LandSAGE Software Design and Development

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Please direct questions and comments to mores.pra@mahidol.ac.th

PART 1 – FLOOD DATA COLLECTION

Based on our research and discussion with natural disaster experts, we identified rainfall, water level, and water discharge to be the most important factors for flood monitoring. Subsequent sections describe the sources used in the data collection and the preprocessing performed on the data before importing them into the LandSAGE software.

Data Sources

MRC (Mekong River Commission) is an intergovernmental organisation established based on an agreement between Cambodia, Laos, Vietnam, and Thailand. The organisation serves as a knowledge hub of water resource management in the Lower Mekong River Basin (LMB). MRC provides various types of data for the LMB region including hydro-meteorological data (e.g. water level, discharge, rainfall, temperature, humidity), geometric data (e.g. cross-section, longitudinal profile of a river) and water quality data (e.g. sediment, salinity, turbidity, concentration, water temperature).

DWR-TH (Department of Water Resources) in Thailand is the core agency for managing water resources. DWR-TH provides daily hydro-meteorological data for flood and drought monitoring including gage height, river water level, discharge, and water depth. These data are collected from five Mekong Hydrological Cycle Observation System (Mekong-HYCOS) stations. One of the stations is in Ubon Ratchathani pilot site.

TMD (Thai Meteorological Department) is the governmental agency responsible for weather monitoring and forecasting. TMD provides climate data such as rainfall, humidity, and temperature for Ubon Ratchathani pilot site and other provinces.

DHRW (Department of Hydrology and River Works) in Cambodia is the main government agency responsible for water and weather related research. Its web portal provides daily flooding information and related warnings. Moreover, it provides monthly water level reports in the hydrograph format and graphs of daily precipitation and water level for each hydrological station.

DWR-LA (Department of Water Resources Management) in Laos is the main agency for managing water resources. DWR-LA has a web portal "LAOWIS: Lao PDR Water Information System" that provides access to public information and data related to water and aquatic environments in Laos including atlas maps related to two pilot basins: Nam Ngum and Nam Sa.

DMH (Department of Meteorology and Hydrology) in Laos is the main agency for managing weather and flood forecasting. DMH is responsible for the telemetric satellite receiving stations, hydrological stations, and earthquake stations across the country. The automated process of data acquisition involves data collection from the sensors and uploading using the GPRS network.

DWRM (Department of Water Resources Management) in Vietnam is responsible for state management of water resources, inventory, and management of a database on water resources.

NHMF (National Hydro-Meteorological Service of Vietnam) is responsible for the hydrometeorology data analysis, provision of information, and weather forecasts. NHMF has graphical reports of weather forecasts and water level and flow forecasts.

We chose MRC as our primary flood-related data source because it has rainfall, water level, and discharge datasets for the four pilot sites of LandSAGE3. We also considered the short project duration and the complexity in interacting with multiple organizations in the selection. In the future, we could use the additional data sources in KH, LA, VN, and TH to complement or supplement the data from MRC, e.g., when MRC data is incomplete.

Data Collection and Preprocessing

MRC provided 67 hydro-meteorological monitoring stations in the Lower Mekong Basin. We identified the four stations providing data for the four pilot sites as follows:

MRC stations used in LandSAGE3.

Station Name	Location	Station Code	Latitude	Longitude
Khong Chiam	Ubon Ratchathani, TH	013801	15.3220	105.4934
Chaktomuk	Phnom Penh, KH	033401	11.5629	104.9352
Tan Chau	Tan Chau, VN	019803	10.8006	105.2480
Vientiane KM4	Vientiane, LA	011901	17.9309	102.6155

These four stations provided 18 time-series datasets of rainfall, water level, and discharge, collected daily at the stations and summarized in the table below. For those factors including both manually measured (by human) and telemetry (data automatically collected by machine) datasets, we preferred the manually measured datasets because the manual measurements provided higher accuracy. Consequently, five datasets were discarded (highlighted in the table below) and only 13 were used in the project. Note that some datasets were calculated from other factors.

Thirteen MRC hydro-meteorological datasets used in LandSAGE3 (Highlighted rows indicate discarded datasets).

Station Name	Dataset	Collection Method	Start Date	End Date
Chaktomuk	Discharge	Daily, Calculated	1960	2002
Chaktomuk	Rainfall	Daily, Manual	1980	2021
Chaktomuk	Water Level	Daily, Manual	1960	2021
Chaktomuk	Water Level	Daily, Telemetry	2008	2021
Vientiane KM4	Discharge	Daily, Calculated	1913	2006
Vientiane KM4	Rainfall	Daily, Telemetry	2010	2021
Vientiane KM4	Water Level	Daily, Telemetry	2008	2021
Khong Chiam	Discharge	Daily Discharge	1966	2021
Khong Chiam	Water Level	Daily, Manual	1966	2021
Khong Chiam	Rainfall	Daily, Manual	2008	2021
Khong Chiam	Rainfall	Daily, Telemetry	2010	2021
Khong Chiam	Water Level	Daily, Telemetry	2010	2021
Tan Chau	Discharge	Daily, Calculated	2003	2006
Tan Chau	Rainfall	Daily, Manual	2007	2021
Tan Chau	Water Level	Daily, Manual	1979	2021
Tan Chau	Discharge	Daily, Manual	2009	2018
Tan Chau	Rainfall	Daily, Telemetry	2010	2021
Tan Chau	Water Level	Daily, Telemetry	2010	2021

We subsequently merged the two discharge datasets of Tan Chau into one. As a result, there were 12 datasets – three (rainfall, water level, and discharge) per pilot site. We scanned all the datasets to determine the quality of data. The results are summarized as follows:

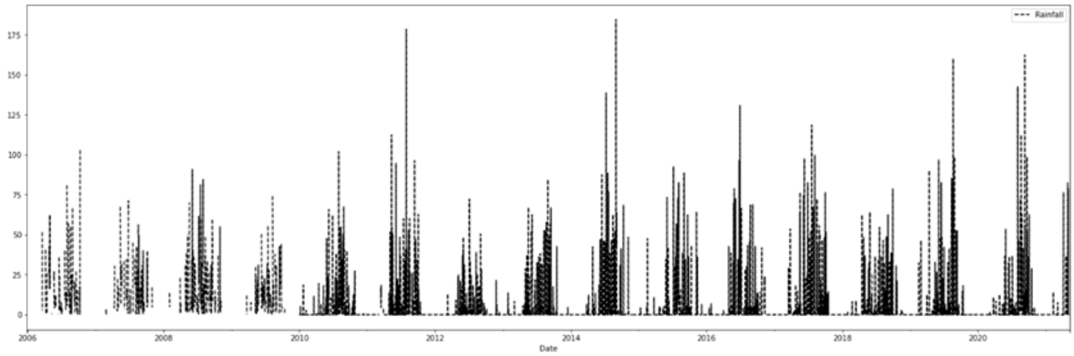
Quality of hydro-meteorological datasets obtained from MRC.

Dataset	Completeness (%)	Imputation	Downsampling
D01: Discharge – Chaktomuk	87.64	Yes	-
D02: Discharge – Vientiane	100	-	-
D03: Discharge – Tan Chau	49.57	Partially	-
D04: Discharge – Khong Chiam	100	-	-

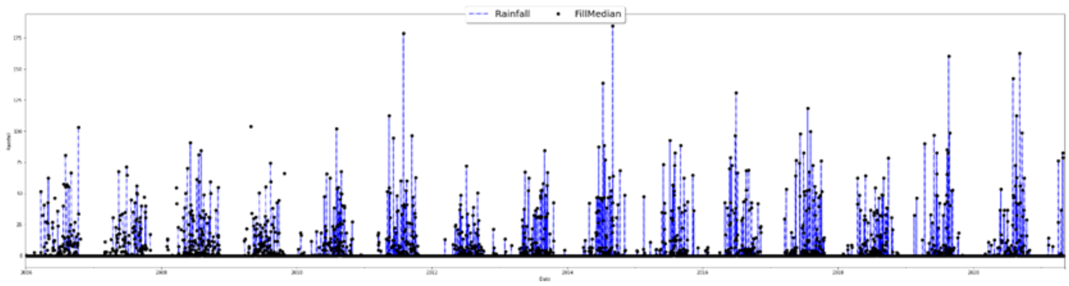
D05: Rainfall – Chaktomuk	100	-	-
D06: Rainfall – Vientiane	80.85	Yes	-
D07: Rainfall – Tan Chau	100	-	Yes
D08: Rainfall – Khong Chiam	89.6	Yes	-
D09: Water Level – Chaktomuk	100	-	Yes
D10: Water Level – Vientiane	100	-	Yes
D11: Water Level – Tan Chau	100	-	Yes
D12: Water Level – Khong Chiam	100	-	Yes

Only 3 datasets (D02, D04, D05) were complete and ready to be formatted for visualization. Each of the other datasets either had missing values or contained multiple values per day (e.g., water levels were measured 1-3 times per day in some stations). To standardize the datasets for visualization, we performed the following data preprocessing:

Imputation: Four datasets (D01, D03, D06, D08) were incomplete. We used data interpolation to fill missing values in the datasets with completeness percentage no less than 80% (D01, D06 and D08). This technique is not suitable for dataset with low completeness percentage such as D3 (49.57%). D3 had two large ranges of missing values starting from January 2007 until June 2009 and from July 2011 until March 2018. We excluded those durations from the interpolation performed on D3. In the future, we will seek an alternative discharge dataset for Tan Chau.



The original rainfall data from Vientiane station that includes missing values.



The rainfall data for Vientiane station after applying data imputation.

Downsampling: The datasets D07, and D09-D12 contained multiple data points per day. We downsampled multiple data points to a single value per day by using their average.

	Date	WaterLevel
0	1/1/1966	3.18
1	1/2/1966	2.96
2	1/3/1966	2.82
3	1/4/1966	2.70
4	1/5/1966	2.60
...	...	...
23363	5/8/2021	3.04
23364	5/8/2021	3.10
23365	5/9/2021	3.04
23366	5/9/2021	3.11
23367	5/10/2021	3.06

[23368 rows x 2 columns]

Date	WaterLevel
1966-01-01	3.180
1966-01-02	2.960
1966-01-03	2.820
1966-01-04	2.700
1966-01-05	2.600
...	...
2021-05-06	3.015
2021-05-07	3.045
2021-05-08	3.070
2021-05-09	3.075
2021-05-10	3.060

[20219 rows x 1 columns]

Water level of Kong Chiam before (Left) and after (Right) downsampling.

After the data preprocessing, we formatted all the datasets into the CSV (Comma-Separated Values) format for importing into the LandSAGE software. The imputation, downsampling, and formatting were implemented using Python scripting, pandas, NumPy and Matplotlib libraries.

PART 2 – LANDSLIDE DATA COLLECTION

We reviewed prior studies of landslides and discussed with natural disaster experts in order to determine the most important factors for assessing landslide risk and impact levels. Also taking into account the availability of data in the four countries, we focused on the following factors in LandSAGE3: Rainfall, DEM (Digital Elevation Model), slope, geologic lithology, geomorphology, land use/cover, landslide inventory/susceptibility, housing distribution, population density, and road density. The last three factors are used to assess the impact from landslides. The other factors are used to assess the risks of landslides. Subsequent sections describe the sources and processes used in the data collection as well as the results and preprocessing performed on the data before importing them into the LandSAGE software.

Data Sources

ODM (Open Development Mekong) is an open data platform providing objective data visualizations that illustrate the development and environmental challenges in the Mekong region. The platform provides data for five countries in the region including Cambodia, Laos, Myanmar, Thailand, and Vietnam.

World Bank Data Catalog is a portal for shared development data. The datasets especially the geospatial data are provided by regions and available for download.

JICA (Japan International Cooperation Agency) provides financial assistance to developing countries for socioeconomic development. Some of its published reports contain maps showing landslide factors such as geomorphology and land cover.

GEOFABRIK is a web portal that provides free geodata based on the OpenStreetMap project including shape files, maps, map tiles, and web mapping solutions.

USGS (United States Geological Survey) Earth Explorer is an online tool enabling users to search and download satellite and aerial imagery. It contains one of the largest databases of remote sensing satellites.

ALOS/ALOS-2 (Advanced Land Observing Satellite) Project of the Earth Observation Research Center (EORC) at the Japan Aerospace Exploration Agency (JAXA) provides High-Resolution Land Use and Land Cover (HRLULC) maps of Japan and Vietnam.

ASTGTM (ASTER Global Digital Elevation Model Version 3) is a data product developed by a collaborative effort between National Aeronautics and Space Administration (NASA) and Japan's Ministry of Economy, Trade, and Industry (METI). It provides a global digital elevation model of land areas at a spatial resolution of 1 arc second.

ADPC (Asian Disaster Preparedness Center) is an international organization working to build the resilience to disasters and climate change impacts in Asia and the Pacific. Some of its published reports include maps showing landslide factors such as DEM and land use.

CCOP (Coordinating Committee for Geoscience Programmes in East and Southeast Asia) is an intergovernmental organization that aims to facilitate the implementation of applied geoscience programs in East and Southeast Asia in order to contribute to economic development and an improved quality of life. It offers geographic information system (GIS) web service that provides visualization of landslide factors such as geologic lithology.

Lao DECIDE Info is Laos government's platform that integrates information from social, economic, environmental and agricultural sectors to facilitate planning and decision making. It provides a repository of maps derived from key national datasets, some of which show landslide factors such as land use, road density, and landslide inventory.

South China Sea serves as an online resource that provides information related to the development, environment, and security issues in the South China Sea region. It provides various types of maps such as economic, environmental, oceanographic, and historical maps.

ISCGM (International Steering Committee for Global Mapping) aims to foster the development of global mapping in order to facilitate environmental protection, mitigation of natural disasters, and to encourage economic growth.

CIESIN (Center for International Earth Science Information Network) is a center at Columbia University that specializes in on-line data and information management, spatial data integration and training, and interdisciplinary research related to human interactions in the environment.

PopulationData.net is a website that provides free information, maps, and statistics of the populations and countries of the World. Information sources are from research centers, universities, governmental and non-governmental agencies, and official statistical sites around the World.

Geo-Ref.net is a website that provides map-related services.

DMR (Department of Mineral Resources) in Thailand serves as the governmental agency for fact-finding related to minerals and geology. Various types of digital and printed thematic geological maps are available for free download and for sale.

LDD (Land Development Department) in Thailand is the governmental organization responsible for soil survey, soil mapping, land improvement and land use planning.

DOPA (Department of Provincial Administration) in Thailand is responsible for administrative affairs nationwide at the levels of provinces, towns, and districts.

GERD (Geotechnical Engineering Research and Development Center) in Thailand is a center at Kasetsart University that conducts research and development on geotechnical and foundation engineering. Its website provides maps related to landslides.

Lao Statistics Bureau is the state agency responsible for the collection and publication of statistics related to the economy, population and society of Laos.

MPWT (Ministry of Public Works and Transport of Laos) provides domestic transport data including map of road density in the raster image format.

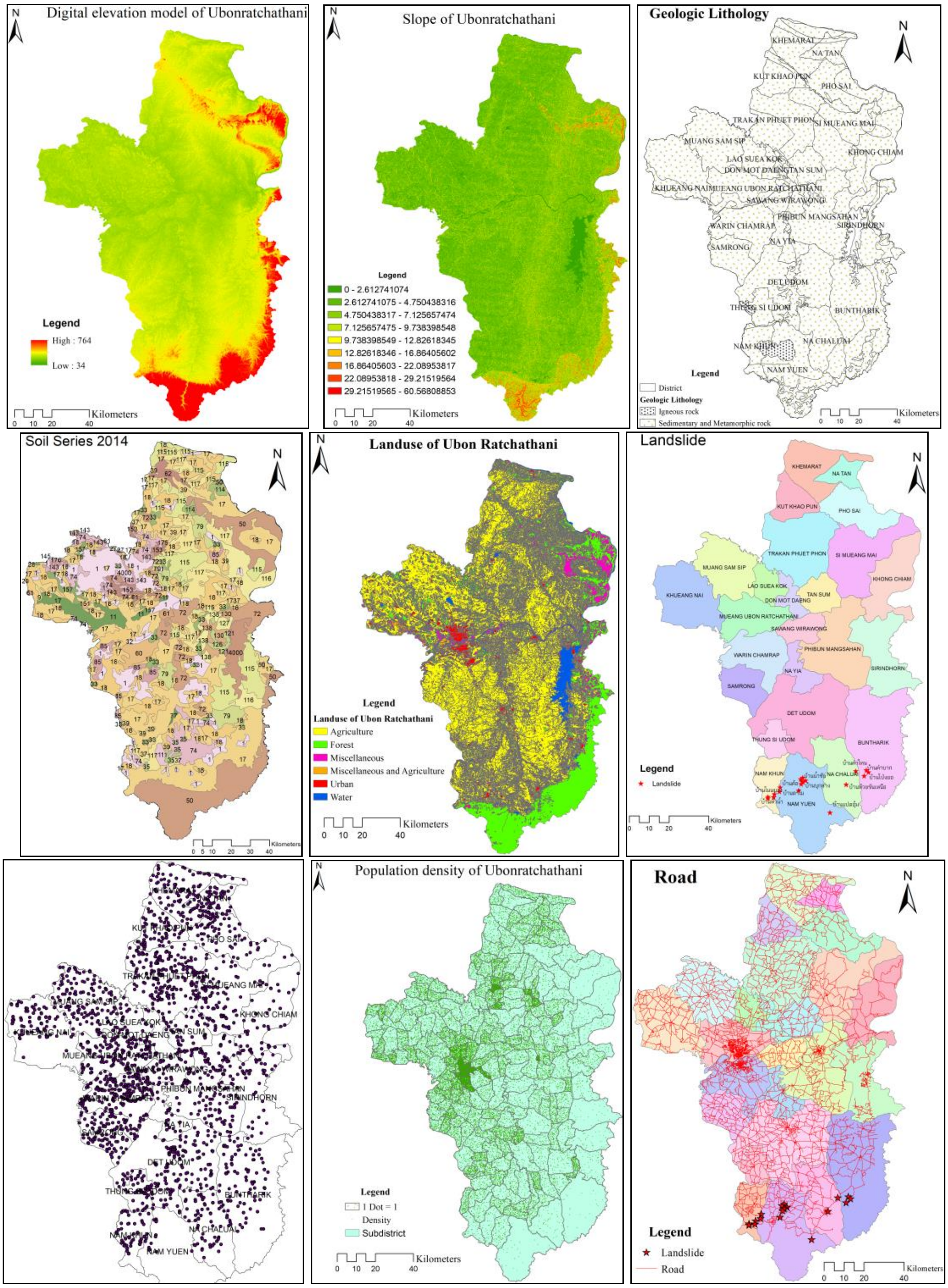
Data Collection for Ubon Ratchathani Pilot Site in Thailand

The data collection results for Ubon Ratchathani are summarized in the following table.

Summary of collected landslide data for Ubon Ratchathani pilot site.

No	Factor	Scope	Data Year	Data Source	Format
1	DEM	Ubon Ratchathani	2013	ASTGTM	TIFF
2	Slope	Ubon Ratchathani	2013	Calculated from DEM	Shapefile
3	Geologic Lithology	Ubon Ratchathani	2014	DMR	Shapefile
4	Geomorphology	Ubon Ratchathani	2000	LDD	Shapefile
5	Geomorphology	Ubon Ratchathani	2014	LDD	Shapefile
6	Geomorphology	Thailand	2018	GERD	Raster
7	Land Use	Ubon Ratchathani	2000	LDD	Shapefile
8	Land Use	Ubon Ratchathani	2007	LDD	Shapefile
9	Land Use	Ubon Ratchathani	2015	LDD	Shapefile
10	Land Use	Ubon Ratchathani	2017	LDD	Shapefile
11	Landslide Inventory	Ubon Ratchathani	2012	LDD	Shapefile
12	Landslide Inventory	Ubon Ratchathani	2018	LDD	Shapefile
13	Housing Distribution	Ubon Ratchathani	2014	LDD	Shapefile
14	Population Density	Ubon Ratchathani	2016	DOPA	Shapefile
15	Population Density	Ubon Ratchathani	2017	DOPA	Shapefile
16	Population Density	Ubon Ratchathani	2018	DOPA	Shapefile
17	Population Density	Ubon Ratchathani	2019	DOPA	Shapefile
18	Population Density	Ubon Ratchathani	2020	DOPA	Shapefile
19	Road Density	Ubon Ratchathani	2014	LDD	Shapefile

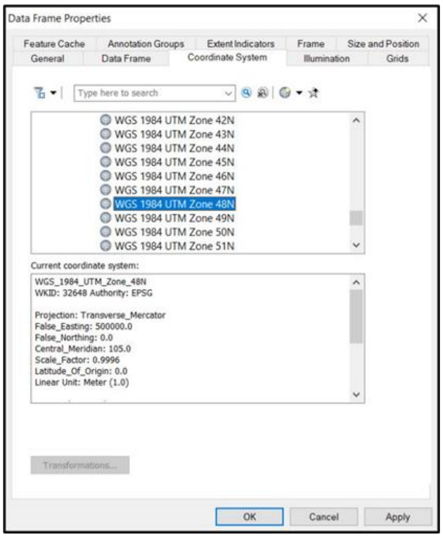
Most of the data were obtained in the shapefile format via personal contacts in the source organizations. We used the ArcGIS mapping and analytics software to transform the TIFF and shapefiles into raster images suitable for visualization in the LandSAGE software. Below are examples of raster images for the different factors.



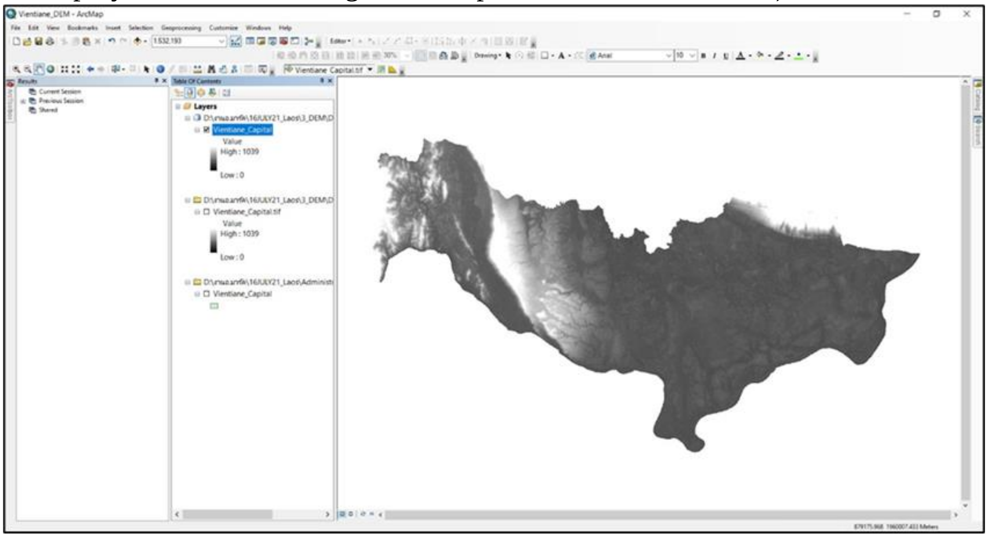
From top to bottom, left to right: maps of DEM, slope, geologic lithology, geomorphology, land use, landslide inventory, housing distribution, population density, and road distribution for Ubon Ratchathani pilot site.

