Muskegon Futures:

Land Transformation Model Description

Muskegon Watershed Research Partnership **Volume 6**

Introduction

Geographers have developed land use models for decades. Many of these models were built to examine the relationship between transportation patterns and urbanization trends or to study the relationship between land prices and land use patterns. However, many of the early models, such as those developed in the 1970s and 1980s, did not perform well and required massive amounts of data, much of which was not available at the time. Interestingly, they were eventually discarded and never again used. In the 1990s, with the advent of geographic information systems and data collected from satellites, more data driven models were developed, such as the one employed here in the Muskegon Mega Model Project. These types of land use change models have now become common place for environmental and economic studies around the world. How does the model work? What kinds of scenarios were developed? What are the strengths of this model and its limitations?

How does the model work?

One of the Muskegon Watershed Research Partnership's projects was to develop an updated (circa 1998) land use map of the watershed using the circa 1978 Michigan Department of Natural Resources MiRIS database. The updated land use database was developed so that we could conduct an accurate land use change analysis and use this change analysis to drive the model into the future. One of our research bulletins summarizes the land use change analysis for the Muskegon River Watershed.

The land use model used in this project, called the Land Transformation Model or LTM2, uses an artificial intelligence tool called an artificial neural network (or simply as neural nets). The neural net is software program that "learns" about complex patterns in data. It is very similar to multivariate statistical routines but neural nets use many nonlinear algorithms to fit to data. We build the model by "feeding" the neural net information about land use changes between two time periods (e.g. 1978 and 1998), and a host of spatial drivers of land use change such as roads, urban infrastructure, elevation, soils, and natural amenities (e.g., proximity to lakes, rivers, and forests). After several days of learning, the neural net provides us with a probability of land use change for each location in our digital map. We then use this information to calibrate and eventually validate our model. A historical analysis of the land use data and population change is used to relate future urban allocations in an area (either at a county or township scale) per person.

Photos Courtesy of AWRI

Inside this issue:

What kinds of scenarios were developed?

We used the LTM to develop two different kinds of models: (1) those that generated future maps of land use based on several different conditions provided by stakeholders in a 2001 workshop and (2) a sequence of historical maps of land use that could be used as a reference for discussing the consequences of future land use trends.

Our forecast models assumed that urban land use expanded between 2 to 4 times the rate of projected population growth. The ratio of urban expansion to population growth is referred to as a sprawl ratio. Analysis of 1/5 of the United States side of the Great Lakes Basin shows that urban land use expanded at 4.4 times the rate of population during the late 1980s and the decade of the 1990s. A sprawl ratio of 2 was used in one of our scenarios (called the reduced sprawl scenario or RUS) so that we could examine "what if" futures if urban land use expansion was controlled by zoning or growth was reduced because of lower population or because economic growth was reduced.

We also found that forests in the watershed were regenerating at a substantial rate between 1978 and 1998. There are a variety of factors that might create this situation, including agricultural failure/abandonment, increased conservation efforts (e.g., farmers enrolling in federal farmland conservation programs), or increased speculative land holdings (builders purchasing land ahead of the urban growth curve for future development). In general, forests increased by 10% over 1978 estimates (it increased from 44% to 48% of the entire watershed during this twenty year period). In several of the scenarios, we assumed that forests would increase in amount at historical averages.

We used the geographic information system (GIS) to create situations where development could not occur (we call these "exclusionary zones). Many stream or main stem buffers were created by simply taking GIS layers of streams and creating a buffer around these which where then input to the model and used to exclude future urban growth. These buffers, or setbacks, were established at two different distances from the main stem of the river, 100m and 300m (FIG. 1, below). Another set of buffers were created by excluding any new development in zones where groundwater travel times were 1 year or less. A map of the distribution of groundwater buffers is shown in FIG. 2 (Top, Pg 3).

