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ABSTRACT

Bottomland hardwoods are one of the most rapidly diminishing wetland ecosystems due to agricultural clearing, development, and reservoir construction. As society has become more aware of the functions of wetlands, so has the importance in conservation of these valuable resources. The objective of this study was to compare the accuracy of Remote Sensing and GIS based functional assessment to the field based Hydrogeomorphic (HGM) approach. Remote sensing models were developed using a combination of soil maps, soil information, QuickBird ® multispectral satellite imagery, LiDAR derived Digital Elevation Model (DEM), and LiDAR derived Canopy Height Model. Results, although mixed, indicated that Remote Sensing and GIS show promise to be an alternative to the traditional field based wetland assessment method.

KEYWORDS

Wetlands, Hydrogeomorphic (HGM), GIS, Remote Sensing, Lidar

The study was conducted at the Stephen F. Austin Experimental Forest, which subsequently will be referred to as the experimental forest, is located approximately 13 kilometers southwest of Nacogdoches, Texas. The experimental forest is a 1,036 hectare tract with approximately 728 hectares of mature bottomland hardwood. The remaining area consists of mature upland hardwood-pine (Texas Parks and Wildlife, 2006). Model expressions for low-gradient, mid-gradient floodplains, and unconnected depressions found in *A Regional Guidebook for Applying the Hydrogeomorphic Approach to Assessing Wetland Functions of Forested Wetlands in the West Gulf Coastal Plain Region of Arkansas* (Klimas et al., 2005) were tested. At the present time, no such guidebook exists for East Texas and it is believed that the wetlands in that region are very similar to those wetlands found in this region.

CLASSIFICATION

Unsupervised classification was used to classify the QuickBird satellite image of the experimental forest. Initial classification specifications for the image was set at 200 classes with a 99% convergence threshold at 100 iterations to ensure that each pixel is 99% certain that it has been classified correctly and that the convergence threshold will be reached prior to the conclusion of all 100 iterations. After a visual assessment comparing the 200 classes in the image with the references, the image was recoded into 11 classes. The recoded image was then recoded again with a binary recode to obtain an image that contained only hardwoods and non-hardwood. The classes containing hardwoods were recoded as 1, while those classes not containing any hardwoods were recoded as 0, resulting in an image containing only areas representing hardwood. Unsupervised classification was then again used on the hardwood only image and the specifications were set at 100 classes with a 99% convergence threshold at 100 iterations. The 100 class hardwood image was then recoded into the following 8 classes: "wet vegetation1", "wet vegetation2", "wet vegetation3", "wet vegetation4", "hardwood1", "hardwood2", "wethardwood1", and "wethardwood2". The eight classes of hardwood vegetation were renamed with dominant species or co-dominant species that was determined after the completion of field work. The generically labeled class "wet vegetation1" was determined to be Overcup Oak (Snags) and Water Elm. Overcup Oak (Snags) was determined to be the dominant species for "wet vegetation2", "wet vegetation3", and "wet vegetation4". Overcup Oak and Slippery Elm were the co - dominant species for the "hardwood1" class. Water Oak and Tupelo were determined to be the co - dominant species for the "hardwood2" class. The class "wethardwood1" had co - dominant species consisting of Sweetgum, Red Maple, and Green Ash and the "wethardwood2" class had co - dominant species of Overcup Oak and Willow Oak. Refer to Figure 1 for the forest land cover classification of the SFA Experimental Forest.

REMOTE SENSING MODEL DEVELOPMENT

Remote sensing models were created for the experimental forest using a combination of soil maps, soil information, high spatial resolution satellite imagery, DEM derived topographic characteristic of slope, and Canopy Height Model derived from LiDAR. The Canopy Height Model gave individual tree location with X, Y, and Z coordinates, crown diameter, and tree height. Tree density and average height were both calculated from this model.

