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Land use/land cover changes in the period of 2015–2020 in AngYai Village, Sikhottabong District, Vientiane Capital, Lao PDR

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Abstract: In this study, land use/land cover (LULC) changes were identified in AngYai Village, Sikhottabong District, Vientiane Capital, Laos, from 2015 to 2020 using the Geographic Information System (GIS) and remote sensing (RS). Topographic maps and Google Earth Pro satellite imagery data were used with ArcGIS 10.8 software to map land use fluctuations. The study area was classified into the six main types of LULC (agricultural, built-up, forest, main roads, waste land, and water bodies) based on field research, geographical conditions, and RS data. The results indicated sizeable increases in the built-up, main roads, and especially waste land areas over the study period. The forest and agricultural land areas decreased during the study period, possibly due to increased urbanization rates, nomadic cultivation, and indiscriminate deforestation in the study area. The river area was affected by the construction of hydroelectric dams and by the climate, leading to the drying up of water sources and causing water body areas to decrease to some extent.

Keywords: remote sensing, GIS, landscape dynamics, sustainable development, forest land loss, AngYai Village, Laos

INTRODUCTION

Land use is the basis of any land management strategy in industrial zones, residential zones, agricultural fields, and areas of grazing, logging, and mining (Ellis 2013, Aliani et al. 2019). Land cover has been defined as an important component of the ecosystem, affecting the climate, hydrographic modeling, biochemical cycles, environmental protection, biodiversity conservation, resource management, and interaction between human activities and the environment (Lambin et al. 2003). How a parcel of land is used is usually affected by its value, and some areas may have advantages for specific uses.

Changing land use is an important aspect of global environmental change (Dolman & Verhagen 2003). Land use/land cover (LULC) changes are influenced by residential, industrial, agricultural, mining, and infrastructure needs. LULC changes are major concerns affecting the economic and sustainable growth of an area (Rawat et al. 2013) and are a direct result of human activities that affect the physical environment (Liu et al. 2002).

The study of the physical characteristics of the Earth's surface has now entered a quantitative phase, harnessing data collected using space-based technology. Location and survey data can be converted into a coverage area in the ARC/INFO platform using interpolation methods. A spatial information system including social, economic, environmental, and LULC changes can be built to support further quantitative research into human–environmental interaction (Jiyuan 2000). Several recent studies have used remote sensing (RS) and the Geographic Information System (GIS) to measure fluctuations in LULC (Michalak 1993, Ghosh et al. 1996, Adewumi et al. 2016).

RS and GIS techniques can accurately map LULC to better select areas for agricultural, urban, and industrial use in a region (Reis et al. 2003, Shalaby & Tateishi 2007). The accurate detection of changes on the Earth's surface is critical to understanding the relationships and interactions between humans and natural phenomena. GIS is a leading tool in the development and application of contemporary regional and urban planning (Alqurashi & Kumar 2013). Current developments in GIS are primarily geared toward improving technical functionality in storing, processing, integrating, and demonstrating spatial data (Michalak 1993, Steiniger & Bocher 2009). Digital change detection techniques based on multi-temporal and multi-spectral RS data have demonstrated tremendous potential in improving our understanding of landscape dynamics, facilitating the detection, identification, mapping, and tracking of differences in LULC patterns over time.

The main objectives of this study are to produce a map of LULC changes in AngYai Village, Laos (where the urban growth rate and population have been increasing) between 2015 and 2020 using RS and the GIS software, and to determine the main causes of variation for each type of land use.

