Imperial College London

Modelling land cover change in the Upper Ganga basin

Simon Moulds, Georgia-Marina Tsarouchi, Ana Mijic and Wouter Buytaert

Department of Civil and Environmental Engineering, Imperial College London

Introduction

Background

Over recent decades the green revolution in India has driven substantial environmental change. Particularly in the Gangetic plains of northern India, land use change and changing irrigation practices may have complex effects on water resources. The Global Land-Atmosphere Coupling Experiment (GLACE) (Koster *et al*., 2004) showed that in northern India there is strong feedback between soil moisture and precipitation.

Motivation

A common historical land cover dataset to drive different climate models is a major requirement for the hydrological assessment of northern India. However, as the spatial and temporal resolution of historic satellite imagery for the region is poor (Goward *et al*., 2006), available data must be interpolated in space and time. This work investigates the ability of the Conversion of Land Use and its Effects at Small regional extent (CLUE-S) modelling framework (Verburg & Veldkamp, 2004; Verburg *et al*., 2002) to generate missing land cover data for the Bhimgodha basin, a sub-basin of the Upper Ganga basin. The study area is shown in Figure 1.

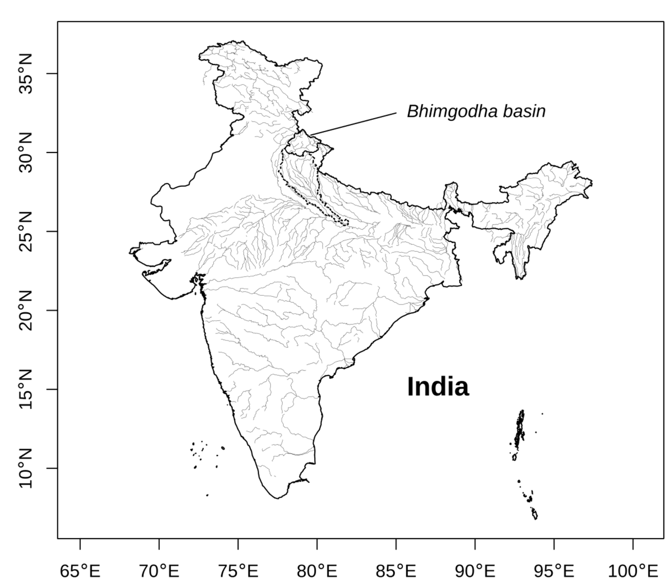

Figure 1: Position of the study area in relation to the river network of the Indian subcontinent. The Upper Ganga basin is delineated with a dashed line. The catchment has a total area of approximately 23,197 km². For modelling purposes this was divided into 500 x 500 m grid cells.

Materials and methods

The CLUE-S model works on an annual time step. It consists of two distinct modules: a non-spatial demand module, which specifies the total area of all land use types at each time step, and a spatially explicit allocation module. The basis of the allocation module is a statistical model defining the suitability of locations for each land cover under consideration, which is assumed to be a function of spatially explicit driving factors. Figure 2 outlines the allocation procedure. For improved flexibility the original interface was recoded in the R programming language.

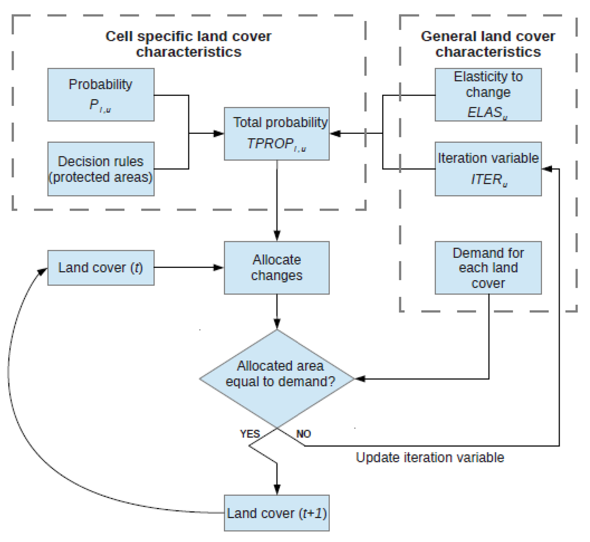

Figure 2: The allocation procedure for grid cell *i* and land cover type *u* used by the CLUE-S model (Verburg *et al*., 2002).

