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Land Change Modeler Application:Summer Internship with Clark Labs

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Coordinator of the Graduate Program in GIS for Development and Environment

Abstract

Land Change Modeler Application: Summer Internship with Clark Labs of Clark University

Siqi Cheng & Nan Ding

This paper is a description of our internship with Clark Labs in the summer of 2015. We worked as research assistants in the Land Change Modeler Application (App) project. This project aimed to display the land cover changes in the United States from 2001 to 2010, show the vulnerability in 48 states and predict changes from the yaer 2050. Our responsibility was to extract eight variables (slope, elevation, surface water, roads, high intensity land, protected areas, county subdivisions, and cultivated crops) in TerrSet, and use them in several models to test the accuracy of prediction.

The internship is a great opportunity for us to learn more about changes of land cover and differences among several land change models. From this internship, we became more familiar with ArcGIS and TerrSet. We highly recommend this internship with Clark Labs to people who are interested in land change analysis. The following pages provides information on the introduction of the organization, our internship responsibilities, and the assessment of our internship.

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Coordinator of the Graduate Program in GIS for Development and Environment

Academic History

Name: Siqi Cheng **Date**: May 2016

Baccalaureate School: Wuhan University

Baccalaureate Subject: B.S., Remote Sensing Science and Technology

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Dedication

I dedicate this paper to my family, friends and those who supported and helped me.

Siqi Cheng

I dedicate this paper to my friends and family for their help and support.

Nan Ding

Acknowledgements

We would like to thank Dr. J. Ronald Eastman for providing us this opportunity to work at Clark Labs. We would like to thank Dr. Jie Tian for his instruction on this internship paper. We would also like to thank Monica Noon and Alison Thieme for your suggestions on this paper. At last, we would like to thank our colleagues at Clark Labs.

Table of Contents

List of Table

List of Illustrations

GLOSSARY

App: Application

ArcGIS: An analytical software created by ESRI

ESRI: Environmental Systems Research Institute

GIS: Geographic Information Science

GISDE: Geographic Information Science for Development and Environment, a program in collaboration with IDCE and Clark University's School of Geography

IDCE: International Development, Community and Environment, a department at Clark University

USDA: U.S. Department of Agriculture

SQL: Structured Query Language

NLCD: National Land Cover Dataset

NED: National Elevation Data

PAD: Protected Areas Database

ALBERSUS83: Projected Coordinate System Albers US 1983

MTFCC: MAF/TIGER Feature Class Code

MLP: Multilayer Perceptron

WNL: Weighted Normalized Likelihood

LCM: Land Change Modeler

RS: Remote Sensing

Chapter 1 Introduction

The rapid development of Geographic Information Science (GIS) and Remote Sensing (RS) has attracted much attention. Throughout our studies at Wuhan University, we became fascinated by its versatile functions and applications in areas like land use change and environmental justice. After graduation, we decided to join the Geographic Information Science for Development and Environment (GISDE) program at Clark University. As graduate students in the GISDE program, we find joy from learning and gain a clear understanding identifying our research interest. In the Advanced Raster GIS class, Siqi and her group focused on the land change analysis in Florida under Dr. Ronald Eastman's suggestion. Dr. Eastman told us that he would start a project concentrated on the land change modeler for the Continental Unites States. In the summer of 2015, we applied to work at Clark Labs as remote sensing analysts to develop our professional skills.

At Clark Labs, we were involved in the Land Change Modeler App project. It is a project cooperated with ESRI. This project is aimed to display the previous land cover changes and predict changes in the future using the ArcGIS Online platform. This summer, we mainly focused on data pre-processing. We extracted eleven variables for 20 states, and tested three land change modelers, including Multilayer Perceptron (MLP), Logistic Regression, and Weighted Normalized Likelihood (WNL). We learned about land changes during ten years in the Continental United States. The analysis tools we used included selection in ArcMap, as well as project, overlay, distance, and the

Land Change Modeler in TerrSet. We became more familiar with ArcGIS and TerrSet from this internship. At the same time, this internship provided us a good opportunity to communicate with different people, not only students at Clark University, but also staffs from different countries.

The paper contains five chapters. Chapter 2 will introduce Clark Labs from its main areas of work, its structure and its strengths. Chapter 3 will explain the nature of our work during in the summer internship. Chapter 4 discusses knowledge gained from this internship. Chapter 5 is the conclusion of this paper.

Chapter 2: Description of the Organization

2.1 Background and Mission

Clark Labs was founded by Professor J. Ronald Eastman in 1987 at Clark University, Worcester, Massachusetts, USA. Clark Labs is responsible for the IDRISI software, which combined geographic information system with remote sensing software. It has been used as a professional PC-based image processing software in more than 180 countries worldwide (Clark Labs, 2015). In 2015, Clark Labs released TerrSet Geospatial Monitoring and Modeling software. TerrSet includes the IDRISI GIS Analysis and IDRISI Image Processing tools, along with an additional constellation of software tools for monitoring and modeling the earth system (Clark Labs, 2015). IDRISI GIS and Image Processing tools laid the foundation for TerrSet software and greatly expands the modelling capacity of the base IDRISI toolset. It provides users with the most extensive set of geospatial tools in the industry in a single, affordable package. This means it is user-friendly as users could use the software without requiring additional add-ons to extensions.

The mission of Clark Labs is to continue its pioneering advancements in areas such as decision support, uncertainty management, classifier development, land change science, time series analysis, and climate change monitoring (Clark Labs, 2015). Through cooperation with several organizations, such as The Gordon and Betty Moore Foundation, Google.org, USDA, the United Nations, Conservation International and World Conservation Society, Clark Labs utilizes its theoretical basis to develop creative research tools, to provide software solutions, and to apply geospatial expertise to a series of practical issues (Clark Labs, 2015).

