Kostecki, 2018). There is a rising trend of storing and visualising ever-increasing spatial and temporal real-time or near-real-time data in order to respond to decision making in a timely manner; for instance, meteorological, environmental, and climatology. This capability was exploited by Gutiérrez et al. (2018) in a study on spatial analysis and geo-visualisation of near-real-time precipitation data obtained from the Global Climate Monitor and Eurostat for southwestern Europe (Eurostat, 2019). This study leveraged the power of PostGIS and other open-source technologies such as QGIS to store and handle CSV-extracted spatial objects within the relational database ecosystem, fulfilling the analysis and visualisation of time-series, and enabling users to view the data near real-time. The study suggested that integration was highly capable of handling ever increasing spatial and time-series data and, meanwhile, delivering excellent analytical and geo-visualisation. The output data were also visualised on the web with the aid of QGIS cloud (Gutiérrez et al., 2018).

2.4 PostGIS databases as a foundation for building open-source Web-GIS applications

There are several terms commonly associated with Web-GIS such as web-map/ping, Geoweb, distributed GIS, internet GIS, map portal and online mapping. Since the term Web-GIS appears regularly during the literature reviews and best reflects the terminology, this literature review uses the term Web-GIS to refer to any form of displaying, creating, or distributing geospatial datasets on the world wide web. Web-GIS applications provide users the ability to access, design, distribute, retrieve, and visualise geospatial information over the web (Hess S, 2002; Neumann, 2008). The open geospatial consortium (OGC), found in 1994, is an international cooperation aiming to integrate geographic information system as part of the world information system. It develops open interface standards, encoding, best practices that facilitate users to interchange geospatial information with other information systems, and encourages

OGC's standardised geospatial information approach amongst its members (Landmap Geoknowledge, n.d-d; OSGeo Live, n.d). OGC's open standards for displaying Web-GIS contents on the web consist of web map service (WMS), web feature service (WFS), and web coverage service (WCS) (Landmap Geoknowledge, n.d-d; OGC, n.d-a). The most widely adopted WMS protocol allows clients to retrieve data in the forms of ready-made georeferenced map images such as jpeg, png. This protocol allows multi-source maps, and interoperability to be displayed for the client, making it easy to view the maps even for devices with limited processing power (Landmap Geoknowledge, n.d-c; Michaelis & Ames, 2017; OGC, n.d-d). The other web-GIS content is the WCS whose protocol allows maps to be visualised on the web, and the contents to be defined by their spatial and temporal characteristics. Users can download the data in various raster formats such as geotiff, hdr, jpeg2000; for instance, digital elevation model (DEM), satellite imagery. These data are suitable for advanced users with access to desktop-based computer for pre-processing and analysis (Landmap Geoknowledge, n.d-a; OGC, n.d-b). The last web-GIS content of OGC is the WFS whose protocol is requesting and disseminating web applications in vector formats at the feature level and export requested data in standard formats such as Geographic Markup Language (GML) based on user's defined geographical extent. This protocol gives users full access to the data. Therefore, users have the freedom to manipulate their preferred way on their local machine (Landmap Geoknowledge, n.d-b; OGC, n.d-c).

Web-GIS technology has been evolving rapidly in previous decades due to the rise of smartphone, internet, and advancement in GIS technology; enabling users to view, generate, analyse, and visualise geospatial data online almost entirely without the need of computer GIS (Mohamad et al., 2016). For instance, people can easily find the shortest route to a location using location-based service. With the aid of the internet, linking information to a location is much more efficient (Veenendaal et al., 2017). The most essential component of Web-GIS is the ability to efficiently distribute and exchange geospatial datasets on the web, enabling individuals to visualise datasets and make decisions in a timely manner. Consequently, the demand of WebGIS in various applications is ever increasing (Singh & Singh, 2014). To build a functional WebGIS, a framework service is required, either proprietary or open source, that connects to the database at the backend and displays the geospatial data over the web browser (Miller, 2017). Currently, there are several options such as MapServer, GeoServer which are open-source, and ArcGIS Server, Oracle, Mango Map which are backed up by companies. A typical infrastructure of Web-GIS involving spatial database, web map server, web server, and mapping libraries is shown in Figure 6. PostGIS has been the best all-rounder for building Web-GIS application using open-source technologies especially when integrating with either MapServer or GeoServer as map server, as well as their superior performance when handling large spatial datasets (Swain et al., 2015; Zhonghai et al., 2009).

The main advantage of PostGIS as back-end database for Web-GIS is that its database and geographical extender has a wider range of support and seamless integration for both proprietary and open-source web map servers, as well as full compliance with OGC standards. Unique spatial functionalities such as data validation, topology check, and coordinates conversion further fulfil the packages (Piórkowski, 2011). However, MySQL is another open-source database with spatial capabilities that can support Web-GIS applications. It is partially dependent on one standard and only 2-d dimension without reference sets and no support for raster data (Piórkowski, 2011; Swain et al., 2015); it also uses minimum bounding rectangles instead of true geometry when executing queries, making it less accurate (Zhonghai et al., 2009). Similarly, WAMP (which stands for Windows/Apache /MySQL/PHP), is a another widely adopted tool for building web applications but this fall short due to incompatibility issues for other operating systems such as Mac and Linux, as well as limitations as mentioned above for MySQL Spatial extender (Agrawal & Gupta, 2014; Singh & Singh, 2014).

MapServer and GeoServer are the most popular open-source WebMap servers for building Web-GIS application. The following sections 2.4.1 and 2.4.2 further explain how these map servers are supported by PostGIS as back-end database.

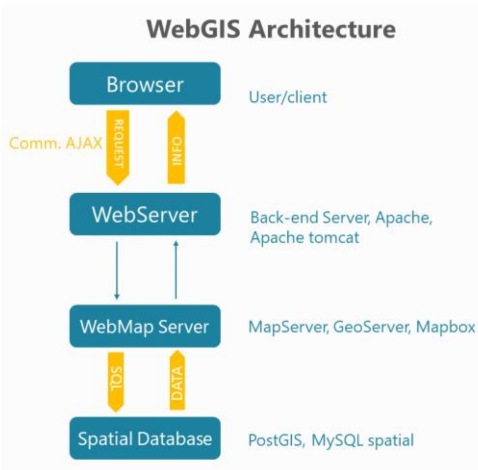


Figure 6. A typical infrastructure of a WebGIS (Miller, 2017, 04:38)

2.4.1 PostGIS database for MapServer application

MapServer, developed by University of Minnesota (Ballatore et al., 2011), is a widely adopted open-source web map server for publishing spatial data online. It is fully compliant with various OGC's web content standards such as WMS, WFS, and WCS; as well as delivering high performance in processing large geospatial datasets (Singh & Singh, 2014). MapServer platform supports a variety of both vector and raster datasets via the Geospatial Data Abstraction Library (GDAL). It runs on the Apache and Microsoft web servers via common gateway interface (CGI) application (Ballatore et al., 2011; Singh & Singh, 2014; Swain et al., 2015). MapServer also has a fully customised support for rendering map symbology file. Several programming languages such as Perl, Java, .NET, PHP are inherently supported with MapServer, and it has seamless connection to relational databases such as Oracle, MySQL and PostGIS (Ballatore et al., 2011). PostGIS compatibility was added following the release of MySQL version 3.5 (Brovelli & Magni, 2003).

There are several Web-GIS applications powered by the integration between MapServer and PostGIS as web-map server and back-end database respectively. For instance, Brovelli and Magni (2003) developed an interactive Web-GIS called ArchaeoGEW for an archaeological site in Northern Italy based on the implementation of PostGIS, MapServer, and Apache web server. The purpose of this Web-GIS was to facilitate easy access to information, for both expert and novice users, for archaeological perspectives including their unique geographical features and significance in order to encourage the conservation efforts of this heritage and the surrounding environment. This Web-GIS achieved significant results as it enabled geospatial information viewing on the web, as well as auxiliary information such as photos and GPS survey. Single and multiple queries could be used to extract data and information, and allowed direct data uploading via web graphical user interface (GUI) to the database. It also enhanced an entire table editing, updating, and displaying simultaneously on the web browser (Brovelli & Magni, 2003). In another study, Singh et al. (2012) successfully built an interactive Web-GIS using complete open-source tools. It was capable of storing and displaying sizeable vector-based administrative spatial datasets of the city of Agra in India, while adding spatial analysis capability for the users, thanks to the implementation of object relational database via PostGIS. The platform, implemented on Microsoft's ASP.NET using MapScript's language, was connected to the spatial database via PostGIS.

MapScript is also available with several popular scripting languages such as Python, Java, and PHP (Singh & Singh, 2014; Swain et al., 2015).

2.4.2 PostGIS for GeoServer application

Like MapServer, GeoServer is an open-source WebMap server developed by the Open Planning Project (TOPP) in 2001. Since the release of GeoServer version 1.5.3, the developer communities looking after GeoServer have grown considerably to account for more than six companies worldwide (Deoliveria, n.d). Besides being fully compliant with OGC's standards of WMS, WFS, and WCS, GeoServer also complies with WFS-transactional, meaning it enables users to edit features directly on the web. In addition, GeoServer expanded its compatibility with OGC's styled layer descriptor (SLD) to allow the rendering of map layer symbology. Other significant features include the support for OpenLayers, Google Earth, and GeoWebCache for map titling (Ballatore et al., 2011). A review study conducted by Swain et al. (2015) and a case study research by Delipetrev et al. (2014) solely focussed on building water resources modelling Web-GIS using open-source technologies, specifically the implementation of GeoServer and PostGIS. The results suggested the integration was capable of publishing water resources geospatial modelling data on the web, enabling multiple users to access, retrieve, and editing water resources related data entirely on the web browser without the need for any software. GeoServer has also implemented web interface for data configurations on the server, making it more user-friendly for searching, presenting, and downloading geospatial maps. It uses Java library Geotools for supporting spatial types vector and raster. Even though GeoServer is open source, it could work greatly with commercial packages. If users experience data workload and slow performance, one resolution is to utilise GeoServer's multiple repository connectivity (Delipetrev et al., 2014). GeoServer is fully compatible with commercial databases such as Esri's ArcSDE (Spatial Database Engine) and Oracle Spatial (Agrawal & Gupta, 2014).

2.5 Employing PostGIS database to manage and geo-process land-use and land cover spatial datasets

There are a number of projects storing and processing land use and land cover (LULC) within the PostGIS database (Bastin et al., 2013; Cousins et al., 2015; Mukhopadhaya, 2016). The LULC are often viewed as complex and dynamic because they often require frequent updates to reflect the changes on the ground. Therefore, updating is an important tool for a spatial database to maintain these data effectively (The Agro-Biodiversity Initiatives, n.d). Land-use and land cover are classifications that convey the characteristics of the earth's surface at a particular location. Land-use generally refers to the human activities and operations on those land parcels in order to gain benefits or cultivate products out of that land. Land cover usually refers to the surface cover or features on the ground - natural and man-made-which are visible on the earth's surface. LULC data are derived from various methods such as participatory mapping, remotely sensed satellite imagery, digitisation, and semi/full classification (Bastin et al., 2013; Coffey, 2013; MAPASYST, 2019). Land classification and its nomenclature is a systematic approach to organise land classes into groups with specific criteria and the relation between them. Often they hold a unique ID field as a primary key which is then used to link with auxiliary information such as land-class or sub-class in order to fulfil those datasets (Di Gregorio, 2005).

In a study by Brovelli et al. (2016), PostGIS database, coupled with other open-source Web-GIS technologies such as GeoServer and Leaflet, was capable of publishing both vector and raster-based LULC onto the web, as well as providing basic GIS functionality as shown in this study. The high-resolution European Urban Atlas land cover data were stored in the respective raster and vector databases and communicate with GeoServer for server-side, interact with spatial data via JavaScript library Leaflet and bootstrap framework for user interface, and render symbology file from the web server. The study successfully established a functional Web-GIS displaying LULC data with some desktop GIS functionalities such as layer selection, activate/deactivate layers, visualise and analyse LULC data and display LULC related photos uploaded by the users (Brovelli et al., 2016). Zambelli et al. (2012) explored PostGIS database in concurrent use with GRASS GIS to develop a model for estimating biomass availability in an Alpine forested area of Italy for renewable energy production. This study showed that PostGIS database had the capability to manage and geo-process large volume of input forest inventory data, as well as optimising calculation in a highly efficient manner. The model successfully identified suitable areas for timber harvesting based on the two input criteria, ground-based harvesting and cable harvesting (Zambelli et al., 2012).

2.6 Managing geospatial datasets within a PostGIS database by small to medium-sized organisations

PostGIS has enabled users to effectively interact with geospatial information within a relational database (Mikiewicz et al., 2017). Many small to medium-sized organisations around the world have embraced this open-source technology to manage their geospatial datasets. For instance, the Institut Géographique National (IGN) (2020), the national mapping agency of France, has adopted the PostGIS back-end database containing all relevant geospatial layers. While using GeoConcept GIS for editing, the data could be synchronised simultaneously between the two platforms. The IGN team could successfully retrieve data from file-based storage and insert them into PostGIS database, allowing users to edit and update data directly from the connected spatial database via GeoConcept. Multiple updates of the same features can be achieved simultaneously. The other feature was the ability to synchronise the data between the backend database and frontend GIS software; an error pop-up will prompt if multiple users are editing the same features (IGN, 2020).

In another study, Zheng et al. (2013) exploited the built-in PostGIS spatial functions in combination with an enhanced wayfinding module based on the Dijkstra algorithm. The study was to create a cost-effective pedestrian wayfinding utilising free and open-source modules and OpenStreetMap API to create a wayfinding that best suits small towns or regional authorities. Various user groups require different approaches to wayfinding according to demand, behaviour, and geographical characters. Therefore, creating a customised wayfinding would best suit each specific user group, and open-source GIS tools are the most efficient and cost-effective. The way-finding module was created based on PostGIS database and java-based module, which had proven to be very efficient and cost-effective, as well as offering flexibility for future refinement. It has been shown that it was a viable tool, especially for small to medium sized administrative organisations or business entities and holds great potential for future scalability (Zheng et al., 2013).

2.7 Utilisation of PostGIS database in other geospatial domains

Location-based service (LBS) has been proliferating in recent decades due to the widespread of mobile phones, internet, social media, and geotagged information (Shankar et al., 2012). LBS utilises the built-in GPS functionality found on today's mobile phones where users can track a person's location through shared or checked-in locations. LBS providers include Google Maps, Yelp or Zagat. Users can identify nearby services, such as restaurants, and obtain auxiliary information such as ratings, photos, or reviews of the location to make their decision. PostGIS was employed in a location-based service development in a study by Shankar et al. (2012) to compile, index, and rank location based on users' crowdsourcing information and users' weighted expertise. PostGIS' primary function in this study was data indexing of the social-media feeds crawling, storing them as tags and sending them to query processor prior to performing the ranking by the engine. Search query was possible due to PostGIS' powerful R-tree indexing. As a result, PostGIS database was a successful integration in this study and delivered exceptional performance (Shankar et al., 2012).

Despite growing interests and developments in integrating GIS datasets into a relational database, much focus has been on the vector format, leaving a gap on raster data especially ever-growing remotely sensed datasets (Lee & Kang, 2010). The study by Lee and Kang (2010) explored the potentials of storing and managing complex remotely sensed raster datasets inside a relational database for fast processing, effective, security, and data integrity. Open-source ORFEO Toolbox (OTB) and PostGIS were chosen to manage and geo-process raster-based imagery due to its multiple-file formats support, enhanced GUI, and database connection capability. OTB has been designed to work exclusively with raster file format and is compatible with several operating systems and databases. PostGIS was proven to be an integral part of this combination, successfully connected to the OTB engine to read and import several raster files such as GeoTiff, Jpeg2000, BMP, PNG, SAR, and Korean National Image Exchange (NIX) file, and display segmentation results on the web applications. OTB is considered one of the most powerful open-source raster toolboxes, capable of handling numerous geoprocessing such as radiometric calibration, supervised classification, and segmentation (Lee & Kang, 2010).

2.8 Limitations of PostGIS database

Despite the power and spatial capabilities of the object relational databases (e.g., PostGIS), relational databases have limitations in certain areas. For example, PostGIS cannot be optimised for the ever-increasing, large geospatial datasets, specifically geospatial big data due to their intact geographical properties. In addition, PostGIS databases lack support for distributed and parallel computing architecture such as Apache Hadoop and NoSQL MongDB, which allows data to spread across multiple servers with increased computational power and not compromise on system performance (Lee & Kang, 2015). Many scientists believe that, in the future, big data will play a crucial role in addressing global issues such as deforestation, threats to nature, eco-environment, and earth science (Lo, 2019). For instance, the recent advent of Google Earth Engine (GEE) has given users the power to process and analyse large geospatial datasets via Google cloud platform on a planetary scale without parallel computation power, thanks to Google's supercomputing infrastructure (Geohackweek, n.d; Gorelick et al., 2017). Furthermore, another limitation of the PostGIS database is actually the nature of being structured. As datasets become bigger, it is more difficult to accommodate those datasets with sufficient level of performance (Lo, 2019). PostGIS is not a viable tool for handling big data and the future potential platform for hosting big data may rest with distributed computing and NoSQL database such as Apache Hadoop, MongoDB, or spatial online analytical processing (SOLAP) (Lee & Kang, 2015; Lo, 2019).

Chapter 3 Research approach and methodology

Phase 1. Compiling data and structuring the PostGIS database

At the start of the research, all selected geospatial and auxiliary datasets obtained from the Ministry of Agricultural and Forestry of Laos (MAF) and official website portal, underwent cleaning, compiling, and structuring in logical order, and in compliance with the requirements of the relational database. PostGIS database and schemas were created to host data tables and establish relationships between them. Schemas were appropriately named to help provide users good comprehension about the table contents residing in each schema. These tasks were carried out in Auckland, New Zealand between April and May 2019.

Phase 2. Developing and testing SQL algorithms within the PostGIS database

Once all the relevant datasets were inserted into appropriate schemas of the spatial database, development SQL algorithms based on two test scenarios began and were tested on a localhost of the spatial database. The SQL algorithm for each test must meet the objectives for returning the results as indicated in testing scenario. Thus, each test was iteratively run and tested until satisfaction was met. Testing of all SQL algorithms was carried out in a replicated environment with appropriate computer equipment. The testing helped to determine the feasibility of the introduced solution and identify areas for improvement prior to the actual test evaluations in Laos. These tasks were carried out in Auckland between June and October 2019.

Phase 3. Validating the utility of the database within a real-world case study

In the last phase of the study, the researcher validated the utility of the database and PostGIS database functionalities via test evaluations with input LULC data at the participating organisation with research participants in Vientiane, Laos between November 2019 and January 2020. The initially developed SQL algorithms were fine-tuned with the participants and testing carried out with respect to available facility infrastructure. Both quantitative and qualitative data were obtained to assist the analysis.

3.1 Participants

Four research participants were invited to take part in the study. Participants were chosen based on the selection criteria that best suited the accountability for using open-source relational database and QGIS. Selected participants were from the participating institutions and included:

- A land-use planning/GIS technical officer
- A forestry technical officer
- A lecturer from Souphanouvong University
- An assistant lecturer from the National University of Laos (NUOL)

3.2 Datasets and organisation

Two data types were used to support this investigation; first, the selected geospatial datasets within the PostGIS database and second, the test evaluation results and qualitative survey data derived from the participant interview. Test evaluations results were analysed to give insight into the assessment based on the pre-determined test scenarios while participant interviews supported the study by revealing the user's exposed experience and perspectives. Different people may have different opinions and perspectives towards the introduced system depending on the conditions and contexts to which they were exposed. Thus, it is essential to find out common perspectives amongst the participants.

Four primary schemas were created to accommodate all vector-based data used in this study. Forty geometric tables and six attribute tables (non-spatial) were imported into each schema using graphical user interface DB Manager on QGIS that was connected to the spatial database. A database schema is a structured collection of tables that provides a logical view of the relational database. It also defines the relationship between tables and how they are organised (Lucidchat.com, n.d; Tutorialspoint.com, n.d). Typically, a schema would contain relevant tables that best match the schema description, so it is easy and logical for the users to locate the table. During the database design, it is a good idea to map out schemas and respective tables on a diagram so that they can be fine-tuned until satisfaction is reached. Upon completing the import of tables, the tables were indexed using GiST scheme (Generalized Search Tree) using the SQL function. Table 3 demonstrates the data organisation in this study.

Table 3. The number of tables and the description of each schema.

Schema	Description	Number of tables
admin	Contains geometric tables associated with administrative data such as boundary, village location, roads/rivers	8
forestry	Contains forestry-related GIS tables, mostly 3-forest category boundary and some management zones	7
LULC	Contains all 18-province village-level land-use and land cover GIS tables (some provinces may have more data than the others)	25
results	Containing resulting tables after executing query	2 (attribute tables to join with additional data)
se	Contains non-GIS attribute tables of social and economic data collected from village-level land-use planning activities	-
public	Public schema by default	6

A study about the local coordinate reference system revealed that there are several geographic coordinate systems (GCS) or datum being used in Lao PDR (e.g., Indian 1954, Indian 1960, Vientiane Datum 1982, Lao Datum 1993), but the primary ones currently used are World Geodetic System 1984 (WGS84) and the Lao National Datum 1997 (Lao1997) (Nilsson & Svensson, 2004). Lao1997 datum represents a local datum whose centre of the spheroid is offset of the original earth centre, and thus a point on the surface of the spheroid is matched to a particular position of the earth. This local datum has the advantage of having the spheroid with good approximation to the size, shape of the sea-level surface, and geographical context of that particular region (Nilsson & Svensson, 2004). Meanwhile, WGS84 is a latest version of the World Geodetic System (WGS). It is a standard coordinate reference system which is based on a spheroid model of the earth and expresses latitude and longitude in angular units (dd:mm:ss or decimal degrees). It is widely used in cartography, geodesy, and satellite navigation systems (Buckley, 2010; GISGeography, 2015).

Since the Global Positioning System (GPS) uses WGS84, and most GPS devices receive satellite signals from GPS navigation satellite systems, they output coordinate references in WGS84 formats. As a result, WGS84 projection has been increasingly adopted and users do not need to transform projection between WGS84 and Lao1997 (Nilsson & Svensson, 2004). The geographic WGS84 datum is often used for small-scale maps such as country, region or province level, providing a much larger geographical extent. Another projection commonly used is the WGS-84 UTM projection, which is a projected coordinate system of the Universal Transverse Mercator (UTM). WGS-84 UTM is projected onto a flat surface, two-dimensional representation of the earth surface and is based on WGS-84 geographic coordinate system for spheroid model. Unlike WGS84 geographical coordinates, UTM projection has a constant linear unit of measurements, so the calculations of distance and land area are much easier (ESRI, n.d; IBM, n.d; Nilsson & Svensson, 2004). Large to medium scale topographic, surveying, and engineering maps - especially site-specific or village-level mapping - usually prefer WGS84 UTM projection as it contains Cartesian coordinates in metric units, making it convenient for calculations (GeoRepository, 2020). Laos lies between UTM Zone 47N and 48N (Northern Hemisphere). For WGS84 UTM projections, the dataset was imported into the spatial database by reprojecting to either UTM 47 or 48. Figure 7 shows the map of the world in UTM projects and zones in Laos as shown in Figure 8.

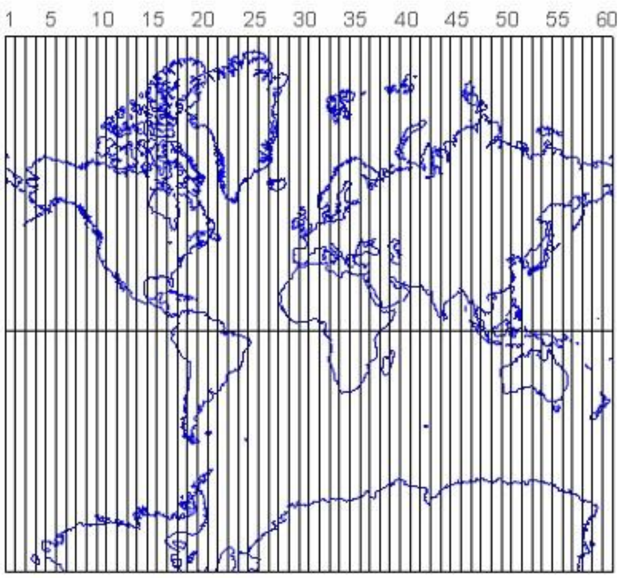


Figure 7. UTM projection divided into different zones for the world.
Source: Penn State College of Earth and Mineral Science https://www.e-education.psu.edu/

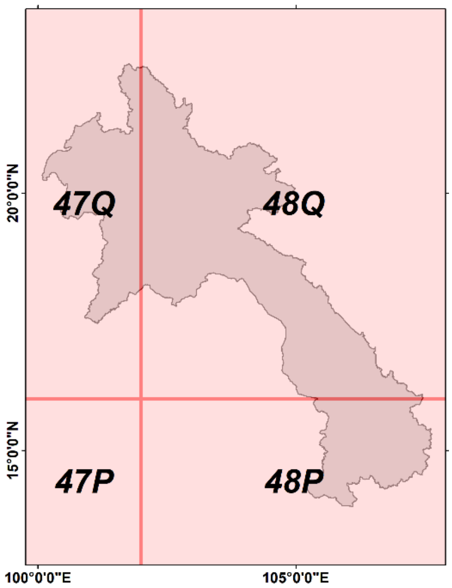


Figure 8. UTM projection zone 47 and 48N that covers Lao PDR.

3.3 Testing scenarios

Two test scenarios were created to help guide the performance evaluations of the introduced solution. The test scenarios were based on the common spatial operations for dealing with LULC datasets. Performance evaluation in test scenario-one was carried out on QGIS and PostgreSQL console (PG admin), remotely connected to the spatial database via LAN connection, to assess selected spatial functions and standard data-retrieval queries. The test evaluation consisted of:

1) Geometry editing which included the on-screen editing of GIS features on QGIS such as creating new geometry and shapes, editing and saving features/tables, and preserving local Lao fonts in the attribute tables.
2) Standard spatial operations which examined the QGIS's merge, union, and clip functions between two and multiple features.
3) Statistics summary which performed the calculation of the LULC data tables and distinctively summarised into respective categories such as administrative province/district, land area, and land typology; and
4) Data-join with auxiliary data whose operations involved selected SQL queries and PostGIS' spatial functions to join geospatial datasets with auxiliary tables in order to further complete the information.

The test scenario-two attempted to perform more complex data manipulation and spatial-join between geometric spatial datasets and attribute tables exploiting native PostGIS functionality over on PostgreSQL console (PG-Admin) using SQL. This test also carried out additional spatial functions that were previously unavailable with the exiting workflow. The test evaluation consisted of:

1) Identifying and locating features within a relationship using PostGIS' algorithm to check/calculate between two or multiple feature tables (e.g., ST_Within) and return the resultant tables if the statement is true. The table can be displayed on PG_Admin as tabular format or plotted for graphical visualisation on third-party applications;
2) Statistics calculation of LULC data by joining with auxiliary information and summarising into major land typology in order to form comprehensive sentiment about the data. This execution can also be coupled with spatial functions to check for relationship between the geometries; and
3) Data-join with auxiliary data (census data) by matching unique identification of administrative regions such as village, district, or province. The resultant tables can be further analysed in the GIS environment; for instance, creating hotspot map, gradated symbols, interpolated map, and other visualised maps.