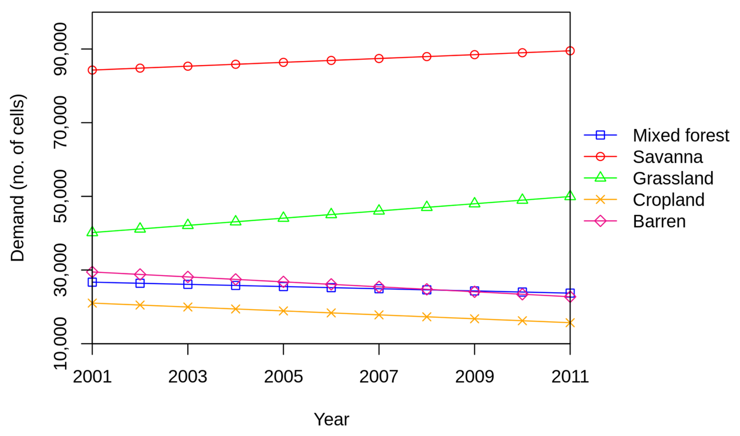

Figure 3: Demand scenario for the simulation. The demand and location of other land covers (water, urban, snow/ice) were assumed to be constant.

Land cover maps for 2001 and 2011 were derived from the MODIS Land Cover Type product (MCD12Q1) and simplified to reflect the dominant land cover types in the Bhimgodha basin. A demand scenario was constructed based on linear interpolation between the two observed points. This is shown in Figure 3. Driving factors were collected from different sources and prepared using Geographical Information System (GIS) software. Statistical analysis was performed on the 2001 map and the model was run for the period 2001 to 2011. The modelled land cover map for 2011 was then compared against the observed map using a multiple resolution procedure (Costanza, 1989).

References

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Results

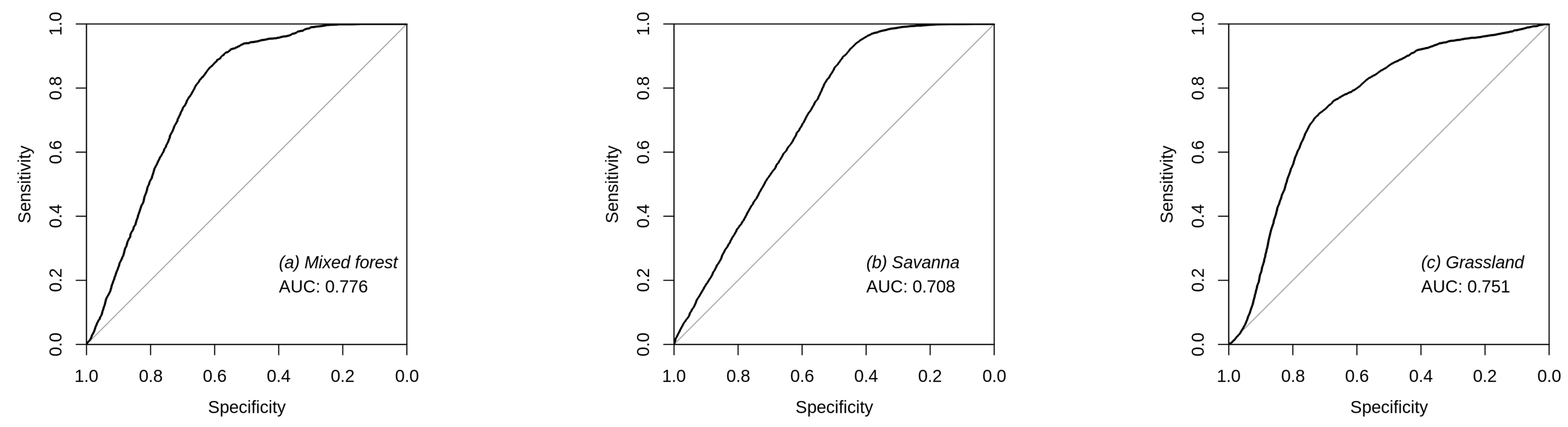
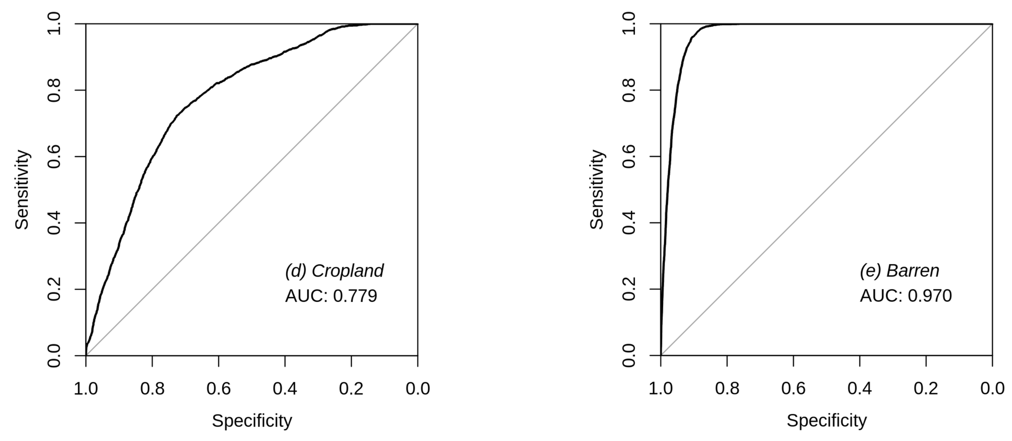


