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主　論　文　の　要　旨

論文題目　Assessment of land resource potential in Mongolia using remote sensing data and machine learning techniques
（リモートセンシングデータと機械学習を用いたモンゴルの土地資源の潜在力の評価）

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論　文　内　容　の　要　旨

This research addresses land resource potential assessment consisting of land suitability, land resources, and land potential. The main objective of this study was to assess and model land resource potential throughout Mongolia using state-of-the-art machine learning techniques and remote sensing data. The investigation is organized into seven chapters.

Chapter 1 provides the definitions, concepts, principles, historical development, and technological achievements of land assessment. Furthermore, the main issues of land assessment and the necessity for assessing land resource potential in Mongolia are described.

Chapter 2 investigates the land suitability assessment for the cropland in Mongolia. The main objective is to develop methods, tools, and criteria for detecting new crop areas with enough capacity for cultivation across the entirety of Mongolia. For the analysis, 9 constraints, and 17 multi-criteria factors, the Multi-Criteria Decision Making (MCDM) method and Geographic Information System (GIS)-based Analytical Hierarchy Processes (AHP) were used.

The integrated assessment of constraint and multi-criteria factor analyses showed that 10.1% of the study area is highly suitable, 14.0% suitable, 15.5% moderately suitable, 16.3% unsuitable, and 12.9% highly unsuitable for cropland, with 31.2% as the constraint area. Within the framework of this research, evaluation methodology and criteria for assessing the suitability of agricultural cropland in Mongolia were developed.

Chapter 3 investigates pasture biomass, which is a component of land resources. The rational use of pastures as a source of feed is a vital issue for livestock pastoralism in Mongolia. The main objective of this study is to develop a robust methodology to estimate pasture biomass. Two regression models were compared and adopted for this study: Partial Least Squares (PLS) and Random Forest (RF). Both methods were trained to predict pasture biomass using a total of 17 spectral indices derived from Landsat 8 imagery as predictor variables. For training, reference biomass data from a field survey of 553 sites were available. This study confirms the high potential of a machine-learning regression model to predict pasture biomass. The developed model can be implemented easily, provided that sufficient reference data and cloud-free observations are available.

Chapter 4 investigates the climatologies of average monthly near-surface air temperature (Ta), which is the main indicator of nature-ecology that determines a nation's economic development, especially in drylands. Direct measurements of Ta at a height of 2 m above ground are only available from a limited number of meteorological stations. For Mongolia, the spatial coverage of these measurements is inadequate. In addition, typical Ta time series comes with many missing values. On the contrary, satellite-derived land surface temperature (LST) data are continuous in both spatial-temporal coverages. The main objective of this study is to develop a robust statistical model to estimate climatologies of monthly average Ta over Mongolia using Moderate Resolution Imaging Spectroradiometer (MODIS) LST time series products and terrain parameters. The PLS and RF regression models were analyzed in this study linking data from 63 automatic weather stations (Ta) with Earth observation (EO) images. Both models were trained to predict Ta climatologies for each of the twelve months, using up to 17 variables as predictors. The four most predictive variables were day/nighttime LST, elevation, and latitude. Using the developed RF models, spatial maps of the monthly average Ta at a spatial resolution of 1 km were generated for Mongolia. This spatial dataset is used to estimate important bioclimatic and climatic variables in Mongolia. The method is transparent and relatively easy to implement.

Chapter 5 investigates bioclimatic and climatic variables (indices) assessment in Mongolia. The main objective is to explore alternative ways and to improve the temporal and spatial resolution of bioclimatic and climatic variables. Two-time series datasets monthly mean Ta, and monthly total precipitation (P) from Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) data were used. Spatial maps of 19 bioclimatic variables and 6 climatic indices at a spatial resolution of 1 km were generated, representing the period 2002-2017. The success of the study was to the fact that climatologies of both Ta, as well as precipitation, can be retrieved from EO data over monthly intervals. In areas with sparse station density, EO data avoids otherwise necessary interpolation techniques. The main limitation of many EO products relates to the fact that data sets are still relatively short and that data from multiple satellites would have to be combined and normalized if longer time series are required. The advantage of the MODIS data set is, that it covers the most recent 15 years. In the future, spatial and temporal resolution and spatial coverage will favor EO data even more than other techniques as new satellites are launched at an unprecedented pace. For future research, recommend focusing on the improved quality, spatial, and temporal resolution of precipitation estimates.

Chapter 6 investigates the land potential assessment in Mongolia. The main objective is to assess land potential in Mongolia using a time series of environmental variables and four different regression models. The analysis used 25 environmental variables related to topography, climate, soil, and vegetation as explanatory variables. Reference biomass data from a field survey of 12988 sites were used for training. The accuracy of the RF model (coefficient of determination (R^2)=0.73) model was much higher than PLS (R^2=0.46), Principle Component Regression (PCR) (R^2=0.55), and Classification and Regression Tree (CART) (R^2=0.60). Using the developed RF model, a spatial distribution map of land potential in Mongolia was generated at a resolution of 500 m. Compared with current pasture use, the land potential map showed that 52.3% of the territory has exceeded the land potential, of which 26.7% highly exceeded. This result showed that it is possible to assess land potential across the huge land surface of Mongolia using machine learning models, a time series of environmental datasets, and training data. In addition, the natural elements and processes are studied, and robust models are developed, while the potential of the newest generation of EO satellites was evaluated while leveraging modern machine learning techniques for information extraction.

Chapter 7 provides a summary conclusion based on the finding from this study. Developed models and spatial distribution maps within this study can contribute to reasonable decisions on sustainable use and land management. Attention needs to be paid to conveying the results that have been acquired to decision-makers and the public.