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CLIMATE CHANGE AND CHANGING LANDSCAPE – A COMPARATIVE EVALUATION ON CHINESE AND HUNGARIAN SAMPLE AREAS

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Abstract

The effects of globalisation are becoming obvious not only in the world economy but in natural processes as well. Increase of deterioration of natural conditions result in more and more decrease of land and water resources. Some experts even suggest that the changing climate of the next several decades can result in the transformation of the natural landscape.
Human activities, global and regional changes of climate and land use destroy the ecological environment, which also make the service function of the local ecosystem damaged constantly. We can improve ecological security of an area through regional land use pattern optimizing. The physical geographical consequences of aridification might be described through the decrease of ground water level, the change of the biomass quantity and quality. Their spatial and temporal variation may reflect the intensity and strength of degradation.
Remote sensing is one of the best tools to follow these processes, applying different databases. Spatial analysis of the gained information may help us to delineate the areas potentially endangered by even a minor climate change.

Key words: aridification, remote sensing, ground water, biomass monitoring, landscape change, land use optimization

INTRODUCTION

In 1972 at the Stockholm Conference the warming atmosphere was only a hypothesis. At the time the 4th report of the Club of Rome also regarded the future damage of the ozone layer as a theoretical problem. Nowadays, however, we talk about the greenhouse effect, or about the 'ozone-hole' as if they were well-known environmental issues already for a long time. Thus, it is not surprising that at first we thought that certain processes might not be influenced by these global processes. Nowadays, however, more and more observational data prove that the effects of global changes can be detected at different places of the Earth lying far away from each other, and they all exhibit very similar transformations. For example, the sample areas demonstrated in the present study, are located at 7000 km from each other, but the characteristics of their changes show many similarities.

In the international scientific community the effects of global warming can mostly be observed in desertification and aridification processes. Though natural and anthropogenic factors caused significant landscape changes in the previous centuries, the climate change makes these changes possibly more quick in the future (Csatári B. 2004, Rakonczai J. 2006, Láng I. et al. 2007, Metz B. et al. 2007). There are several uncertainties, and we do not know which changes will be irreversible. Connections within the landscape system are very complicated, that is, in the course of our research we can only use "indicators" which can demonstrate the process related to changes.

The real problem is, however, whether the affected regions are able to adapt to the changes. Experiments, carried out on the sample areas, support the above mentioned changes, but the environmental policy decisions of the countries can only follow up the events. The social adaptation to the changes demands to be not only a passive observer of (or, to be astonished by) the processes, but to adjust our activities and cultivation to these changes.

Effects of landscape changes and assessment possibilities

Considering the analysis of more than one hundred years of data and the experienced definite fall in precipitation in the latest 20 years – that can be figured out more or less trend-like – we heard many times that aridification has been evolving in Hungary. Comprehensive national evaluations carried out by different methods show a significant – at least 40-50 mm – annual fall in precipitation during a century on a national scale and the latest wetter years did not change the decreasing nature of the trend. The effects of increasing temperatures, decreasing precipitation, decreasing groundwater levels and the change of soil moisture content are the most dominating landscape factors. Lack is even more significant in certain parts of the Great Hungarian Plain, mainly in the Danube-Tisza Interfluve (*Fig. 1*). In this case GIS and multispectral remote sensing are the best methods to follow landscape dynamic processes, applying different databases (Mezősi G. – Szatmári J. 1998, Rakonczai J. – Kovács F. 2006a).

Farming-Pastoral Zone of Northern China is a vulnerable ecotone, which can be comparable to population hunger zone of African Sahel (*Fig. 2*). The climate of the study area is changeable, distribution of precipitation is uneven, the vegetation is destroyed seriously, proportion of the desertificated area is large, the ecological environment is fragile. High-intensity human activities as the excess reclamation, grazing and excavation, destroy the ecological environment, especially the natural vegetation which makes the service function of the local ecosystem constantly damaged. For the special geographical position and ecological sheltering function, the construction and protection of ecological environment in the study area is important for farming, animal husbandry and sustainable development of not only the study area but as well in the adjoined Beijing-Tianjing area (Wang J. et al. 1999, Verburg P. H. et al. 2000).

