DLS manual:
(Version 2007)

Xiangzheng Deng, Hongbo Su, Jinyan Zhan, Qun'ou Jiang

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1. DLS: Model description

1.1 Description

Changes in land system hold major implications for natural resources, productivity and rural living conditions. Environmental and socio-economical impacts from the dynamics of land system are to be expected ranging from regional to global scale. The model tools are always of importance to analyze the dynamics or impacts of land system. A comparison on the current land use change models showed that a new model could benefit from the incorporation of decision rules, a multi-scale approach, adding scale-dynamics by applying focal functions and taking driving factors into account from socio-economic and biophysical background. The objective of this manual includes, firstly, applying Dynamics of Land System (DLS) to a case study area and then analyzing the model performance.

DLS, a model of scenarios analyses on dynamics of land system at a regional scale, is presented in this manual. At the version of 2007,Version 2007, DLS represents the land use types in a rastered way which means that a resolution will be chosen and used to create grid cells with more homogeneous information than grid cells at lower or aggregated resolutions. Therefore, it is well possible to represent e.g. the land uses by the dominant land use type in the grid cell. DLS regards each fundamental cell as the homogeneous observation and to conduct the simulation of land systems in some certain raster-based scales.

1.2 Components of the DLS model

DLS consists of a scenario module, a module for spatial analyses, and conversion rules that influence a spatial explicit allocation module. The scenario module contains the changes in demand on a yearly basis in area per land use type. The demand module calculates the demands for specified land use types for a given time frame, with time steps of a year. The spatial analysis is based on a spatial regression analysis of driving factors from the socio-economic and biophysical dimensions about the changes of land systems. The conversion rules represent the influences from factors of land managements and the common conversion rules among land uses.

Apart from that, we also need to consider the boundary on dynamics of land system, i.e., we need to isolated those areas without possibility to have land use/cover changes happened.
Another thing to be addressed is that we still need to consider the uncertainty of the model results because the influence of conversion rules regarding dynamics of land use types and protection status e.g. park boundaries, non-linear behavior of demands, time-dependent driving factors and quality of input data are kept time variant.

Given that the framework of DLS considered the linkage to application-specific models with respect to economic, social or environmental issues. So, it is a suitable tool for decision-making in land use planning, environmental protection and natural resource management, by simulating different scenarios of land dynamics.

The model is capable of capturing complex behavior from actors of land uses; input of non-linear change of demands, different conversion rules and dynamic driving factors caused the various succession pattern of land system.

Land system is complex (Figure 1). To describe changes of land uses and the possible future trajectories, land use change models should integrate five dimensions of driving factors – variability of geophysical conditions, environmental changes, changes of trade environment, changes of institutions and policies closely related with land management dimensions (Veldkamp and Fresco, 1997; Turner II et al. 1995; Deng 2000, Deng et al, 2003). Not only should all these factors be included when modeling the dynamics of land system, but also the dynamics of these factors should be incorporated, meaning the changes in geophysical and environmental conditions, and changes of trade environment, and land management policies.

One of our assumptions during developing DLS is that the dynamics of land system, identified spatially explicit succession of land uses, is influenced by the previous land uses and driving factors in the cell and the land uses and driving factors of surrounding cells. Besides, we think that dynamics of land systems are determined by characteristics which are from socio-economic and biophysical origin. Especially on regional level, decisions made by stakeholders have much influence on the succession patterns of land systems (Figure 1).

