MİMARLIKTA İLERİ ARAŞTIRMALAR

Editör: Dr.Öğr.Üyesi Saadet GÜNDOĞDU

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Mimarlıkta İleri Araştırmalar

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İscehisar/AFYONKARAHİSAR

www.yazyayinlari.com

yazyayinlari@gmail.com

info@yazyayinlari.com

İÇİNDEKİLER

LAND USE LAND CHANGE UTILIZING THE QGIS MOLUSCE PLUGIN

Selcuk ALBUT[1]

1. INTRODUCTION

Considering the limitations of population expansion, it is improbable that agricultural producing areas can be substantially expanded on Earth. Consequently, fulfilling the requirements for agricultural goods necessitates enhancing the yield per unit area in agriculture. The application of technology, such as Remote Sensing and Geographic Information Systems, is crucial for the monitoring, analysis, and planning of agricultural operations.

GIS software enables the generation of maps and other visual representations of geographic data for analytical and presentation objectives. A GIS with these capabilities is a crucial tool for visualizing geographical data and developing decision support systems tailored to your requirements (Fig.1).

Geographic Information Systems (GIS) are essential tools in several fields, enabling the display, analysis, and interpretation of geographical data. The accessibility and functionality of GIS technology have been transformed by open-source GIS software and its wide array of plugins. QGIS, noted for its user-friendly interface, powerful features, and engaged development community, is a significant player in this field.

[1] Prof.Dr. Tekirdag Namik Kemal University, Faculty of Agricultre, Biosystem Eng. Dept. salbut@gmail.com ORCID No: 0000-0002-0055-632X

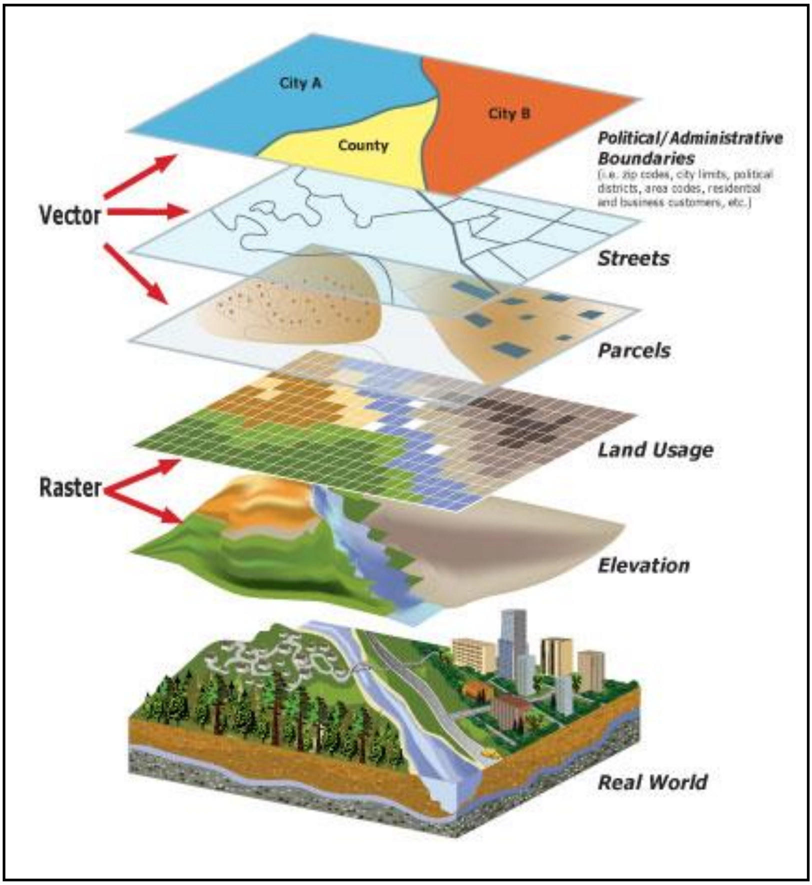


Figure 1. GIS data structure (NOAA's National Weather Service, n.d.)

QGIS is characterized by its ecosystem of plugins, which are modular improvements that increase the program's capability. Plugins range from fundamental utilities to sophisticated analytical capabilities to meet varied user needs. These plugins may be seamlessly included into the QGIS interface, augmenting its functionality without requiring substantial expertise in coding or software development.

Land use planning is an effective instrument for reconciling competing and occasionally conflicting uses to attain food secu-rity, economic development, energy provision, environmental conservation, and other goals (Konukcu et al. 2017).