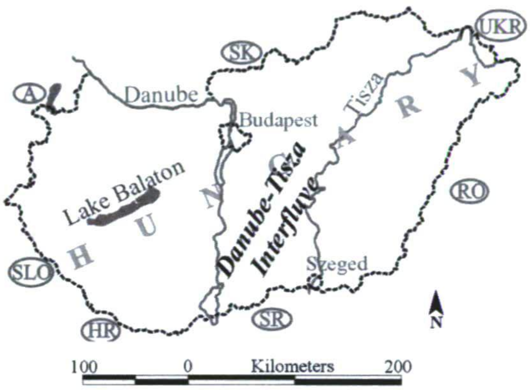

Fig. 1 The study area in Hungary

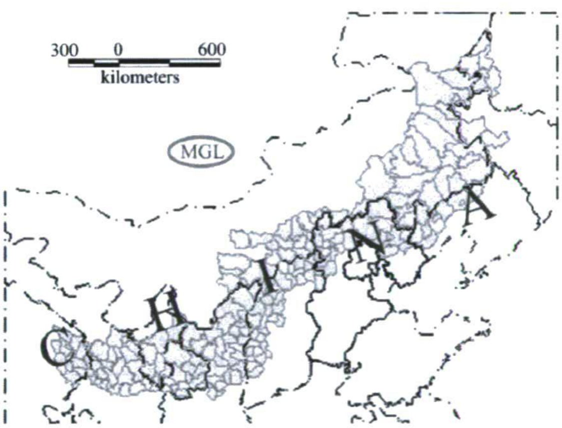

Fig. 2 The scope of the Farming-Pastoral Zone of Northern China

The essentials of land use pattern optimization are reasonable allocation of land resources and optimized landscape planning, which can harmonize the relationship of ecological, economic and social benefits (He C. et al. 2004). The LUOS model developed in the research overcomes all above limitation and considers synthetically the impact of natural and social factors on land use pattern optimization.

ENVIRONMENTAL CONSEQUENCES OF CHANGE IN WATER CYCLE – HUNGARIAN CASE STUDY

The change of natural water cycle is the most important factor in environmental changes which through several direct and indirect effects transform the characteristics of landscape components (*Fig. 3*).

Short term changes are evident: droughts and poor crop, floods, inland water. The most important long term effect is the decrease of ground water – though it is not obvious for the first sight. The decrease of ground water, however, influences processes through many interactions. On one hand, deeper groundwater level causes that vegetation can hardly reach and utilize it which results a decrease in biomass and in case of more significant transformation vegetation change can occur (on cultivated lands it forces the change of plants). On the other hand, the change of ground water modifies the vertical movement of water and salt in soils which results the genetic transformation of soils. In the consequences of this aridification processes may start or in case of arid soils it may generate a process that decreases salt. In both cases the change in the quality of the soil is accompanied with the transformation of the natural vegetation.

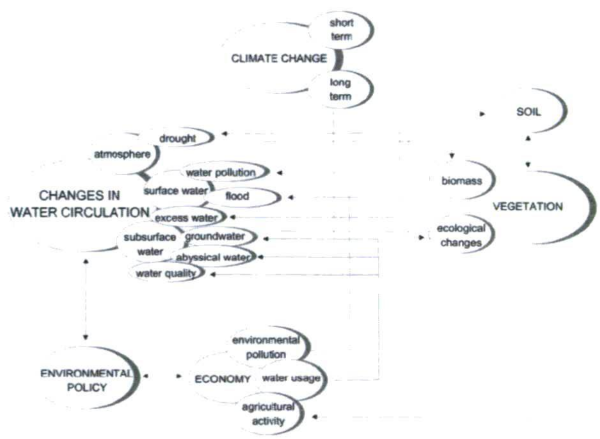

Fig. 3 The environmental consequences of the change of natural water cycle

Aridification as a geographical process with its direct consequences is hard to evaluate because there could be poor crop in a year with average rainfall as well, if the distribution of precipitation is unfavorable, respectively little rainfall can be replaced by irrigation. The complicated process is well-apprehensible when examining the year of 2000; in this year there were large areas covered by inland water at the end of winter and at the beginning of spring. There were great floods in the course of the year but later there was so serious lack of precipitation that the national precipitation average was around 400 mm which was unprecedented in the 20th century.

