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GLOBAL DEFORESTATION PREDICTION: SUMMER INTERNSHIP AT CLARK LABS

TIANZE LI & YASHEE JOSHI

DEGREE WILL BE CONFERRED MAY 2017

A GISDE FINAL PROJECT PAPER

Submitted to the faculty of Clark University, Worcester, Massachusetts,

in partial fulfillment of the requirements for the degree of

Masters of Science in Geographic Information Sciences for Development and Environment

in the Department of International Development, Community, and Environment

Accepted on the recommendation of

Dr. Yelena Ogneva-Himmelberger, Project Advisor

Abstract

Global Deforestation Prediction: Summer Internship at Clark Labs

Tianze Li & Yashee Joshi

This paper is a description of our internship with Clark Labs in the summer of 2016. We worked as research assistants in the Deforestation Risk Prediction project for Ecosystem Services team. This goal of the project was to predict deforestation at global, continental and national level. Our responsibilities were to choose the variables that may influence the deforestation and to use Land Change Modeler in TerrSet to test the variables and create the deforestation prediction maps. We highly recommend this internship with Clark Labs to other GISDE students who are interested in land change analysis.

Dr. Yelena Ogneva-Himmelberger, Project Advisor

Academic History

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Research Assistant –Clark Labs, Worcester, MA (2017)

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Dedication

Yashee Joshi:

Behind a successful woman, there is a loving dad!

I would like to say a heartfelt thanks to my father for his constant encouragement and support. Without his vision, I would never have been able to make it this far. I want to thank my mother for giving me enough space to make my decisions and believing in me. I would never have been able to make this far without such loving and open-minded parents. For every time you have shown trust in me, ma papa, you have helped me become stronger than ever. I truly, am blessed to have you. In addition, I want to thank Dhyey Bhatpuria for sticking by me through thick and thin like a rock. Lastly, my special thanks goes to Tianze Li and my other classmates and friends.

Tianze Li:

This final paper is dedicated to my parents who offered me constant support and encouragement for my major.

Acknowledgements

We would like to thank Professor Ronald Eastman, Director of Clark Labs for giving us this opportunity to work in Clark Labs. A heartfelt thanks to our Stefano Crema, who guided us through the internship. In addition, we would like to specially thank Tammy Woodard for keeping us motivated and being a great resource. Lastly, we want to extend our thanks towards Diane Sutter and Peter Wason for helping us to get through with the internship.

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1. Introduction

Clark University has one of the best Geography programs in the country. GIS for Development and Environment (GISDE) is a part of Geography as well as the International Development for Community and Environment departments in Clark. The Master's Program for GISDE requires 12 credits of core courses and other courses along with a GIS related internship or research for fulfillment. As long as the internships are strictly GIS-based, they can be chosen by the students. For the summer, we chose to do the internship at Clark Labs. Clark Labs had been given the contract by Conservation International for studying and generating global deforestation risk layer based on suite of deforestation drivers. Our duties involved collecting the driver variables, studying their impacts on globe, continents and countries and to create deforestation risk maps. The skills on Raster GIS and TerrSet software that we learned as GISDE master's candidates helped us a lot in this internship. The structure of the methodology was semi-designed in the sense that some steps were clear from the beginning, but some had to be thought of during the process. A lot of trial-and-error was involved. The work was equally divided between the both of us.

This report describes the internship in various chapters. The description of the organization is given in chapter 2. The description of our responsibilities, contributions and methodologies that we developed for the internship is in chapter 3. Chapter 4 and chapter 5 are about assessing the internship and conclusion about the internship.

2. About the Organization

2.1 Background:

Clark Lab was formed in 1987 by J Ronald Eastman with a mission:

"Clark Labs is dedicated to the research and development of geospatial technologies for effective and responsible decision making for environmental management, sustainable resource development and equitable resource allocation." [1]

Clark Labs is known for its flagship product, Idrisi GIS and Image Processing software. The organization is based within Graduate School of Geography at Clark University, Worcester, Massachusetts that pioneers in fields of decision support, uncertainty management, classifier development, land change science, time series analysis, and climate change monitoring. In 2015, Clark Labs released TerrSet software which includes IDRISI GIS Analysis and IDRISI Image Processing and other tools for monitoring and modelling earth system. TerrSet is used in more than 180 countries by researchers and professionals for PC-based Image Processing. The software includes Land Change Modeler, Earth Trends Modeler, GeOSIRIS, Ecosystems Services Modeler, Habitat and Biodiversity Modeler, and Climate Change Adaptation Modeler along with the IDRISI GIS and Image Processing tools. These models and tools serve as building blocks for addressing environmental challenges. [1]

Clark Labs troubleshoot for raster data as it provides solutions to the users for environment and earth science related issues. IDRISI as well as TerrSet are very powerful and useful for image processing and modelling related to earth trends, ecosystem and climate change adaptation.

