Integration of GIS, RS and forest inventory for landscape modeling

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Abstract

LANDIS is a forest model that simulates forest dynamics at large spatial and temporal scales. One of the main input files is a map of the tree species distribution as 10-year age cohorts on the landscape. To derive the species-age composition map for a fragmented forest landscape in north-central Indiana, forest inventory data is used to compute the major species proportions by size class and land type, based on forest plot locations. The land types are constructed from soil layers (Soil Survey Geographic Database). Forest patches are digitized from high-resolution aerial photographs and rasterized. Multiple species of a certain age are then randomly assigned to each forest pixel according to their respective proportions on a given land type. The species-age map is the initial forest condition that is used by LANDIS for simulating forest processes and disturbance interactions, which results in successive forest landscapes. Preliminary results of forest landscape simulations with and without land-use change disturbance are compared at landscape and forest patch levels. The simulation experiment shows that forest fragmentation increases as a result of land-use change, and forest composition and structure are affected, especially at forest patch level.

Introduction

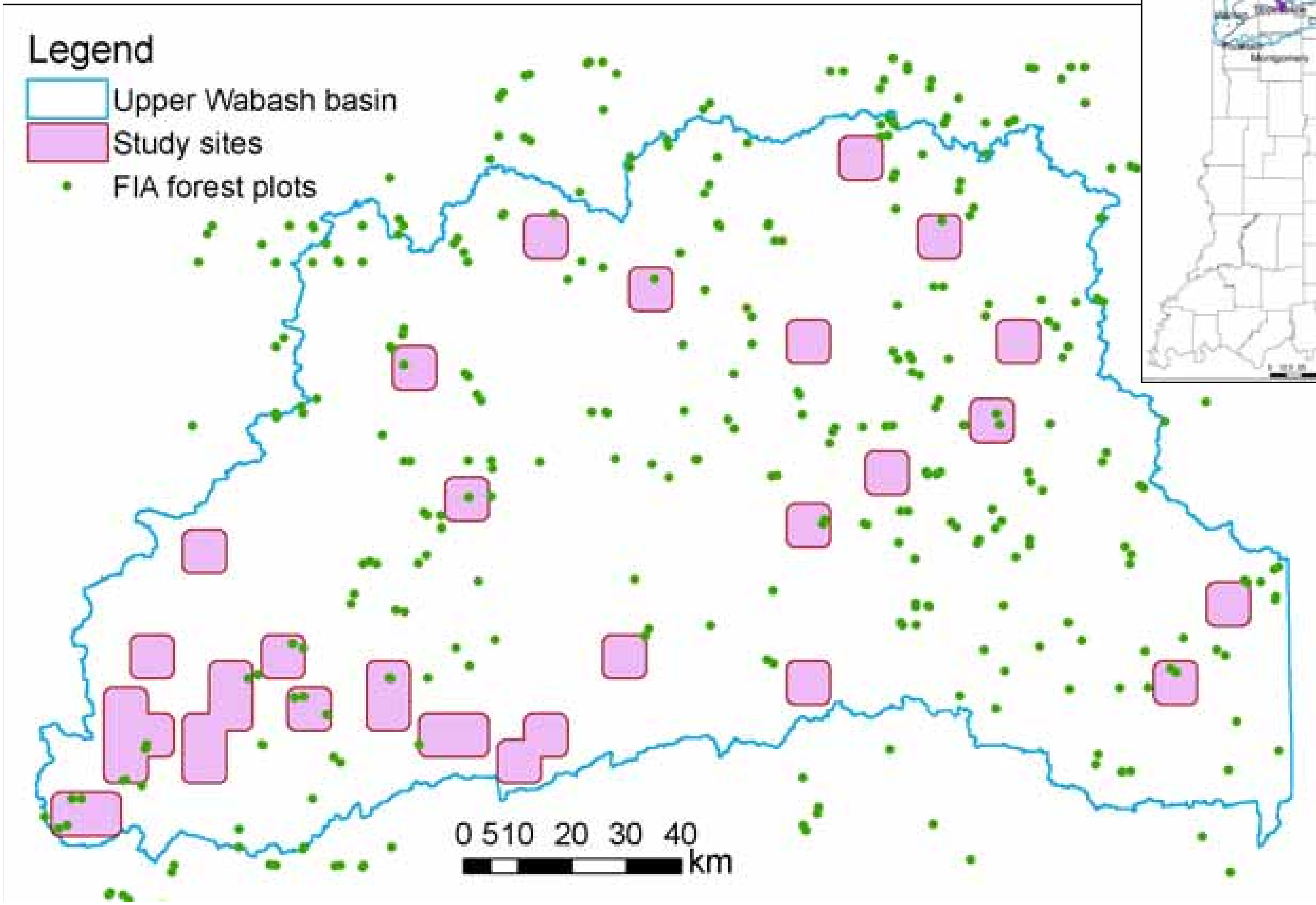
Forest ecosystems in north-central Indiana are highly fragmented and forest management activities are reduced.
Forests have important ecological roles and provide multiple benefits for people and wildlife.

