https://doi.org/10.29227/IM-2025-01-02-041 *Received: 30 Oct 2024, Accepted: 01 May 2025, Published: 01 Sep 2025*

Evaluating Land-use changes (LUCs) and their impacts on ecosystem service values in Srepok river basin, Vietnam

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Abstract: *Ecosystems provide multiple benefits, are crucial for human well-being, and vary with both the quantity and quality of ecosystems. The Srepok River Basin in Vietnam has experienced land-use changes (LUCs) in recent decades. LUCs lead to adjustments in the ecosystem and the services it provides. In this study, we determined the ecosystem service value (ESV) and its temporal variation in the Srepok River Basin based on historical and projected LUCs using the Conversion of Land-Use and its Effects (CLUE-s) model. The results revealed significant changes in land-use structure and pattern under different land-use scenarios. The ESV slightly increased from 6,501 million USD (2010) to 6,668 million USD(2080), with trends in LUCs projected to follow the general trend of decreasing forest areas and shrubland and increasing urban areas and agricultural land. Development (such as agricultural expansion, deforestation, and urbanization) often overlooks the value of ecosystem services, with potentially disastrous consequences. Therefore, quantifying these impacts is necessary to make appropriate decisions during these changes.*

Keywords: *CLUE-s; ecosystem services; land-use change; Srepok River Basin*

1. Introduction

Ecosystem services (ESs) are critical to humanity because they provide goods and services such as energy, materials, and non-material benefits, which contribute to the generation of human prosperity. Since the mid-1990s, particularly after the study reported by Costanza et al. (1997), a substantial amount of interdisciplinary research has been conducted on the theories and practices of the ES at various scales (Fisher and Kerry Turner 2008; Spangenberg and Settele 2010; Salzman et al. 2018). The Millennium Ecosystem Assessment (MEA) report, which is a significant assessment of human impacts on the environment, categorized four major relevant ESs, including provisioning services (products derived from ecosystems), regulating services (benefits derived from ecosystem processes), cultural services (non-material benefits derived from ecosystems), and supporting services (services necessary for the production of all other ESs) (MEA 2005). The quantity and quality of ES vary depending on the category and condition of the ecosystem, as ESs are controlled by fundamental ecological processes and structures (Shrestha and Acharya, 2021). Estimating the ES values (ESVs) in monetary units is one of the common approaches to quantify the benefits of ESs (Costanza et al., 2014). In response to LUCs, changes in ESVs vary spatially and temporally.

Land-use changes (LUCs) are directly connected with the sustainable development of regions and are the clearest performance indicator of the impact of anthropogenic activities on the natural ecosystem (Blumstein and Thompson, 2015). Research on LUCs has also been increasingly updated. Various models are used to predict future land-use/land-cover changes. The understanding of the interactions between ecological and anthropogenic activities can be strengthened and improved by assessing the changes in ecosystems. land-use has been significantly altered because of anthropogenic activities, resulting in a comprehensive degradation of the ES provided by the ecosystem. LUCs models are an important approach to quantitatively analyze key processes and assess the patterns and effects of possible LUCs (Zhang et al. 2013). The Conversion of Land-Use and its Effects (CLUE-s) model is a spatially explicit model that has been used to simulate the dynamics of land-use/land-cover changes (Verburg et al. 2002). The model has been successfully applied to predict LUCs in many regions worldwide, such as the Pearl River Delta, China (Hu et al., 2020), Ho Chi Minh City, Vietnam (Adhikari, Mohanasundaram, and Shrestha, 2020), and Bogota, Colombia (Clerici et al., 2019). Additionally, the CLUE-s model is appropriate for the study of LUCs at small and medium scales and can simulate possible LUCs in the future.

The Srepok River Basin, situated in the central highlands of Vietnam, has undergone rapid and intensive development, primarily driven by agricultural activities. Due to the dramatic increase in world coffee prices, significant LUCs occurred in the 1980s and 1990s. In addition, population growth and human-

https://doi.org/10.29227/IM-2025-01-02-041 *Received: 30 Oct 2024, Accepted: 01 May 2025, Published: 01 Sep 2025*

induced development also expedited land-use/land-cover changes (Ty et al., 2012). Within the Srepok River Basin, the rural settlements and the expansion of hydropower dams have encroached on an increasing number of forest areas. Emerging challenges include the extensive use of rural land and the conflict between the demand and supply of urbanized land. In tropical developing countries with agrarian economies and rapidly growing populations, such as Vietnam, these changes have become more pronounced.

This study aims to predict future LUCs and to assess their impact on ESVs in the Srepok River Basin. The results will prove invaluable in the design of payments for environmental services, with positive implications for natural resource management and rural development policies.

2. Geological background

Fig. 1. Location of the Srepok River Basin

Figure 1 depicts the Srepok River Basin, which is situated between latitudes 11°45′ and 13°15′N and longitudes 107°15′ and 109°00′ E. The total area and population of the basin are approximately 12,000 km^2 and 2.5 million, respectively (GSO 2019). The topographical elevation of the basin exhibits a gradient, with elevations ranging from 140 to 2,400 meters above sea level. This gradient is observed to decrease from northwest to southeast. The climate is characterized by the tropical monsoon, with two distinct seasons. The six-month rainy (i.e., wet) season occurs from May to October, while the six-month dry season spans from November to April of the following year. The annual temperature exhibits a range of 20 to 25°C, and the yearly precipitation varies between 1,700 and 2,300 mm. The soil characteristics of this region are conducive to agricultural development. It is notable that agricultural land accounts for more than 50% of the total area in the basin. The region's primary agricultural products are coffee, rubber, cashew, black pepper, and fruit, which are cultivated for both domestic and export markets (CCAFS-SEA 2016). In the present era, Vietnam has become the second-largest exporter of coffee in the world. The Srepok River Basin is of significant importance to Vietnam's agricultural economy, as the majority of coffee beans are produced there.

3. Methodology

In this study, the CLUE-s model was employed to simulate the LUC scenarios for the years 2030, 2050, and 2080, based on historical LUC tendencies at the Srepok River Basin. The key steps include: (1) setting up and calibrating the CLUE-s model; (2) land-use scenario projections based on past tendencies of LUC classes in the 2005–2015 period and future population and precipitation using the CLUE-s model; and (3) calculating the ESV changes to assess the potential impacts of LUCs under different land-use scenarios.

3.1. Data sources

In this study, the land-use data were obtained from the European Space Agency (ESA) in 2010 and 2015. The land-use map has a spatial resolution of 300 m. We categorized the land-use map into five primary types for the study region, including forest, urban, agriculture, shrubs, and water surfaces. To evaluate the accuracy of the ESA classification results, the study employed Google Earth software as a verification tool. This analysis for the Srepok River Basin yielded an overall accuracy of 93% and 95% for the 2010 and 2015 land-use classifications, respectively. In addition to the land-use data, other data were collected, including topography, soil characteristics, administrative map, population density, and precipitation levels. The data are summarized in Table 1.