3.4 Equipment

Primary equipment used for conducting the evaluation were the existing and accessible IT infrastructure at the participating institution in Lao PDR and some equipment from the Auckland University of Technology (AUT). The following Tables 4 and 5 detail the equipment used in this study.

Table 4. List of software applications.

List of equipment	Specification	Remark
PostgreSQL	PostgreSQL relational database	Version 11.5 August-2019 downloaded from www.enterprisedb.com
PostGIS	Geographical objects extender PostGIS for PostgreSQL relational database	Version 2.5 via PostgreSQL's online stack builder installation
QGIS	QGIS – GIS software	Version 3.8 (Zanzibar)
Python	Python 3	Version 3.7.3 April 2019 downloaded from Anaconda website
Lao script	Lao application and font	Version 8 downloaded from www.laoscript.net UTF-8 encoding

Table 5. List of hardware equipment.

List of equipment	Specification	Remark
PC Computer	Intel Core i5 2.5 GHz RAM 8 GB Windows 8 Professional	The desktop computer hosting PostGIS database
Laptop computer	Intel Core i7 2.6 GHz RAM 16 GB Windows 10 Professional	This laptop is used for accessing the spatial data via LAN
Network LAN connection	Network LAN using CAT 5 cable. With internet connection	Network LAN between PC, ethernet switch and client user
Ethernet Switch	10 Gigabit Ethernet Switch	To extend connection between computer and the network

3.5 Data analysis

Evaluation-based statistical figures were analysed in comparison with the performance obtained from the existing workflows at the participating institutions. Statistical analysis was plotted in Microsoft Excel in order to determine the overall performance efficiency from the statistical perspective. The analysis and interpretation of qualitative data such as participant interviews, observation, or questionnaire required several steps to determine and conclude the research findings. Based on Leavy (2017), the process generally consists of the following steps:

1) Data preparation and organisation
2) Initial immersion of the data
3) Data coding
4) Code categorising and developing themes
5) Interpretation

Data preparation and organisation, such as transcribing or scanning the data, are the first step for the researcher to prepare the data for analysis. The second step is to make an initial immersion of the data in order to gain the first sight and feeling of the data collected prior to analysing (Leavy, as cited in Hesse-Biber & Leavy, 2006, 2011). This step also helps the researcher to develop initial ideas and plans that are necessary for conducting the following steps. The third step is considered the most important - coding - wherein the researcher breaks down essential pieces of collected data into meaningful code by assigning a word or phrase to a segment of data. The selected code should carry the essence and meaning of the data segment (Leavy, as cited in Saldaña, 2009). The fourth step is the categorising and developing themes of the collected codes by collating similar or related codes together. It is also vital to identify patterns, relationships, and repeated themes amongst the codes. Once codes are split into groups, it is important to spot emerging themes. The final step is the interpretation of the data by the researcher, determining the meaningful interpretation of the collected data and answering what do the data really mean (Leavy, as cited in Hesse-Biber & Leavy, 2011). Once the findings from the two approaches start to unfold, they would be cross-compared and evaluated to form perspectives between the two data types.

3.6 Ethical compliance

An important aspect of this study was to conduct research activities ethically. Ethical concerns were appropriately addressed according to the AUT Ethics Committee's (AUTEC) ethical guidelines and advices to ensure the research adhere to legal obligations, culture and social practices, and academic requirements. Sandu (2019) emphasised the importance of ethics compliance, stating that it is about delivering the research findings and results with precision and honesty, presenting the author's contribution with accuracy and fairness. The researcher must ensure all the participants involved are protected throughout the process, and the researcher is committed to preventing and mitigating any potential conflict of interest. An ethics application was served as a safeguard for both the researcher and the participants as reflected on the core vision of AUTEC. This research obtained ethics approval from AUTEC on 1st May 2019 and is valid for three years until 30th April 2022. The following ethical considerations were addressed during the study.

- Research participants were recruited by a third party via a formal contract agreement in order to avoid potential conflict of interests, prior to the commencement of any activity.
- Participant interviews were conducted outside of their office area in order to promote more freedom and avoid conflict of interest or work-related influences.
- Contract agreement took into account the obligations of the researcher and participants in order to ensure that (1) potential risks were mitigated, (2) deception was prevented, (3) cultural/social sensitivity were suitably addressed, and (4) research adequacy was fulfilled.
- Identifiable information was replaced by the use of generic terms including fictitious names where applicable. Confidential information and data will not be published unless agreed by the concerned parties.
- Paper-based information including agreement, consent form, interview questions, and research findings were stored with the secondary supervisor located at the School of Science, Faculty of Health and Environmental Science, AUT city campus.

3.7 Limitations and difficulties

AUT and Faculty of Health and Environmental Science provided constant support and guidance for the researcher to carry out this study. Nevertheless, there were several limitations experienced throughout the study as below:

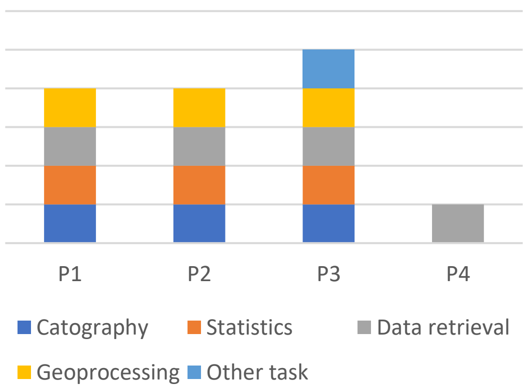
- It was difficult to motivate Lao research participants without financial reward. There was not much funding involved in this study and people would rather participate in a research project with financial incentives.
- Many Laotian people do not view academic research as a fruitful way of acquiring knowledge since they perceived that academic research lacks local participation and the long-term commitment needed to produce reliable scientific outcomes.
- Obtaining official approvals was a lengthy process involving various communication and formal requests.
- It was difficult to gain permission from participating institutions to access IT and network equipment since there were concerns over security, confidentiality, or risk for data being disclosed, corrupted or lost.

Chapter 4 Research findings and analysis

Test evaluation records on PostGIS console (PG admin) were captured to determine the performance and efficiency of the spatial database using input LULC data. Time intervals were manually recorded to represent the performance efficiency of participants' task operations. A set of features (shapefiles) were prepared in advance and logical order. Manual time records were treated as the baseline for the comparison. Evaluations results were analysed on Excel spreadsheets, and participant perspectives were analysed using the qualitative research method.

4.1 Participants background competency

Three out of four participants were categorised as competent users with several years of experience in spatial data management and land-use planning activities; only one participant was considered a novice as he primarily used GIS to aid his decision-making and planning. There were various GIS-related tasks involved, up to four and more. Most participants were familiar with geodatabase from ESRI, while only one person had experience with Microsoft Access for managing relational data. QGIS was the only open-source GIS software in which they were familiar with its functionalities and spatial analysis tools. Some participants further enhanced its potentials by integrating it with various applications such as land registration/titling, mobile data-collection, and relational database. Figure 9 and Figure 10 demonstrate the information on the participants' background competency.



P = participant

Figure 9. Primary GIS related jobs

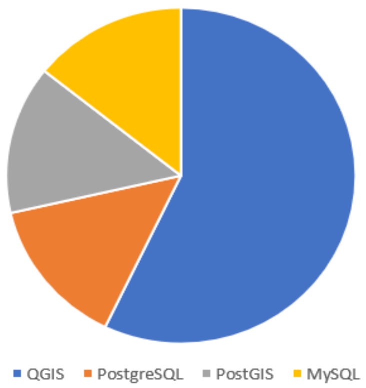


Figure 10. Open-source GIS and relational database software package

4.2 Results of test scenario-one

The test evaluations of scenario-one included two primary test functions with a total of 10 specific tests performed on QGIS and standard SQL query on PostGIS console (PG admin) with the datasets remotely connected to the spatial database via LAN connection. The results are summarised in Table 6.

Table 6. Evaluation results of test scenario-one.

Test evaluation	Time taken (sec)	Latency	Execution
I. Geometry editing capability (Determine if the task is functional, not on efficiency)			
1.1 Create features on QGIS	-	No	Success
1.2 Edit features using cut tool	-	No	Success
1.3 Save features and tables	-	Yes	Success
1.4 Font encoding	-	-	Success
II. Standard spatial operations			
2.1 Merge features (two or multiple)	480	No	Success
2.2 Union features (two or multiple)	10	No	Success
2.3 Clip (two features)	89	No	Success
III. Summarise LULC statistics	Time taken (msec)	Latency	Execution
3.1 Calculate and summary LULC and sort by district, province, and land typology.	570	No	Success
IV. Spatial join with auxiliary data			
4.1 Spatial join with auxiliary data and geometric data	429	No	Success
4.2 Storing and applying LULC land-class	-	-	Unsuccessful

4.3 Analysis and discussion of test scenario-one

The test evaluations, exploiting merge and clip functions using datasets connected to the spatial database, were performed on QGIS. They took around 480 and 89 seconds respectively, while the union took considerably lesser time at only 10 seconds. As expected, these three standard operations took longer times when compared to the performance using locally stored datasets of the computer. Notably, the time taken to execute union function was almost identical between the datasets of the two directories. Figure 11 shows the time differences of operations performed on the spatial database and localhost (locally stored on a computer’s hard drive). Meanwhile, simple SQL query performed on PG admin performed fast and efficient at only 570 milliseconds with no latency encountered. Similarly, queries coupled with PostGIS' spatial functions were successfully executed at only 429 milliseconds. SQL queries were able to iteratively group sub-landclasses into major land typology for better comprehension, especially from the land management perspective. Additionally, encoding UTF-8 when initiating a new database would allow PostGIS database to preserve the Lao characters storing in the attribute tables. Thus, there is no need to encode UTF-8 every time a new table is created. Exported tables could be used interchangeably between GIS and spreadsheet applications without any loss of font-embedded information. Figure 12 shows a screenshot of an attribute table resulting from SQL query with the Lao characters preserved.

Furthermore, based on the qualitative data of the test scenario-one, the participants noted that working on datasets that are connected to the centralised spatial database via LAN connection was feasible using the existing IT infrastructure found at a typical government office in Lao PDR. The findings suggested some minor latency when executing SQL select statements, and notably the delays when saving the table during the editing mode on the QGIS. Apart from that, cut, create, edit, or aggregate features are functional with no delay communicating to the data source.

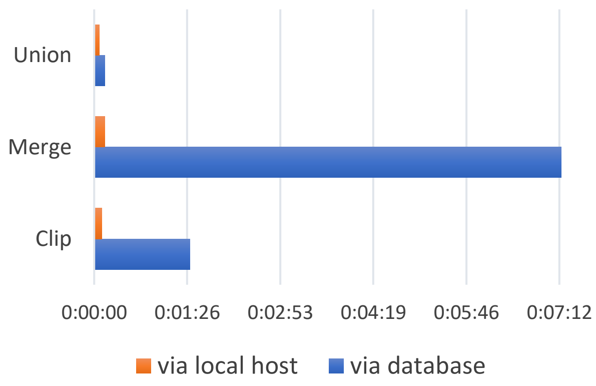
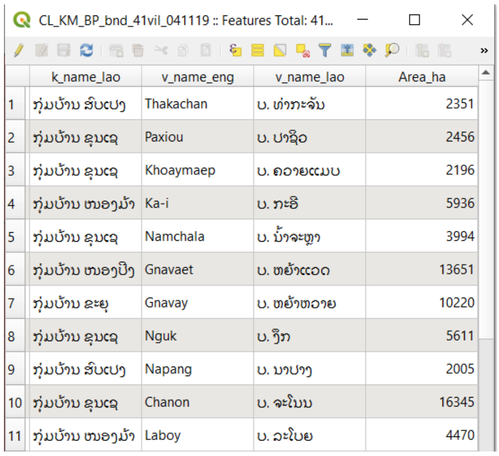


Figure 11. Test evaluation of spatial operations performed on spatial database and localhost


CL_KM_BP_bnd_41vil_041119 :: Features Total: 41...

	k_name_lao	v_name_eng	v_name_lao	Area_ha
1	ກຸ່ມບ້ານ ສົບເປງ	Thakachan	ບ. ທ່າກະຈັນ	2351
2	ກຸ່ມບ້ານ ຊຸນເຊ	Paxiou	ບ. ປາຊີວ	2456
3	ກຸ່ມບ້ານ ຊຸນເຊ	Khoaymaep	ບ. ຄວາຍແມບ	2196
4	ກຸ່ມບ້ານ ໜອງມ້າ	Ka-i	ບ. ກະອີ	5936
5	ກຸ່ມບ້ານ ຊຸນເຊ	Namchala	ບ. ນໍ້າຈະຫຼາ	3994
6	ກຸ່ມບ້ານ ໜອງປິງ	Gnavaet	ບ. ຫຍ້າແວດ	13651
7	ກຸ່ມບ້ານ ຂະຍຸ	Gnavay	ບ. ຫຍ້າຫວາຍ	10220
8	ກຸ່ມບ້ານ ຊຸນເຊ	Nguk	ບ. ງຶກ	5611
9	ກຸ່ມບ້ານ ສົບເປງ	Napang	ບ. ນາປາງ	2005
10	ກຸ່ມບ້ານ ຊຸນເຊ	Chanon	ບ. ຈະໂນນ	16345
11	ກຸ່ມບ້ານ ໜອງມ້າ	Laboy	ບ. ລະໂບຍ	4470

Figure 12. Lao characters encoded with UTF-8 is preserved after writing and saving.

4.4 Results of test scenario-two

The test evaluations in this scenario comprise five specific tests performed entirely on PG admin using the SQL query statement in combination with PostGIS' spatial functions in order to determine the performance of the spatial database when handling LULC datasets. The test results are shown in Figure 13 with some notable findings including;

(1) the queries between two or multiple tables using only matching value without PostGIS functions returned the results fast and efficient; for instance, the spatial-join query between three tables using matching unique value took only 522 milliseconds to return the results. (2) The concurrent execution between SQL select query and PostGIS functions took considerably longer time, especially the use of intersect function (ST_Intersects), which took approximately 131 seconds.

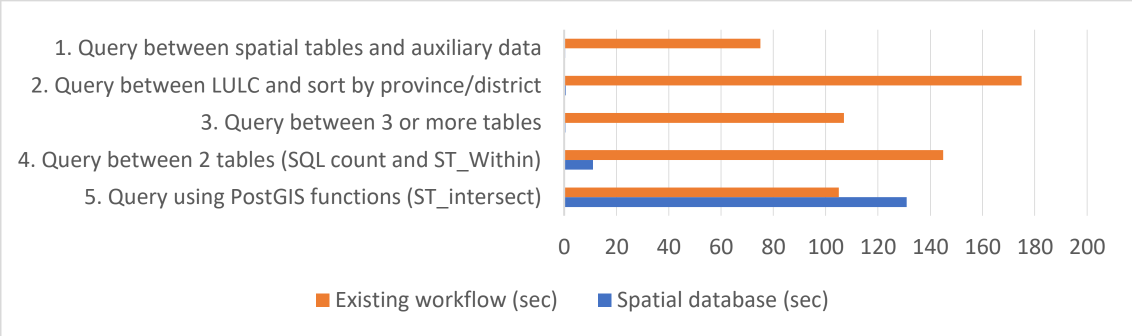


Figure 13. Test evaluations between existing workflow and execution on spatial database

4.5 Analysis and discussion of test scenario-two

The evaluations of scenario-two involve multi-complex SQL queries by joining multiple auxiliary tables (both geometric and non-geometric) and spatial data manipulation using PostGIS' functions. The test requires the system to perform increased iterations and processing with input LULC data derived from each schema of the database. For instance, a query matching field ID or wildcard requires the system to look for matching ID or given wildcard from one table to another iteratively; or using geometric function where the system has to perform geometry calculation/checking and then return the results accordingly. From the five tests conducted, it is noticeable that geometric intersection took longer times to execute when compared to other similar operations. This could be due to the fact that PostGIS database has to iteratively check for the intersection between the target table's every single bounding box and the input table bounding boxes; and then return results with specified table values. The same circumstance applies to functions such as within or union (ST_Within, ST_Union). To sum up, the tests using both SQL query and PostGIS' spatial functions with the LULC took longer times compared to only single SQL query as shown in test numbers four and five of Figure 13 above.

However, qualitative data suggest that most participants think the spatial database has great potential for delivering spatial functionality, especially working with LULC data. They expressed that the integration has outstanding performance featuring fast and efficient data retrieval, ability to store attribute/data-join tables, and potent built-in functions, as well as the efficient search query. The common themes emerging from the test scenario-two are summarised as follows:

- The efficient retrieval of LULC data from the spatial database is key to geospatial management, planning, and decision making. Participants were satisfied with the level of efficiency in data retrieval of the introduced solution. Data retrieval is not limited to just one SQL select statement; sub-queries can enhance the search and specify the results. Highly structured data and indexing also enable PostGIS to access and retrieve data very fast.

  PostGIS database has potentials for retrieving land-use and land cover data that are stored inside the relational database, we could be able to retrieve almost anything within seconds and export the resultant table to any specified schema. (Participant 1)

- The second theme that emerged from the interview-based data was the capability of the PostGIS database to manipulate the data. PostGIS enabled users to create, retrieve, update, or delete records, tables, and schemas directly via SQL select statement or graphical user interface (GUI) on QGIS when connected to the database. PostGIS was capable of assigning land-use typology value in a new field of the existing LULC table and group sub-landclasses into major land typology, which was previously unavailable. This data manipulation enhanced land-use data summary and presentation. Additionally, when using concurrently with QGIS, it gives users the power GIS capabilities without compromising on native spatial functions.

  PostGIS is able to manipulate the data effectively. From the test, we can use, edit, and update the datasets directly connected to the database. It was impressive that we could add new values to the existing LULC tables automatically, and we could group them into meaningful land-use classes. Moreover, QGIS's native functions and third-party plug-ins fill the need for our everyday tasks. (Participant 3)

- PostGIS enhanced relational database for handling geographical objects with various spatial functionalities. During the test, a number of spatial functions such as ST_Intersects, ST_Within were performed to calculate and manipulate the data. The findings suggested that the spatial database was capable of handling LULC data efficiently, able to retrieve the results as accurately as in the traditional approach.

  We have tested a number of PostGIS functions during the study. In particular, the test which involves retrieving the information of villages enclaving in a national protected area (forested area) and then join with land-use planning data to provide complete information of those target villages. It provided useful information about the land-use and their geographic features, able to visualise and compare the land-use information and the forestry data; this would take us so much time to do it manually. (Participant 1)

4.6 Summary of the evaluation results

Both scenarios tested the introduced spatial database to a certain extent, particularly in managing and processing large and complex LULC spatial datasets within the spatial database. A total of 15 specific tests, of both test scenarios, were carried out to evaluate the systems, which saw over 70 percent increase in performance in both test scenarios in direct comparison with the existing workflow. Nevertheless, the efficiency of the existing workflow, which is based on the performance conducted manually by the participants, may be affected by user competency and speed. Under a typical circumstance, a user has to complete between two and three steps in a single test. Specific test tasks in this scenario involving several manual steps are likely to take longer times. Meanwhile, generalised Search Tree (GiST) indexing, using the minimum bounding box of geometry, was applied to the LULC datasets and was proven to speed up the processing and return the query more efficiently. However, the test witnessed some latency, particularly in test scenario-one, when making changes to the editing feature. Nevertheless, to put the test results into perspective, the findings are summarised according to the aspects of potentials, limitations, and recommended future improvement.

<u>Potentials</u>

- PostGIS database is effective at manipulating data via complex queries, returning the results efficiently. Joining more than two tables is possible, which was not available previously with the traditional GIS, making it useful to query between multiple data features including non-geometric tables while adding supplementary spatial functions such as geographical calculation (e.g., intersects, union).

- By using SQL, users can make changes to the tables in a highly effective manner. For instance, grouping and assigning sub-landclasses into respective typology landclasses can be automatically done and applied with other geographical features, making this task like batch processing.
- Storing spatial datasets inside a relational database opens up access to the built-in geographical extender as found on PostGIS and QGIS' spatial capabilities for performing various data manipulation and geoprocessing.
- The speed of executing each SQL query is fast and efficient but varies depending on the complexity and the iteration of each command.

Limitations

- Some queries did not return the results as expected, particularly when applying multiple data-sorting such as order-by or where clauses.
- There was some latency when saving the editing table during the editing mode on QGIS. However, other operations tested did not encounter this issue.
- The database lacked the ability to transform the codes into some form of GUI commands for ease of use. Some SQL codes were difficult for the participants to understand.

Recommended future improvements

- There were some limitations for data visualisation. The resultant tables only appeared in tabular format on the database console (PG admin) unless visualising using third-party applications or libraries.
- Suggestion has been made to optimise the code and the workflow to reduce or eliminate the latency when attempting to make changes to the datasets that are remotely connected to the PostGIS via LAN connection. Each indexing scheme may react and speed up the process differently between datasets; thus, each indexing should be closely evaluated for best possible performance.
- Another aspect to note is that PostGIS can only import and store specific formats. Particular GIS file format cannot be stored within the spatial database. One such file format is the land classification symbology layer file such as ArcGIS's lyr file-format

or QGIS's qml (**Error! Reference source not found.**). Layer file is an integral part of LULC data; it is helping to improve data integrity and visualisation. Unable to store this file type within respective schema of the spatial database makes it inconvenient for users.

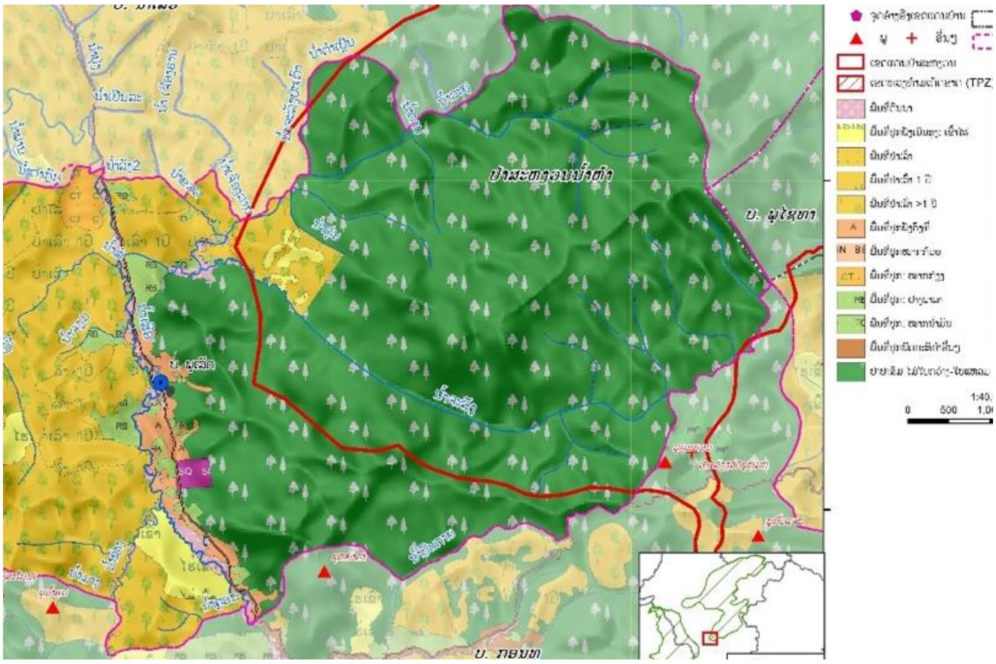


Figure 14. An extraction of a village LULC map with a land-class symbology (qml) applied.

4.7 Potential variables affecting PostGIS database evaluation

A number of potential variables were observed during the evaluations, which could play a role in affecting the performance of the PostGIS and hinder it from the utmost potentials. The details of each variable are discussed in the following.

Existing IT and computer infrastructure

At typical small to medium-sized government offices in Lao PDR there was limited access to IT and computer infrastructure as well as internet access. The computer hosting the PostGIS database in this study was a desktop-grade computer with less computing power such as processing and memory, and was considered an entry-level computer. This was a like variable since it was delivering only basic power with regards to its available resources. It was also observed that the computer was running other applications in the background and being used for GIS applications by other users. This could be a variable that effected the performance speed as well as hard-disk writing speed since it was performing multitasks simultaneously.

LAN cable connection and internet speed

The benchmark of transmission speed and data transfer bandwidth of newer versions, such as CAT-6, CAT-6e or CAT-7, promise to provide higher transmission speed and performance than the CAT-5 on which the performance evaluation was based. It is likely that the performance could have been improved if the spatial database is based on a newer version of CAT cable types. (Martindale, 2020; PlanetTechUSA, 2019).

Even though the internet was not part of the evaluation, since the datasets were communicated with the spatial database via local LAN connection, a spatial database connection test using internet WiFi was not carried out since due to fluctuating internet speed and high traffic during working hours.

Other potential variable

Since solid-state drive (SSD) hard drives have become much more affordable in recent years, most computers today are equipped with a SSD hard drive for running the operating system (OS) for faster processing and data retrieval (Hoffman, 2014; Hohl, 2018). Several online sources provide benchmark comparison on sequential read/write speed between the hard-disk drive (HDD) and SSD. For instance, it has been suggested that NVMe M.2 SSD is approximately four-time faster than the traditional HDD, reading/writing at 3,500/2,500 MB/s respectively; while the HDD has the maximum speed at only 160 MB/s (Jacobi, 2013; Rubens, 16 Jan 2019; TekHattan, 2019). This could affect the test results since PostGIS database was evaluated based on the computer with HDD, which possibly made the reading/writing of data slower when comparing to the SSD. In addition, HDD is also known for having regular drops in speed while reading or writing multiple files simultaneously or having applications running at the background (EASEUS, 2020; Lucia, 2020).

The other variable potentially affecting the evaluation of the PostGIS was the research participants’ competency and knowledge dealing with relational database and GIS applications. Some users were not very competent and lacked fundamental understandings about the relational PostGIS database and QGIS which could have resulted in providing inaccurate responses, and be easily influenced during the interview. If the research participants were to be more competent and knowledgeable about the working topic and research, it is likely that they would be able to provide more precise responses and more constructive opinions and suggestions.

Chapter 5 Discussions on PostGIS database evaluation and participants' perception

The preceding chapters have presented the performance-based evaluations of the introduced spatial database with the integration with QGIS; including, participants' perceptions, findings, and results of both test scenarios. This chapter summarises key discussions resulting from the implementation of the introduced spatial database for managing selected LULC data in comparison with existing knowledge and literatures. At the end of the chapter, recommendations are made to guide the implementation of open-source spatial database for a developing country such as Lao PDR, particularly utilising PostGIS database and QGIS.