2.2 Products:

Idrisi Selva provides around 300 modules for analysis and display of digital spatial information. The Land Change Modeler exists in Idrisi and also as an extension to ArcGIS. Some other resources include CartaLinx, which is a spatial database development and topological editing tool. There is a selection of data archives for time series analysis and manuals on utilizing GIS and remote sensing for specific application areas. TerrSet comes with a user manual that can be translated to Spanish.

2.3 Collaborations:

Clark Labs has Gordon and Betty Moore Foundation, Google.org, USDA, the United Nations, Conservation International and World Conservation Society as the partnering organizations. This helps Clark Labs to develop much more innovative and customized research tools, troubleshoot for organizations in need and apply geospatial proficiency to real world problems. [1]

2.4 Structure:

Clark Labs is a non-profit organization with J Ronald Eastman as the founder, who is also a professor at Graduate School of Geography, Clark University. The organization works in three core groups, the testing group, the programming group and the analyst group. The testing group is responsible for the algorithm testing for new modules and the technical support. The programming group takes care of the algorithms, does improvements in the existing modules and designs new modules for the software. The analyst group does the analysis of the projects in Clark Labs.

2.5 GIS at Clark Labs:

As Clark Labs is involved in creating and developing GIS and Image Processing software, the GIS environment within the organization is very impressive. The product, TerrSet, provides several fundamental tools for GIS analysis along with python scripting environment.

The land change modeler analyses land cover change by taking in the before and after categorical maps. The modeler will yield the gains and losses for every land category and produce a map for transition potential based on the changes that took place in past while making prediction for land use of the coming years. This Land Change Modeler supports the Reduced Emission from Deforestation and forest Degradation (REDD) project.

The Habitat and Biodiversity Modeler (HBM) models the species distribution and finds the habitat suitability and calculates the biodiversity.

To map the effects of REDD and to quantify the effect, a tool called GeOSIRIS was developed. Price of carbon, carbon emission and other economic parameters can be given as input to this modeler which then gives effective opportunity cost and a map of potential agricultural revenue and expected carbon emission with or without proposed REDD policy.

The outputs from the Land Change modeler or the Climate Change Adaption modeler can be used in the Ecosystem Services Modeler for assessing natural capital for sustainable development. It is a vertical application in Terrset that is useful in the study of

land change and conservation. The tools provided by this application are robust in a way that they help in the analysis of change that in turn assists in planning for that area [1]. The Climate Change Adaptation Modeler models future global sea level rise and future climate change along with suitability of crop for over 2700 species and species distribution.

Clark Labs developed an extension for Land Change Modeler for ArcGIS, Land Change Modeler v.2.0 for ArcGIS upon receiving funding for ESRI. [2]

3. Internship Work Responsibilities

3.1 About the project:

Clark Labs was contracted by Ecosystem Services team, Gordon and Betty Moore Foundation, Conservation International to prepare deforestation risk maps for globe, continents and countries. We researched about the potential drivers that affect deforestation. These drivers would serve as independent variables while the deforestation layer would be the dependent layer. The technique used was Multi-Layer Perceptron in Land Change Modeler in TerrSet.

We were provided with some of the variables and the tree cover images for 2000 (Figure 2) and 2014 (Figure 3) and rest of the data we procured or downloaded. The tree cover images were used as the land cover images for two time periods. The data that we downloaded was that of soil properties (Harmonized World Soil Database), above ground biomass (Figure 4), crop suitability data (Figure 5), Elevation data (Figure 7) from which slope was derived, the boundaries for globe, continents and countries, World Population, Biomes and Ecoregions.

Our task was to identify the drivers that affect the deforestation the most on global, continental and country-wise scale and prepare the deforestation risk maps for all the three levels.

3.2 Processing the data:

The modeler requires us to input two land cover images for earlier and later dates. We gave tree cover images for 2000 and 2014 as the inputs for earlier and later land cover images. Cross tabulation between these two images will yield us the information

about the change from tree-cover to no tree-cover. This can be used to create the change and the persistence maps which would help in creating the empirical likelihood with change and with persistence and further to create normalized likelihood for some of the variables. The Multi-Layer Perceptron (MLP) can be run for the continuous data only and thus normalized likelihood was calculated for the variables that were categorical and not continuous. Empirical Likelihood for change and empirical likelihood for persistence were calculated for computing normalized likelihood for the variables of soil, biomes, ecoregions, countries, states and provinces and protected areas. The original variables for soil, biomes, ecoregions, countries, states and provinces and protected areas were replaced by their respective normal likelihood variables and remaining variables were used as they were. There was a total of 24 variables and two land cover images. These variables were grouped together in a raster group file. The 24 variables were given as an input into the model's Multilayer Perceptron (MLP) within the modeler. Half of the pixels are set aside to be the testing pixels per class and the other half are the training pixels. MLP uses 50% of the pixels in testing. MLP was run with a different sample size of training pixels (i.e., 10000, 20000 and 50000) for 24 variables and then eliminating the least important variables. The skill measure was used to decide the importance of the variables. A table in excel was created to get a fair idea of most and least important variables. This exercise was done for all the three levels (i.e., global, continental and country level). Figure 1, shows how the variables are ordered and their skill measures. The most important variables that remained consistent with the number of run are in green cell. The second most important variables that remained consistent with the run are

in yellow cell and the least important variables that remained consistent with the number of run are in red cell. This way, we were able to decide for the driver variables that affected the deforestation. These excel sheets were made for the three levels of study.