2.2 Expertise and Location

Clark Labs investigates geospatial technologies for analyzing and displaying of spatial data for environmental management, sustainable development and resource allocation since 1987(Clark Labs, 2015). Both IDRISI and TerrSet are highly useful tools for image processing and modeling for land change, earth trends, ecosystem, and climate change adaptation. Generally speaking, Clark Labs concentrates on solving problems with raster data. By investigating these phenomena, Clark Labs is designed to provide help to users in solving the most challenging problems of the environment and ordinary tasks of the earth science community.

Clark Labs is based within the world-renowned Graduate School of Geography at Clark University, Worcester, Massachusetts, USA (Clark Labs, 2015).

2.3 Organizational Structure

Clark Labs is a non-profit organization employing over twenty people. The founder, Dr. J. Ronald Eastman, is a tenured professor at Clark University, Graduate School of Geography. He pursued his Ph.D. degree at Boston University and then joined Clark University in 1982 (Clark Labs, 2015).

Clark Labs is composed of three core groups. The first one is the testing group, responsible for technical support and algorithm testing of new modules. The second one is the programming group. They optimize algorithms, improve existing modules and design new modules to develop geospatial analysis of TerrSet. The last group is the analyst group, responsible for most of analysis projects at Clark Labs.

Half of the current staff are graduate students at Clark University. Professor Eastman welcomes students who would like to work on his projects, or discuss and develop their own ideas and projects. The employees consist of U.S. citizens, European citizens and Asian citizens. As a result of the diverse culture, the staff held a lunch party on every Thursday in the summer so that the staff could learn more about other cultures and conventions. In this harmonious atmosphere, the staff does their work with creativity and efficiency.

2.4 GIS within the Organization

TerrSet provides several analytical tools for users to manipulate geospatial data, especially raster data, to explore the rapidly changing world. IDRISI GIS Analysis tools include not only traditional tools that provide solutions for day-to-day GIS professional, but also advanced procedures to solve more complicated issues.

Generally, the IDRISI GIS Analysis tools include several key features (Clark Labs, 2015):

a. Database Query: queries raster and vector files and report basic statistics in histograms, tabulations and profiles. Vector data can be accessed and edited by SQL language.

b. Derivative Mapping: creates new data layers as a function of existing layers and enter map layers as variables in models.

c. Distance and Context: runs Euclidian and cost distance procedures for aggregation and disaggregation.

d. Spatial Statistics: acquires description of spatial characteristics, including point distribution measures, image regression, logistical regression, autocorrelation procedures and others.

e. Decision Support and Uncertainty Management: supports multi-criteria and multi-objective decision making which includes tools and procedures for suitability mapping and land allocation.

f. Surface Analysis: derives patterns, trends, and topological features, to delineate watersheds and viewsheds. It also includes traditional distance and buffer analysis tools.

g. Change and Time Series Analysis: identifies and quantifies change across multiple images and to predict land cover change.

h. Model Deployment Tools: Image Calculator to construct algebraic and logical formulas with map layers as variables and Macro Modeler to exposes all the IDRISI Analysis tools as objects that can be linked with map layers in an algorithmic chain.

2.5 Strengths and Weakness

TerrSet is a flagship product of Clark Labs as its spatial analysis tools including approximately three hundred modules. TerrSet is designed for a variety of users, such as GIS professionals, urban planners, land change analysts and environmental scientists, a statistically relevant yet convenient and easy way to complete their projects. For instance, the land change modeler provides users with several methods to analyze changes that are already happening and also predict possible changes in the future. TerrSet also produces high-quality outputs from classification, earth trend analysis, and time series analysis.

In addition, Clark Labs plays a pioneering role in uncertainty management. Uncertainty management includes the soft reclassification procedure that allows one to map the probability of a location being above or below a threshold, and the generation of normal and rectilinear distributions for uncertainty analysis such as Monte Carlo methods (Clark Labs, 2015).

A notable weakness of Clark Labs is contributed to its lack of funds. Since Clark Labs is a non-profit organization, there is no marketing department for selling products. Maximizing profit is not the main purpose for Clark Labs. IDRISI and TerrSet are used more commonly for academic requirements, and the student pricing is quite affordable. Because of the affordable price, Clark Labs does not acquire considerable profit from selling products. This makes it difficult for Clark Labs to devote much involvement to develop new and advanced procedures. It would be more efficient if the organization could improve its business model to acquire more funds.

2.6 Effectiveness and Efficiency

Because of a friendly and harmonious working atmosphere, the staff at Clark Labs has high efficiency in their work. Researchers in our group excel at communication. By comparing which software is more suitable for projection, ArcMap or TerrSet, discussing the choices of projections, adjusting the sequence of modules, and analyzing the reasons of results with low accuracy, work tends to progresses faster than anticipated at Clark Labs.

Chapter 3: Internship Responsibilities

As interns at Clark Labs, we were involved in the Land Change Analysis project in the summer of 2015. This project was performed in collaboration with ESRI, who supported us by putting the results on ArcGIS Online. The final result is a map of the continental United States. When users select the state of interest, it automatically zooms to that state and displays five clickable buttons. The first and second buttons display the raster images of National Land Cover Dataset (NLCD) 2001 and 2011 for the selected state. The third button displays the change map from 2001 to 2011. The forth one is the potential transitions by the year 2050. Users can access the probability values of these transitions by selecting areas of interest. The last button is the vulnerability of each land cover type, calculated by aggregating transition information for each state.