This is the reason why we looked for complex indicators in our research that do not investigate only one or another event (range of events) but are capable of signifying tendencies (as a matter of fact they are not infallible either).

Regional-size groundwater drop

Detailed research proved that the drop in rainfall was only one of the reasons of the change and it is a complex process in which social effects play important role besides natural elements. The most important factors that elicit aridification are as follows: lack of precipitation, increasing exploration of confined groundwater, frequent irrigation due to lack of precipitation, canals and other waterways and change in soil utilisation. On the Danube-Tisza Interfluve (where groundwater drop is the most relevant) there are about 500 measure stations on an area of 10.000 km^2 and more than half of them have data which can be used for long-term evaluation.

We analyzed the data of the wells by geoinformatic equipment and at the same time we checked their reliability by geostatistical methods. We can define the regional and temporal process of groundwater drop (*Fig. 4*) and besides we can produce exact figures with regard to the rate of water shortage.

The Danube-Tisza Interfluve, ascending between two great rivers as a ridge (the highest parts are higher by 40-80 m), and the subsurface water cycle of the area, namely the supply of groundwater, depends predominantly on precipitation. It has been found that, in the area mainly affected by the changes, decreasing groundwater is in close connection with the relief (orography) (Rakonczai J. 2006).

We could also realize that the supply of groundwater in particular parts of the area is in even closer connection with the meteorological relations; thus, a wetter period may help to re-establish its former state (*Fig. 5*). All this information, however, supports the idea that mainly the drier climate is responsible for the shortage. Several rainy years can reduce the water shortage of the area (*Table 1*), but there is an area of about 1500 km^2 where the rate of depression is so great that the process can hardly return to normal. The degree of aridification is well presented by the years of 1995 and 2003, when the decrease of ground water was 4.8 km^3, almost reaching (85%) the total water usage of Hungary.

The goal was to observe natural water resources through the dynamism of vegetation in a growing season from 1992 to 2005 with high temporal resolution AVHRR and MODIS images. The applied method of predicting net biomass production is the determination of the Normalized Vegetation Index (NDVI). Four major vegetation classes were examined (Kovács F. 2007).

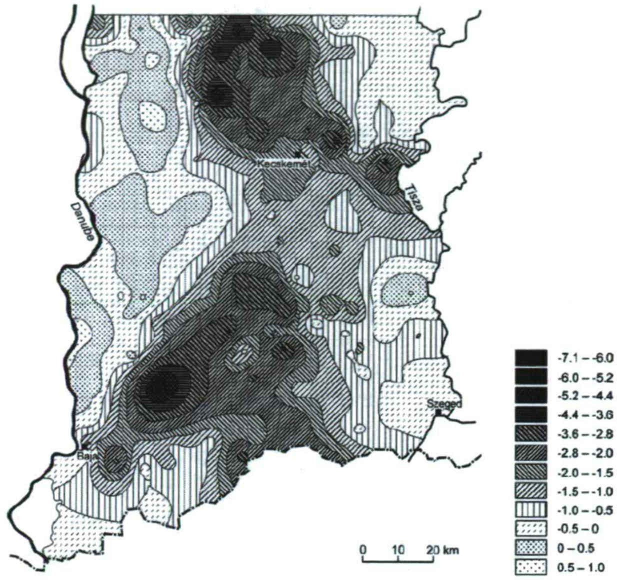

Fig. 4 The level of groundwater in March 2003 (in relation to the average of 1971-1975)