DEM Raster Image Generation:

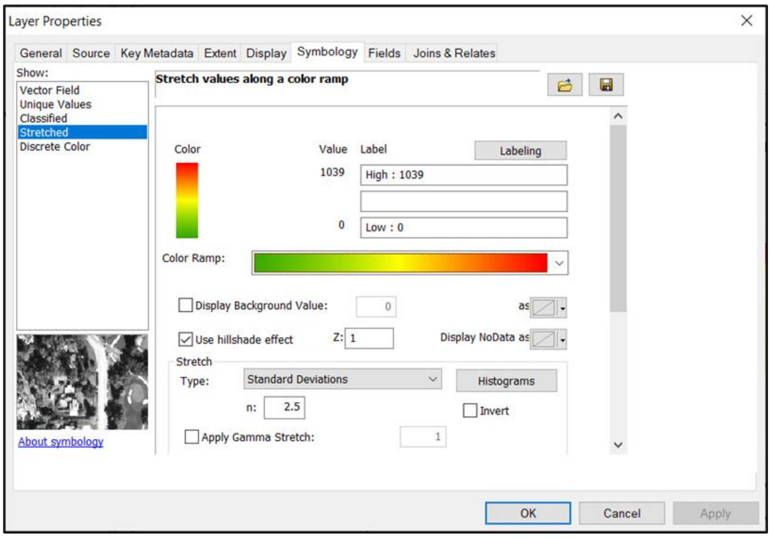
- In ArcGIS, select “Data Frame Properties” and then “Coordinate System”, and choose “WGS 1984 UTM Zone 48N”.



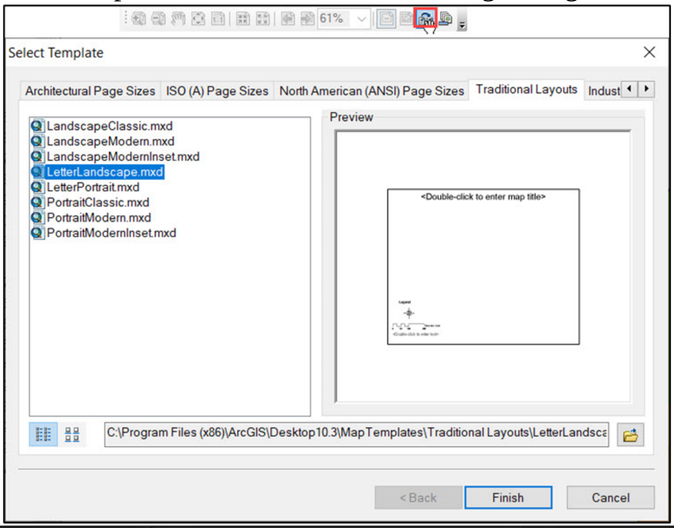
- Import DEM and administration boundary. (Note that the picture below shows the Vientiane pilot site that employed the same raster generation process as described here)

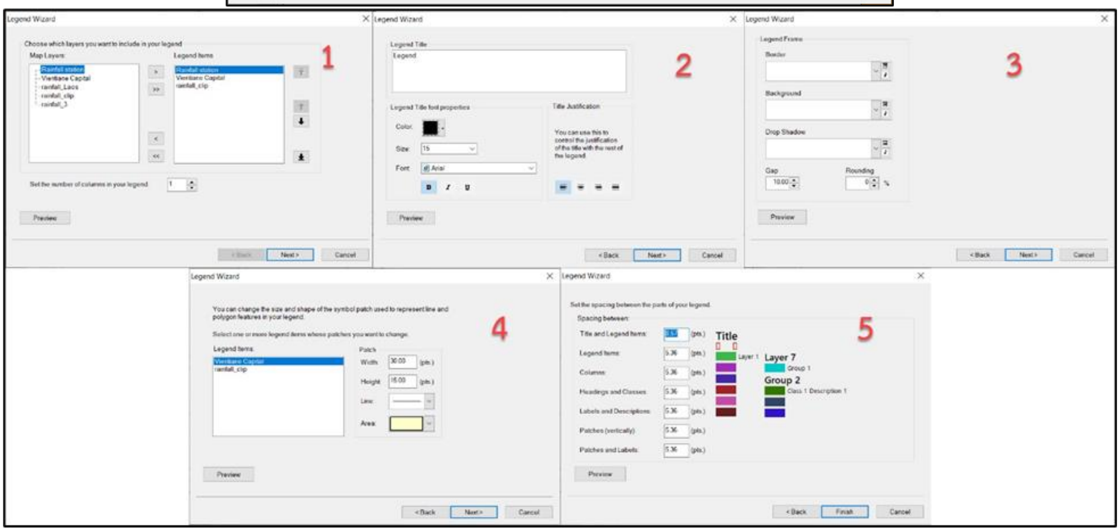


- Change “DEM Color Ramp” from the “Symbology” tab in the “Layer Properties” dialog box.

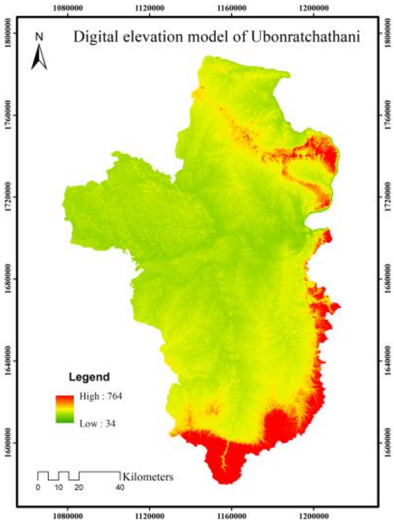


- Set map layout and add components such as north arrow, legends, grid, and title.



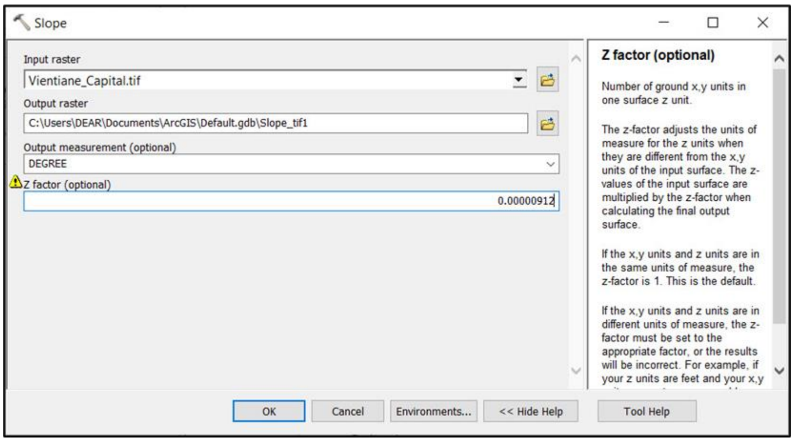


- Final result:



Slope Raster Image Generation:

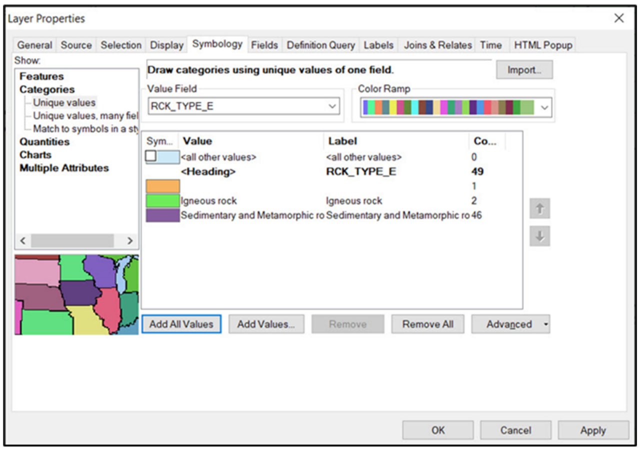
- In ArcGIS, select “Data Frame Properties” and then “Coordinate System”, and choose “WGS 1984 UTM Zone 48N”.
- Import DEM and administration boundary.
- Under “ArcToolbox” –> “Spatial Analyst Tools” –> “Surface”, choose the “Slope” tool. Set the Z factor to 0.00000912.



- Set map layout and add map components before generating the raster image using the steps explained for DEM.

Geologic Lithology Raster Image Generation:

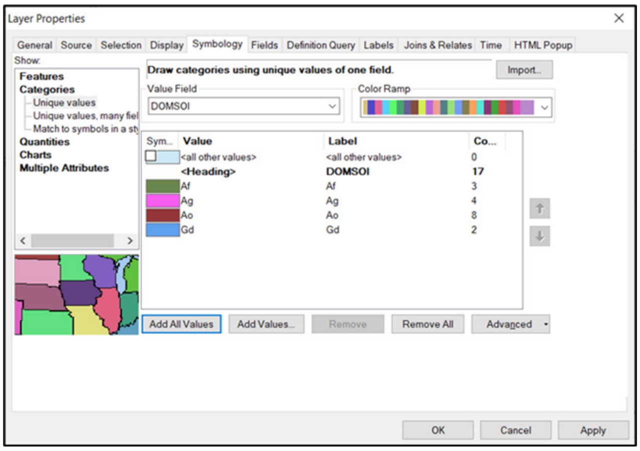
- Set the coordinate system to “WGS 1984 UTM Zone 48N”, and then import geologic lithology data and administrative boundary.
- From the “Symbology” tab of the “Layer Properties” dialog box, classify lithology by setting attribute values of the field “RCK_TYPE_E”.



- Set map layout and add map components before generating the raster image.

Geomorphology Raster Image Generation:

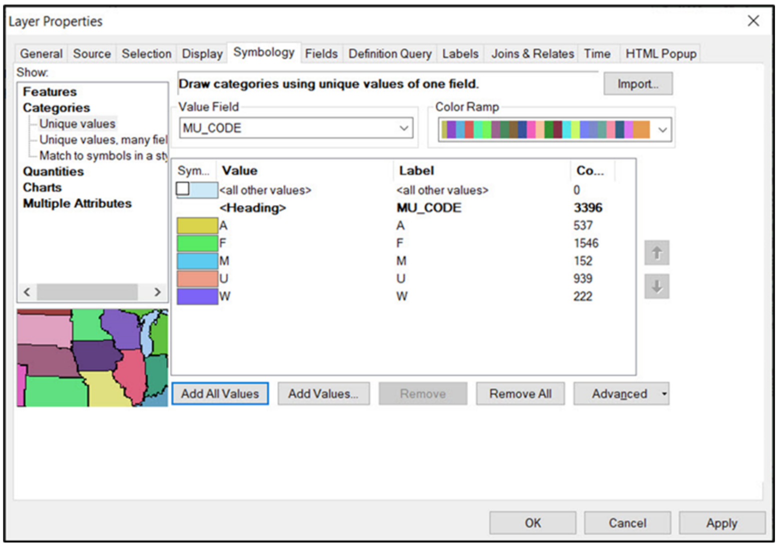
- Set the coordinate system to "WGS 1984 UTM Zone 48N", and then import soil series data and administrative boundary.
- From the "Symbology" tab of the "Layer Properties" dialog box, classify soil groups by setting attribute values of the field "DOMSOI".



- Set map layout and add map components before generating the raster image.

Land Use Raster Image Generation:

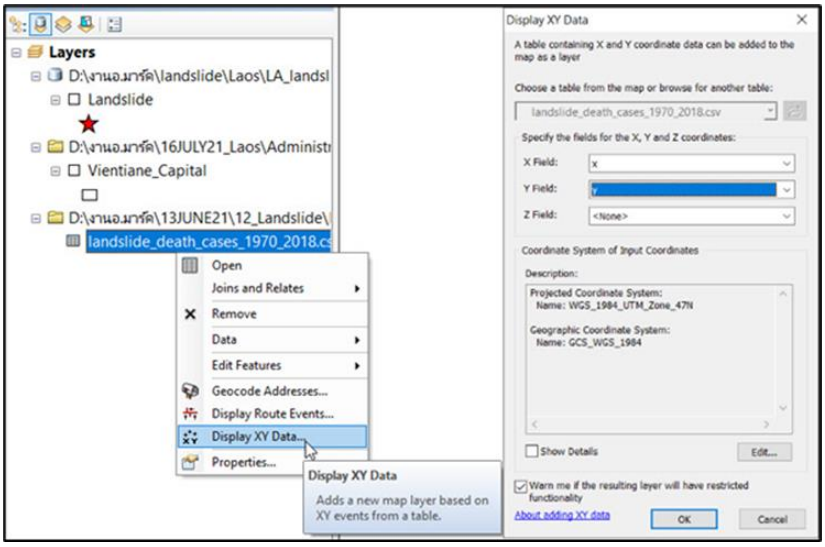
- Set the coordinate system to "WGS 1984 UTM Zone 48N", and then import land use data and administrative boundary.
- From the "Symbology" tab of the "Layer Properties" dialog box, classify land use by setting attribute values of the field "MU_CODE". We used 1st level classification that consists of agriculture (A), forest (F), urban (U), water (W) and miscellaneous (M) areas.



- Set map layout and add map components before generating the raster image.

Landslide Inventory Raster Image Generation:

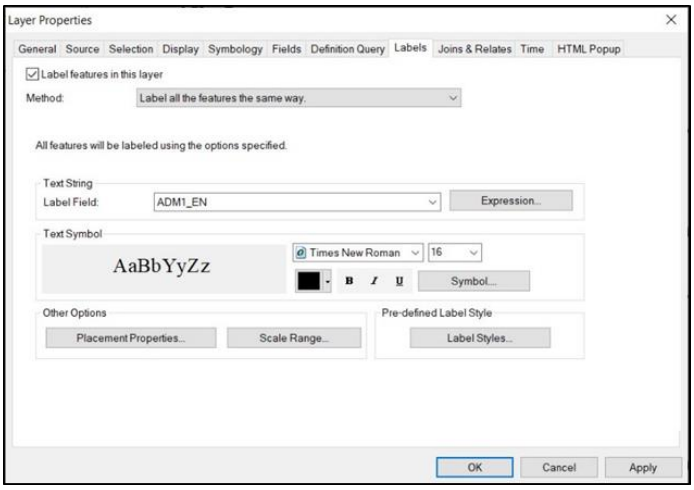
- Set the coordinate system to "WGS 1984 UTM Zone 48N".
- Together with the administrative boundary, import landslide inventory data into ArcGIS. Data in the shapefile format can be imported directly. For data in tabular (Excel) format containing X and Y coordinates, we can use the "Display XY Data" function to add a new map layer based on the XY events from the table.



- Set map layout and add map components before generating the raster image.

Housing Distribution Raster Image Generation:

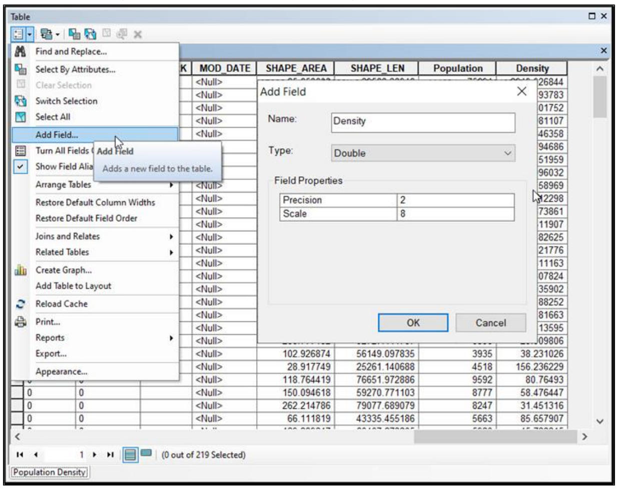
- Set the coordinate system to "WGS 1984 UTM Zone 48N", and then import housing distribution data and administrative boundary.
- Label each house using the "Labels" tab in the "Layer Properties" dialog box. Each house appears as a point on the generated map.



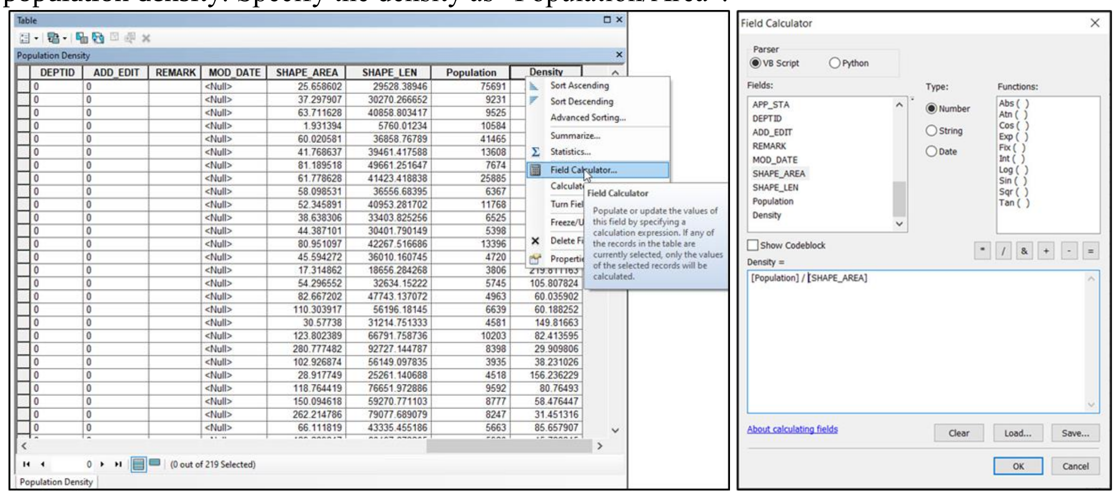
- Set map layout and add map components before generating the raster image.

Population Density Raster Image Generation:

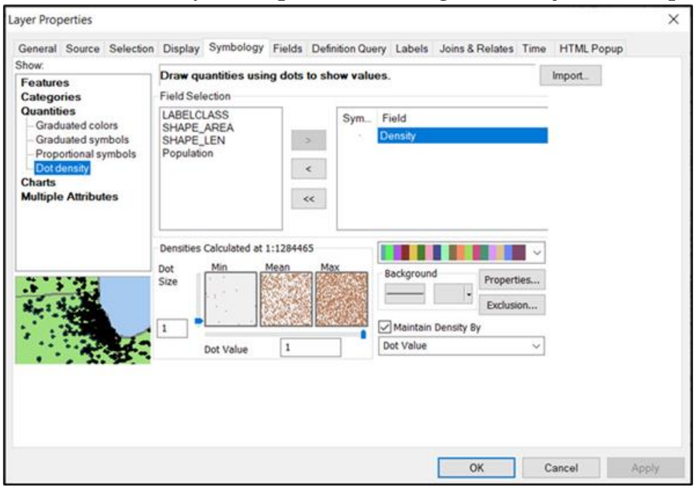
- Set the coordinate system to “WGS 1984 UTM Zone 48N”.
- Import administrative boundary data that contains population data.
- In the attribute table of administrative boundary, choose “Add Field” and then set “Name” to “Density”, “Type” to “Double”, “Precision” to “2”, and “Scale” to “8”.



- In the table, right click the “Density” header and choose “Field Calculator” to calculate population density. Specify the density as “Population/Area”.



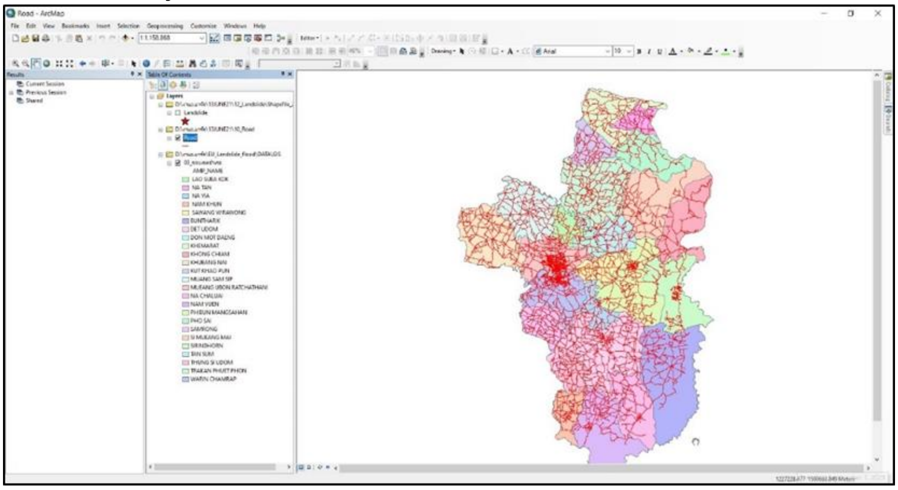
- Use “Dot Density” tool in the “Layer Properties” dialog box to symbolize population density map.



- Set map layout and add map components before generating the raster image.

Road Density Raster Image Generation:

- Set the coordinate system to “WGS 1984 UTM Zone 48N”, and then import road data and administrative boundary.



- Set map layout and add map components before generating the raster image.