The major anthropogenic disturbance is land use change and is mainly driven by urban sprawl. Thus, an important research question is: How is land use change affecting forests in a fragmented landscape?

This is explored using the forest landscape and disturbance model LANDIS (Mladenoff and He, 1999) and the land transformation model LTM (Pijanowski et al., 2002) on 25 sites in the Upper Wabash region (Figure 1 and 2).

Figure 1. Upper Wabash basin in Indiana

Figure 2. Study sites in north-central Indiana



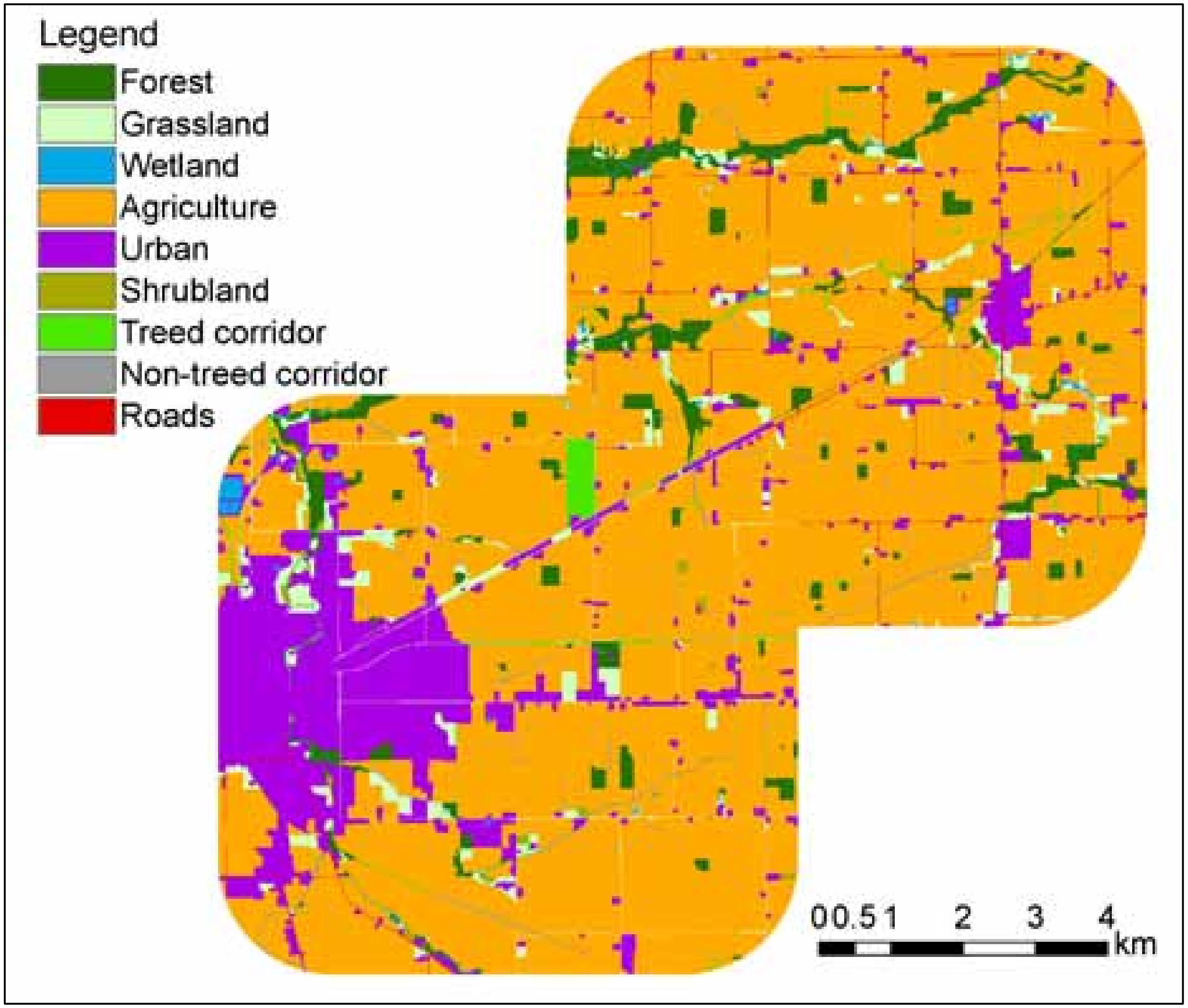


Figure 3. Land use for Michigantown site (Clinton county)

Objective

The major challenge in setting up LANDIS model is the creation of the species composition map in a fragmented landscape, using the limited forest inventory data available. The objective is to obtain a realistic representation of the forest landscape.