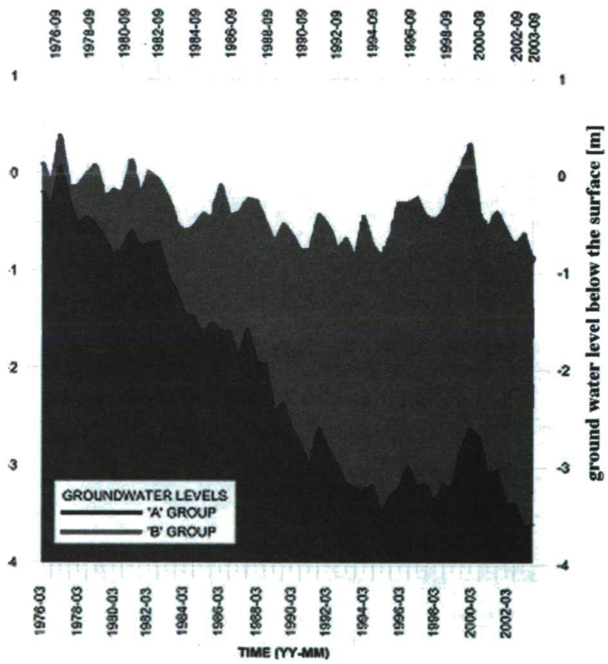

Fig. 5 Temporal change of average groundwater level in the two different types of landscape in the study area (in relation to the average of 1971-1975). Group A: wells that show significant decrease of soil water level; Group B: wells that have immediate hydraulic connections to the surface water supply (i.e. to the rivers)

Table 1 Approximate volumes of soil water deficit in relation to the early 1970's (1971-1975) in the Danube-Tisza Interfluve

Year	*Water deficit (km^3)*
1980	1,15
1985	2,32
1990	4,08
1995	4.80
2000	2,84
2003	4,81

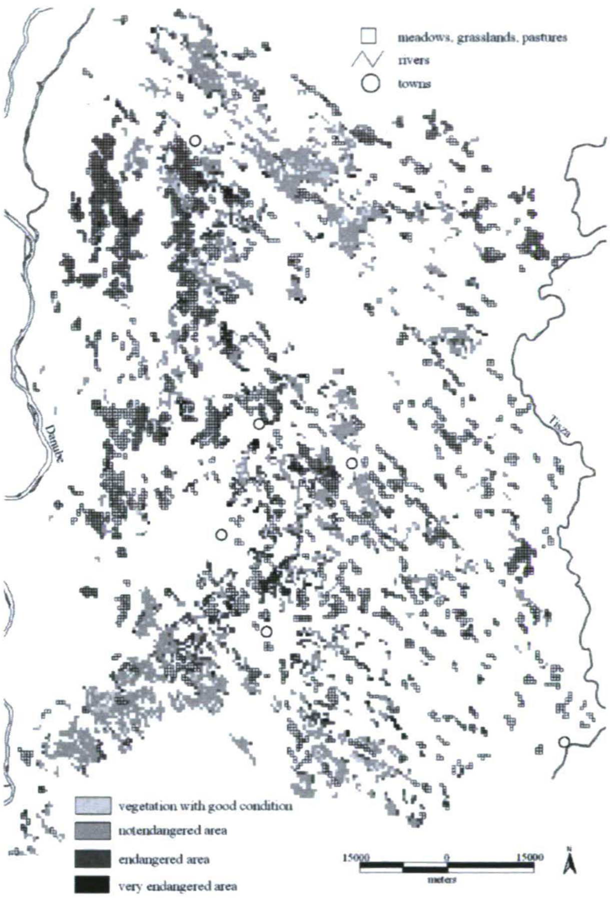

Fig. 6 NDVI-based regional distribution of the effects of aridification in the Danube-Tisza Interfluve

Regional multispectral biomass monitoring

Considering the distributions of precipitation, so-called average profiles were constructed for the individual classes on the basis of the average values of the wetter periods between 1996 and 1999, and 2001-2004. The spatial and temporal analysis of alterations from these average profiles may be used to determinate the dynamics of vegetation growth and to support the delineation of areas threatened by permanent biomass-loss.

A negative average NDVI data trend has been observed primarily in the months of April, July and September to 2003. The 10-15% changes in deep-rooted arboreal surfaces, within this short period, are very dangerous.