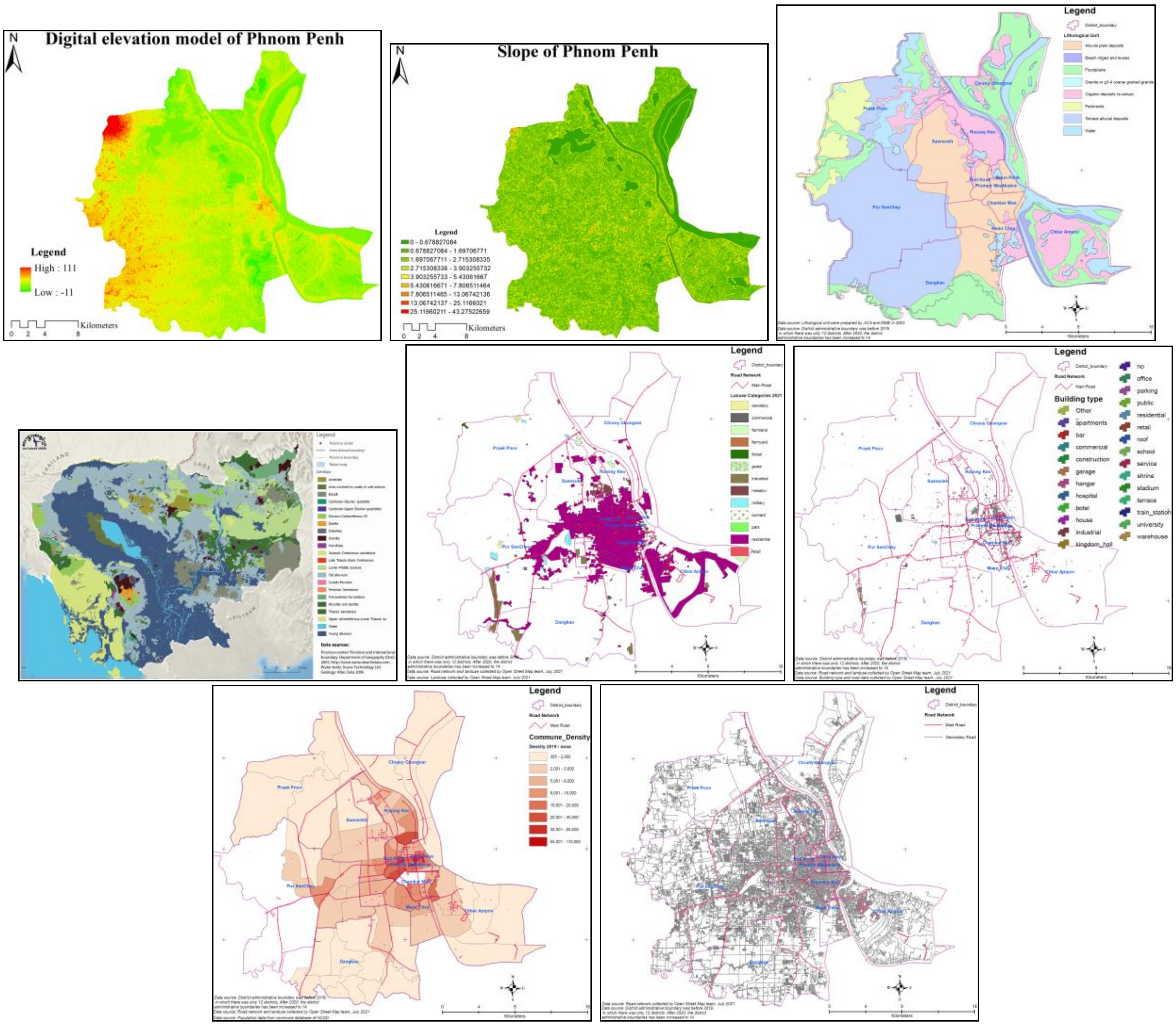
Data Collection for Phnom Penh Pilot Site in Cambodia

The data collection results for Phnom Penh are summarized in the following table.

Summary of collected landslide data for Phnom Penh pilot site.

No	Factor	Scope	Data Year	Data Source	Format
1	DEM	Phnom Pen	2014	USGS Earth Explorer	TIFF
2	Slope	Phnom Pen	2014	Calculated from DEM	Raster
3	Geologic Lithology	Cambodia	2006	ODM	Raster
4	Geologic Lithology	Phnom Penh	2003	Cambodia Team	Raster
5	Geomorphology	Cambodia	2005	JICA	Raster
6	Geomorphology	Phnom Penh	2006	ODM	Shapefile
7	Land Use	Cambodia	2013	ODM	Raster
8	Land Use	Phnom Penh	2003	World Bank Data Catalog	Shapefile
9	Land Use	Phnom Penh	2007	Cambodia Team	Raster
10	Land Use	Phnom Penh	2017	World Bank Data Catalog	Shapefile
11	Land Use	Phnom Penh	2021	Cambodia Team	Raster
12	Land Cover	Phnom Penh	2013	JICA	Raster
13	Land Cover	Phnom Penh	2015	JICA	Raster
14	Housing Distribution	Cambodia	2011	ODM	Raster
15	Housing Distribution	Phnom Penh	2021	Cambodia Team	Raster
16	Population Density	Cambodia	2000	CIESIN	Raster
17	Population Density	Cambodia	2013	PopulationData.net	Raster
18	Population Density	Cambodia	2019	Geo-Ref.net	Raster
19	Population Density	Phnom Penh	2014	Cambodia Team	Raster
20	Population Density	Phnom Penh	2015	Cambodia Team	Raster
21	Population Density	Phnom Penh	2016	Cambodia Team	Raster
22	Population Density	Phnom Penh	2017	Cambodia Team	Raster
23	Population Density	Phnom Penh	2018	Cambodia Team	Raster
24	Population Density	Phnom Penh	2019	Cambodia Team	Raster
25	Road Density	Cambodia	2020	ODM	Shapefile
26	Road Density	Phnom Penh	2021	Cambodia Team	Raster

Majority of the data were obtained in the raster format. Our collaborators from the Institute of Technology of Cambodia including Dr. Kong CHHUON, Dr. Sambo LUN, and Dr. Sytharith PEN used shapefiles from the OpenStreetMap (via GEOFRABRIK) to generate raster images for several factors in the ArcGIS software. According to the collaborators, Phnom Penh consists mostly of flat lands, so the chance of landslide is low. We could not find the landslide inventory data for Phnom Penh. We used the ArcGIS software to transform the TIFF and shapefiles into raster images using the procedures described in the Thailand section. Below are example raster images for the different factors.

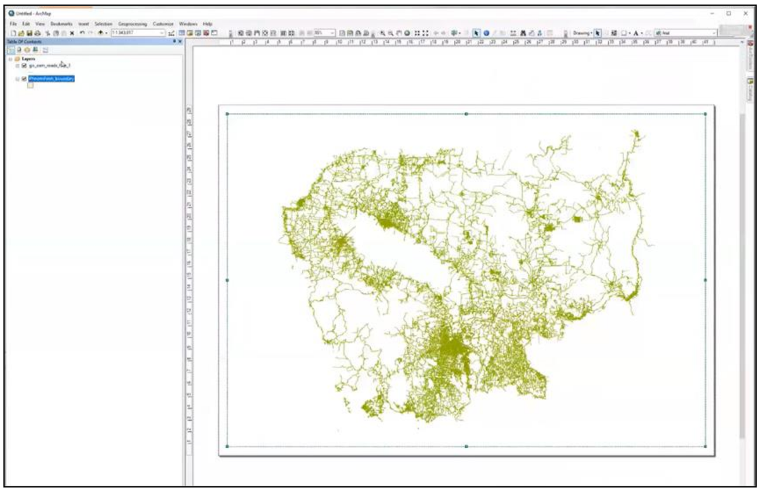


From top to bottom, left to right: maps of DEM, slope, geologic lithology, geomorphology, land use, housing distribution, population density, and road distribution for Phnom Penh pilot site.

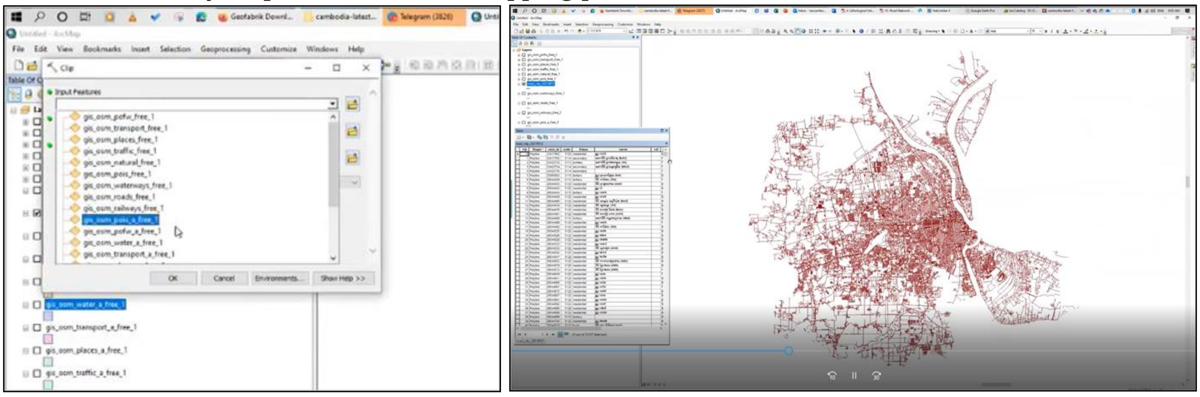
Map Generation by the Cambodia Team:

The Cambodia team downloaded geologic lithology, land use, housing distribution, population density, road density, and administrative boundary data in the shapefile format from GEOFRABRIK. They then used the ArcGIS software to generate raster images from these shapefiles. We summarize the steps they used as follows:

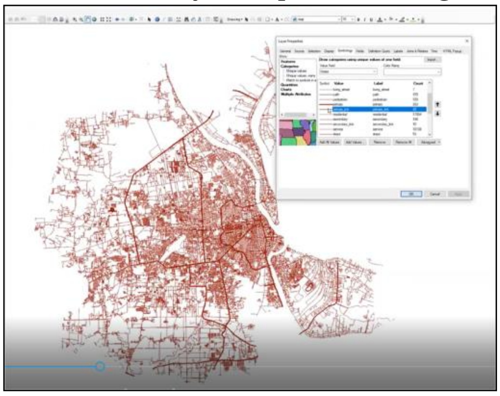
- Import a shapefile into a new layer. In this example, we use the road data.



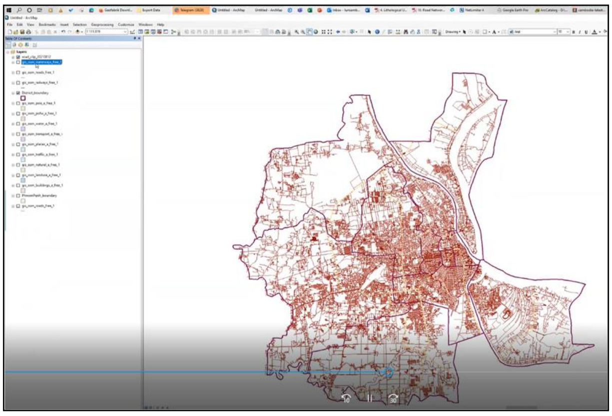
- Extract the area of interest, in this case, Phnom Penh by using the “Clip” tool. Note that a Phnom Penh boundary map is needed in the clipping process.

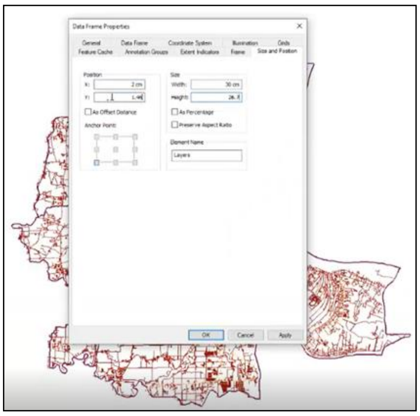


- Customize the lines and colors via the “Layer Properties” dialog box.

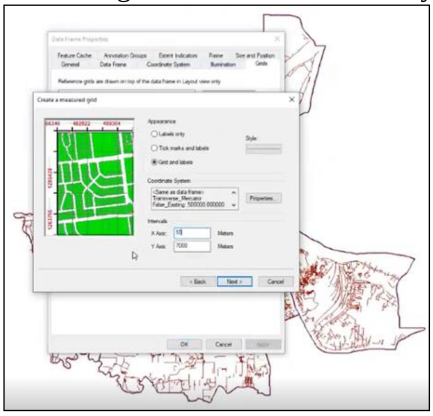


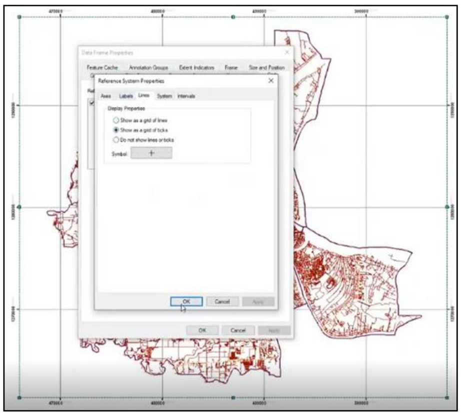
- Add the boundary and set the map size.



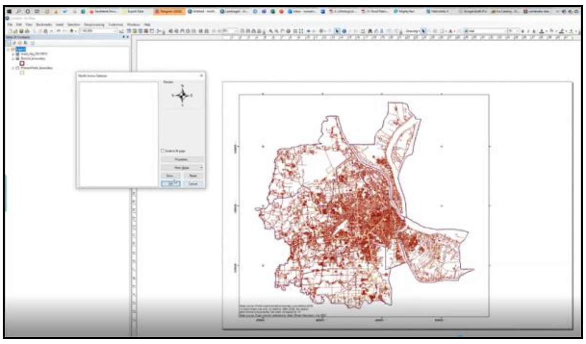


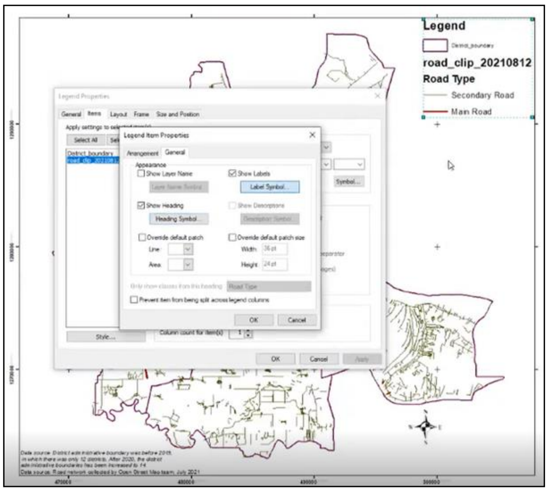
- Create a measured grid and add a reference system.



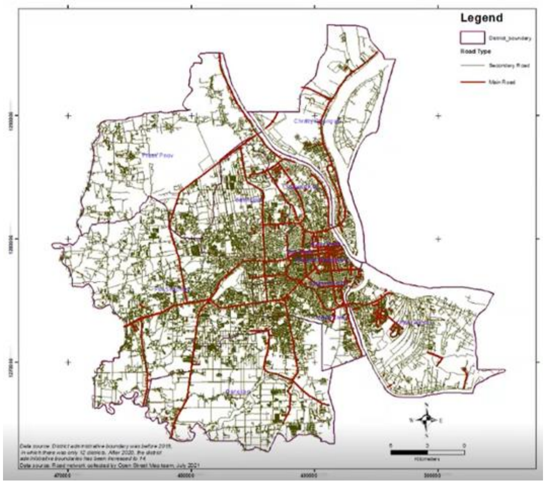


- Insert compass symbol, scale bar, and legends. Legends can be customized using the “Legend Item Properties”.





- The final raster image is shown below.


Legend
District_boundary
Road Type
Secondary Road
Main Road
Data source: District administrative boundary was before 2015, in which there was only 12 districts. After 2020, the district administrative boundaries has been increased to 14
Data source: Road network collected by Open Street Map team, July 2021

Data Collection for Vientiane Capital Pilot Site in Laos

The data collection results for Vientiane Capital are summarized in the following table.

Summary of collected landslide data for Vientiane Capital pilot site.

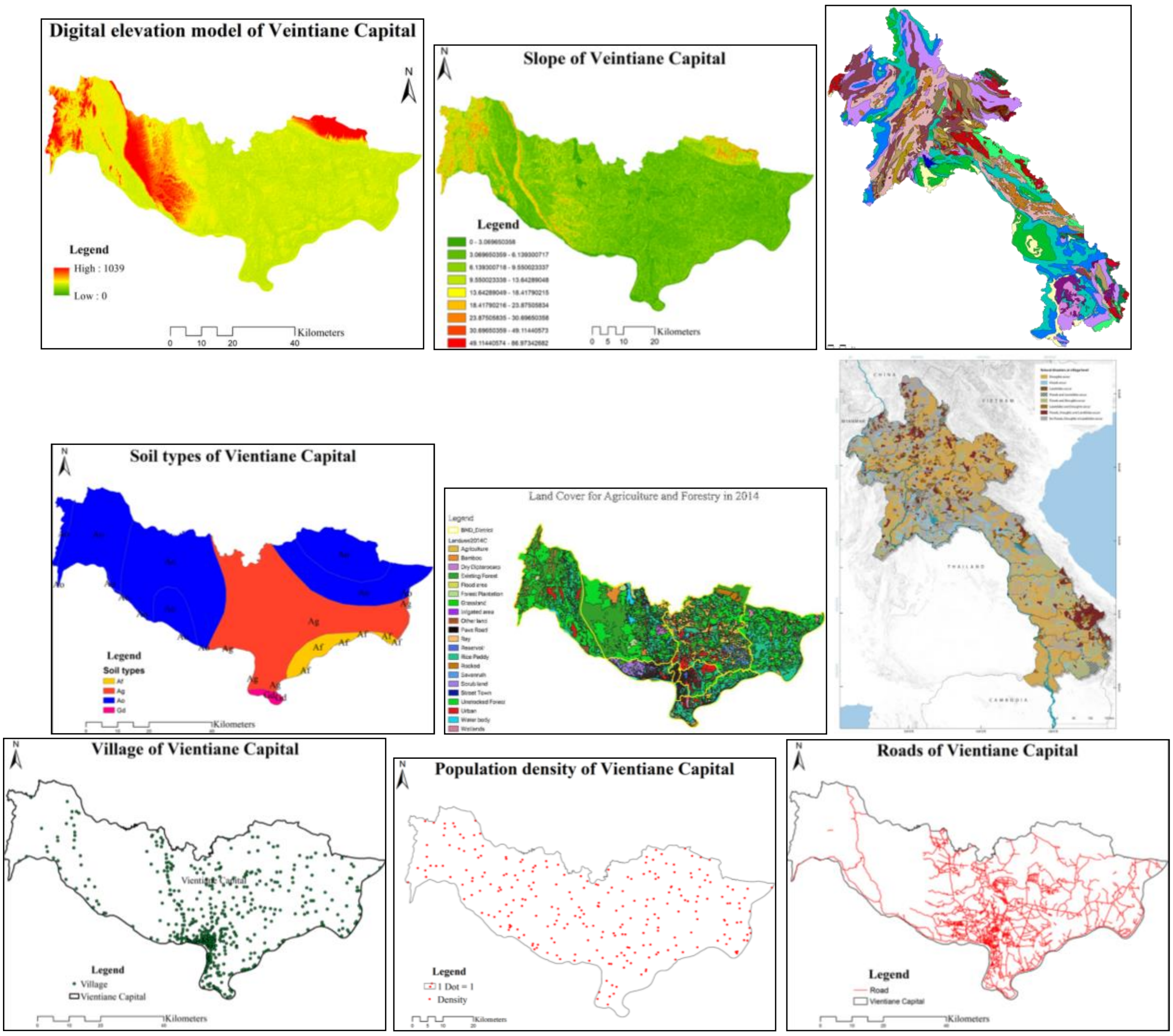
No	Factor	Scope	Data Year	Data Source	Format
1	DEM	Vientiane	2007	Research Paper[1]	Raster
2	DEM	Laos	2010	ADPC	Raster
3	DEM	Vientiane	2013	ASTGTM	TIFF
4	DEM	Vientiane	2018	Research Paper[2]	Raster
5	Slope	Vientiane	2013	Calculated from DEM (3)	Raster
6	Slope	Vientiane	2018	Research Paper[2]	Raster
7	Geologic Lithology	Vientiane	2007	Research Paper[1]	Raster
8	Geologic Lithology	Laos	2016	CCOP	Raster
9	Geomorphology	Vientiane	2007	ODM	Shapefile
10	Land Use/Cover	Laos	2002	Lao DECIDE Info	Raster
11	Land Use/Cover	Vientiane	2004	Research Paper[2]	Raster
12	Land Use/Cover	Laos	2009	ADPC	Raster
13	Land Use/Cover	Vientiane	2013	Research Paper[2]	Raster
14	Land Use/Cover	Vientiane	2014	Research Paper[3]	Raster
15	Land Use/Cover	Vientiane	2017	Research Paper[3]	Raster
16	Land Use/Cover	Vientiane	2018	Research Paper[2]	Raster
17	Landslide Susceptibility	Laos	2010	ADPC	Raster
18	Landslide Inventory	Laos	2011	Lao DECIDE Info	Raster
19	Housing Distribution	Vientiane	2015	ODM	Shapefile
20	Housing Distribution	Laos	2019	Lao Statistics Bureau	Raster
21	Population Density	Laos	2005	ADPC	Raster
22	Population Density	Laos	2019	ODM	Shapefile
23	Road Density	Laos	2010	ADPC	Raster
24	Road Density	Laos	2011	Lao DECIDE Info	Raster
25	Road Density	Vientiane	2018	World Bank Data Catalog	Shapefile
26	Road Density	Laos	2019	MPWT	Raster

[1] V. Xayavong, "A Geophysical Study of Vientiane Basin, Lao PDR", Thesis (M.S., Geophysics), *Prince of Songkla University*, 2008.

[2] C. Faichia, Z. Thong, J. Zhang, X. Liu, E. Kazuva, K. Ullah, and B. Al-Shaibah, , "Using RS Data-Based CA–Markov Model for Dynamic Simulation of Historical and Future LUCC in Vientiane, Laos", *Sustainability 2020*, 12(20), 8410, doi:10.3390/su12208410.

[3] S. Praseuth, D. P. Tuan, C. M. Duc, H. B. Quang, and T. N. Thi Nhat, "Mapping Land Cover Types in Vientiane, Laos Using Multi-temporal Composite Landsat 8 Images", *In Proc. of 6th NAFOSTED Conference on Information and Computer Science (NICS)*, Dec. 2019, pp. 563–568.

Majority of the data were obtained in the raster format. Our collaborators from the National University of Laos including Mr. Khamphanh Sithavong, Mr. Khamseum Sooriyamath, and Mr. Bounhome Chansavang coordinated with the Lao Statistics Bureau and the Ministry of Public Works and Transport of Laos to obtain the 2019 housing distribution (20) and 2019 road density (26) data. We used the ArcGIS software to transform the TIFF and shapefiles into raster images using the procedures described in the Thailand section. Below are example raster images for the different factors.



From top to bottom, left to right: maps of DEM, slope, geologic lithology, geomorphology, land use, landslide inventory, housing distribution, population density, and road distribution for Vientiane Capital pilot site.