Methods

Forest inventory data is available at region level from Forest Service's Forest Inventory and Analysis (FIA) database and from field data collected by Upper Wabash Ecosystem Projects (UWEP) at Purdue University on each of the 25 sites. One site is considered a landscape for LANDIS model (example in Figure 3). The most frequent tree species are grouped in 13 species groups (e.g. sugar maple, red oak, hickory, white oak, etc.) based on life history similarities.

SSURGO soil data is used to define and map soil moisture classes. The seven drainage classes are generalized in three soil moisture classes: dry, mesic and wet (Figure 4). Forest data and soil data (in tabular and map format) are used to compute species proportions by soil moisture class and by tree size class (small, medium and large, based on tree diameter).

The species composition map is an important LANDIS input file and represents the original species distribution on forest patches, as species-age cohorts (10-year age class). The high resolution aerial photographs for the study sites are digitized as land use maps and rasterized with a 10 m cell size. Each forest pixel on a grid is populated with trees of different species and of the same age class.

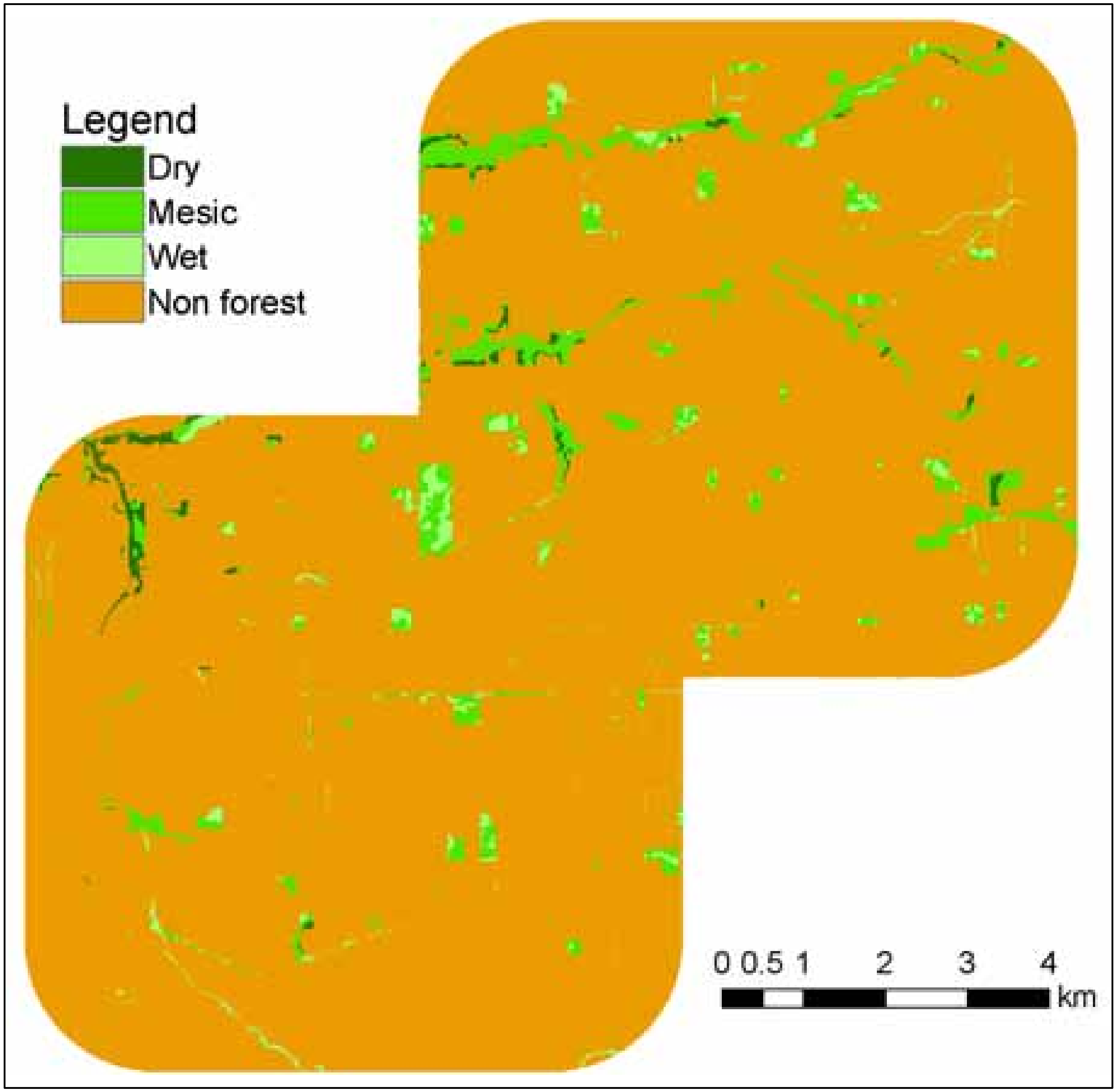


Figure 4. Soil moisture classes for forest patches on Michigantown site

Methods: Species distribution algorithm

This algorithm is using the land use grid map, the soil moisture grid map, species proportions by moisture class and size class and other proportions derived from forest inventory data to assign several tree species and an age class for each forest pixel on the map. The general steps are (also presented in Figure 5):