FIG. 3 (Middle, Pg 3) show some of the output of the LTM2 forecast model. Note that urban, shown in red, increases along major road corridors and expands from current urban centers. Development along county roads is particularly strong in the lower portion of the watershed.

The backcast LTM model given in FIG.4 (Bottom, Pg 3) shows strong fluctuations in agriculture over the years. In the late 1930s, many agricultural lands were abandoned and the land was eventually acquired by the state and converted to state forests. The decades that followed saw an increase in forests and a considerable increase in urban. Future trends of urban suggest that the amount of urban could double over current values between now and 2040. We used historical data from the US census (housing data) and from the USDA crops database (amount of land in farms) to generate the backcast maps.

As a final note, most land use change modelers consider their models as tools that create *plausible* futures. In other words, these are not predictive tools but rather quantitative approaches that use historical information and detailed maps to create future landscapes that are one of a host of possible landscapes that could result given certain policy, economic and behavioral factors. When these future maps are used in combination with a variety of scenarios, a comparative analysis provides insights on the impact of different development rates, setbacks, forest regeneration and historical trajectories on ecological integrity of the watershed.

Buffer setback map used in LTM

FIGURE 1

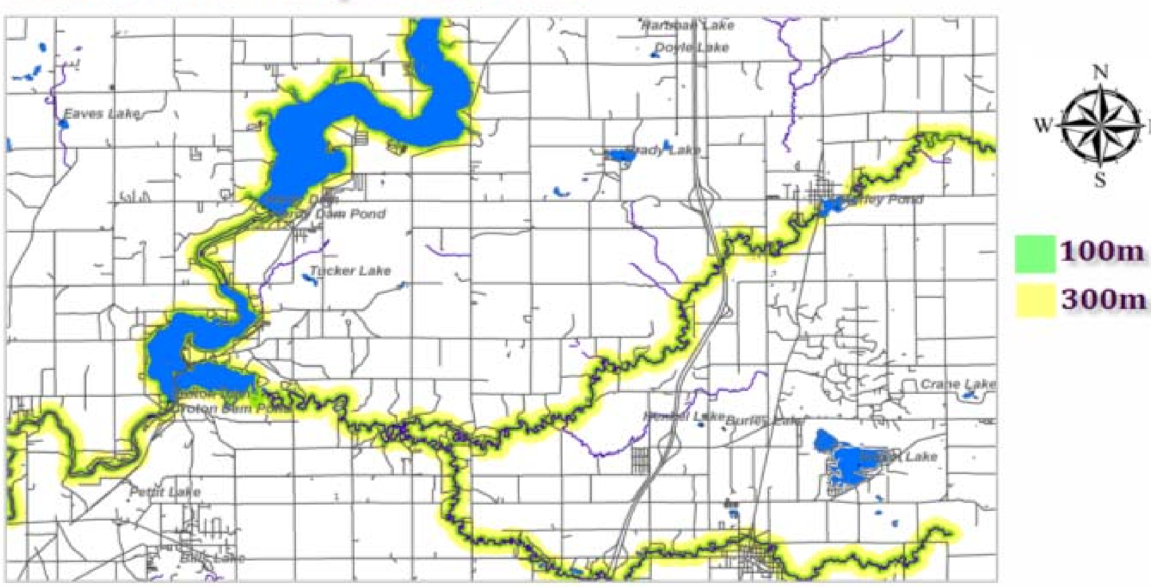
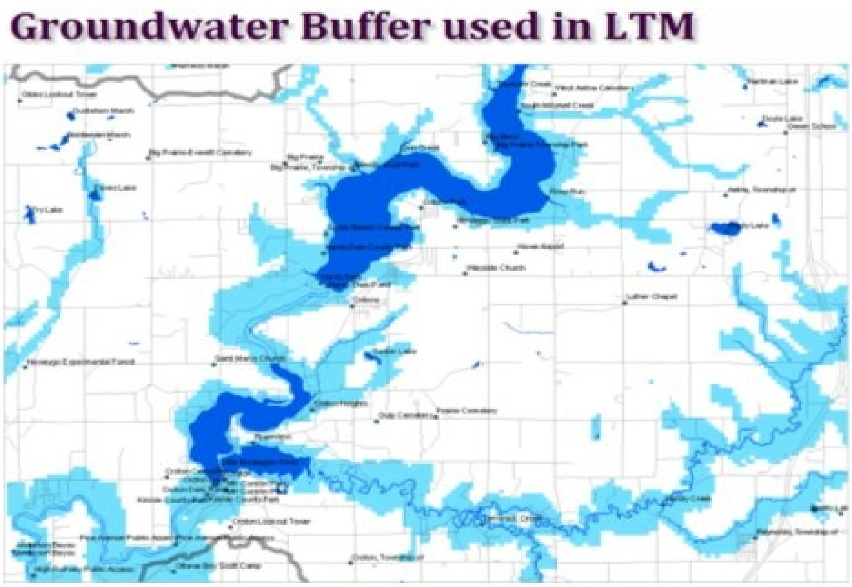