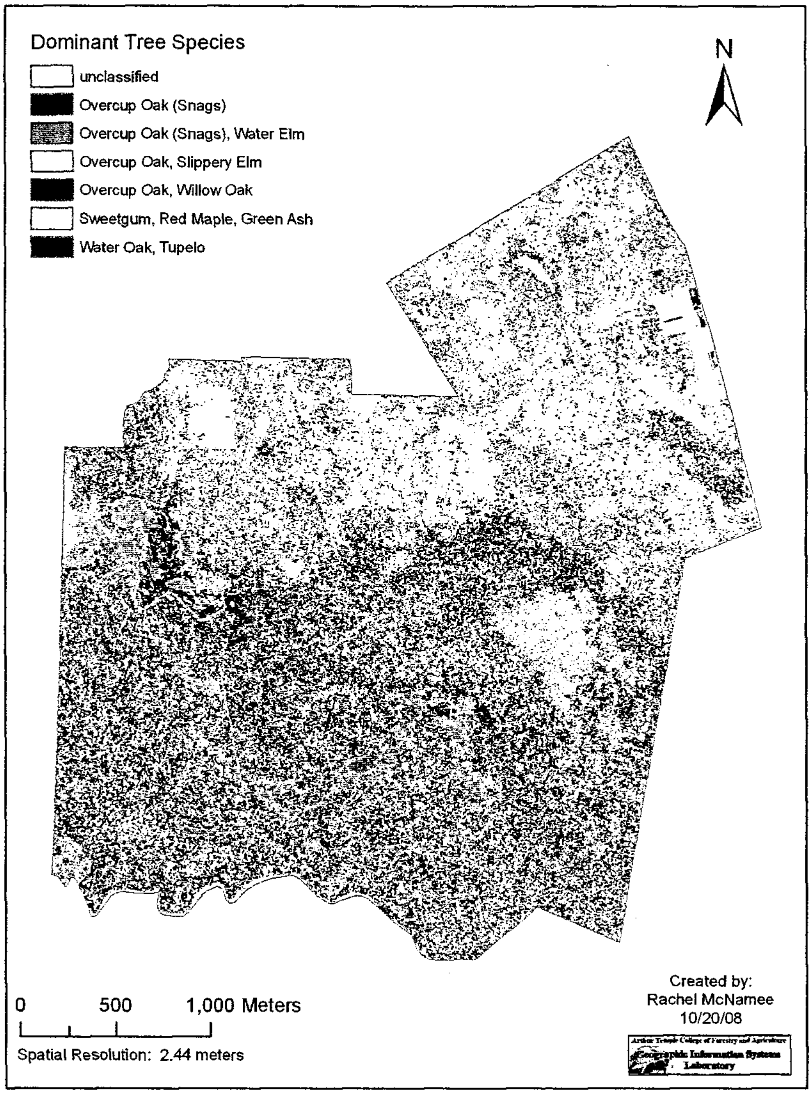

Figure 1. SFA Experimental Forest Land Cover Map.

The remote sensing models for this research were developed on ArcGIS® 9.3 Model Builder. Input data for the models were originally in either vector or raster format. Both vector and raster data were recoded from categorical scale to numerical scale. Those inputs that were vectors were converted to raster format through rasterization. Rasterization is necessary so that the final output of the model would be a raster dataset with pixel values representing the strength of the wetland functions. The low ratings were recoded as 1, medium ratings as 2, and high ratings as 3. These raster inputs were combined using the map algebra tool (addition) to yield a single layer output. Each pixel value total was then divided by the highest possible value total to give the ratio pixel value. For example, if there were a total of four inputs for a model, the added pixel value total could range from 4 to 12 and the Functional Capacity Index (FCI) or ratio pixel value could thus range from 0.25 to 1.0.

The following GIS data layers were used for the models: digitized wetland polygons, soil data, land cover type map, roads, streams, LiDAR DEM, and LiDAR Canopy Height Model.