1. Identify if it is a forest cell, if not change value to 0 and go to next cell
2. Identify the soil moisture class
3. Use random number and size class proportion by soil moisture class to assign a size class
4. Use random number and age class proportion by size class to assign an age class
5. Use random number and species proportions by moisture class and size class to assign species
6. Repeat step 5 N times (N - the number of trees per pixel for that moisture and size class)
7. Sort the species for that cell, remove duplicate species
8. Compare the species association (forest type) to see if it is one of the possible species associations for that size class
9. If yes, go to next cell, if not repeat steps 5-8
10. Sort and assign ID to each species association
11. Create map of species composition and file of map attributes (the list of the species and age combinations)

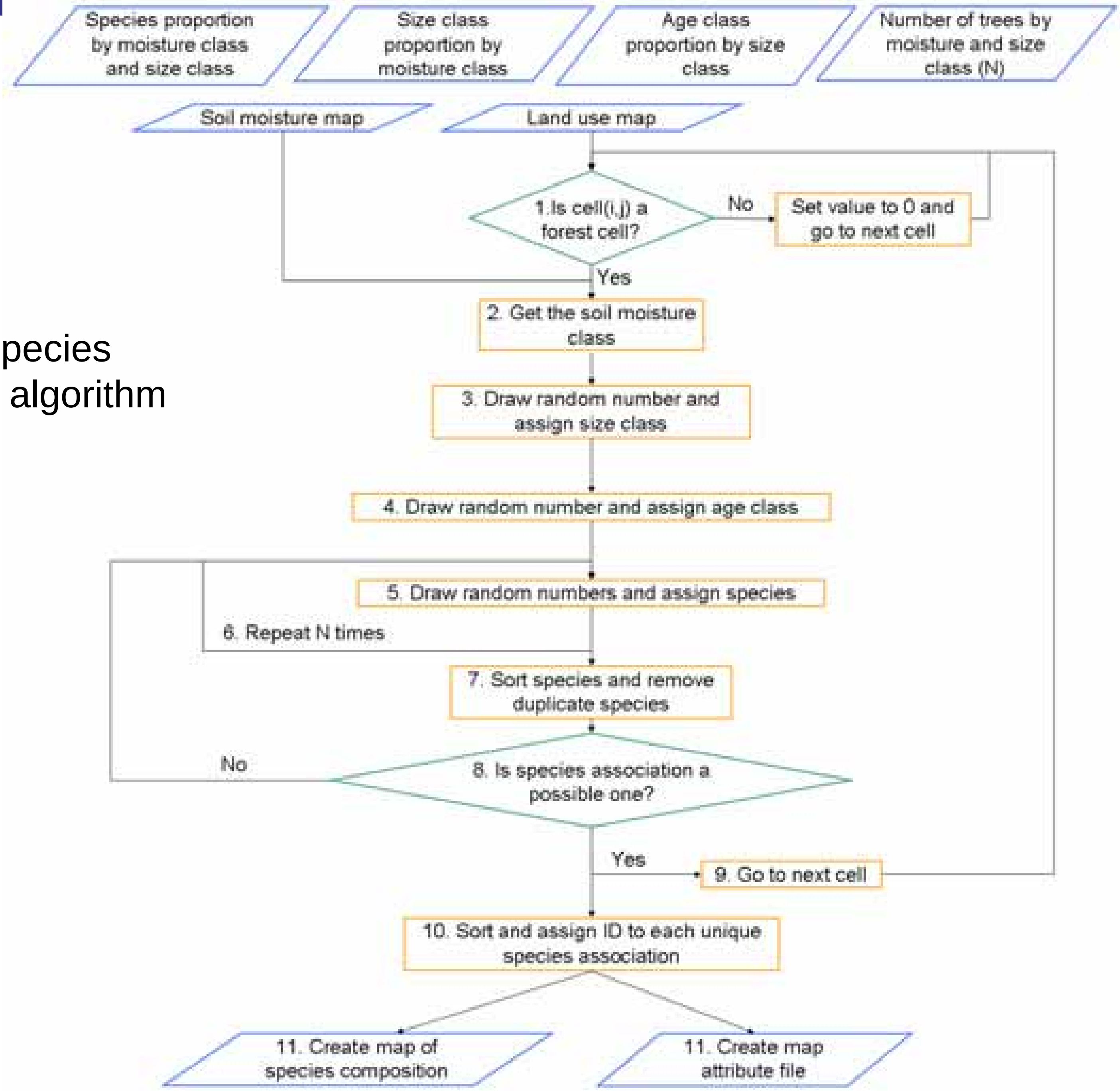
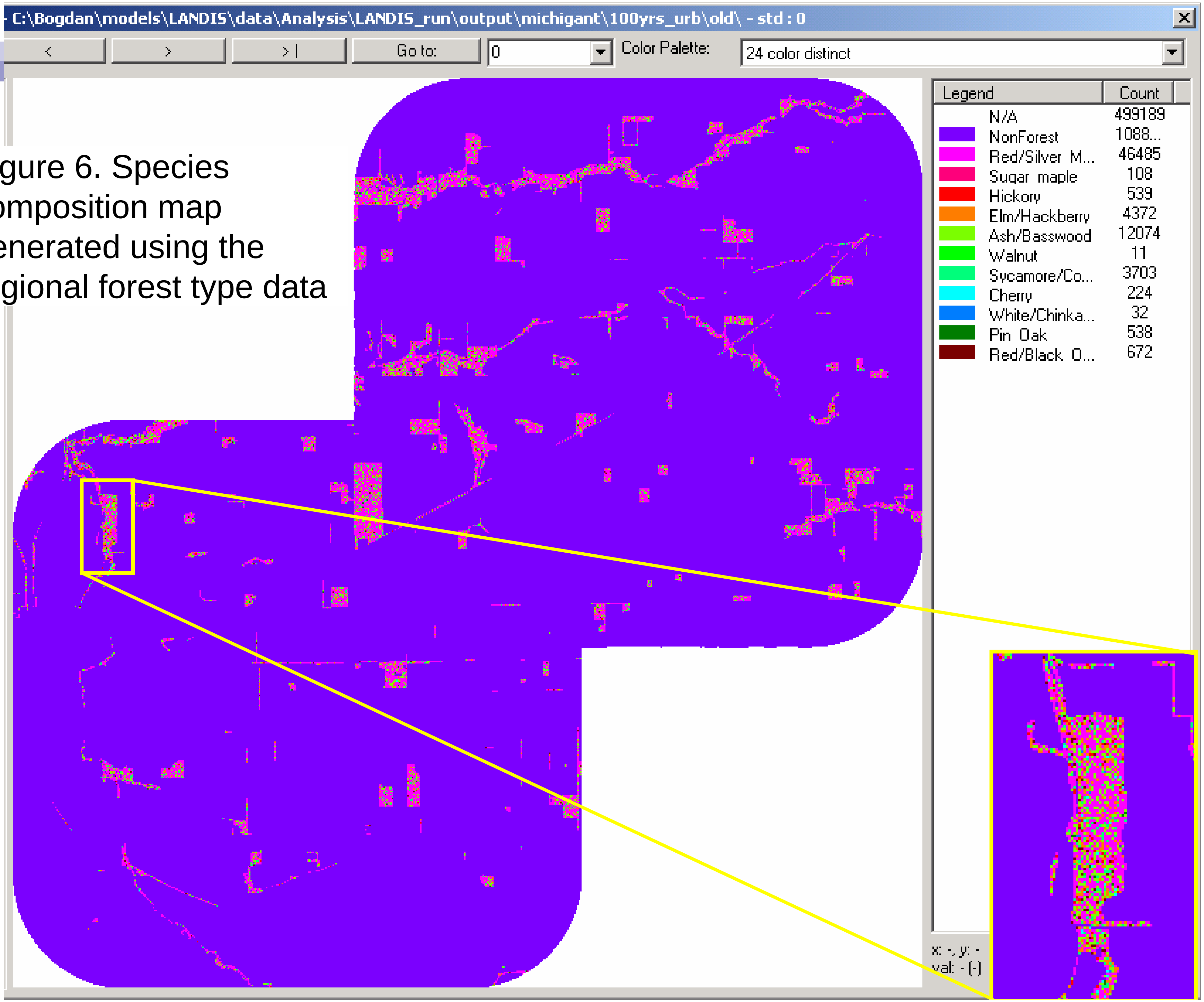