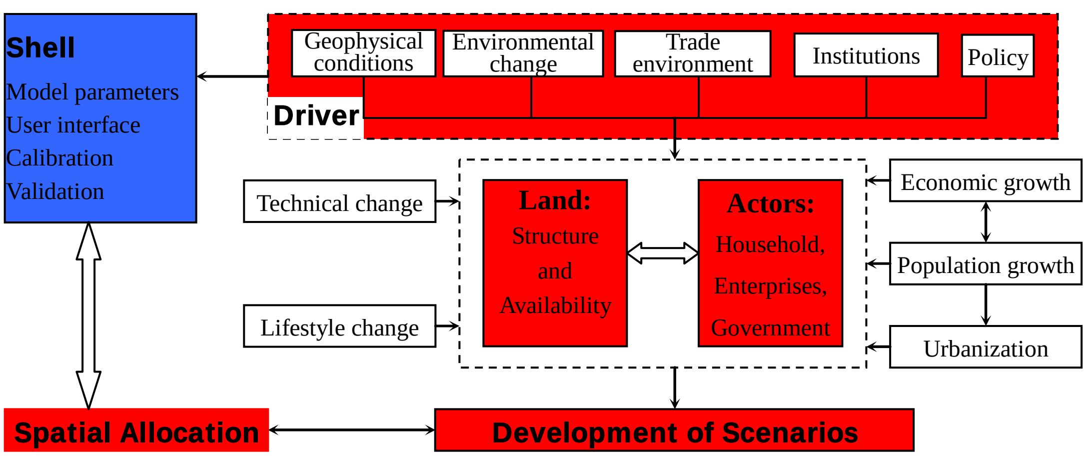


Figure 1 Structure of the main components of the DLS model

2. Data and Methodology

2.1 Data

The spatially explicit data was used to find the most important determinants of the dynamics of land systems. A case study of Dongying prefecture, China, is to be conducted to illustrate the steps to prepare the data and specify the regression analysis in this manual.

Dongying, located in the estuary of Yellow River in Shandong province, also is a city with five county administrative regions (Figure 2). As an industrial city, dramatic changes have taken place its pattern of land system in the past two decades affected by biophysical, social and economic factors.

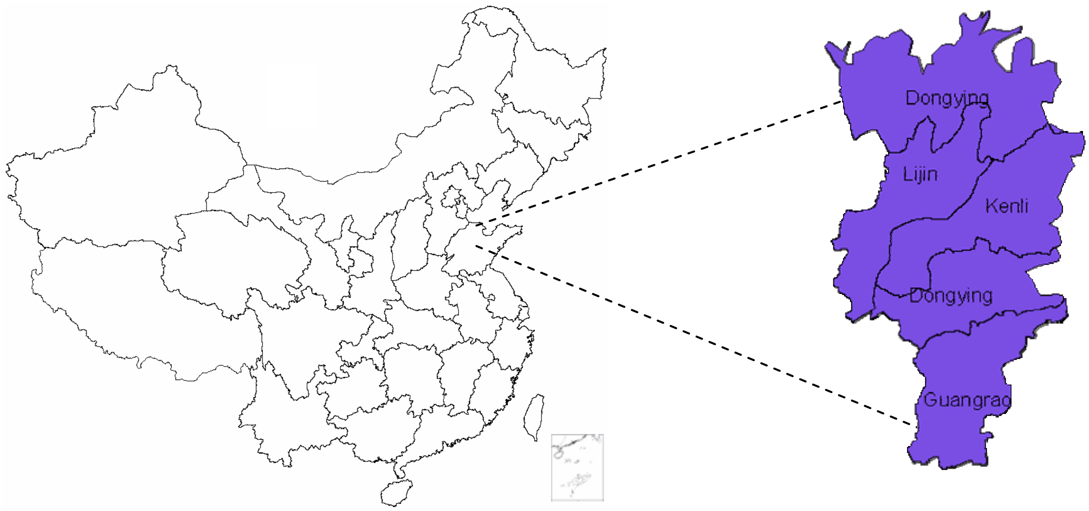


Figure 2 The location of Dongying prefecture in China

2.1.1 Reclassification of land uses

The basic cell size is 500 m^2 in the case of Dongying. Prior to conducting the regression analysis, a reclassification of land use types will be completed (Table 1) to generate the binary dependent variables.

Table 1 Reclassification of land use types

Code	Land use types	Description
0	Cultivated land	Original data include both paddy and non-irrigated uplands.
1	Forestry area	Natural or planted forests with canopy covers greater than 30%; land covered by trees less than 2 meters high, with a canopy cover greater than 40%; land covered by trees with canopy cover between 10 to 30%; and land used for tea-gardens, orchards and nurseries.
2	Grassland	Lands covered by herbaceous plants with coverage greater than 5% and land mixed rangeland with the coverage of shrub canopies less than 10%.
3	Water area	Land covered by natural water bodies or land with facilities for irrigation and water reservation, including rivers, canals, lakes, permanent glaciers, beaches and shorelines, and bottomland.
4	Built-up area	Land used for urban and rural settlements, industry and transportation.
5	Unused land	The rest of all other lands.

