Visualizing the certainty for extrapolations from models of landscape change.

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1. Extended Abstract

This paper describes a general method to estimate the level of certainty for extrapolations from predictive models of landscape change through time. The method assumes that extrapolations to points farther into the future are less certain than extrapolations to points nearer to the present, so the predictive power of a model decays as the model predicts to points farther into the future. At some very distant time, the model's prediction eventually has an accuracy equivalent to what we would expect due random chance. The proposed method estimates how fast the certainty of a model's prediction decays to randomness, based on measurement of validation over a previous time interval for which data are available. The method can be used for any number of categories, thus can be applied to many types of land change models.

Figure 1 shows the strategy of the technique, which relies on two model runs as represented by the dark boxes. The purpose of the first model run is to assess the model's predictive accuracy; the purpose of the second model run is to extrapolate landscape change into the future. The calibration information for Run 1 consists of maps that show land cover at time 0, land cover at time 1, and factors that influence land cover change, such as slope and proximity to edges of patches. Run 1 predicts the land cover for time 2, where an empirical map of land cover is available for validation. Measurement of the accuracy of the prediction from Run 1 is saved for later use. The calibration information for Run 2 consists of maps that show land cover at time 1, land cover at time 2, and the same factors used in Run 1. The model is re-calibrated for Run 2, which predicts the land cover for some future time. The prediction for the future time is then adjusted for its level of certainty, based on the saved validation information from Run 1.

We illustrate the technique with the land change model Geomod (Pontius *et al.*, 2001; Pontius and Malanson, 2005). The model predicts change in Forest within the Ipswich Watershed in northeastern Massachusetts, where time 0 is 1971, time 1 is 1985, and time 2 is 1999 (Pontius and Schneider, 2001; Schneider and Pontius, 2001). Run 1 produces a prediction for 1999 that is 91% correct, due mainly to persistence in the land cover. The measurement of validation considers the predictive accuracy for each of the possible transitions between Forest and Non-Forest from 1985 to 1999. Run 2 begins with the land cover map of 1999 shown in Figure 2, where each pixel is either pure black or pure white depending on whether it is Forest or Non-Forest. Run 2

extrapolates the land cover to many points in time, extending into the future as far as 2097. The model produces a prediction for each pixel to be either Forest or Non-Forest, and then the proposed method converts the crisp prediction into a probability to account for the estimated level of certainty of the prediction. The certainty derives from the measurement of validation of Run 1, combined with the assumption that the model's predictive accuracy decays exponentially over time to randomness for each of the possible transitions between the land cover categories. Figure 3 shows the prediction for 2097 adjusted for uncertainty; so the darkness of the shade of grey indicates the probability of Forest, given the model's prediction.

The proposed method is the next development in an increasingly helpful series of techniques designed to allow both experts and non-experts to visualize the certainty in model predictions (Pontius and Batchu, 2003; Pontius *et al.*, 2003; Pontius and Spencer, 2005). The technique explicitly separates calibration information from validation information in a manner that allows for appropriate measurement of the model's predictive accuracy (Pontius *et al.*, 2004; Pontius and Pacheco, 2004). Readers may obtain the VBA program from the authors in order to apply the proposed method for their own modeling applications.

2. Figures

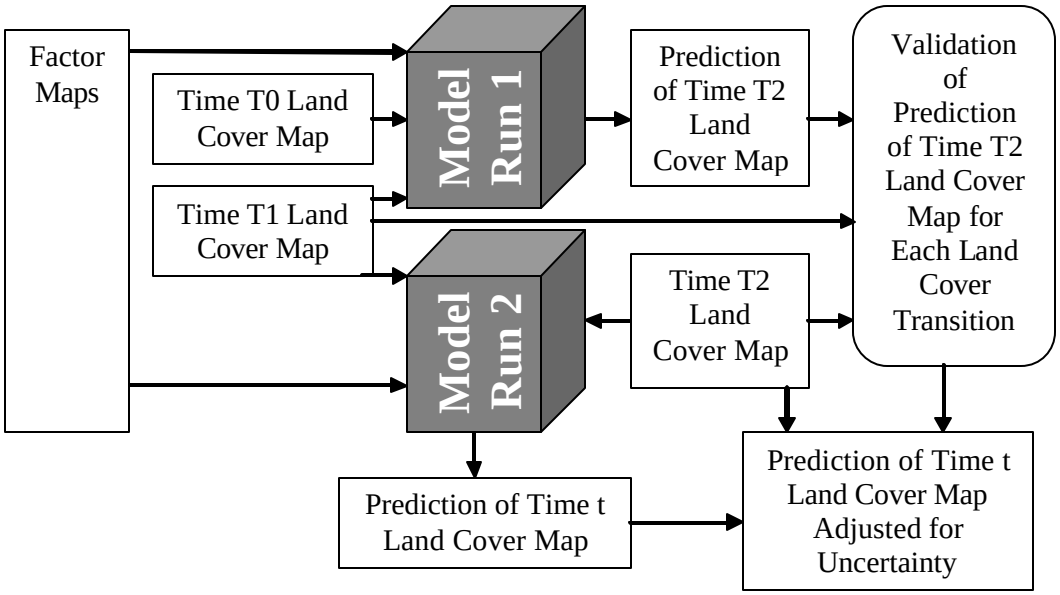

Figure 1. Flows of information for the technique to extrapolate land cover change with an estimated level of uncertainty.