Figure 4: Evaluation of the statistical analysis using the Receiver Operating Characteristic (ROC). In general, the higher the area under the curve (AUC), the better the fit of the model. The statistical model for barren land results in the highest AUC, due to a strong relationship with elevation. Savanna, which tends to fill gaps between other more location-sensitive land covers, has the lowest AUC value.



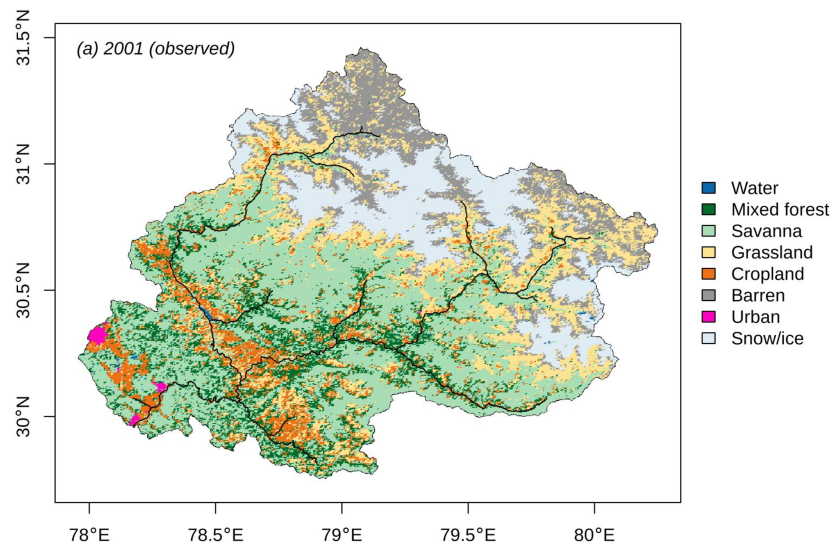
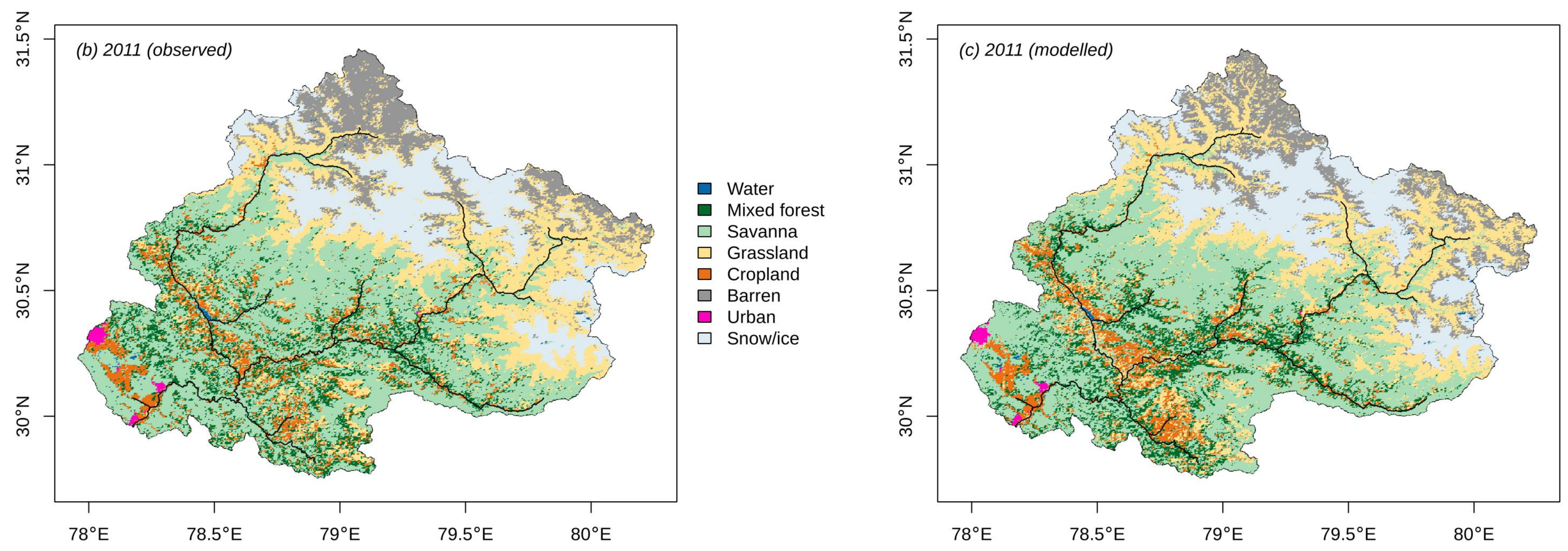