2.1.2 Description of driving factors

As addressed earlier, the land use pattern is supposed to be influenced by several factors, e.g., the patterns of geophysical conditions including elevation, slope, and geology, the environmental variables including distance to road, et al. in the case study of the Dongying City, constrained by the data variability, only 13 potential important driving factors on land system were selected (Table 2).

Table 2 Driving factors for the dynamics of land systems in the Dongying prefecture

Driving factors	Explanation/used classes (units between parentheses)
Population density[1]	(inh/km^2), extrapolated surface data generated based on the spatially explicated analyses on the relationship between population distribution and other factors that might affect inhabitations.
GDP[2]	Values of Gross Domestic Products in 2000, 10000 $yuan/km^2$
Landform	0: Mountains 1: Hills 2: Mesa 3: Plain and bottomland 4: Table board of Loess Plateau
Soil texture	1~10 levels rectifying the coarseness of soil, the higher the value is, the coarser the soil.
Contents of organic matter	%, the higher the values is, the higher of the contents of the organic matter in the top soil
Soil PH value	PH values of soil, the higher the value is, the lower the acidity of the soil
Depth of soil	Depth of top soils
Elevation	Digital Elevation Model (m)
Slope	Slope derived from DEM (0.01 degrees)
Air temperature	Mean annual temperature (0.1℃)
Cumulated temperature (≥0℃)	Annually cumulated temperature of daily mean air temperature over 0 ℃ (0.1℃)
Cumulated temperature (≥10℃)	Annually cumulated temperature of daily mean air temperature over 10 ℃ (0.1℃)
Radiation, %	0-100 continuous values rectifying the spatial variability of the sun radiation
Distance to province capital	Geometric distance to nearest province capital
Distance to the railway	Distance to the nearest railway
Distance to the highway	Distance to the nearest highway
Distance to the expressway	Distance to the nearest expressway

2.2 Methodology

2.2.1Developping the scenario

The scenario module of DLS can be constructed based on the specific needs in the study area. Various options are possible, e.g. linear trend extrapolations or economic models. Here, we predict the various scenarios of dynamics of land systems of the study area by spatial analyses. That is, by the adjustments of the flexible variables, we develop the scenarios of the dynamics of land systems.

The spatially explicit allocation module has to fulfill the results of the scenario module by allocating

[1] The original data of population and economy were derived from statistical data at county level. The population density map was extrapolated onto the surface with the spatial resolution of 1 by 1 square kilometre.

[2] The GDP value of each county was also interpolated onto the surface with the spatial resolution of 1 by 1 square kilometer according to the relationship between GDP and factors that might affects economic growth.

changes of land uses into each grid cell. Driving factors originally identified by five dimensions but reclassified onto two kinds (geophysical factors and social-economic factors) for the brevity will be considered and used in the spatial allocation procedures of DLS model. (Figure 3)