Data Collection for Tan Chau (in An Giang Province) Pilot Site in Vietnam

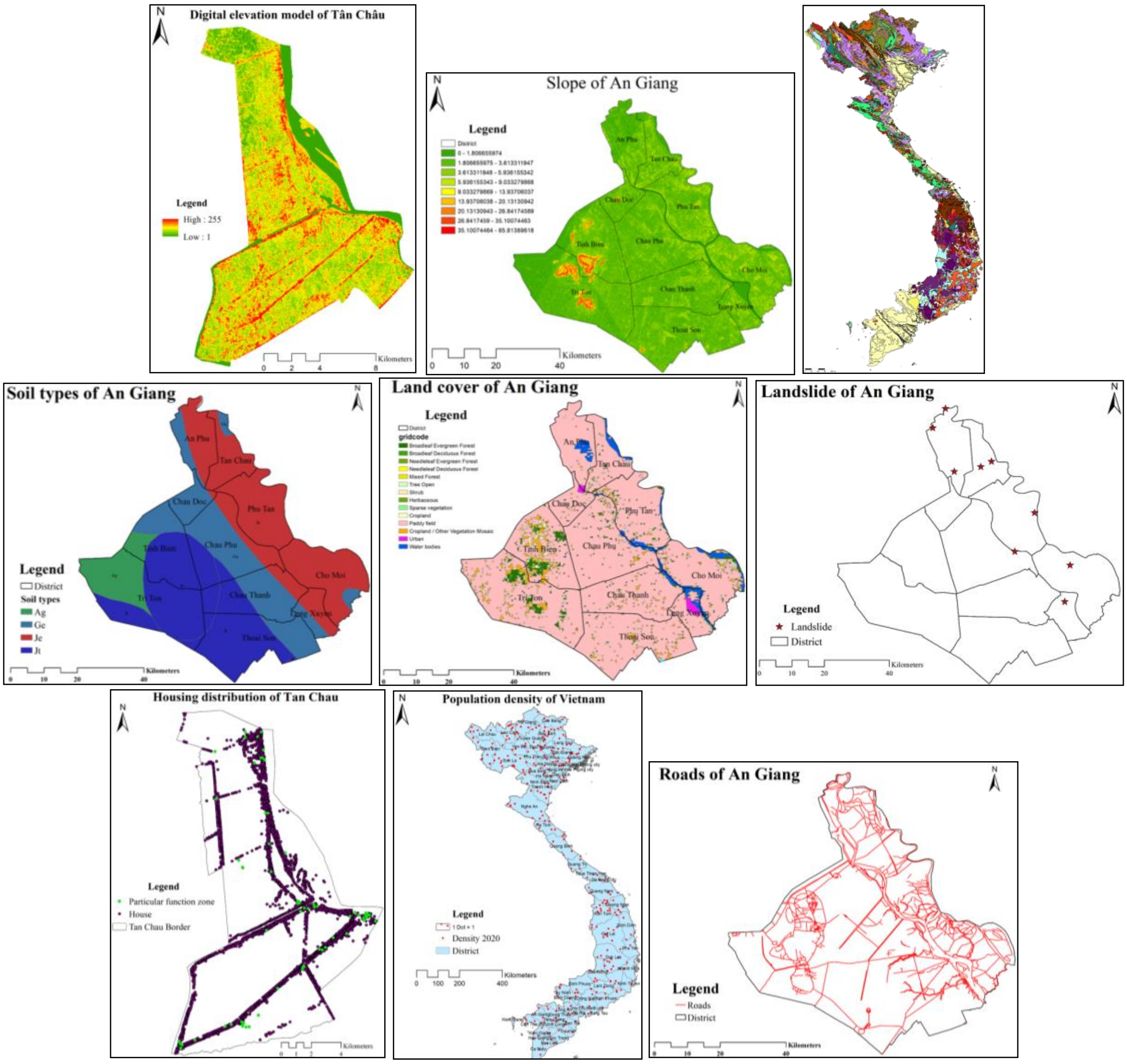
The data collection results for Tan Chau are summarized in the following table.

Summary of collected landslide data for Tan Chau pilot site.

No	Factor	Scope	Year	Data Source	Format
1	DEM	Tan Chau	2013	ASTGTM	TIFF
2	DEM	Vietnam	2016	ODM	Raster
3	Slope	An Giang	2013	Calculated from DEM (1)	Raster
4	Geologic Lithology	Vietnam	2018	CCOP	Raster
5	Geomorphology	An Giang	2007	World Bank Data Catalog	Raster
6	Geomorphology	An Giang	2016	ODM	Shapefile
7	Land Use/Cover	Southern Vietnam	2007	ALOS/ALOS-2	Raster
8	Land Use/Cover	An Giang	2009	ODM	Shapefile
9	Land Use/Cover	An Giang	2013	ODM	TIFF
10	Land Use/Cover	Vietnam	2015	ALOS/ALOS-2	Raster
11	Land Use/Cover	Vietnam	2016	ALOS/ALOS-2	Raster
12	Land Use/Cover	Southern Vietnam	2017	ALOS/ALOS-2	Raster
13	Land Use/Cover	Vietnam	2018	ALOS/ALOS-2	Raster
14	Land Use/Cover	Tan Chau	2021	Vietnam Team	Shapefile
15	Landslide Inventory	Vietnam	2017	Research Paper[1]	Raster
16	Landslide Inventory	An Giang	2020	ODM	Shapefile
17	Housing Distribution	Tan Chau	2013	Vietnam Team	Shapefile
18	Population Density	Vietnam	2000	CIESIN	Raster
19	Population Density	Vietnam	2004	South China Sea	Raster
20	Population Density	Vietnam	2011	ODM	CSV
21	Population Density	Vietnam	2012	ODM	CSV
22	Population Density	Vietnam	2013	ODM	CSV
23	Population Density	Vietnam	2014	ODM	CSV
24	Population Density	Vietnam	2015	ODM	CSV
25	Population Density	Vietnam	2016	ODM	CSV
26	Population Density	Vietnam	2017	ODM	CSV
27	Population Density	Vietnam	2018	ODM	CSV
28	Population Density	Vietnam	2019	ODM	CSV
29	Population Density	Vietnam	2020	ODM	CSV
30	Road Density	Vietnam	2008	JICA	Raster
31	Road Density	Tan Chau	2013	Vietnam Team	Shapefile
32	Road Density	Tan Chau	2016	ISCGM	Shapefile
33	Road Density	An Giang	2018	World Bank Data Catalog	Raster

[1] M. N. Dinh and H. Nguyen, "Mapping Landslide Events in Vietnam Using the Global Landslide Catalog and GIS", In Proc. of. FIG Working Week, April 2019, Available Online at http://www.fig.net/resources/proceedings/fig_proceedings/fig2019.

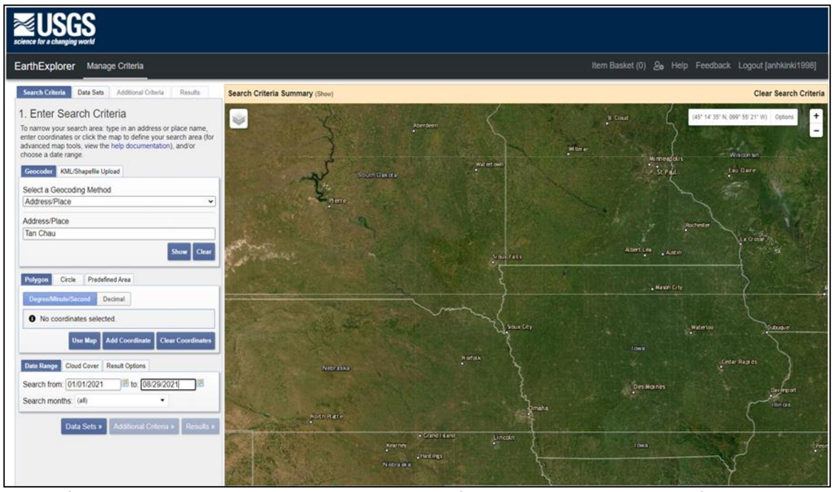
We obtained data in various formats. Our collaborators from the FIMO Center at the Vietnam National University including Dr. Bui Quang Hung, Mr. Minh Nguyen Nhat, and Ms. Nguyen Ha Linh provided the 2021 land use/cover (14), 2013 housing distribution (17) and 2013 road density (31) data. They generated the land use/cover shapefile from Landsat 8 images. We used the ArcGIS software to transform the shapefiles, TIFF, and CSV files into raster images using the procedures described in the Thailand section. Below are example raster images for the different factors.



From top to bottom, left to right: maps of DEM, slope, geologic lithology, geomorphology, land use, landslide inventory, housing distribution, population density, and road distribution for Tan Chau pilot site.

Generating Land Cover Map from Landsat 8 Images: (as used by the Vietnam Team)

- Download Landsat 8 images for a desired area from an online source such as the Google Earth Engine or the USGS Earth Explorer. The picture below shows the Earth Explorer's "Search Tool" that enables the user to download data for a specific location and date as well as specifying other search criteria.



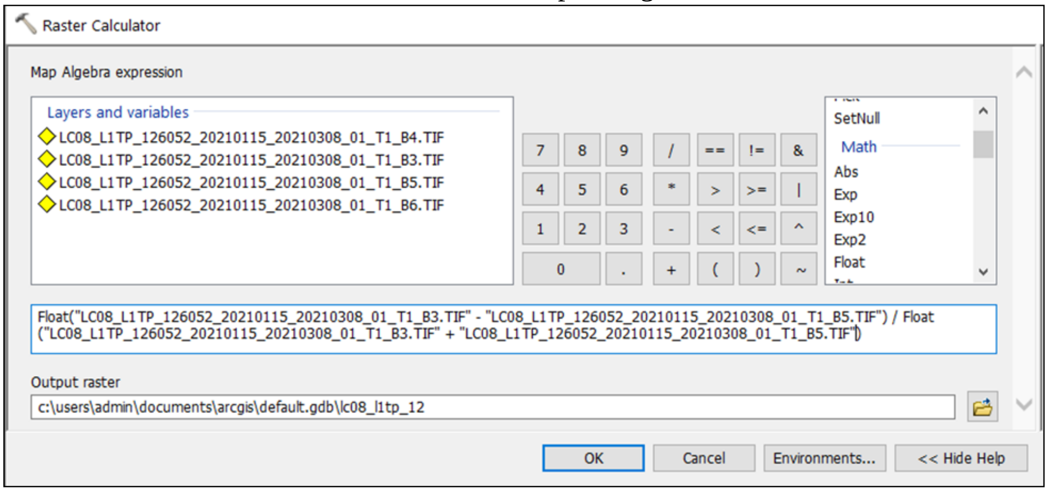
- In the ArcGIS software, import the bands needed for the calculation of a desired index. The table below shows band descriptions.

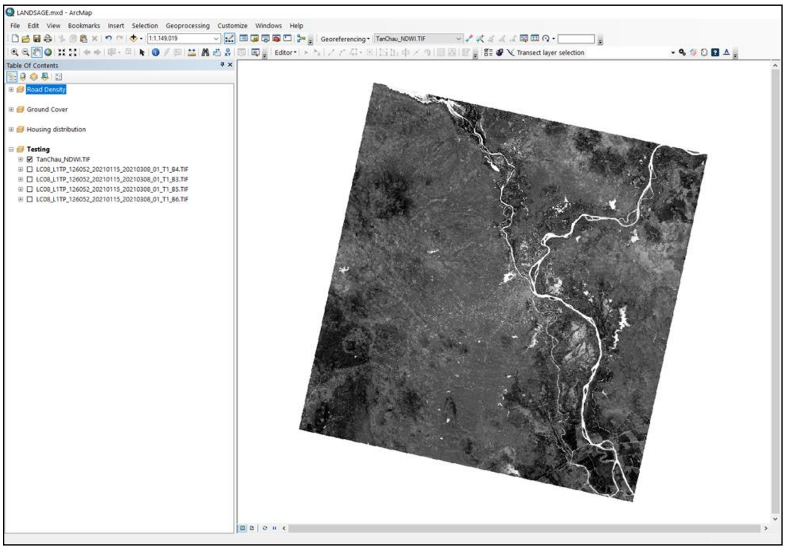
	Bands	Wavelength (micrometers)
Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) Launched February 11, 2013	Band 1 - Coastal aerosol	0.43 - 0.45
	Band 2 - Blue	0.45 - 0.51
	Band 3 - Green	0.53 - 0.59
	Band 4 - Red	0.64 - 0.67
	Band 5 - Near Infrared (NIR)	0.85 - 0.88
	Band 6 - SWIR 1	1.57 - 1.65
	Band 7 - SWIR 2	2.11 - 2.29
	Band 8 - Panchromatic	0.50 - 0.68
	Band 9 - Cirrus	1.36 - 1.38
	Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19
	Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51

- In this example, we are interested in the NDVI (vegetation), NDBI (building), and NDWI (water) indices. The formula used for calculating each index is given below.

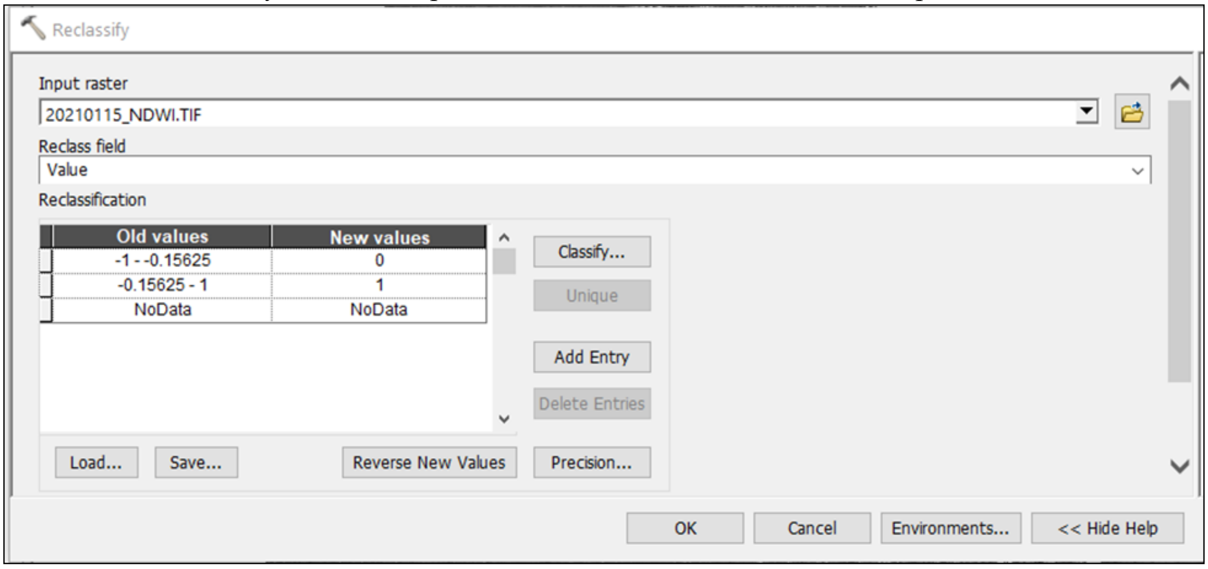
$$NDVI = (NIR - RED) / (NIR + RED)$$
$$NDBI = (SWIR1 - NIR) / (SWIR1 + NIR)$$
$$NDWI = (GREEN - NIR) / (GREEN + NIR)$$

- Use the "Raster Calculator" tool and fill in the formula for an index. The example below shows the calculation for the NDWI index and the corresponding result.

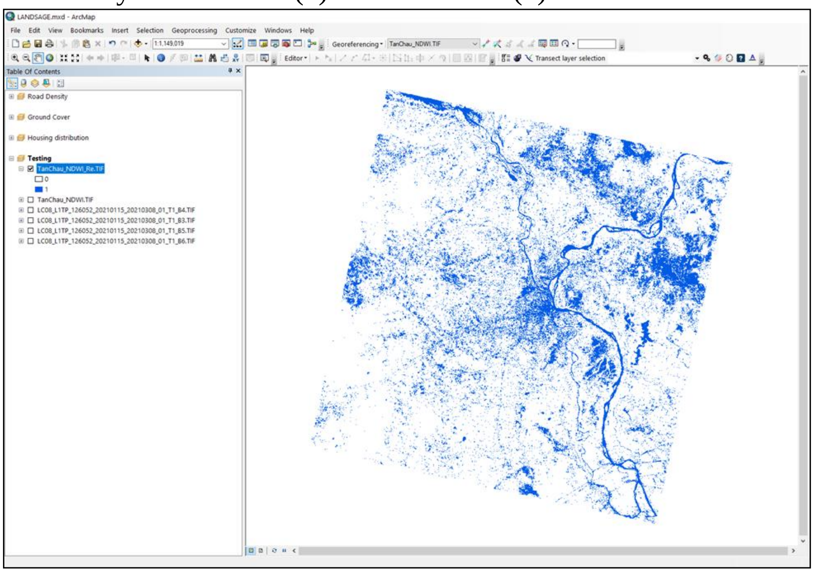




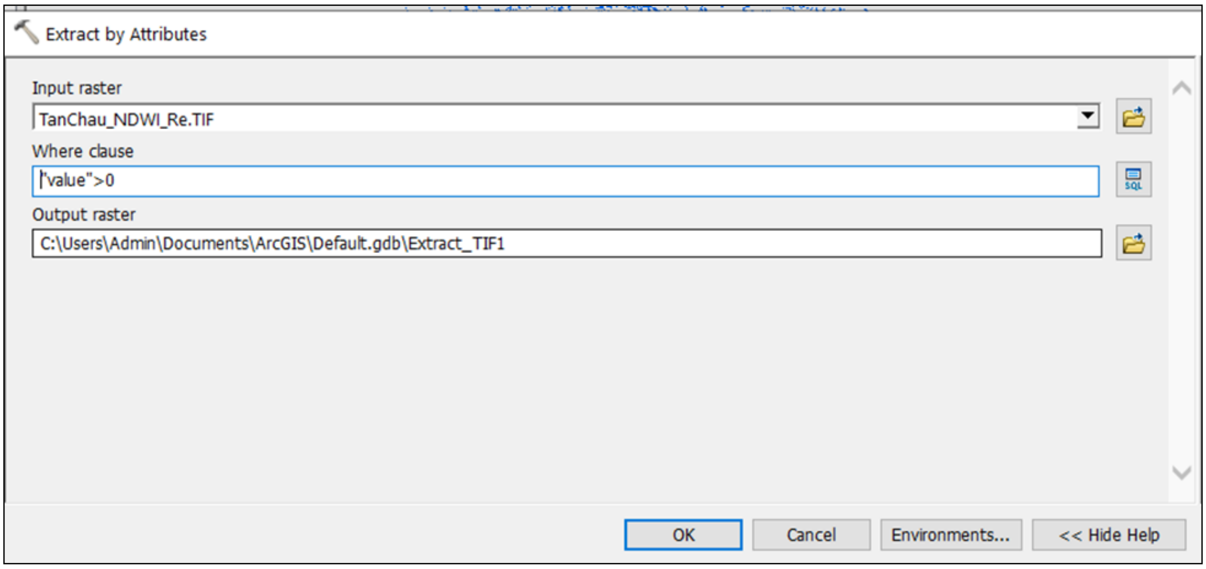
- Use the “Reclassify” tool to setup two classes and values as shown in the picture below.



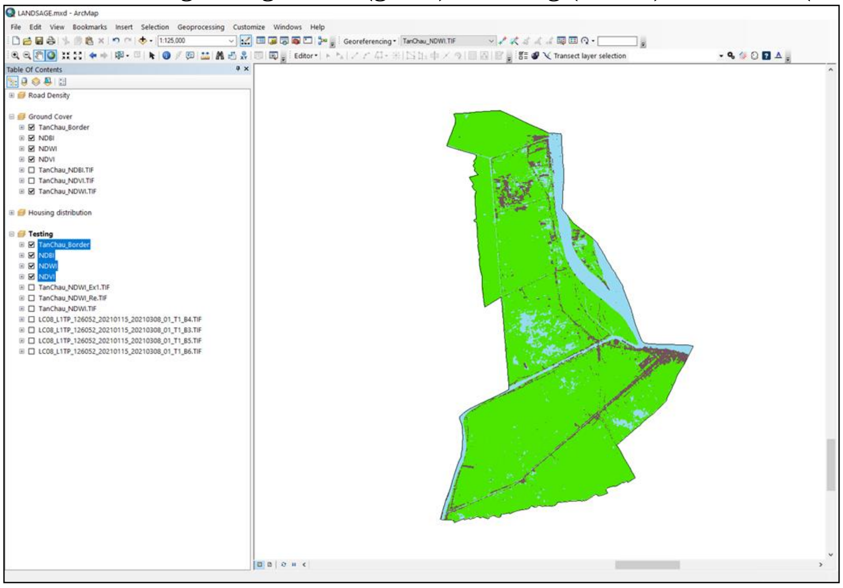
- This will result in a layer with water (1) and non-water (0) areas.



- Use the “Extract by Attributes” tool to extract only the water areas.



- Cut the layer to include only the region of interest (in this example, it is Tan Chau in Vietnam). Perform similar steps for the NDVI and NDBI indices. Combine the results into a simple land cover map below consisting of vegetation (green), building (brown), and water (blue) areas.