FIGURE 2



Areas in light blue indicate where groundwater travel times are one year or less. These areas may be hydrologically sensitive to impervious surfaces from urban land use. These areas were excluded from future development when compiling these projections.

FIGURE 3

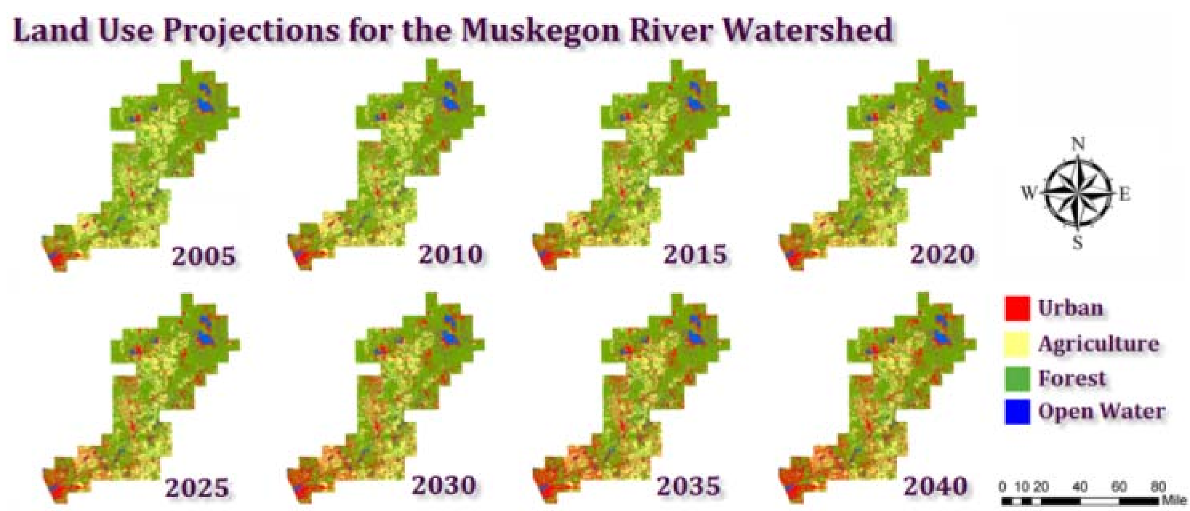
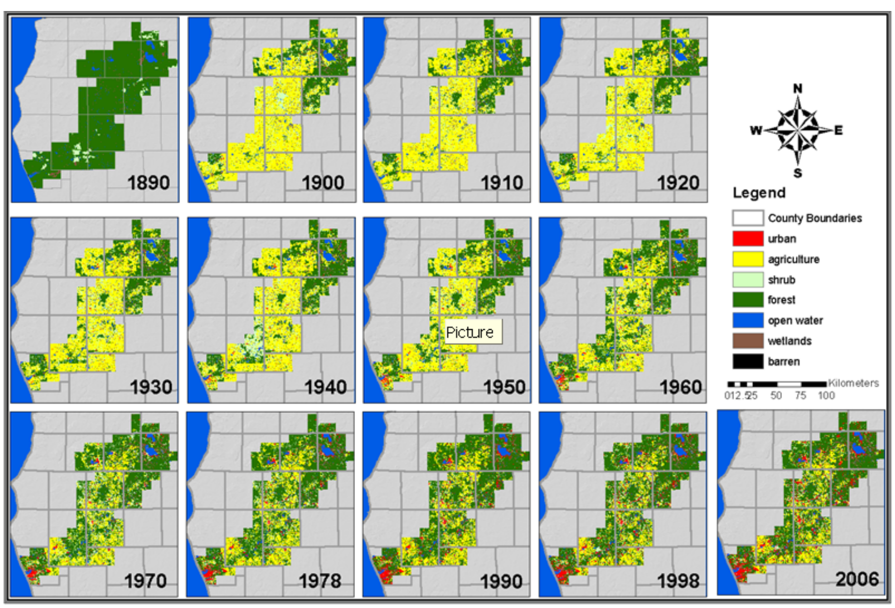