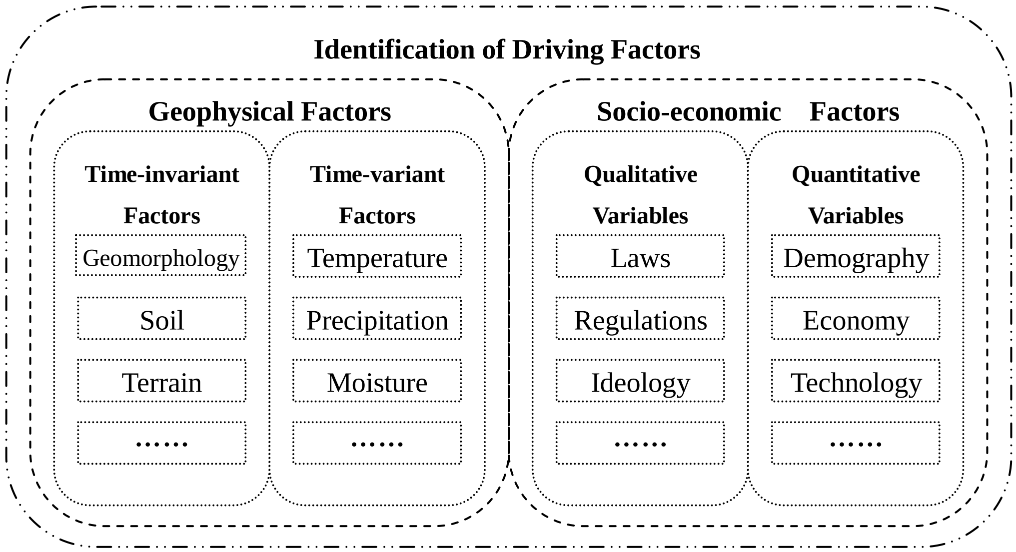


Figure 3 Driving factors identified in DLS model

The scenario module is a separate module from the model framework, in that sense, its results are indispensable input in DLS, the ways in which these results, however, are obtained are flexible. It is possible to use all kind of economic methods to derive a result.

2.2.2 Spatial regression analyses

The spatial regression analysis provides the model with response functions for dynamics of land system identified by changes of land uses. In these functions, driving factors have been given certain weight coefficients. It is assumed that the coefficients used in the response functions are constant, but the driving factors can be time-variant. The response functions can be visualized into rastered probability maps of the study area, based on the locational suitability (rastered maps of driving factors), giving the probability of the occurrence of a certain land use type per cell.

DLS uses empirically defined relationships between land use and its driving factors as model input. In a land use system, the occurrence of a certain land use, like, for instance, the paddy field, will be predicted by several independent values, also called the driving factors of land use. Its probability is a function of the logit coefficients with the spatial lag terms of driving factors.

A fitted logistic regression function with the spatial lag terms of driving factors could be represented in this form:

$$\pi = \frac{\exp(b_0 + \sum_{j=1}^{n} b_j X_j + \sum_{j=1}^{n} \rho W_{mn} X_j)}{1 + \exp(b_0 + \sum_{j=1}^{n} b_j X_j + \sum_{j=1}^{n} \rho W_{mn} X_j)}$$

where the X are the independent variables and π is the probability that the dependent variable is *1*, meaning that some certain land use exist. A unit increase in the first independent variable is associated with an exp(b_j) plus exp(ϱW_{mn}) unit increase in the probability that the land use change will occur or not. W_{mn} is the spatial weight identifying the neighborhood between observation m and observation n. ϱ is the estimated coefficient of spatial lag term of X_j. b_j is the estimated coefficient of Xj. b_0 is the residual constant of the equation.

2.2.3 Conversion rule

The conversion rule in DLS model determines which conversions are allowed for some certain of land use. Two types of decision rules are incorporated. The first type indicates the stability of land use types. The second type can label cells as protected area, in which no changes is land uses are allowed. The setting of the conversion rule is a value between 0 and 1, and is valid for a complete land use type. A land use type that is not very dynamic, because it is for instance based on long term investments, like plantations or residential area, or e.g. forest, will have the value of 1. The opposite is true for the value of zero.

2.2.4 Spatial allocation

Figure 4 is a detailed diagram on the spatial allocation of the model structure of DLS than figure 1. It shows the three main types of input data for the spatial allocation: local characteristics, regional characteristics and historical characteristics (past land use map) which have covered all the factors of five dimensions (Figure 1) and two aspects (Figure 4).