Land is a finite resource increasingly affected by conflicting, incompatible utilizations. Fertile land in rural areas is declining due to population expansion, pollution, erosion, desertification, climate change, and urbanization. On the remaining land, many local, national, and international players with differing socioeconomic positions and influence compete to achieve food security, economic development, energy provision, environmental conservation, and additional objectives. Integrated land use planning can provide balance among various competing and even conflicting purposes (Wehrmann, 2011). The comprehensive strategy for land resource planning and management necessitates the involvement of all stakeholders in decision-making about the future of land, together with the identification and evaluation of all biophysical and socio-economic attributes of land units. This requires the identification and assessment of a use or non-use for each land unit that is technically viable, commercially practical, socially acceptable, and ecologically sustainable (FAO, 1995). Changes in land use profoundly influence future adjustments in the Earth's climate, which subsequently have considerable implications for future land-use modifications (Agarwal et al., 1999). Vitousek (1994) notes that three extensively documented global changes include the increasing levels of carbon dioxide in the atmosphere, alterations in the biochemistry of the global nitrogen cycle, and ongoing transformations in land use and land cover. Land use planning and the necessary supporting data are crucial for developing nations that frequently have substantial environmental and demographic challenges (FAO, 1995).

MOLUSCE (Modules for Land Use Change Evaluation) is a QGIS plugin intended for the analysis of land use and forest cover alterations over various timeframes, modeling land use/cover transition potential, and simulating prospective land use and cover changes. This software program facilitates the investigation, modeling, and simulation of changes in Land Use and Land Cover (LULC) (Alshari & Gawali, 2022). The plugin incorporates known methods for analyzing land use and cover change, urban environments, and forestry projects and applications (Khawaldah et al., 2020). In the field of geographical analysis, modeling, and modifying transition potentials, methods for understanding land use and land cover (LULC) mechanisms have advanced swiftly (Hamad et al., 2018). Reliable and replicable simulation models may be utilized to examine the factors influencing historical, current, and future predictions and their significance in various situations (Das & Sarkar, 2019).

The MOLUSCE plugin streamlines modeling and simulation tasks for users through its accessible and simple interface. The graphical user interface (GUI) has seven fundamental components, as elucidated by the MOLUSCE plugin: Inputs, Evaluation Correlation, Area Changes, Transition Potential Modeling, Cellular Automata Simulation, Validation, and Messages are listed in order (Alshari & Gawali, 2021).

The class dynamics were modeled using cellular automata in the MOLUSCE (Land Use Change Simulation Modules) plugin of QGIS (Quantum GIS) software and the CA-ANN (Cellular Automata - Artificial Neural Network) model, taking into account land and forest use trends in the studied area, as well as natural degradations over the past twenty years (Vorobyev et al. 2023).

Google Earth Engine (GEE) has shown to be an effective tool for obtaining high-resolution Sentinel 2 satellite imagery across large areas, processing these pictures, and using and exporting findings in classification studies. Owing to its cloud-based design, GEE performs tasks swiftly and effectively, utilizing several servers independent of local computer capabilities. Data for 12 bands and 21 vegetation indices for each irrigation parcel were transferred to MS Excel for use in the IMP statistical tool. Classification was performed with Artificial Neural Networks. (Sener, 2019).

2. What's MOLUSCE plugin

MOLUSCE is a complimentary QGIS plugin designed to automate the process of addressing such inquiries. This plugin is installed similarly to other modules via the official repository within QGIS (Asia Air Survey Co., Ltd., n.d., Kazakov, 2024).

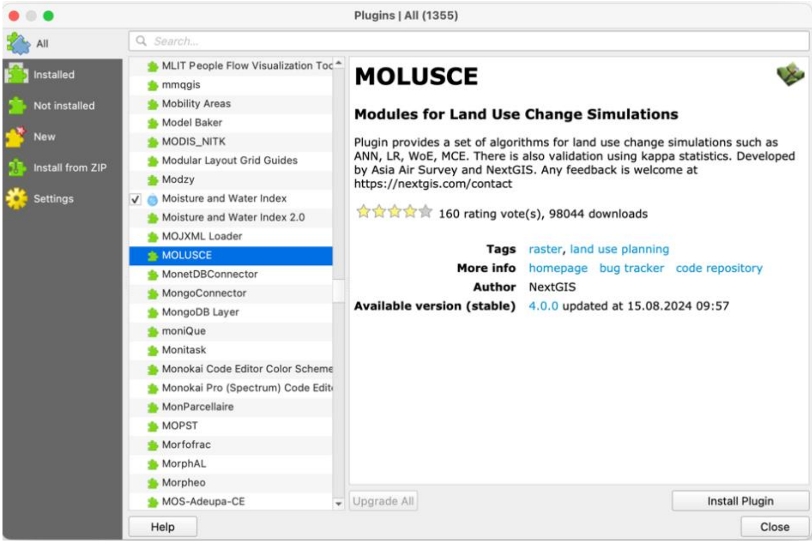


Figure 2. A screenshot of MOLUSCE plugin install.