MATERIALS AND METHODS

Study area

The Lao People's Democratic Republic (known as "Laos") is a small country in Southeast Asia with a total land area in 2015 of 232,064 km^2 (98%) and a water area of 4,763 km^2 (2%) (Department of National Mapping 2015). Our chosen study area is AngYai Village in Sikhottabong District, Vientiane Capital. This area is rich in natural resources, with one side bordering the Mekong River, one of the largest rivers in the world. Most of the village is located on the plains of Vientiane Capital; the terrain is a combination of lowlands and hilly areas with an average elevation of 300 m above sea level. The total population of the AngYai Village region is 780 according to the 2020 census. Annual rainfall is 1,100–1,500 mm, with an average of approximately 1,168 mm. There is a clear distinction between the rainy season (May–October) and the dry season (November–April). The average annual temperature reaches a maximum of 32.5°C in May and a minimum of 9.5°C in January (Department of Meteorology and Hydrology 2015). The government has expanded development in the area to increase agriculture, industry, and tourism. Socio-economic development has increased the demand for land and caused land-use to fluctuate greatly. A map of the study area is shown in Figure 1.

Data collection

For this study, we collected local data (current state of production, socio-economic conditions, statistics, and land inventory in 2015–2020), natural climate conditions, and LULC fluctuations and their causes. The data were mainly from topographic maps and RS. RS geographic reference data and consolidated data were obtained from the Department of National Mapping, Lao PDR, and Google Earth Pro software. Topographic maps were referenced online, downloaded from Map Laos (https://maps-laos.com) and Worldwide Elevation Map Finder (https://elevation.maplogs.com), and converted to a digital model using the scanning function. Topographic maps were geographically referenced with longitude and latitude using ArcGIS 10.8 software and instruments for spatial analysis and boundary demarcation of the study area.

Before preprocessing and classifying satellite images, field surveys were conducted across the entire study area using a Global Positioning System (GPS) device. The surveys were conducted to obtain accurate positioning point data for each LULC included in the classification scheme.