	Skill	0.4322	0.4113	0.4029	0.4209	0.4021	0.4193	0.4163
	Skill change	0.5905	0.5425	0.5574	0.5521	0.5516	0.5563	0.6384
	Skill Persistance	0.2756	0.2789	0.247	0.2895	0.2518	0.2823	0.1922
		10000	20000	30000	10000	10000(18)	10000(18)2	20000(16)
Independent variable 1	AS_Distance_airports	11	12	7	12	10	11	2
Independent variable 2	As_Distance_railroads	6	16	2	11	2	3	5
Independent variable 3	AS_Distance_roads	14	23	16	20			
Independent variable 4	AS_Distance_trails	10	5	4	7	12	9	3
Independent variable 5	AS_Distance_urban_areas	15	11	12	16	14	15	12
Independent variable 6	AS_Elevation	7	7	10	10	11	8	9
Independent variable 7	AS_AGB	8	10	5	5	8	14	6
Independent variable 8	AS_Human_Influence_index	17	8	22	14	16	13	16
Independent variable 9	AS_Irrigation_Area	12	4	6	9	7	5	13
Independent variable 10	NL-AS_Protected_areas	21	22	19	21			
Independent variable 11	NL-AS_Soil_Depth	20	20	18	19			
Independent variable 12	NL-AS_Soil_Drainage	22	13	13	15	9	16	14
Independent variable 13	NL-AS_soil_pH	16	15	21	23			
Independent variable 14	NL-AS_soil_texture	18	21	17	17			
Independent variable 15	NL-AS_countries	9	14	9	4	6	6	11
Independent variable 16	AS_Opportunity_Cost	19	17	20	22			
Independent variable 17	AS_precipitation	3	3	8	6	13	10	15
Independent variable 18	AS_slope	5	6	3	8	3	7	7
Independent variable 19	AS_temperature_mean	4	2	14	3	4	4	8
Independent variable 20	AS_World_Population_2000	23	19	11	13	15	12	10
Independent variable 21	NL-AS_biomes	13	18	23	18			
Independent variable 22	NL-AS_Ecoregions	1	9	1	1	1	2	1
Independent variable 23	AS_Crop_Suitability	2	1	15	2	5	1	4

Figure 1: Variables and their importance with various runs

Below are the images for the two land-cover images that were used in the Land Change model as the earlier and the later images.