The workflow comprises the subsequent steps:

1. Acquire land cover maps for several time intervals and a collection of probable explanatory variables;
2. Compute the probabilities of transitions between classes;
3. Construct a model utilizing Artificial Neural Networks (ANN), logistic regression, Weights of Evidence, or Multi-Criteria Evaluation to elucidate transitions based on factor variables.

4. Utilize this model for prediction.
5. Authenticate the outcome with empirical evidence.

MOLUSCE stands for Methods Of LUCE. The plugin performs the following technique (Landscape Change Analysis With MOLUSCE - Methods and Algorithms — GIS-Lab, n.d.):

- Obtains raster data of land use categories for time period A (historical), raster data of land use categories for time period B (contemporary), and rasters of explanatory variables or factors.
- Develops a model that forecasts land use alterations from historical to contemporary periods.
- Forecasts future land use alterations utilizing a developed model, the present condition of land use, and existing factors.
- A model is an algorithm utilized for predicting land use transitions.
- A state raster is a single-band raster in which each pixel is designated a land use category.
- The input state raster is a single-band raster representing historical data.
- The output state raster is a single-band raster that represents the current state. The anticipated outcome of the model's prediction is achieved when a user trains the model to forecast (input raster, factors) leading to an output raster.
- A factor raster is a raster representation of explanatory variables. The rasters may consist of either a single band or many bands.

- The transition class, or simply 'transition,' pertains to information regarding changes in land use. Each alteration (e.g., forest to non-forest) can be perceived as a movement of land use classifications (represented as pixels) from the Input state raster to the Output state raster.
- The change map is a single-band integer raster that contains data regarding transitions. The category values of the change map correspond one-to-one with the transition classes.

3. MOLUSCE Functions

The MOLUSCE user interface offers an intuitive design with clearly defined modules and functionality. The following text offers a succinct summary of the essential modules of MOLUSCE.

The input module integrates land use/cover maps from many epochs, together with biophysical and socio-economic driving force data, such as road networks, rivers, topography, and demographic information.

Area change analysis: Assesses modifications in land use/cover between two time periods (T1 and T2). Transition matrices for land use and cover change, as well as land use change maps, are produced.

Modeling methodologies: Four approaches, namely Artificial Neural Networks (ANN), Logistic Regression (LR), Multi-Criteria Evaluation (MCE), and Weights of Evidence (WoE), are utilized for estimating the likelihood of land use/cover change transitions.

Simulation: Displays transition potential maps, confidence function (experimental), and simulation results. A predicted land use/cover map is produced via a Monte Carlo Cellular-automata modeling approach.

Validation: This sub-module utilizes Kappa statistics (standard Kappa, Kappa histogram, and Kappa location) to evaluate the precision of the simulated land use/cover maps.

4. How to use MOLUSCE

Executing the module by selecting the command in the "Raster/MOLUSCE/MOLUSCE" menu, as seen in Figure 3 of the QGIS software, will reveal the main window of the MOLUSCE module's Inputs tab. We will examine the alternatives in the MOLUSCE module individually (Asia Air Survey Co., Ltd., n.d., Kazakov, 2024).

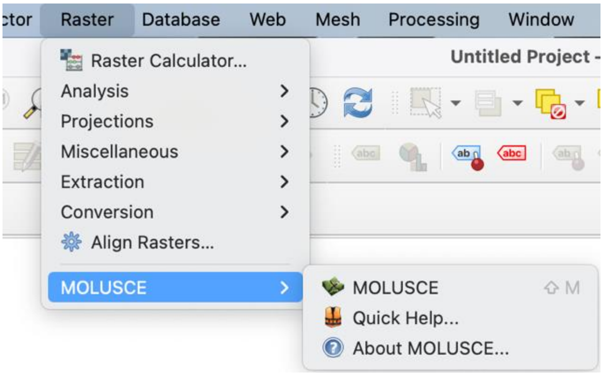


Figure 3. MOLUSCE menu view.