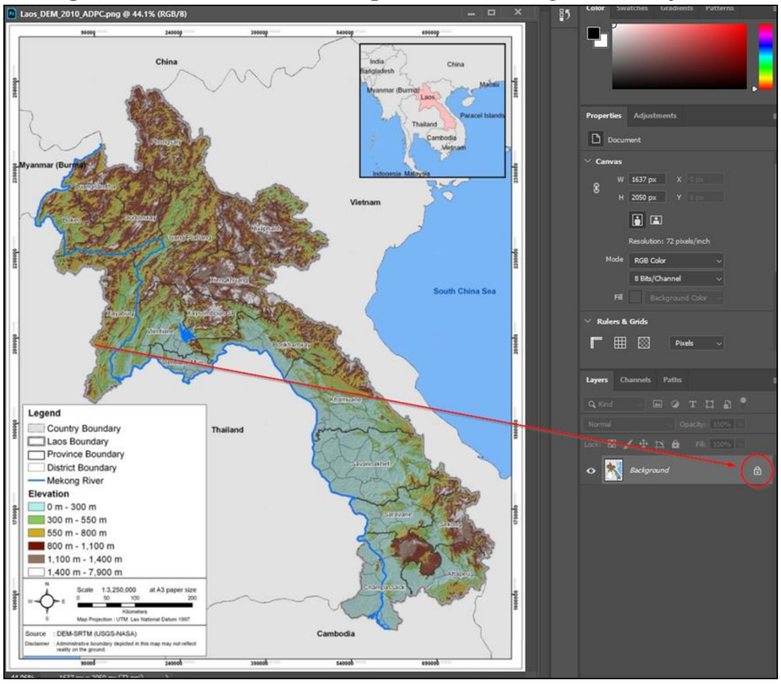


Data Preprocessing before Importing into the LandSAGE Software

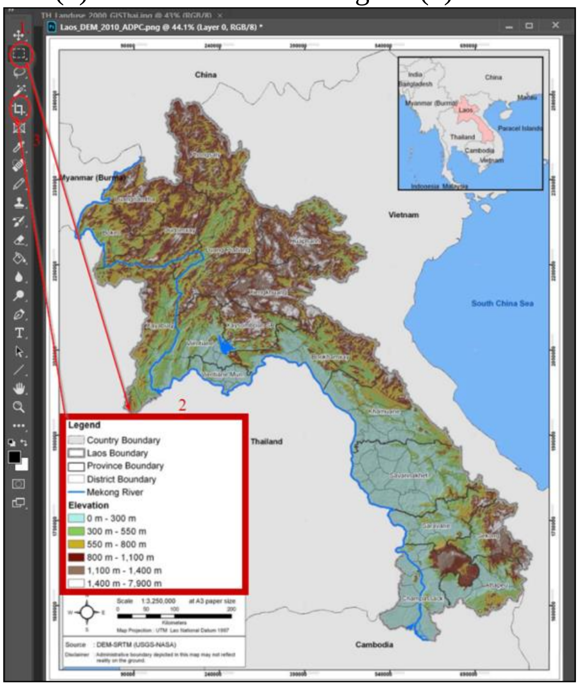
Each of the collected raster images was preprocessed to extract its map and legend components for uploading into the LandSAGE software. In addition, the latitudes and longitudes of the upper left and lower right corners of the map were identified for aligning the map to the base map of Lower Mekong Basin for geographically-correct visualization.

Legend Extraction:

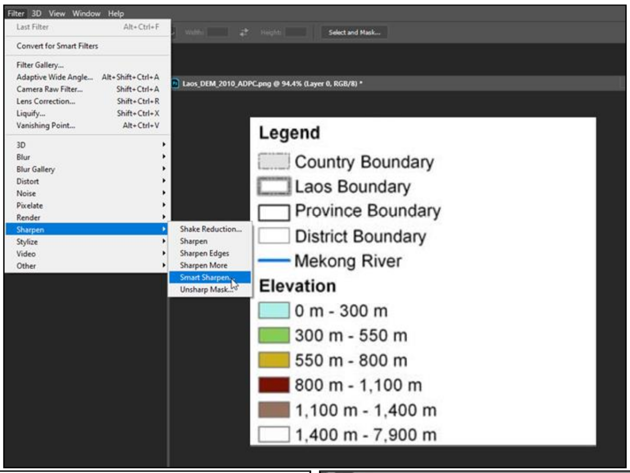
- Open the raster image in the Adobe Photoshop. Set the *Background Layer* to workable.

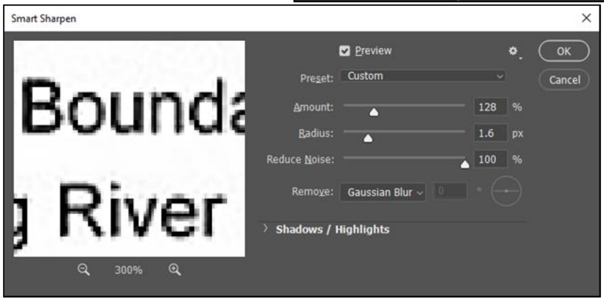


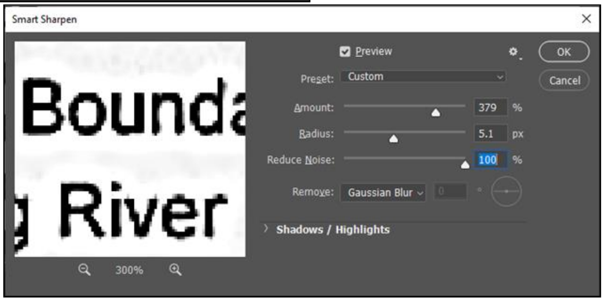
- Use the *Selection Tool* (1) to select the area of legend (2) and then use the *Crop Tool* (3).



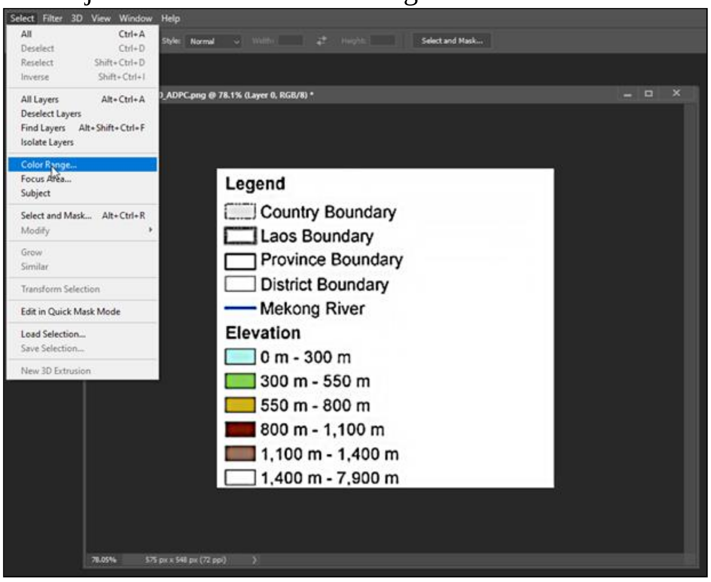
- We can use the *Smart Sharpen Filter* to enhance the image clarity. Note that too high sharpen amount can make the image noisy. The *Reduce Noise Value* should be set to 100%.

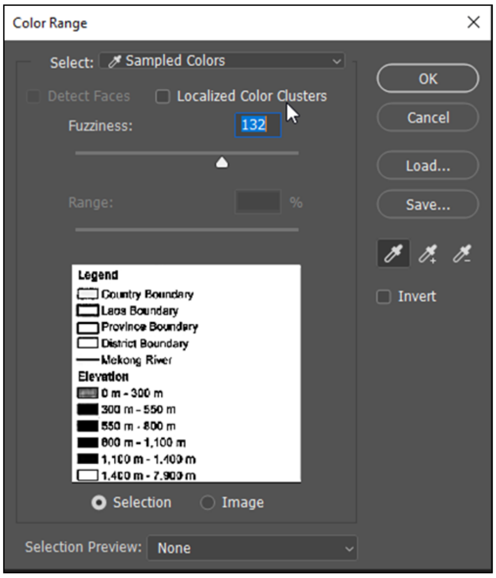




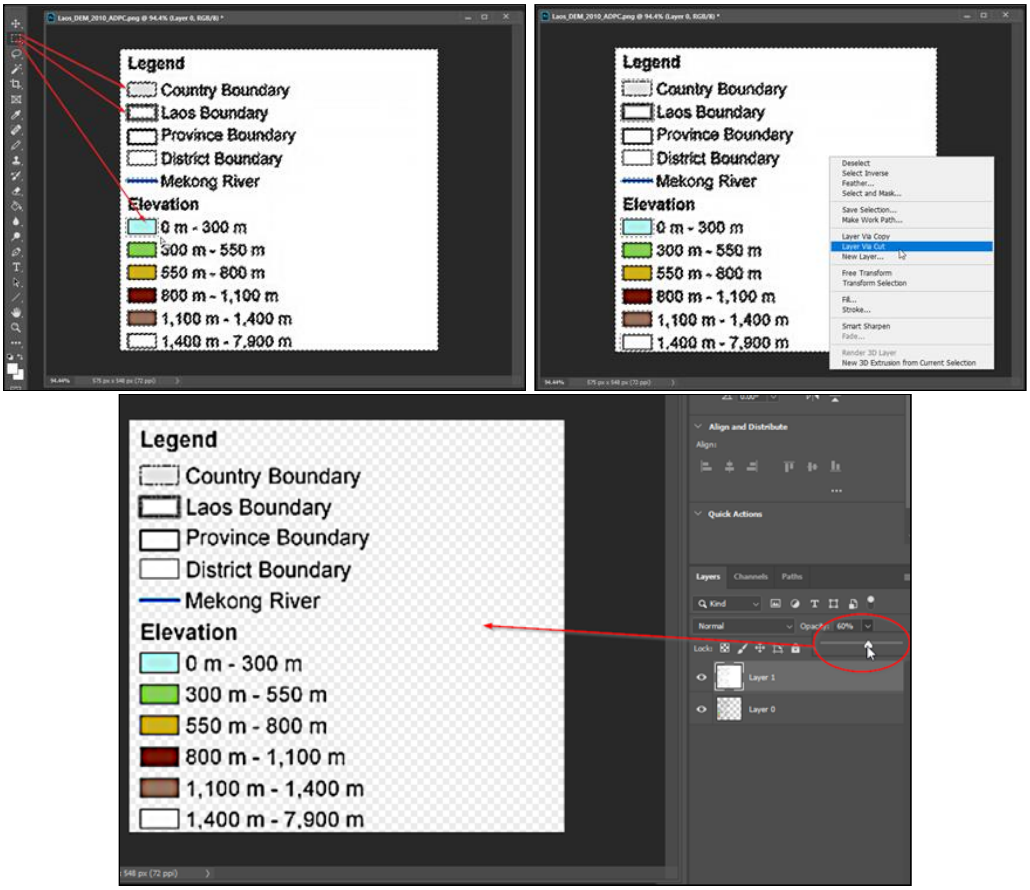


- To make the background transparent, use the *Color Range Function* and select the data area. Adjust the *Fuzziness Level* to get the best result.

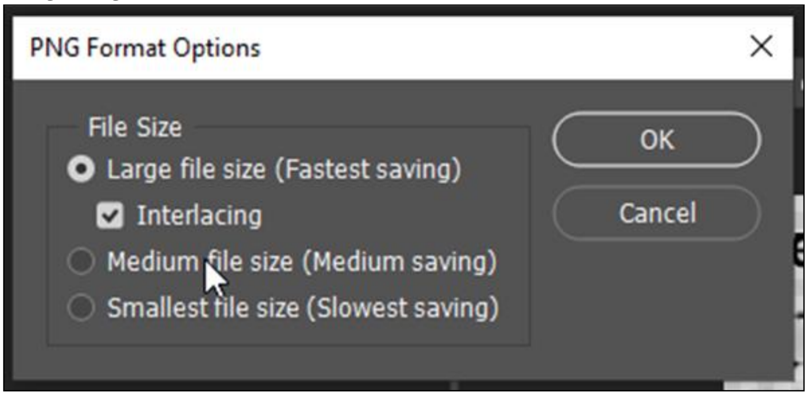




- Deselect all needed areas, remove (cut) the layer, and adjust the opacity.

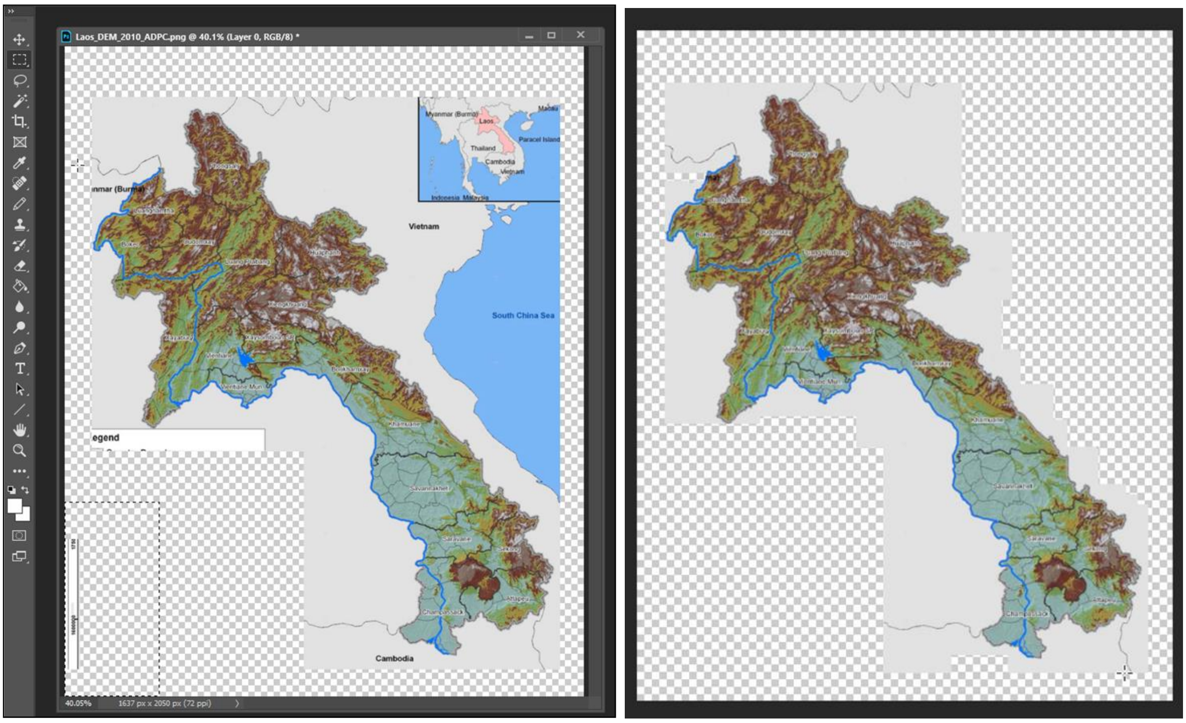


- Save the resulting image in the PNG "interlaced" format.

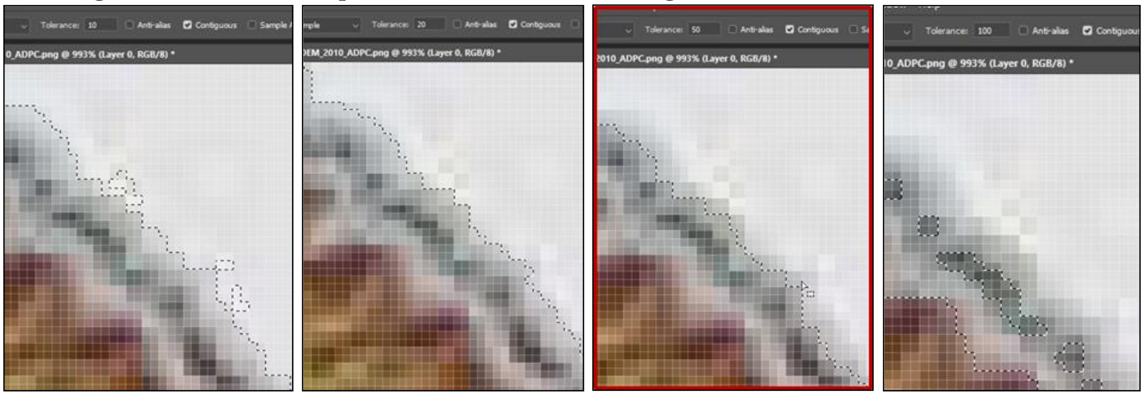


Map Extraction:

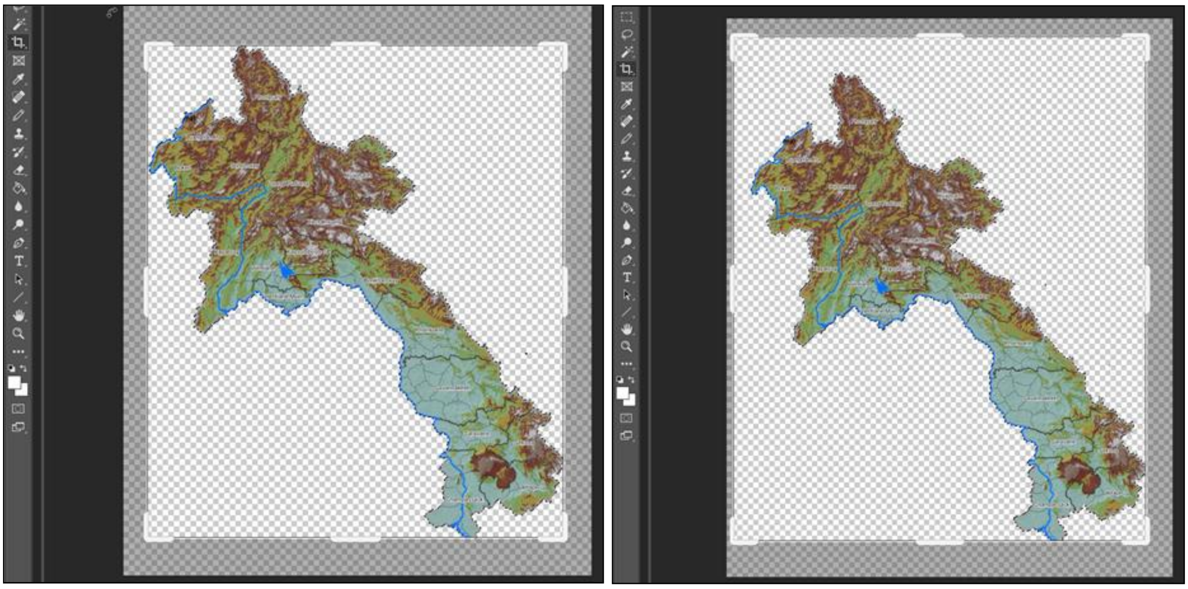
- Open the raster image in the Adobe Photoshop. Set the *Background Layer* to workable.
- Use the Selection Tool to remove unwanted objects such as the legend and borders. Use the *Magic Wand Tool* to remove an unwanted object that overlaps the map area. In the example below, the black text portion outside the map area near the upper left is removed.



- Use the *Magic Wand Tool* to crop the map area. Find the *Tolerance Level* that gives the best extraction. The example below compares the tolerance values of 10 (left), 20, 50, and 100 (right). Too high values can cut map area. The tolerance of 50 gives the best result.



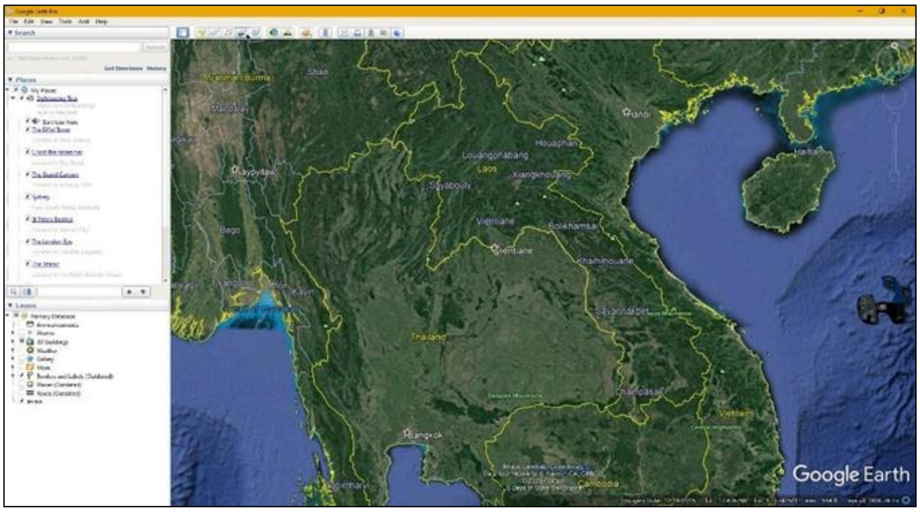
- Make sure that the leftmost, rightmost, topmost, and bottommost of the map align with the image borders. The example below shows good (left) and bad (right) alignments.



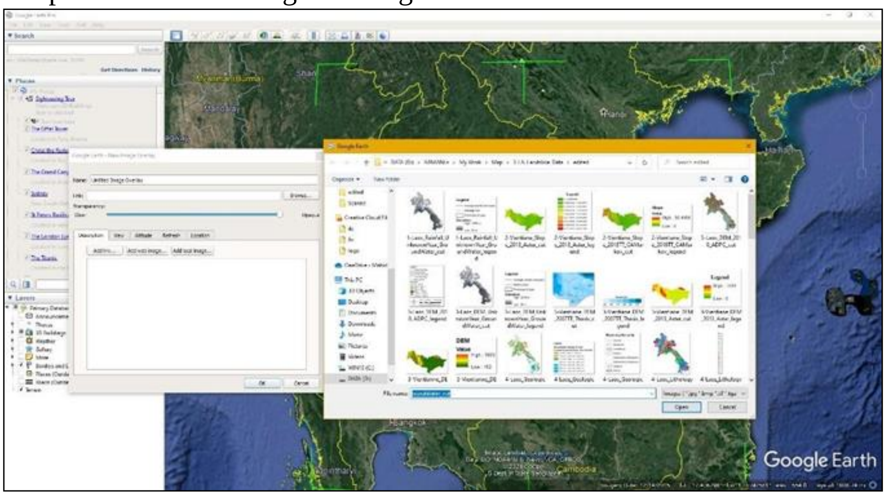
- Save the resulting image in the PNG “interlaced” format.

Map Alignment:

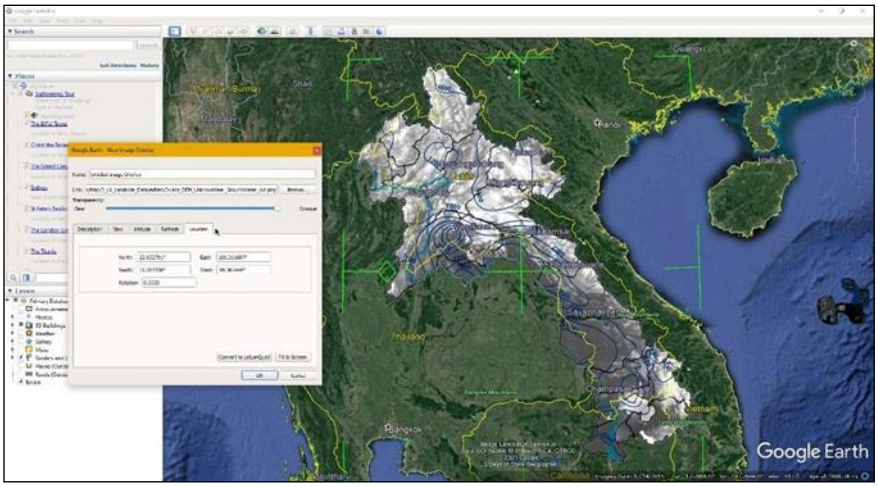
- In Google Earth Pro, look for the area of the raster image (map component), then click *Add Image Overlay*.