Tab. 1. Input dataset utilized in the current study

3.2. LUC modeling

The CLUE-s model was developed by Wageningen University to project the spatial patterns of LUCs under scenarios of socioeconomic development and growing population. The CLUE-s model includes three modules: (1) the demand module, which is based on past tendencies of land-use classes or scenarios of land-use planning to estimate land-use demand; (2) the statistical analysis module, which is based on the status or historical land-use patterns and the driving factors to conduct regression analysis, and (3) the space allocation module, which is based on the results of the spatial analysis to determine the spatial patterns of the demands for land-use classes. Further details of the CLUE-s theoretical description can be found elsewhere (Verburg et al., 2002). The model set-up was conducted using the following three steps: restricted areas and conversion parameters between land-use classes, characteristics and suitability of land-use classes, and spatial land-use allocation.

3.2.1. land-use specific conversion settings

In the current study, ten protected areas and national parks were identified as restricted areas of change (Figure 1), with a total restricted area of approximately 2,866 km^2 (accounting for approximately 24% of the total study area). To characterize the individual land-use types, two sets of parameters were required: the conversion elasticity and the land-use conversion matrix. In the case, a spatial policy is provided, the conversion can be indicated in a land-use conversion matrix if it is subject to certain restrictions. For each land-use type, a conversion parameter was specified, ranging from 0 (easy conversion) to 1 (irreversible change). This parameter indicates the relative elasticity of the change (Verburg et al., 2002). In this study, the conversion parameters were determined to be 0.8, 1.0, 0.7, 0.4, and 1.0 for the land-use types of forest, urban areas, agriculture, shrubs, and water surfaces, respectively.

3.2.2. Determination of the characteristics of the Srepok River Basin.

It is anticipated that LUCs will occur at locations where there is the highest preference for a specific type of land use. A logistic regression model was constructed to determine the characteristics of different land-use types at the Srepok River Basin. We designated the present land-use type as the dependent variable and the driving factors as the independent variables, following the study of Zheng et al., (2012). Subsequently, the coefficients derived from the logistic regression model were employed to calculate the probability map for each land-use type. The location characteristics are defined by the following equation (1):

$$Log\left(\frac{P_i}{1\text{-}P_i}\right)=\beta_0+\beta_1 X_{1,i}+\beta_2 X_{2,i}+\ldots+\beta_n X_{n,i} \qquad (1)$$

where P_i is the probability of a grid cell for the target land-use type at location i; X is the driving factor; and β are the coefficients derived from the logistic regression model.

Tab. 2. Regression coefficients of the driving factors for different land-use types in the current study

We used the relative (or receiver) operating characteristic (ROC) to measure the fitness of a logistic regression model in an ordinary least squares regression. An ROC value of 0.5 indicates a completely random model, whereas a perfect fit model results in an ROC value of 1.0. The model's accuracy will be deemed acceptable if the ROC value exceeds 0.7 (Luo et al. 2010). Table 2 lists β_n ,β_o, and ROC values for each land-use type. As demonstrated in Table 2, the ROC values for all land-use types exceed 0.8, indicating that the regression results were of an excellent quality.

3.2.3. Spatial land-use allocation

The spatial land-use allocation module can be calculated for each grid cell. This module is based on the current land-use distribution map of the Srepok River Basin area and is combined with the probability of land-use suitability, land-use demand, spatial policy, land-use conversion elasticity, conversion sequence, and the total probability (TPROP). According to TPROP, LUCs can be distributed to each spatial unit within the study area. This allocation was conducted through an iterative process.

The LUC modeling scheme for the Srepok River Basin is displayed in Figure 2. The LUC data from 2005 were utilized as the baseline, while the data from 2015 were employed for calibrating the CLUE-s model. The Kappa coefficient (K) is a standard metric for assessing the reliability of LUC simulations. A K value exceeding 0.81 indicates a reasonable result of LUC simulation (Gong et al. 2019). In the current study, future LUC maps in 2030, 2050, and 2080 of the Srepok River Basin were created based on the past tendencies of land-use types in the period of 2005–2015, combined with growing population and precipitation in the future.

Fig. 2. Flowchart of LUC modeling for the Srepok River Basin

According to socioeconomic statistical information from 2005 to 2018, the population growth and the demand for land-use types were extrapolated for 2030, 2050, and 2080, as presented in Table 3. The future precipitation in 2030, 2050, and 2080 was inherited from a previous study (Nhi and Khoi, 2021).

3.3. Assessment of ESV

The framework for the ES assessment in the current study is based on the studies on ESVs conducted by Costanza et al., (1997) and Costanza et al., (2014). The total ESV was calculated using Eq. (2):

$$ESV=\sum \mathrm{A_k} \times \mathrm{v_k} \qquad (2)$$

where ESV is the total ecosystem service value; A_k is the area (ha); and v_k is the value coefficient (USD ha^{-1} per year) for land-use type k.

4. Results

https://doi.org/10.29227/IM-2025-01-02-041 Received: 30 Oct 2024, Accepted: 01 May 2025, Published: 01 Sep 2025

4.1. Current Land-use Change

4.1.1. Analysis of LUCs during the period 2005 – 2015

In 2005, the land-use structure was composed of 43% agricultural land and 57% non-agricultural land. This proportion shows that using land for agricultural purposes was predominant, reflecting the tendency to utilize the available land for local people. However, the land-use plan indicates that there was a substantial variation between land-use types for several districts and provinces in the catchment area until 2020. In particular, converting agricultural land (paddy land, annual crops, perennial crops, productive forest land, and special-use forests) to non-agricultural land, converting both non-agricultural and non-residential land to residential land, along with the use of idle land in the future.

Tab. 4. Land-use transition probability matrix from 2005 to 2015 (Unit: ha)

The volatility of land-use fluctuations from 2005 to 2015 witnessed significant changes (Table 4). Forest land fluctuates strongly, with 222,069 ha converted to agricultural production, from the native forest and grassland (approximately 2% and 17% change in total area, respectively). Urban land also changed significantly; approximately 4,837 ha of the annual crops had been urbanized into residential land. The area of unused land was expanded into predominantly forestry land, annual and perennial crops comprising approximately 205,575 ha. The water area increased by approximately 2,487 ha compared with 2005, which was likely attributed to the expansion of the aquaculture area and the construction of water reservoirs.

4.2.3. Simulation of land-use in the current period

The results of the land-use map simulation for 2015 are presented in Figure 3. The comparison between the monitoring and simulation indicates a high similarity between the two land-use maps for 2015. The spatial accuracy between observation and simulation results was demonstrated in Figure 3. The cross-matrix table was also employed for a comprehensive evaluation of the simulation results (Table 5).