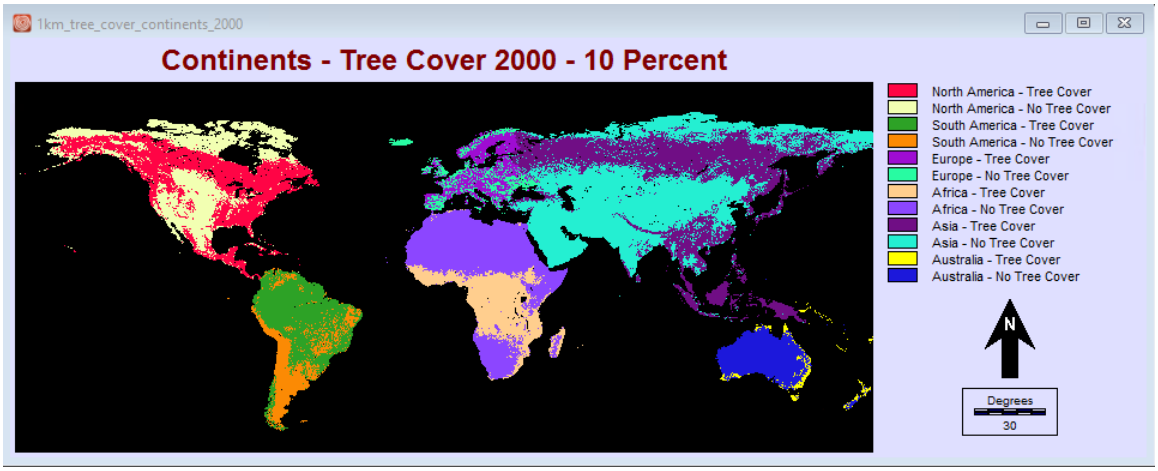

Figure 2: 10 percent Tree Cover for the year 2000

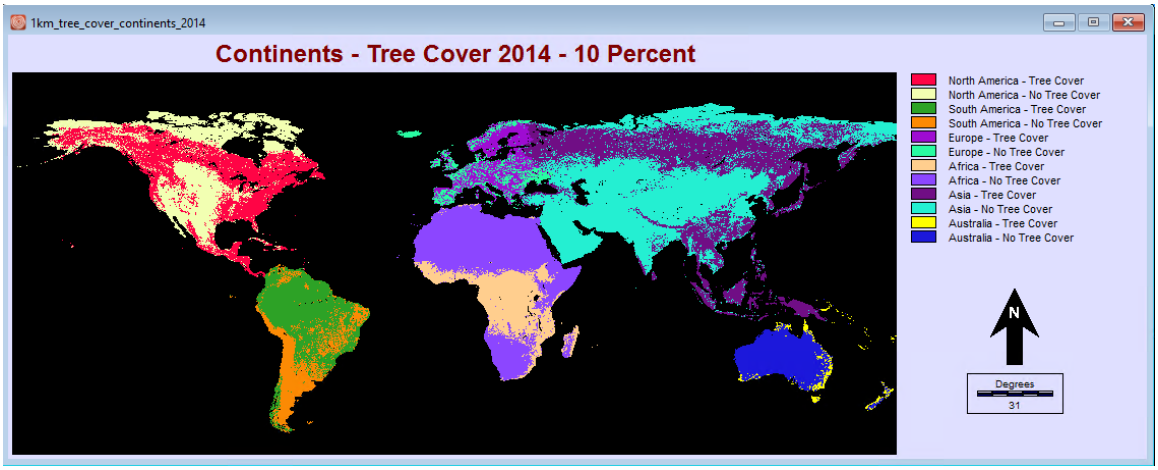

Figure 3: 10 percent Tree Cover for the year 2014

Below are some of the 24 drivers that were selected for the study.