4.1. Inputs

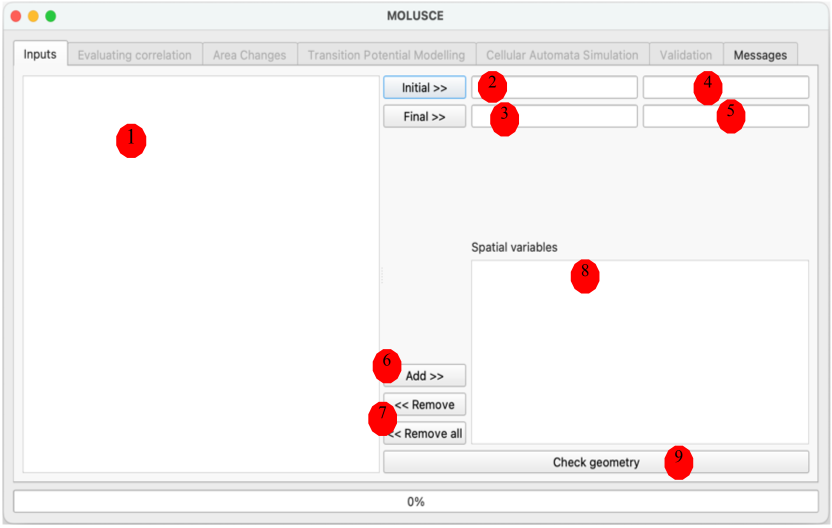
A screenshot of the Inputs tab is presented in Figure 4.

Input Data can be imported via the inputs tab. To upload your data, adhere to the following steps.

1. Import all necessary rasters in the input tab (step **1**).

2. Import the original and final land use/cover maps as demonstrated in stages **2** and **3**. The base map establishes the geometry of all output files, including pixel size, scaling, and projection.

Figure 4. A screenshot of MOLUSCE Inputs tab view.



3. Steps **4** and **5** indicate the respective years. The user may input information here if the relevant years do not populate automatically.

4. Steps **6** and **7** illustrate the functionality of the add/remove buttons for including or eliminating geographical variables.

5. The selected spatial variables are presented in step **8**.

6. The geometry verification button is a crucial step to determine if the geometry of the chosen raster is congruent (step **9**).

4.2. Evaluating correlation

The correlation evaluation module comprises three methodologies for execution. Analysis of corrections:

1. Pearson's correlation.

2. Cramer's coefficient.

3. Joint information uncertainty.

The user may opt for a two-way raster comparison by selecting a primary raster and a secondary raster, or review all rasters stored into MOLUSCE.

The user can execute the correlation by clicking the check button situated at the bottom of the display.

4.3. Area changes

The update tables button generates class statistics and transition matrix tables. The class statistics table presents the initial and final land use/cover change (LUC) areas.

The transition matrix illustrates the percentage of pixels transitioning from one land use or cover type to another. The "Create Change Map" button will produce a map of change classifications. This will be automatically incorporated into QGIS and stored as a GeoTiff.

4.4. Transition potential modelling

MOLUSCE employs Artificial Neural Networks (ANN), Multi-Criteria Evaluation (MCE), Weights of Evidence (WoE), and Logistic Regression (LR) techniques to model the possibility for land use/cover transitions. The user may choose a technique from the dropdown menu.

Artificial Neural Networks (ANN), Weight of Evidence (WoE), and Logistic Regression (LR) are machine learning algorithms that analyze training data to identify underlying trends. However, MCE is distinct: it is a paradigm wherein an expert (the user) articulates the significance of aspects based on their expertise in the subject. Subsequently, the expert's knowledge is converted into a computational model that evaluates transition potentials.

4.4.1. Artificial Neural Network (ANN)

MOLUSCE employs a fully connected Multi-Layer Perceptron for modeling. The define samples function specifies the number of samples and the sampling mode. The generated sampling points can be preserved and exhibited.

Five inputs are utilized to tailor the ANN modeling.

- The neighborhood delineates the number of adjacent pixels surrounding the current pixel. Size=1 corresponds to 9 pixels (3x3 area), size=2 corresponds to 25 pixels (5x5), and so forth.
- The learning rate, momentum, and maximum number of iterations delineate the characteristics of the learning process. A high learning rate and momentum facilitate rapid learning; nevertheless, this might result in instability throughout the learning process, as evidenced by spikes on the graph. A diminutive learning rate coupled with momentum results in stable although sluggish learning.
- The input string for hidden layers accepts a numerical list. N1, N2, ..., Nk, where N1 denotes the number of neurons in the first hidden layer, N2 represents the number of neurons in the second hidden layer, and Nk indicates the number of neurons in the last hidden layer (k-th layer). If the user inputs the string "2," a network including one hidden layer with two neurons will be generated. To establish a network with two hidden layers, the user must input two integers, for example, "10 2," resulting in a network including 10 neurons in the first hidden layer and 2 neurons in the second.