Fig. 3. Change detection from simulation to observation maps

Tab. 5. Matrix of area of land-use distribution observation and simulation in 2015

In general, the simulation results of forest land, agricultural, shrub, and water use types in 2015 had simulation accuracies above 0.9. However, urban land provided a lower simulation accuracy than the other land types because of the changes in urban land due to population growth. Residents also greatly affect the concentration of urban areas; therefore, population growth scenarios were added to urban planning locations through 2030, which were developed by local government, according to the master plan decision, and socio-economic development to 2020, with a vision to 2030 of the local Government. However, the overall accuracy of the simulation (0.96) is especially high. This demonstrates that the CLUE-S model can simulate the process of changing land-use in the study area. This well-calibrated CLUE-S can be used to predict future LUCs based on population growth rates and climate change scenarios.

Notably, there is no single model that can capture all the processes of LUCs at different spatial and temporal scales, because of the limited ability to enumerate entire the factors driving and influencing the change process; moreover, the historical period is long enough to provide a general view and insights to better simulate future scenarios. Each model has its advantages and limitations. In this study, factors driving the process of changing scales in socio-economic policies were integrated into this model, which are not yet specific in the future; these results can therefore serve as the basis for comments and reviews for policymakers.

4.2. Future LUC

4.2.1. Predict Land-use Demand

According to local socio-economic statistical information from 2010 to 2018, the basis of this prediction is the population growth and projected LUCs for 2010–2080 using the CLUE-S model.

Similarly, based on the rainfall data from 1990 to 2018, the climate change scenarios for the Srepok River Basin were constructed based on the simulation results of five atmospheric circulation models (EC-EARTH, GFDL-CM3, HadGEM2-ES, MIROC5, and MPI-ESM-MR) for emissions scenario RCP 4.5 from 2021 to 2080 (with three representative periods are 2030s, 2050s, 2080s). The RCP 4.5 scenario is a medium emissions scenario with the assumption of maintaining the current level of development in the future. The land-use demand was extrapolated according to the naturally linear increasing demand based on the historical period from 2005 to 2015. The LUC and land-use demand scenarios for the past and future stages are presented in Table 5.

4.2.2. Evaluation of LUCs under different scenarios

Based on the simulation results, the spatial distribution map of land-use for 2030, 2050, and 2080 under the development scenario in the Srepok River Basin is illustrated in Figure 4.

In general, the simulation results of LUCs over the years 2030, 2050, and 2080 are relatively reasonable in terms of both conversion trends and distribution locations. The general trend of the areas of construction and agricultural land increases significantly, leading to a decline in forest land and vacant shrublands. In particular, the water surface area exhibits a slight change of approximately 5% in comparison with that in 2010, because this type of land-use is difficult to convert into other types, and a portion of the increased area is converted from forest land and shrubs corresponding to the expansion of aquaculture areas or the construction of ponds and reservoirs in the future. In terms of the location of conversion, for each type of land-use being converted, the area to be converted is contiguous, transferring between land-use types. For each land-use expansion, the extended site is usually adjacent to land used for that land-use type.

LUCs occur in all districts in the catchment area. The scattered forest areas in Cu M'gar, Cu Kuin, Krong Pak, and Cu Jut districts are projected to disappear by 2030, and a large forest area in Dak Glong and Dam Rong districts will decline by 2050. By 2080, only patches of forests in protected areas will remain. As for urban areas, development will be focused toward the center of the area, such as Buon Me Thuot city and a small area in districts Krong Pak, Krong Ana, Cu M'gar, Buon Don, and Dak Mil. Most of the districts and provinces have strongly developed agricultural land, but most of it is in to Dak Glong and Cu Jut districts. The results of land-use shift simulation are displayed per year, and scenarios are shown in Figures 4 and 5, respectively.

Fig. 4. Land-use change map under the scenario combines population growth and climate change RCP 4.5 in **a**) 2030, **b**) 2050, **c**) 2080;

Tab. 6. Land-use area of the river basin for the historical period and future scenario (ha)

Fig. 5. Changes in land-use from 2005 to 2080

Urban land in the future is projected to increase significantly and be along major roads, but by 2080, total urban areas under the scenario reach approximately 306.2 ha. This demonstrates that when there is climate change, urban development capacity is limited; on the other hand, promoting agricultural development.

Figure 5 illustrates the increasing and decreasing trends of each land-use type, in which forest, agricultural land, and grassland are represented as a bar chart, and the vertical axis on the left-hand side of the graph shows the values in the area of these land types. Because areas of the rest of the land-use types (water area and urban) are relatively small compared with the areas of forest and agricultural land, they are represented as a line chart, and the values are provided along the vertical axis on the right-hand side of the graph.

Figure 6 illustrates the change in land-use in the period from 2005 to 2010, where the grassland area decreased sharply, and the agricultural area increased during this period. The period 2005-2010 witnessed a substantial shift between types of land-use in the common land fund. In the future stages, when the local government has applied scrupulous regulations in the conversion of land-use purposes.

Fig. 6. Changes in LU from 2010 to 2080 under the scenario

4.3. Changes in ESV

In the Srepok River basin, agricultural land occupies the largest share compared with the other land types, followed by forest land, and of the five land-use types, urban land occupies the smallest area. However, over time, with the trend of socioeconomic development in the future, this will cause the urban land area to increase, but not significantly.

In this study, the ESV was calculated according to Costazan (1997). Total ESV decreased from 1,177 to 720 million USD between 2010 and 2080, primarily due to deforestation, leading to a decrease in the ESV from the forest (962 million USD to 495 million USD). Land-use types with low ESVs, such as agricultural land and urban land, were noted to increase in the area. The ESV of water did not change significantly, according to the ES values as per two studies reported by Costanza in 1997 and 2014. Moreover, agriculture increased slightly, urban land remained at 0 during the 75 years, and grasslands decreased slightly. Comparing the trend of total ESV in 2 studies (Costanza et al., 1997 and 2014), over the period 2010-2080, the total values of ES are quite different, specifically in the 1997 report, total ESV decreased, while total ESV increased in the 2014 work. This difference is due to the differences in the increasing and decreasing trends of each component land-use type. Specifically, in the 1997 study, the overall trend decreased due to the reduction of forests and grasslands. In the 2014 study, forests and grasslands were noted to continue to decrease; however, the remaining three categories, namely, water, agriculture, and urban areas, now had larger ESVs and tended to increase, leading to an overall increasing trend for total ESV (Table 7).

Tab. 7. Srepok River Basin land-use classes and the corresponding ecosystem value

The ESVs calculated according to Costanza et al., (1997) are presented in Figure 6, with the value represented in the line chart, and the value axis is the vertical axis on the right-hand side of the chart.