RESULTS

The output from the Cycling of Nutrients developed model is shown on Figure 2 and the output from the Export of Organic Carbon developed model is shown on Figure 3. Figure 4 and Figure 5 show the output from Detain Precipitation and Detain Floodwater developed models. The Maintain Plant Communities and Provide for Terrestrial Wildlife outputs are shown on Figure 6 and Figure 7. These figures show the total pixel value received and the ratio pixel value or FCI. Refer to Table 1 for Pearson Correlation Coefficient Results, Table 2 for Paired Sample T-Test Results, and to Table 3 for Root Mean Square Error Results.

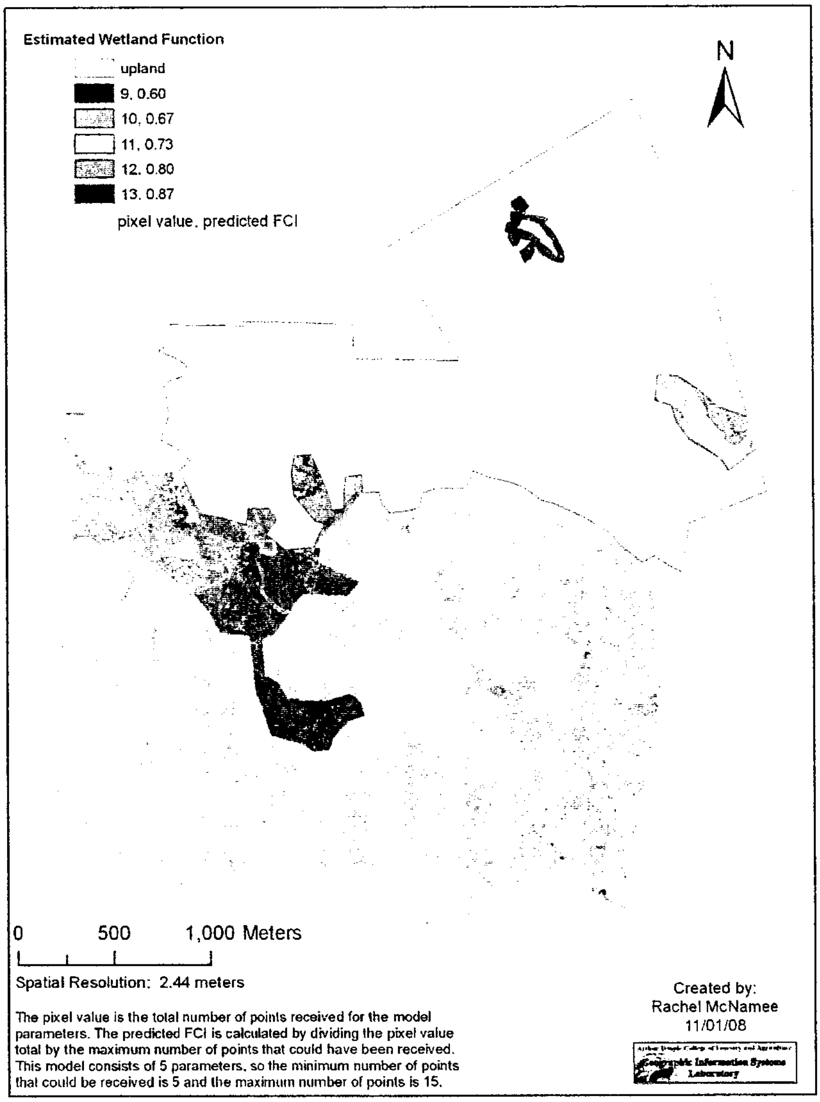

Figure 2. Cycling of Nutrients Model Output.