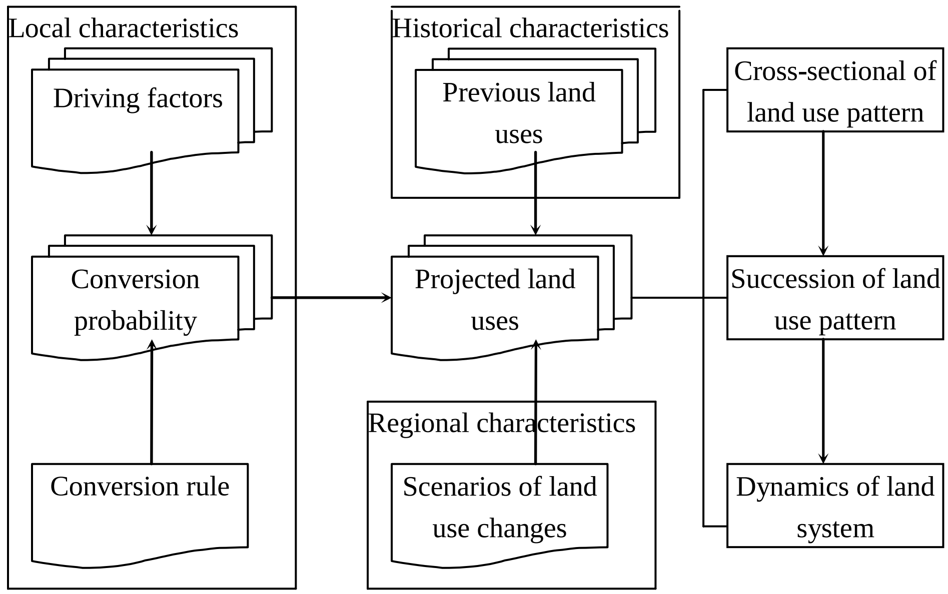


Figure 4 Spatial allocation scheme of DLS model

Regarding local characteristics, spatial explicit driving factors are incorporated into a probability map by logistic regression with spatial lag effect term of independent variables. These probability maps are derived for each land use type. Other local characteristics are the decision rules concerning protection status.

Regional characteristics include the demand for all land use types and decision rules regarding the stability of these land use types. To apply these conversion rules, the historical characteristics should be known. Therefore, a land use map for the year previous to the predicted year is necessary (Figure 3).

The spatial allocation module will first calculate the number of cells participating in the allocation. Cells that are part of a protected area or that have a land use with a stability value of 1 and increasing demand, will be assigned to their previous land use, and are excluded from further calculations. For all cells taken into account, the model will calculate land use comparison values for the different land use types. In these calculations three different situations can be distinguished:

1. If a land use was already presented in the cell the year before, and the stability is less than 1, then the model will first calculate that land use type the sum of the probability of the concerning year, the stability of concern, and a certain compensation factor:

$$L_{i,k} = P_{i,k} + C_k + S_k$$

where $L_{i,k}$ is the comparison value for land use type k in a grid cell i, $P_{i,k}$ is the probability derived for the concerning land use type and grid cell, C_k and S_k are the compensation factor and stability for land use k.

2. The second condition considers the situation that the land use was not yet present. Here S_k becomes equal to zero, so $L_{i,k}$ is made up only of the probability factor ($P_{i,k}$) and compensation factor (C_k).
3. The third condition excludes the possibility that the cell is assigned to a land use type that has a decreasing demand, was not present the previous year, and had a stability of 1.

The land use type with the highest $L_{i,k}$ will be allocated to the cell, if allowed considering the stability settings. See also Figure 5.

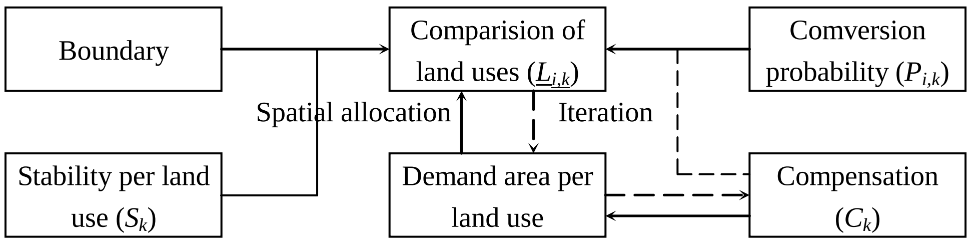
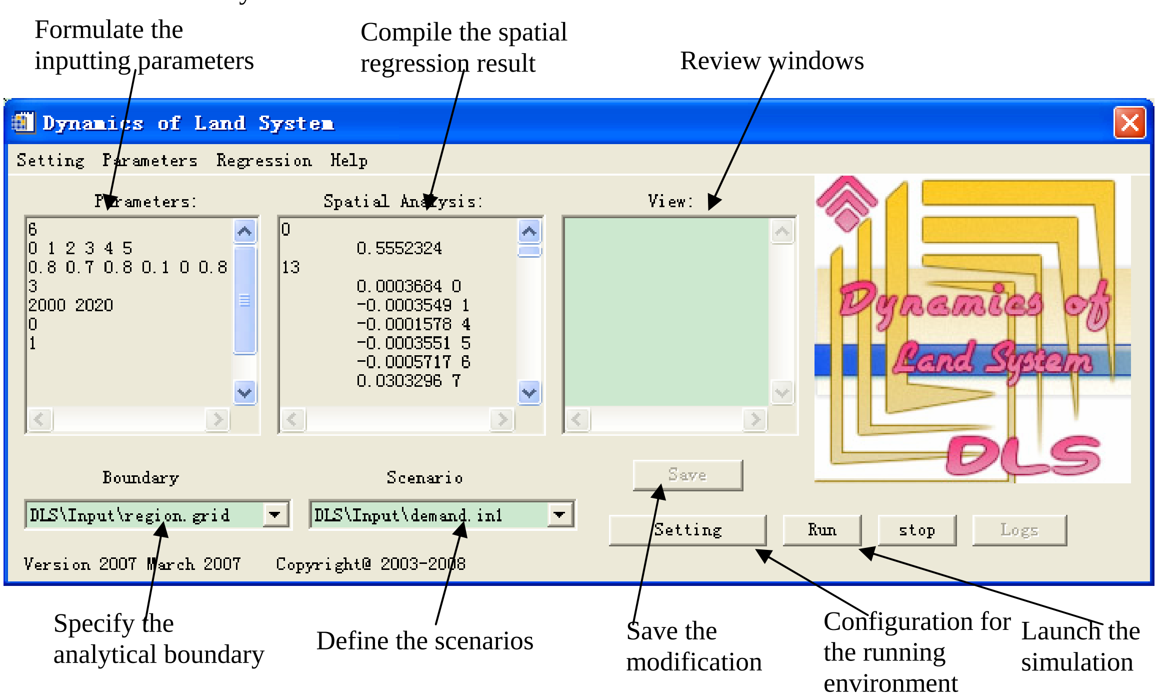