The amount of biomass produced is decreasing in one third of the vegetated area according to the spatial analysis of the 1992-2001 period. The reaction to the aridification process is unfavourable in one third of the mixed forests areas, in one fourth of the deciduous forests areas, one fifth of the coniferous areas and 42 % of grass-meadow-pasture areas.

The amount of produced biomass is decreasing by 16% in the vegetated areas as it was shown by the spatial analysis of the 2001-2004 period (*Fig. 6*). The response to the aridification process is unfavorable in one fifth of the mixed forest areas, in one seventh of the deciduous forest areas, in one third of the coniferous forest areas and in one seventh of grass-meadow-pasture areas.

A decreasing vegetation activity can be expected throughout the vegetation period with the exception of May, and according to the results derived by several approaches August-September can be regarded as a potentially imperiled month. The continously decreasing NDVI trend is very alarming in June and July, because these month are supposed to produce the greatest amount of biomass.

Landscape changes due to climate change

Between 1976 and 1978 we carried out detailed geographical research in the south-eastern part of Hungary, in the "puszta" (deserted area) near Szabadkígyós. We made an exact micro-morphological map on one of the characteristic alkaline benches of the area and together with botanists marked sample fields for mutual analysis (Rakonczai J. 1986). In the course of the measurements made in 2003 we could observe not only bench erosion but the change of vegetation and soil, too (Rakonczai J. – Kovács F. 2006b). The once eroded alkaline flats that were free of vegetation became covered by homogenous grass, bench erosion totally eliminated the former benches and grass and saline vegetation spots with static emerged, while bare alkaline surfaces disappeared. The permanent groundwater deficit caused a spectacular landscape change (*Fig. 7*).

SIMULATING LAND-USE PATTERN OPTIMIZATION IN NORTHERN CHINA

The emphases of land-use pattern optimizing simulation in the study area are gross demand controlling and spatial allocation (1km×1km), namely exact non-spatial simulation and spatial simulation (*Fig. 8*). In this case not only the optimized structure of land use in given conditions is well-known, but also its developing status, which results in the shortcomings of static research of normal linear planning (Jeffrey L. et al. 1997).

1986

2003

Fig. 7 Once sodic spots that became covered by grass during a quarter of a century in the "puszta" near Szabadkígyós.

According to the land resources characters of the study area and our research aim, six variables are set up which are cultivated land, forestland, grassland, water body, residential land and unused land, expressed with $x_1, x_2 \ldots x_6$ respectively. Target function is set up on the basis of sustainable development (Eq. 1). The gross demand controlling scheme is the allocated result of all kinds of land-use types when function value reaches its maximum.

$$F(x) = 2180.068\,x_1 + 523.290\,x_2 + 733.885\,x_3 + 10567.339\,x_4 + 2507216.814\,x_5 + 68.283\,x_6 \quad (1)$$

Spatially distributed combination of cell state is expressed by multidimensional integral matrix (*Fig. 9*).

In this study we used the 1989, 1994, 1999 NOAA/AVHRR remote sensing images, the meteorological data (precipitation, sunshine, temperature) of 194 observatories in 1961-2000 derived from Meteorological Administration, while statistical population data and other economic data of county areas regional in 1953, 1964, 1982, 1997, 2001 were provided by the National Bureau of Statistics of China.

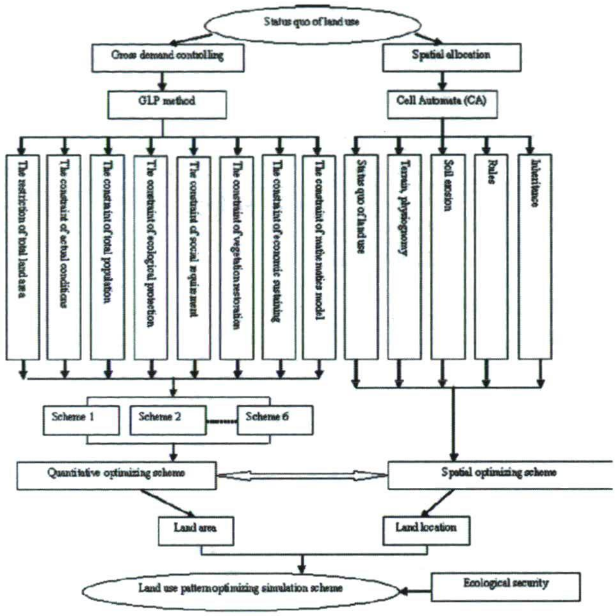

Fig. 8 LUOS model frame of land use pattern optimizing simulation under ecological security

