Modeling Land Use Dynamics by Integrating Biophysical and Human Dimensions (CLUE) Costa Rica 1973-1984.

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1.   Abstract

As a pilot study potential biophysical and human land use drivers in Costa Rica were evaluated using multi-variate statistical methods in a nested scale analysis. The reconstructed land use drivers and their quantified effects on land use were applied within a dynamic framework CLUE (Conversion of Land Use and its Effects) to model land use dynamics in Costa Rica from 1973 to 1984. Our pilot study demonstrates that a land use/cover system can described as a scale-dependent hierarchical system and that its dynamics can be satisfactorily modeled as functions of biophysical and human drivers.

2.   Introduction

Most land cover modification and conversion is nowadays driven by human use rather than natural change [1, 2]. In general, land use is viewed to be constrained by biophysical factors such as soil, climate, relief and vegetation. On the other hand, human activities that make use of or change land attributes are considered as the proximate sources of land use/cover change. Interpretations of how such land use/cover driving forces act and interact is still controversial, especially with respect to the assessment of the relative importance of the different forces and factors underlying land use decisions in specific cases [2].

There is also an increasing need in global change research for more realistic and integrated modeling of land cover conversions as a result of land use changes. There are several problems related to such modeling:
- Dynamics of natural vegetation vs. Agricultural use.
- Spacial scales, global vs. Regional.
- Temporal scales, rapid agricultural changes vs. Relatively slow climate changes.
- Identification of relevant land use drivers, socio/economic vs. Biophysical.

In order to investigate these problems, we selected Costa Rica with its diverse environment and rapidly growing populations, as a first pilot study to attempt modeling land use related drivers and their temporal and spacial variability. Potential land use drivers for Costa Rica were identified and combined in a geo-referenced census [3, 6] and biophysical [7, 8] data set (Figs.1)
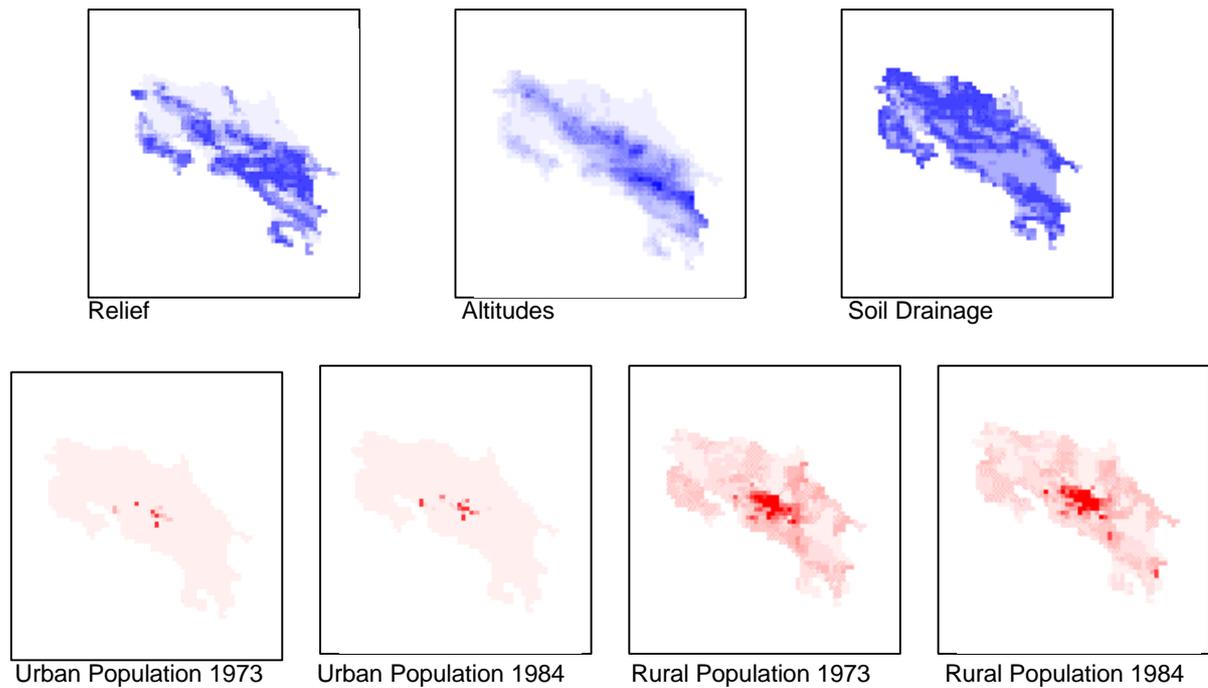
Relief   Altitudes   Soil Drainage

Urban Population 1973 Urban Population 1984 Rural Population 1973 Rural Population 1984

Figure 1. Some biophysical characteristics of Costa Rica:
- Relief (flat [white] to mountainous [blue])
- Altitude (sea level [white] to > 3000m [blue]
- Soil drainage (poorly drained [white] to extremely well
 drained [blue])

Some human characteristics of Costa Rica:
- Urban population 1973 and 1984 (low [white] to high
 population density [red])
- Rural population 1973 and 1984 (low [white] to high
 population [red]).