During the three months, we mainly focused on extraction of ten variables: slope, elevation, distance to surface water, distance to primary roads, distance to secondary roads, distance to local roads, distance to high intensity areas in 2001, distance to high intensity areas in 2011, protected areas, and county subdivisions. There were six people working on this project and forty-eight states to analyze, thus each intern was allocated to a dozen states.

3.1 Data Resources

There are various data we used in Land Change Analysis, including NLCD, National Elevation Data (NED), USA surface water, roads, Protected Areas Database (PAD), and county subdivisions.

Data	Source	Format
NLCD (2001&2011)	U.S. Geological Survey	TIFF
NED	ArcGIS	TIFF
USA Surface Water	ArcGIS	TIFF
Roads	the United States Census Bureau	Shapefile
PAD	Already Collected by Clark Labs	Shapefile
County Subdivisions	the United States Census Bureau	Shapefile

Table 1 Data Information

3.1.1 NDCD Land Cover Data

The NLCD 2001 and NLCD 2011 land cover data sets are provided by the U.S. Geological Survey. There are a total of twenty land cover classes (see Figure 1): open water, perennial ice/snow, developed open space, developed low intensity, developed medium intensity, developed high intensity, barren land (rock/sand/clay), deciduous forest, evergreen forest, mixed forest, dwarf scrub, shrub/scrub, grassland/ herbaceous, sedge/herbaceous, lichens, moss, pasture/hay, cultivated crops, woody wetlands, and emergent herbaceous wetlands.

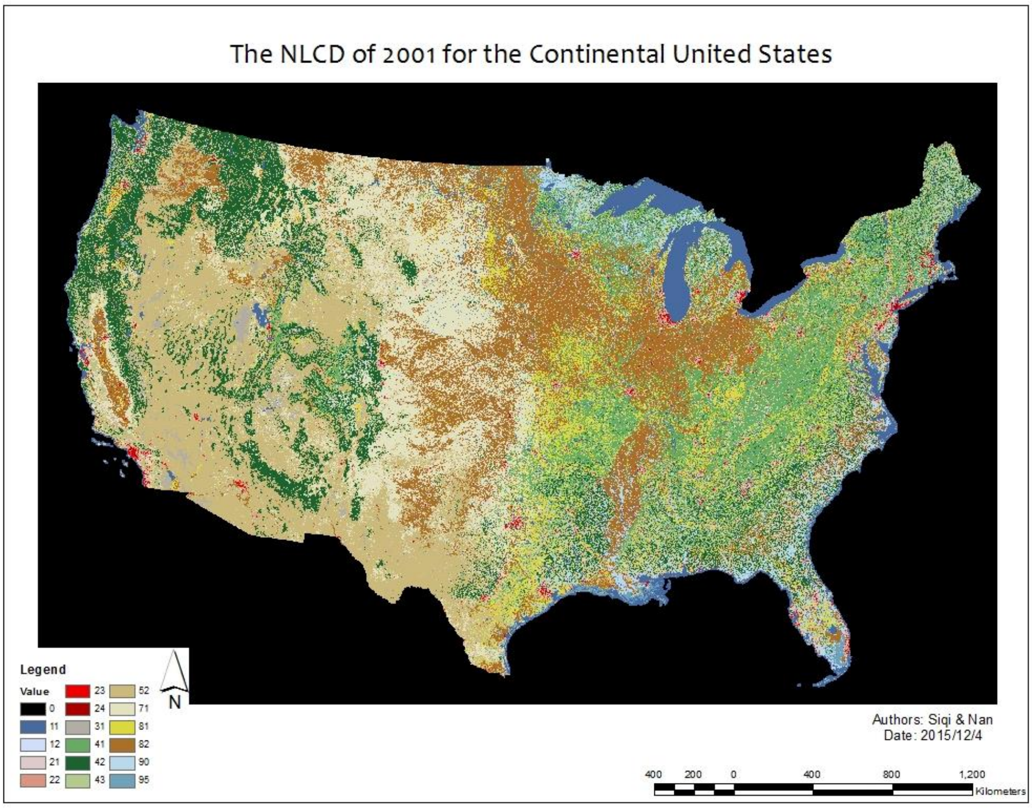


Figure 1 Land Cover of the U.S. in 2001.

3.1.2 NED

Through Clark Labs we were able to access National Elevation Data (NED) data via ArcGIS with 30x30 m resolution. We used this data to derive maps showing elevation and slope.

3.1.3 USA Surface Water

The USA surface water data was also was provided by ArcGIS, Environmental Systems Research Institute (ESRI). Surface water takes many forms including lakes, ponds, streams, rivers, canals, aqueducts, etc. Each cell in this raster layer indicates whether there is surface water within its areas, including intermittent streams and water bodies (ArcGIS, 2015). This data is displayed as a 30m cell size raster derived from the locations of features.

3.1.4 Roads

The 2011 TIGER/Line shapefiles are available through the United States Census Bureau's Mater Address File/Topologically Integrated Geographic Encoding and Referencing (MAF/TIGER) database (John E.Bryson & Robert M.Groves, 2011). These files display roads for every state in the U.S.

3.1.5 PAD

The PAD data were previously collected by Clark Labs. The protected areas were in one shapefile with attribute tables that includes state specific information.