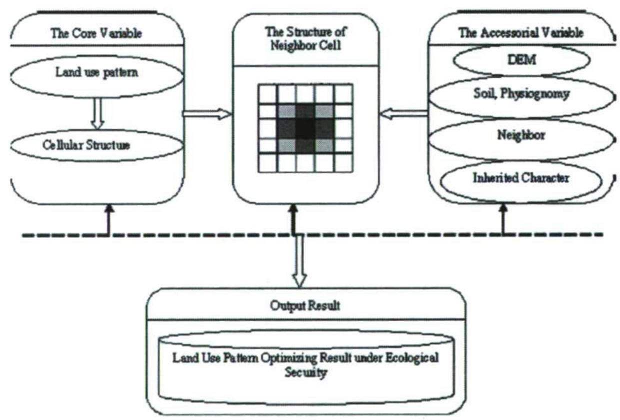

Fig. 9 The structure of the CA model

Results – Gross demand controlling

In line with actual conditions of the study area, we choose representative upper limit, lower limit and middle value of population and yield per hectare in GLP. Thus, we receive 9 types of optimizing schemes (*Table 2*). The population increasing speed of schemes 1, 2, 6 are 8.17‰, 8.43‰, 8.93‰, while those of schemes 3, 4, 5 are 8.17‰, 8.43‰, 8.93‰, respectively. Economic development speed is very fast and ecological environ-

Table 2 Comparison of all land use pattern optimizing simulation schemes

	Actuality	*Scheme 1*	*Scheme 2*	*Scheme 3*	*Scheme 4*	*Scheme 5*	*Scheme 6*	*Remark*
Population	71405938	78301350	81791975	78301350	81791975	82208977	82208977	
Yield kg/ha	1515	2100	2100	1890	1890	1890	2100	
Cultivated land (ha)	16850805	13054299	13627922	14500250	15146662	15223885	13701496	
Forestland (ha)	9264880	9264880	9268954	9268954	9264880	9264393	9264393	
Grassland (ha)	43039881	46817052	46235282	45367027	44720616	44643393	46165782	
Water body (ha)	79010	79010	79010	79010	79010	79010	79010	*
Residential land (ha)	72049	91384	95457	91384	95457	95944	95944	
Unused land (ha)	3342830	3342830	3342830	3342830	3342830	3342830	3342830	*