5.1 Comparison between the introduced PostGIS database and the existing workflow

<u>Discussion on geometry editing, spatial operations, database connection</u>

A number of tests and observations were employed to evaluate the geometry editing and spatial operations of the introduced PostGIS database. Editing of spatial table geometries, including create, edit, and save tool, were tested to evaluate the performance and functionality of the spatial database. It was observed that only the saving-feature test encountered some delays during the execution. The other tests performed as good as the localhost data directory. The findings were consistent with the scholars' literatures as follows:

- The study confirmed the suggestion of Cagnacci and Urbano (2008) that QGIS' connection with the PostGIS database enabled users to perform selection of locations and access to read/write data directly on the client-side. Furthermore, PostGIS could also automate storing and saving of datasets into the spatial database using automated scripts. Sveen (2019) also highlighted that PostGIS has superior geospatial operations and capabilities when compared to NoSQL database such as MongoDB.
- The study also proved the claim by Lee and Kang (2010) that PostGIS database connection was capable of connecting the database with client-side applications such as QGIS with sufficient power and efficiency. For instance, it allowed the data transfer of very large datasets, enhanced transaction integrity and

accommodated numerous spatial operations and analysis, efficient clustering, and load balancing thanks to its ability to utilise multi-processor computer and efficient use of computing resources. This is consistent with the results of the current study. Despite having limited computing power, the data transfer during geometry editing and spatial operation was still sufficient to ensure smooth implementation.

When compared with the existing approach where users manage their geospatial datasets locally on their computer hard drive or via USB connection with external hard drive, it was observed that the operations via the spatial database experienced some minor latency, especially when saving editing features. Figure 15 shows the time differences between the introduced spatial database and existing workflow of the three spatial functions in test scenario-one. The shortest was union function, while clip and merge functions were 82 and 480 seconds (8 minutes) respectively. Except for the merge operation, the time execution via spatial database should be practically acceptable in real life. However, since the merge function took the most extended time, further optimisation should be made to improve the efficiency. Alternatively, PostGIS database excelled in preserving the user-defined font encoding. As implemented in this study, Lao font with UTF-8 encoding was well preserved, making it very convenient for users to use the exported data tables without additional steps to embed the font. On the contrary, the existing workflow would have to assign UTF-8 encoding every time they create new table as shown in Figure 16.

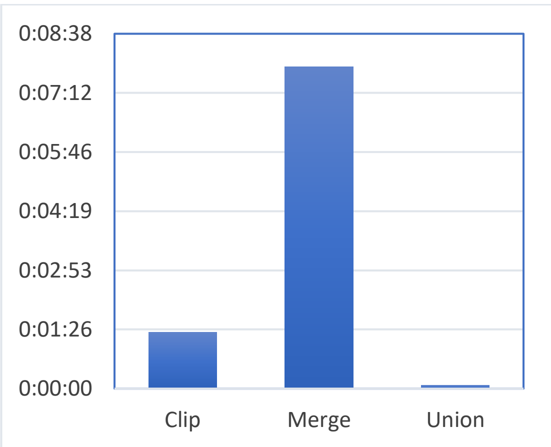


Figure 15. Time difference of spatial functions between the introduced approach and exiting workflow.

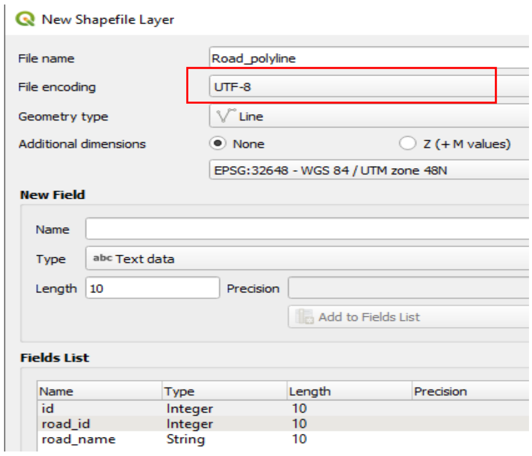


Figure 16. Select encoding style when creating a table on QGIS.

Discussion on data manipulating and performance efficiency

Data manipulating and performance efficiency of the spatial database were evaluated in both test scenarios including the functionalities previously unavailable in the existing workflow. The findings were discussed and compared with relevant scholars' literatures and findings as follows:

- This study confirmed the claim by Cagnacci and Urbano (2008) that the integration between PostGIS and QGIS provides sufficient analytical tools for performing spatial analysis. Users could easily integrate PostGIS database with a variety of software applications such as R, GRASS, and MapServer. The integration compatibility gives users the flexibility to implement various applications related to geospatial information.
- As emphasised in the comparison study by Bartoszewski et al. (2019a) and Sveen (2019), datasets residing within a relational database constituted a highly efficient spatial data management and have superior efficiency due to the highly structured of datasets which were required by the object-relational database such as PostGIS.
- The evaluation also confirmed Shankar et al.'s (2012) study which claimed that PostGIS' indexing, such as GiST index, substantially accelerated the search query and processing.

During the testing, some latency existed when saving the editing features of the datasets remotely connected to the spatial database, which was not an issue when using datasets from the local directory. This issue could be alleviated by increasing data transfer speed between the spatial database and client users. In this case, connecting to the database via high-performance LAN cables and faster hard disk file reading/writing such as using SSD hard drive could help eradicate or minimise the latency when executing the queries or saving the editing features.

5.2 Participant perceptions on PostGIS database

Perception on information/data retrieval and integrated solution

Information retrieval is an essential component of any database. With PostGIS' geospatial capability, users could retrieve both the information from the relational database and geospatial data by incorporating spatial functions alongside traditional SQL statements using WHERE clause. Additionally, when connected to the database such as on QGIS, users could query and visualise information manually via user interface. Due to the highly structured data tables, relationship, indexing, and PostGIS' features, the spatial database is capable of retrieving data and information in a highly efficient manner as shown in both test scenarios, which were supported by the responses from the participants' interview data. Overall, participants were satisfied with the level of efficiency delivered by the spatial database. It could retrieve relational data tables while adding spatial operations, geo-processing, statistics calculation, and data-join with auxiliary data. Nevertheless, the main trade-off is the amount of time spent to standardise and structure tables and database components in order to allow speedy information retrieval; for instance, assigning as primary key, unique field to facilitate data-join. Additionally, the participants expressed that the integration between PostGIS database and QGIS as spatial database is simple and practical to implement with existing IT equipment found at typical government organisation in Laos. Especially in the context of LULC data, storing files within the database brings many advantages as well as helping to securely locate all datasets in one centralised location.

<u>Perception on spatial functions and manipulation</u>

The spatial database's native spatial functions, in combination with QGIS's and its third-party plug-ins, have the power to effectively manipulate spatial datasets. Data manipulation consists of various approaches, but the test was primarily implemented based on data-join (matching ID and wild-card), geometric calculation/interpolation, and spatial analysis tools (merge, clip, and other tools). The test results using both PostGIS' and QGIS' spatial functions suggested that the spatial functionality performed significantly faster in obtaining the results with minor delays encountered. Certain functions with multiple input layers with combined SQL select statements and PostGIS' functions took longer times to execute. While QGIS is only capable of handling one simple geometry data type, PostGIS database is filling this gap by handling both geographic and geometry objects (PostGIS.net). With PostGIS, users could automate geoprocessing tasks more efficiently with SQL on any console that is able to connect to the database; likewise, they will have to use python console on QGIS to exploit these features. Nevertheless, limited reporting information was given after each execution on PostGIS as it only shows if the operation was successfully executed or failed.

Chapter 6 Conclusion and recommendations

6.1 Summary

This research examined the viability of the open-source relational database, particularly the PostgreSQL database and its geographical extender PostGIS, in concurrent use with QGIS to manage multi-level LULC data in Lao PDR. It aimed to examine if this integration is a viable solution as the spatial database for the organisation with limited access to financial resources. The test assessment was carried out based on the test scenario designed for a real practical environment in order to reflect the viability, potentials, and constraints of the spatial database. Additionally, semi-structured interviews were employed to gain in-depth insight into the perspectives of the participants involved in the test evaluations. The analysis revealed the feedback and perspectives towards the introduced spatial database. Overall, this study suggests that integration between PostGIS and QGIS functioning as a spatial database for managing LULC data is positive and has several potentials upon users' configuration and adaptability as suggested below.

- The participants expressed the integration between PostGIS database and QGIS as spatial database is intuitive and feasible to implement with existing IT equipment found at a typical government organisation in Laos. The spatial database itself demonstrated ease of use in the context of managing LULC data. It also centralised all the datasets in one location.
- The introduced spatial database is proven to be viable for spatial querying with an increase in performance over the exiting workflow. The findings from both test scenarios suggested that the overall efficiency and performance have increased to over 70 percent compared with exiting workflow. The spatial database has been very efficient with the input LULC datasets throughout the tests. This is in conjunction with the participants' responses.
- The spatial database offers several capabilities that were previously unavailable. Processing multiple and complex geospatial datasets are feasible thanks to the ability to combine SQL and PostGIS' spatial functions in a single SQL select statement. For instance, SQL queries can be used to filter results, which are then used to perform analysis using PostGIS' spatial functions such as buffer and

calculate distance. Spatial querying between GIS data and non-spatial data such as census data and auxiliary information tables could be achieved using SQL console or any compatible language when connected to the database.

- Qualitative data suggested that three out of four participants felt confident that spatial database has great potentials for delivering sufficient spatial capabilities, particularly managing LULC data directly from the spatial database, as well as the ability to manipulate data effectively.
- PostGIS' primary limitation is that it accommodates limited data types, and in structured order only. Storing some other types such as land-class symbology file is not possible. Another limitation of PostGIS is that data must be stored in tabular structures with or without geometry. Slight latency was encountered when making changes to the table. PostGIS database has a limited user interface besides database console used for SQL query execution. Thus, it is quite difficult for beginner users who struggle to put together a functional SQL select statements.

6.2 Recommendations for developing a functional spatial database for a resources-constraint environment

PostGIS database

Despite being a freely accessible and open-source software, installing and utilising the PostGIS database for the organisation requires preparation and readiness. The approaches below highlight some of the necessary steps in setting up an integration functioning as a spatial database for the organisation.

GIS Software and user competency

QGIS, which is open-source and available at no cost, has been amongst the best alternatives to commercial GIS applications to date (Dartmouth College, 2020; GISGeography, 2020). It is highly compatible with various open-source and commercial RDBMS, including the PostGIS database. While ArcGIS only gives users the ability to access and read the datasets and contents within the PostGIS database, QGIS gives users full access to the database to which it is connected, including the writing access and data manipulation. Therefore, QGIS is the perfect choice of GIS software to integrate with spatial database, particularly the PostGIS database as an experiment in this study.

In the meantime, user competency is a crucial aspect in the successful installation of the spatial database. From this study, lessons revealed that users' fundamental knowledge and understanding of GIS, relational database, and structural data management are essential to fully set it up with minimal time wastage. A recommendation is to provide training on the fundamentals of setting up and using the spatial database, which may include writing basic SQL, data organisation, building relationship, spatial functions, and GIS.

Third-party plug-ins

While the PostGIS database and QGIS have a vast number of spatial functionalities, there are still additional plug-ins (adds-on) from third-party developers, and the numbers are growing. Users may need to find out more about the add-ons and test their compatibility with the spatial database since not all of them are fully functional with the database. Installing third-party plug-ins for QGIS can be made via plug-in toolbar, while add-ons for PostgreSQL are available on their respective websites, and users need to follow the installation guidelines.

Data organisation

Organising data tables, schemas, and their nomenclature is a crucial component of any relational database; they should follow logical order to make it easily accessible and understandable by team members. It also makes it easy for users to make changes and updates to the datasets. Before importing tables into the database, data tables must be cleaned and generalised to standard format for later data-join and query. Schemas should hold a unique name that represents the contents of the tables residing in each respective schema. This would make it easy for users to locate the tables accordingly. In addition, a table must contain an ID field or unique field ID as a primary key or as an identifier.

During the test, it was noticed that some SQL select statements associated with long and uppercased schemas failed to execute the query. Thus, it is recommended to name tables and schemas in lowercase and in short form to avoid any potential failure when executing. One common practice is to have information tables and metadata, providing auxiliary information about each table, primary key, unique field, and other relevant information.

Computer and IT infrastructure

IT and computer infrastructure play a pivotal role in hosting a successful spatial database enabling simultaneous access to geospatial datasets. An investment in sufficient computer and IT infrastructure is required to meet the requirements of this integrated technology. In practice, IT infrastructure requirements vary from the organisation depending on its size, the number of users, specific needs, and budget. Thus, consulting with IT and network experts is highly recommended. For instance, Basille (2015) suggested minimum hardware requirements for running PostGIS server including CPU, memory, hard disk, and other hardware components. Nevertheless, the following recommendations are for a small to medium-sized organisation to run a functional spatial database based on the lessons learned from this study.

- Personal computer (PC) with sufficient operating power running on Windows OS can be used to host the spatial database and be accessed by multiple users in the organisation provided that the PC is running during accessing time. As demonstrated in this study, a lower-end desktop PC, running on Windows 8, was able to host the spatial database. This suggested that PostGIS database consumes fewer resources and power to run, making it suitable for small to medium-sized organisations with limited access to expensive and large IT infrastructures. Alternatively, a server computer may be considered if the organisation has adequate resources to maintain, manage, and configure. Since a server computer is designed to store and process data at increased efficiency, it would likely provide much higher performance.
- The test was carried out with LAN cable CAT-5 and did not compare with the newer versions of LAN cable such as CAT-6 and CAT-7. On paper, newer versions of network LAN cable are promised to provide higher performance and speed due to their higher transmission and bandwidth (Lucidchat.com, n.d; PlanetTechUSA, 2019). For instance, CAT-6 cable type could support maximum data transmission up to 10 Gbps and bandwidth at 250 Mhz. Nevertheless, higher data transfer speed and bandwidth using new CAT LAN cables have not been tested to determine if it would improve the overall performance, geo-processing and data retrieval of the spatial database.

- During the evaluation, a test connection to the spatial database via WiFi was conducted to determine if it can be used via WiFi on the same network. PostGIS database was able to communicate via WiFi. However, due to the internet fluctuation, a proper test was not carried out. Therefore, if the spatial database is to be connected via WiFI, stable internet with good speed is recommended to secure a good connection. PostGIS database must be assigned to a static internet protocol addresses (IP address) in order to allow access to the same IP address every time users access the database. By default, PostGIS database limits the number of accessible IP addresses; therefore, the user must be authenticated to gain access to the database.

6.3 Recommendation and future research direction

As this study involved only four participants and one test evaluation the findings cannot be generalised to the entire small to medium-sized organisations in Lao PDR, especially for those who are interested in adopting PostGIS and QGIS as their primary spatial database system. Further research into this issue should include a larger sample size to be more representative for broader users and organisations, including private sectors which tend to have more financial flexibility to go into deeper research and experiment. Future research could be comparative, considering findings from other organisations who implement the spatial database with other means of relational database and geographic extender. In addition, future studies may investigate the following compatible functionalities, which may be useful for further enhancing the spatial database and usability.

- Evaluate the functionality of PostGIS as the back-end spatial database supporting the building of WebGIS, utilising the open-source webmap servers such as MapServer and GeoServer since it is more likely that LULC would have to be published on the WebGIS as part of the scalability effort. It is good to know how the PostGIS database works with these web-map servers particularly in relation to these specific LULC datasets.
- Assess other compatible applications, either commercially or open source, but still based on the PostGIS database in order to enhance the usability and diversify user application. For instance, using third-party applications to enhance data visualisation or mobile application for data collection.

- Assess integrate development environment (IDE) that is compatible with PostGIS database in order to create a more customised and user-friendly interface so that users can execute the frequently used query, and it is not limited to specific datasets.
- Evaluate other plug-in or add-on that could enable spatial database to store other data types such as land-use symbology file type.

References

Agrawal, S., & Gupta, R. D. (2014). Development and comparison of open source based Web GIS frameworks on WAMP and Apache Tomcat web servers. *The International Archives of Photogrammetry, Remote Sensing and Spatial Information Sciences, 40*(4), 1. https://doi.org/10.5194/isprsarchives-XL-4-1-2014

Ballatore, A., Tahir, A., McArdle, G., & Bertolotto, M. (2011). A comparison of open source geospatial technologies for web mapping. *International Journal of Web Engineering and Technology, 6*(4), 354-374. https://doi.org/10.1504/IJWET.2011.043440

Bartoszewski, D., Piorkowski, A., & Lupa, M. (2019a). The comparison of processing efficiency of spatial data for PostGIS and MongoDB databases. In *International Conference: Beyond Databases, Architectures and Structures* (pp. 291-302). https://doi.org/10.1007/978-3-030-19093-4_22

Bartoszewski, D., Piorkowski, A., & Lupa, M. (2019b). The comparison of processing efficiency of spatial data for PostGIS and MongoDB databases. In *International Conference: Beyond Databases, Architectures and Structures* (pp. x-x). https://doi.org/...

Basille, M. (2015, 08 May). *Re: Hardware requirements for a PostGIS server*. Retrieved from https://www.postgresql.org/message-id/54DBE7F2.4010202@ase-research.org

Bastin, L., Buchanan, G., Beresford, A., Pekel, J. F., & Dubois, G. (2013). Open-source mapping and services for Web-based land-cover validation. *Ecological Informatics, 14*, 9-16. https://doi.org/https://doi.org/10.1016/j.ecoinf.2012.11.013

Bocetta, S. (2019). *Comparing 3 open source databases: PostgreSQL, MariaDB, and SQLite*. Opensource.com. Retrieved from https://opensource.com/article/19/1/open-source-databases

Brovelli, M. A., Fahl, F. C., Minghini, M., & Molinari, M. E. (2016). *Land user and land cover maps of Europe: a WebGIS platform*. https://doi.org/10.5194/isprs-archives-XLI-B7-913-2016

Brovelli, M. A., & Magni, D. (2003). An archaeological web GIS application based on Mapserver and PostGIS. *International Archives of Photogrammetry Remote Sensing and Spatial Information Sciences, 34*(5/W12), 89-94.

Buckley, A. (2010). *WGS84 vs. NAD83*. Retrieved from https://www.esri.com/arcgis-blog/products/arcgis-desktop/mapping/wgs84-vs-nad83/

Cagnacci, F., & Urbano, F. (2008). Managing wildlife: A spatial information system for GPS collars data. *Environmental Modelling & Software, 23*(7), 957-959. https://doi.org/10.1016/j.envsoft.2008.01.003

Chaudhry, N., & Yousaf, M. M. (2019). *Spatial querying of mineral resources using PostGIS*. Paper presented at the 2nd International Conference on Advancements in Computational Sciences (ICACS), University of Lahore, Pakistan.

Cimpianu, C. (2017). *Store your spatial data in a Relational Database Management System (RDBMS)*. GISCourse. Retrieved from https://www.giscourse.com/store-your-spatial-data-in-a-relational-database-management-system-rdbms/

Coffey, R. (2013). *The difference between “land use” and “land cover”*. Michigan State University. Retrieved from https://www.canr.msu.edu/news/the_difference_between_land_use_and_land_cover

Cousins, S. A., Auffret, A. G., Lindgren, J., & Tränk, L. (2015). Regional-scale land-cover change during the 20th century and its consequences for biodiversity. *Ambio, 44*(1), 17-27. https://doi.org/10.1007/s13280-014-0585-9

Dartmouth College. (2020). *Geographic information systems/science: Open source software*. Dartmouth College. Retrieved from https://researchguides.dartmouth.edu/gis/opensource

Delipetrev, B., Jonoski, A., & Solomatine, D. P. (2014). Development of a web application for water resources based on open source software. *Computers & Geosciences, 62*, 35-42. https://doi.org/10.1016/j.cageo.2013.09.012

Deoliveria, J. (n.d). *GeoServer: A geospatial server for everyone*. Geospatial World. Retrieved from https://www.geospatialworld.net/article/geoserver-a-geospatial-server-for-everyone/

Di Gregorio, A. (2005). *Land cover classification system: Classification concepts and user manual: LCCS* (Vol. 2). Food & Agriculture Org.

Dudoit, S., Gentleman, R. C., & Quackenbush, J. (2003). Open source software for the analysis of microarray data. *Biotechniques, 34*(S3), S45-S51.

EASEUS. (2020). *What makes a hard drive slow?* Dartmouth College. Retrieved from https://www.easeus.com/partition-manager-software/hard-drive-very-slow-suddenly.html

ESRI. (n.d). *What are projected coordinate systems?* ESRI. Retrieved from https://desktop.arcgis.com/en/arcmap/10.3/GUIDE-BOOKS/MAP-PROJECTIONS/ABOUT-PROJECTED-COORDINATE-SYSTEMS.HTM

Eurostat. (2019). *Your key to European statistics.* Retrieved from https://ec.europa.eu/eurostat/home?

Geohackweek. (n.d). *Introduction to Google Earth Engine*. Geohackweek. Retrieved from https://geohackweek.github.io/GoogleEarthEngine/01-introduction/

GeoRepository. (2020). *WGS 84 / UTM zone 48N*. Retrieved from https://georepository.com/crs_32648/WGS-84-UTM-zone-48N.html

GISGeography. (2015). *World Geodetic System (WGS84)*. Retrieved from https://gisgeography.com/wgs84-world-geodetic-system/

GISGeography. (2020). *13 free GIS software options: Map the world in open source*. Dartmouth College. Retrieved from https://gisgeography.com/free-gis-software/

Gorelick, N., Hancher, M., Dixon, M., Ilyushchenko, S., Thau, D., & Moore, R. (2017). Google Earth Engine: Planetary-scale geospatial analysis for everyone. *Remote*

Sensing of Environment, 202, 18-27. https://doi.org/https://doi.org/10.1016/j.rse.2017.06.031

Gutiérrez, J. A. A., Aguilar-Alba, M., & Naranjo, J. M. C. (2018). GIS and geovisualization technologies applied to rainfall spatial patterns over the Iberian peninsula using the global climate monitor web viewer. *GISTAM*, 79-87. https://doi.org/10.5220/0006703200790087

Hess S. (2002). *GRASS on the web*. In Proceedings of the Open Source GIS–GRASS Users Conference 2002, Trento, Italy.

Hoffman, C. (2014). *The ultimate guide to proper SSD management*. PC World. Retrieved from https://www.pcworld.com/article/2110095/the-ultimate-guide-to-proper-ssd-management.html

Hohl, N. (2018). *How to install your OS on an SSD to improve system performance*. Newegg. Retrieved from https://www.newegg.com/insider/how-to-improve-pc-performance-by-installing-your-os-on-an-ssd/

IBM. (n.d). *Projected coordinate systems*. IBM Knowledge Center. Retrieved from https://www.ibm.com/support/knowledgecenter/SSCJDQ/com.ibm.swg.im.dashdb.spatial.doc/doc/csb3022b.html

Jacobi, J. L. (2013). *Benchmarks don't lie: SSD upgrades deliver huge performance gains*. PC World. Retrieved from https://www.pcworld.com/article/2048120/benchmarks-dont-lie-ssd-upgrades-deliver-huge-performance-gains.html

Keohavong, C. (2009). *Lao PDR geological and mineral occurance map.* Department of Geology and Mines, Ministry of Energy and Mines of Lao PDR.

Kostecki, R. (2018). Application of the spatial database for shoreline change analysis and visualisation: Example from the western Polish coast, southern Baltic Sea. *Quaestiones Geographicae, 37*(3), 25-34. https://doi.org/10.2478/quageo-2018-0023

Landmap Geoknowledge. (n.d-a). *Web Coverage Services (WCS)*. Landmap Geoknowledge. Retrieved from http://learningzone.rspsoc.org.uk/index.php/Learning-Materials/Introduction-to-OGC-Standards/3.2-Web-Coverage-Services-WCS

Landmap Geoknowledge. (n.d-b). *Web Feature Services (WFS)*. Landmap Geoknowledge. Retrieved from http://learningzone.rspsoc.org.uk/index.php/Learning-Materials/Introduction-to-OGC-Standards/3.3-Web-Feature-Service-WFS

Landmap Geoknowledge. (n.d-c). *Web Map Services (WMS)*. Landmap Geoknowledge. Retrieved from http://learningzone.rspsoc.org.uk/index.php/Learning-Materials/Introduction-to-OGC-Standards/3.1-Web-Map-Services-WMS

Landmap Geoknowledge. (n.d-d). *What is the OGC?* Landmap Geoknowledge. Retrievedfrom http://learningzone.rspsoc.org.uk/index.php/Learning-Materials/Introduction-to-OGC-Standards/1.1-What-is-the-OGC

Leavy, P. (2017). *Research design: Quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches*. Guilford Publications.

Lee, J.-G., & Kang, M. (2015). Geospatial big data: Challenges and opportunities. *Big Data Research, 2*(2), 74-81.

Lee, K.-W., & Kang, S.-G. (2010). Open source remote sensing of ORFEO toolbox and its connection to database of PostGIS with NIX file importing. *Korean Journal of Remote Sensing, 26*(3), 361-371.

Lo, F. (2019). *Big data technology*. Retrieved from https://datajobs.com/what-is-hadoop-and-nosql

Lucia, T. (2020). *How to increase hard drive speed*. recoverit. Retrieved from https://recoverit.wondershare.com/computer-problems/how-to-increase-hard-drive-speed.html

Lucidchat.com. (n.d). *What is a database schema?* Retrieved from https://www.lucidchart.com/pages/database-diagram/database-schema

MAPASYST. (2019). *What is the difference between land use and land cover?* Retrieved from https://mapasyst.extension.org/what-is-the-difference-between-land-use-and-land-cover/

Martindale, J. (2020). *How to choose an Ethernet cable*. Retrieved from https://www.digitaltrends.com/computing/different-types-of-ethernet-cables-explained/

Marx, C. (2019). *Install Postgres/PostGIS and get started with spatial SQL*. ZevRoss. Retrieved from http://zevross.com/blog/2019/12/04/install-postgres-postgis-and-get-started-with-spatial-sql/

Michaelis, C., & Ames, D. (2017). *Web Feature Service (WFS) and Web Map Service (WMS)*. Retrieved from https://doi.org/10.1007/978-3-319-17885-1_1480

Mikiewicz, D., Mackiewicz, M., & Nycz, T. (2017). *Mastering PostGIS: Create, deliver, and consume spatial data using PostGIS* [Electronic document]. Packt. Retrieved from http://ezproxy.aut.ac.nz/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cat05020a&AN=aut.b23795104&site=eds-live

Miller, M. (2017a). What can a spatial database do for you? Millermountain. Retrieved from http://millermountain.com/geospatialblog/2017/10/18/spatial-database/

Miller, M. (2017b). Client server architecture for Web GIS [Video file]. Retrieved from https://www.youtube.com/watch?v=DpGkZSl5inQ&t=393s

Mohamad, A. A., Pugi, N. A., & Zainol, H. (2016). The GIS application in smartphone for tourism. MATTER: International Journal of Science and Technology, 2(1). https://doi.org/10.20319/Mijst.2016.s21.5969

Mukhopadhaya, S. (2016). Land use and land cover change modelling using CA-Markov case study: Deforestation analysis of Doon Valley. *Journal of Agroecology and Natural Resource Management, 3*, 1-5.