FIGURE 4



What are the assumptions, strengths and limitations of the model?

To keep the model simple, we had to make several assumptions about the future. Many researchers that apply forecast models have to accept these kinds of assumptions because the future is for the most part uncertain or data needed to drive the model are not available.

We used population projections from the State of Michigan to drive the model to 2040. Forecasts of 2070 and 2100 are made by simply doubling 2035 urban allocations to create a 2070 urban map. We had to assume that the current road network would remain the same over this time period as we did not have reliable maps of future transportation corridors. We also fixed the boundaries of the state forests and did not allow these areas to be developed (or sold, which is possible). The model also assumed that the spatial patterns observed in the past (.e.g., that roads were very important to urban development), would remain as strong in the future. The neural net learned to "see" scattered urban development that probably resulted from cheap transportation (i.e., inexpensive gas) which might not be true for the future.

Forest regrowth was an entirely new routine developed for this project. Forest regrowth was allowed across the watershed but not in areas that were wetlands or had been urban. We assigned forest subclasses (upland and lowland) based on the forest subclass of a nearest neighbor.

One of the strengths of the model is that it can predict changes in land use with a fair degree of accuracy at a small spatial scale. The research lab at Purdue which developed the model is well known for its use of sophisticated validation and calibration tools. These were applied to the model used in this project. The model predicts well at a 0.5 to 1.0 km scale. The model has been used and tested around the world and is used by a large community of modelers at university and research institutes in and outside of the US. It is part of a larger set of models that is being used and examined carefully by a community of researchers interested in the science of land use change modeling. One of its greatest strengths is that it can handle large amounts of data so large regions such as the MRW can be studied in combination with other models, such as hydrologic and climate change models. It is also built so that it can be interfaced with a GIS so that it can be used to create maps and be integrated with other models that rely on GIS technology.

There are several limitations to the model. First, we do not forecast economic trends so the peaks and valleys of economic cycles are not represented in the model. Any current downturns in the economy had surrogates during the 1978 to 1998 time period (such as the economic downturn of the early 1980s) so it is assumed that the historical analysis used to parameterize the forecast model contains economic peaks and valleys. Second, we assume that urban expansion and population growth ratios are fixed over time, in reality, this change likely depends upon economic conditions. Finally, relationships between transportation patterns and urban change that are explicit in the model; in other words, changes in fuel prices, or changes in transportation networks, are not considered in this model.

People interested in finding out more about the model can visit the following web site: http://ltm.agriculture.purdue.edu/ltm.htm. Visitors can download the model, be provided with a multi-media tutorial (with data) and be provided with access to forecasts from other studies.

Photos Courtesy of AWRI