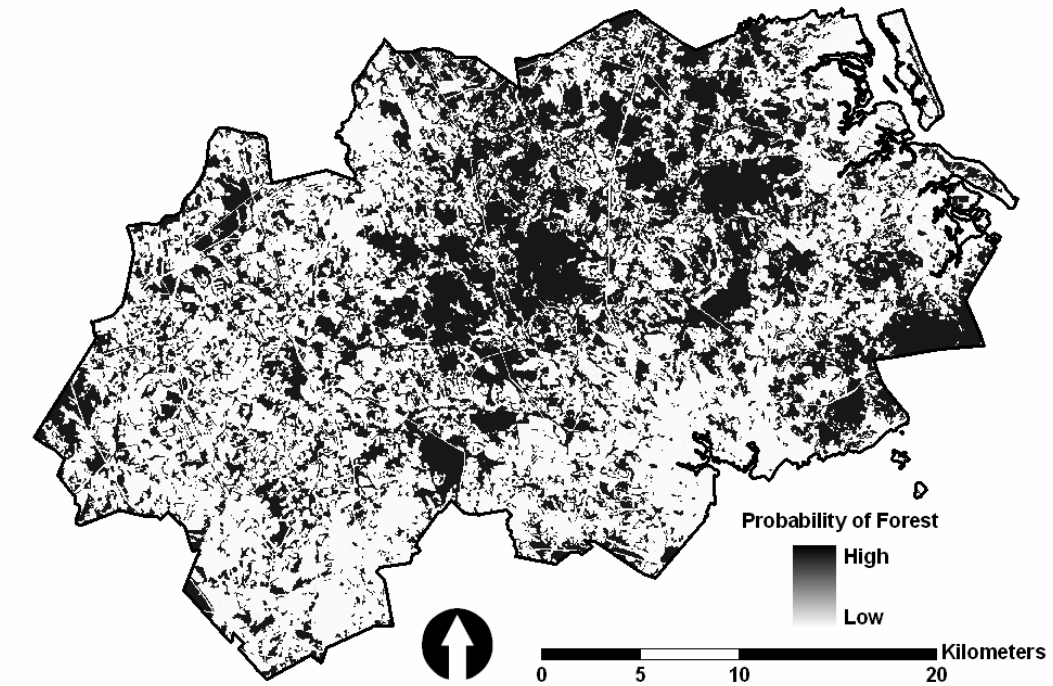

Figure 2. Forest in Black and Non-Forest in White for 1999, which is the beginning of the extrapolation for the 22 towns of the Ipswich River Watershed.

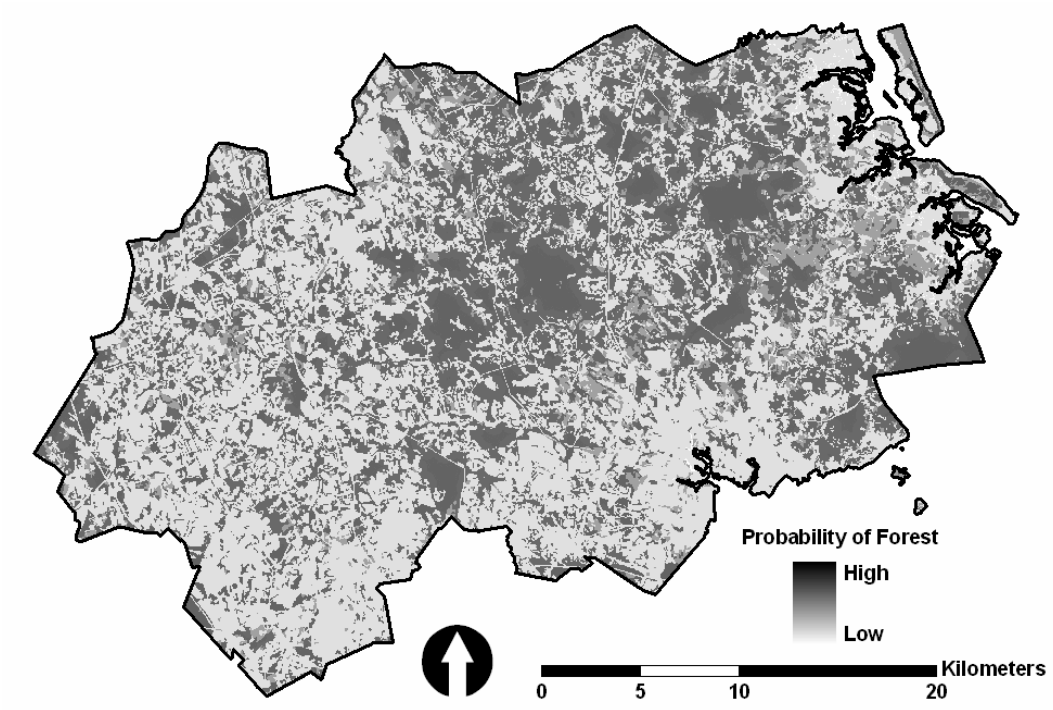

Figure 3. Probability of Forest in shades of gray for 2097, which is the end of the extrapolation for the 22 towns of the Ipswich River Watershed.

3. Acknowledgements

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