Neumann, A. (2008). Web mapping and web cartography. In *Encyclopedia of GIS* (pp. 1261-1269). Springer.

Obe, R., & Hsu, L. (2011). PostGIS in action (2nd ed.). Manning.

OGC. (n.d-a). *Open Geospatial consortium standards*. Open Geospatial Consortium. Retrieved from https://www.ogc.org/standards

OGC. (n.d-b). *Web coverage service*. Open Geospatial Consortium. Retrieved from https://www.ogc.org/standards/wcs

OGC. (n.d-c). *Web feature service*. Open Geospatial Consortium. Retrieved from https://www.ogc.org/standards/wfs

OGC. (n.d-d). *Web map service*. Open Geospatial Consortium. Retrieved from https://www.ogc.org/standards/wms

Omni Sci. (2019). *Open source database definition*. Omni sic. Retrieved from https://www.omnisci.com/technical-glossary/open-source-database

Open Geo. (2019). *Introduction to PostGIS*. Retrieved from http://revenant.ca/www/postgis/workshop/introduction.html

OSGeo Live. (n.d). *Open Geospatial consortium standards*. OSGeo Live. Retrieved from https://live.osgeo.org/archive/10.5/en/standards/standards.html

Pastewski, P. (2017). *Find your way with the power of PostGIS & pgRouting*. pgRouting commuity. Retrieved from https://blog.daftcode.pl/find-your-way-with-the-power-of-postgis-pgrouting-66d620ef201b

pgRouting. (2020). *pgRouting Project*. pgRouting commuity. Retrieved from https://pgrouting.org/

Piórkowski, A. (2011). Mysql spatial and postgis–implementations of spatial data standards. *Electronic Journal of Polish Agricultural Universities, 14*(1), 1-8.

PlanetTechUSA. (2019). *Ethernet cables: Difference between Cat5 vs Cat6 vs Cat7 cable types*. Retrieved from https://planetechusa.com/ethernet-cables-difference-between-cat5-vs-cat6-vs-cat7-cable-types/

PostGIS.net. *Chapter 5. Using PostGIS: Building applications*. Retrieved from https://postgis.net/docs/manual-1.4/ch05.html

PostGIS.net. *PostGIS documentation*. Retrieved from https://postgis.net/docs/manual-2.5/

PostGIS.org. *Case studies - Institut Géographique National, France*. Retrieved from http://www.postgis.org/documentation/casestudies/ign/

PostgreSQL.org. (2019). *A brief history of PostgreSQL*. Retrieved from https://www.postgresql.org/docs/8.4/history.html

Prescient & Strategic (P&S) Intelligence Private Limited. (2019). *Geographic Information System (GIS) market research report*. Retrieved from https://www.psmarketresearch.com/market-analysis/geographic-information-system-market

Refraction Research. (2019). *PostGIS history*. Retrieved from http://www.refractions.net/products/postgis/history/

Rubens, P. (16 Jan 2019). *SSD vs. HDD speed*. Enterprise Storage. Retrieved from https://www.enterprisestorageforum.com/storage-hardware/ssd-vs-hdd-speed.html

Sandu, A. (2019). *Ethics in research practice and innovation*. Information Science Reference. Retrieved from http://ezproxy.aut.ac.nz/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=cat05020a&AN=aut.b2597225x&site=eds-live

Shankar, P., Huang, Y.-W., Castro, P., Nath, B., & Iftode, L. (2012). Crowds replace experts: Building better location-based services using mobile social network interactions. *2012 IEEE International Conference on Pervasive Computing and Communications* (pp. 20-29). Lugano, Switzerland.

Shukla, D., Chirag Shivnani, C., & Shah, D. (2016). Comparing oracle spatial and postgres PostGIS. *IJCSE, 7*, 95-100.

Singh, P. S., Chutia, D., & Sudhakar, S. (2012). Development of a web based GIS application for spatial natural resources information system using effective open source software and standards. *Journal of Geographic Information System, 4*(03), 261. https://doi.org/10.4236/jgis.2012.43031

Singh, S. P., & Singh, P. (2014). Mapping spatial data on the web using free and open-source tools: A prototype implementation. *Journal of Geographic Information System, 6*(01), 30. https://doi.org/10.4236/jgis.2014.61004

Sveen, A. F. (2019). Efficient storage of heterogeneous geospatial data in spatial databases. *Journal of Big Data, 6*(1), 102. https://doi.org/10.1186/s40537-019-0262-8

Swain, N. R., Latu, K., Christensen, S. D., Jones, N. L., Nelson, E. J., Ames, D. P., & Williams, G. P. (2015). A review of open source software solutions for developing water resources web applications. *Environmental Modelling & Software, 67*, 108-117. https://doi.org/https://doi.org/10.1016/j.envsoft.2015.01.014

TekHattan. (2019). *SSD vs HDD speed, lifespan, and reliability*. Retrieved from https://tekhattan.com/blog/hardware/ssd-vs-hdd-speed-lifespan-and-reliability/

The Agro-Biodiversity Initiatives. (n.d). *Land use planing*. TABI.la. Retrieved from https://www.tabi.la/activities/land-use-planning/land-use-planing/

The Institut Géographique National (IGN). (2020). *National Geographic Institute of France*. Retrieved from http://www.ign.fr/institut/activites/cartographie

Tjukanov, T. (2018). *Why should you care about PostGIS? — A gentle introduction to spatial databases*. Medium. Retrieved from https://medium.com/@tjukanov/why-should-you-care-about-postgis-a-gentle-introduction-to-spatial-databases-9eccd26bc42b

Tutorialspoint.com. (n.d). *Database schema*. Retrieved from https://www.tutorialspoint.com/dbms/dbms_data_schemas.htm

Veenendaal, B., Brovelli, M. A., & Li, S. (2017). Review of web mapping: Eras, trends and directions. *ISPRS International Journal of Geo-Information, 6*(10), 317. https://doi.org/10.3390/ijgi6100317

Wikipedia Contributors. (2019). *PostgreSQL_Wikipedia*. Retrieved from https://en.wikipedia.org/wiki/PostgreSQL

Wikipedia Contributors. (2020). *World geodetic system*. Retrieved from https://en.wikipedia.org/wiki/World_Geodetic_System

Zambelli, P., Lora, C., Spinelli, R., Tattoni, C., Vitti, A., Zatelli, P., & Ciolli, M. (2012). A GIS decision support system for regional forest management to assess biomass availability for renewable energy production. *Environmental Modelling & Software, 38*, 203-213. https://doi.org/10.1016/j.envsoft.2012.05.016

Zheng, J., Zhang, Z., Ciepluch, B., Winstanley, A. C., Mooney, P., & Jacob, R. (2013, 01//). A PostGIS-based pedestrian way finding module using OpenStreetMap data. *2013 21st International Conference on Geoinformatics*, 1. Retrieved from http://ezproxy.aut.ac.nz/login?url=http://search.ebscohost.com/login.aspx?direct=true&db=edb&AN=91769728&site=eds-live

Zhonghai, Z., Bin, Z., Wenwen, L., Griglak, B., Caiseda, C., & Qunying, H. (2009). *Evaluating query performance on object-relational spatial databases*. Retrieved from https://doi.org/10.1109/ICCSIT.2009.5234509

Zouagui, A., Laissaoui, A., Benmansour, M., Hajji, H., Zaryah, M., Ghazlane, H., Cherkaoui, F. Z., Bounsir, M., Lamarani, M. H., Khoukhi, T. E., Amechmachi, N., & Benkdad, A. (2017). *Implementation of information system to respond to a nuclear emergency affecting agriculture and food products - Case of Morocco*. Retrieved from https://www-pub.iaea.org/iaeameetings/IEM9p/Session5/2Zouagui.pdf

Appendices

Appendix A: Ethics Approval letter from AUTEC

The Ethics was approved from AUTEC on 1st May 2019 and is valid until 30th April 2022.

TE WĀNANGA ARONUI O TĀMAKI MAKAU RAU

Auckland University of Technology Ethics Committee (AUTEC)

Auckland University of Technology
D-88, Private Bag 92006, Auckland 1142, NZ
T: +64 9 921 9999 ext. 8316
E: ethics@aut.ac.nz
www.aut.ac.nz/researchethics

1 May 2019

Brad Case
Faculty of Health and Environmental Sciences

Dear Brad

Re Ethics Application: **19/40 Using open-source database spatial database and GIS to manage multi-scale land use/land cover data in Lao PDR**

Thank you for providing evidence as requested, which satisfies the points raised by the Auckland University of Technology Ethics Committee (AUTEC).

Your ethics application has been approved for three years until 30 April 2022.

Standard Conditions of Approval

1. A progress report is due annually on the anniversary of the approval date, using form EA2, which is available online through http://www.aut.ac.nz/research/researchethics.
2. A final report is due at the expiration of the approval period, or, upon completion of project, using form EA3, which is available online through http://www.aut.ac.nz/research/researchethics.
3. Any amendments to the project must be approved by AUTEC prior to being implemented. Amendments can be requested using the EA2 form: http://www.aut.ac.nz/research/researchethics.
4. Any serious or unexpected adverse events must be reported to AUTEC Secretariat as a matter of priority.
5. Any unforeseen events that might affect continued ethical acceptability of the project should also be reported to the AUTEC Secretariat as a matter of priority.

Please quote the application number and title on all future correspondence related to this project.

AUTEC grants ethical approval only. If you require management approval for access for your research from another institution or organisation, then you are responsible for obtaining it. If the research is undertaken outside New Zealand, you need to meet all locality legal and ethical obligations and requirements. You are reminded that it is your responsibility to ensure that the spelling and grammar of documents being provided to participants or external organisations is of a high standard.

For any enquiries, please contact ethics@aut.ac.nz

Yours sincerely,

Kate O'Connor
Executive Manager
Auckland University of Technology Ethics Committee

Cc: kongkeo.s@gmail.com; Graham Hinchliffe

Appendix B: Participant Information Sheet

Participant Information Sheet (English version)

Date Information Sheet Produced:

24 April 2019

Project Title

Using open-source database spatial database and GIS to manage multi-scale land use/land cover data in Laos.

a) An Invitation

My name is Mr. Kongkeo Sivilay. I am currently undertaking the Master of Geospatial Science at Auckland University of Technology (AUT) in Auckland, New Zealand under the New Zealand Scholarship program.

I will be conducting this research between February 2019 and March 2020 to fulfil my MSc of Geospatial qualification. My research aims at using the open-source database spatial database and GIS to manage multi-scale land use/land cover data in Laos. The study intends to investigate if (1) the integrated open-source solution allows for spatial querying with a measurable performance increase over existing workflows, and (2) does such solution offer capabilities which were previously unavailable.

The spatial database will be used to manage selected land-use/land cover GIS data from the Department of Forestry (DoF) and the Department of Agricultural Land Development and Management (DaLaM). The data would be stored and tested in the newly-established spatial database. This research study is expected to provide a new alternative for the departments to effectively manage GIS data and relevant non-spatial data. This is a good opportunity to capitalise on the use of freely available and open-source software while not compromising on productivity.

This is largely a self-funded research. However, I will be receiving partial financial support for home-located research from NZ Scholarship Scheme and AUT's Health and Environmental Science Faculty. The research is expected to take place between 08th and 31st July 2019.

Therefore, I would like to formally invite you to take part in this project to explore the potential capabilities of the open-source spatial database. It is really the way forward for the future and it is the ideal solution for developing countries like Laos PDR. Your detailed obligations are stated in the research agreement.

If you agree to participate in the research after carefully reading this Information Sheet, research agreement and other relevant information, please provide an email response to me.

b) What is the purpose of this research?

The research intends to investigate the integration of the open-source spatial database PostgreSQL, the spatial extension PostGIS and desktop GIS application QGIS for the management and analysis of regional datasets by:

1) Incorporating Laos regional datasets into an open-source spatial database (PostgreSQL/PostGIS) as a solution for managing vector-based GIS data and non-spatial data.
2) Measuring the capabilities of such a solution in a practical setting.

This research study fulfils the requirements for the completion of MSc of Geospatial at Auckland University of Technology for the primary researcher. Participants' involvement such as opinion, thought and feedback will be mentioned in the related academic documentation and/or future publication.

c) How was I identified and why am I being invited to participate in this research?

Your contact of details has been obtained during the previous work encounter with the primary researcher particularly during the village-level participatory land use planning and national forestry boundary re-delineation.

You are cordially invited to take part in the research via email. You have the rights to accept or decline. It is really up to you. You have the potentials and skills that fit the selection criteria of my research. I am sure that your participation will positively contribute to the success of my research project.

d) How do I agree to participate in this research?

Your participation in this research is voluntary (it is your choice) whether or not you choose to participate will neither advantage nor disadvantage you. You will be able to withdraw from the study at any time. If you choose to withdraw from the study, then you will be offered the choice between having any data that is identifiable as belonging to you removed or allowing it to continue to be used. However, once the findings have been produced, the removal of your data may not be possible.

e) What will happen in this research?

You will participate in the research with me for about 1 hour per week during lunchtime for approximately 1 month in total duration. Firstly, we will be working on migrating the data onto the integrated spatial database. Then, we will be running the performance test based on the designed scenarios. Finally, I will be interviewing you for feedback, opinion, and thoughts regarding the implementation of the solution.

f) What are the discomforts and risks?

The research is expected to have some minor discomfort in employment-related. Your time spent with the research may affect your abilities to deliver the work productively.

g) How will these discomforts and risks be alleviated?

The employment-related discomfort will be minimised by conducting the research during the lunchtime break between 12.30-1.30 pm (1 hour). This timing will not affect work hours as the afternoon work likely starts at 1.30pm.

h) What are the benefits?

The participants could be potentially benefited from the practical experience and training they will receive during the course of the research project. They will have hands-on spatial database management as well as QGIS. Upon completion of the study, GIS data and non-spatial data, which have been structurally organised on the spatial database, are expected to allow faster processing time and increased productivity. This could greatly benefit his/her organisation.

There are a number of benefits for the primary researcher undertaking study in this discipline. Relational database management system (RDBMS) is a powerful tool to handling large and complex geospatial data which plays a key role in data management and helps businesses make better decision. Thus, capitalizing on freely-available open-source software RDBMS has several benefits for the researcher's home country. Firstly, the country is still regarded as financial constraint and has difficulties obtaining proprietary software licenses. Secondly, there is substantial amount of spatial and non-spatial data in relation to agriculture and forestry land-use and land cover; and therefore, it is a great opportunity for the researcher to test out the RDBMS with these data. In addition, he could utilise the skills and knowledge to apply to work setting; and learn to solve problem. And more importantly, he will be able to fulfil the Master of Science qualification at AUT.

The study will certainly benefit the wider community, especially Laotian GIS and database communities. They will have the information to replicate in other important domains such as health, education, trade, etc. Findings and knowledge resulting from this study could be passed on and shared amongst the community members.

i) Who will take the ownership after the research?

The researcher will give full access and ownership to the respective departments upon completion of the research by allocating the spatial database onto the department's central computer. The system will be co-owned between the participant and the researcher upon the study in Laos because the researcher still needs to complete the analysis and performance-based tests on the system. The detailed ownership obligations are outlined in the research agreement.

j) What compensation is available for injury or negligence?

It is unlikely to have any potential injury or negligence resulting from participating in the research. All the works will be implemented in the safe environment within the office. Therefore, there will be no compensation.

k) How will my privacy be protected?

You have the options whether you wish to be identified or not in the research findings. Your privacy will be protected regardless of your decision. You always have the choice to refuse to answer any question you feel uncomfortable with. If the interview involves private questions, it will be conducted in a private room or in a discreet location as agreed between the parties. In case of publication, if names, position, and organisation are required to be referred to, they will be in the form of fiction or using generic terms.

l) What are the costs of participating in this research?

The cost of participating, approximately 1-hour during lunchtime per week during the one-month research period, will be the time spent in the research which will be compensated by the payment of the researcher. Nevertheless, you are encouraged to seek formal authorisation from your organisation or immediate supervisor. This is to ensure you will be granted permission to work with the researcher, and lost-time could be mitigated in advance.

m) What opportunity do I have to consider this invitation?

You will have two weeks to consider this invitation. You have the rights to accept or decline the invitation.

n) Will I receive feedback on the results of this research?

You will receive feedback on the results of the research via a written report which will be submitted to you after the completion of the research or beginning of 2020.

o) What do I do if I have concerns about this research?

You are more than welcomed to ask for information or raise any concern at any time with the primary researcher via any forms of communication. In addition, the participants can be in touch with the supervisor for a private discussion. All conversational information will be treated highly confidential.

Any concerns regarding the nature of this project should be notified in the first instance to the Project Supervisor, Dr. Bradley Case – Bradley.case@aut.ac.nz, phone number 09-9219999 ext. 5231

Concerns regarding the conduct of the research should be notified to the Executive Secretary of AUTEC, Kate O'Connor, *ethics@aut.ac.nz*, 921 9999 ext. 6038.

a) Whom do I contact for further information about this research?

Please keep this Information Sheet and a copy of the Consent Form for your future reference. You are also able to contact the research team as follows:

- Dr. Bradley Case - Primary Supervisor Bradley.case@aut.ac.nz, phone: +64-9-9219999 ext. 5231
- Graham Hinchliffe - Secondary Supervisor Graham.hinchliffe@aut.ac.nz, phone: +64-9-9219999 ext. 9627
- Kongkeo Sivilay - Primary Researcher Kongkeo.s@gmail.com, mobile phone: +856-20-55552719 (Laos).

Researcher Contact Details:

- Kongkeo Sivilay - Primary Researcher Kongkeo.s@gmail.com, mobile phone: +856-20-55552719 (Laos mb).

Project Supervisor Contact Details:

- Dr Bradley Case - Primary Supervisor Bradley.case@aut.ac.nz, phone: +64-9-9219999 ext. 5231

Example of email wording to participant

Sabaidee Participant My name is Mr. Kongkeo Sivilay. I am currently undertaking the Master of Geospatial Science at Auckland University of Technology (AUT). I wish to invite you to participate in my research which will be taking place between July and September 2019. Please find the information on the **Information Sheet** attached herewith. If you need further information or would like to be in touch with me, please let me know. Please respond to this email to let me know if you agree to participate in this research. It is totally fine to decline this invitation. It is really up to you. Please let me know by ……………… (date). Best regards, Kongkeo Sivilay MSc of Geospatial Student - AUT

Participant Information Sheet (Lao version)

ຂໍ້ມູນການຄົ້ນຄ້ວາວິໃຈ ສໍາລັບຜູ້ເຂົ້າຮ່ວມ

ວັນທີ່ ທີ່ສ້າງເອກະສານຂໍ້ມູນການຄົ້ນຄ້ວານີ້:

24 ເມສາ 2019

ຫົວຂໍ້:

ການນໍາໃຊ້ລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ ແລະ GIS ຮູບແບບໂອເພີນຊອດສ ເຂົ້າໃນການບໍລິຫານຈັດການຂໍ້ມູນການນໍາໃຊ້ທີ່ດິນ/ການປົກຫຸ້ມໜ້າດິນຫຼາຍລະດັບໃນ ສປປລາວ.

a. ໜັງສືຮຽນເຊີນ:

ຂ້າພະເຈົ້າ ທ້າວກອງແກ້ວ ສີວິໄລ ປະຈຸບັນກໍາລັງສຶກສາລະດັບປະລິນຍາໂທ ໃນສາຂາວິທະຍາສາດສາລະສົນເທດທາງພູມສາດ ທີ່ມະຫາວິທະຍາໄລເຕັກໂນໂລຢີໂອກແລນ (AUT) ທີ່ເມືອງໂອກແລນ, ປະເທດນິວຊີແລນ ພາຍໃຕ້ທຶນຂອງລັດຖະບານນິວຊີແລນ.

ຂ້າພະເຈົ້າ ຈະເຮັດຫົວບົດຄົ້ນຄ້ວາວິໃຈ ລະຫວ່າງເດືອນກຸມພາ 2019 ເຖິງ ມີນາ 2020 ເພື່ອເປັນຫົວບົດຈົບ ຊັ້ນປະລິຍາໂທ ສາຂາວິທະຍາສາດສາລະສົນເທດທາງພູມສາດ. ຫົວບົດຄົ້ນຄ້ວາຂອງຂ້າພະເຈົ້າ ແມ່ນສຶກສາ "ການນໍາໃຊ້ລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ ແລະ GIS ຮູບແບບໂອເພີນຊອດສ ເຂົ້າໃນການບໍລິຫານຈັດການ ຂໍ້ມູນ ການນໍາໃຊ້ທີ່ດິນ/ການປົກຫຸ້ມໜ້າດິນຫຼາຍລະດັບໃນ ສປປລາວ", ໂດຍມີຈຸດປະສົງ ເພື່ອຄົ້ນຄ້ວາວ່າ (1) ລະບົບຖານຂໍ້ມູນແບບປະສົມປະສານ ສາມາດສ້າງແບບສອບຖາມຂໍ້ມູນເຊີງພື້ນທີ່ໄດ້ຢ່າງມີປະສິດທິຜົນກ່ວາການ ດໍາເນີນແບບປະຈຸບັນ ຫຼື ບໍ່ ແລະ (2) ລະບົບຖານຂໍ້ມູນນີ້ ມີເຄື່ອງມືຄວາມສາມາດ ທີ່ສາມາດປະຕິບັດການ ໂດຍທີ່ບໍ່ເຄີຍມີມາກ່ອນ.

ລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ ແລະ GIS ຈະຖືກນໍາມາໃຊ້ໃນການຄົ້ນຄ້ວາໃນຄັ້ງນີ້ ເພື່ອທົດລອງຈັດການຂໍ້ມູນການນໍາໃຊ້ທີ່ດິນ/ການປົກຫຸ້ມໜ້າດິນ ບາງສ່ວນຂອງກົມປ່າໄມ້ (DoF) ແລະ ກົມຄຸ້ມຄອງ ແລະ ພັດທະນາທີ່ດິນກະສິກໍາ (DaLaM). ຂໍ້ມູນຈະຖືກຈັດເກັບໃນລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ ທີ່ຈະສ້າງຂຶ້ນມານີ້ ແລະ ນໍາມາທົດລອງການຈັດຕັ້ງປະຕິບັດທາງພູມີສາດຕ່າງໆ (Geo-processing). ຫົວບົດຄົ້ນຄ້ວານີ້ ຄາດວ່າຈະສາມາດສະແດງໃຫ້ເຫັນໂອກາດ ທາງເລືອກດ້ານການບໍລິຫານຈັດການຂໍ້ມູນ GIS ແລະ ຂໍ້ມູນອື່ນໆທີ່ກ່ຽວຂ້ອງ ໄດ້ຢ່າງມີປະສິດທິພາບ. ມັນເປັນໂອກາດທີ່ດີ ທີ່ຈະໃຊ້ປະໂຫຍດຈາກໂປແກຼມລະບົບຖານຂໍ້ມູນໂອເພີນຊອດສ ທີ່ບໍ່ເສຍຄ່າ ແຕ່ຍັງຄົງມີປະສິດທິຜົນສູງ.

ການຄົ້ນຄ້ວາແມ່ນນໍາໃຊ້ງົບປະມານຕົວເອງ. ເຖິງຢ່າງໃດກໍ່ຕາມ, ຂ້າພະເຈົ້າກໍ່ໄດ້ຮັບເງິນບາງສ່ວນ ເພື່ອມາດໍາເນີນການຄົ້ນຄ້ວາທີ່ປະເທດຂອງຕົນ ເປັນຕົ້ນແມ່ນຈາກຜູ້ໃຫ້ທຶນການສຶກສາ ແລະ ຄະນະວິທະຍາສາດສຸຂະພາບ ແລະ ສິ່ງແວດລ້ອມ, ມະຫາວິທະຍາໄລເຕັກໂນໂລຢີໂອກແລນ. ຄາດວ່າການຄົ້ນຄ້ວາຈະດໍາເນີນລະຫວ່າງວັນທີ່ 08 ຫາ 31 ກໍລະກົດ 2019.

ສະນັ້ນ, ຂ້າພະເຈົ້າ ມີຈຸດປະສົງເຊີນທ່ານເຂົ້າຮ່ວມເປັນສ່ວນໜຶ່ງຂອງການຄົ້ນຄ້ວານີ້ ເພື່ອພ້ອມກັນສໍາຫລວດບັນດາທ່າແຮງ ຂອງລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ຮູບແບບໂອເພີນຊອດສ. ຮູບແບບນີ້ ຈະເປັນຮູບແບບທີ່ຈະຖືກນໍາໃຊ້ຫລາຍໃນອະນາຄົດ ແລະ ຈະເປັນວິທີທາງອອກ ທີ່ຕອບໂຈດໄດ້ດີ ແລະ ເໝາະສົມທີ່ສຸດ ເປັນຕົ້ນແມ່ນບັນດາປະເທດກໍາລັງພັດທະນາ ເຊັ່ນປະເທດລາວເຮົາ. ລາຍລະອຽດພັນທະຂອງທ່ານໃນການຄົ້ນຄ້ວາ ແມ່ນໄດ້ລະບຸໄວ້ ໃນສັນຍາຄົ້ນຄ້ວາວິໃຈ.

ຖ້າທ່ານປະສົງທີ່ຈະເຂົ້າຮ່ວມການຄົ້ນຄ້ວາພາຍຫຼັງອ່ານ ເອກະສານຂໍ້ມູນການຄົ້ນຄ້ວານີ້, ໃບສັນຍາການຄົ້ນຄ້ວາ ວິໃຈ, ແລະ ບັນດາຂໍ້ມູນທີ່ກ່ຽວຂ້ອງ ຢ່າງລະອຽດ, ທ່ານສາມາດຕອບຮັບຜ່ານອີເມວ ພ້ອມດ້ວຍຄັດຕິດ ໜັງສືນ ຍິນຍອມ ທີ່ທ່ານໄດ້ເຊັນ.

b. ຈຸດປະສົງຂອງການຄົ້ນຄ້ວາວິໃຈນີ້ແມ່ນຫຍັງ?

ບົດຄົ້ນຄ້ວານີ້ ມີຈຸດປະສົງທີ່ຈະສຶກສາການນໍາໃຊ້ແບບປະສົມປະສານ ລະຫວ່າງລະບົບຖານຂໍ້ມູນ PostgreSQL ແລະ ເຄື່ອງມືວິເຄາະເຊີງພື້ນທີ່ PostGIS ແລະ ໂປແກຼມ QGIS ຮູບແບບໂອເພີນຊອດສ ເພື່ອການບໍລິຫານຈັດການ ແລະ ວິເຄາະຂໍ້ມູນລະດັບພາກພື້ນ ໂດຍການ:

3) ລວບລວມ ແລະ ເຊື່ອມໂຍງບັນດາຂໍ້ມູນລະດັບພາກພື້ນຂອງລາວ ເຂົ້າໄປຈັດເກັບຮັກສາໃນລະບົບຖານ ຂໍ້ມູນເຊີງພື້ນທີ່ (PostgreSQL/PostGIS) ເພື່ອວິເຄາະ ແລະ ບໍລິຫານຈັດການຂໍ້ມູນ GIS ແລະ ຂໍ້ມູນ ທົ່ວໄປຜ່ານລະບົບຖານຂໍ້ມູນນີ້.
4) ປະເມີນ ແລະວັດແທກ ປະສິດທິຜົນຄວາມອາດສາມາດຂອງວິທີການຕອບໂຈດນີ້ຜ່ານການທົດລອງໃນສະຖານະການຕົວຈິງ.