Note: * Supposed to be unchanged

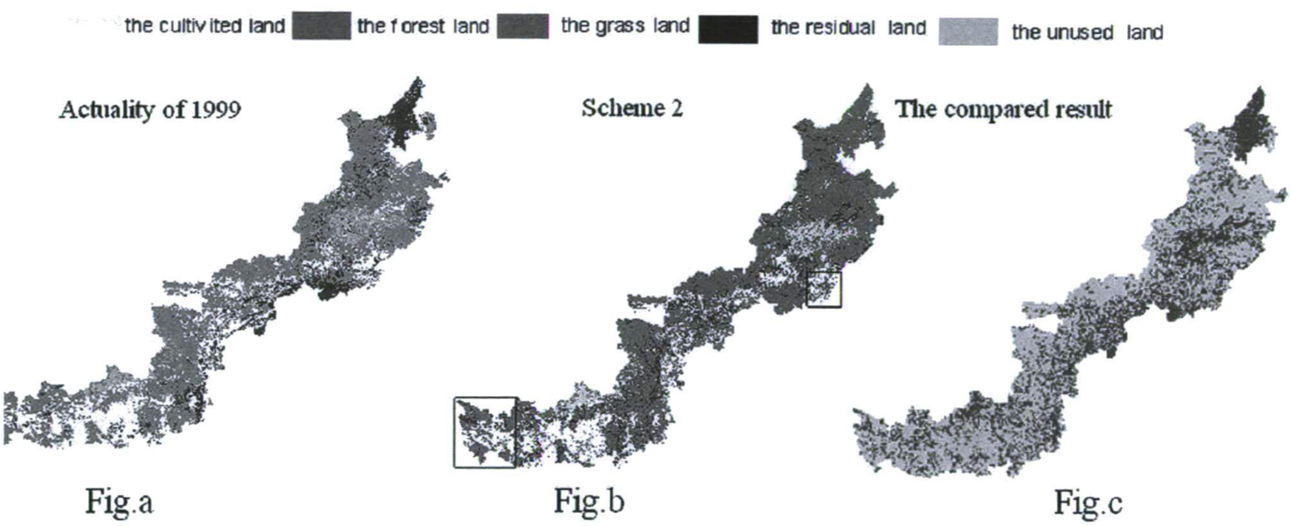

Fig. 10 The result of land-use pattern optimizing simulation

mental quality is relatively high in Scheme 1, which is difficult to be come true. Scheme 4 is similar to it except that the grain yield is less than the latter. Scheme 5 is alike to Scheme 2, the different of them is that the economic benefit of the former is worse than the latter. Controlling the population birthrate at 8.93‰, we can receive Scheme 3, the shortcoming of which is that the ecological benefit is not ideal. Economic, ecological and social benefit in Scheme 2 can be harmonized, which is an ideal optimizing scheme.

RESULTS – SPATIAL ALLOCATION

An ideal spatial distribution pattern map can be produced after the spatial calculation of CA module according to the gross demanding result of scheme 2 (*Fig. 10b*). The compared result map before and after land use pattern optimization is as *Fig. 10c*, which is the overlapped result of land use pattern optimizing result of scheme 2 and land-use actuality map. And the statistical result after comparison and analysis is as *Table 3*.

The amplificatory result map of *Fig. 10b*, as *Figs. 11a-b*, demonstrates that the cultivated land convert to forestland those gradient is steeper than 25°, which carry out the policy of cultivated land "grain for green" those gradient is steeper than 25°. This policy can reduce the phenomena of soil loss, land desertification and land quality descending. *Figs. 11c-d* are the demonstrations that residential land increases. The cells surrounding residential land cell can convert to other types of land in the order of grassland, cultivated land and forestland.

Table 3 Simulated land use conversions based on scheme 2

Type of conversion	*Area of converted land (ha)*	*Type of conversion*	*Area of converted land (ha)*
from cultivated land to forest	270870	from grassland to residential land	263520
from cultivated land to grassland	570389	from grassland to forest	111619
from cultivated land to residential land	2520	from forest to residential land	9975

DISCUSSION AND CONCLUSION

In the latest decade aridification could be observed in the Hungarian Great Plain not only because there has been a steady decrease in rainfall but it has multiplying effects. In the short run precipitation shortage can be measured in the annual change of the vegetation but permanent shortage could lead to regional groundwater deficit. This latest could elicit the genetic change of soils which could lead to the change of the natural vegetation even in a lifetime!

The negative effect rooting in destroyed ecological environment will spread to the whole North China, especially Beijing-Tianjin area, if current development ways continue. Thus, the land-use pattern optimizing simulation under ecological security condition is very important. The LUOS model can easily be applied to land-use pattern optimizing simulation of the study area.

From the point of view of remote sensing, the interesting qualitative parameters for the analysis of landscape change is quite limited, but can be more operative and expense-efficient in the future. For dynamic research, good time resolution earth observation remote sensing data are available, having more and more detailed spatial resolution (almost free data). Throughout a year some maximum value composite (MVC) images are