Figure 5 Detailed Spatial allocation steps

3. Application of the DLS Model

3.1 The interface

The user-interface deals with the configuration of all input-variables of the model. Only if these variables are correctly entered the model can be run.



3.2 Compiling the input files

3.2.1 Main Parameters

The parameters at the left most column in the user interface can be edited by clicking to invoke the menu button 'Input' under the menu of parameters and saved by clicking the Save button. By doing so, user can update the input parameters used for the simulation of land use changes.
NOTE: The main parameter file can also be edited by notepad or any other text editor. The main parameter file is called 'main.1' and is located in the installation directory.

The 'Main parameters' are ordered on seven lines:

Line 1: Number of land uses addressed in the study

Line 2: Contains the coding numbers of the land use types, should start with 0 (cf. Table 1).

Line 3: Contains the codes corresponding with the conversion rule per land use to identify the status of allowed changes and behavior of land uses (cf. Table 3).

Line 4: Convergence criteria: average deviation between demanded changes and actually allocated changes as a percentage (default: 0.35). Followed by:

Line 5: Start year and end year of simulation.

Line 6: Number of explanatory factors that change every year followed by the coding of these explanatory factors.

Line 7: ArcView switch: 1: ArcView headers will be printed in output files; 0: no headers in output files (suitable for e.g., Idrisi). **Note: If the ArcView file type is chosen, all input files should contain an ArcView header.**

Table 3. Codes corresponding with the conversion rule per land use.

Value Description of behavior
0: All changes allowed, independent of direction of demand at aggregate level
0-1: All changes are allowed (comparable to value 0), however, the higher the value, the more difficult it will be to allocate this land use type on land that is allocated to another land use type that is also increasing. At high values new land of this land use type will preferably allocated at land now allocated to a land use type of which the demand decreases.
1: If demand for considered land use type increases, it is impossible that other land use types convert land already allocated to this land use type. This setting is relevant for land use types that are difficult to convert, e.g., urban settlements (which will not very likely be converted into agricultural uses). If demand for the considered land use type decreases it is impossible that land previously allocated to other land use types is allocated to this land use type. This setting stabilizes the system and prevents that in case of deforestation other areas are reforested at the same time.