ບົດຄົ້ນຄ້ວານີ້ ແມ່ນຈໍາເປັນສໍາລັບການຈົບຊັ້ນປະລິຍາໂທ ສາຂາວິທະຍາສາດສາລະສົນເທດທາງພູມສາດ ທີ່ມະຫາວິທະຍາໄລເຕັກໂນໂລຢີໂອກແລນ (AUT) ສໍາລັບນັກຄົ້ນຄ້ວາ. ການມີສ່ວນຮ່ວມຂອງຜູ້ເຂົ້າຮ່ວມ ເຊັ່ນວ່າ ຄວາມຄິດເຫັນ, ຄໍາແນະນໍາ ຈະຖືກລະບຸໃນເອກະສານທີ່ກ່ຽວຂ້ອງກັບການສຶກສາ ຫຼື ສື່ສິ່ງພິມ ໃນອານາຄົດຖ້າຖືກຕີພິມ ແລະ ເຜີຍແຜ່. ຖ້າຈໍາເປັນທີ່ຕ້ອງໄດ້ລະບຸຊື່ຂອງຜູ້ເຂົ້າຮ່ວມ, ມັນຈະເປັນນາມສົມມຸດ.

c. ເປັນຫຍັງຂ້ອຍຈຶ່ງຖືກເລືອກໃຫ້ເຂົ້າຮ່ວມການຄົ້ນຄ້ວາວິໃຈນີ້?

ນັກຄົ້ນຄ້ວາ ໄດ້ມີຂໍ້ມູນຕິດຕໍ່ຂອງທ່ານ ຜ່ານການເຮັດວຽກໃນເມື່ອກ່ອນ ເປັນຕົ້ນແມ່ນຜ່ານການເຮັດວຽກກັບບັນ ດາໂຄງການທີ່ກ່ຽວຂ້ອງການກັບວາງແຜນຄຸ້ມຄອງນໍາໃຊ້ທີ່ດິນກະສິກໍາ-ປ່າໄມ້ ແລະ ການກໍານົດເຂດແດນ 3 ປະເພດ ປ່າ. ສະນັ້ນ ທ່ານຈຶ່ງເປັນບຸກຄະລະກອນ ທີ່ເໝາະສົມສໍາລັບການເຂົ້າຮ່ວມການຄົ້ນຄ້ວາວິໃຈໃນຄັ້ງນີ້, ທ່ານໄດ້ຮັບ ການເຊື້ອເຊີນເຂົ້າຮ່ວມຜ່ານຈົດໝາຍອີເມວ. ທ່ານມີສິດທີ່ ຈະຕອບຕົກລົງ ຫຼື ປະຕິເສດການເຂົ້າຮ່ວມ, ຂຶ້ນຢູ່ກັບການຕັດສິນໃຈຂອງທ່ານ. ທ່ານມີທັກສະ ແລະ ຄວາມສາມາດ ຕາມເງື່ອນໄຂການຄົ້ນຄ້ວາ ທີ່ຂ້າພະເຈົ້າໄດ້ກໍານົດ. ຂ້າພະເຈົ້າເຊື່ອໝັ້ນວ່າ ການເຂົ້າຮ່ວມຂອງທ່ານ ຈະປະກອບສ່ວນທີ່ດີຢ່າງຍິ່ງ ໃຫ້ກັບຜົນສໍາເລັດຂອງການຄົ້ນຄ້ວາວິໃຈໃນຄັ້ງນີ້.

d. ແລ້ວຂ້ອຍຈະຕົກລົງເຂົ້າຮ່ວມ ກິດຈະກໍາຄົ້ນຄ້ວານີ້ໄດ້ແນວໃດ?

ການເຂົ້າຮ່ວມການຄົ້ນຄ້ວາວິໃຈນີ້ ແມ່ນເປັນການປະກອບສ່ວນແບບສະໝັກໃຈ (ທ່ານຕັດສິນໃຈເອງ) ແລະ ການຕອບຕົກລົງ ຫຼື ປະຕິເສດ ຈາກການຄົ້ນຄ້ວານີ້ ຈະບໍ່ສົ່ງຜົນທ້ອນທາງລົບໃດໃດຕໍ່ກັບທ່ານ. ທ່ານສາມາດຖອນຕົວອອກຈາກການຄົ້ນຄ້ວານີ້ ໄດ້ທຸກເວລາ ຖ້າເຫັນວ່າຈໍາເປັນ. ຖ້າທ່ານຖອນຕົວອອກຈາກການເຂົ້າຮ່ວມການຄົ້ນຄ້ວານີ້ ທ່ານຈະມີ ສອງທາງເລືອກ, ທາງເລືອກທີ່ໜຶ່ງ ແມ່ນສະເໜີໃຫ້ລຶບຂໍ້ມູນ ທີ່ສາມາດລະບຸຄວາມເປັນຕົວຕົນ ຂອງທ່ານ ອອກຈາກການຄົ້ນຄ້ວາ, ສ່ວນອັນທີ່ສອງ ແມ່ນອະນຸຍາດໃຫ້ນໍາໃຊ້ຂໍ້ມູນດັ່ງກ່າວ ຕໍ່ໄປຈົນສິ້ນສຸດ. ແຕ່ຢ່າງໃດກໍ່ຕາມ, ພາຍຫຼັງທີ່ໄດ້ສໍາເລັດການວິເຄາະແລ້ວ ແມ່ນບໍ່ສາມາດລຶບຂໍ້ມູນອອກໄດ້.

e. ແມ່ນຫຍັງຈະເກີດຂຶ້ນ ພາຍຫຼັງດໍາເນີນການຄົ້ນຄ້ວານີ້?

ທ່ານຈະໄດ້ເຂົ້າຮ່ວມກິດຈະກໍາຄົ້ນຄ້ວາ ກັບຂ້າພະເຈົ້າ ປະມານ 1 ຊົ່ວໂມງເວລາພັກທ່ຽງ ໜຶ່ງວັນ ໃນແຕ່ລະອາທິດ ເປັນໄລຍະເວລາປະມານໜຶ່ງເດືອນ. ກ່ອນອື່ນໝົດ, ພວກເຮົາຈະຕ້ອງໄດ້ເກັບ ແລະ ສັງລວມຂໍ້ມູນທັງໝົດ ແລ້ວນໍາ ເຂົ້າໄປເກັບໄວ້ໃນລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່. ຫຼັງຈາກນັ້ນ, ພວກເຮົາຈຶ່ງເລີ່ມຕົ້ນການວິເຄາະ ປະສິດທິພາບຂອງລະບົບ ຖານຂໍ້

ມູນ ໂດຍອີງໃສ່ການຈຳລອງສະຖານະການທີ່ໄດ້ອອກແບບໄວ້ກ່ອນໜ້ານີ້. ທ້າຍສຸດ, ຂ້າພະເຈົ້າ ຈະສຳພາດທ່ານ ເພື່ອລວບລວມຄວາມຄິດເຫັນ ແລະ ຄຳແນະນຳ ພາຍຫຼັງທີ່ໄດ້ສຳເລັດການດຳເນີນການຄົ້ນຄ້ວາທົດລອງ.

f. ຈະມີຄວາມສ່ຽງ ແລະ ຄວາມອຶດອັດໃຈຫຍັງແດ່?

ຄາດວ່າບົດຄົ້ນຄ້ວານີ້ ຈະສ້າງຄວາມອຶດອັດໃຈເລັກນ້ອຍ ເປັນຕົ້ນແມ່ນລົບກວນການເຮັດວຽກຂອງທ່ານ. ການເສຍເວລາເຂົ້າຮ່ວມອາດສົ່ງຜົນສະທ້ອນ ຕໍ່ປະສິດທິພາບໃນການປະຕິບັດງານຂອງທ່ານ.

g. ແລ້ວຄວາມສ່ຽງ ແລະ ຄວາມອຶດອັດໃຈນີ້ຈະໄດ້ຮັບການແກ້ໄຂແນວໃດ?

ຄວາມສ່ຽງ ແລະ ຄວາມອຶດອັດໃຈນີ້ ແມ່ນຈະຮັບການແກ້ໄຂ ໂດຍການດຳເນີນການຄົ້ນຄ້ວາ ເຊັ່ນ ການສັງລວມຂໍ້ ມູນ , ການວິເຄາະ, ການສຳພາດ... ໃນຊ່ວງເວລາພັກທ່ຽງ ລະຫວ່າງເວລາ 12.30-1.30 ເຊິ່ງເປັນເວລາຫຼັງພັກກິນເຂົ້າ ທ່ຽງ ເພື່ອຫຼີກລ່ຽງ ລົບກວນເວລາເຮັດວຽກຂອງທ່ານ.

h. ຜົນປະໂຫຍດຈະປະກອບມີຫຍັງແດ່?

ຄາດວ່າຜົນປະໂຫຍດທີ່ຜູ້ເຂົ້າຮ່ວມ ຈະໄດ້ຮັບຈະປະກອບມີການຝຶກອົບຮົມ ແລະ ປະສົບການຕົວຈິງ ທີ່ໄດ້ຈາກການເຂົ້າຮ່ວມ ແລະ ລົງມືທຳ ເປັນຕົ້ນແມ່ນຈະໄດ້ຄວາມຮູ້ດ້ານການບໍລິຫານຈັດການຂໍ້ມູນ GIS ເທິງລະບົບຖານຂໍ້ມູນ ເຊີງພື້ນທີ່ ຮູບແບບໂອເພີນຊອດສແລະ ໂປແກມ QGIS. ຂໍ້ມູນຂອງອົງກອນ ຈະໄດ້ຮັບການຈັດລຽງຢ່າງເປັນລະບົບ ໃນຖານຂໍ້ມູນ ເພື່ອເພີ່ມປະສິດທິພາບໃນການປະມວຍຜົນ ແລະ ປະສິດທິຜົນ ເຊິ່ງນີ້ຈະປະກອບສ່ວນສ້າງຜົນປະ ໂຫຍດໃຫ້ແກ່ອົງການລາວ.

ຈະປະກອບມີຫລາຍຜົນປະໂຫຍດ ແກ່ນັກຄົ້ນຄ້ວາ ທີ່ສຶກສຶກສາຫົວຂໍ້ນີ້ ເນື່ອງຈາກວ່າ ລະບົບຖານຂໍ້ມູນເຊີງສຳພັນກັນ (RDBMS) ແມ່ນເປັນເຄື່ອງມືທີ່ມີປະສິດທິພາບ ໃນການບໍລິຫານຈັດການ ກັບຂໍ້ມູນພູມີສາດຂະໜາດໃຫຍ່ ແລະ ມີຄວາມຊັບຊ້ອນ ເຊິ່ງມີບົດບາດສຳຄັນໃນການບໍລິຫານຈັດການຂໍ້ມູນຂອງອົງກອນ ແລະ ຍັງຊ່ວຍໃຫ້ອົງກອນ ສາມາດຕັດສິນໃຈໄດ້ດີຍິ່ງຂຶ້ນ. ສະນັ້ນ ການສຶກສາລະບົບຖານຂໍ້ມູນ RDBMS ແບບໂອເພີນຊອດສ ຍັງມີຜົນປະ ໂຫຍດດີຫລາຍຢ່າງໃຫ້ປະເທດຂອງຜູ້ກ່ຽວອີກ. ອັນທີ່ໜຶ່ງ ແມ່ນປະເທດຜູ້ກ່ຽວຍັງຖືວ່າ ຂາດເຂີນດ້ານທຶນຮອນ ເພື່ອຈັດຊື້ໂປແກມພານິດ. ອັນທີ່ສອງ ແມ່ນປະກອບມີຂໍ້ມູນຂະໜາດໃຫຍ່ ທີ່ຕິດພັນກັບວຽກງານການວາງແຜນ ທີ່ດິນກະສິກຳ ແລະ ປ່າໄມ້, ສະນັ້ນ ຈຶ່ງເປັນໂອກາດທີ່ດີ ເພື່ອໃຫ້ນັກຄົ້ນຄ້ວາ ສາມາດທົດລອງລະບົບຂໍ້ມູນນີ້ ກັບບັນດາຂໍ້ມູນທີ່ມີນີ້. ນອກນັ້ນ ນັກຄົ້ນຄ້ວາ ຍັງສາມາດປະຍຸກໃຊ້ຄວາມຮູ້ ແລະ ທັກສະ ທີ່ໄດ້ຮ່ຳຮຽນ ເຂົ້າໃນສະ ຖານະການຕົວຈິງ ແລະ ແກ້ໄຂບັນຫາ. ແລະ ສິ່ງສຳຄັນທີ່ສຸດ ແມ່ນສາມາດສຳເລັດຫົວບົດຈົບຊັ້ນປະລິຍາໂທ ສາຂາວິ ທະຍາສາດສາລະສົນເທດທາງພູມີສາດ ຈາກມະຫາວິທະຍາໄລເຕັກໂນໂລຢີໂອກແລນ.

ການຄົ້ນຄ້ວາ ຍັງຈະປະກອບສ່ວນສ້າງຜົນປະໂຫຍດ ໃຫ້ແກ່ບັນດາສະມາຊິກຜູ້ຊົມໃຊ້ ເປັນຕົ້ນແມ່ນຜູ້ນຳໃຊ້ລະບົບຖານຂໍ້ມູນ ແລະ GIS ໃນລາວ. ພວກເຂົາຈະໄດ້ຮັບຂໍ້ມູນ ແລະ ຮຽນຮູ້ຈາກການຈັດຕັ້ງປະຕິບັດ ເພື່ອນຳໄປຜັນຂະຫຍາຍໃນຂົງເຂດວຽກງານອື່ນໆ ເຊັ່ນ: ສາທາລະນະສຸກ, ສຶກສາ, ການຄ້າ ເປັນຕົ້ນ. ຜົນການຄົ້ນຄ້ວາວິໃຈ ແລະ ຂໍ້ມູນຂ່າວສານຕ່າງໆ ທີ່ໄດ້ຈາກການສຶກສານີ້ ຈະຖືກແປເປັນພາສາທ້ອງຖິ່ນ. ທັກສະ ແລະ ຄວາມຮູ້ ຈະຖືກຖ່າຍ ທອດໃຫ້ກັບບັນດາສະມາຊິກ.

i. ໃຜຈະເປັນເຈົ້າຂອງລະບົບ ທີ່ເຮົາພັດທະນາຂຶ້ນມານີ້?

ນັກຄົ້ນຄ້ວາຈະມອບສິດໃນການເຂົ້າເຖິງຖານລະບົບຖານຂໍ້ມູນ ແລະ ຄວາມເປັນເຈົ້າການທັງໝົດ ໃຫ້ກັບແຕ່ລະກົມພາຍຫລັງສຳເລັດ ການຄົ້ນຄ້ວາວິໃຈ ໂດຍການໂອນຖານຂໍ້ມູນທັງໝົດລົງໄປໃສ່ໃນຄອມພິວເຕີ ທີ່ເປັນສ່ວນກາງ. ຖ້າມີເງື່ອນໄຂອຳນວຍ, ຈະໂອນຖານຂໍ້ມູນດັ່ງກ່າວລົງເຄື່ອງຄອມພິວເຕີ NAS. ວິທີນີ້ຈະສາມາດອຳນວຍໃຫ້ຫລາຍຄົນໄດ້ນຳໃຊ້ຖານຂໍ້ມູນ. ລາຍລະອຽດພັນທະຄວາມເປັນເຈົ້າ ຈະລະບຸໄວ້ໃນ ສັນຍາການຮ່ວມມືຄົ້ນຄ້ວາວິໃຈ.

j. ຈະປະກອບມີມາດຕະການຊົດເຊີຍຫຍັງແດ່ ໃນກໍລະນີໄດ້ຮັບບາດເຈັບ ຫລື ຄວາມບໍ່ເອົາໃຈໃສ່?

ຄາດຄະເນວ່າຈະບໍ່ໄດ້ຮັບອາການບາດເຈັບ ຫລື ການລະເລີຍຈົນນຳພາໄປສູ່ອາການບາດເຈັບໃນເວລາເຂົ້າຮ່ວມການຄົ້ນຄ້ວາວິໃຈ ເນື່ອງຈາກການດຳເນີນການທຸກຢ່າງແມ່ນເຮັດພາຍໃນຫ້ອງການ ທີ່ປອດໄພ. ສະນັ້ນ ຈະບໍ່ມີມາດຕະການຊົດເຊີຍໃດໃດ.

k. ຂໍ້ມູນຄວາມເປັນສ່ວນຕົວຂອງຂ້ອຍ ຈະໄດ້ຮັບການປ້ອງກັນແນວໃດ?

ທ່ານມີທາງເລືອກວ່າ ທ່ານຕ້ອງການໃຫ້ຜົນການຄົ້ນຄ້ວາສາມາດລະບຸຄວາມເປັນຕົວທ່ານ ຫລື ບໍ່. ຂໍ້ມູນຄວາມເປັນສ່ວນຕົວຂອງທ່ານ ຍັງຈະໄດ້ຮັບການປ້ອງກັນ ບໍ່ວ່າທ່ານເລືອກກໍລະນີໃດ. ທ່ານມີສິດທີ່ຈະບໍ່ຕອບຄຳຖາມ ຖ້າທ່ານຮູ້ສຶກວ່າ ຄຳຖາມນັ້ນບໍ່ເໝາະສົມ. ຖ້າມີການສຳພາດຄຳຖາມລັກສະນະສ່ວນຕົວ ແມ່ນຈະຕ້ອງໄດ້ດຳເນີນໃນຫ້ອງ ທີ່ມີຄວາມເປັນສ່ວນຕົວ.

l. ຈະມີຄ່າໃຊ້ຈ່າຍຫຍັງແດ່ ເພື່ອເຂົ້າຮ່ວມການຄົ້ນຄ້ວາໃນຄັ້ງນີ້?

ມີພຽງຕົ້ນທຶນເວລາ ທີ່ຈະສູນເສຍໄປກັບການຄົ້ນຄ້ວາວິໃຈ, ຄາດວ່າຈະໃຊ້ເວລາປະມານ 1 ຊົ່ວໂມງຕອນທ່ຽງ 1 ວັນເປັນໄລຍະເວລາປະມານ 1 ເດືອນ. ເຊິ່ງເວລາທີ່ສູນເສຍໄປນີ້ ຈະຖືກຊົດເຊີຍດ້ວຍຄ່າຕອບແທນຂອງນັກຄົ້ນຄ້ວາ ທີ່ ຈະຈ່າຍໃຫ້ກັບທ່ານ. ແຕ່ເຖິງຢ່າງໃດກໍ່ຕາມ, ຈະເປັນການດີຢ່າງຍິ່ງຖ້າ ທ່ານສາມາດຂໍອະນຸຍາດຢ່າງເປັນທາງການ ຈາກຫ້ອງການ ຫຼື ຫົວໜ້າຂອງທ່ານ ກ່ອນຕັດສິນໃຈເຂົ້າຮ່ວມ ເພື່ອຮັບປະກັນໄດ້ຮັບອະນຸຍາດເຂົ້າຮ່ວມ ແລະ ສາ ມາດຈັດແຈງລ່ວງໜ້າ ເວລາທີ່ຈະເສຍໄປກັບການເຮັດກິດຈະກຳຄົ້ນຄ້ວາ.

m. ຂ້ອຍໄດ້ຮັບໂອກາດຫຍັງແດ່ ໃນການພິຈາລະນາເຂົ້າຮ່ວມການຄົ້ນຄ້ວາວິໃຈນີ້?

ທ່ານຈະມີເວລາພິຈາລະນາສອງອາທິດ ເພື່ອຕັດສິນໃຈເຂົ້າຮ່ວມການຄົ້ນຄ້ວານີ້. ທ່ານມີສິດທີ່ຈະຕົກລົງ ຫຼື ປະຕິເສດທີ່ຈະເຂົ້າຮ່ວມ.

n. **ຂ້ອຍຈະໄດ້ຮັບຮູ້ ຜົນວິໃຈຂອງການຄົ້ນຄ້ວາ ນີ້ບໍ່?**

ທ່ານຈະໄດ້ຮັບຜົນການສຶກສາຄົ້ນຄ້ວານີ້ ໃນຮູບແບບບົດລາຍງານ ເຊິ່ງຈະມອບໃຫ້ທ່ານ ພາຍຫຼັງສຳເລັດການຄົ້ນ ຄ້ວາວິໃຈ ຫຼື ປະມານຕົ້ນປີ 2020.

o. ຖ້າໃນກໍລະນີ ທີ່ຂ້ອຍມີຂໍ້ຂ້ອງໃຈ ຫລື ຄຳຖາມກ່ຽວກັບການຄົ້ນຄ້ວານີ້?

ຖ້າໃນກໍລະນີ ທີ່ທ່ານມີຂໍ້ຂ້ອງໃຈ ຫຼື ຕ້ອງການຢາກສອບຖາມຂໍ້ມູນໃດໜຶ່ງກ່ຽວກັບການຄົ້ນຄ້ວານີ້, ທ່ານສາມາດຕິດຕໍ່ ຫານັກຄົ້ນຄ້ວາໄດ້ຕະຫລອດເວລາຜ່ານຮູບການສື່ສານໃດກໍ່ໄດ້ທີ່ສະດວກຕໍ່ທ່ານ. ນອກນັ້ນ, ທ່ານຍັງສາມາດຕິດຕໍ່ກັບ ອາຈານທີ່ປຶກສາ ເພື່ອສົນທະນາບັນຫາສ່ວນຕົວ. ຂໍ້ມູນການສົນທະນາຈະເກັບຮັກສາເປັນຄວາມລັບຢ່າງດີ.

ຖ້າມີຂໍ້ຂ້ອງໃຈກ່ຽວກັບການຈັດຕັ້ງປະຕິບັດການສຶກສາຄົ້ນຄ້ວານີ້, ແມ່ນຕ້ອງໄດ້ແຈ້ງໃຫ້ກັບອາຈານທີ່ປຶກສາກ່ອນອື່ນໝົດ ທ່ານ ດຣ ແບຼດລີ່ ເຄດສ - Bradley.case@aut.ac.nz, ໂທລະສັບ 09-9219999 ໝາຍເລກຕິດຕໍ່ພາຍໃນ 5231. ຖ້າມີຂໍ້ຂ້ອງໃຈກ່ຽວກັບການປະພຶດຂອງການສຶກສາຄົ້ນຄ້ວານີ້, ແມ່ນຕ້ອງໄດ້ແຈ້ງໃຫ້ກັບຫົວໜ້າເລຂາ ຄະນະຮັບຜິດຊອບການດຳເນີນການຄົ້ນຄ້ວາແບບມີຫລັກຈະລິຍະທຳ (AUTEC): ທ່ານ ນາງເຄດ ໂອຄໍເນີ - ethics@aut.ac.nz, ໂທລະສັບ 09-9219999 ໝາຍເລກຕິດຕໍ່ພາຍໃນ 6038.

p. ຂ້ອຍຄວນຕິດຕໍ່ຫາໃຜ ໃນກໍລະນີທີ່ຂ້ອຍຕ້ອງການຂໍ້ມູນເພີ່ມເຕີມ?

ກະລຸນາເກັບຮັກສາ ເອກະສານຂໍ້ມູນຄົ້ນຄ້ວານີ້ ແລະ ໜັງສືຍິນຍອມ ໄວ້ກັບທ່ານເພື່ອເປັນບ່ອນອ້າງອີງໃນອະນາຄົດ. ຖ້າໃນກໍລະນີ ທີ່ທ່ານຕ້ອງການຂໍ້ມູນເພີ່ມເຕີມ, ທ່ານສາມາດຕິດຕໍ່ ຫາທີມງານນັກຄົ້ນຄ້ວາດັ່ງຕໍ່ໄປນີ້:

- ທ່ານ ດຣ ແບຼດລີ່ ເຄດສ - ອາຈານທີ່ປຶກສາຕົ້ນຕໍ Bradley.case@aut.ac.nz, ໂທລະສັບ 09-9219999 ຕໍ່ 5231
- ທ່ານ ກຼາແຮມ ຮິນຄລິບ - ອາຈານທີ່ປຶກສາສຳຮອງ Graham.hinchliffe@aut.ac.nz, ໂທລະສັບ 09-9219999 ຕໍ່ 9627
- ທ່ານ ກອງແກ້ວ ສີວິໄລ - ນັກຄົ້ນຄ້ວາ Kongkeo.s@gmail.com, ໂທລະສັບ: +85620-55552719 (ເບີລາວ)

ຂໍ້ມູນຕິດຕໍ່ນັກຄົ້ນຄ້ວາ:

- ທ່ານ ກອງແກ້ວ ສີວິໄລ - ນັກຄົ້ນຄ້ວາ Kongkeo.s@gmail.com, ໂທລະສັບ: +85620-55552719 (ເບີລາວ)

ຂໍ້ມູນຕິດຕໍ່ອາຈານທີ່ປຶກສາຕົ້ນຕໍ:

- ທ່ານ ດຣ ແບຼດລີ່ ເຄດສ - ອາຈານທີ່ປຶກສາຕົ້ນຕໍ Bradley.case@aut.ac.nz, ໂທລະສັບ 09-9219999 ຕໍ່ 5231

ຕົວຢ່າງເນື້ອໃນຈົດໝາຍອີເມວ ທີ່ຈະຂຽນເຊື້ອເຊີນຜູ້ເຂົ້າຮ່ວມການຄົ້ນຄ້ວາ

ສະບາຍດີທ່ານ,

ຂ້າພະເຈົ້າ ທ້າວກອງແກ້ວ ສີວິໄລ ປະຈຸບັນກຳລັງສຶກສາລະດັບປະລິນຍາໂທ ໃນສາຂາວິທະຍາສາດສາລະສົນເທດທາງພູມສາດ ທີ່ມະຫາວິທະຍາໄລເຕັກໂນໂລຢີໂອກແລນ, ທີ່ເມືອງໂອກແລນ, ປະເທດນິວຊີແລນ.

ຂ້າພະເຈົ້າ ຢາກເຊີນຊວນທ່ານເຂົ້າຮ່ວມ ການຄົ້ນຄ້ວາວິໃຈຂອງຂ້າພະເຈົ້າ ລະຫວ່າງເດືອນກໍລະກົດ ຫາ ກັນຍາ 2019. ກະລຸນາສຶກສາຂໍ້ມູນຈາກ **ເອກະສານຂໍ້ມູນການຄົ້ນຄ້ວາວິໃຈ** ທີ່ຄັດຕິດມາພ້ອມນີ້.