To update the latest currency value, we used the ES value of Costanza et al. (2014) to calculate future land-use scenarios. To determine the current changes, ES values for the three years 2005, 2010, and 2015 were calculated from the land-use maps collected for this study area. The trend indicates that total ESV during the period 2005-2010 increased by approximately 5%, but in terms of the component ESVs, there was a substantial shift; agriculture increased sharply and grasslands plummeted over the 5-year period, which corresponds to changes in these land-use types. However, the ESV exhibited a softer transition in the period of 2010-2015, owing to the intervention of the Government's planning policies that made the land-use change under control, as evidenced by the insignificant changes in the ESV during this period (Table 8).

In the scenario, the combined population growth with the RCP4.5 emissions, the results indicate that the total ESV is approximately 5.5 times higher than the value according to the 1997 study (column chart with value axis on the left-hand side of the chart, Figure 7).

Fig. 7. Total ESV is calculated by values from the 1997 and 2014 studies

Tab. 8. ES value for the historical periods (USD x 10^6/yr)

The agricultural land type, with the largest share of area, accounts for the largest share of the total ESV of the basin (approximately 70%), and urban areas account for the lowest proportion of the ESV (about 5%). The total estimated ecosystem service values (ESV in USD × 10^6/year) for each land-use category are listed in Table 9.

Tab. 9. ES value under the RCP4.5 combine population scenario - Ecosystem service value (USD x 10^6/yr)

5. Discussion

In 2010, the Vietnamese Government enacted a national policy on payment for ecosystem services (PES). A substantial number of studies have calculated the ESV in different regions of Vietnam: mangroves in Ca Mau Province (Vo et al., 2015); wetlands in Can Gio (McDonough et al., 2014); Mekong Delta (Berg et al., 2017); Northern Highland in Sapa (Dang et al., 2020); forest land (To et al., 2019); North-Western uplands of Vietnam (Nguyen et al., 2020); Forests in Central Vietnam (Paudyal et al., 2020). However, until now, there have been no studies assessing LUCs and their impact on ESVs in Vietnam.

Applying the CLUE-S model to calculate and simulate the LUCs and build conversion scenarios is a new approach compared with the traditional statistical and measurement methods. The LUCs in the Srepok Basin were calculated based on the current land-use status in 2005-2015 and factors affecting the change of land-use types (including natural and artificial factors). In all considered scenarios, when any factor is added, the population growth or climate change will result in high growth or severe decline in the study area. This method is capable of representing, to some extent, the complex processes of land-use systems at different scales. Therefore, this method is also useful for the examination of the drivers of land-use complexities, including the analysis of land-use policies and their impacts on LUCs. In addition, the model simulates the possible LUCs in the scenarios that are likely to occur due to socio-economic and environmental reasons. In general, the CLUE-S model serves as a tool for understanding the potential impacts of LUCs on terrestrial ecosystems and providing scientific support for land-use planning and management.

In addition to the contributions to understanding the ecosystem services flows and the degree of interdependence between ESV and LUC, there are some limitations associated with the current study. (1) Results of the study done by Costanza et al., (2014) have contributed greatly to the ESV calculation. However, the ESVs differ spatially and temporally. Concerning spatial variations, Costanza's study (2014), which was a global-scale study, may not accurately present the actual values of ES at the local scale (Srepok River Basin). Moreover, development varies by country or region. Urban land will differ between developed and developing countries, such as between New York City (US) and Buon Me Thuoc City (Srepok River Basin, Vietnam). In terms of time, the Costanza (2014) study calculated the ESV in 2011, and the current study was performed in 2021; over the past 10 years, the world has experienced substantial volatility, and the monetary value has changed significantly (Ainscough et al., 2018). (2) By using the global land-use maps, uncertainty arose in the input data of the CLUE-S model. The uncertainty is undeniable, although the simulation was carefully validated against the current land-use distribution map at the provincial scale. However, in terms of spatial coverage and temporal resolutions, the global data are cost-effective and realistic to quantify LUCs with high accuracy over a large area. (3) While simulating future scenarios, the accuracy of the simulation decreases with increased time spans in the future, despite careful calibration.

Although this study still has some limitations, the method used in it is an efficient approach that provides a benchmark to encourage further detailed studies on assessing the impact of development on ES. It is essential to provide valuable knowledge to planners and decision-makers to consider the ESVs, owing to the inevitability of LUCs. This study is the first one to attempt to quantify the dynamics of ESVs in the Srepok River Basin. The methodology employed in this study is straightforward to replicate, with minimal financial implications, and helps in predicting variations in LUCs and ESVs. The findings of this study may prove useful in formulating land-use policies and promoting conservation in other case regions, especially in rapidly developing areas in Vietnam. The valuation of ecosystem services in monetary units does not mean that they should be treated as private commodities that can be traded in private markets (Wood, 2014). Moreover, expressing this knowledge of LUCs and ESVs helps us understand that the ES valuation in monetary units is an estimate of their benefits to society. To make development decisions, the trade-off between enhanced GDP and damage to ecosystem services is limited. The awareness of the benefits of ES to society serves as a powerful and indispensable communication tool to facilitate more balanced decisions.

1. Conclusion

In this study, the CLUE-s model demonstrated that it can effectively simulate the process of LUCs for the study area. The future land-use structure was forecasted, which indicates insignificant changes compared with the present. Accordingly, forecasting the future LUCs based on population growth and climate change scenarios from the well-calibrated model is highly reputable. The projected results suggest that the area of agricultural and construction land will increase, with the coinciding trend of a decrease in forest and shrubland, within a fixed area. These are the interchanged relationships. Compared with the historical data (2005), the water area has slightly changed because of the expansion of aquaculture areas and the construction of reservoirs in the future.