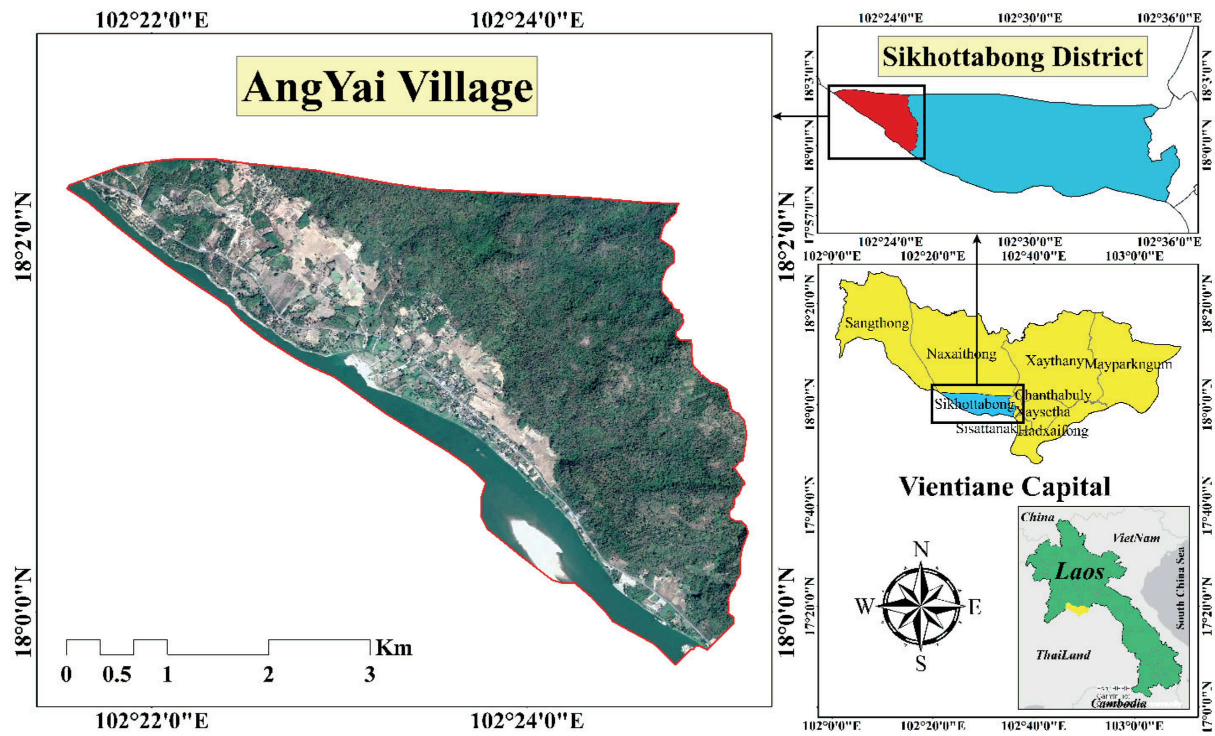

Fig. 1. Map of study area, AngYai Village

Image pre-processing and classification

Satellite image data were downloaded using Google Earth Pro software and a reference coefficient was generated using ArcGIS 10.8 software to match the Universal Transverse Mercator projection of WGS84 and datum zone 48. The satellite images were cropped based on predetermined study area boundaries. In classification, pixel markers were identified through field surveys to collect GPS points for land-use classification and related land-use maps. The delineated classes were defined as agricultural, built-up, forest, main roads, waste land, and water bodies (Tab. 1). The designated GPS locations were denoted as "training sites" and were identified by the user. Generally, a layer of vectors was digitized on the raster scene. The vector layer consisted of polygons overlaying different land-use types. The training sites were used to develop markers correlated with similar subjects in the study area.

Table 1
Classes delineated from the field surveys

No.	Class	Description
1	Agriculture	Cultivated outfields, homestead garden fields and small scattered plots of grazing lands
2	Built-up	Residential, commercial, industrial, mixed urban
3	Forest	Land covered with natural and plantation forests
4	Main roads	Transportation, roads
5	Waste land	Land areas of exposed soil and barren area influenced by human activity
6	Water bodies	River, open water, lakes, ponds and reservoirs

LULC change detection

This study used the post-classification change detection technique, performed in ArcGIS 10.8 software. Urban environment researchers have used post-classification for its efficiency in detecting the location, nature, and rate of change (Xu et al. 2018). Pixel-based comparison was used to generate information and interpret changes more efficiently using "from-to" information. Pairs of categorical images from different data were compared using cross-tabulation to identify qualitative and quantitative changes between 2015 and 2020. A two-way cross-matrix was obtained using this procedure to describe the main patterns of change in the study area (Butt et al. 2015).

RESULTS AND DISCUSSION

LULC information, in the form of maps and statistical data, is critical to space planning and land management for agriculture, forest, grassland, and urban-industrial areas, environmental research, and economic production. Understanding LULC is important in overcoming problems concerning biochemical cycles, loss of production ecosystems, biodiversity, deterioration of environmental quality, loss of agricultural land, destruction of wetlands, and loss of fish and wildlife habitat (Mallupattu & Reddy 2013). The main reasons for LULC changes are rapid population growth, rural-to-urban migration, reclassification of rural areas as urban areas, lack of ecological service pricing, poverty, lack of understanding of biophysical constraints, and use of ecologically incompatible technologies.

As there were many datasets, we used RS and GIS software to quantify land use. From RS image analysis, field surveys, and the study area conditions, we classified the study area into six LULC types: agriculture, built-up, forest, main roads, waste land, and water bodies, as shown in Figures 2 and 3. The study area covered an area of 1,245.63 ha and exhibited LULC changes from 2015 to 2020.