ຖ້າທ່ານຕ້ອງການຂໍ້ມູນເພີ່ມເຕີມ ຫລື ຕ້ອງການສົນທະນາກັບຂ້າພະເຈົ້າ ເພື່ອປະກອບການຕັດສິນໃຈ, ກະລຸນາແຈ້ງໃຫ້ຂ້າພະເຈົ້າຮັບຊາບ.

ກະລຸນາຕອບໂດຍການຕອບກັບອີເມວສະບັບນີ້ ເພື່ອໃຫ້ຂ້າພະເຈົ້າຮັບຮູ້ວ່າທ່ານປະສົງທີ່ຈະເຂົ້າຮ່ວມການຄົ້ນຄ້ວານີ້ ຫລື ບໍ່. ຖ້າເປັນໄປໄດ້ກະລຸນາ ແຈ້ງໃຫ້ຂ້າພະເຈົ້າຮັບຮູ້ພາຍໃນວັນທີ່................

ຂໍຂອບໃຈ ແລະ ຮູ້ບຸນຄຸນເປັນຢ່າງຍິ່ງ,

ກອງແກ້ວ ສີວິໄລ

ນັກສຶກສາມະຫາວິທະຍາໄລ AUT

Appendix C: Participant Interview Questions (English and Laotian)

Interview Questions for Participant Feedback

ຄຳຖາມສຳພາດຜູ້ເຂົ້າຮ່ວມການຄົ້ນຄ້ວາ

Title: Using open-source database and GIS to manage multi-scale landuse/land cover in Laos **ຫົວຂໍ້:** ການນຳໃຊ້ລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ ແລະ ເຄື່ອງມື GIS ຮູບແບບໂອເພີນຊອດສ ເຂົ້າໃນການບໍລິຫານຈັດການຂໍ້ມູນການນຳໃຊ້ທີ່ດິນ/ການປົກຫຸ້ມໜ້າດິນຫຼາກຫຼາຍລະດັບໃນ ສປປລາວ.

Date/time ວັນເວລາ................................Location ສະຖານທີ່.................................

I. Introductory questions/ຄຳຖາມພາກນຳສະເໜີ

1. How long have you worked with spatial data, land-use/land cover, social-economic data or database?
   ທ່ານເຮັດວຽກກ່ຽວກັບການຈັດການບໍລິຫານຂໍ້ມູນ GIS, ຂໍ້ມູນການວາງແຜນນຳໃຊ້ທີ່ດິນ/ການປົກຫຸ້ມໜ້າດິນ, ເສດຖະກິດສັງຄົມ ຫລື ລະບົບຖານຂໍ້ມູນ ດົນປານໃດແລ້ວ?
   ....

2. How often do you work with the data mentioned above? ທ່ານເຮັດວຽກກັບຂໍ້ມູນດັ່ງກ່າວຖີ່ປານໃດ?
   - ○ *Everyday ທຸກໆວັນ*
   - ○ *2-3 times per week 2-3 ຄັ້ງ/ອາທິດ*
   - ○ *Once in a month ຄັ້ງ/ເດືອນ*
   - ○ *Others/ອື່ນໆ....................*

3. What kind of GIS-related task do you perform most of the time? ທ່ານນຳໃຊ້ເຄື່ອງມື GIS ຫຍັງເປັນສ່ວນໃຫຍ່ ກັບບັນດາຂໍ້ມູນດັ່ງກ່າວ?
   - ○ *Cartographic mapping ການເຮັດແຜນທີ່*
   - ○ *Calculating statistics ການຄິດໄລ່ສະຖິຕິ*
   - ○ *Querying for data/information ການສ້າງແບບສອບຖາມເພື່ອເອົາຂໍ້ມູນ.*
   - ○ *Geoprocessing (calculating, geometry transformation, join…) ການນຳໃຊ້ເຄື່ອງມືຕ່າງໆ(ຄິດໄລ່, ການເຊື່ອມຕໍ່ຕາຕະລາງ)*
   - ○ *Others/ອື່ນໆ...*

II. Questions to obtain perceptions on spatial database/GIS for managing multi-level dataset ຄຳຖາມເພື່ອຮັບຮູ້ມຸມມອງເບື້ອງຕົ້ນຂອງຜູ້ເຂົ້າຮ່ວມກ່ຽວກັບ ລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ ແລະ GIS ເພື່ອບໍລິຫານຈັດການຂໍ້ມູນພື້ນທີ່ຫລາກຫຼາຍລະດັບ.

4. Have you ever managed GIS data and non-spatial data in some form of database such as Esri's Geodatabase, Microsoft Access...? If yes, please explain your experience and scope of use.

ທ່ານເຄີຍໄດ້ຈັດການຂໍ້ມູນ GIS ແລະ ຂໍ້ມູນຕາຕະລາງ ໃນຮູບແບບຖານຂໍ້ມູນດັ່ງເຊັ່ນ ຈີໂອດາຕາເບສ, ໄມໂຄຊອບແອັກແຊັດ.ຖ້າທ່ານເຄີຍ,ກະລຸນາເລົ່າປະສົບການຜ່ານມາ ແລະ ຂອບເຂດການນຳໃຊ້.

....

....

5. If the answer to the above question is yes, how do you find the approach when compared to traditional practice or existing workflow? For example, productivity and usability.
   ຖ້າຄຳຕອບຂ້າງເທິງແມ່ນເຄີຍໃຊ້ໃນໄລຍະຜ່ານມາ, ທ່ານຄິດແນວໃດຕໍ່ກັບລະບົບຖານຂໍ້ມູນດັ່ງກ່າວ ເວລາສົມທຽບກັບການປະຕິບັດແບບດັ້ງເດີມ ເຊັ່ນປະສິດທິພາບ ແລະ ຄວາມສະດວກສະບາຍ.

   ....

   ....

6. Have you ever experienced any open-source GIS software and spatial database such as QGIS, PostgreSQL/PostGIS? If yes, please describe your experience.
   ທ່ານເຄີຍໄດ້ທົດລອງ ໂປແກມ GIS ຫລື ລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ ທີ່ເປັນລະບົບໂອເພີນຊອດສບໍ່? ເຊັ່ນໂປແກມ QGIS, PostgreSQL PostGIS, ຖ້າທ່ານເຄີຍ, ກະລຸນາເລົ່າປະສົບການຜ່ານມາໃຫ້ຟັງແດ່.

   ....

   ....

III. Questions to obtain feedback, thoughts, and opinions about the introduced solution after completing the installation of the spatial database. ຄຳຖາມເພື່ອຮັບຮູ້ຄວາມຄິດຄຳເຫັນ ແລະ ຄຳແນະນຳ ກ່ຽວກັບລະບົບຖານຂໍ້ມູນ ເຊີງພື້ນທີ່ ທີ່ໄດ້ທົດລອງນີ້ ພາຍຫລັງ ສຳເລັດຕິດຕັ້ງ ແລະ ທົດລອງໃຊ້.

7. What do you think about the two scenarios?
   ທ່ານຄິດເຫັນແນວໃດຕໍ່ກັບປະສິດທິພາບ ຂອງສອງຮູບແບບການຈຳລອງ?

   Scenario1/ຮູບແບບການຈຳລອງທີ່ 1:

   Positive/ຂໍ້ດີ:..

   Shortcomings/ຂໍ້ດ້ອຍ:

   ....

   Need to improve/ຂໍ້ຄວນປັບປຸງ:

   ....

   Scenario2/ຮູບແບບການຈຳລອງທີ່ 2:

   Positive/ຂໍ້ດີ:

   ....

   Shortcomings/ຂໍ້ດ້ອຍ:

   ....

   Need to improve/ຂໍ້ຄວນປັບປຸງ:

   ....

8. How much do you understand all the code?
   ທ່ານເຂົ້າໃຈລະຫັດໂຄດຫລາຍນ້ອຍພຽງໃດ

☐very little ນ້ອຍດຽວ ☐some ບາງຈຳນວນ ☐almost all ເກືອບເຂົ້າໃຈໝົດ

9. During the testing, do you think are there any variable that could affect the overall effectiveness or productivity of the spatial database?
ທ່ານຄິດວ່າໃນລະຫວ່າງການທົດລອງ, ໄດ້ມີຕົວແປໃດບໍ່ທີ່ອາດສົ່ງຜົນກະທົບຕໍ່ກັບປະສິດທິພາບໂດຍລວມຂອງລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ນີ້?

……

……

10. In your opinion, what do you think about the effectiveness of this spatial database solution and in comparison with the existing workflow?

ທ່ານມີຄວາມຄິດເຫັນແນວໃດຕໍ່ກັບປະສິດທິພາບ/ປະສິດທິຜົນຂອງລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ ທີ່ໄດ້ຄົ້ນຄ້ວາທົດລອງນີ້ ໂດຍສົມທຽບກັບລະບົບຖານຂໍ້ມູນທີ່ນຳໃຊ້ຢູ່ໃນປະຈຸບັນ?

……

……

11. Do you think the integrated open-source solution could improve the efficiency and productivity of land-use/land cover data management, and is the right solution for Laos PDR?
ທ່ານຄິດວ່າລະບົບຖານຂໍ້ມູນ GIS ແບບປະສົມປະສານນີ້ຈະສາມາດຊ່ວຍເພີ່ມປະສິດທິພາບ ແລະ ຄວາມສະດວກສະບາຍໃນການບໍລິຫານຈັດການຂໍ້ມູນການນຳໃຊ້ທີ່ດິນ/ການປົກຫຸ້ມໜ້າດິນ ແລະ ເປັນວິທີການທີ່ສາມາດຕອບໂຈດຄວາມຕ້ອງການໃນລາວ?

……

……

12. Describe your involvement in installing the spatial database in your department?
ທ່ານຮູ້ສຶກແນວໃດກ່ຽວ ການມີສ່ວນຮ່ວມຂອງທ່ານໃນການຕິດຕັ້ງລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ ໃນໜ່ວຍງານຂອງທ່ານ?

……

……

13. Tell me about your overall experience working in the research?
ໂດຍລວມແລ້ວ ທ່ານຮູ້ສຶກແນວໃດກ່ຽວກັບການຈັດຕັ້ງປະຕິບັດການຄົ້ນຄ້ວາໃນໄລຍະຜ່ານມາ?

……

……

14. Would you like to receive the research findings and results upon final completion of the research?
ຖ້າຫົວບົດຄົ້ນຄ້ວານີ້ສຳເລັດສົມບູນ ທີ່ຕ້ອງການຮັບຮູ້ຜົນວິໃຈ ແລະ ຄົ້ນພົບຂອງການຄົ້ນຄ້ວານີ້ ຫລືບໍ່?

……

Thank you for taking part in the research!

ຂໍຂອບໃຈທ່ານຢ່າງຍິ່ງທີ່ຮ່ວມການຄົ້ນຄ້ວາ!

....

ຂໍ້ມູນຕິດຕໍ່ນັກຄົ້ນຄ້ວາ:

Researcher Contact Details:

- Kongkeo Sivilay - Primary Researcher Kongkeo.s@gmail.com, mobile phone: +64-22-4959213, +8562055552719.

  ທ່ານ ກອງແກ້ວ ສີວິໄລ - ນັກຄົ້ນຄ້ວາ Kongkeo.s@gmail.com, ໂທລະສັບ: +85620-55552719 (ເບີລາວ)

Supervisor Contact Details:

ຂໍ້ມູນຕິດຕໍ່ອາຈານທີ່ປຶກສາຕົ້ນຕໍ:

- Dr Bradley Case - Primary Supervisor Bradley.case@aut.ac.nz, phone: +64-9-9219999 ext. 5231
  ທ່ານ ດຣ ແບຼດລີ່ ເຄດສ - ອາຈານທີ່ປຶກສາຕົ້ນຕໍ Bradley.case@aut.ac.nz, ໂທລະສັບ 09-9219999 ຕໍ່ 5231

Appendix D: Participant Research Agreement (English and Laotian)

RESEARCH AGREEMENT

between

Mr. Kongkeo Sivilay

and

Provincial Forestry Division and Agricultural Development and Management,

Provincial Agriculture and Forestry of Luang Prabang Province (PAFO)

WHEREAS **Mr. Kongkeo Sivilay,** an academic student of Geospatial Science of School of Science, Health and Environmental Science Faculty, Auckland University of Technology (AUT), Auckland, New Zealand; hereafter referred to as "**the researcher**".

WHEREAS **Miss/Mr TBD,** technical staff of Provincial Forestry Division (PoF) and Provincial Agricultural Land Management and Development (PaLaM), Provincial Agriculture and Forestry Office (PAFO), Luang Prabang, Laos PDR; is the research assistant and hereafter referred to as "**the participant**".

WHEREAS the researcher and the participant have expressed their desire to participate in a research project entitled **using open-source spatial database and GIS to manage multi-scale land use/land cover data in Laos**, hereafter referred to as "**research project**".

This research agreement is based on the mutual understanding between the researcher and the participant, which ultimately forms a formal agreement and hereafter referred to as "**the agreement**".

Therefore, this agreement witnesses that in consideration of the mutual understanding and agreements and subject to terms and condition as set out in this agreement, the parties agree to undertake the research project as follows;

I. BACKGROUND

The researcher is currently undertaking a Master of Science in Geospatial between 2018-2020 at School of Science, Health and Environmental Science Faculty, Auckland University of Technology (AUT) under NZ Scholarship Program. The researcher aims at completing the research thesis as a pathway to complete the MSc degree here at AUT.

The researcher has the interest in the subject of spatial database management and open-sources software to manage multi-level and complex GIS data in relation to land-use and land cover in Laos PDR where currently there is limited and non-existence of effective spatial database at governmental institutions.

Provincial Forestry Division (PoF) and Provincial Agricultural Land Management and Development Division (PaLaM), Provincial Agriculture and Forestry Office (PAFO) are the main governmental institutions who are in charge of managing GIS and non-spatial data in relation to forestry and agricultural, resources and land, agro-biodiversity, agro-forestry, non-timber forest product (NTFP), agricultural census data, inventory, etc.

Thus, these two divisions are suitable for this research. They also have capable and skilful workforce and therefore were selected for this study.

GENERAL PROVISION

This agreement has been created in Laotian and English. If there is any discrepancy between the two version. The Laotian version shall prevail. Each party shall keep a copy of this agreement.

II. DEFINITION

Whenever the words, expressions and term appear in this agreement, they shall be interpreted according to the definition hereafter in the following unless implicitly or explicitly expressed otherwise in the text;

1) **“Research title”** is the summary of the main ideas of the study which the researcher will be working on.
2) **“Research team in Laos”** includes the researcher and research participants of the target office in Laos.
3) **“Research project”** means the research activities taking place in the target office in Laos in the given timeframe as outlined in the Term and Scope.
4) **“Background intellectual property”** means prior intellectual property of individual or his/her organisation, developed, produced or obtained by a party before this research project.
5) **“Arising intellectual property”** mean all intellectual property individual or collectively made and developed during the term of this agreement and directly as the result of this research.
6) **“Party”** means either the researcher or the participant; “Parties” means both the researcher and the participant.
7) **“Joint owner”** means the state of ownership of any given intellectual property, data, or physical equipment by both parties as outlined in this agreement.
8) **“Introduced solution”** means the introduced approach involving the use of open-source spatial database PostgreSQL, spatial extension PostGIS and desktop GIS application QGIS in order to handle and manage GIS and non-spatial data.

III. RESEARCH PROJECT

1) Research summary: this research project itself will be undertaking between February 2019 and March 2020 to fulfil the researcher’s requirements for Master of Geospatial Science of AUT. Nevertheless, the research activity involving the participant, which will be taking place in Vientiane, Laos PDR, will only last for 1 month between 12^{th} Nov – 12^{st} Dec 2019 as set forth in section 5 of this agreement. The research is aiming to investigate the integration of the open-source spatial database to manage multi-scale land-use and land cover data in Laos; and measure the capabilities of the introduced solution based on the designed scenarios.
2) The research project will trial the introduced solution at the participating department for a month by migrating the data onto the database and then perform productivity and efficiency measurement. Additional interview-based information will be used to quantify the satisfaction of the introduced solution.

3) Research team in Laos: including (1) the researcher, (2) a forestry division technical staff and (3) a PaLaM technical staff from Provincial Agriculture and Forestry (PAFO).

IV. TERM AND SCOPE

This agreement is in effective only between **12th November 2019** and **12th December 2019** unless extended by written agreement from the Parties or terminated according to section 15 of this Agreement. The scope of this agreement applies to this timeframe only and shall cease the effectiveness from the end date.

V. DURATION AND LOCATION

The duration of this agreement is between **12th November 2019** and **12th December 2019**, and the research will take place at The Agro-Biodiversity Initiative (TABI Luang Prabang), PAFO.

VI. CONTRIBUTION

1) The total monetary payment of the researcher for the participant is 500,000 Laotian Kip as an appreciation for efforts and time spent with the research project. The researcher is happy to provide this monetary amount to participant towards the end of this agreement.
2) The payment shall be made in cash to the participant. Each party shall keep a copy of signed receipt for future reference.

VII. EQUIPMENT

1) Hardware: the primary hardware used for this research project is the researcher's laptop computer. However, the participants could use their private or work computer if they access it. Depending on the participant's department's IT infrastructure, they may have access to network attached storage (NAS) with high-speed internet access equipment.
2) Software: the research project aims at utilising all the open-source software. Thus, they can be sourced from the world-wide-web free of charge. The software shall be installed on the machine prior to the commencement of the research project.
3) Internet connectivity: If in case the internet connection at the department is unstable for the team to work and/or not available. Alternatively, the researcher shall provide a 4G mobile internet connection at the researcher's cost for data.

VIII. OBLIGATIONS

1) Obligation of the researcher: the researcher must be accountable for all the obligations listed in this agreement. In addition, the researcher shall take the overall lead of the research project. The research must ensure the research activities are being carried out according to the timeframe.
2) The researcher shall proceed the contribution payment to the participant(s) upon the completion of the research project in Laos as set forth in section 7 of this agreement.
3) Obligation of the participant: the participant, under this agreement, agrees to fully parti-cipate in the research project. The participant has the responsibility to help facilitate the research activity such as prepare facility, documentation, making appointment, etc.

IX. CONFIDENTIALITY

1) The researcher agrees that he may receive proprietary and confidential data and information (confidential information) from the participant and his/her department in regards for this research project. The researcher agrees, therefore, that such information and data received from the participant, treated as confidential will not be disclosed to any third party or used for its own purposed without the written consent from the participant.
2) Participants’ signed written consent forms shall be kept with the researcher’s secondary supervisor office at the School of Science of AUT for the period of six years. After six year, those forms shall be shredded.
3) The researcher agrees, if requested in writing by the participant to return promptly all or partial confidential information at the completion of the research from any means of storage. In case data are stored on a physical hard drive, they must be irretrievably deleted after the data has been transferred to the participant. The obligations for confidentiality shall last for a period of six years beyond the expiration or earlier termination of this agreement.
4) If a party is welling to publish the research findings in the academic journal, confidential information which are sensitive to the other party shall not be published without given consent from the other party.

X. PRIVACY PROTECTION

1) As point out in the research Information Sheet, the participant has the choices to whether he/she will be identifiable in the research findings. And he/she shall have the rights to decline any uncomfortable questions which may arise during the interview. All private questions shall be conducted in a private room.
2) In case of earlier withdrawal from the research by the participant, he/she shall have the rights to have any identifiable information erased from the research unless the findings have already been made.
3) The researcher has the liability to protect any identifiable information of the participant including his/her organisation regardless of any circumstances.

XI. RESULTS OF THE RESEARCH

The researcher will keep will keep the participant informed of the research results and findings obtained from the work in regard to the research project in the form of media as agreed by both parties. Nevertheless, the participants are expected to treat the provided results and findings as confidential information as set forth in section 10 above unless otherwise agreed to in writing by the parties.

XII. INTELLECTUAL PROPERTY AND OWNERSHIP

1) Any background intellectual property already belonging to either party or that is developed, produced or obtained by a party before or outside of the scope of this project, shall not be relevant to this agreement.
2) Party may use the background intellectual property of the other party solely for this research project and shall not affect the background intellectual property and its ownership.
3) Arising intellectual property, which is developed, produced or obtained entirely by the staff or member of one party when implementing this research project, shall remain the property of that party in accordance with applicable policies and collective agreements.
4) Arising intellectual property, which is made jointly by employee, staff or any team member of both parties, shall be jointly owned by the parties.
5) Upon completion of this research project in Laos, the researcher will provide full access and ownership to the respective departments by allocating the spatial database on the central computer or ideally on a network-attached storage (NAS)

computer. However, the system is co-owned between the participant and the researcher. He still has the system on his computer and still needs it to continue his research activities.

XIII. PUBLICATION OF RESEARCH FINDINGS

1) The parties acknowledge the importance of publishing articles in the appropriate academic journals, research websites or other platforms as well as students having the rights to present their thesis without delays.
2) If the research project will be jointly published, authorship and contribution of the research project will be determined according to the academic standards and customs. Proper acknowledgement shall be made for the contribution of each party.
3) In case the prosed research is not a joint publication, the party wishing to make the publication inform the other party thirty (30) days with written notice and provide the manuscript and abstract. This is to give the other party the time to check their intellectual property which may be disclosed in the manuscript or abstract.

XIV. TERMINATION

Either party has the right to terminate this agreement which ultimately abort its participation in the research project with or without given reasons by giving five (5) days written notice to the other party. Nothing in this agreement shall rescind the obligations that may have accrued or the privileges of that party up to the date specified in the written notice of the termination.

<u>Contact information:</u>

Research team:

- Dr Bradley Case - Primary Supervisor Bradley.case@aut.ac.nz, phone: +64-9-9219999 ext. 5231
- Graham Hinchliffe - Secondary Supervisor Graham.hinchliffe@aut.ac.nz, phone: +64-9-9219999 ext. 9627
- Kongkeo Sivilay - Primary Researcher Kongkeo.s@gmail.com, mobile phone: +856-20-55552719 (Laos mb).

11 Nikau Street, Eden Terrace, Auckland, NZ, 1021 (NZ address:) Sisavath Village,

Chanthabouly District, Vientiane, 01000 (Laos Address)

Research participant:

- Mr. Somwang Keodara – technical officer at PALAM division
- Mr. Sayasith – technical officer at Forestry division

In witness where the parties here to have duly executed this agreement as of the date written below.

Accepted by and signed:

The Researcher - Mr. Kongkeo Sivilay (Signature, Name)	**The participant** – Mr. Somwang Keodara – technical officer at PALAM division +85620-56658777 Or represented by duly authorised representative
Dated……………………………………………	Dated…………………………………………………
	The participant – Mr. Sayasith – technical officer at Forestry division +85620-55175152 Or represented by duly authorised representative Dated…………………………………………………

Witnessed by:

Name: (Signature and organisation)	Name: (Signature and organisation)
Dated………………………………………………	Dated…………………………………………………

ສັນຍາການຄົ້ນຄ້ວາວິໃຈ

ລະຫວ່າງ

ທ່ານ ກອງແກ້ວ ສີວິໄລ

ແລະ

ຂະແໜງຄຸ້ມຄອງ ແລະ ພັດທະນາທີ່ດິນກະສິກຳ, ຂະແໜງປ່າໄມ້ ພະແນກກະສິກຳ ແລະ ປ່າໄມ້ ແຂວງຫຼວງພະບາງ.

ທ່ານ ກອງແກ້ວ ສີວິໄລ ,ນັກສຶກສາລະດັບປະລິຍາໂທ ສາຂາວິທະຍາສາດສາລະສົນເທດພູມສາດຄະນະ , ມະຫາວິທະຍາໄລເຕັກໂນໂລຊີໂອກແລນ ,ວິທະຍາສາດສຸຂະພາບ ແລະ ສິ່ງແວດລ້ອມ(AUT), ເມືອງໂອກແລນປະເທດນິວຊີແລນ ,; ຕໍ່ໄປນີ້ໃຫ້ເອີ້ນວ່າ "**ນັກຄົ້ນຄ້ວາ**".

ທ່ານ………… ເປັນພະນັກງານວິຊາການ ,.ຂອງຂະແໜງປ່າໄມ້(PoF)/ ຂະແໜງຄຸ້ມຄອງ ແລະ ພັດທະນາທີ່ດິນກະສິກຳ (PaLaM) ,ພະແນກກະສິກຳ ແລະ ປ່າໄມ້ ແຂວງຫຼວງພະບາງ, ສປປລາວ. ຮັບໜ້າທີ່ ເປັນຜູ້ຊ່ວຍນັກຄົ້ນຄ້ວາ ແລະ ຕໍ່ໄປນີ້ໃຫ້ເອີ້ນວ່າ "**ຜູ້ເຂົ້າຮ່ວມ**".

ນັກຄົ້ນຄ້ວາ ແລະ ຜູ້ເຂົ້າຮ່ວມ ມີຄວາມປະສົງ ທີ່ຈະເຂົ້າຮ່ວມ ໃນຫົວບົດຄົ້ນຄ້ວາທີ່ມີຊື່ວ່າ: ການນຳໃຊ້ລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ ແລະ GIS ຮູບແບບໂອເພີນຊອດສ ເຂົ້າໃນການບໍລິຫານ ຈັດການຂໍ້ມູນການ ນຳໃຊ້ທີ່ດິນ/ການປົກຫຸ້ມໜ້າດິນຫຼາຍລະດັບໃນ ສປປລາວ ຕໍ່ໄປນີ້ໃຫ້ເອີ້ນວ່າ "**ການຄົ້ນຄ້ວາວິໃຈ**".

ສັນຍາການຄົ້ນຄ້ວານີ້ ແມ່ນສ້າງຂື້ນບົນພື້ນຖານຄວາມເຂົ້າໃຈ ລະຫວ່າງ ນັກຄົ້ນຄ້ວາ ແລະ ຜູ້ເຂົ້າຮ່ວມ ເຊິ່ງໄດ້ກາຍມາເປັນພັນທະສັນຍາ ທາງການລະຫວ່າງ ສອງຝ່າຍ, ຕໍ່ໄປນີ້ໃຫ້ເອີ້ນວ່າ "**ສັນຍາການຄົ້ນຄ້ວາວິໃຈ**"

ສະນັ້ນ ສັນຍານີ້ ໂດຍພິຈາລະນາ ຕາມຄວາມເຂົ້າໃຈ ແລະ ບັນດາຂໍ້ຕົກລົງລະຫວ່າງສອງຝ່າຍ ແລະ ອີງຕາມເງື່ອນໄຂ ທີ່ລະບຸໄວ້ໃນສັນຍາສະບັບນີ້, ທັງສອງຝ່າຍຕົກລົງ ທີ່ຈະດຳເນີນກິດຈະກຳການຄົ້ນຄ້ວາວິໃຈດັ່ງຕໍ່ໄປນີ້;

1) **ຄວາມເປັນມາ**

ປະຈຸບັນນີ້ ນັກຄົ້ນຄ້ວາ ກຳລັງສຶກສາໃນລະດັບປະລິຍາໂທ ສາຂາວິທະຍາສາດສາລະສົນເທດພູມສາດ ລະຫວ່າງປີ 2018-2020 ທີ່ຄະນະວິທະຍາສາດສຸຂະພາບ ແລະ ສິ່ງແວດລ້ອມ, ມະຫາວິທະຍາໄລ ເຕັກໂນໂລຊີໂອກແລນ (AUT), ເມືອງໂອກແລນ, ປະເທດນິວຊີແລນ ພາຍໃຕ້ທຶນສະໜັບສະໜູນ ຈາກລັດຖະບານນິວຊີແລນ. ນັກຄົ້ນຄ້ວາ ມີຈຸດປະສົງທີ່ເຮັດສຳເລັດ ຫົວບົດການຄົ້ນຄ້ວາ ເພື່ອບັນລຸການສຶກສາລະດັບປະລິຍາໂທ ທີ່ມະຫາວິທະຍາໄລເຕັກ ໂນໂລຊີໂອກແລນແຫ່ງນີ້.