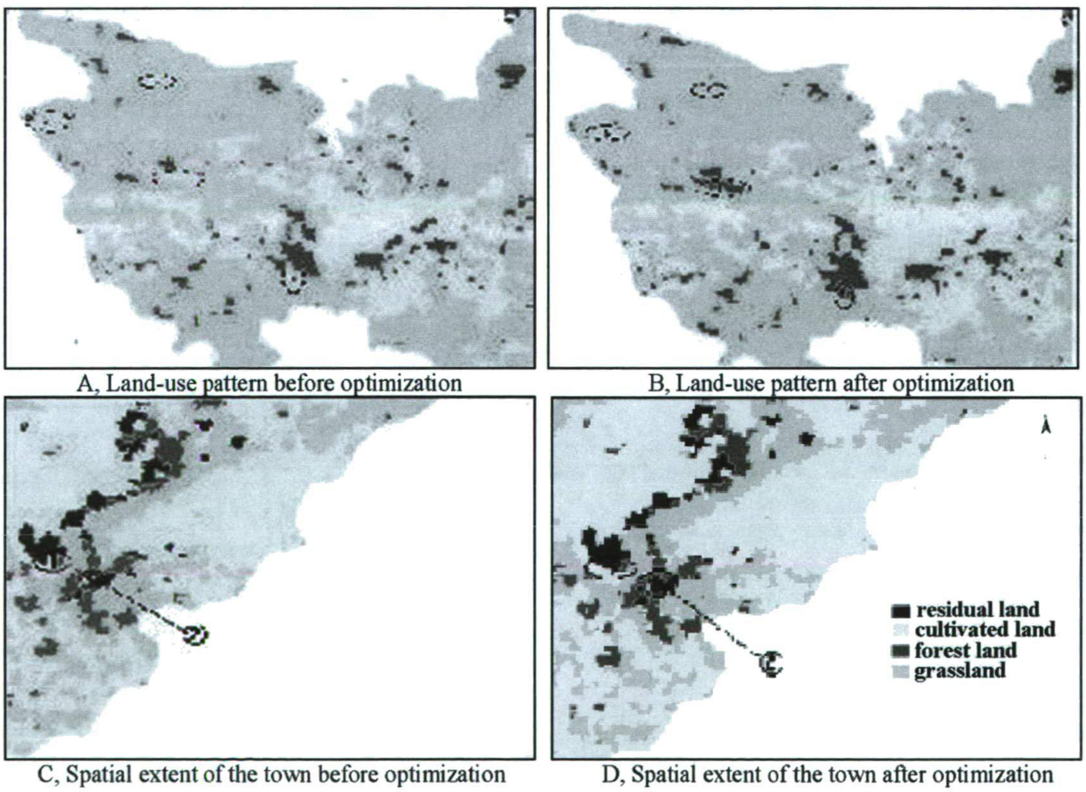

Fig. 11 Comparison of the simulated land-use distribution (cultivated land and residential land) before and after the optimization
Note: *Fig. a* and *b* correspond to the area 'a' of *Fig. 10b*. *Figs. c* and *d* correspond to the area 'b' of *Fig. 10b*

available offering good spatial data sampling which can be used well in the dynamic analysis even in areas of heterogeneous land use, on the regional scale. Our opinion is that this is the best possibility to observe the spatial and temporal evaluation of the effects of climate change on the landscape. We propose to develop a regional geographical monitoring, which could apply the methods introduced in this paper. The elements of the constructed system are the database–use and methods–evaluation, which could be supported with low expenses during operation. The new perspective for the future in long-term multi-spectral analysis is the development of connection between the data of different satellite images, making possible to use high temporal resolution images with high spatial resolution images (e.g. MODIS-LANDSAT).

The system is open. Therefore, it can be developed to be more objective with the assessment of other effectively endangered areas and with other landscape factors. Naturally, we can use the available spatial or statistical data, and this is one of the greatest possibilities of GIS in the complex geographical analysis. One example of application is the digital surface model, what we can use in the multidisciplinary examinations of longer and better time resolution data: i.e. meteorological indices or groundwater data. The more different data compared the more objective the results will be, but we must give greater importance to some dominant landscape factor (e.g. precipitation, wetness conditions, land use).

We need immediate arrangement and action to keep back waters and to make the water compensation stronger in the area and to validate the national decision. From geographical viewpoint the Danube-Tisza Interfluve and Northern China are sensitive areas, therefore the climatic effects and the unjudicious anthropogenic activity are very dangerous and increase the effect each one other. They also cause irreversible processes in the strongly protected and in quasi-native areas.

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