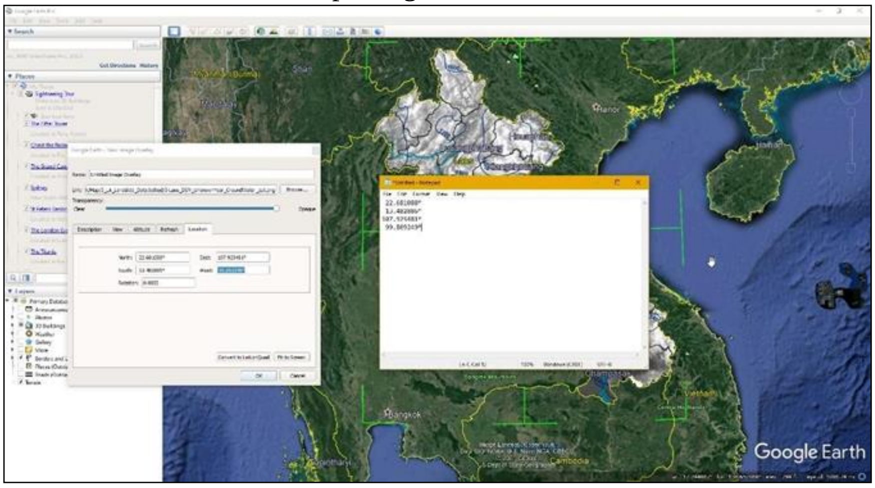
- Browse and upload the raster image to Google Earth Pro.



- Translate, rotate, and stretch the image to align it to the corresponding area on the base map as best possible.



- After the alignment, save the latitudes and longitudes of the upper left and lower right corners of the raster image for importing into the LandSAGE software via its backend interface. If the alignment involves rotation, modify the original raster image in Adobe Photoshop by applying rotation of the same amount before importing it into the LandSAGE software.

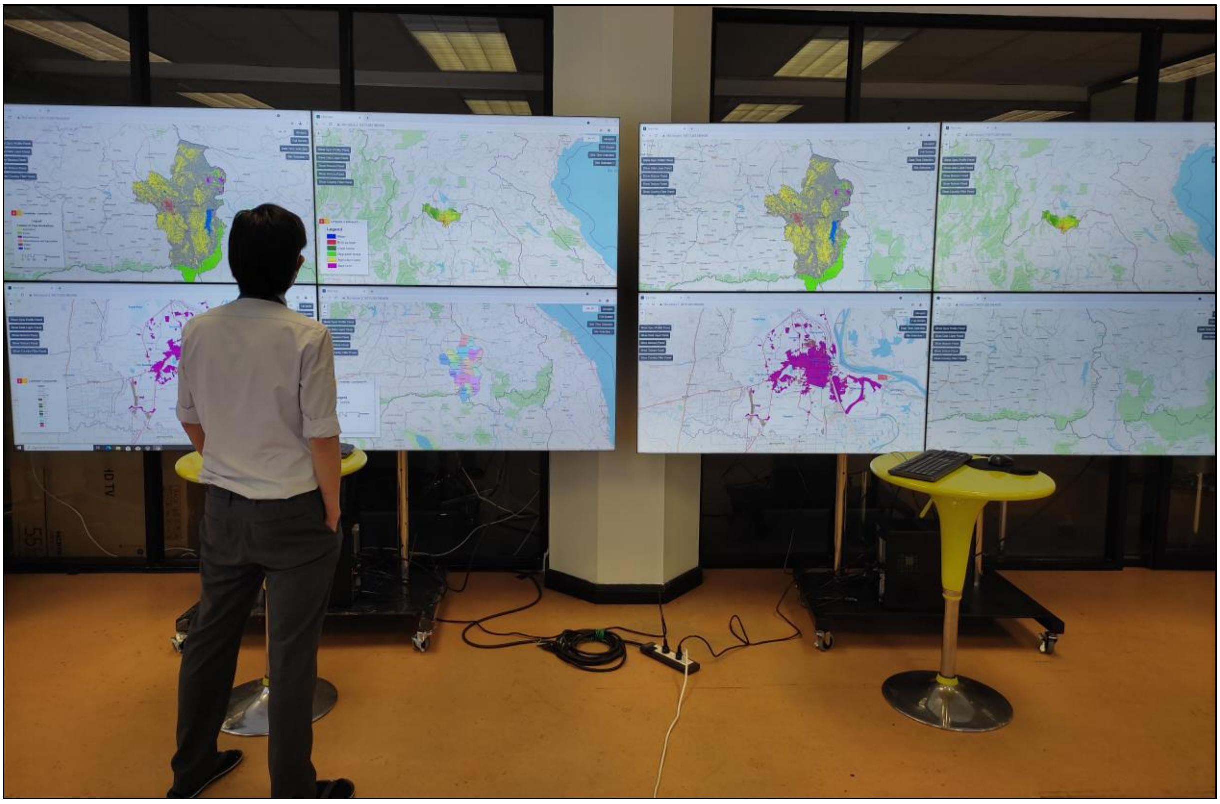


PART 3 – SOFTWARE DESIGN AND DEVELOPMENT

Design Overview

The LandSAGE software has been designed to satisfy the following requirements:

Utilization of expansive screen space for visualization: Prior research shows that the large screen of CyberCANOE on real estate enables the researcher to view large amounts of ultrahigh-resolution information. These data help them draw conclusions faster, more accurately, and with more confidence than with traditional displays. The expansive screen space also facilitates collaborative information exploration by a team of researchers.

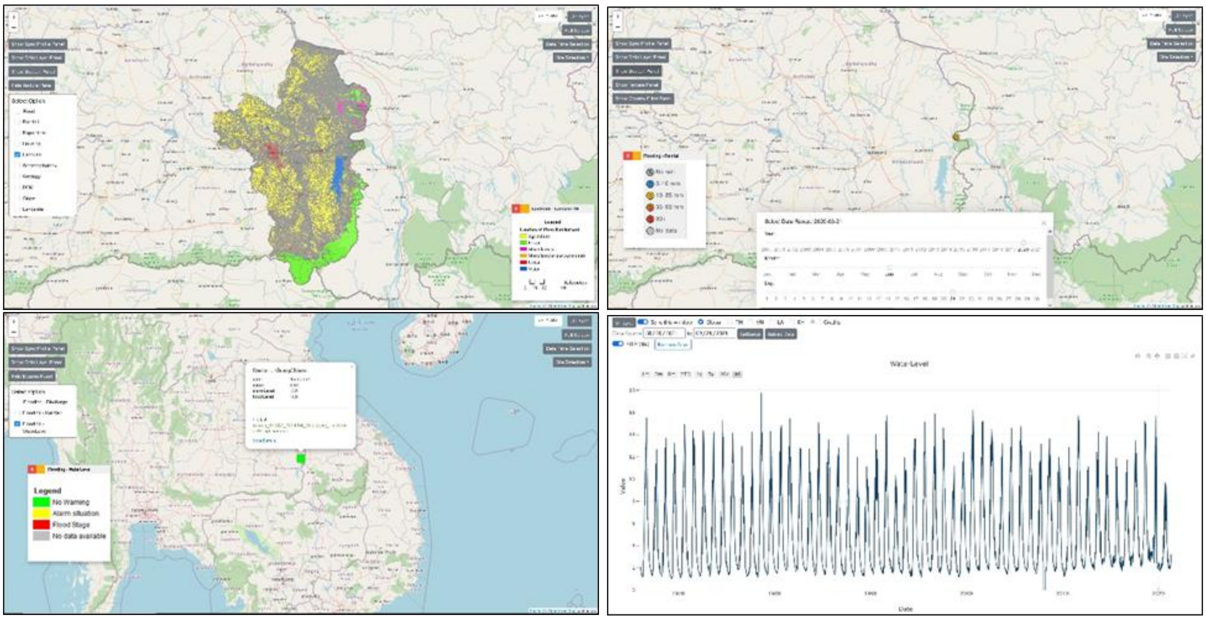


Two interconnected CyberCANOEs (large tiled-display walls) running the LandSAGE software.

Visualization of and interaction with natural disaster data: The LandSAGE software supports visualization of 3 flood and 10 landslide factors.

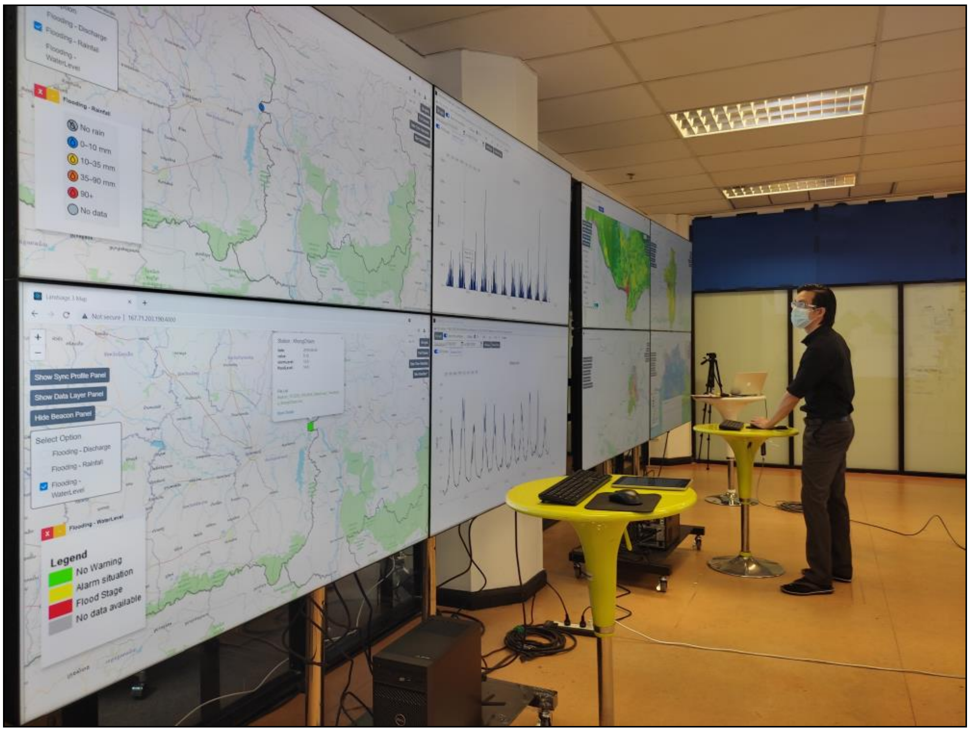
- Flood factors: Rainfall, water level, and discharge.
- Landslide factors: Rainfall, DEM, slope, geologic lithology, geomorphology, land use/cover, landslide inventory/susceptibility, housing distribution, population density, and road density.

The user can toggle the display of each factor on a base map of the Lower Mekong Basin. For a landslide factor, a corresponding raster image (texture) is overlaid on the base map (see below, top left). For a flood factor, a corresponding hydro-meteorological station is displayed as an icon on the base map. The color of an icon indicates status, e.g., red color for flood or very heavy rainfall, green for normal condition (top right). The user can hover the mouse cursor over an icon to pop up an overview information (bottom left) and click on the icon to bring up more detailed information in the form of time-series graph in a separate window (bottom right). The visualization can be toggled per each country of Cambodia, Laos, Vietnam, and Thailand. The user can navigate on the map by using pan and zoom interaction, and can navigate through time using a time slider widget (top right). Similarly, the user can explore a graph by using pan and zoom.



Example visualizations: Top left – Texture of land use of Ubon Ratchathani province in Thailand. Top Right – Icon representing rainfall station is drawn on the base map. The color indicates status. At the bottom is the time slider widget. Bottom Left – Overview information of water level station. Bottom Right – Graph of hydro-meteorological time-series data.

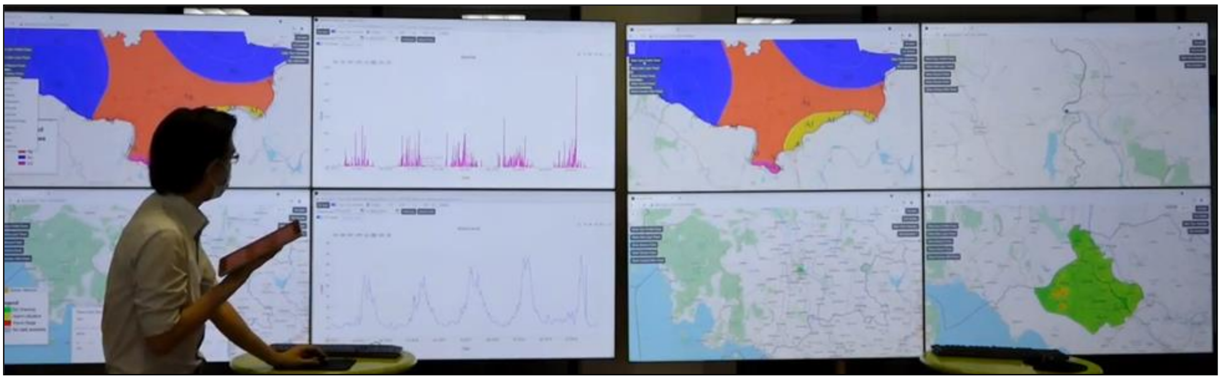
Multiple views of information: The user can add, remove, and juxtapose multiple views (windows) of flood and landslide factors on the display wall, with each view presenting an adequate level of detail (resolutions), thus reducing the need for window switching. This facilitates exploring a range of relationships and forming hypotheses. The picture below shows an example view arrangement to facilitate discovery of relationships between various factors.



Multiple view arrangement to facilitate relationship exploration and forming of hypotheses.

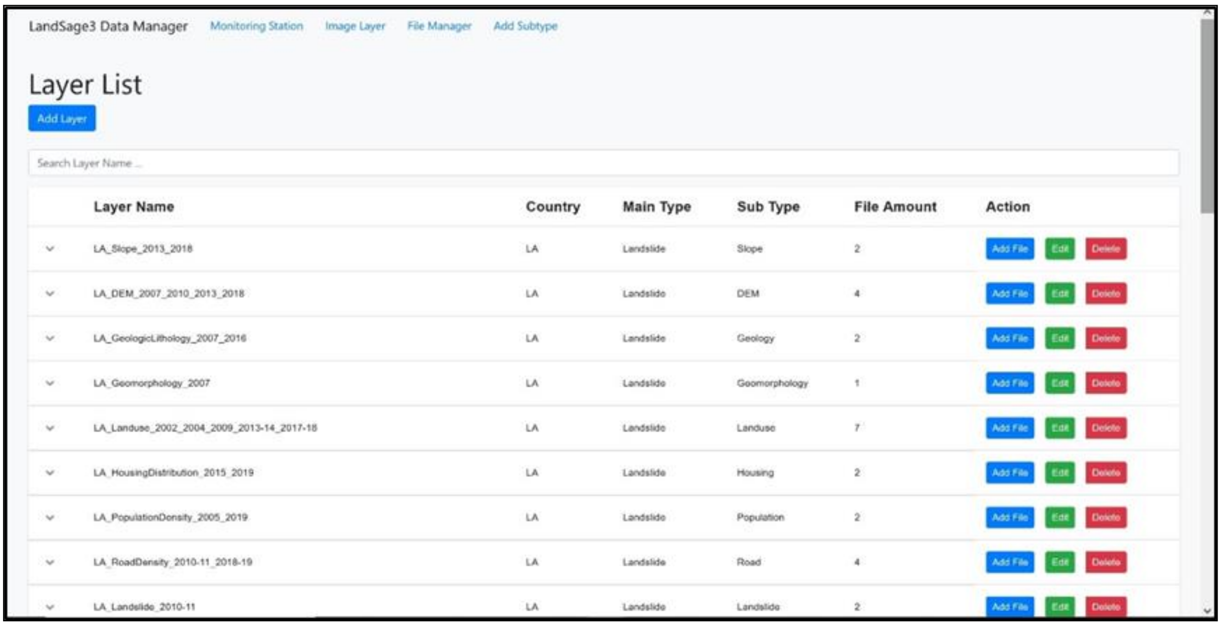
View synchronization: To further aid the relationship exploration, the LandSAGE software supports synchronization of map location, time point, and factor selection across multiple views. When the location synchronization is enabled, as the user pans the map in one view to a new location, all the other views will synchronously pan the maps to this new location. When the time synchronization is enabled, as the user navigates to a new time point in one view, all the other views will synchronously navigate to this new time point. When the factor synchronization is enabled, as the user toggles a factor in one view (called "active"), all the other views will synchronously display the same factors as that in the active view.

Multiple user support: Multiple users can work with the LandSAGE software simultaneously in front of the display wall. Each user can use their laptop to add or remove a visualization (view) to and from the wall, as well as to interact with any visualizations already on the wall (e.g., to arrange multiple visualizations into proper layout). Additionally, A visualization on one wall can be synchronized to another wall (see below) to support collaboration between multiple walls that are geographically distributed across Asi@Connect's networks.



Two CyberCANOEs running the LandSAGE software with their top-left windows synchronized.

Backend data management: The LandSAGE software provides an easy-to-use backend interface allowing non-technical users to add, remove, and edit data for visualization.



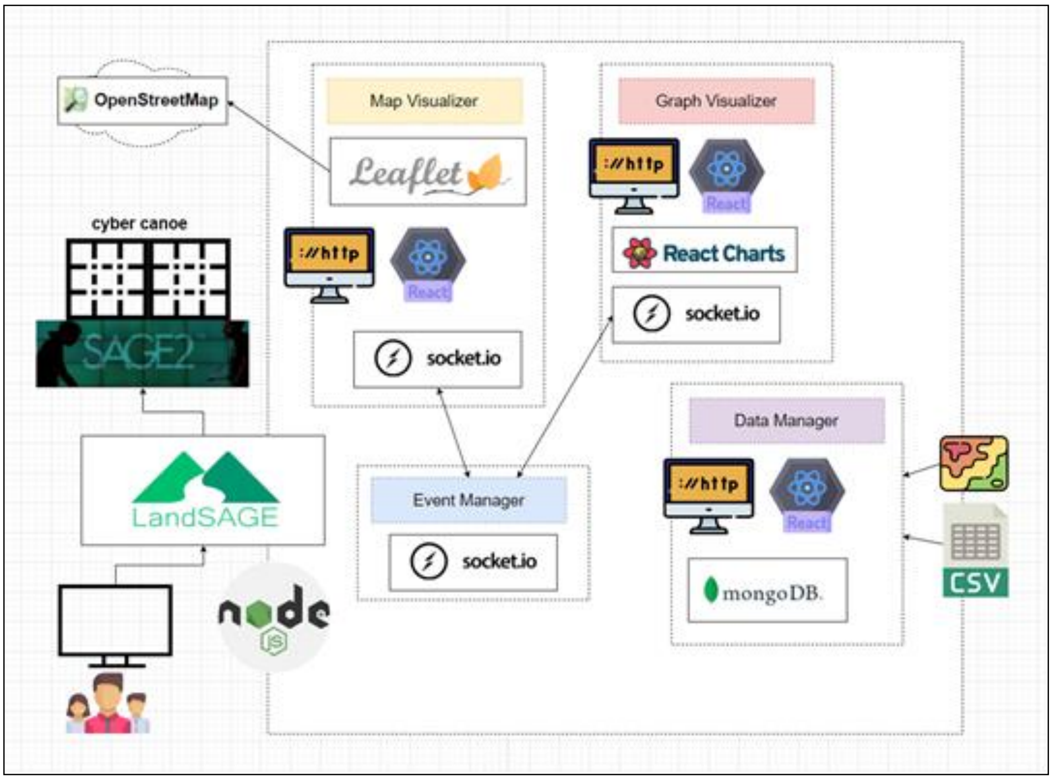
Backend interface that facilitates data management for non-technical users.

Implementation Overview

After an extensive technology review, we chose the following tools for the LandSAGE software implementation:

- Node.js for the main scripting
- React.js for UI
- Leaflet + OpenSteetMap for interactive map visualization
- Plotly.js for graph generation and visualization
- Socket.IO for view synchronization
- MongoDB for data management

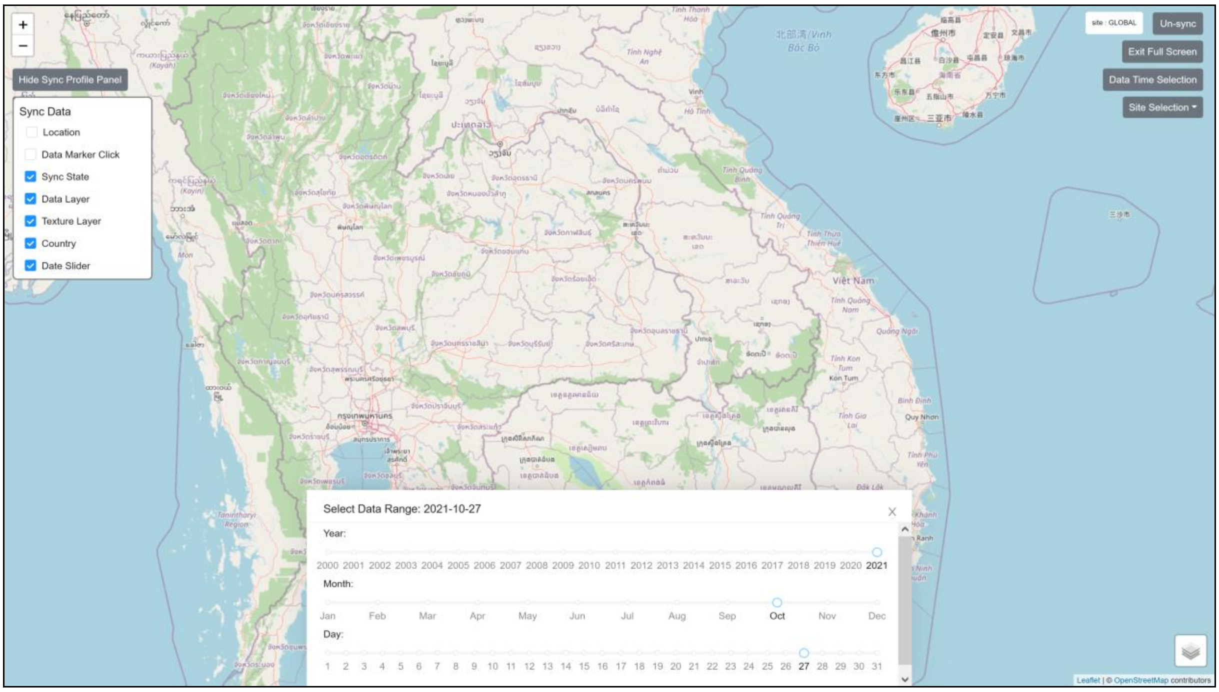
These tools are open source making it easy for TEIN community to extend or deploy the LandSAGE software in the future. We also found them to be efficient, lightweight, and provide great control over their functionalities. OpenStreetMap is a map of the world and free to use under an open license. Our implementation adopted micro-service architecture that divided the application into multiple services, with each service having a single dedicated goal. There are currently four services in the LandSAGE software consisting of map visualizer, graph visualizer, event manager (for view synchronization), and data manager (including backend interface). The diagram below shows how the different components of the LandSAGE software fit together.