Figure 5: Observed land cover in 2001 and 2011 and modelled land cover in 2011. The river network is shown as a black line. It can be seen that the increase in grassland in the upper part of the catchment is well represented by the model. However, it does not reflect the decrease in size of the central cropland belt.



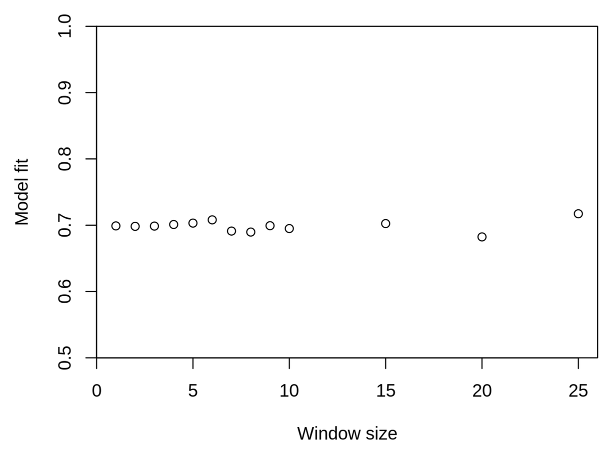


Figure 6: Plot showing goodness of fit against window size (n x n grid cells of 500 x 500 m). The multiple resolution procedure gives an indication of how well the model simulates the pattern of land use change at the aggregate scale by allowing for “near misses”. In this case, the fact that model fit does not improve with window size shows that the model does not adequately reflect the observed pattern of land use change when considering the whole catchment. Nevertheless, a model fit of approximately 0.7 is considered reasonable.

Conclusions and future work

- The results show that the CLUE-S model is able to predict the observed land cover change in the study area with a success rate of approximately 70%.
- Decreasing the resolution of the observed and modelled maps does not improve the fit, indicating that the model output does not reflect the pattern of land cover change at the aggregate scale. This may result from the simplistic demand scenario used for the simulation.
- Model performance may be improved by using a more accurate demand scenario and incorporating dynamic driving factors, such as meteorological data, into the statistical analysis.
- Further work could investigate the application of CLUE-S to spatial interpolation, for the case where satellite images for the study area are only partially available because of cloud cover or missing data.

Acknowledgements

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