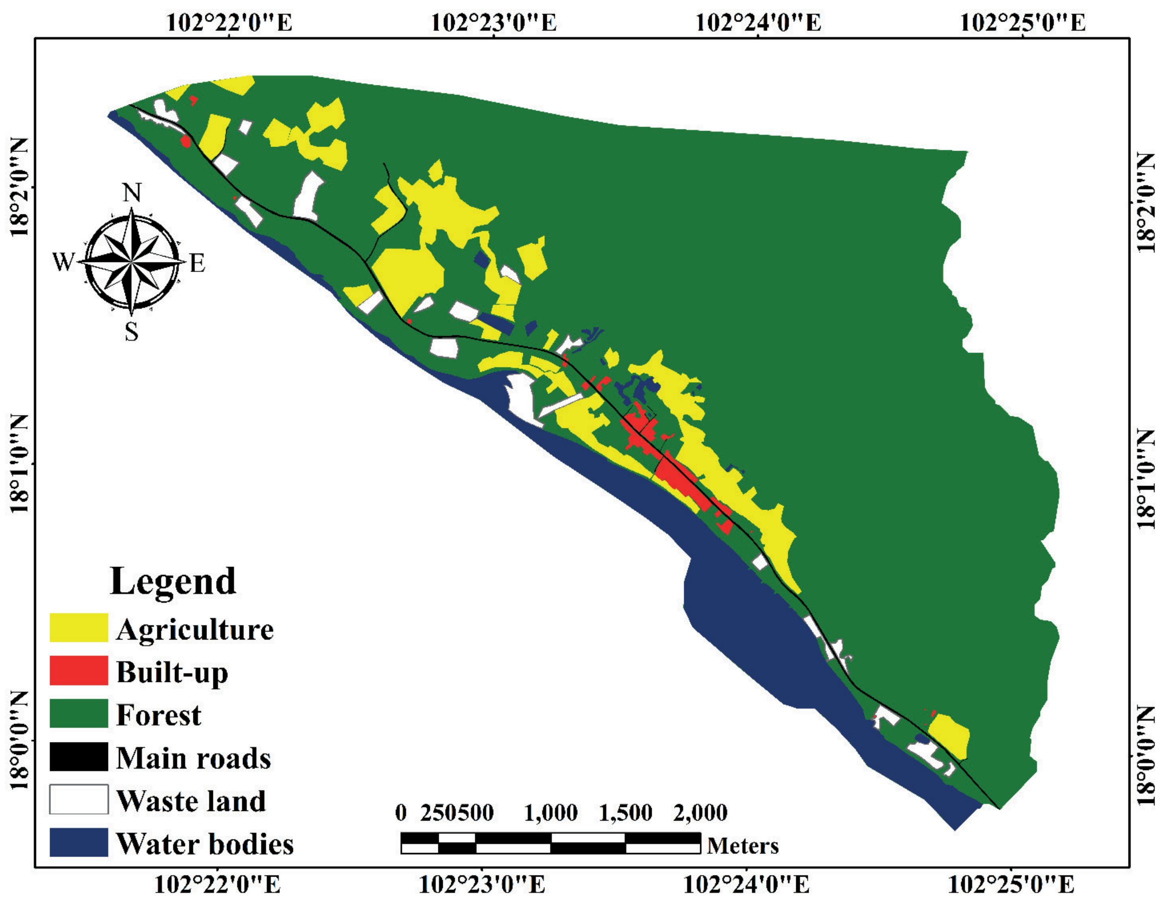

Fig. 2. Map of land use in AngYai Village in 2015

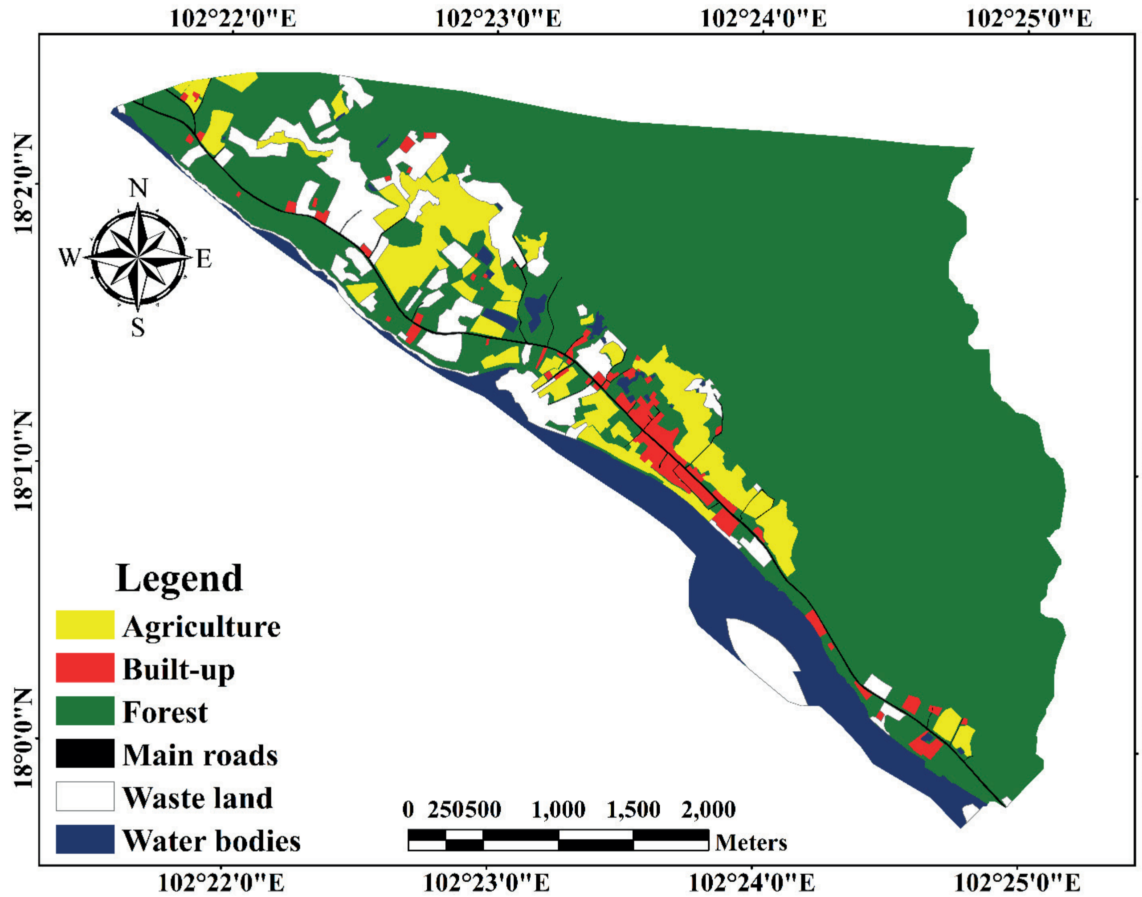

Fig. 3. *Map of land use in AngYai Village in 2020*

Table 2 shows the LULC changes in the agriculture, built-up, forest, main roads, waste land, and water bodies areas in AngYai Village from 2015 to 2020. Comparing land use in 2015 and 2020 from toposheets and satellite images indicates that a large amount of forest land in the study area was converted into agricultural land to meet the needs of households. The Laos economy in general, and the study area in particular, is currently focused on agriculture in addition to industrial development. The government always seeks to create favorable conditions for cultivation but there are many difficulties with natural climate conditions and a lack of cultivation knowledge, especially regarding chemicals and pesticides that pollute the environment and deteriorate soil quality (Zalidis et al. 2002). These issues have led to nomadic cultivation, which reduced the agricultural land area from 142.32 ha in 2015 to 132.48 ha in 2020 (Tab. 2).

Table 2
Land use in AngYai Village from 2015 to 2020

Type of land use	Area [ha]		Change
	2015	2020	
Agriculture	142.32	132.48	−9.84
Built-up	26.49	38.88	12.39
Forest	870.09	803.16	−66.93
Main roads	10.96	11.20	0.24
Waste land	73.72	139.42	65.70
Water bodies	122.05	120.49	−1.56
Total	**1,245.63**	**1,245.63**	–

The built-up land area, including dwellings, was developed for non-agricultural purposes such as public works; communication works were expanded in accordance with the state investment policy to develop the area. According to the census, the population increased from 758 (2015) to 780 (2020), increasing demand for housing, shops, and public works. The built-up area increased from 26.49 ha (2015) to 38.88 ha (2020) (Tab. 2).