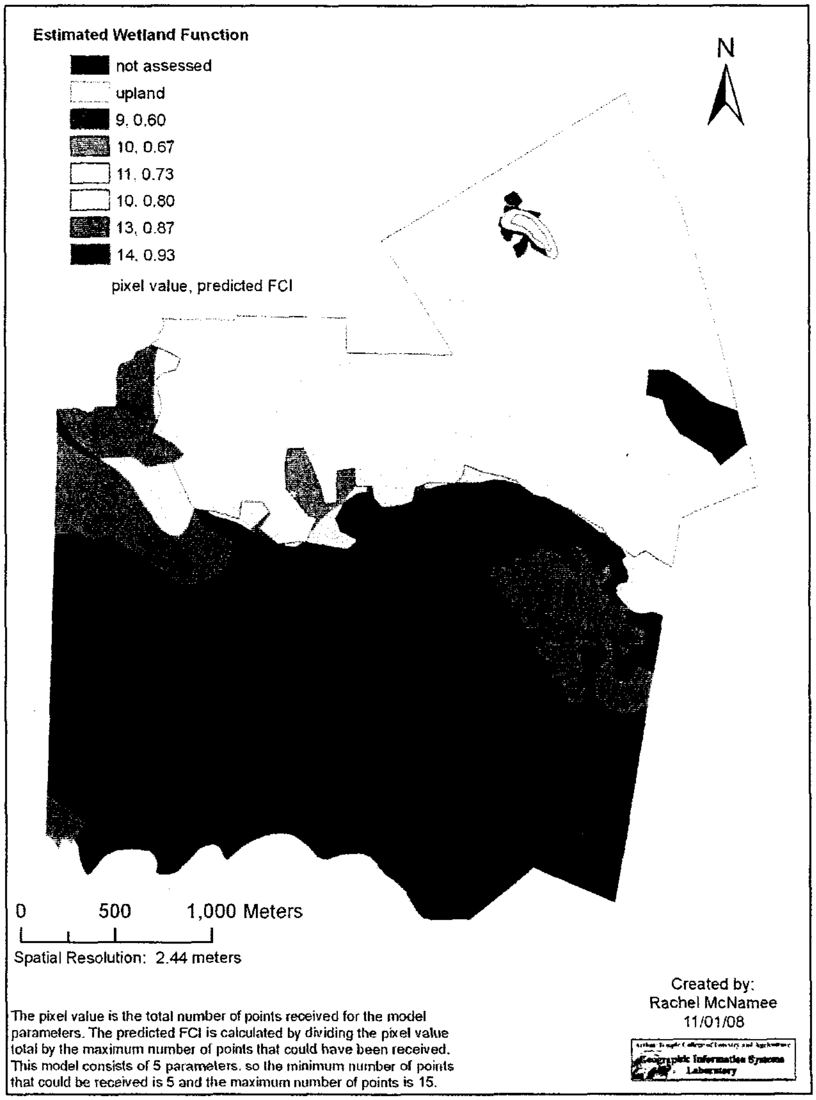

Figure 3. Export of Organic Carbon Model Output.