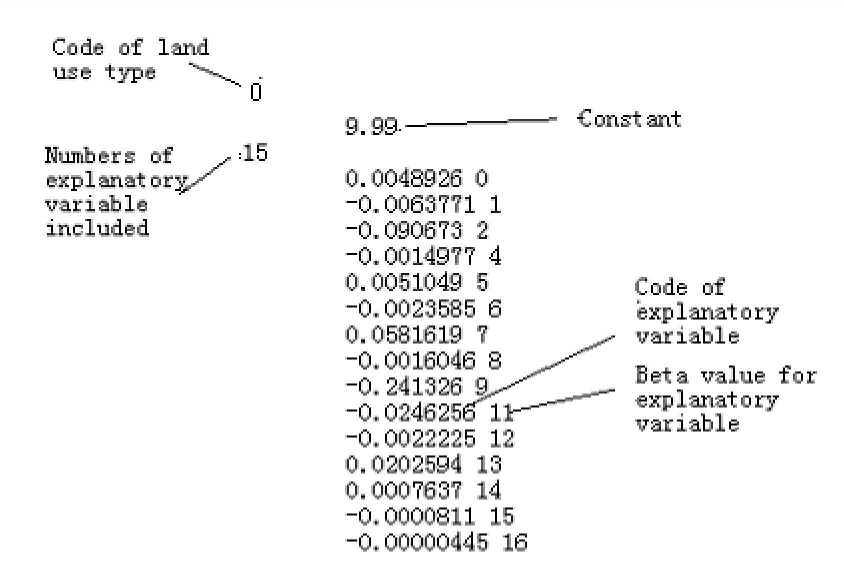
3.2.2 Spatial Analysis

The main part of the user interface is the file that contains the regression equations for the different land uses appears. If users click the menu button *Modify* under the menu of *Regression*, they can edit the file. An alternative way to edit the text file is to search and open the file alloc1.reg, which is located in the installation directory, using any text editor and save the file after making revisions.

This text file has the following format:

Line 1: Number code for each kind of land use.
Line 2: Constant of regression equation for each land use.
Line 3: Numbers of explanatory variable included in regression equation for each land use.
Line 4: On each line the beta for the explanatory variable and the code of the explanatory factor.
Following lines: Repeat the same sequence for the other land use types

If more than one region is considered and different regressions are derived for the different regions the sequence above should be replicated for the different regions.



3.2.3 <u>Developing the scenario</u>

Scenarios for DLS are with two components: 1) local restrictions that need to be selected in the boundary window and 2) a defined or calculated demand at the level of the study area as a whole to be selected in the ' scenario' window.
In these windows a selection is made of conditions specified in input files located in the installation directory. Users need to make sure that the input files are correctly prepared. If an error occurs the model will directly exit.

<u>Boundary</u>:
All files in the installation directory called regi*.* will appear in the selection box. These files should contain a boundary grid indicating for which grid cells of land uses could be changed, which, in other words, means that only active cells are used for calculations.
The files can be arranged according to rectangular grid or in one single column. When using a column based file, the file starts at the top left value of the grid, followed by the second value at the first row etc. Note: if ArcView option in *main.1* is chosen, this input files should contain an ArcView header.

```
9999 -9999 -9999 -9999 -9999 -9999 -9999 0 0 0 0 0 0
9999 -9999 -9999 -9999 -9999 -9999 -9999 0 0 0 0 0 0
9999 -9999 -9999 -9999 -9999 -9999 -9999 0 0 0 0 0 0
9999 -9999 -9999 -9999 -9999 -9999 -9999 0 0 0 0 0 0
9999 -9999 -9999 -9999 -9999 -9999 0 0 0 0 0 0 0 0 0
9999 -9999 -9999 -9999 -9999 0 0 0 0 0 0 0 0 0 0 0 0
9999 -9999 -9999 -9999 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
9999 -9999 -9999 -9999 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
9999 -9999 -9999 -9999 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
9999 -9999 -9999 -9999 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
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9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999 -9999
```

Scenario:

All files names in the installation directory that are named after demand.in* will be listed in the selection window. These files contain for each year that needs to be simulated the demand (in the same units as the model specification). The first line specifies the number of years for which demand is included in this file. This should at least be the number of years for which the simulations are to be made. After that, every line contains the demands for the respective land use types for one year. The order of the land uses should be the same as in the main parameter file and the second line of the file contains the demands for some certain year.

```
14601   56    2904   1728   3585   2560
14584   54    2892   1736   3612   2556
14567   53    2881   1744   3638   2555
14550   52    2869   1752   3664   2553
14533   50    2857   1760   3689   2550
14516   49    2847   1768   3714   2548
14499   48    2837   1776   3738   2545
14482   47    2827   1784   3762   2542
14465   46    2817   1792   3787   2538
14449   45    2810   1796   3811   2536
14430   45    2803   1801   3834   2534
```

3.3 Configuration

In case of a new application of the model for an area of different size than earlier applications it is needed to configure the model. Press the button *Setting* and then select the *setting.txt* file to conduct the configuration for the model.