Figure 5. Species distribution algorithm

Figure 6. Species composition map generated using the regional forest type data



Improvement of the species distribution algorithm

Figure 6 shows the species composition map as generated by the previous algorithm. The detail of a forest patch shown on the right indicates a certain degree of spatial randomness in the species distribution. In order to improve the species distribution, local forest inventory data (UWEP plots) for a site is used to limit the number of species associations and their spatial distribution.

The UWEP plots for the Michigantown site are used to generate Voronoi polygons (each side of a Voronoi polygon is at equal distance between a pair of points, Figure 7). Each polygon is a part of the landscape that is populated with species associations specific to the UWEP plot corresponding to that polygon. This results in a more uniform spatial distribution of species at forest patch level (Figure 8). A comparison at forest patch level (Table 1 – for the patch in the detail of Figure 6 and 8) of the species distribution shows a smaller number of species and a smaller number of uniform species patches for the “local” map, which is more realistic.

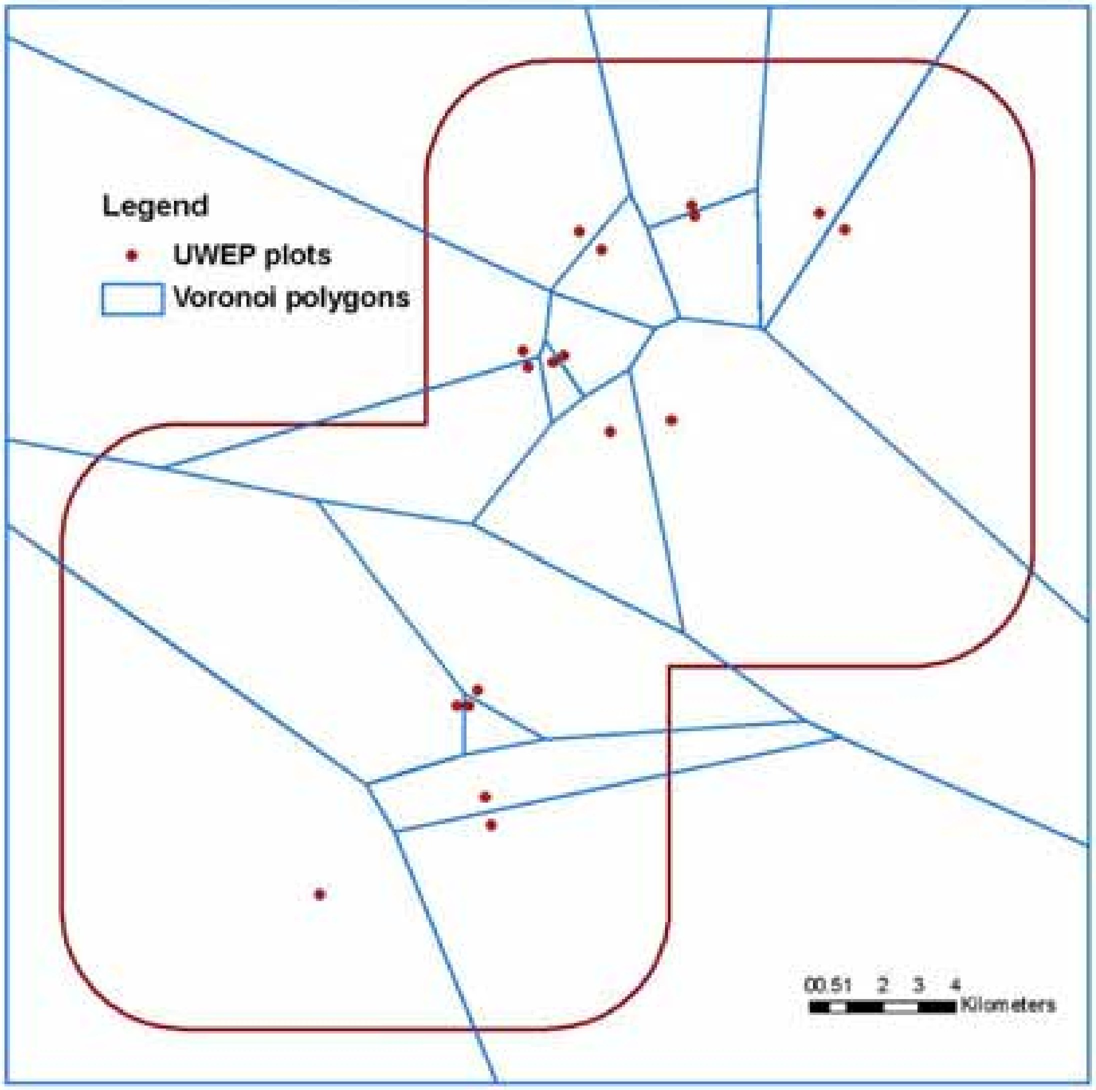
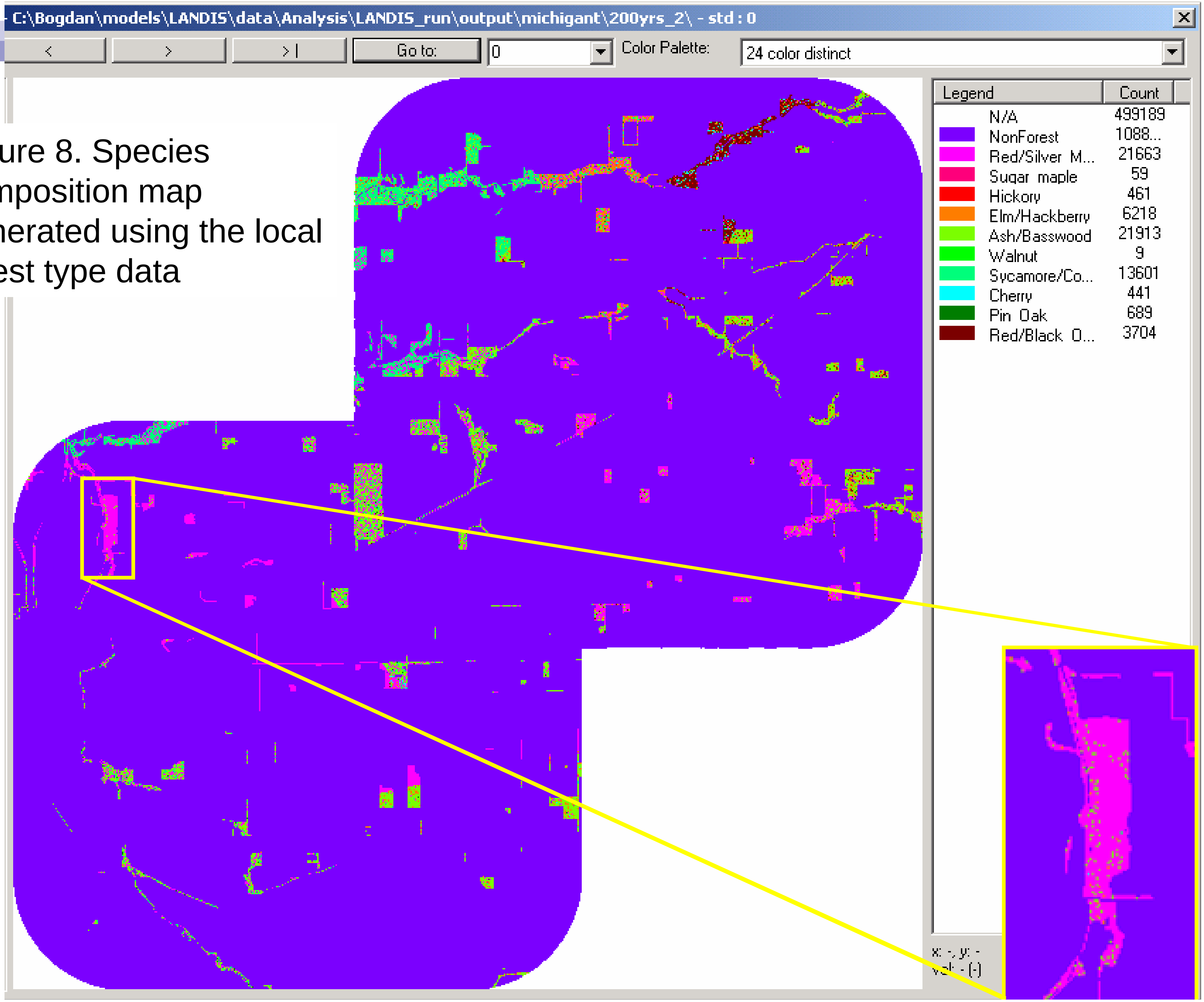