Proposed outputs for the current learning iteration are as follows:

- The area of the graph. Includes inaccuracies in the training and validation datasets. This is the primary information regarding the learning process. The graph is editable and can be saved as an image.
- The minimum validation overall error encompasses data regarding the minimum reached error on the validation set of samples.
- The overall accuracy of the delta encompasses the disparity between the minimum attained error and the present error.
- The present validation Kappa indicates the Kappa value.

The training process can be initiated by hitting the train neural network button and terminated at any moment using the stop button.

The learning algorithm evaluates the achieved accuracy on training and validation sample sets and retains the optimal neural network in memory. The training procedure concludes upon reaching the maximum iteration count, at which point the optimal neural network will be utilized to generate transition potentials.

4.4.2. Multi Criteria Evaluation (MCE)

The MCE model considers the expert perspective on the signi-ficance of the predictors. The user conducts pairwise comparisons of the factors and articulates their significance for the transition potentials. Comparisons are conducted on Saaty's scale.

A coefficient of "1" between variables A and B indicates that the factors hold equal significance in the transition process. The coefficient "9" between factors A and B indicates that factor A significantly surpasses factor B in importance.

4.4.3. Weights of Evvidence (WoE)

The WoE method suggests two approaches for establishing range breaks. The user may establish multiple intervals or designate the values for range breaks.

Pressing the calculate range breaks button generates the weights information for each transition. Upon user satisfaction with the weights, the train model button may be activated.

4.4.4. Logistic Regression (LR)

The LR method enables the specification of samples (quantity and sampling mode) and facilitates the saving and visualization of the generated sampling points.

Inputs Two inputs are utilized to tailor the LR modeling:

- The maximum iteration specifies the total count of iterations.
- The neighborhood delineates the number of adjacent pixels surrounding the current pixel. Size=1 corresponds to 9 pixels (3x3 region), size=2 corresponds to 25 pixels (5x5), and so forth.

Outputs: The subsequent outputs are suggested for the present learning iteration.

- The pseudo R-squared indicates the model's goodness-of-fit.
- The coefficients tab.
- The tab for standard deviations.
- The tab for p-values.

The user can execute the model by clicking the fit model button.

4.4.5. Cellular Automata Simulation

After selecting and training a technique from the transition potential modeling tab, the user can thereafter access the cellular automata simulation tab.

Three types of output maps are generated. A checkbox at the commencement of each output is offered to enable the user to activate only what is essential. A browse button at the conclusion of each output enables the saving of each map.

- The transition potential maps prefix button enables the selection of the prefix for the names of transition potential maps. The transition potential map illustrates the likelihood of conversion from one land use or cover type to another. Transition potential values span from 0 (indicating low transition potential for change) to 100 (indicating great transition potential). Transition potential maps will be generated based on the respective land use/cover alterations (e.g., “forest to unstocked forest” transition potential, “forest to non-forest” transition potential).

- The function of certainty.

- The simulation yields a simulated land use/cover map.

4.4.6. Validation

The validation tab allows the user to check, authenticate, and compare the simulation results. To begin the validation process, reference and simulated land use/cover maps must be supplied. The former refers to a land use/cover map (T3). T1 represents the initial land use/cover, whereas T2 indicates the final land use/cover employed in the model. A browse button located at the end of each output enables the loading of the selected map. A bidirectional comparison is performed between the reference land use/cover (T3) and the simulated land use/cover maps.

To do a three-way map comparison, the user may choose the risk class validation map checkbox. The three-way map comparison implicitly utilizes the original land use/cover map (T1), the reference land use/cover map (T3), and the simulated land use/cover map.

The multiple-resolution budget method is utilized in MOLUSCE as well. The user can determine the quantity of validation iterations and initiate the process by pressing the start validation button. The graph is editable and can be saved as an image.

The total accuracy, including percentage of correctness, Kappa (overall), Kappa (histo), and Kappa (loc), can be computed by selecting the calculate Kappa button.

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İscehisar / AFYONKARAHİSAR
Tel : (0 531) 880 92 99
yazyayinlari@gmail.com • www.yazyayinlari.com