The trends of the land-use shifts were considered as factors in the changes in the ES value. The total ES values estimated under the future land-use scenario suggest that they share the same upward trend, and the ES values between the scenarios are not significantly different. This result can be explained by the insignificant difference between forecasted future land-use results. The ESVs in the future scenarios are approximately 6535, 6580, and 6669 million USD for the periods of 2030, 2050, and 2080, respectively. The future predicted value of ES is slightly higher than in the historical periods (2005, 2010, and 2015). Controlling for the decline in forest cover, water surface, and a negligible degree of urbanization in this area leads to an upward trend in the ES value. The positive trend of this forecast does not completely represent an auspicious future in the Srepok basin, as an erroneous change in planning direction in policies might lead to negative results. Therefore, this study provides supportive insights into local planning policies. In addition, there have been no similar studies conducted in this study area, or even in Vietnam, thereby setting a benchmark for carrying out further such studies in Vietnam.

https://doi.org/10.29227/IM-2025-01-02-041 *Received: 30 Oct 2024, Accepted: 01 May 2025, Published: 01 Sep 2025*

Tables and figures (with descriptions)

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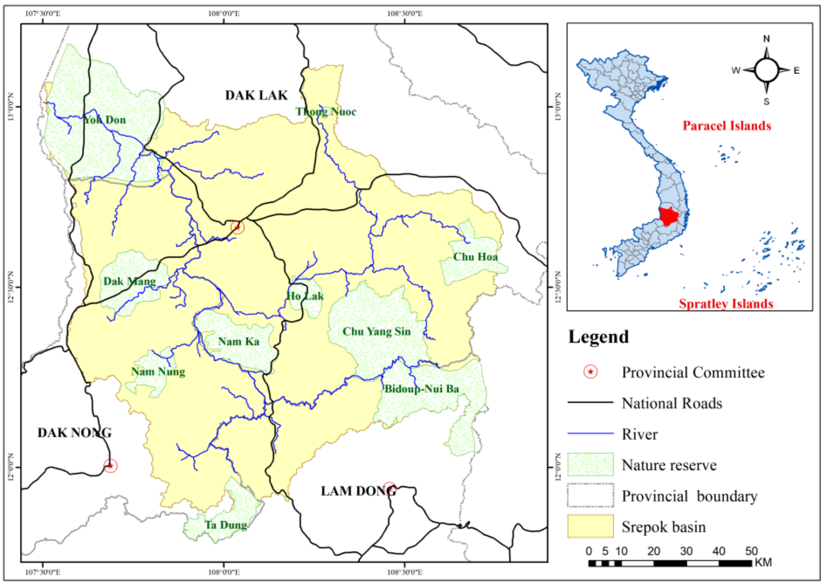