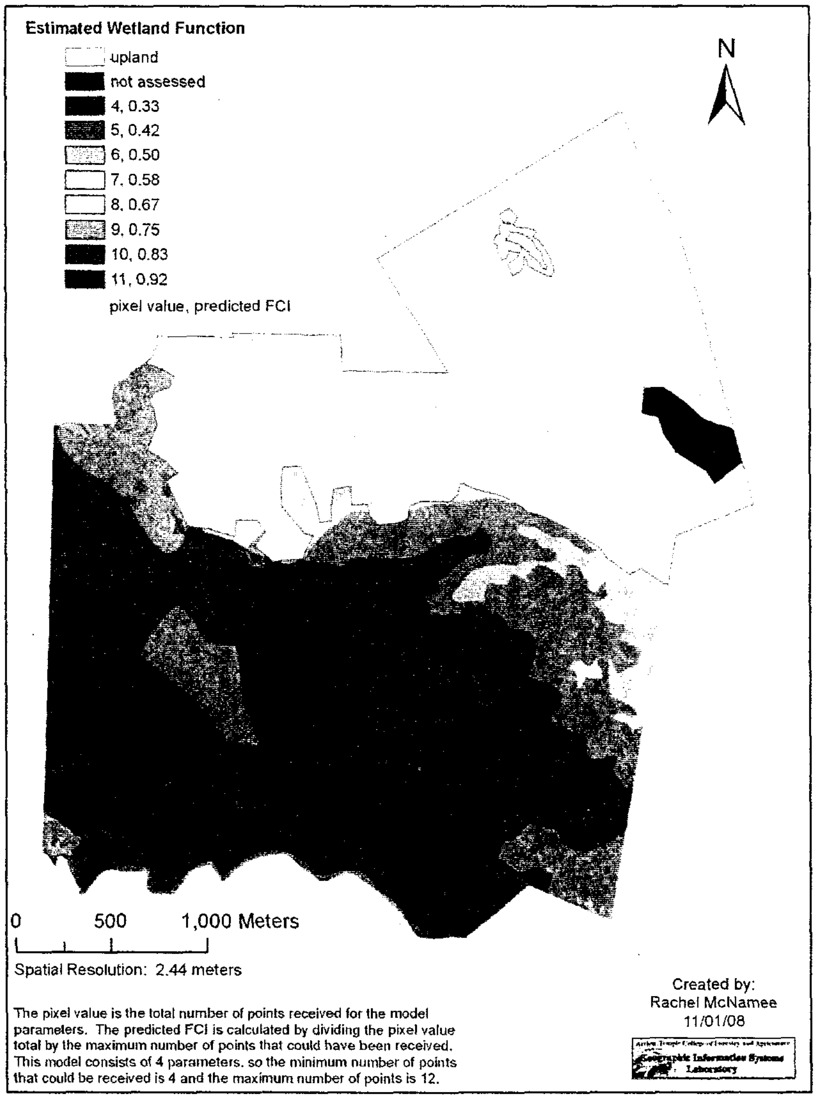

Figure 4. Detain Precipitation Model Output.