As can be seen in Table 2, the forest area including natural forest areas, protected forest land, and special-use forest land managed by the Ministry of Defense, decreased from 870.09 ha (2015) to 803.16 ha (2020) due to deforestation, indiscriminate forest burning, logging for semi-export production, illegal use of natural resources, deforestation to plant trees of economic value, and deforestation for settlement. The area is mainly agricultural land, built-up land, and waste land that has extended deep into forest areas. Renovation and new infrastructure construction such as reservoirs and road networks are also causes of decreasing forest area in the region (Sharma et al. 2020).

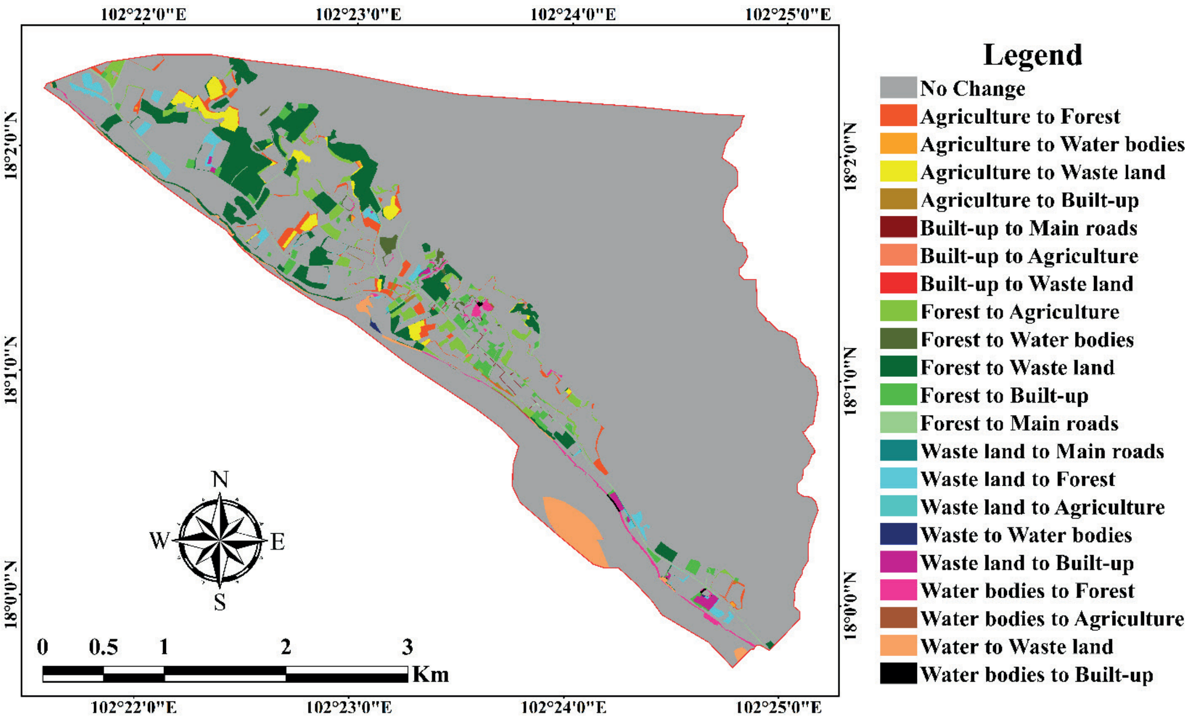

Fig. 4. *Map of land use/land cover changes in AngYai Village in 2015–2020*

Table 3
Cross-tabulation of land cover classes between 2015 and 2020 [ha]