Fig. 1. Location of the Srepok River Basin

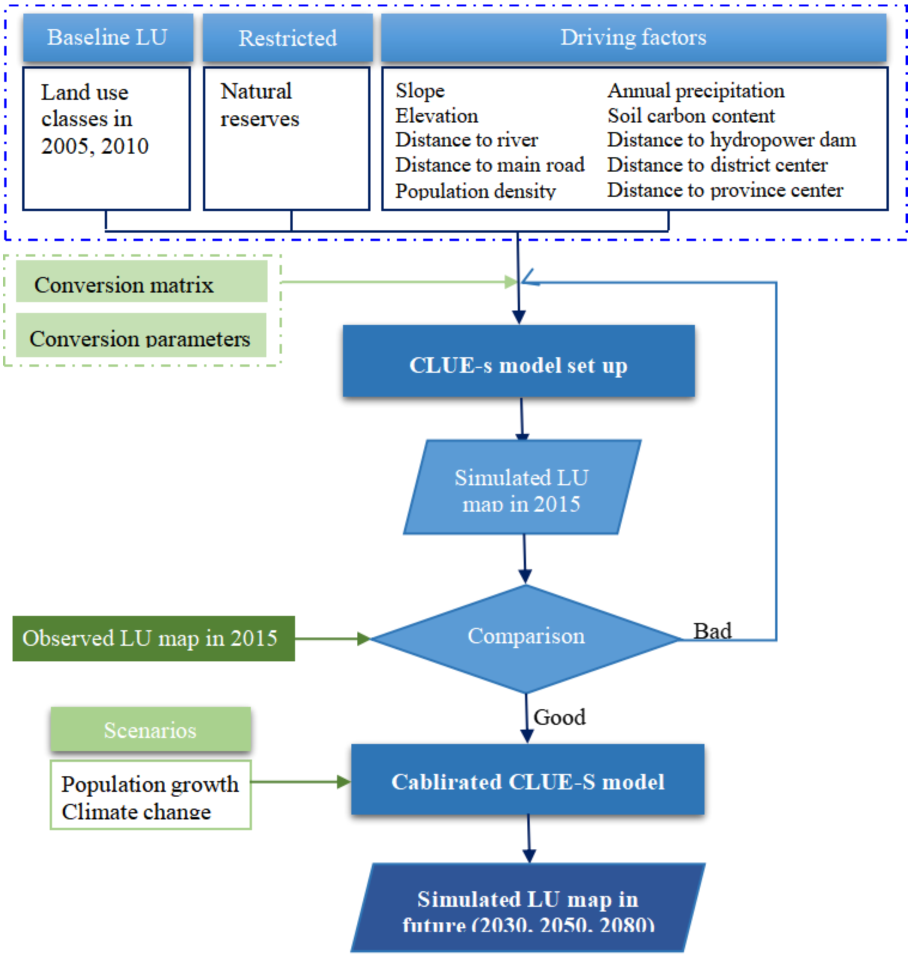

Fig. 2. Flowchart of LUC modeling for the Srepok River Basin

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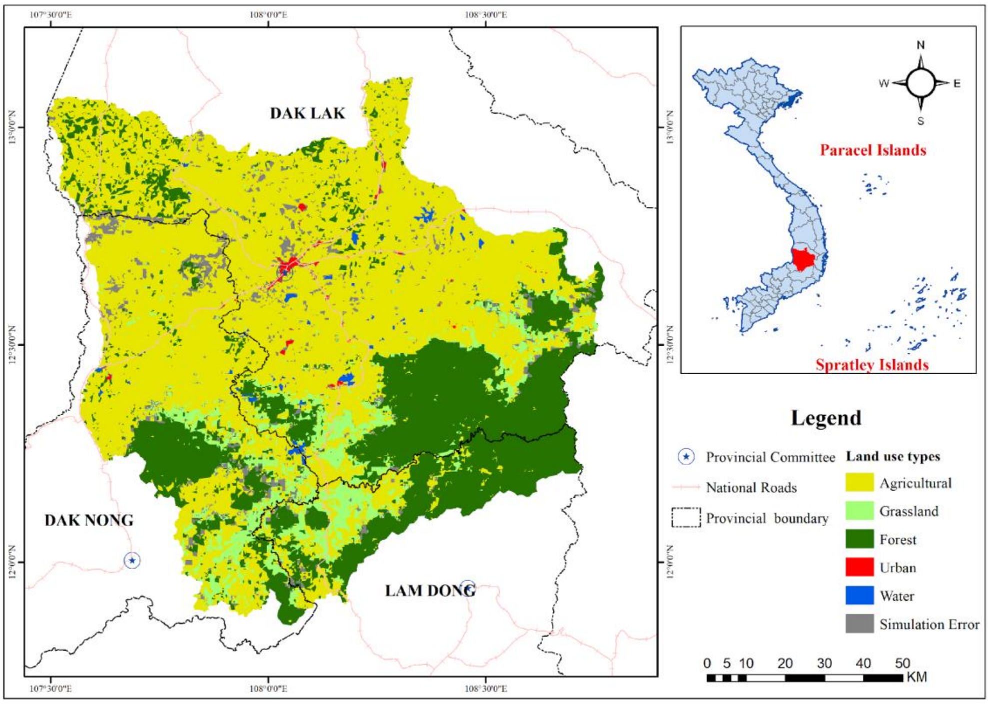
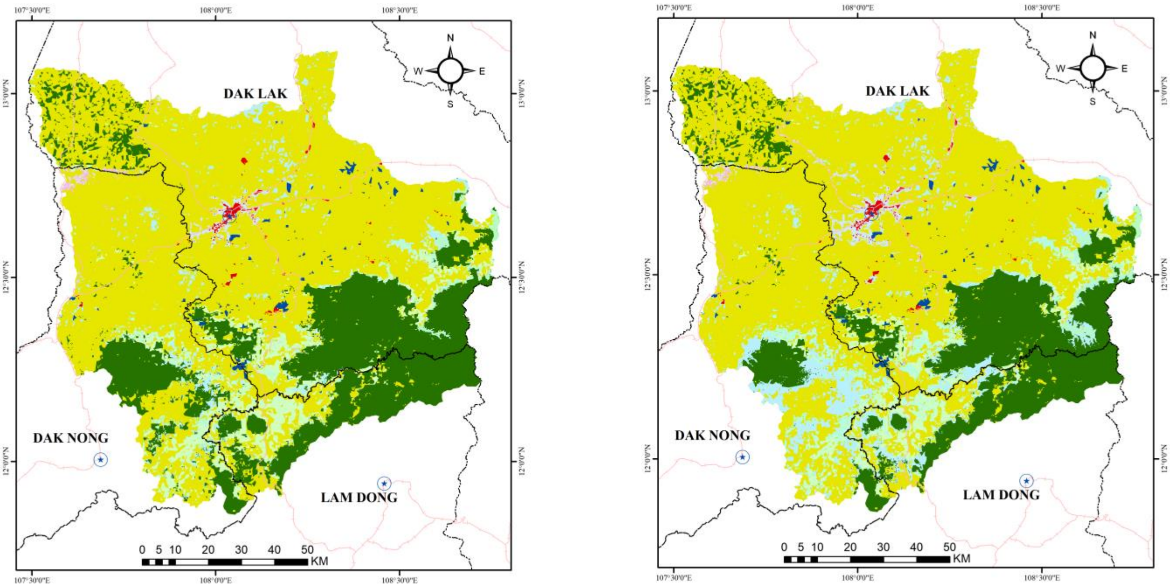
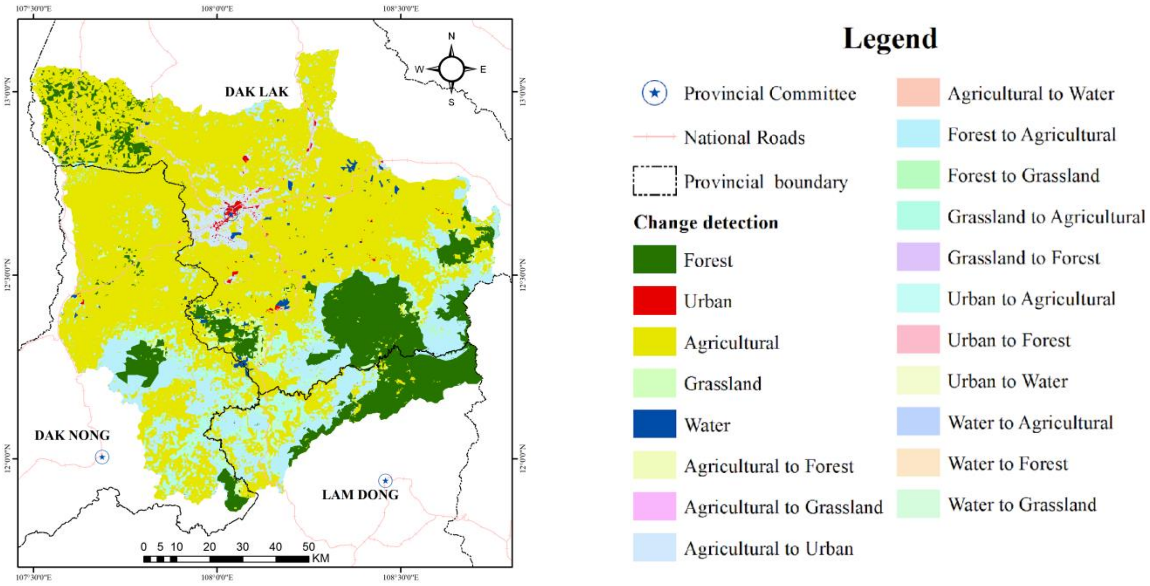


Fig. 3. Change detection from simulation to observe the map



a) During 2015-2030

b) During 2015-2050



c) During 2015-2080

Fig. 4. Land-use change map under the scenario combines between population growth and climate change RCP 4.5 in **a**) 2030, **b**) 2050, **c**) 2080;