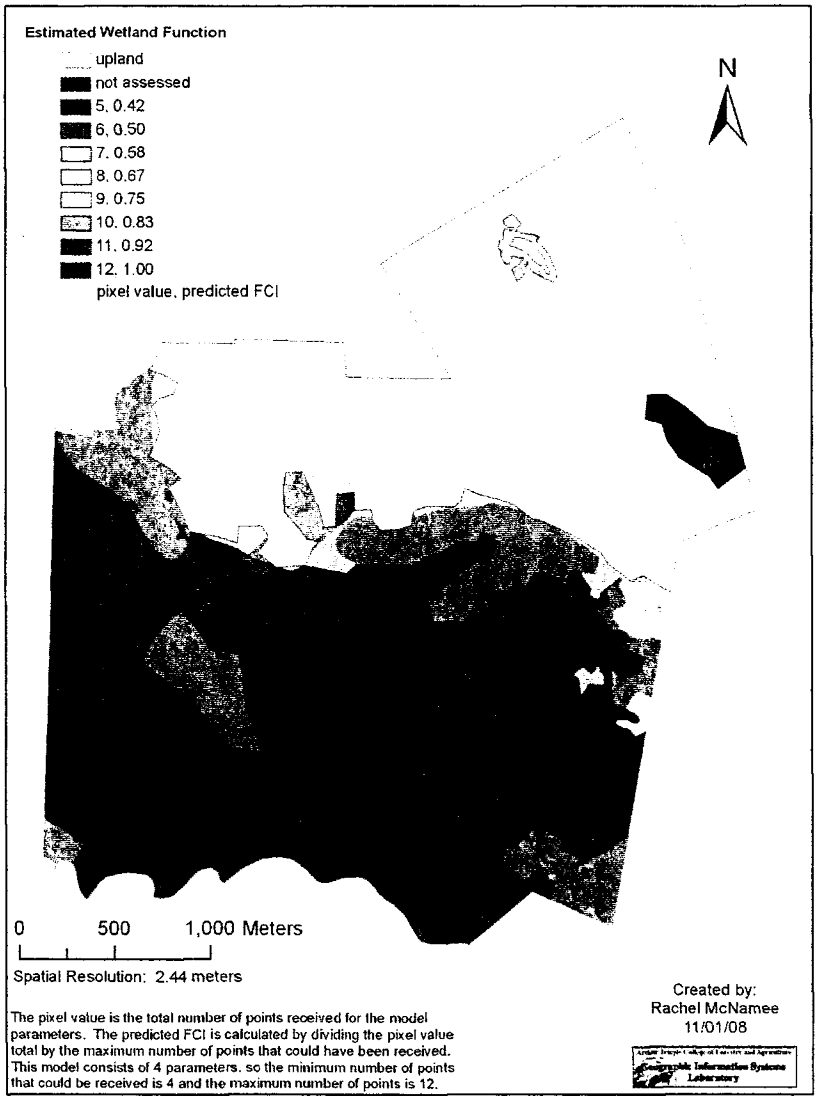

Figure 5. Detain Floodwater Model Output.

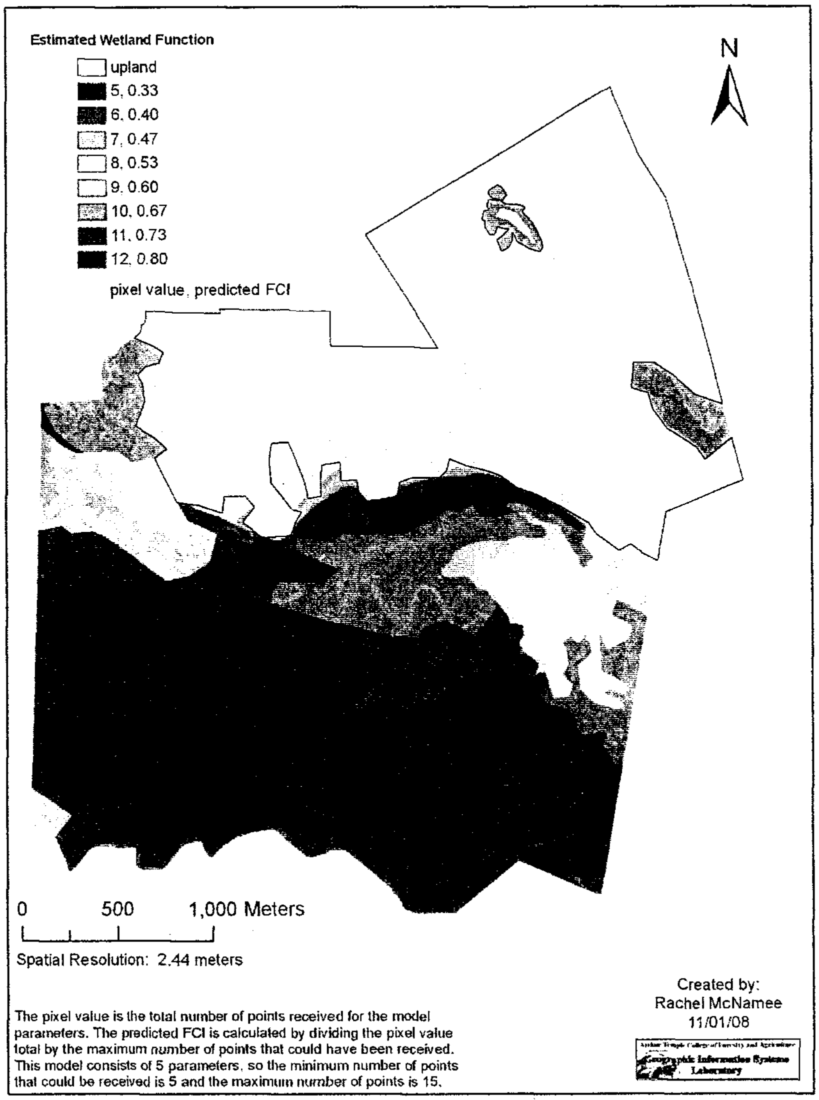

Figure 6. Maintain Plant Communities Model Output.