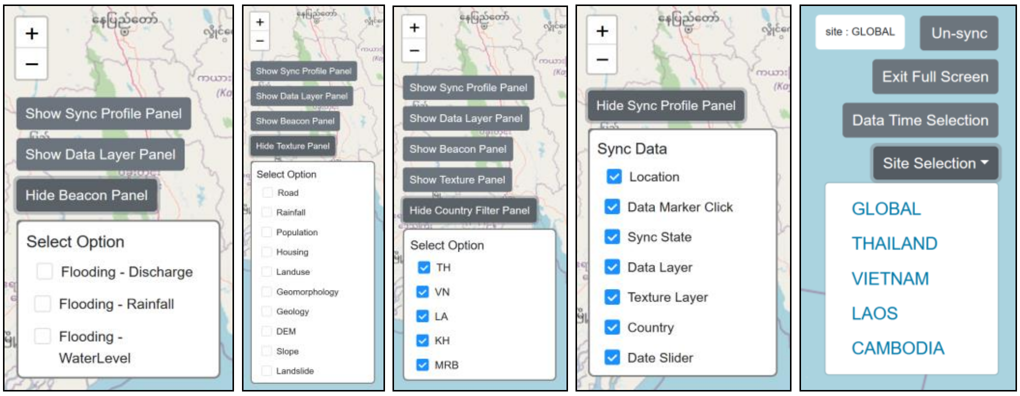
LandSAGE software architecture

Map Visualizer Service

User Interface for Map Visualizer



Map visualizer user interface showing the Date Time Selection panel at the bottom.



From left to right: Beacon, Texture, Country Filter, Sync Profile, and Site Selection panels.

Beacon Panel is used to toggle the display of each flood factor on the base map.

Texture Panel is used to toggle the display of each landslide factor on the base map.

Country Filter Panel chooses the countries for which to display flood and landslide factors.

Date Time Selection Button toggles the display of time slider widget that is used to indicate the current time point. For each flood and landslide factor, the data nearest to the current time point is displayed.

Sync Profile Panel controls synchronization between multple views (windows). The synchronization can be toggled for the following parameters: map location, flood factor selection, landslide factor selection, country selection, and time point. A view is only synchronized with other views of the same site. The site that a view belongs to is chosen from the *Site Selection Panel* and is indicated at the upper right corner of the screen. In the example figures above, the chosen site is GLOBAL. There are currently five supported sites. The other four are THAILAND, VIETNAM, LAOS, and CAMBODIA. The synchornization is supported for both within-wall and between-walls.

Sync/Un-sync Button toggles the view synchronization in all the windows of the same site.

+/– Buttons are used to zoom into and zoom out of the map.

Full Screen Button toggles between the full screen and windowed display.

Implementation Note for Map Visualizer

Important functions implemented in the map visualizer include:

initialSocketEvent initializes the “Socket.IO” library and connects to the event manager in order to subscribe to synchronization events.

updateTextureOverlay updates textures on the map when the user or a broadcasting event from the event manager changes the landslide factor selections.

updateBeacon updates beacons on the map when the user or a broadcasting event from the event manager changes the flood factor selections.

renderSiteSelection sets the *Site Selection Dropdown* options and the action when the user selects an option.

renderCountryFilterPanel sets the *Country Filter Panel* options and the action when the user selects an option.

renderTexturePanel sets the *Texture Panel* options and the action when the user selects an option.

renderBeaconPanel sets the *Beacon Panel* options and the action when the user selects an option.

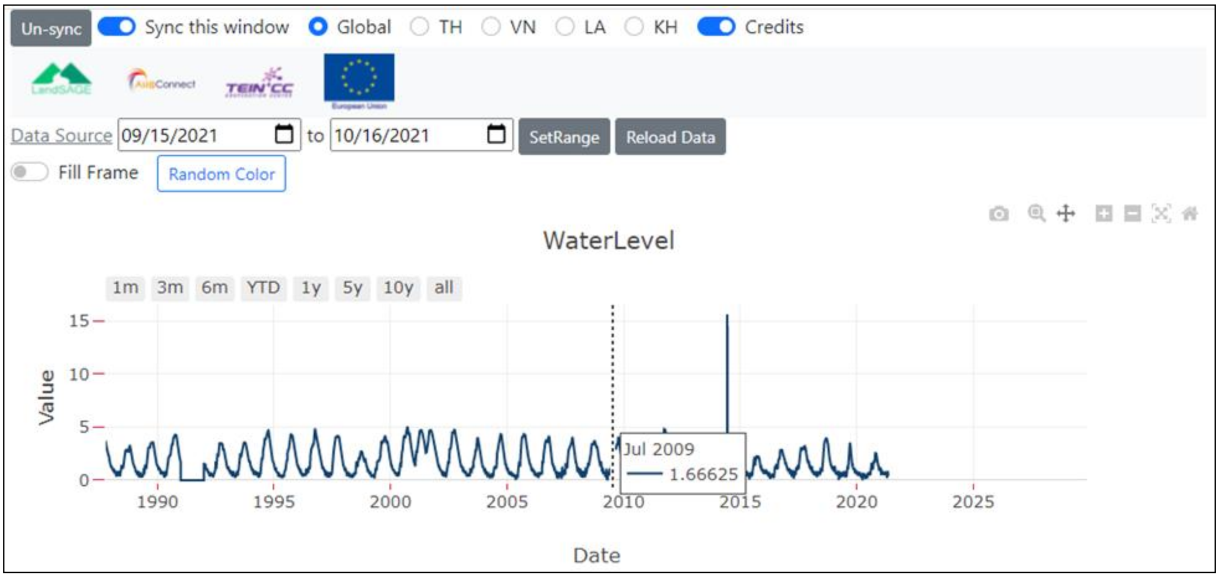
renderBottomDrawer setups the time slider and the action when the time point is changed.

renderLegend setups the legend window for a flood/landslide factor and the actions when the user hides, drags, or closes the legend window.

render triggers the complete map rendering.

Graph Visualizer Service

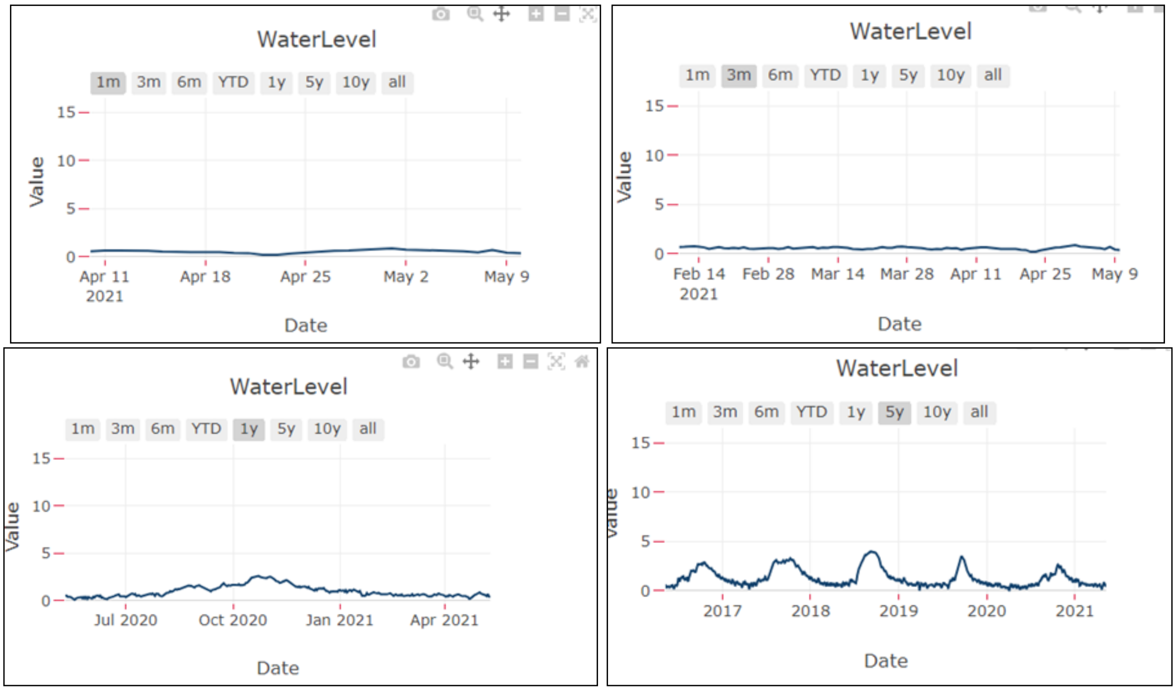
User Interface for Graph Visualizer



Graph visualizer user interface for time-series data.

SetRange Button is used to confirm the time range (window) in which to display the associated time-series data. The time range is specified using the two textboxes to the left of the button.

Time Range Buttons are used to select pre-defined ranges including 1 month, 3 months, 6 months, 1 year, 5 years, 10 years, and showing all the data.



Example time ranges: 1 month, 3 months, 1 year, and 5 years.

Graph Interaction: The user can interact with the graph content as follows:

- Hover the mouse pointer over a time point to see the value in a small popup window.
- Left click and drag the mouse pointer horizontally to slide the time window left and right.

- Scroll the mouse wheel to zoom into and out of the data (decreasing and increasing the time range)

Camera Button on the right hand side is used to save a snapshot of the graph in PNG image format.

Sync/Un-sync Button toggles the view synchronization in all the windows of the same site.

Sync This Window Switch toggles time point synchronization for this window. Note that only time point synchronization is available in graph views.

Site Radio Buttons are used to select the site (GLOBAL, TH, VN, LA, or KH) for this window.

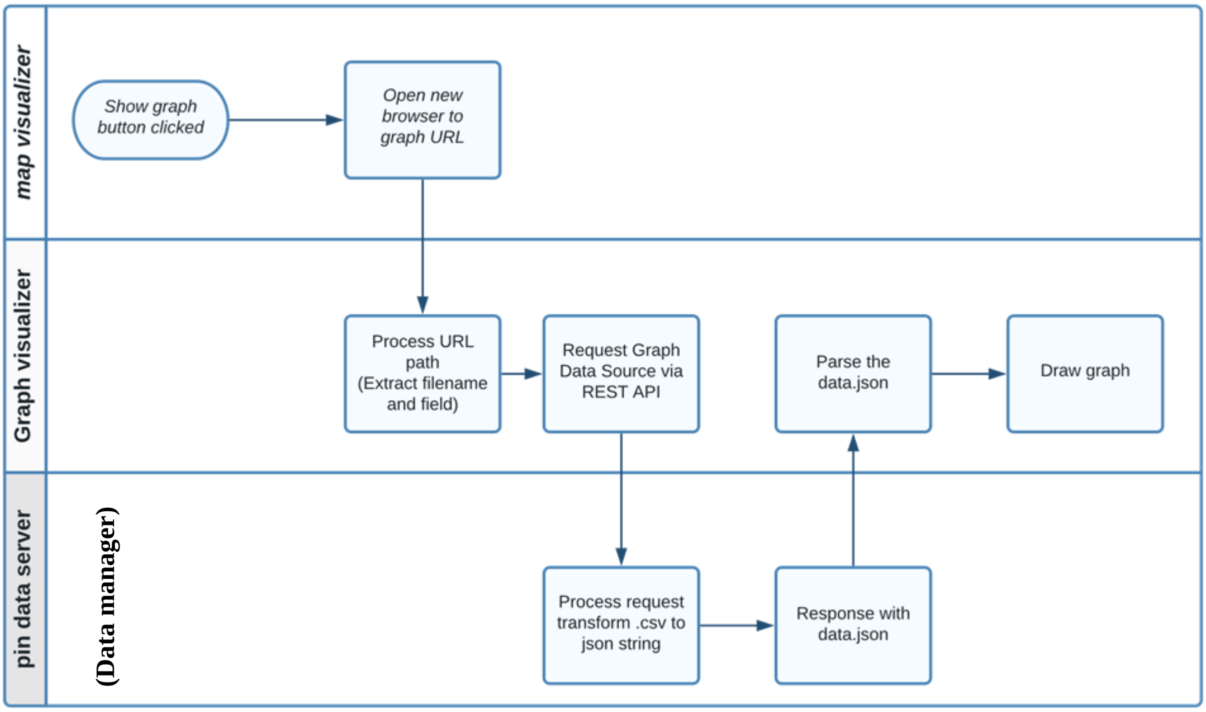
Credits Switch toggles the display of LandSAGE project, Asi@Connect, TEIN*CC, and the European Union logos.

Fill Frame Switch is used to make the graph fill the empty space in the window.

Random Color Button randomizes the color used to draw the graph.

Implementation Note for Graph Visualizer

The map visualizer instantiates the graph visualizer to display a graph of hydro-meteorological time-series data. The input to the graph visualizer is a CSV filename that is subsequently forwarded to the data manager via the REST API to request actual time-series data.



Communication between map visualizer, graph visualizer, data manger (also called pin data server).

The data is returned from the data manager in the JSON format. The structure of the JSON data is shown below.

Fields in the JSON data received from the data manager

Field Name	Description
Data	Array of data for drawing a chart

Error	Error message from data preparation
delimiter	The field separation character
linebreak	The line break character
aborted	The success of data parsing
truncated	Is the data partial or whole?
cursor	The number of characters in the JSON data
fields	The field names used to extract time points and associated values (combined into data points)

The important fields are *Data* and *fields*. *Data* contains the array of data points (each consisting of a time point and associated value) in the graph, while *fields* specifies attributes to be extracted in *Data*.


```
{"data":[{"Date":"1979-04-01","WaterLevel":"0.73"},
{"Date":"1979-04-02","WaterLevel":"0.68"},
{"Date":"1979-04-03","WaterLevel":"0.63"},
{"Date":"1979-04-04","WaterLevel":"0.59"},
{"Date":"1979-04-05","WaterLevel":"0.55"},
{"Date":"1979-04-06","WaterLevel":"0.49"},
{"Date":"1979-04-07","WaterLevel":"0.45"},
{"Date":"1979-04-08","WaterLevel":"0.51"},
{"Date":"1979-04-09","WaterLevel":"0.53"},
```


Part of JSON data showing the Data Field.


```
,{"Date":"2021-05-
10","WaterLevel":"0.393333333"}
],"errors":[],"meta":
{"delimiter":",","linebreak":"\
r\n","aborted":false,"truncated
":false,"cursor":275363,"fields
":["Date","WaterLevel"]}}
```

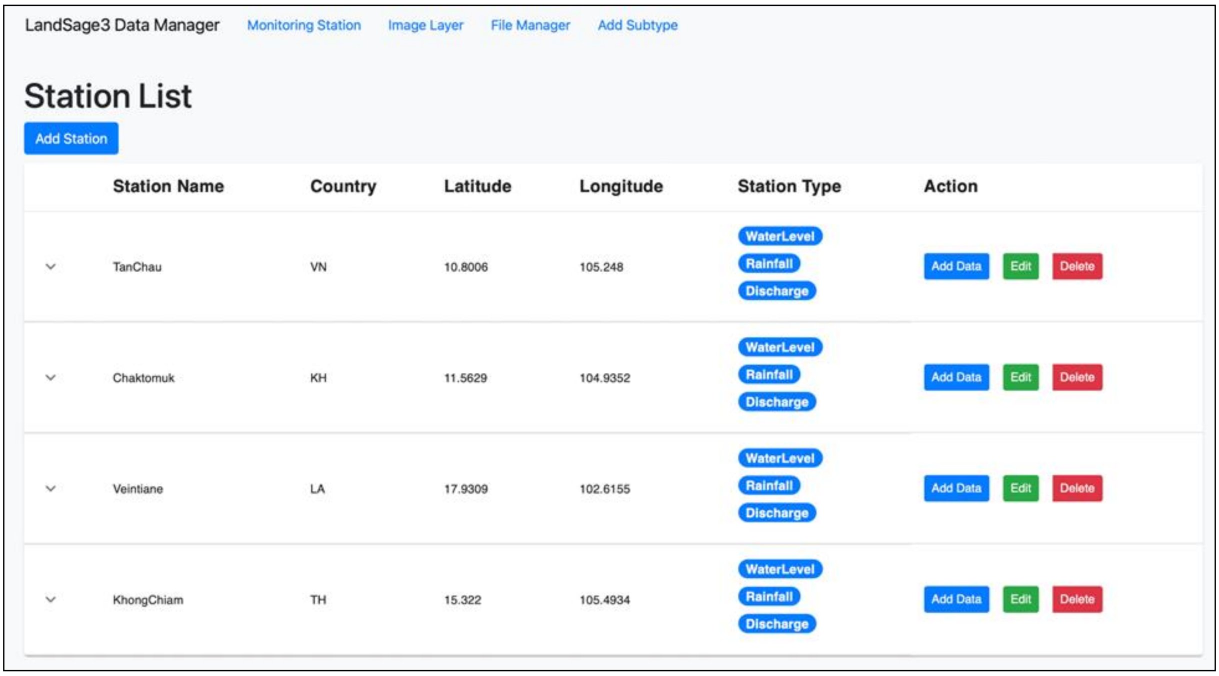

Part of JSON data showing *fields* at the bottom.

For view synchronization, a time point from the map visualizer is mapped to the time range in the graph visualizer that is centered on the time point with the range of two months. A time range from the graph visualizer is mapped to a time point in the map visualizer by using the center of the range.

Data Manager Service

The service provides four main functions: *Monitoring Station* (for managing hydro-meteorological monitoring stations), *Image Layer* (for managing raster images or textures), *File Manager* (general file management), and *Add Subtype* (for adding custom data types).

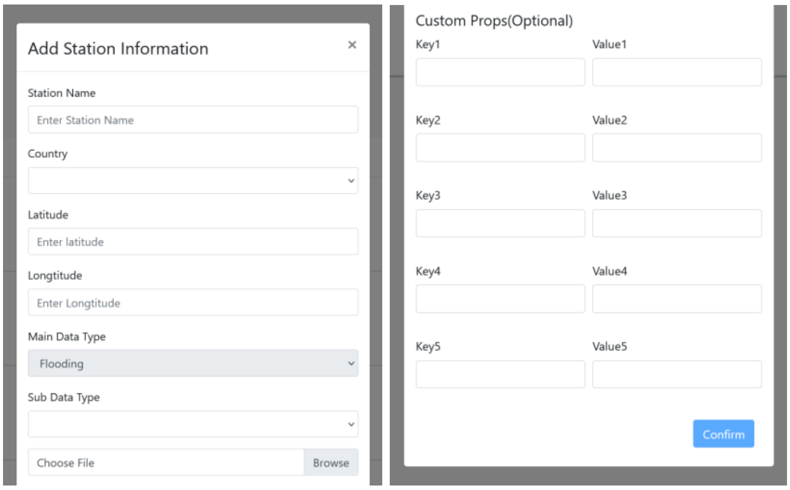
User Interface for Monitoring Station



User interface for managing hydro-meteorological monitoring stations.

This is the default page of the data manager service. It lists all the hydro-meteorological monitoring stations from MRC stored in the LandSAGE software database. The *Station Type Column* shows the types of data (rainfall, water level, and discharge) bound to each station.

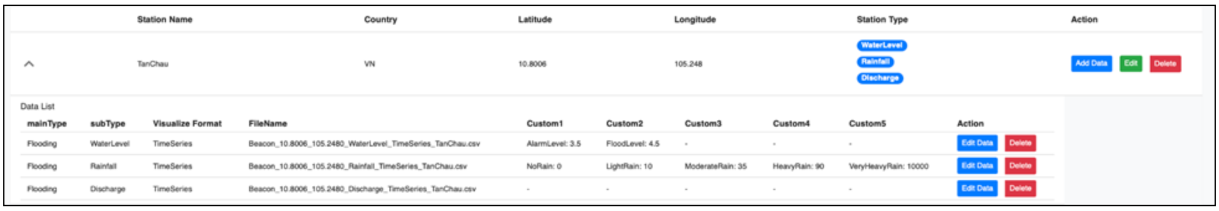
Add Station Button is used to add a new station into the database. All the information except the custom properties are required before submission. Data is bound to the station by uploading a CSV file containing time-series data using the *Browse Button*. *Sub Data Type Dropdown* specifies whether the uploaded data is rainfall, water level, or discharge.



Top half (Left) and bottom half (Right) of the Add Station dialog box.

Add Data Button is used to bind additional data to the station. *Edit Button* is used to edit the station information including name, country, latitude, and longtitude. *Delete Button* is used to delete the station from the database.

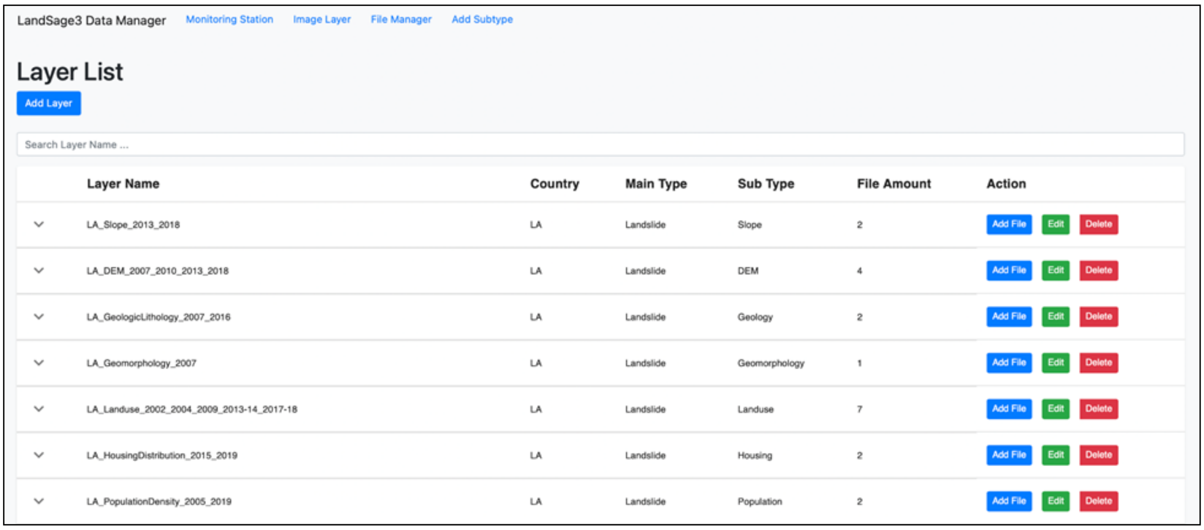
The downward arrow head to the left of a station name can be clicked to expand/collapse the station details showing all the data bound to the station.