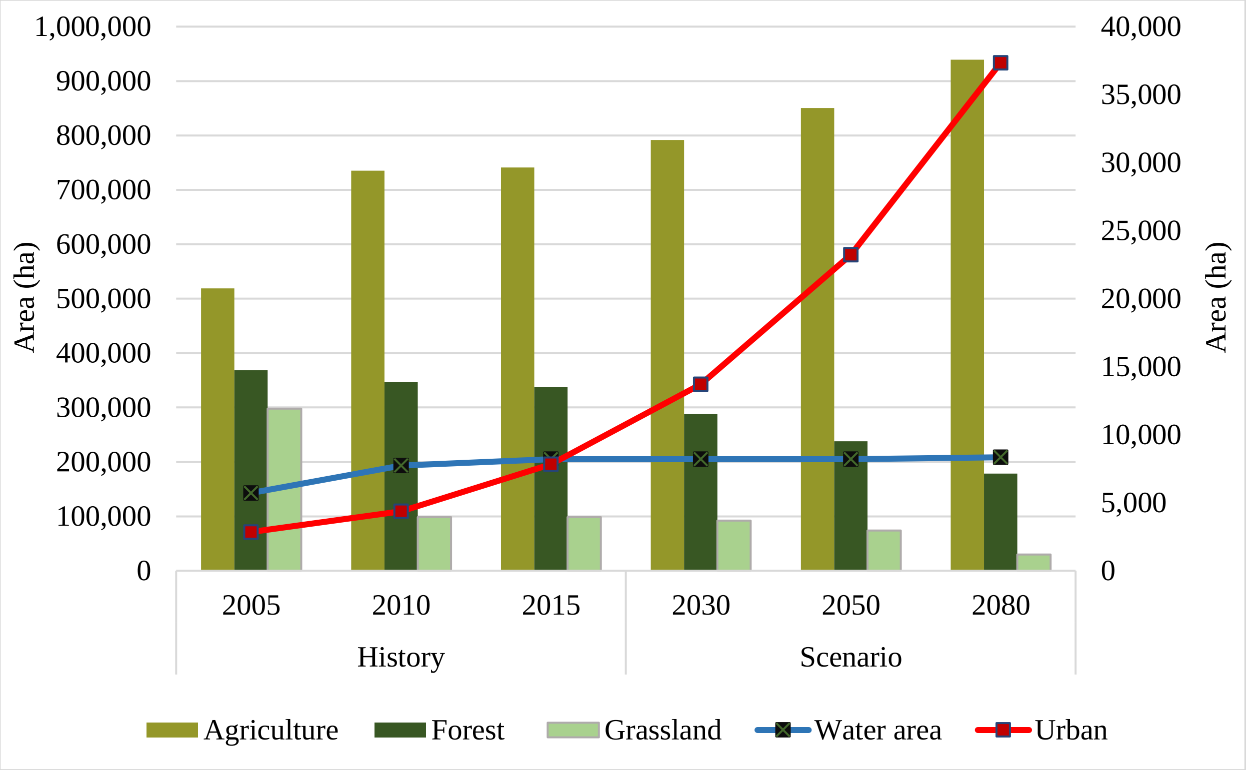


Fig. 5. Changes in land-use from 2005 to 2080

https://doi.org/10.29227/IM-2025-01-02-041 *Received: 30 Oct 2024, Accepted: 01 May 2025, Published: 01 Sep 2025*

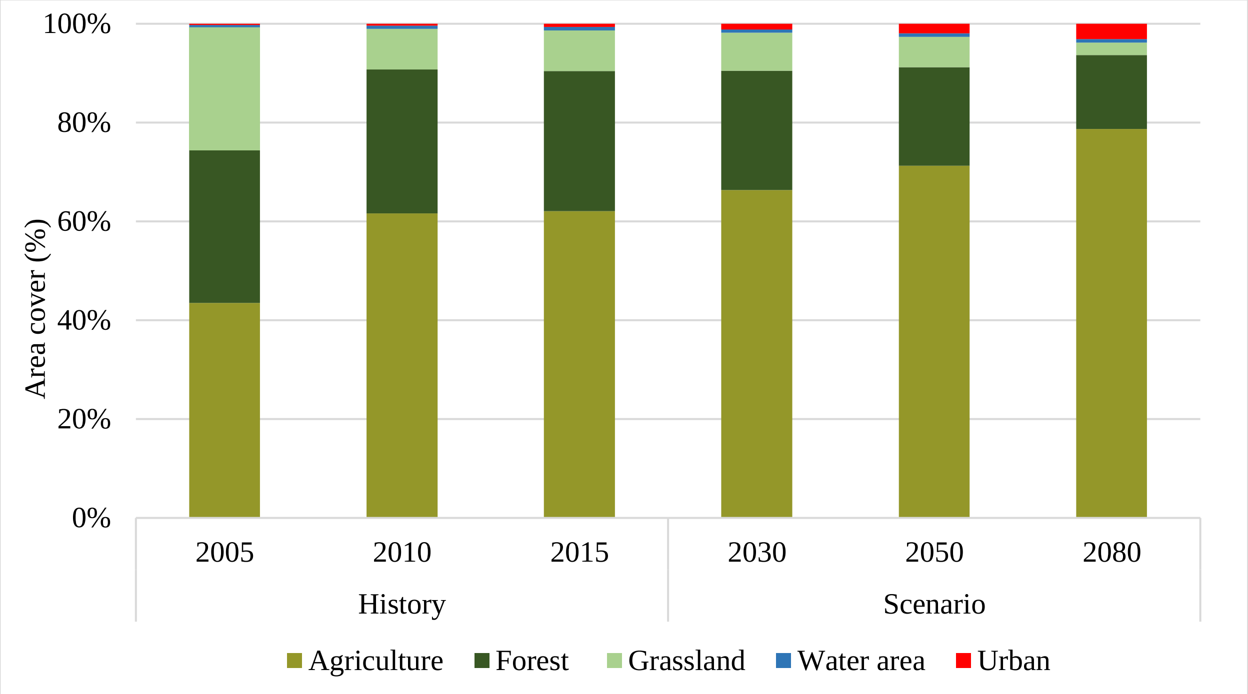


Fig. 6. Changes in LU from 2010 to 2080 under the scenario

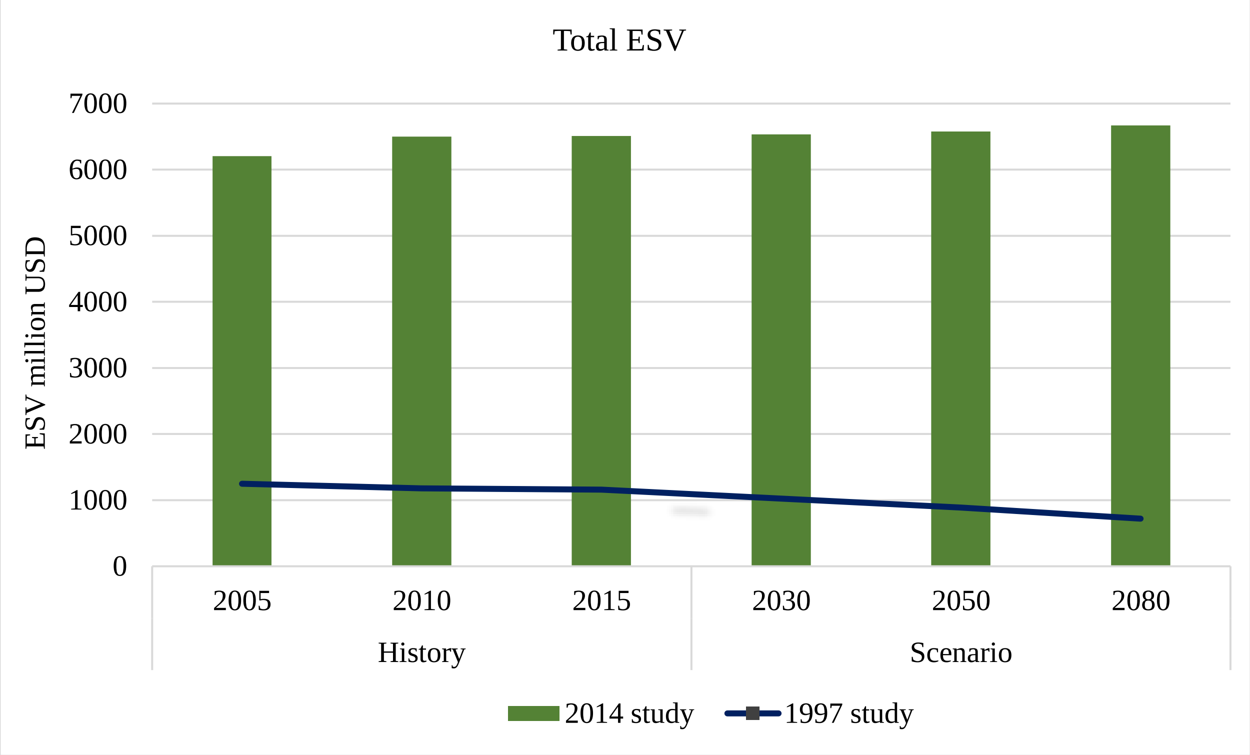


Fig. 7. Total ESV calculates by values from 1997 and 2014 study

https://doi.org/10.29227/IM-2025-01-02-041 *Received: 30 Oct 2024, Accepted: 01 May 2025, Published: 01 Sep 2025*