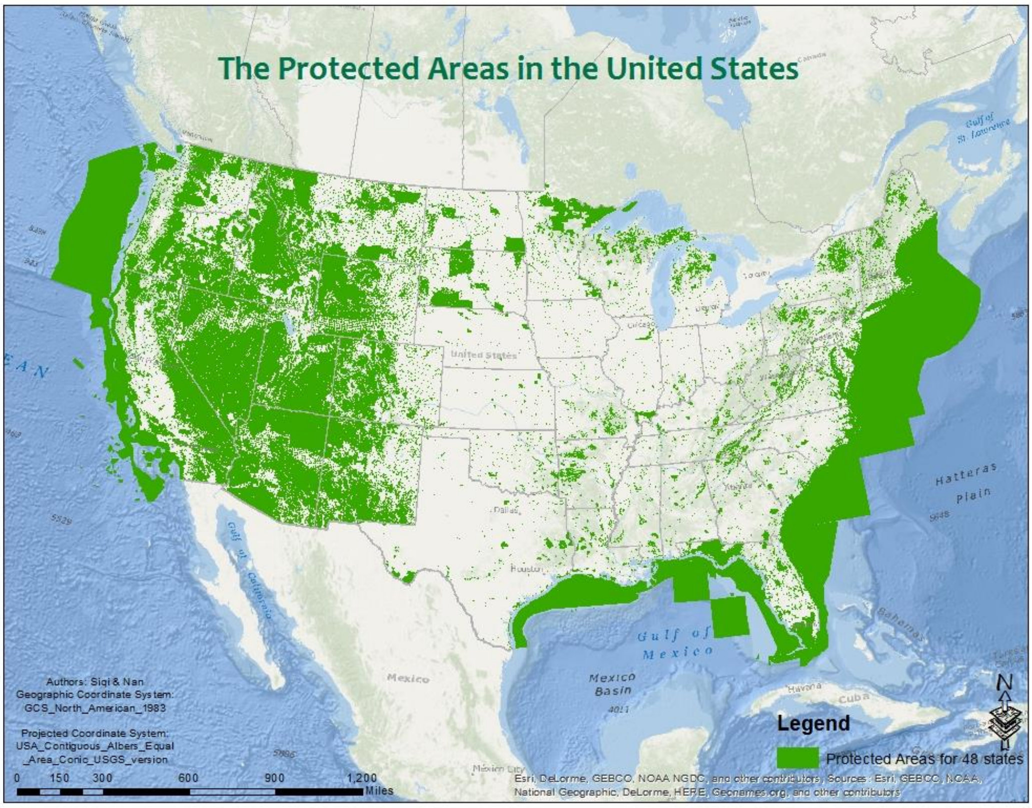


Figure 2 Protected Areas in the U.S.

3.1.6 County Subdivisions

County subdivision data was also available from the United States Census Bureau. We downloaded county subdivisions for each state in shapefile format.

3.2 Data Pre-processing

Generally, data pre-processing consists of projection, clip, overlay, calculation distance. After pre-processing, ten variables were extracted for each state to analyze the transitions from 2001 to 2011 and predict the possibility values of transitions in 2050.

3.2.1 NLCD 2001 and 2011

First, we used a buffered state shapefile to clip the NLCD land cover image in ArcMap and set the value to zero for pixels with no data, and exported the result as a TIF image. Then we opened this TIF image in TerrSet and converted it into RST file format which is the common file format of TerrSet. We made sure the reference system was set to Albers US 83, the master reference system in this project. We imported the non-buffered state shapefile as vector file, and converted the vector into raster file. The final step was to multiply the NLCD rater file and the non-buffered state vector file. We did this for both 2001 and 2011.

3.2.2 Exclusion Ocean from Images

As the U.S. had many states which were coastal, the state shapefile was unable to differentiate the coast line. We worked on coastal states in order to identify their coast line and obtain the final NLCD image. We reclassified the land cover image to display sea as a value of zero and land as a value of one. We did this for both the 2001 and 2011 images. Then we used this 2001 image to cover 2011 image and got the final mask for the state. Finally, we multiplied the final mask to each land cover image and obtained the final mask of NLCD in two years.