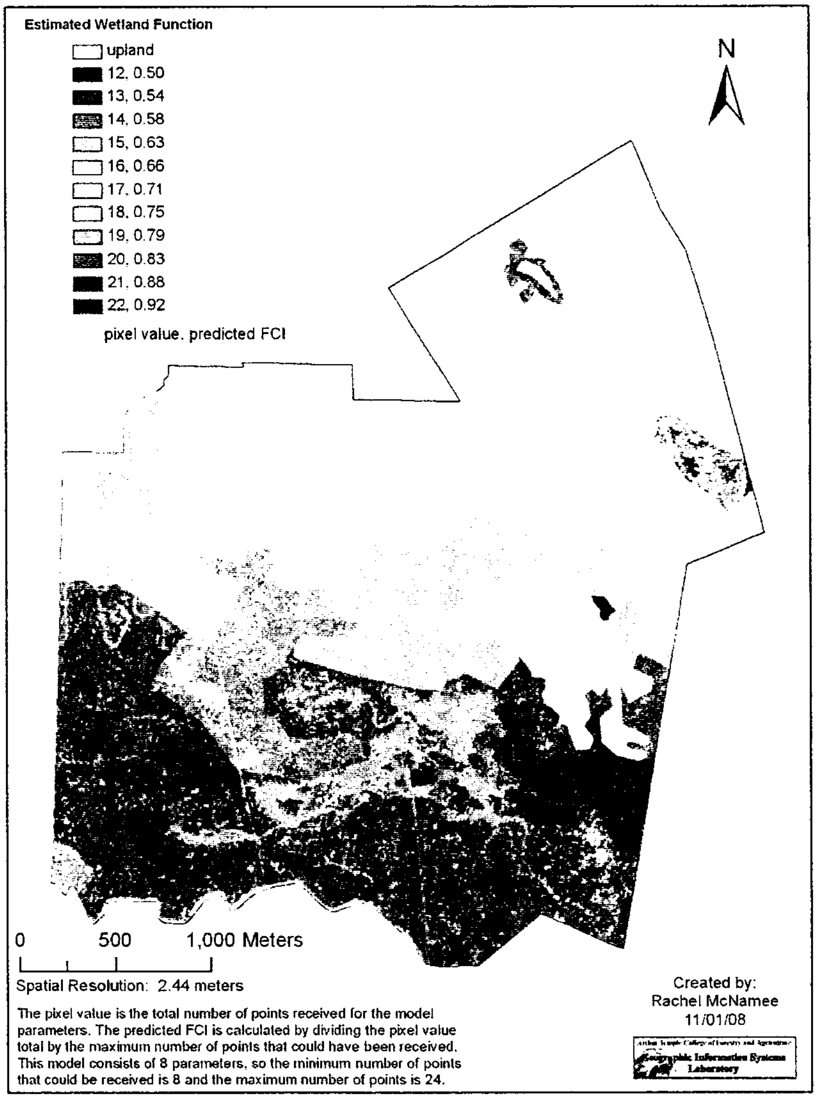

Figure 7. Provide for Terrestrial Wildlife Model Output.

Table 1. Pearson Correlation Coefficient Results.

Variable	r	p-value	0.05 alpha level
Cycle of Nutrients [1]	-0.01	0.89	not significant
Export of Organic Carbon [2]	0.69	< 0.001	significant
Biogeochemical Average [2]	0.45	< 0.001	significant
Detain Precipitation [2]	-0.05	0.63	not significant
Detain Floodwater [2]	0.58	< 0.001	significant
Hydrology Average [2]	0.42	< 0.001	significant
Maintain Plant Communities [1]	0.11	0.28	not significant
Provide for Terrestrial Wildlife [1]	0.33	< 0.001	significant
Habitat Average [1]	0.27	0.01	significant
Overall Wetland Average [1]	0.44	< 0.001	significant

[1] denotes a sample size of 104
[2] denotes a sample size of 101

Table 2. Paired Sample T-Test Results.