ນັກຄົ້ນຄ້ວາ ມີຄວາມສົນໃຈໃນຫົວຂໍ້ການບໍລິຫານຈັດການຖານຂໍ້ມູນເຊີງພື້ນທີ່ ແລະ ໂປແກມໂອເພີນຊອດສ ເພື່ອຈັດການຂໍ້ມູນ GIS ທີ່ສັບຊ້ອນ ແລະ ຫຼາກຫຼາຍ ເປັນຕົ້ນແມ່ນຂໍ້ມູນການຄຸ້ມຄອງນຳໃຊ້ທີ່ດິນ ແລະ ປົກຫຸ້ມໜ້າດິນ ໃນ ສປປລາວ, ເຊິ່ງປະຈຸບັນນີ້ຖືວ່າ ຍັງຄ່ອນຂ້າງຈຳກັດ ຫຼື ຍັງບໍ່ທັນມີ ວິທີການຈັດການຖານຂໍ້ມູນເຊີງພື້ນທີ່ ທີ່ມີປະສິດທິພາບ ໃນບັນສະຖາບັນຂອງລັດຖະບານ.

ຂະແໜງປ່າໄມ້ (PoF) ແລະ ຂະແໜງຄຸ້ມຄອງ ແລະ ພັດທະນາທີ່ດິນກະສິກຳ (PaLaM), ພະແນກກະສິ ກຳ ແລະ ປ່າໄມ້ ແຂວງຫຼວງພະບາງ (PAFO) ແມ່ນອົງການຈັດຕັ້ງຂອງລັດຕົ້ນຕໍ ທີ່ຮັບຜິດຊອບຄຸ້ມຄອງ ແລະ ຈັດການຂໍ້ມູນ GIS ແລະ ຂໍ້ມູນທົ່ວໄປທີ່ກ່ຽວຂ້ອງກັບ ຊັບພະຍາກອນ ແລະ ທີ່ດິນປ່າໄມ້, ທີ່ດິນກະ ສິກຳ, ຊີວະນານາພັນກະສິກຳ ແລະ ປ່າໄມ້, ເຄື່ອງປ່າຂອງດົງ, ຂໍ້ມູນສະຖິຕິກະສິກຳ ແລະ ການສຳຫລວດ ປ່າໄມ້. ສະນັ້ນ ສອງຂະແໜງການນີ້ ຈຶ່ງເປັນຫ້ອງການທີ່ເໝາະສົມທີ່ສຸດ ສຳລັບການຄົ້ນຄ້ວານີ້ ແລະ ພວກເຂົາຍັງມີຖັນແຖວພະນັກງານທີ່ມີທັກສະ ຄວາມສາມາດທີ່ດີ, ສະນັ້ນ ຈຶ່ງຖືກເລືອກສຳລັບການສຶກສາໃນຄັ້ງນີ້.

2) **ບົດບັນຍັດທົ່ວໄປ**

ສັນຍາສະບັບນີ້ປະກອບມີສອງພາສາ, ພາສາລາວ ແລະ ພາສາອັງກິດ. ຖ້າກຳລະນີເກີດມີຂໍ້ຂາດເຄື່ອນລະຫວ່າງສອງສະບັບ ແມ່ນໃຫ້ເອົາສະບັບພາສາລາວເປັນຫຼັກ. ແຕ່ລະຝ່າຍຕ້ອງເກັບໄວ້ 1 ສະບັບ.

3) **ຄວາມໝາຍຄຳສັບ**

ໃນເມື່ອໃດກໍ່ຕາມ ທີ່ມີຄຳສັບ ຫຼື ຄຳເວົ້າ ເຫຼົ່ານີ້ປະກົດຢູ່ໃນສັນຍາສະບັບນີ້, ຄຳເຫຼົ່ານີ້ ຈະຕ້ອງຖືກແປຄວາມໝາຍ ດັ່ງເນື້ອໃນລຸ່ມນີ້ ຍົກເວັ້ນກໍລະນີໄດ້ອະທິບາຍຄວາມໝາຍນັ້ນ ຢູ່ໃນປະໂຫຍກດັ່ງກ່າວ.

1) "**ຫົວບົດຄົ້ນຄ້ວາ**" ແມ່ນສັງລວມແນວຄວາມຄິດ ຂອງບົດຄົ້ນຄ້ວາວິໃຈທີ່ ນັກຄົ້ນຄ້ວາຈະເຮັດສຶກສາຄົ້ນຄ້ວາ.
2) "**ທີມຄົ້ນຄ້ວາຢູ່ລາວ**" ປະກອບມີ ນັກຄົ້ນຄ້ວາ ແລະ ຜູ້ເຂົ້າຮ່ວມຂອງຫ້ອງການເປົ້າໝາຍຢູ່ສປປລາວ..
3) "**ການຄົ້ນຄ້ວາວິໃຈ**" ໝາຍຄວາມວ່າ ກິດຈະກຳຄົ້ນຄ້ວາ ທີ່ຈະຈັດຕັ້ງປະຕິບັດ ໃນຫ້ອງການເປົ້າ ໝາຍໃນສປປລາວ ອີງຕາມໄລຍະທີ່ກຳນົດ ດັ່ງທີ່ໄດ້ລະບຸໃນເງື່ອນໄຂ ແລະ ຂອບເຂດຂອງສັນຍາ ສະບັບນີ້.
4) "**ສັບສິນທາງປັນຍາກ່ອນໜ້ານີ້**" ໝາຍເຖິງ ສັບສິນທາງປັນຍາ ຂອງບຸກຄົນ ຫຼື ອົງກອນຂອງລາວ, ທີ່ໄດ້ພັດທະນາ, ສ້າງຂຶ້ນ ຫຼື ໄດ້ມາ ໂດຍຝ່າຍໜຶ່ງ ກ່ອນການດຳເນີນການຄົ້ນຄ້ວານີ້.

5) “**ສັບສິນທາງປັນຍາທີ່ເກີດຂຶ້ນ**” ໝາຍເຖິງ ສັບສິນທາງປັນຍາ ຂອງບຸກຄົນ ຫຼື ສ່ວນລວມ, ທີ່ໄດ້ພັດ ທະນາະ, ສ້າງຂຶ້ນ ຫຼື ໄດ້ມາ ໃນຊ່ວງການດຳເນີນສັນຍາສະບັບນີ້ ແລະ ຜົນໄດ້ຮັບຂອງການຄົ້ນຄ້ວາ ນີ້ໂດຍກົງ.
6) “**ຝ່າຍ**” ໝາຍເຖິງຝ່າຍໃດຝ່າຍໜຶ່ງຂອງສັນຍາ ອາດໝາຍເຖິງນັກຄົ້ນຄ້ວາ ຫລື ຜູ້ເຂົ້າຮ່ວມ; “**ສອງຝ່າຍ**” ໝາຍເຖິງ ທັງສອງນັກຄົ້ນຄ້ວາ ແລະ ຜູ້ເຂົ້າຮ່ວມ.
7) “**ຄວາມເປັນເຈົ້າຂອງຮ່ວມ**” ໝາຍເຖິງສະຖານະຄວາມເປັນເຈົ້າຂອງ ຂອງສັບສິນປັນຍາໃດໜຶ່ງ, ຂໍ້ມູນ ຫຼື ເຄື່ອງມືອຸປະກອນ ດັ່ງທີ່ລະບຸໃນສັນຍາສະບັບນີ້.
8) “**ວິທີການທີ່ນຳສະເໜີ**” ແມ່ນແນວທາງວິທີການທີ່ນຳສະເໜີ ໃນການຄົ້ນຄ້ວານີ້ ໂດຍການນຳເອົາລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ PostgreSQL ທີ່ມີເຄື່ອງມື PostGIS ແລະ ໂປແກຼມໂອເພີນຊອດສ QGIS ມາບໍລິຫານຈັດການຂໍ້ມູນພູມສາດ ແລະ ຂໍ້ມູນທົ່ວໄປຕ່າງໆ .

4) ການຄົ້ນຄ້ວາວິໃຈ

1) **ການຄົ້ນຄ້ວາໂດຍຫຍໍ້:** ການຄົ້ນຄ້ວາວິໃຈນີ້ ຈະເລີ່ມຕົ້ນໃນເດືອນກຸມພາ 2019 ແລະ ຕ້ອງສຳເລັດ ໃນເດືອນມີນາ 2020 ເພື່ອເປັນການບັນລຸ ການສຶກສາໃນລະດັບປະລິຍາໂທ ສາຂາວິທະຍາສາດສາ ລະສິນເທດພູມສາດ ທີ່ຄະນະວິທະຍາສາດສຸຂະພາບ ແລະ ສິ່ງແວດລ້ອມ, ມະຫາວິທະຍາໄລເຕັກໂນ ໂລຊີໂອກແລນ (AUT). ແຕ່ວ່າກິດຈະກຳການຄົ້ນຄ້ວາທີ່ປະກອບມີຜູ້ ເຂົ້າຮ່ວມຄົນລາວ, ດຳເນີນຢູ່ ນະຄອງຫລວງວຽງຈັນ, ສປປລາວ, ຈະໃຊ້ເວລາພຽງແຕ່ 1 **ເດືອນ ລະຫວ່າງວັນທີ່** 12 **ພະຈິກ** – 12 **ທັນວາ ປີ** 2019 ດັ່ງທີ່ລະບຸໄວ້ໃນມາດຕາ 5 ຂອງສັນຍາສະບັບນີ້. ການຄົ້ນຄ້ວາວິໃຈນີ້ ມີຈຸດປະສົງ ທີ່ຈະສຶກສາຊອກຄົ້ນຂະບວນການເຊື່ອມໂຍງລະບົບຖານຂໍ້ມູນເຊີງ ພື້ນທີ່ ເພື່ອມາບໍລິຫານຈັດການ ຂໍ້ມູນການຄຸ້ມຄອງນຳໃຊ້ທີ່ດິນ ແລະ ການປົກຫຸ້ມໜ້າດິນ ໃນ ສປປລາວ ແລະ ປະເມີນປະສິດທິພາບ /ປະສິດທິຜົນຂອງການທົດລອງນີ້ ອີງຕາມການຈຳລອງ ສະຖານະການທີ່ໄດ້ອອກແບບໄວ້.
2) ການຄົ້ນຄ້ວາວິໃຈນີ້ ຈະທຳການທົດລອງ ວິທີການທີ່ນຳສະເໜີ ກັບບັນດາຫ້ອງການທີ່ເຂົ້າຮ່ວມເປັນ ໄປໄລຍະເວລາ 1 ເດືອນ ໂດຍການໂອນຂໍ້ມູນທີ່ມີ ເຂົ້າໄປໃນລະບົບຖານຂໍ້ມູນ ແລະ ຫຼັງຈາກນັ້ນຈະ ທຳການປະເມີນ ວັດແທກຄວາມສາມາດ ປະສິດທິພາບ ແລະ ປະສິດທິຜົນ. ນອກນັ້ນ, ຂໍ້ມູນທີ່ໄດ້ ຈາກການສຳພາດ ຈະຖືກນຳມາໃຊ້ ເພື່ອປະເມີນຄວາມພຶງພໍໃຈຂອງຜູ້ເຂົ້າຮ່ວມຕໍ່ກັບລະບົບດັ່ງກ່າວ.
3) **ທີມງານຄົ້ນຄ້ວາຢູ່ລາວ** (2) ,ນັກຄົ້ນຄ້ວາ (1) ຈະປະກອບມີ :ພະນັກງານວິຊາການຂະແໜງປ່າໄມ້ , (3)ພະນັກງານວິຊາການຂະແໜງຄຸ້ມຄອງ ແລະ ພັດທະນາທີ່ດິນກະສິກຳ, ພະແນກກະສິກຳ ແລະ ປ່າໄມ້ທີ່ມີຫ້ອງການປະຈຳທີ່ຫຼວງພະບາງ, ສປປລາວ.

5) **ເງື່ອນໄຂ ແລະ ຂອບເຂດ**

ສັນຍາສະບັບນີ້ ແມ່ນມີຜົນສັກສິດ ລະຫວ່າງ **ວັນທີ່ 12 ພະຈິກ – 12 ທັນວາ ປີ 2019** ນອກຈາກຈະ ໄດ້ຖືກຂະຫຍາຍໄລຍະເວລາອອກໄປ ຫຼື ຖືກຍົກເລີກກ່ອນເວລາທີ່ກຳນົດ ໂດຍການເຫັນດີຈາກທັງສອງຝ່າຍ ອີງຕາມມາດຕາ 15 ຂອງສັນຍາສະບັບນີ້. ຂອບເຂດສັນຍາສະບັບນີ້ ແມ່ນມີຜົນສະເພາະຕາມໄລຍະເວລານີ້ ເທົ່ານັ້ນ ແລະ ຈະໝົດຜົນສັກສິດພາຍຫຼັງສິ້ນສຸດຕາມວັນທີ່ ທີ່ກຳນົດ

6) **ໄລຍະເວລາ ແລະ ສະຖານທີ່**

ໄລຍະເວລາຂອງສັນຍາສະບັບນີ້ ແມ່ນລະຫວ່າງ **ວັນທີ່ 12 ພະຈິກ – 12 ທັນວາ ປີ 2019**, ແລະ ການຄົ້ນຄ້ວາຈະໄດ້ ດຳເນີນທີ່ ໂຄງການພັດທະນາການຜະລິດນິເວດກະສິກຳຢູ່ເຂດພູດອຍພາກເໜືອ (TABI), ພະແນກກະສິກຳແຂວງຫຼວງພະບາງ.

7) **ການປະກອບສ່ວນ**

1) ຈຳນວນເງິນທັງໝົດທີ່ນັກຄົ້ນຄ້ວາ ຍິນດີຈ່າຍໃຫ້ກັບຜູ້ເຂົ້າຮ່ວມແມ່ນ 500,000 ກີບ ເພື່ອເປັນການຕອບແທນ ຄວາມພະຍາຍາມ ແລະ ແຮງງານທີ່ໄດ້ທຸ່ມເທ ໄປກັບການຄົ້ນຄ້ວາໃນຄັ້ງນີ້. ເງິນຈຳນວນດັ່ງກ່າວຈະຈ່າຍໃຫ້ກັບຜູ້ເຂົ້າຮ່ວມພາຍຫຼັງສິ້ນສຸດການຄົ້ນຄ້ວາຢູ່ລາວ ຫລື ອີງຕາມສັນຍາສະບັບນີ້.
2) ຈຳນວນເງິນທັງໝົດທີ່ນັກຄົ້ນຄ້ວາ ຍິນດີຈ່າຍໃຫ້ກັບຜູ້ເຂົ້າຮ່ວມແມ່ນ 500,000**ກີບ** ເພື່ອເປັນ ການຕອບແທນ ຄວາມພະຍາຍາມ ແລະ ແຮງງານທີ່ໄດ້ທຸ່ມເທ ໄປກັບການຄົ້ນຄ້ວາໃນຄັ້ງນີ້. ເງິນຈຳນວນດັ່ງ ກ່າວຈະຈ່າຍໃຫ້ກັບຜູ້ເຂົ້າຮ່ວມພາຍຫຼັງສິ້ນສຸດການຄົ້ນຄ້ວາຢູ່ລາວ ຫລື ອີງຕາມສັນຍາສະບັບ ນີ້.
3) ການຈ່າຍເງິນຈະເປັນ **ເງິນສົດ** ໃຫ້ກັບຜູ້ເຂົ້າຮ່ວມແຕ່ລະຝ່າຍຕ້ອງໄດ້ເກັບໃບບິນຮັບເງິນ ເພື່ອ .ເປັນບ່ອນອີງໃນອະນາຄົດ .

8) **ອຸປະກອນ**

1) **ອຸປະກອນເຄື່ອງມື**: ອຸປະກອນຕົ້ນຕໍ ທີ່ຈະນຳໃຊ້ໃນການຄົ້ນຄ້ວານີ້ ແມ່ນຄອມພິວເຕີພົກພາ ຂອງນັກຄົ້ນຄ້ວາ ທີ່ຈະໃຊ້ເປັນສ່ວນໃຫຍ່. ແຕ່ຢ່າງໃດກໍ່ຕາມ, ຜູ້ເຂົ້າຮ່ວມ ສາມາດນຳໃຊ້ຄອມພິວເຕີ ຂອງຕົນຫລື ຂອງອົງກອນ ກໍ່ໄດ້ຖ້າມີ. ນອກນັ້ນ ພະແນກໄອທີ ຂອງອົງກອນຂອງຜູ້ເຂົ້າຮ່ວມ ອາດຈະຍັງປະກອບມີຄອຍພິວເຕີ ທີ່ສາມາດເກັບຂໍ້ມູນລວມສູນ (NAS) ແລະ ສາມາດເຂົ້າເຖິງໄດ້ຫລາຍຄົນ ຜ່ານລະບົບອິນເຕີເນັດ.
2) **ຊອບແວຣ**: ການຄົ້ນຄ້ວານີ້ ຈະປະຍຸກໃຊ້ລະບົບຊອບແວໂອເພັນຊອດສ ເຊິ່ງບໍ່ມີຄ່າໃຊ້ຈ່າຍໃດໃດ. ສະນັ້ນ .ສາ ມາດຊອກຫາ ແລະ ດາວໂຫລດໂປຼແກມເຫຼົ່ານີ້ໄດ້ຈາກເວັບໄຊ ,ຊອບແວຈະຕ້ອງໄດ້ຕິດ ຕັ້ງລົງໃສ່ເຄື່ອງຄອມພິວເຕີ ກ່ອນດຳເນີນການຄົ້ນຄ້ວານີ້.
3) **ການເຊື່ອມຕໍ່ອິນເຕີເນັດ**: ໃນກໍລະນີທີ່ການເຊື່ອມຕໍ່ອິນເຕີເນັດ ທີ່ຫ້ອງການຂອງກົມ ບໍ່ສະຖຽນ ແລະ ບໍ່ສະດວກຕໍ່ການເຮັດວຽກຂອງນັກຄົ້ນຄ້ວາ ແລະ ຜູ້ເຂົ້າຮ່ວມ. ນັກຄົ້ນຄ້ວາຈະຈັດຫາອຸປະກອນເຊື່ອມ ຕໍ່ອິນເຕີເນັດ 4G ເພື່ອມາເຊື່ອມຕໍ່ທົດແທນ ການລະບົບອິນເຕີເນັດຫ້ອງການ ແລະ ,ນັກຄົ້ນຄ້ວາຈະຮັບຜິດຊອບເຕີມເງິນເພື່ອຊື້ດາຕາ.

9) **ພັນທະໜ້າທີ່**

1) **ພັນທະຂອງນັກຄົ້ນຄ້ວາ**: ນັກຄົ້ນຄ້ວາ ມີຄວາມຮັບຜິດຊອບໃນການຈັດຕັ້ງປະຕິບັດພັນທະ ທັງໝົດ ທີ່ໄດ້ລະບຸໃນສັນຍາສະບັບນີ້ ,ສຳຄັນໄປກວ່ານັ້ນ .ນັກຄົ້ນຄ້ວາຕ້ອງແມ່ນ**ຜູ້ນຳພາໂດຍລວມ** ໃນການ ຈັດຕັ້ງປະຕິບັດຄົ້ນຄ້ວາໃນຄັ້ງນີ້ .ນັກຄົ້ນຄ້ວາຕ້ອງຮັບປະກັນວ່າທຸກກິດຈະກຳຄົ້ນຄ້ວາ ແມ່ນໄດ້ປະຕິ ບັດໄປຕາມກອບເວລາທີ່ກຳນົດ.
2) ນັກຄົ້ນຄ້ວາ **ຕ້ອງໄດ້ຊຳລະເງິນ** ໃຫ້ກັບຜູ້ເຂົ້າຮ່ວມ ພາຍຫຼັງສິ້ນສຸດການຄົ້ນຄ້ວາຢູ່ລາວ ດັ່ງທີ່ໄດ້ລະບຸໄວ້ໃນມາດຕາ 7 ຂອງສັນຍາສະບັບນີ້.
3) **ພັນທະຂອງຜູ້ເຂົ້າຮ່ວມ** ,ພາຍໃຕ້ສັນຍະສະບັບນີ້ ,ຜູ້ເຂົ້າຮ່ວມ :ແມ່ນມີຄວາມມຸ່ງໝັ້ນໃນການຄົ້ນຄ້ວານີ້, ສະນັ້ນຈະຕ້ອງໄດ້ຊ່ວຍ ປະສານງານ ອຳນວຍຄວາມສະດວກ ຕໍ່ບັນດາກິດຈະກຳການຄົ້ນຄ້ວາ ເຊັ່ນ ກະກຽມສະຖານທີ່ ສິ່ງອຳນວຍຄວາມສະດວກ.ເອກະສານ ແລະ ການນັດໝາຍຕ່າງໆ ,

10) **ຂໍ້ມູນທີ່ເປັນຄວາມລັບ**

1) ນັກຄົ້ນຄ້ວາ ເຂົ້າໃຈດີວ່າ ລາວຈະໄດ້ຮັບຂໍ້ມູນທີ່ມີເຈົ້າຂອງ ແລະ ຂໍ້ມູນທີ່ເປັນຄວາມລັບ ຂໍ້ມູນຄວາມ) ລັບ ຈາກບັນດາຜູ້ເຂົ້າຮ່ວມ (ຫຼື ຈາກອີງກອນຂອງພວກເຂົາເຈົ້າເພື່ອການດຳເນີນການຄົ້ນຄ້ວາໃນຄັ້ງນີ້. ນັກຄົ້ນຄ້ວາ ຕົກລົງ ວ່າຈະຮັກສາຂໍ້ມູນດັ່ງກ່າວເປັນຄວາມລັບ ແລະ ຈະບໍ່ ເປີດເຜີຍ ສິ່ງຕໍ່ໃຫ້ກັບພາກສ່ວນທີ່ສາມ ຫຼື ນຳໄປໃຊ້ໃນລັກສະນະສ່ວນຕົວ ໂດຍປາສະຈາກການຍິນຍອມຈາກຜູ້ເຂົ້າຮ່ວມ.
2) ເອກະສານໜັງສືຍິນຍອມ ທີ່ຜູ້ເຂົ້າຮ່ວມໄດ້ເຊັນ ຈະຖືກເກັບຮັກສາໄວ້ທີ່ຫ້ອງການ ຂອງອາຈານທີ່ປຶກສາສຳຮອງທີ່ຄະນະວິທະຍາສາດສຸຂະພາບ ແລະ ສິ່ງແວດລ້ອມ ມະຫາວິທະຍາໄລເຕັກໂນໂລຊີໂອກ , ແລນເປັນໄລຍະເວລາ ອາຈານທີ່ປຶກສາສຳຮອງ ຈະທຳການທຳ ,ປີນີ້ 6 ພາຍຫຼັງສິ້ນສຸດໄລຍະ .ປີ 6ລາຍໜັງສືຍິນຍອມນີ້ທັງໝົດ.
3) ນັກຄົ້ນຄ້ວາ ຕົກລົງ ຖ້າມີການຮຽກຮ້ອງເປັນລາຍລັກອັກສອນ ໃຫ້ສົ່ງຄືນ ຂໍ້ມູນຄວາມລັບທັງໝົດ , ຫລື ສ່ວນໃດໜຶ່ງພາຍຫຼັງສິ້ນສຸດການຄົ້ນຄ້ວາ ຈາກອຸປະກອນເກັບຮັກສາຂໍ້ມູນທັງໝົດ, ຕ້ອງໄດ້ສົ່ງຄືນໃຫ້ກັບຜູ້ເຂົ້າຮ່ວມ. ໃນກໍລະນີທີ່ເກັບຮັກສາໄວ້ໃນຮາດດິດສ, ແມ່ນຈະຕ້ອງໄດ້ລຶບຂໍ້ມູນທັງໝົດພາຍຫລັງທີ່ໄດ້ສົ່ງຂໍ້ມູນໃຫ້ກັບຜູ້ເຂົ້າຮ່ວມ. ພັນທະໃນການເກັບຮັກສາຂໍ້ມູນຄວາມລັບ ແມ່ນມີໄລຍະເວລາ 6 ປີ ພາຍຫຼັງສິ້ນສຸດສັນຍາສະບັບນີ້ ຫຼື ມີການຍົກເລີກສັນຍາກ່ອນກຳນົດ.
4) ຖ້າຝ່າຍໃດໜຶ່ງ ຕ້ອງການທີ່ຈະຕີພິມ ຜົນການຄົ້ນຄ້ວາວິໃຈ ໃນເວລະສານວິຊາການ ຫຼື ການສຶກສາຂໍ້ , ມູນຄວາມລັບ ເຊິ່ງເປັນທີ່ລະອຽດອ່ອນຕໍ່ກັບອີກຝ່າຍ ແມ່ນຈະຕ້ອງບໍ່ຖືກຕີພິມ ,ໂດຍປາສະຈາກ ການຍິນຍອມ.

11) **ການປ້ອງກັນຂໍ້ມູນຄວາມເປັນສ່ວນຕົວ**

1) ດັ່ງທີ່ລະບຸໃນເອກະສານ ຂໍ້ມູນການຄົ້ນຄ້ວາວິໃຈ, ຜູ້ເຂົ້າຮ່ວມຈະມີທາງເລືອກວ່າ ທ່ານຕ້ອງການ ໃຫ້ຜົນການຄົ້ນ ຄ້ວາສາມາດລະບຸຄວາມເປັນຕົວທ່ານ ຫລື ບໍ່. ນອກນັ້ນ, ຜູ້ເຂົ້າຮ່ວມມີສິດທີ່ ຈະບໍ່ຕອບຄຳຖາມ ຖ້າຮູ້ສຶກວ່າ ຄຳຖາມນັ້ນບໍ່ເໝາະສົມ ເຊິ່ງອາດເກີດຂຶ້ນໄດ້ໃນເວລາສຳພາດ. ຖ້າມີການສຳພາດຄຳຖາມລັກສະນະສ່ວນຕົວ ແມ່ນຈະຕ້ອງໄດ້ດຳເນີນໃນຫ້ອງສ່ວນຕົວ.