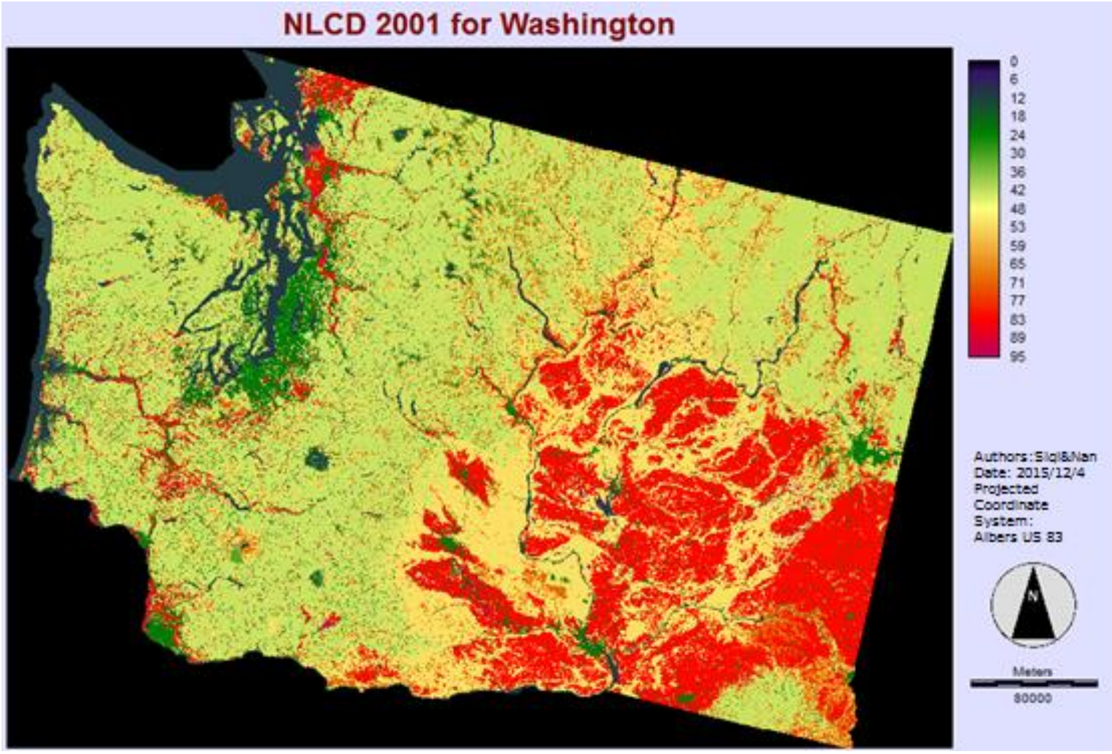


Figure 3 Land Cover in Washington in 2011.

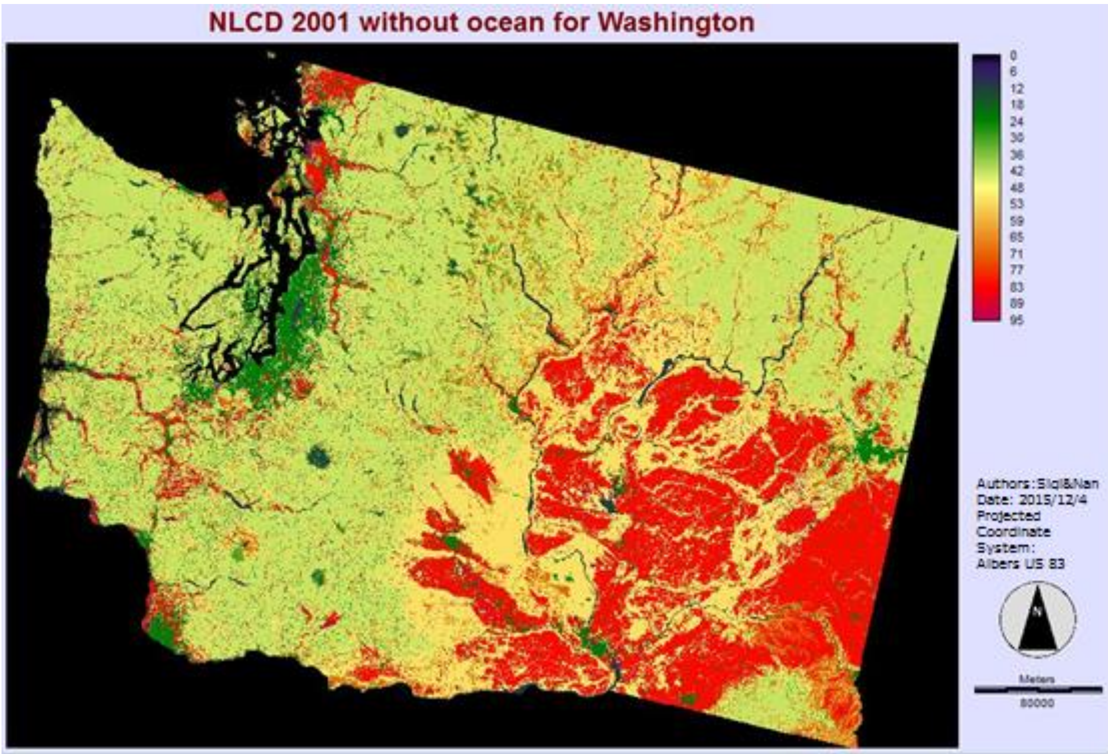


Figure 4 Land Cover with Exclusion Ocean.

3.2.3 Elevation and Slope

We clipped the NED data with the buffered states and imported into TerrSet. Then we multiplied the final mask of the state to the projected elevation image and get the final mask of the elevation. To create slope we calculated slope in percentage, and also multiplied the final mask of the state to the result of slope image and get the final mask of the slope.

3.2.4 Distance to Surface Water

The surface water data were derived from the same source as the elevation data and includes lakes, ponds, streams, rivers, and canals (ArcGIS, 2015). We imported the Surface Water layer into Terrset and created a map displaying distance to surface water. Because different land covers have various demand for water, different distances to the surface water might affect their transitions.