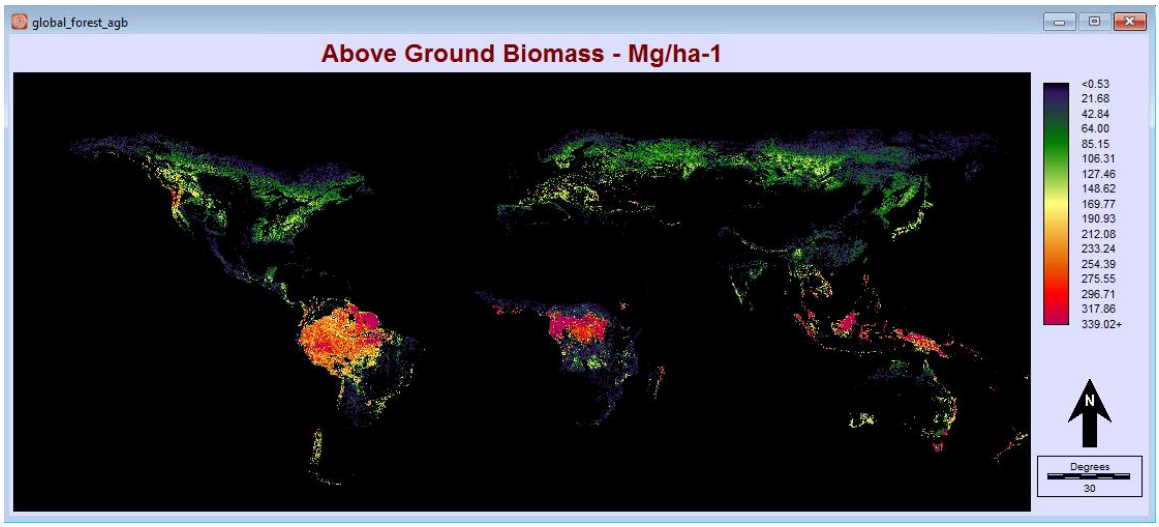

Figure 4: Above Ground Biomass for globe

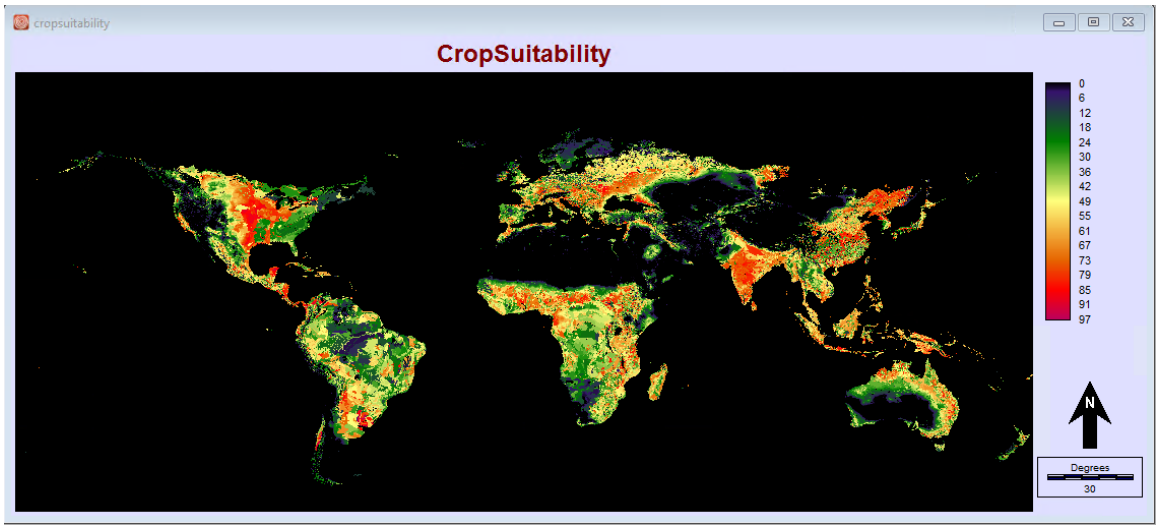

Figure 5: Crop Suitability for globe

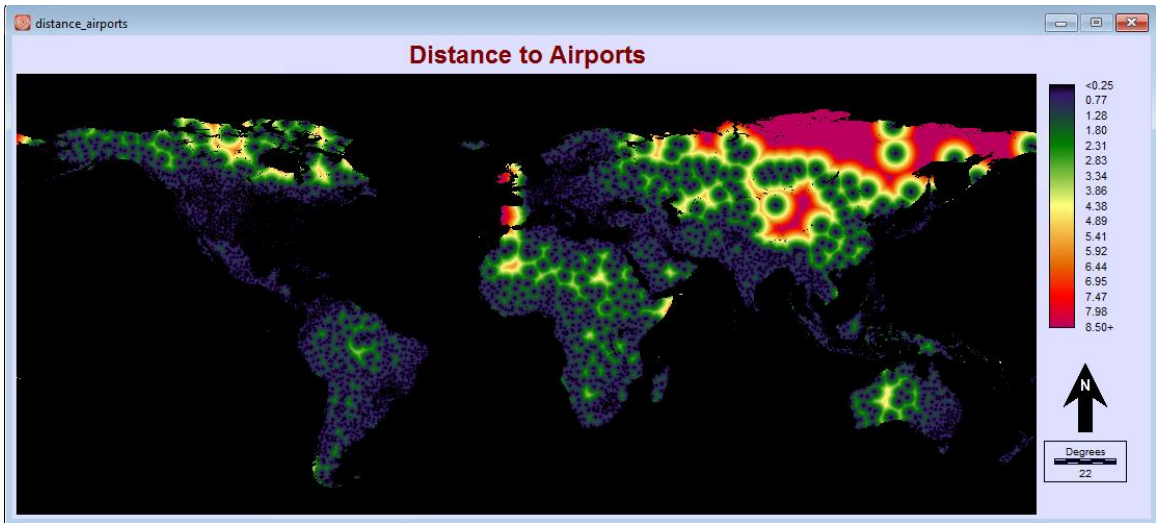

Figure 6: Distance to Airports for globe

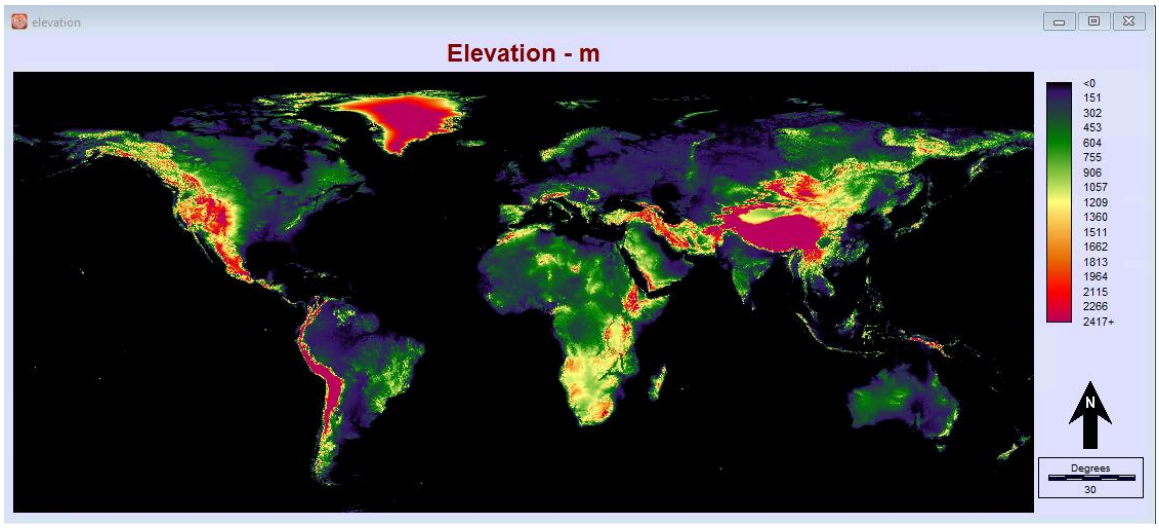

Figure 7: Elevation for globe

After the MLP is run for the three levels, what is obtained is the transition potential images. Below are the figures depicting the transition potential images.