Variable	Model Mean	Field Mean	t value	p-value	0.05 alpha level
Cycle of Nutrients [1]	0.72	0.80	-7.12	< 0.001	significant
Export of Organic Carbon [2]	0.89	0.68	15.48	< 0.001	significant
Biogeochemical Average [2]	0.81	0.74	6.59	< 0.001	significant
Detain Precipitation [2]	0.78	0.91	-7.49	< 0.001	significant
Detain Floodwater [2]	0.87	0.66	13.12	< 0.001	significant
Hydrology Average [2]	0.82	0.78	3.37	0.001	significant
Maintain Plant Communities [1]	0.69	0.80	-7.82	< 0.001	significant
Provide for Terrestrial Wildlife [1]	0.76	0.83	-7.47	< 0.001	significant
Habitat Average [1]	0.73	0.82	-9.02	< 0.001	significant
Overall Average [1]	0.78	0.78	0.47	0.64	not significant

[1] denotes a sample size of 104
[2] denotes a sample size of 101

Table 3. Root Mean Square Error Results.

Variable	RMSE	Field Mean	Sampling Error (%)
Cycle of Nutrients [1]	0.02	0.80	2.50
Export of Organic Carbon [2]	0.06	0.68	8.82
Biogeochemical Average [2]	0.01	0.74	1.35
Detain Precipitation [2]	0.04	0.91	4.40
Detain Floodwater [2]	0.07	0.66	10.61
Hydrology Average [2]	0.02	0.78	2.56
Maintain Plant Communities [1]	0.03	0.80	3.75
Provide for Terrestrial Wildlife [1]	0.01	0.83	1.20
Habitat Average [1]	0.02	0.82	2.44
Overall Wetland Average [1]	0.01	0.78	1.28

[1] denotes a sample size of 104
[2] denotes a sample size of 101

DISCUSSION

The objective of this study was to determine if Remote Sensing and Geographic Information Systems can be used to assess the ecological functions of bottomland hardwood wetlands. This objective was met with mixed results.

While each individual analysis is important, the combination of the three analyses is a more accurate depiction of the performance of the developed models.

Models with a low RMSE are more desirable than those with a high r value. It is possible to have a high r value with a high RMSE as this is evidenced in the Export of Organic Carbon function. The Export of Organic Carbon function had the highest r value of 0.69 ($p < 0.001$), but also had a high RMSE value (0.06) and sampling error percentage (8.82%). While the high correlation for this function suggests that the model moved in the same direction as what was found in the field, the RMSE value showed that there was a difference in the values obtained from the field and obtained from the model. For example, the model based FCI for one area is 0.50 and the corresponding field based FCI for the same area is 0.60. The model based FCI for another area is 0.80 and the corresponding field based FCI is 0.85. A positive correlation exists in this example because the model FCI is increasing along with the field FCI. However, a difference exists between the corresponding hypothetical model and field FCIs. The Detain Floodwater function is another example of a moderately high correlation ($r = 0.58$) but has the highest RMSE value (0.07) and sampling error percentage (10.61%) for all functions and function averages.

The Paired Sample T-Test showed that all the functions and function averages except for the Overall Wetland Average had significantly different corresponding field and model means. It is advantageous of an ecological study such as this, to make note of the functions with the closer differences because statistically significant and ecologically significant hold different meanings. The Export of Organic Carbon function and the Detain Floodwater function had the most difference between its field and model means. The Hydrology Average had the least amount of difference between its field and model means of those functions that were said to be significantly different.

Of all the functions and function averages, the Overall Wetland Average appeared to be the most successful, as it had a significant ($p < 0.001$) moderate positive correlation ($r = 0.44$), the means between the model and field were not shown to be different (t value = 0.47, $p = 0.64$), and also for its exhibition of a moderate RMSE value and sampling error percentage (0.09, 11.54% respectively).

As previously cautioned, the Overall Wetland Average may or may not prove to be useful due to the fact that it involves the combination of very different wetland functions and it is not thought to be very practical for management purposes. While the Overall Wetland Average might not be useful, the average category ratings (Biogeochemical Average, Hydrology Average, and Habitat Average), which consist of similar functions, are believed to still be useful due to one's ability to manage for two similar functions.

LITERATURE CITED

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