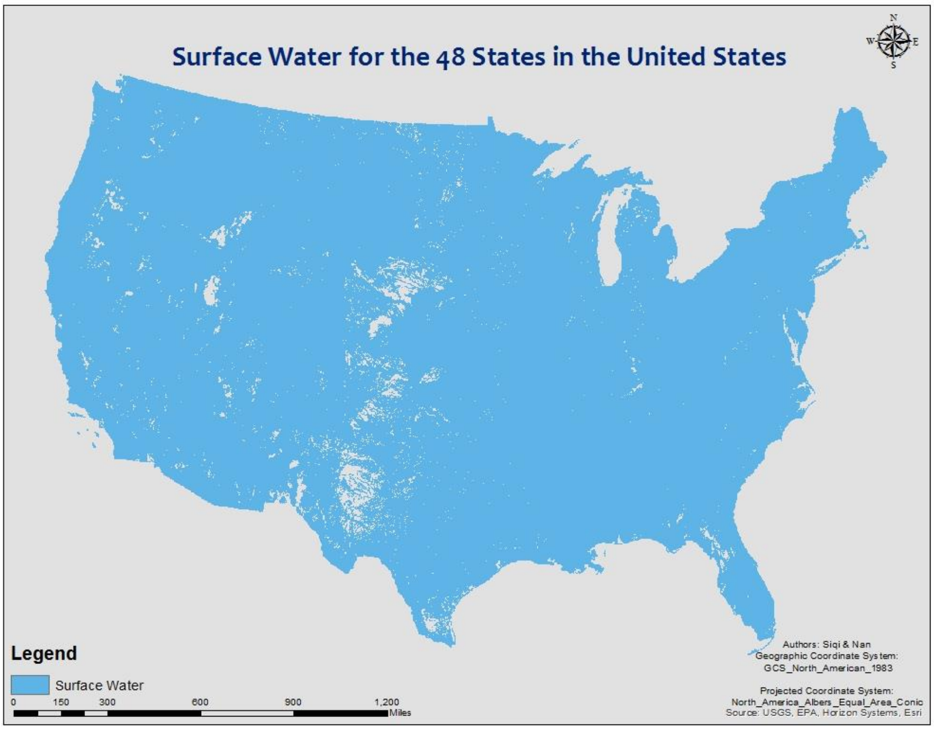


Figure 5 Raw Data of Surface Water in the United States.

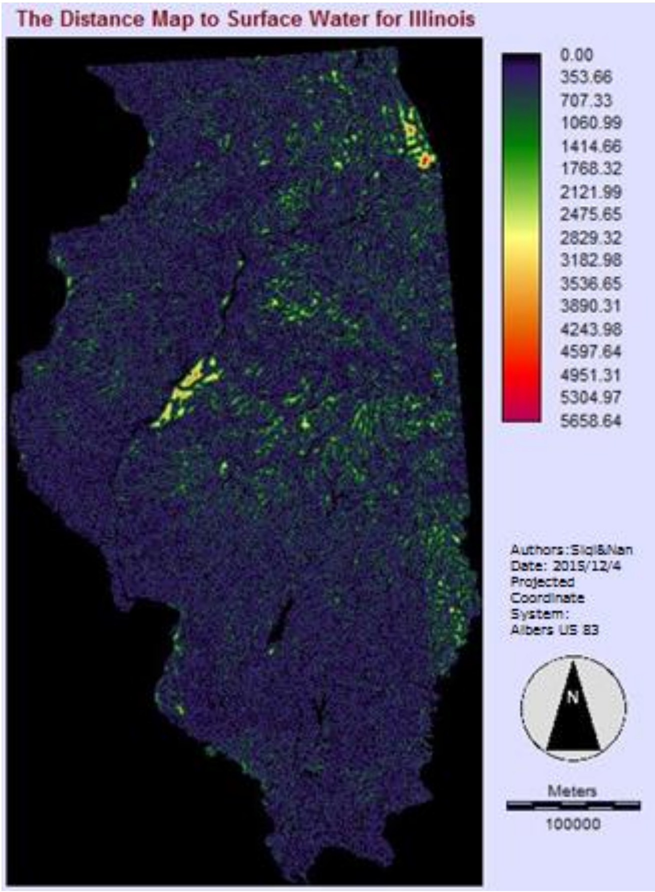
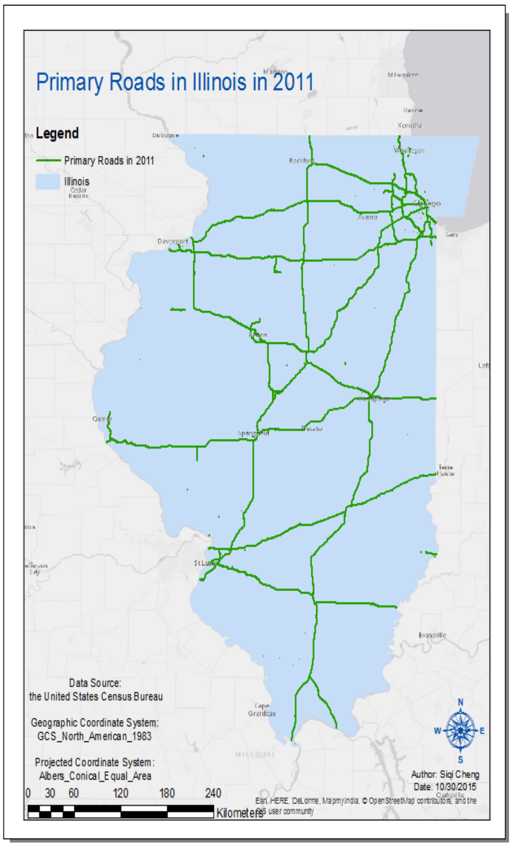


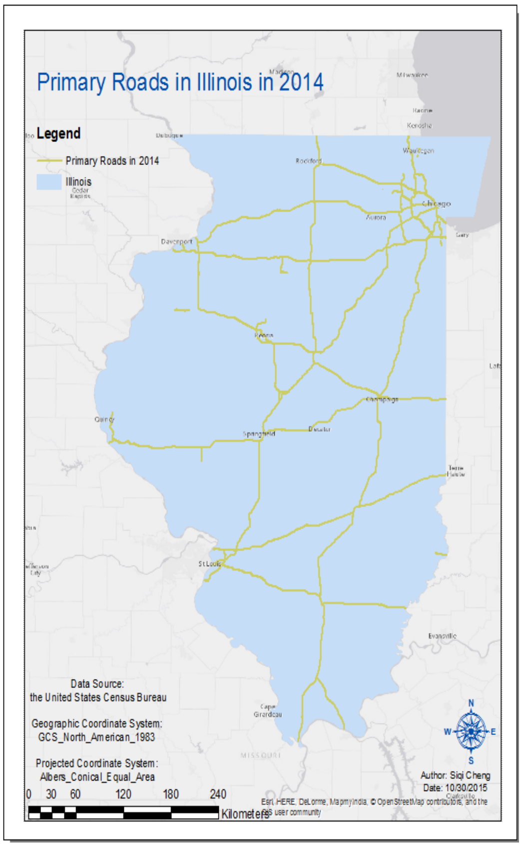
Figure 6 Distance to Surface Water of Illinois.