The Tan Chau station is expanded to show all the data bound to the station.

Edit Data Button and *Delete Button* are used to edit and delete each data bound to the station, respectively.

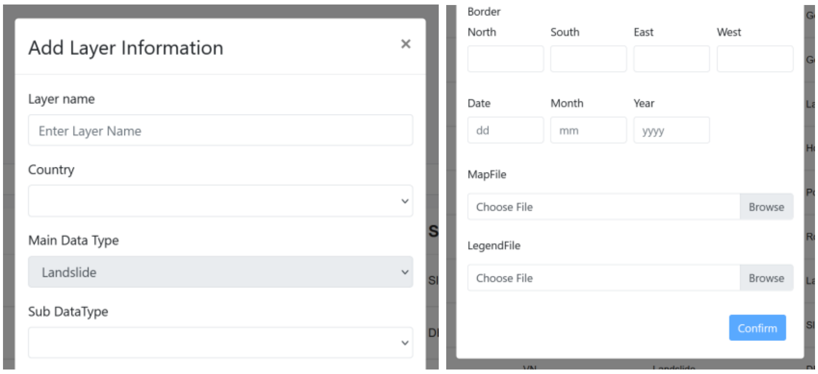
<u>*User Interface for Image Layer*</u>



User interface for managing landslide factors.

This page lists all the landslide factors stored in the LandSAGE software database classified by country and type (DEM, slope, geomorphology, geologic lithology, etc., see the *Sub Type Column)*. The *File Amount Column* shows the number of textures bound to each factor.

Add Layer Button is used to add a new landslide factor into the database.

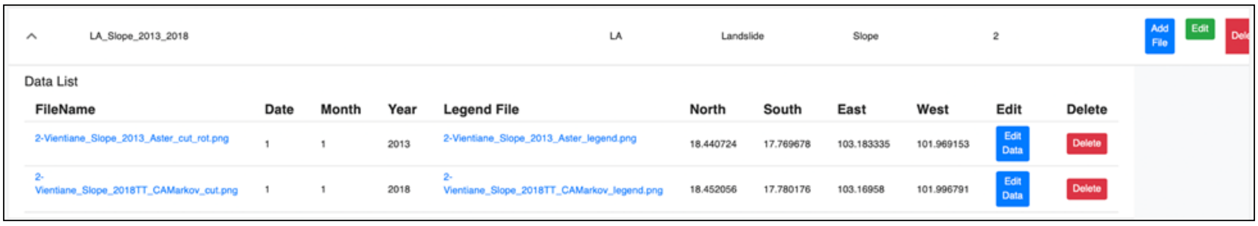


Top half (Left) and bottom half (Right) of the Add Layer dialog box.

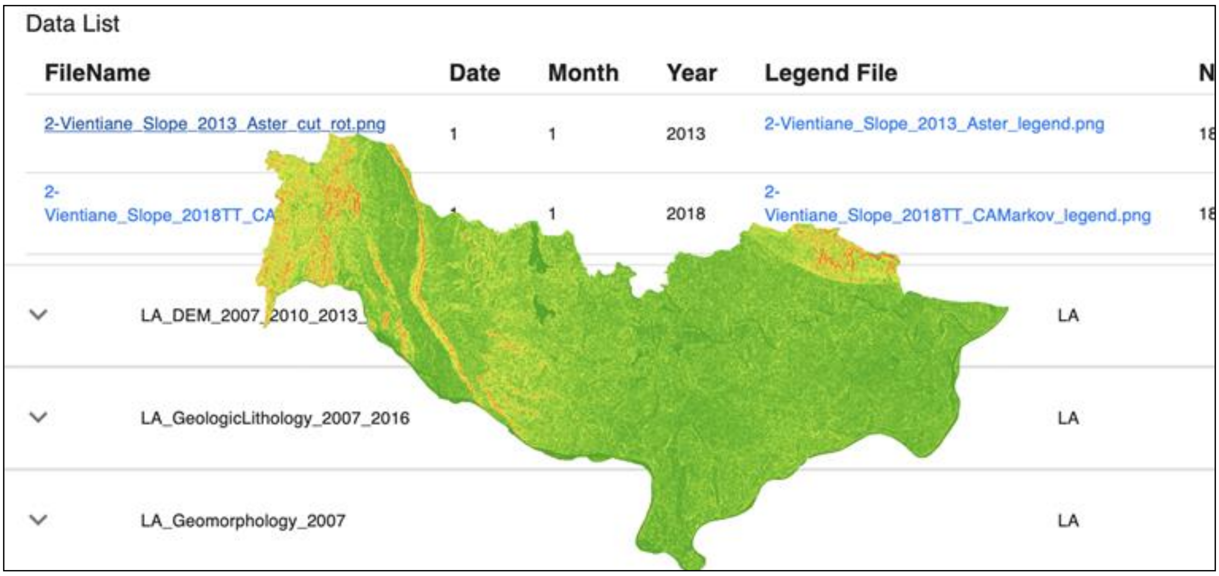
The user has to specify the lattitudes and longitudes of the upper-left and lower-right corners of the texture on the base geographic map, as well as the year of data the texture represents. The user has to specify two raster images in the PNG format, one for the texture itself and the other for the associated legend.

Add File Button is used to bind additional texture (and its legend) to the factor. Note that each factor can have multiple textures for the different years of data. Instead of uploading a new legend, the user can choose one of the previously uploaded legend for the factor. *Edit Button* is used to edit the factor information including name, country, and type. *Delete Button* is used to delete the factor from the database.

The downward arrow head to the left of a factor name can be clicked to expand/collapse the factor details showing all the textures bound to the factor. The user can get a preview image of a texture or legend by hovering the mouse cursor over the filename.



The slope factor of Laos is expanded to show all the textures bound to the factor.

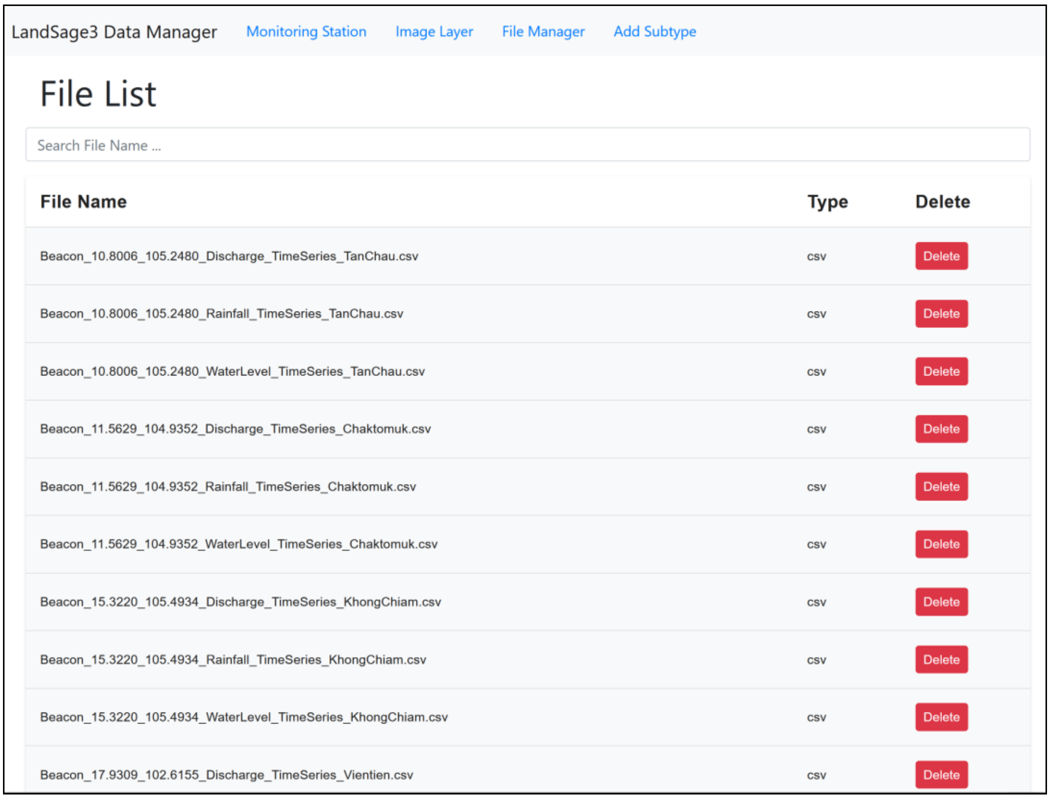


Preview image of the slopes of Vientiane Captial (Laos) in 2013.

Edit Data Button and *Delete Button* are used to edit and delete each texture bound to the factor, respectively.

<u>User Interface for File Manager</u>

This page lists all the files uploaded into the LandSAGE software database. This can include a CSV file containing hydro-meteorological time-series data for a flood factor and a PNG file containing a texture or legend image for a landslide factor. The user can manually delete each file using the *Delete Button*.



LandSage3 Data Manager | Monitoring Station | Image Layer | File Manager | Add Subtype

File List

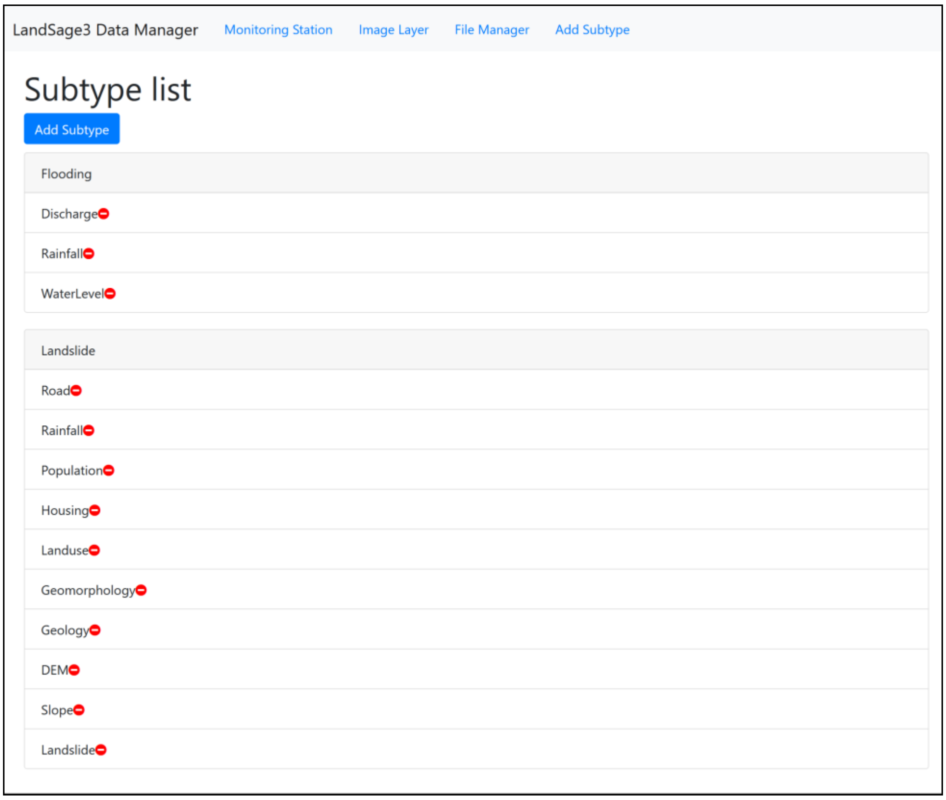
Search File Name ...

File Name	Type	Delete
Beacon_10.8006_105.2480_Discharge_TimeSeries_TanChau.csv	csv	Delete
Beacon_10.8006_105.2480_Rainfall_TimeSeries_TanChau.csv	csv	Delete
Beacon_10.8006_105.2480_WaterLevel_TimeSeries_TanChau.csv	csv	Delete
Beacon_11.5629_104.9352_Discharge_TimeSeries_Chaktomuk.csv	csv	Delete
Beacon_11.5629_104.9352_Rainfall_TimeSeries_Chaktomuk.csv	csv	Delete
Beacon_11.5629_104.9352_WaterLevel_TimeSeries_Chaktomuk.csv	csv	Delete
Beacon_15.3220_105.4934_Discharge_TimeSeries_KhongChiam.csv	csv	Delete
Beacon_15.3220_105.4934_Rainfall_TimeSeries_KhongChiam.csv	csv	Delete
Beacon_15.3220_105.4934_WaterLevel_TimeSeries_KhongChiam.csv	csv	Delete
Beacon_17.9309_102.6155_Discharge_TimeSeries_Vientien.csv	csv	Delete

User interface for managing files in the LandSAGE software database.

<u>User Interface for Add Subtype</u>

This page enables the user to add (using the *Add Subtype Button*) or delete (using the minus sign next to the type name) data type in the LandSAGE software. For example, it can be used to add a new type of flood or landslide factor.



User interface for managing data types in the LandSAGE software.

Implementation Note for Data Manager

The data manager exposes the following 15 services that enable the map visualizer and graph visualizer to request information from the database. For each service, the associated endpoint, request parameter(s), and an example response are given below.

I. *Get all beacon filters*

EndPoint: data/beaconFilter/
Parameter: -
Return: {
    “Data”: [
        {
            “mainType”: “Flooding”
            “subTypes”: [“Discharge, Rainfall, WaterLevel”]
        }
    ]
}

II. *Get all texture filters*

EndPoint: /data/textureFilter/
Parameter: -
Return: {
    “Data”: [
        {
            “mainType”: “Landslide”
            “subTypes”: [“Road”, ”Population”, ”Housing”, ”Landuse”, ”Geomorphology”,
                “Geology”, “DEM”, “Slope”]
        }
    ]

}

III. Get the file list (all CSV & texture files in the database)

Endpoint: /data

Parameter: -

Return: {

```
Return: {
    "fileList": ["Beacon_17.928_102.620_TimeSeries_Vientien.csv",
                 "Beacon_17.9309_102.6155_TimeSeries_Ubon.csv",
                 "Road.png",
                 "Road_cut.png",
                 "Road_Map_cut.png"
    ]
}
```

IV. Get all stations

Endpoint: /data/beacon

Parameter: -


```
Return: [ {
    "_id": "60eae7730c44f64aec02fd2a",
    "name": "Station8",
    "lat": 23,
    "long": 22,
    "fileList": [ {
        "_id": "60eae7730c44f64aec02fd2b",
        "mainType": "Weather",
        "subType": "Dedf",
        "visualFormat": "TextureMap",
        "fileType": "texture",
        "fileName": "846fb3121c337057030c81c0c587f8c1.png"
        "custom": [ {
            "_id": "6112d53ad0f054490442033d",
            "key": "WaterLevel",
            "value": "Medium"
        }, {
            "_id": "6112d53ad0f054490442033e",
            "key": "",
            "value": ""
        }, {
            "_id": "6112d53ad0f054490442033f",
            "key": "",
            "value": ""
        }, {
            "_id": "6112d53ad0f0544904420340",
            "key": "",
            "value": ""
        }, {
            "_id": "6112d53ad0f0544904420341",
            "key": "",
            "value": ""
        } ]
    } ],
```

```
        "createdAt": "2021-07-11T12:43:31.990Z",
        "updatedAt": "2021-07-11T12:43:31.990Z"
    }, {
        …(Other  stations)…
    } ]
```

V. Get information of a specific station

Endpoint: /data/beacon/{:id}

Parameter: id

Return: [{


```
        "_id": "60eae7730c44f64aec02fd2a",
        "name": "Station8",
        "lat": 23,
        "long": 22,
        "fileList": [ {
            "_id": "60eae7730c44f64aec02fd2b",
            "mainType": "Weather",
            "subType": "Dedf",
            "visualFormat": "TextureMap",
            "fileType": "texture",
            "fileName": "846fb3121c337057030c81c0c587f8c1.png"
            "custom": [ {
                "_id": "6112d53ad0f054490442033d",
                "key": "WaterLevel",
                "value": "Medium"
            }, {
                "_id": "6112d53ad0f054490442033e",
                "key": "",
                "value": ""
            }, {
                "_id": "6112d53ad0f054490442033f",
                "key": "",
                "value": ""
            }, {
                "_id": "6112d53ad0f0544904420340",
                "key": "",
                "value": ""
            }, {
                "_id": "6112d53ad0f0544904420341",
                "key": "",
                "value": ""
            } ]
        } ],
        "createdAt": "2021-07-11T12:43:31.990Z",
        "updatedAt": "2021-07-11T12:43:31.990Z"
    }, ]
```

VI. Filter stations with one filter parameter

Endpoint: /data/beaconFilter/{:x}

Parameter: x (mainType, subType, or country)

Return: [{


```
        "_id": "60eae7730c44f64aec02fd2a",
```

"name": "Station8",
"country": "th"
"lat": 23,
"long": 22,
"fileList": [{
"_id": "60eae7730c44f64aec02fd2b",
"mainType": "Weather",
"subType": "Dedf",
"visualFormat": "TextureMap",
"fileType": "texture",
"fileName": "846fb3121c337057030c81c0c587f8c1.png"
"custom": [{
"_id": "6112d53ad0f054490442033d",
"key": "WaterLevel",
"value": "Medium"
}, {
"_id": "6112d53ad0f054490442033e",
"key": "",
"value": ""
}, {
"_id": "6112d53ad0f054490442033f",
"key": "",
"value": ""
}, {
"_id": "6112d53ad0f0544904420340",
"key": "",
"value": ""
}, {
"_id": "6112d53ad0f0544904420341",
"key": "",
"value": ""
}]
}],
"createdAt": "2021-07-11T12:43:31.990Z",
"updatedAt": "2021-07-11T12:43:31.990Z"
}, {
…(Other stations in the filtered list))…
}]

VII. Filter stations with two filter parameters

Endpoint: /data/beaconFilter/{:x}/{:y}
Parameter: x (country or maintype), y (maintype or subtype)
Return: See *VI*

VIII. Filter stations with three filter parameters

Endpoint: /data/beaconFilter/{:x}/{:y}/{:z}
Parameter: x (country), y (maintype), z (subtype)
Return: See *VI*

IX. Get all textures

Endpoint: /texture

Parameter: -
Return: [{
"_id": "60f3c53ee316002c94f8cdb4",
"textureName": "Population",
"mainType": "Landslide",
"subType": "Population",
“country” : “th”,
"fileList": [{
"border": {"N": 15.1, "S": 2.1, "E": 3.1, "W": 4.1
},
"_id": "60f3c588e316002c94f8cdb7",
"textureFilename": "Population_density_map_cut.png",
"legendFilename": "Population_density_map_legend.png",
"date": 1,
"month": 1,
"year": 2021,
"fileType": "texture"
},
{
...(Other files)…
}],
"createdAt": "2021-07-18T06:07:58.259Z",
"updatedAt": "2021-07-18T09:48:14.811Z"
},
{
...(Other textures)…
}]

X. Get information of a specific texture

Endpoint: /texture/{:id}
Parameter: id
Return: See *IX*

XI. Filter textures using a single filter parameter

Endpoint: /textureFilter/{:filter}
Parameter: filterword (e.g., THA, Flooding, WaterLevel)
Return: See *IX*

XII. Filter textures using two fitler parameters

Endpoint: /textureFilter/{:filterword1}/{:filterword2}
Parameter: Two filterword’s (e.g., THA, Flooding, WaterLevel)
(**Note that filter words cannot be of the same type)
Return: See *IX*

XIII. Filter textures using three filter parameters

Endpoint: /textureFilter/{:filterword1}/{:filterword2}/{:filterword3}
Parameter: Three filterword’s (e.g.,. THA, Flooding, WaterLevel)
(**Note that filter words cannot be of the same type)
Return: See *IX*

XIV. GetTextureImageFile by filename

Endpoint: /data/texture/{:filename}

Return: image data stream

(**If error, return 404.png)

XV. Get the borders of a texture image

Endpoint: /data/texture/{:filename}/border

```
Return {
    Border: {N: "102.1" S:"103.1" E:"12.1" W:"49.1"
    },
    fileName: "test.png"
}
```

The utility libraries used in the implementation of data manager are listed in the "package.json" file. Each button of the data manager executes a function that is contained in either one of the "render*.jsx" files. The conversion from the CSV format to the JSON format is done using the "react-papaparse" library.

Event Manager Service

As the user interacts with an instance (window or view) of the map visualizer or graph visualizer, an event can be generated depending on the type of interaction. The generated event is forwarded to the event manager. The map and graph visualizers can generate the following events.

MAP_CAMERA is generated when the user pans the map and contains the latitude and longitude of the new map center.

MAP_ZOOM is generated when the user zooms into or out of the map and contains the new zoom level.

SYNC is generated when the user clicks the *Sync/Un-sync Button* and contains the synchronization command (sync or un-sync all instances).

CHANGE_DATE_RANGE is generated when the time point (slider) in the map visualizer is modified and contains the new time point.

CHANGE_DATE_XRANGE_SLIDER is generated when the time range in the graph visualizer is modified and contains the new time range.

BEACON_SELECTED is generated when the user selects/unselects a flood factor in the *Beacon Panel* and contains the list of currently selected flood factors.

TEXTURE_SELECTED is generated when the user selects/unselects a landslide factor in the *Texture Panel* and contains the list of currently selected landslide factors.

COUNTRY_SELECTED is generated when the user selects/unselects a country in the *Country Filter Panel* and contains the list of currently selected countries.

Upon receiving each of the above events, the event manager then broadcasts a similar event of the same nature to other instances of the map and graph visualizer. The outbound (broadcasting) events have the same names as the inbound counterparts but with the prefix "SEND_" and contain identical data. The list of broadcasting events includes: *SEND_MAP_CAMERA*, *SEND_MAP_ZOOM*, *SEND_SYNC*, *SEND_CHANGE_DATE_RANGE*, *SEND_CHANGE_DATE_XRANGE_SLIDER*, *SEND_BEACON_SELECTED*, *SEND_TEXTURE_SELECTED*, and *SEND_COUNTRY_SELECTED*.

Note that the map and graph visualizers only send an event to the event manager when the *Sync/Un-sync Button* is set to "Sync" and the corresponding entry in the *Sync Profile Panel* is selected (in the case of map visualizer) or the *Sync This Window Switch* is ON (in the case of graph visualizer). Similar rules apply when receiving an event from the event manager.