2) ໃນກໍລະນີທີ່ ຜູ້ເຂົ້າຮ່ວມຍົກເລີກສັນຍາການຄົ້ນຄ້ວາກ່ອນກຳນົດ, ຜູ້ເຂົ້າຮ່ວມມີສິດສະເໜີໃຫ້ລຶບ ຂໍ້ມູນ ທີ່ສາມາດລະບຸຄວາມເປັນຕົວຕົນອອກຈາກການຄົ້ນຄ້ວາ ເວັ້ນເສຍແຕ່ວ່າໄດ້ສຳເລັດການວິ ເຄາະຂໍ້ມູນແລ້ວ.

3) ນັກຄົ້ນຄ້ວາມີພັນທະໃນການປົກປ້ອງຂໍ້ມູນທີ່ສາມາດລະບຸຄວາມເປັນຕົວຕົນຂອງຜູ້ເຂົ້າຮ່ວມ ລວມທັງອີງກອນຂອງລາວ ບໍ່ວ່າຈະເກີດກໍລະນີໃດໃດກໍ່ຕາມ.

12) ການປ້ອງກັນຂໍ້ມູນຄວາມເປັນສ່ວນຕົວ

ນັກຄົ້ນຄ້ວາ ຈະແຈ້ງໃຫ້ຜູ້ເຂົ້າຮ່ວມຮັບຊາບຜົນການຄົ້ນຄ້ວາ ແລະ ຜົນໄດ້ຮັບ ທີ່ໄດ້ຈາກການຄົ້ນຄ້ວາເປັນໄລຍະຢ່າງສະໜໍ່າສະເໝີ ໂດຍຈະສື່ສານລາຍງານໃນຮູບແບບທີ່ສອງຝ່າຍໄດ້ຕົກລົງ. ເຖິງຢ່າງໃດກໍ່ຕາມຜູ້ ເຂົ້າຮ່ວມ ຕ້ອງໄດ້ພະຍາຍາມຮັກສາຜົນໄດຮັບ ແລະ ສິ່ງທີ່ຄົ້ນພົບ ຈາກການຄົ້ນຄ້ວາວິໃຈ ເປັນຄວາມລັບ ດັ່ງທີ່ໄດ້ລະບຸໄວ້ໃນມາດຕາ 10 ຂອງສັນຍາສະບັບນີ້ ເວັ້ນເສຍແຕ່ໄດ້ລະບຸເປັນຢ່າງອື່ນ ແບບເປັນລາຍລັກອັກສອນຈາກທັງສອງຝ່າຍ.

13) ສັບສິນທາງປັນຍາ ແລະ ຄວາມເປັນເຈົ້າຂອງ

1) ສັບສິນທາງປັນຍາກ່ອນໜ້ານີ້ ທີ່ເປັນຂອງຝ່າຍໃດໜຶ່ງ ທີ່ໄດ້ຖືກພັດທະນາ, ສ້າງຂຶ້ນ ຫລື ລວບລວມມາໄດ້ ກ່ອນການດຳເນີນການຄົ້ນຄ້ວານີ້ ແມ່ນບໍ່ກ່ຽວຂ້ອງກັບເນື້ອໃນສັນຍາສະບັບນີ້.

2) ຝ່າຍໃດໜຶ່ງ ອາດນຳໃຊ້ ສັບສິນທາງປັນຍາກ່ອນໜ້ານີ້ຂອງອີກຝ່າຍ ເພື່ອຜົນປະໂຫຍດຂອງການຄົ້ນຄ້ວາຄັ້ງນີ້ເທົ່ານັ້ນ ເຊິ່ງຈະບໍ່ສົ່ງຜົນສະທ້ອນຫຍັງ ຕໍ່ກັບສັບສິນທາງປັນຍາກ່ອນໜ້ານີ້ ແລະ ສິດຄວາມເປັນເຈົ້າຂອງ.

3) ສັບສິນທາງປັນຍາທີ່ເກີດຂຶ້ນ ທີ່ໄດ້ພັດທະນາະ, ສ້າງຂຶ້ນ ຫຼື ໄດ້ມາ ໂດຍບຸກຄົນ ຫຼື ສະມາຊິກໃນທີມງານຂອງຝ່າຍໜຶ່ງ ໃນຊ່ວງການດຳເນີນສັນຍາສະບັບນີ້, ແມ່ນ ຈະເປັນສັບສິນທາງປັນຍາ ຂອງຝ່າຍນັ້ນໂດຍອີງຕາມລະບຽບການ ແລະ ສັນຍາທີ່ກ່ຽວຂ້ອງ.

4) ສັບສິນທາງປັນຍາທີ່ເກີດຂຶ້ນ ທີ່ໄດ້ພັດທະນາະ, ສ້າງຂຶ້ນ ຫຼື ໄດ້ມາ ແບບສ່ວນລວມໂດຍບຸກຄົນ ຫຼື ສະມາຊິກໃນທີມງານ ຂອງສອງຝ່າຍ ໃນຊ່ວງການດຳເນີນສັນຍາສະບັບນີ້, ແມ່ນ ຈະເປັນສັບສິນທາງປັນຍາ ຮ່ວມກັນຂອງສອງຝ່າຍ.

5) ໃນເມື່ອສິ້ນສຸດການຄົ້ນຄ້ວາວິໃຈຢູ່ສປປລາວ, ນັກຄົ້ນຄ້ວາຈະມອບສິດໃນການເຂົ້າເຖິງ ແລະ ຄວາມເປັນເຈົ້າຂອງ ໃຫ້ກັບແຕ່ລະຫ້ອງການທີ່ເຂົ້າຮ່ວມການຄົ້ນຄ້ວາ ຄັ້ງນີ້ ໂດຍການໂອນຖ່າຍ ລະບົບຖານຂໍ້ມູນເຊີງພື້ນທີ່ ໃສ່ຄອມພິວເຕີທີ່ເປັນສ່ວນກາງ ຫລື ລະບົບ (NAS) ຖ້າເປັນໄປໄດ້ ແລະ ມີເງື່ອນໄຂພຽງພໍ. ແຕ່ຢ່າງໃດກໍ່ຕາມ ລະບົບທີ່ພັດທະນາຂຶ້ນມານີ້ ຍັງຖືວ່າເປັນເຈົ້າຂອງລວມ ລະຫວ່າງ ນັກຄົ້ນຄ້

ວາ ແລະ ຜູ້ເຂົ້າຮ່ວມ ເພາະວ່ານັກຄົ້ນຄ້ວາ ຍັງຕ້ອງໄດ້ທຳການວິເຄາະ ແລະ ປະ ເມີນປະສິດທິພາບ ເພື່ອປະກັບໃສ່ຫົວບົດຈົບຊັ້ນ.

14) ການຕີພິມຜົນການຄົ້ນຄ້ວາວິໃຈ

1) ທັງສອງຝ່າຍ ເອກະພາບຮັບຮູ້ເຖິງຄວາມສຳຄັນຂອງການຕີພິມຫົວບົດຄົ້ນຄ້ວາ ໃນເວລະສານວິຊາການ ເວັບໄຊທາງການສຶກສາ ຫລື ຮູບໃບໃດໜຶ່ງ ທີ່ເໝາະສົມ ແລະ ການອຳນວຍຄວາມສະດວກ , ໃຫ້ນັກສຶກສາ ໄດ້ນຳສະເໜີ ບົດວິທະຍານິພົນ ໂດຍປາສະຈາກການລ່າຊ້າ.
2) ຖ້າການຄົ້ນຄ້ວາວິໃຈ ຈະຖືກຕີພິມຮ່ວມ ການປະພັນ ແລະ ການປະກອບສ່ວນຂອງການຄົ້ນຄ້ວາ ,ວິໃຈ ຈະຖືກກຳນົດຕາມມາດຕະຖານດ້ານການສຶກສາ ແລະ ການຈັດຕັ້ງປະບັດຜ່ານມາ. ຈຳເປັນ ຕ້ອງມີການອ້າງອີງຢ່າງແທດເໝາະ ໃຫ້ກັບການປະກອບສ່ວນຂອງແຕ່ລະຝ່າຍ.
3) ແຕ່ຖ້າກໍລະນີທີ່ ການຄົ້ນຄ້ວາວິໃຈ ຈະບໍ່ຖືກຕີພິມຮ່ວມ ,ຝ່າຍຈະຕີພິມ ຕ້ອງໄດ້ແຈ້ງອີກຝ່າຍໜຶ່ງ ເປັນລາຍລັກອັກສອນ 30 ວັນ ພ້ອມດ້ວຍເນື້ອໃນ ແລະ ບົດຄັດຫຍໍ້ຂອງການຄົ້ນຄ້ວາທີ່ຈະຕີພິມ, ເພື່ອເປັນການເປີດໂອກາດໃຫ້ອີກຝ່າຍມີເວລາທົບທວນເນື້ອໃນ ແລະ ສັບສົນທາງປັນຍາ ເຊິ່ງອາດ ຈະຖືກຕີພິມລົງໃນເນື້ອໃນ ແລະ ບົດຄັດຫຍໍ້ຂອງການຄົ້ນຄ້ວາດັ່ງກ່າວ.

15) ການຍົກເລີກສັນຍາ

ຝ່າຍໃດຝ່າຍໜຶ່ງ ມີສິດທີ່ຈະຍົກເລີກສັນຍາສະບັບນີ້ ເຊິ່ງໝາຍຄວາມວ່າເປັນອັນສິ້ນສຸດພັນທະ ແລະ ການເຂົ້າຮ່ວມການຄົ້ນຄ້ວາວິໃຈນີ້ ໂດຍແຈ້ງກ່ອນລ່ວງໜ້າ ວັນ 5ແບບເປັນລາຍລັກອັກສອນ ເຊິ່ງອາດ ຈະໃຫ້ ຫລື ບໍ່ໃຫ້ເຫດຜົນຂອງການຂໍຍົກເລີກສັນຍາໝາຍຄວາມວ່າຈະ .ສິ້ນສຸດພັນທະ ແລະ ຜົນສັກສິດ ທັງໝົດທີ່ມີ ຮອດພຽງແຕ່ມື້ແຈ້ງຍົກເລີກສັນຍາ.

<u>ຂໍ້ມູນຕິດຕໍ່:</u>

ທີມງານຄົ້ນຄ້ວາ

- ທ່ານ ດຣ ແບຼດລີ່ ເຄດສ - ອາຈານທີ່ປຶກສາຕົ້ນຕໍ Bradley.case@aut.ac.nz, ໂທລະສັບ 09-9219999 ຕໍ່ 5231
- ທ່ານ ກຼາແຮມ ຮິນຄລິບ - ອາຈານທີ່ປຶກສາສຳຮອງ Graham.hinchliffe@aut.ac.nz, ໂທລະສັບ 09-9219999 ຕໍ່ 9627
- ທ່ານ ກອງແກ້ວ ສີວິໄລ - ນັກຄົ້ນຄ້ວາ Kongkeo.s@gmail.com, ໂທລະສັບ: +85620-55552719 (ເບີລາວ)

  ເຮືອນເລກທີ່ 11 ຖະໜົນນິເກົາ, ເຂດອີເດນເທີເຣດສ, ເມືອງໂອກແລນ, ປະເທດນິວຊີແລນ 1021 (ທີ່ຢູ່ປະເທດນິວຊີແລນ)
  ບ້ານສີສະຫວາດ, ຖະໜົນທົ່ງສ້າງນາງ, ເມືອງຈັນທະບູລີ, ນະຄອນຫລວງວຽງຈັນ, ສປປລາວ (ທີ່ຢູ່ປະເທດລາວ)

ທີມງານຜູ້ເຂົ້າຮ່ວມ

- ທ່ານ ສົມຫວັງ ແກ້ວດາລາ - ພະນັກງານວິຊາການ ຂະແໜງຄຸ້ມຄອງ ແລະ ພັດທະນາທີ່ດິນກະສິກຳ
- ທ່ານ ໄຊຍະສິດ .- ພະນັກງານວິຊາການ ຂະແໜງປ່າໄມ້

ໂດຍມີພະຍານຈາກທັງສອງຝ່າຍເຂົ້າຮ່ວມເປັນສັກຂີພິຍານທັງສອງຝ່າຍຈຶ່ງຕົກລົງເຊັນສັນຍາ ເພື່ອເຮັດໃຫ້ສັນຍາ , .ສະບັບນີ້ມີຜົນສັກສິດ ນັບແຕ່ວັນທີ່ທີ່ລົງລາຍເຊັນ

<u>ເຫັນດີ ຕົກລົງ ແລະ ເຊັນສັນຍາ:</u>

ນັກຄົ້ນຄ້ວາ - ທ່ານກອງແກ້ວ ສີວິໄລ

(ລາຍເຊັນ)

ວັນທີ່…………………………………

ຜູ້ເຂົ້າຮ່ວມ – ທ່ານ. ສົມຫວັງ ແກ້ວດາລາ -

ພະນັກງານວິຊາການ ຂະແໜງຄຸ້ມຄອງ ແລະ ພັດທະນາທີ່ດິນກະສິກຳ

+85620-56658777

ວັນທີ່…………………………………

ຜູ້ເຂົ້າຮ່ວມ – ທ່ານ ໄຊຍະສິດ .- ພະນັກງານວິຊາການ ຂະແໜງປ່າໄມ້

+85620-55175152

ວັນທີ່……………………………………

<u>ພະຍານ:</u>

ຊື່:	ຊື່:
(ລາຍເຊັນ ແລະ ອົງກອນບ່ອນເຮັດວຽກ)	(ລາຍເຊັນ ແລະ ອົງກອນບ່ອນເຮັດວຽກ)
ວັນທີ່………………………………	ວັນທີ່……………………………………

Appendix E: Test scenarios

Testing scenario	Scenario-based performance testing
DALAM, MAF, Vientiane, LA ❖ **<u>Scenario 1</u>**: measuring the improvements over the current practice.	**I.** Standard GIS operations 1. GUI geometry editing directly from the database via QGIS 3.6 2. Perform standard spatial operation such as merge, union, clip, dissolve. **II.** Testing spatial query and analysis for specific tasks: 1. Calculate the statistics of village land-use management plans/land cover data, 3 forest categories (3FC) and export into tabular format. 2. Perform spatial analysis such as spatial correlation, spatial clustering heatmap. 3. Perform spatial join between land-use/land cover and land classes table
❖ **<u>Scenario 2</u>**: testing new functionality.	**III.** Testing spatial queries between multiple spatial dataset. 3.1 **List all the village locations** in relation to the management zones of the 3FC (national conservation, protection and production forest). 3.2 **Calculate statistics** of villages which has completed land-use management plan in comparison with the 3FC. 3.3 **Locate and summarise the upland agriculture area** for village clusters which have relative risks to deforestation, comparing with the digitized upland cultivation area to monitor their conformance to the land-use management plans. **IV.** Testing queries between spatial and non-spatial data. 4.1 **Find the villages** with highest quantity of agroforestry products harvesting for a particular region (district, province), sort them by income and quantity; and display their location on the map. 4.2 **Find the villages** of a particular region based on socio-economic, agroforestry and demographic statistics. For example, population living in poverty, high number of unemployed individuals, high population density, etc. and display their location on the map.

Appendix F: PSEUDO Code to guide writing SQL codes that could address the scenario-based evaluations.

	<u>Scenario 1</u>:	**Performance measurement**
1	Getting things ready.	• Import relevant libraries • Use psycopg2 for database connection – connect to postgres database • List all existing databases. • Create if a database named "spatial_database " using if not exists function; • Create schemas to store all relevant shapefiles. • Use DB Manager on QGIS (GUI) to import tables into respective schemas.
2	Standard GIS operations	• Editing/create features with datasets connected to remote database • Perform standard spatial operations (merge, clip, dissolve)
3	Testing standard spatial query and analysis **List all the village locations** in relation to the management zones of the 3FC (national conservation, protection and production forest).	• Perform spatial join to obtain the number of villages within a particular forest area. • Select NPA name, zone name and village name From NPA table and village location; • Join NPA using ST_Contains (geometry)
4	**Calculate statistics** of villages which has completed land-use management plan in comparison with the 3FC.	• Select CLUFC and FLUMZ overview, village name, From LULC and sort the following land typology; (1) Fixed agriculture (2) Upland agriculture (3) Forestry land (4) Other land ❖ Do the same for land-use zoning features. • Select CLUFC and FLUMZ, FROM LULC JOIN FLUMZ-join-table;
	<u>Scenario 2</u>:	❖ **Performance measurement**
5	**Locate and summarise the upland agriculture area** for village clusters which have relative risks to deforestation, comparing with the digitized upland cultivation area to	• Select CLUFC and FLUMZ overview, village name, From LULC and sort the following land typology; (5) Fixed agriculture (6) Upland agriculture (7) Forestry land

	monitor their conformance to the land-use management plans	(8) Other land ❖ Do the same for land-use zoning features. • Select CLUFC and FLUMZ, npa_name, FROM LULC JOIN NPA WHERE ST_DISTANCE
6	**Find the villages** with highest quantity of agroforestry products harvesting for a particular region (district, province), sort them by income and quantity; and display their location on the map.	• Select village name, NTFP FROM village location INNER JOIN SE.NTFP on vil_code WHERE sorting quantity GROUP BY village name ORDER BY NTFP quantify.
7	**Find the villages** or region based on socio-economic/demographic census data. E.g poverty, unemployment rate, etc.	• Select village name, NTFP FROM village location INNER JOIN SE.NTFP on vil_code WHERE sorting quantity GROUP BY village name ORDER BY NTFP quantify.
8	**Locate and summarise the upland agriculture area** for village clusters which have relative risks to deforestation, comparing with the digitized upland cultivation area to monitor their conformance to the land-use management plans	• Select village name, CLUFC/FLUMZ FROM LULC JOIN NPA village location. WHERE ST_CONTAINS AND ST_DISTANCE.

SQL Codes developed for the performance evaluations.

 # Create Indexing using GIST (Generalised Search Tree) scheme for all geometric features that were part of the scenario-based testing

```
CREATE INDEX spatial_indexing
ON forestry.national_conservation
USING GIST (geom);
```

Using this function to perform the rest of features.

 # Scenario 1

- List the village locations in relation to the 3FC

- *Get total number of villages in relation to any given three forest category (3FC)*

```
SELECT COUNT(a.geom)
FROM admin.vil_location AS a
JOIN forestry.national_conservation AS b
ON ST_Within(ST_Transform(a.geom, 32648), ST_Transform(b.geom, 32648));
Or – to list the village names
SELECT a.vname, a.village
FROM admin.vil_location AS a
JOIN forestry.national_conservation AS b
ON ST_Within(ST_Transform(a.geom, 32648), ST_Transform(b.geom, 32648));
```

- *List village or get total number of villages within a specific national protected area (E.g Namha NPA) and export into a new table*

```
SELECT a.vname, a.village, a.geom, b.lao_name, b.eng_name INTO
forestry.village_namha_npa
FROM admin.vil_location AS a
JOIN forestry.national_conservation AS b
ON ST_Within(ST_Transform(a.geom, 32648), ST_Transform(b.geom, 32648))
WHERE b.eng_name = 'Namha';
```

- *List village or get total number of villages within a specified NPA and respective management zone.*

```
SELECT a.vname, a.village, a.geom, b.eng_name, c.zone, c.name_lao
FROM admin.vil_location AS a
JOIN forestry.national_conservation AS b
INNER JOIN forestry.npa_mgt_zone AS c USING (npa_id)
ON ST_Within(ST_Transform(a.geom, 32648), ST_Transform(c.geom, 32648))
WHERE c.npa_id = 'npa12' AND c.zone = 'TPZ';
```

#Scenario 2

- Find the villages with highest quantity of agroforestry products harvesting for a particular region (district, province), sort them by income and quantity; and display on the map.

- *List village according to highest quantity of **NTFP and income**,*

```
SELECT v.vname, v.village, v.geom, n.ntfp_laoname, n.sci_name, n.unit,
n.qty_total, n.price_all
FROM admin.vil_location AS v
INNER JOIN se.se_ntfp AS n ON n.vil_code = v.vil_code
WHERE n.qty_total IS NOT NULL AND n.price_all IS NOT NULL
GROUP BY v.vname, v.village, v.geom, n.ntfp_laoname, n.sci_name, n.unit, n.qty_total,
n.price_all
ORDER BY n.qty_total DESC, n.price_all DESC, v.vname;
```

- *List village according to status and its percentage of **aquatic species**, except the records that contain null values*

```
SELECT v.vname, v.village, v.geom, a.species_laoname, a.species_engname,
a.status_la, a.status_percent, a.reason_la
FROM admin.vil_location AS v
INNER JOIN se.se_aquatic AS a ON a.vil_code = v.vil_code
WHERE a.status_la IS NOT NULL AND a.status_percent IS NOT NULL
GROUP BY v.vname, v.village, v.geom, a.species_laoname, a.species_engname,
a.status_la, a.status_percent, a.reason_la
ORDER BY a.status_percent DESC, v.vname;
```

- *List village according to highest quantity of **income***

```
SELECT v.vname, v.geom, SUM(income.sell_rice) AS total_rice_sale,
SUM(income.sell_fish) AS total_fish_sale, SUM(income.other_produce) AS
total_other_produce_sale, SUM(income.sell_ntfp) AS total_ntfp_sale,
SUM(income.sell_charcoal) AS total_charcoal_sale, SUM(income.sell_wood) AS
total_wood_sale, SUM(income.handicratf) AS total_handicraft_income,
SUM(income.business) AS total_business_income, SUM(income.labour) AS
total_labour_income, SUM(income.salary) AS total_salary_income, SUM
```

```
(income.others) AS total_other_income, SUM(income.from_overseas) AS
total_overseas_income
FROM admin.vil_location AS v
INNER JOIN se.se_income AS income ON income.vil_code = v.vil_code
GROUP BY v.vname, v.geom
ORDER BY v.vname ASC;
```

- *List village according to highest quantity of* ***population*** *(major ethnicity, population, workforce, rice requirement and livestock)*

```
SELECT v.vname, p.vil_code, SUM (p.tot_mem) AS totalpop, SUM (p.lab_main) AS
totalmainlabor, SUM (p.lab_2nd) AS totalseclabor, mode () WITHIN GROUP (ORDER BY
p.ethnic_hus_lao) AS mainethnicity, mode () WITHIN GROUP (ORDER BY
p.occu_main_lao) AS mainoccupation, mode () WITHIN GROUP (ORDER BY
p.occu_2nd_lao) AS secondaryoccupation, mode () WITHIN GROUP (ORDER BY
p.rice_def_kg) AS ricerequirement_kg
FROM admin.vil_location AS v
RIGHT JOIN se.se_population AS p USING (vil_code)
GROUP BY v.vname, p.vil_code
ORDER BY v.vname;
```

- *List village according to highest quantity of* ***wildlife*** – return significant species and their status which are currently being consumed in the village, more than 55 household in the village.

```
SELECT v.vname AS VillageName, v.geom, w.species_laoname AS species_in_lao,
w.forest_type AS as_found_inforest, w.no_hh_using AS totalHH_using, w.status_lao AS
current_status
FROM admin.vil_location AS v
JOIN se.se_wildlife AS w USING (vil_code)
WHERE w.no_hh_using >= 50
GROUP BY v.vname, v.geom, w.species_laoname,w.forest_type, w.no_hh_using,
w.status_lao
ORDER BY v.vname;
```

- *List village according to highest quantity of* ***wood***

```
SELECT v.vname AS VillageName, w.species_laoname AS species_in_lao, w.sci_name AS
species_scientific_name, w.no_hh_use AS total_hh_using, w.unit AS unit, w.qty_all AS
total_quantity, w.price_all AS total_wood_income, w.as_found_inforest AS
as_found_inforest
FROM admin.vil_location AS v
JOIN se.se_wood AS w USING (vil_code)
WHERE w.no_hh_use >= 50
GROUP BY v.vname, species_in_lao, species_scientific_name, w.no_hh_use, unit,
total_quantity, total_wood_income, as_found_inforest
ORDER BY v.vname;
```

Calculate statistics of villages which has completed land-use management plan in comparison with the 3FC. Summarise village land-use statistics of four major land typology based on respective province/district

- ***Summarise*** *FLUMZ and CLUFC data and sort by district (do the same for CLUFC)*

```
SELECT flum.overview_c AS Land_typology,
```

```
flum.d_name_lao AS District_Name, SUM(ROUND(flum.area_ha)) AS AreaFLUM_Ha,
COUNT(flum.subcatz_id) AS No_of_PlotFLUM
FROM lulc.lp_flumz AS flum
GROUP BY District_Name, Land_typology
ORDER BY District_Name;
```

- ***Summarise*** *FLUMZ and CLUFC data and sort by province (do the same for CLUFC)*

```
SELECT flum.overview_c AS Land_typology,
flum.p_name_lao AS Province_Name, SUM(ROUND(flum.area_ha)) AS AreaFLUM_Ha,
COUNT(flum.subcatz_id) AS No_of_PlotFLUM
FROM lulc.lp_flumz AS flum
GROUP BY Province_Name, Land_typology
ORDER BY Province_Name;
```

- ***Determine*** *if the village land-use and cover lie within the boundary of the three forest categories (3FC)*

```
SELECT a.lao_name AS npaLaoname, a.eng_name AS npaEngname, b.v_name_lao,
COUNT(b.v_name_eng), SUM(b.area_ha), b.geom as geomB
FROM forestry.national_conservation AS a, lulc.ap_clufc AS b
WHERE ST_Intersects(a.geom, b.geom)
GROUP BY npaLaoname, npaEngname, b.v_name_lao, geomB;
```

- ***Determine*** *if any particular village land-use and cover lies within the controlled used zone (CUZ) or total protected zone (TPZ) boundary of any national protected area (NPA), and return those land-use and, total land area, NPA name if the statement is true*

```
SELECT a.v_name_lao, COUNT(a.v_name_eng), SUM(a.area_ha), a.geom, f.lao_name
    AS npaLaoname, f.eng_name AS npaEngname, f.geom, f.zone
FROM lulc.ln_clufc AS a, (
    SELECT a.lao_name, a.eng_name, b.zone, b.name_lao, b.geom
    FROM forestry.national_conservation AS a
    JOIN forestry.npa_mgt_zone AS b USING (npa_id)
    WHERE a.npa_id = 'npa12' AND b.zone = 'TPZ' OR b.zone = 'CUZ') AS f
WHERE ST_Intersects(a.geom, f.geom)
GROUP BY npaLaoname, npaEngname, a.v_name_lao, a.geom, f.zone, f.geom;
```

From above query – summarise the total land areas in the four land typology

```
SELECT a.overview_c, SUM(a.area_ha), f.lao_name AS npaLaoname, f.zone
FROM lulc.ln_clufc AS a, (
    SELECT a.lao_name, a.eng_name, b.zone, b.name_lao, b.geom
    FROM forestry.national_conservation AS a
    JOIN forestry.npa_mgt_zone AS b USING (npa_id)
WHERE a.npa_id = 'npa12' AND b.zone = 'TPZ') AS f
WHERE ST_Intersects(a.geom, f.geom)
GROUP BY a.overview_c, f.zone, npaLaoname;
```