Analysis of Land Suitability for the potential expansion of paddy fields using MCE-AHP and GIS-based approach
GIS と AHP 法を用いた水田面積の潜在的な拡大に関する土地利用の適性

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1.Introduction

Rice is the primary grain consumed, ensuring food security in Lao PDR. Rice fields cover two-thirds of the country's total cropland, contributing to the achievement of national rice self-sufficiency goals. However, the increasing population leads to rising demands for rice consumption and land for housing, contributing to transforming the farmland into urban areas, particularly in Vientiane Capital, Lao PDR. The rapid urbanization driven by economic reforms in Laos has led to ineffective management of land use/land cover (LULC), resulting in a decline in suitable land for rice production. Particularly, in the Mak Hieo River (MHR) watershed, Vientiane Capital, about 23% of paddy fields transformed into urban areas between 1989 and 2021. Hence, analyzing land suitability for rice cultivation amidst ongoing urbanization is essential to tackle inadequate rice supply within the watershed.

GIS is indeed a powerful tool for spatial analysis. However, while GIS facilitates the overlaying of spatial variables, it does not inherently address the decision-making process regarding the relative importance of the variables. To address this issue, the Multi-Criteria Evaluation-Analytical Hierarchy Process (MCE-AHP) was employed to determine the suitable weighting of variables. The integration of MCE-AHP and GIS-based approaches is common for globally assessing paddy land suitability. Meanwhile, in Lao PDR, a study utilized the Random Forest technique to evaluate land suitability for paddy rice production across the entire country, albeit with a coarse spatial resolution. This study aims to develop a paddy land suitability map and identify areas with potential for paddy field expansion.

2 . Materials and Methods

The MHR watershed in Vientiane Capital, Lao PDR, was selected as study area, covering 454 km^2 (Fig. 1, left). Annual rainfall averages 1700 mm, with monthly temperatures ranging from 21 ºC to 32 ºC. Predominant soil types include loam and sandy loam. This study utilized eight factors closely associated with soil (texture, pH(H_2O), depth), climate (rainfall), topography (slope, elevation, distance to river), and LULC map, following the Land Evaluation Framework proposed by FAO (1976). The soil factors sourced from the Department of Agricultural Land Management. Slope and elevation data were derived from USGS, while river network obtained from OpenStreetMap. The inverse distance weighted

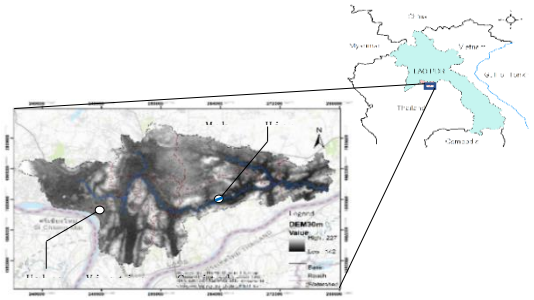

Fig. 1. Location of the study area

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(IDW) method was applied to produce annual rainfall map. LULC map was adapted from a previous study. All raster datasets (30m x 30m) were standardized into four suitability classes according to FAO (1976): highly suitable areas (S1), moderately suitable areas (S2), low suitability (S3), and unsuitable areas (N). The weights for each criterion were determined using the AHP method, which relies on pairwise comparison matrices, and were evaluated based on a consistency ratio (CR) of <0.1. The weighted overlay tool was performed in ArcMap by overlaying the criteria raster files and calculating the sum of the products of influenced weight values and the rating score of each criterion (Eq.1). The land suitability map was compared to the 2021 LULC map.

$S = \sum_{n=1}^{n}(w_i r_i)$ .....(Eq.1)

where S is the suitability index, n is the number of criteria, wi represents the weight of criterion i, and ri represents its rating or suitability value.

3. Results and Discussion

The suitability map illustrated in Fig. 2, outline the suitable areas for rice cultivation within the watershed. The areas under S1, S2, S3, and N were 7992 ha, 16,694 ha, 4878 ha, and 14,209 ha, respectively. Furthermore, 1181 ha were excluded due to marshland and river coverage. Notably, the highly suitable land mainly aligns with the existing paddy fields. Unsuitable areas were identified as urban areas in the LULC map, including areas with high elevation and slopes > 12%. Similarly, in Indonesia, Adrian et al. (2022) revealed that only 11% of the study area offers high suitability for rice production and about 61% was unsuitable due to mountainous

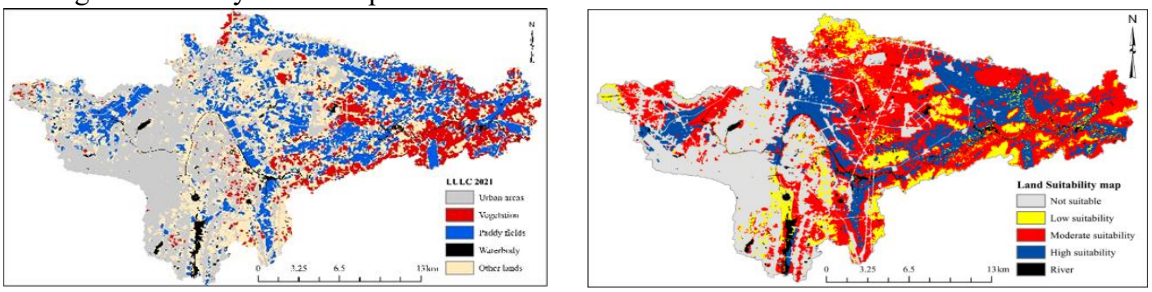

Fig. 2. The 2021 LULC map (left) and Land suitability map (right)

terrain and non-compliance with land use management regulations for agricultural activities. The overlaid results suggested that the existing rice-growing area may be situated on all suitability classes and poorly retained water of sandy soil. However, new highly potential areas for expanding paddy fields were identified, totaling 2965 ha. The proportion of identified suitable areas within the current rice-growing areas under high, moderate, and low suitability were 55.14%, 38.34%, and 6.25%, respectively. Thus, the suitability map appears reasonable since no areas fell under the "not suitable" class.

4. Conclusion

The spatial analysis utilizing MCE-AHP and GIS-based approach offers a comprehensive database for decision-makers to craft sustain-able agricultural land management policies at the local level. However, this study is constrained by the limited availability of spatial data. Future research should expand the scope by incorporating additional factors crucial for assessing land suitability for rice production.