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Tab. 1. Input dataset utilized in the current study

Data type	Description	Source
DEM	Digital elevation model, a spatial resolution of 90 m	Shuttle Radar Topography Mission
LU	land-use classes in 2005, 2010, and 2015, with a spatial resolution of 300 m	European Space Agency
Soil	Soil types and properties, with a spatial resolution of 10km	Food and Agriculture Organization
Administrative map	Administrative centers and boundaries at provincial and district scales, roads, natural reserves, and river networks	Open Development Vietnam
Socioeconomy	Population density, area for each land-use type in the period of 2005–2018	Statistical Yearbooks of provinces
Precipitation	Yearly precipitation data in the period of 2005–2018 from 10 rain gauge stations	Statistical Yearbooks of provinces

Tab. 2. Regression coefficients of the driving factors for different land-use types in the current study

Driving factors\ Land-use types	Forest land	Urban	Agricultural land	Shrubland	Water bodies
Slope	0.06750	-0.47912	-0.00486	0.22346	-0.78937
Elevation	0.00534			-0.00394	-0.00134
Distance to the river		-0.00006			-0.00011
Distance to main road	0.00006	-0.00065	0.00768		0.00006
Population density	-0.00377	0.00157		-0.00117	
Annual precipitation	0.00182	-0.00093	-2.68329	-0.00250	-0.00245
Soil carbon content	0.84164	0.58134		0.76484	0.37786
Distance to the hydropower dam					-0.00003
Distance to district/city center	-0.00003	-0.00003	-0.00005	0.00005	
Constant (β_0)	-7.09337	-2.34952	3.06243	2.59150	1.61032
ROC	0.861	0.930	0.811	0.818	0.871

Tab. 3. The land-use demands in the Srepok River Basin in the past and future

	2005	2015	2030	2050	2080
Forest land (ha)	368,525	327,264	287,833	237,438	178,518
Urban (ha)	2,850	5,779	14,179	23,673	37,915
Agricultural land (ha)	518,913	758,097	791,779	850,712	939,111
Shrubland (ha)	297,656	94,770	91,589	73,456	29,585
Water bodies (ha)	5,719	7,753	8,283	8,383	8,534

Tab. 4. Land-use transition probability matrix from 2005 to 2015 (Unit: ha)

2005 2015	Forest	Urban land	Agricultural land	Grassland	Water area	Total area in 2005
Forest	**336,850**		21,981	8,069	1,625	368,525
Urban land		**2,850**				2,850
Agricultural land	138	4,837	**513,425**	19	494	518,912
Grassland	1,163	113	205,575	**90,413**	394	297,656
Water area		25			**5,694**	5,719
Total area in 2015	338,150	7,825	740,981	98,500	8,206	**1,193,662**

Tab. 5. Matrix of area of land-use distribution observation and simulation in 2015

Observation Simulation	Forest	Urban	Agriculture	Shrubland	Water area	Total observation	Observation accuracy
Forest	**317,338**		6,944	3,019		327,300	**0.97**
Urban	6	**4,644**	863			5,513	**0.84**
Agriculture	17,644	3,156	**730,663**	6,269	494	758,225	**0.96**
Grassland	3,163		2,513	**89,213**		94,888	**0.94**
Water area		25			**7,713**	7,738	**1.00**
Total simulation	338,150	7,825	740,981	98,500	8,206	**1,193,663**	
Simulation accuracy	**0.94**	**0.59**	**0.99**	**0.91**	**0.94**		Unit: ha

Tab. 6. Land-use area of the river basin for the historical period and future scenario (ha)

Land-use type **Scenarios**		**Agriculture**	**Forest**	**Grassland**	**Water area**	**Urban**
History	2005	518,913	368,525	297,656	5,719	2,850
	2010	735,356	347,569	98,631	7,738	4,369
	2015	740,981	338,150	98,500	8,206	7,825
RCP4.5 & population	2030	791,731	288,069	91,969	8,194	13,700
	2050	850,594	237,813	73,844	8,194	23,219
	2080	939,381	178,681	29,913	8,344	37,344

Tab. 7. Srepok river basin land-use classes and the corresponding ecosystem value

Srepok river basin land-use classes	Equivalent biome from Costanza et al., (2014)	Ecosystem service value (US$/ha/year)		Change (2014-1997)
		Costanza et al., (1997)	Costanza et al., (2014)	
Agriculture	Cropland	126	5,567	5,441
Forest	Forest – Tropical	2,769	5,382	2,613
Grassland	Grass/Rangelands	321	4,166	3,845

Water area	Lakes/Rivers	11,727	12,512	785
Urban	Urban	-	6,661	6,661

Tab. 8. ES value for the historical periods (USD x 10^6/yr)

Land-use type	**2005**	**2010**	**2015**
Agriculture	2,888.79	4,093.73	4,125.04
Forest	1,983.40	1,870.62	1,819.92
Grassland	1,240.04	410.90	410.35
Water area	71.55	96.81	102.68
Urban	18.98	29.10	52.12
Total	**6,202.76**	**6,501.15**	**6,510.12**

Tab. 9. ES value under the RCP4.5 combine population scenario - Ecosystem service value (USD x 10^6/yr)

Land-use type	**2030**	**2050**	**2080**
Agriculture	4,407.57	4,735.26	5,229.54
Forest	1,550.39	1,279.91	961.66
Grassland	383.14	307.63	124.62
Water area	102.52	102.52	104.40
Urban	91.26	154.66	248.75
Total	**6,534.87**	**6,579.98**	**6,668.96**

Acknowledgements

In memory of our supervisor, Associate Professor Dao Nguyen Khoi. Pham Thi Loi was funded by the Master, PhD Scholarship Programme of Vingroup Innovation Foundation (VINIF), code VINIF.2023.TS.063.

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