	2020						
2015	**Agriculture**	**Built-up**	**Forest**	**Main roads**	**Waste land**	**Water bodies**	**Total**
Agriculture	**110.10**	0.87	14.31	–	14.78	2.22	**142.32**
Built-up	0.16	**19.23**	7.07	–	0.03	–	**26.49**
Forest	21.68	15.25	**743.41**	0.22	71.58	17.95	**870.09**
Main roads	–	–	–	**10.96**	–	–	**10.96**
Waste land	0.10	3.03	32.38	0.02	**33.57**	4.62	**73.72**
Water bodies	0.40	0.50	5.99	–	19.46	**95.70**	**122.05**
Total	**132.48**	**38.88**	**803.16**	**11.20**	**139.42**	**120.49**	–

The main roads are also important, making travel and exchange of goods between economic regions more convenient, and contributing to socio-economic development (Buys & Miller 2011). In the past five years, the study area has been renovated, expanded, and developed with more main roads. The land area of main roads increased slightly from 10.96 ha (2015) to 11.20 ha (2020) and is expected to increase in the coming years (Tab. 2).

In 2015, the waste land area was 73.72 ha (Tab. 2). After five years of indiscriminate forest product exploitation and uncontrolled nomadic cultivation by local authorities, forest and agricultural land areas that were once home to rare wildlife species became arid waste land areas, bringing the total waste land area to up 139.42 ha in 2020 (Arshad et al. 2020).

The Mekong River flows through the study area, providing self-sufficiency in agriculture, village transport, and fishing, and a source of domestic water. Hydroelectricity was generated from the tributaries of the river (Udomchoke et al. 2010). In addition, artificial ponds were created to store water for agricultural purposes in the dry season. Climate and weather changes and watershed hydroelectric dams have caused the river to dry up, creating empty mounds of protruding land that have narrowed the flow and reduced the area of water bodies from 122.05 ha in 2015 to 120.49 ha in 2020 (Tab. 2).

Using the GIS for post-classification comparison of change detection, a change map was generated to understand the spatial change pattern over time. For an overview of the five years of research, two classified maps were overlaid to create an LULC variability map (Fig. 4) and a cross-tabulation matrix. The cross-tabulation matrix (Tab. 3) allows us to obtain more conspicuous findings in LULC change analysis and shows the nature of change of different land cover classes. Of the 870.09 ha of forest area in 2015 – 743.41 ha was still forest class in 2020, but 93.26 ha was converted to waste land and agriculture and rest to built-up, water bodies, and main roads. At the same time, 32.38 ha of waste land in 2015 was converted to the forest class by 2020. Waste land (73.72 ha in 2015) mainly lost area to forest land, retaining a total of 33.57 ha in 2020. The agriculture area decreased from 142.32 ha in 2015 to 132.48 ha in 2020; 110.14 ha was replaced mainly by forest and waste land. Forest land (21.68 ha) was mainly replaced by agriculture land in 2020 (Tab. 3). Water bodies retained 95.70 ha of the 122.05 ha in 2015; the difference was mostly replaced by waste land in 2020. The built-up area retained 19.23 ha of the 26.49 ha in 2015; the difference was mainly replaced by forest land in 2020. The main road area increased from 10.96 ha (2015) to 11.20 ha (2020) (Tab. 3).

Analysis of LULC changes in AngYai Village, Sikhottabong District, Vientiane Capital indicates that some areas changed from one LULC type to another. The land-use changes were for the benefit of the residents of AngYai Village, who use natural resources to meet their basic needs, and have produced regional changes. LULC changes in AngYai Village from 2015–2020 indicate that waste land area increased the most and forest land area decreased the most.

CONCLUSION

This study examined LULC changes in AngYai Village, Sikhottabong District, Vientiane Capital using GIS technology and RS data. The results show that LULC changed considerably between 2015 and 2020. Construction land, waste land, and main road land areas increased; forest, water body, and agricultural land areas decreased. This study demonstrates the impact of population and development activities on LULC variation, showing that integrating GIS and RS technology is effective for urban planning and management. The information can be modeled and used to forecast LULC changes and their direct and indirect impacts, to assess the social consequences, and to help establish the practice of providing data and information concerning products, services, and tools enabling a wide range of users including environmental managers, policy makers, and readers obtain a better understanding of the surrounding LULC variations.

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