3.4 Running the model

The model can be run by simply pressing the *Run* button. Then the procedure can be put in the list of view one by one. The result, for example, can be saved in the file of …*\dls\out*.... The name of file is

Cov#.1.

The LOG-file contains in addition to general run-time information also some iteration parameters. These are listed for each step made.

Respectively:
1. Iteration steps
2. Allocated cover for land use types (in this case 3 times);
3. Iteration parameters for land use types (again 3);
4. Maximal deviation between demand and allocated land use (%);

```
__++__   simulation for year        1   __+__
         0        9.990000       15
         1        1.430000       12
         2      -10.71000        12
         3       -7.420000       15
         4       15.00000        12
         5       -7.290000       13


demand direction for cove 0 is -1; demand:14582.5
demand direction for cove 1 is -1; demand:54.4646
demand direction for cove 2 is -1; demand:2892.29
demand direction for cove 3 is 1; demand:1735.84
demand direction for cove 4 is 1; demand:3612.42
demand direction for cove 5 is -1; demand:2556.46
         1  1  2346.000  .......  2  0.4946179  .......  3  -83.91222  .....  4  533.9241  5  0.494
         2     2358.000  .......     0.4928499  .......     -83.82993  .....     533.5919     0.492
         3     2483.000  .......     0.4891140  .......     -82.97274  .......   529.7994     0.489
         4     2604.000  .......     0.4861680  .......     -82.14298  .......   526.7820     0.486
         5     2814.000  .......     0.4832534  .......     -80.70290  .......   520.9688     0.483
         6     3307.000  .......     0.4757171  .......     -77.32214  .......   507.3214     0.475
         7     4471.000  .......     0.4741953  .......     -69.33997  .......   433.6589     0.474
         8     5440.000  .......     0.4543327  .......     -62.69501  .......   406.8347     0.454
         9     11905.00  .......     0.4539492  .......     -18.36105  .......   269.3092     0.453
        10     13096.00  .......     0.4537334  .......     -10.19373  .......   235.3395     0.453
        11     13931.00  .......     0.4534021  .......     -4.467684  .......   213.2249     0.453
        12     14244.00  .......     0.4532594  .......     -2.321275  .......   204.5604     0.453
        13     15326.00  .......     0.4534521  .......      5.098577  .......   174.6082     0.453
        14     15456.00  .......     0.4536064  .......      5.990057  .......   171.0095     0.453
        15     15556.00  .......     0.4538198  .......      6.675810  .......   168.2412     0.453
        16     15740.00  .......     0.4638404  .......      7.937596  .......   162.9539     0.463
        17     13560.00  .......     0.4634529  .......     -7.011829  .......   181.4734     0.463
```

3.5 Exporting the results

Model results are stored for each year separately in two different formats.
Results for individual land use types are stored in files called: *cov1_#.** (where # indicates the code for the land use type and * indicates the year). While for each year also a file is stored containing all land use types called *cov_all.** (where * indicates the year). In these files a unique value for each land use type is stored. The results in these files contain all new values for all grid cells and can be easily read by ArcView GIS software.

4. Conclusion

DLS can incorporate the functional complexity of the land system. It takes the structural complexity into account by incorporating bottom-up effects of dynamics of land systems, which can be identified by cross-sectional patterns and their spatial successions over time (Figure 3) due to local conditions and top-down influences of regional land use change.

Concluding, the DLS model seems suitable to represent the complex system of areas of small regional extent, but structurally defined validation and calibration is needed for further insights. Further research could also aim at the linkage to application-specific models with respect to economic, social or environmental issues. If so, DLS has the potential to become a suitable tool for decision-making in land use planning and natural resource management.

5. Technical Support and Contact information

- Email: dls07.admin@gmail.com
- Telephone:86-10-6488-8980
- Fax: 86-10-6485-6533