3.2.5 Distance to Roads

In ArcGIS, we selected primary roads, secondary roads, local roads, and ramps from the 2011 TIGER/Line shapefiles by attribute MAF/TIGER Feature Class Code Definitions (MTFCC). MTFCC was a code definition table established to clarify and classify geographic objects of features by the United States Census. Each feature class was assigned with a 5-digit code, types of feature class (points, linear, or areal) and their description. Then we exported them as new shapefiles. These shapefiles were imported into TerrSet and converted them into raster files. We then created distance images and overlaid them with the state mask. We noticed that there were errors in the results and chose to use more recent road data from 2014 TIGER/Line shapefiles as there was better connectivity.



A Primary Roads in 2011

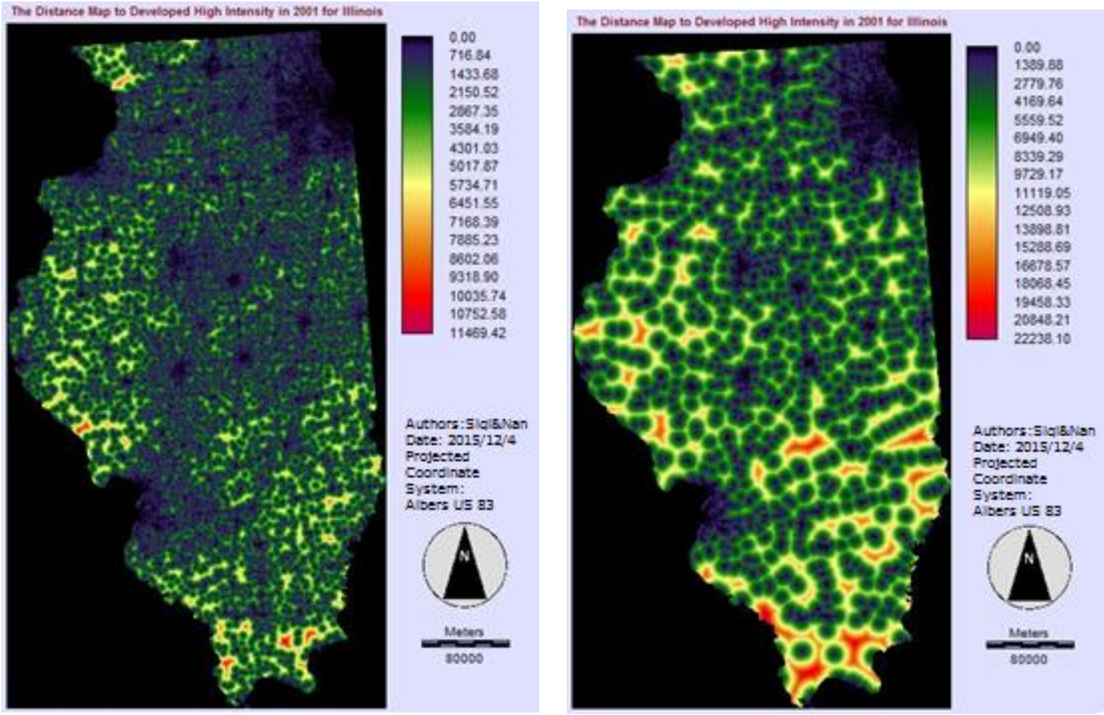


B Primary Roads in 2014

Figure 7 Differences of Primary Roads between 2010 and 2014.

3.2.6 Distance to Developed, High Intensity Land

This data was derived from the NLCD 2001 and 2011 raster images using the BREAKOUT module in TerrSet. It is noteworthy that many road intersections were classified as “Developed, High Intensity” land cover which might reduce accuracy of the distance calculation to high intensity land cover. Professor Eastman developed a procedure to solve this problem. First, the Boolean images of “Developed, High Intensity” land cover class was grouped together. Then we created a shape index and masked out pixels that exceeded the shape index. At this time, the raster images were more accurate for the distance calculation.



A Before the GROUP module B After the GROUP module

Figure 8 Differences between Two Distance Maps to Developed, High Intensity in 2001 of Illinois.

3.2.7 PAD

We imported the vector file into TerrSet, converted it to a raster file, and reclassified the values to show only protected and not protected areas. Finally we multiplied this result with state mask and obtained the final mask of PAD area.

3.2.8 County Subdivisions

The county subdivisions data was imported in Terrset as vector file and projected into ALBERSUS83. We overlaid the data with the state mask and output the county subdivisions image excluding ocean, similar to the methods in 3.2.2.

3.2.9 Distance to Cultivated Crops

We extracted the Cultivated Crops land cover from NLCD 2001 land cover image and calculated the distance to cropland. This variable was applied only when analyzing the transition potential from some land cover to Cultivated Crops land cover. The variable was not under consideration at first, but was found that it did affect the accuracy of the analysis results to the transitions to cropland.