3. Results and Discussion

Potential drivers were evaluated applying multi-variate statistical methods in a nested scale analysis, using six artificial aggregation scale [9], Spatial distribution of potential biophysical (annual temperature, relief/precipitation and soil) and human (urban and rural population) drivers were statistically related to the distribution of pastures, arable lands, permanent crops, natural and secondary vegetation, for 0.1° (6') grid units and five artificially aggregated spatial scales. Multiple regression models describing land use/cover variability have changing model fits and varying contributions of biophysical and human factors, indicating a considerable spatial scale dependence of land use/cover type has its drivers. The observation that for both years each land use/cover type has its own specific scale dependencies, suggests a rather scale dependent system. In Costa Rica two land use/cover trends between 1973 and 1984 can be discerned: 1) intensification in the urbanized Central Valley and its surroundings where agriculture is extended to steeper and less favourable soils due to a high population density; 2) land use expansion in remoter areas, where the extension of arable land and pastures increased at the cost of natural vegetation (mainly forest). This deforestation was not driven by land shortage. Most changes in agricultural land use from 1973 to 1984 seem to be driven by changes in population density and to be limited to specific biophysical environments [9].

To support future efforts to model land use/cover dynamics by its drivers, a dynamic framework to simulate *Conversion of Land Use and its Effects* (CLUE) was developed [10]. CLUE attempts to simulate land use conversion and change in space and time as a result of interacting biophysical and human drivers.

The CLUE framework was applied for Costa Rica to construct a first multi-scale dynamic land use model (CLUE-CR) simulating changes in natural vegetation, pastures, arable land, permanent crops and a rest group simultaneously. Initial simulations (for example Fig. 2, pastures and rangeland changes simulated for 10 years) demonstrate a plausible and realistic land use dynamics as steered and controlled by population and biophysical conditions.

4.   Conclusions

The project resulted in the development of concepts for handling the highly dynamic features of land use change and its drivers or a small country (Costa Rica) at different spatial scales [9]. An analysis of Costa Rican land use/cover system distribution and their dynamics at six different spatial scale demonstrated that the human/biophysical dimensions of land use/cover systems are scale dependent. Each land cover has its own specific set of human and biophysical scale related drivers.

CLUE-CR simulations (Fig. 2) suggest that the integrated approach of CLUE to model land use/cover dynamics as a function of its drivers [10], will contribute to more realistic simulations of land use/cover changes.

It can thus be finally concluded that a land use/cover system can be described as a scale-dependent hierarchical system and that its dynamics can be satisfactorily modeled as being driven by biophysical and human factors.
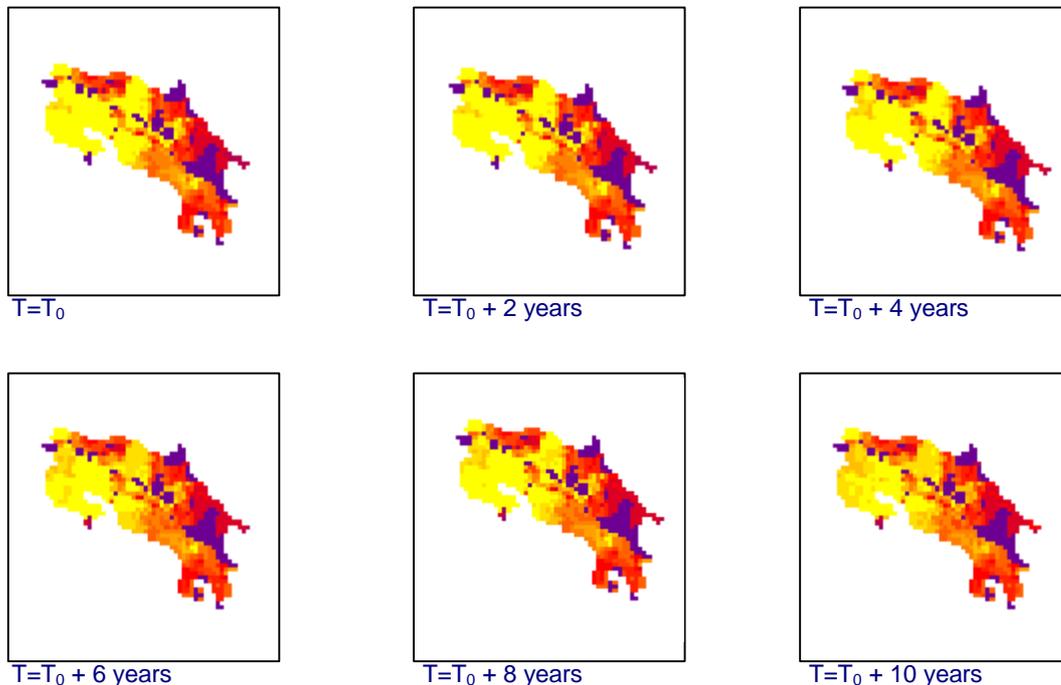
T=T_0 T=T_0 + 2 years   T=T_0 + 4 years

T=T_0 + 6 years   T=T_0 + 8 years   T=T_0 + 10 years

Fig 2: Initial CLUE-CR simulation (10 years) of pasture/rang land dynamics, controlled by population and biophysical drivers in 1973-1984. (<5% cover [purple] to >70% [yellow]

5.   References

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