Figure 7. Voronoi polygons from UWEP plot locations

Figure 8. Species composition map generated using the local forest type data



Patch data	# Species Patches	Largest patch index	Patch richness	Shannon's Diversity index	Simpson’s Diversity Index
Year 0, Local forest type data	102	93.75	5	0.260	0.118
Year 0, Regional forest type data	615	41.27	11	1.468	0.670
Year 200, Local forest type data	331	76.77	11	0.851	0.387
Year 200, Regional forest type data	478	11.69	11	1.379	0.667

Table 1. Comparison of species landscape metrics between the two species composition maps, at 0 and 200 years, in one forest patch

Coupling of LANDIS and LTM

A simple land use change (LUC) scenario based on 1980-2000 trends of urban area increase is used to update the land type map in LANDIS at two time steps. As a result, forest patches become smaller, more fragmented or completely disappear (Table 2 and Figure 9, detail).

Species proportions at landscape level are not significantly different between the No LUC and the LUC scenario, except for sugar maple and red/black oak (Table 3). This is in part due to the fact that LUC is affecting significantly just a few forest patches, and the change in species composition for those patches (relatively small in size) is not affecting the composition at landscape level.

More significant changes are likely to be seen for LUC scenarios that update the land type map more frequently and for landscapes where the LUC is affecting a larger number of forest patches.

TYPE	No LUC	LUC	No LUC	LUC	No LUC	LUC
	%	%	patch density	patch density	mean patch area	mean patch area
Agriculture	74.4	69.6	0.99	1.52	74.8	45.8
Forest	4.8	4.4	1.00	1.03	4.8	4.3
Urban	13.1	19.5	2.71	2.34	4.8	8.3