3.3 Land Change Modeling Test

We analyzed the transition potentials using Land Change Modeler (LCM). Three models were applied in this step and compared for both accuracy and run time. The first model was MLP Neural Network that used five original variables and two evidence likelihood maps. To ensure that the modeling is representative, we run the model two to three times until we were satisfied with the result. The second model was Logistic Regression. The procedure was similar to MLP but it runs slower. However, unlike MLP and Logistic Regression, the third model WNL would use “binned” explanatory variables that was aimed to set their range from 0 to 99. WNL had the shortest running time and sometimes it showed a higher accuracy than the other two models. LCM determined the three largest anthropogenic changes and three largest natural changes[1]. Evidence Likelihood maps for the County Subdivision and Protected Areas were also created in the LCM.

[1] Anthropogenic changes are transitions where the NLCD 2011 land cover class are anthropogenic. Natural changes are transitions where both the NLCD 2001 and 2011 land cover classes are natural. Anthropogenic land covers include Developed, Open Space, Developed, Low Intensity, Developed, Medium Intensity, and Developed, High Intensity. The rest of land covers are natural land covers.

Chapter 4 Internship Assessment

4.1 Siqi Cheng

The internship at Clark Labs was an invaluable experience for me. I learned a lot during this summer at Clark Labs, not only because I applied and improved on the skills I learned at Clark, but also because I gained a deeper understanding of theories behind the TerrSet modules.

4.1.1 Skills Learned During the Internship

In this three-month internship, I became more skilled in TerrSet (IDRISI). For example, when extracting variables, the concepts and modules I learned in class and practiced in laboratories exercises made me adequately prepared for this job, such as the DISTANCE module, the RECLASS module, and the OVERLAY module. Therefore I was able to comprehend the pre-possessing procedure and go over the steps quickly. It saved us a lot of time and exceeded the expectations of Professor Eastman.

It was also a good opportunity to develop new skills. My responsibilities at Clark Labs consisted of variables extraction and land change modeling tests. I became more familiar with searching for data. Elevation and surface water of the continental United States were downloaded from ESRI. Roads data from the United Stated Census Bureau contained a large amount of roads, but we had to download them county by county in each state. It was worth noting that data from the official websites like the United States Census Bureau might have many errors, so checking data for accuracy was necessary. For the land change modeling tests, our group spent a significant amount of time and effort on them. We tried several models: MLP, Logistic Regression and WNL. I learned more about the advantages and disadvantages of these models. Both Logistic Regression and WNL had similar accuracy, but WNL ran faster than the other two modules. Although our group sought and discussed a perfect model, which would have a higher accuracy and a shorter running time, I enjoyed the process of discovery and learned new things each time.

4.1.2 Skills Learned at Clark University

This internship was mainly related to three courses, Introduction to Remote Sensing (RS), Introduction to GIS and Advance Raster GIS. Simple processes like merge or clip work were finished in ArcMap, a software which was used in Introduction to GIS. Introduction to Remote Sensing gave us basic understanding of many modules in TerrSet. The core concepts of land change analysis were taught by Professor Eastman in Advanced Raster GIS. Communication was of great importance at while working at Clark Labs. This internship provided me with an opportunity to improve my spoken English and prepare for a future career.

4.1.3 Recommendations

My work experiences in Clark Labs solidified what I learned at Clark University and fostered the acquisition of new skills. I will recommend this great internship to those who want to work as a GIS/RS analysts in the future, who would like to think about land change issues and dare to accept challenges associated with this topic.

4.2 Nan Ding

4.1.1 Skills and Experience Learned

By doing an internship at Clark Labs this summer, I have obtained a great deal of experience working as a GIS analyst. During the internship, I participated in data preprocessing and land change model comparison, both of which helped me gain a better understanding of land change modeling. Working at Clark Labs was the first time for me to work at a non-profit organization in the U.S., a unique experience for me. My advisor (Professor Eastman) and other colleagues were friendly, and the atmosphere in the lab was always amicable. The data processing portion of the internship contained a large amount of detailed steps. I have learned that contact and communication in time are really required in the workplace. At Clark Labs, don't hesitate to ask questions. Appropriate communication helps efficient cooperation. Prudence was also important. Sometimes I found there was a mistake in the data preprocessing part which led to an incorrect result in land change analysis. Then I had to redo the data preprocessing part which was time-consuming.

The requirement for this internship was basic knowledge of remote sensing, GIS, and specifically, the knowledge of land cover change which was covered by Professor Eastman during course Advanced Raster GIS. Also the operational capacity for TerrSet and ArcGIS was needed for data pre-processing and land change model testing. This was covered by many courses which I have taken when I was a first year GISDE student, including Intro to GIS, Intro to Remote Sensing, Advanced Vector GIS, and Advanced Raster GIS. I learned about land cover and land change analysis before this internship from course, Advanced Raster GIS, which was taught by Professor Eastman.

I would like to pursue a career in land change analysis in the future. Thus, this internship was valuable for me as work experience.

4.2.2 Recommendations

I would recommend this internship to GISDE students who are interested in land change analysis. The program I participated was a large program cooperated with ESRI and will continue for a relatively long time. Clark Labs and the partnership with ESRI will continue to provide opportunities and positions as time goes on. It is also a chance for students to work during the semester as a part-time job/internship, since work at Clark Labs is located on-campus.

Chapter 5 Conclusion

Clark University and GISDE program has provided us with high quality educations and given us the opportunity to work at Clark Labs. Our internship with Clark Labs this past summer was a great experience. This internship allowed us to not only use and review knowledge learned from class, but also acquire more knowledge and understanding of land change analysis. We also made efficient network with our colleagues, who were both friendly and helpful with professional tasks. This internship matched our expectations as a valuable and professional experience. It also gave us more ideas about our future careers. We will also take what we have gained from this experience into our future jobs. We are also pleased to continue working on this project and extend this internship into a longer term work. We are grateful for this experience and would recommend this internship to those interested in land change analysis.

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