Table 2. Changes in landscape metrics after land use change

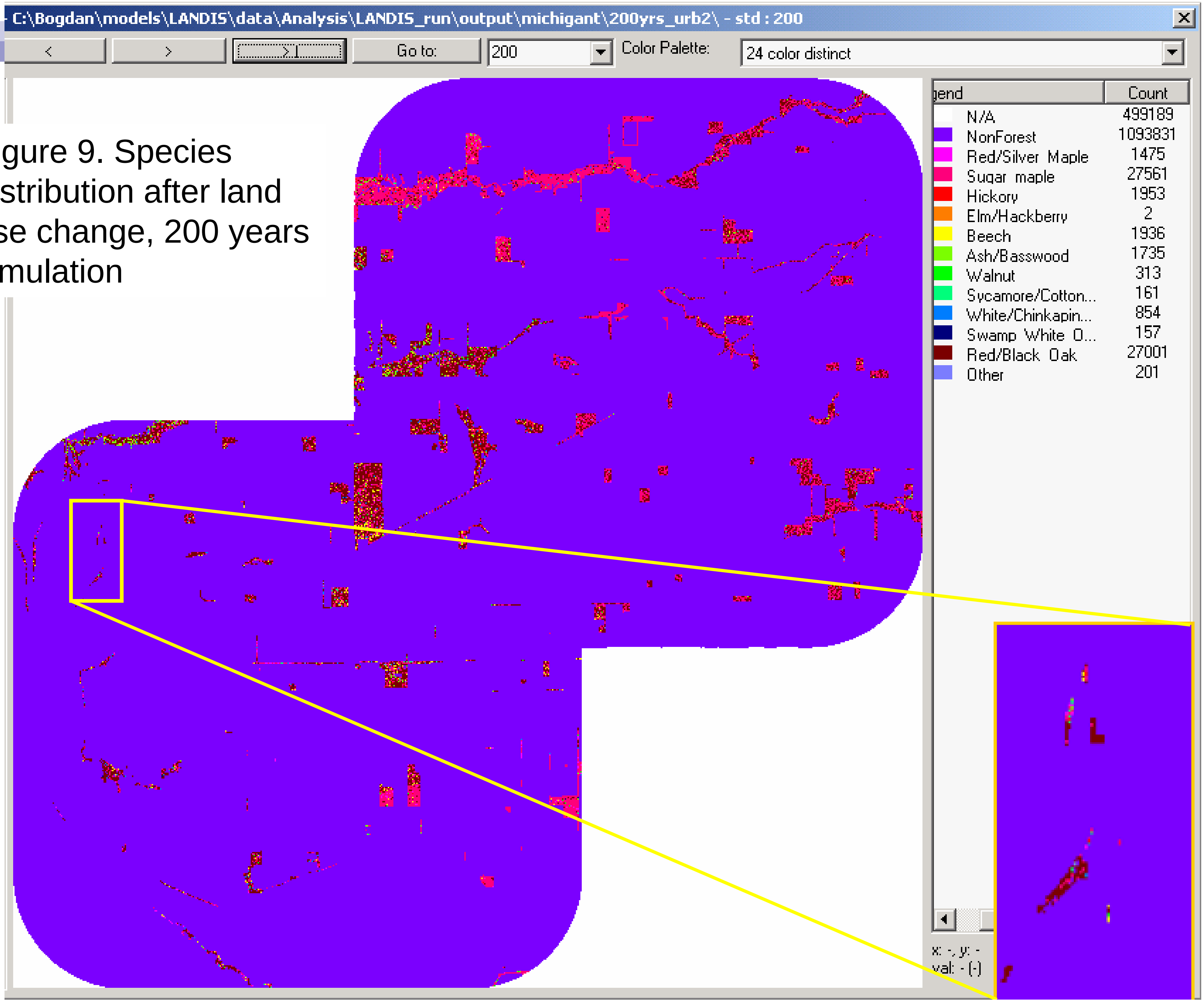


Figure 9. Species distribution after land use change, 200 years simulation

Species groups	No LUC		LUC	
	Pixels	%	Pixels	%
Red/Silver maple/Green ash	1570	2.3	1475	2.3
Sugar maple	28820	42.1	27561	43.6
Hickory	1981	2.9	1953	3.1
Elm/Hackberry	9	0.0	2	0.0
Beech	2103	3.0	1936	3.1
White Ash/Basswood	1687	2.4	1735	2.8
Walnut	328	0.5	313	0.5
Sycamore/Cottonwood	231	0.3	161	0.2
White/Chinkapin oak	938	1.4	854	1.3
Swamp White oak	154	0.2	157	0.3
Red/Black oak	30701	44.8	27001	42.8

Table 3. Species composition using the local forest type data

Future directions

Future improvements in LANDIS setup involve reducing the randomness of species distribution in the species composition map by: (1) Generalizing size class and forest type within a window or a patch, (2) Reducing the number of forest types to the most frequent ones, and (3) Changing the spatial distribution of species within a forest patch related to edge/interior location.

A different type of LUC scenario is one that allows new forest patches to establish on abandoned farmland and shrubland. Other scenarios will be based on different rates of LUC. The testing of these scenarios on different landscapes will look at relationships between landscape configuration and the pattern of change in forest structure and composition.

The coupling of the LANDIS model with the land use change model LTM allows the study of different land use change scenarios effects on forest structure, composition, and forest patch geometry at different temporal and spatial scales. It is also an useful tool for finding the possible implications for landscape planning as a way of mitigating the negative effects.

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