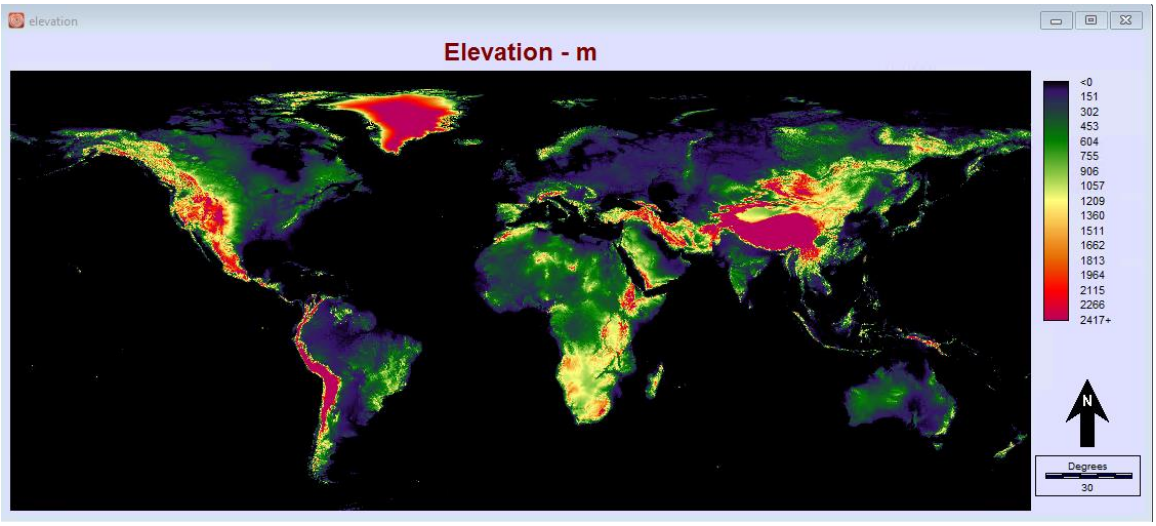

Figure 8: Transition Potential image for globe

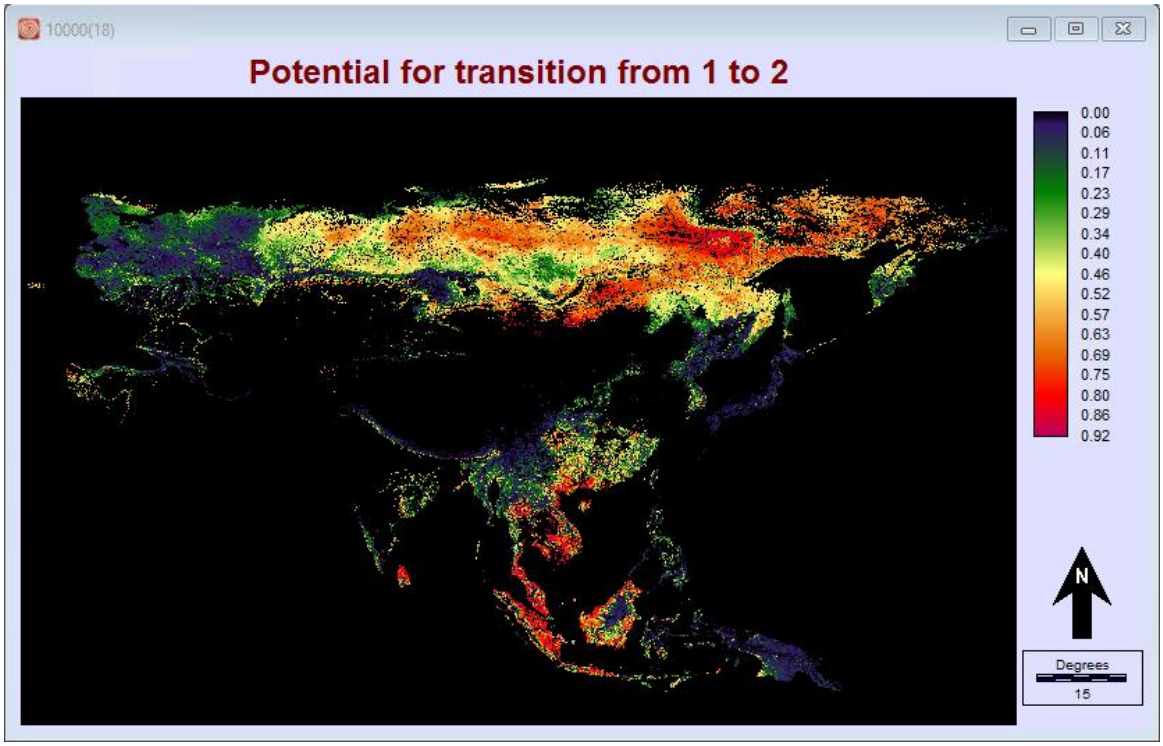

Figure 9: Transition Potential image for continent- Asia

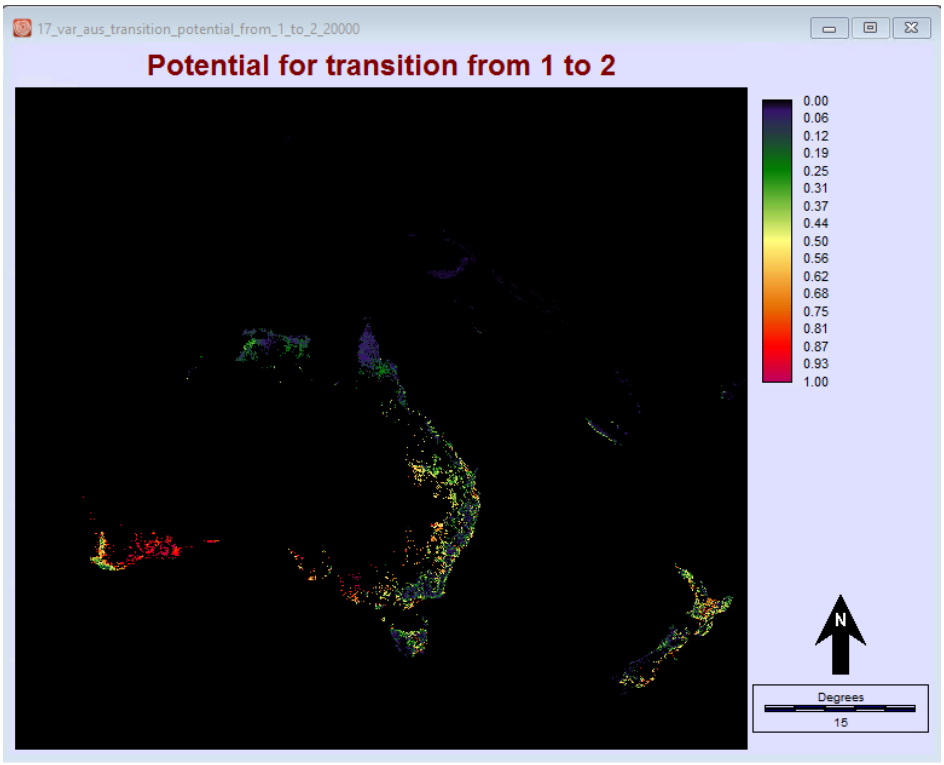

Figure 10: Transition Potential image for continent- Oceania

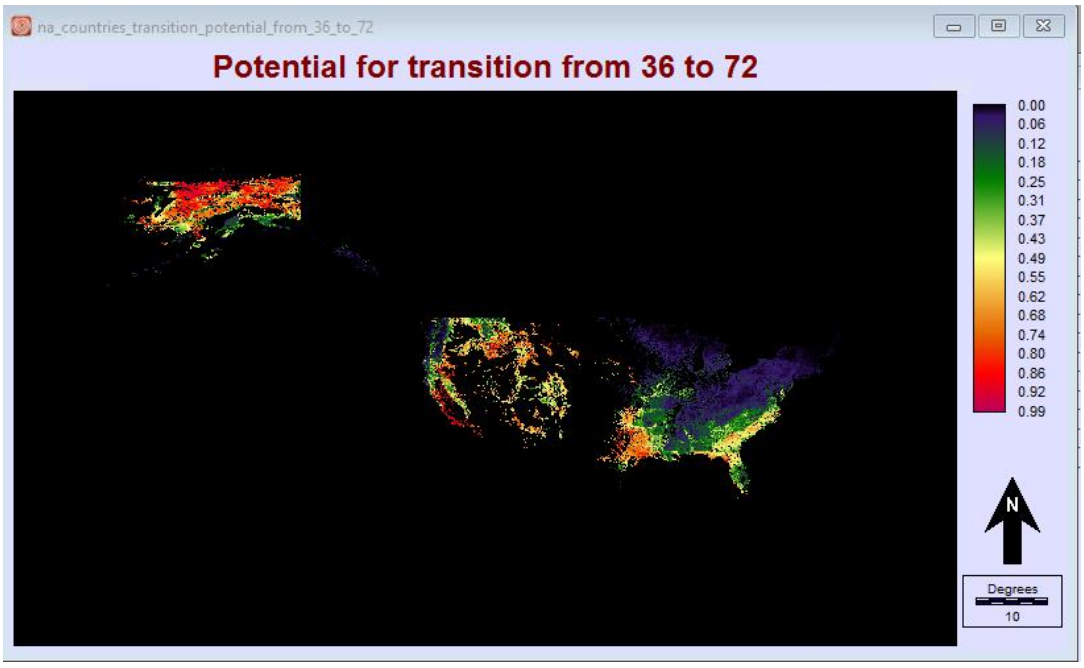

Figure 11: Transition Potential image for country-USA

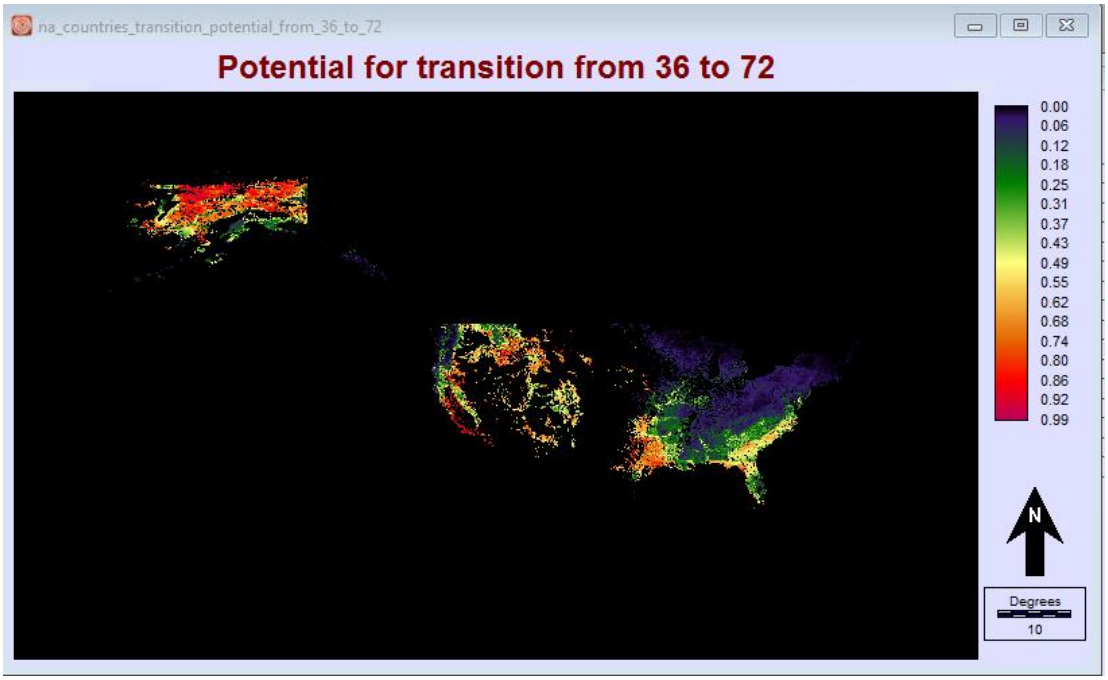

Figure 12: Transition Potential image for country-Brazil

4. Internship Assessment

4.1 Tianze Li

The internship in Clark Labs during this summer was a fantastic and invaluable experience for me. Not only because the skill I learned and practiced, but learning how to be a professional analyst. This internship required some basic GIS and Remote Sense knowledge and skills. More important, it required the ability to solve the problem without the prior knowledge.

During this almost four-month internship, I learned all the basic steps and requirements for doing the analysis. For example, preparing the data is the basic and necessary skill that any analyst needs to have. Where could I find data? What data could I use? How to organize data before analyzing? For my task during the internship, I needed to prepare 24 variables for MLP. Some of the variables, such as slope, elevation, I only needed to reproject while keeping a record of the website that was used to download the data. For some variables, such as crop suitability, human influence index and opportunity cost, there aren't any official websites that provide the data but some people did similar research and upload their result on a website. Some variables, such as distance to the airport (Figure 6) or distance railroads, I need to create them depending on some original data such as railroads. Another very import part is evaluating the results. Because our methodology has some random element influence, the result was different every time I run the analysis. After comparing the result by skill, skill change, skill persistence and accuracy, one was chosen as the final result. And finally, I also needed to organize all the data in the same format in order to use it.

The internship is mainly related to four major courses: Introduction to Remote Sensing, Advance Raster, introduction to Geographic Information System and international development. I used a lot of knowledge and skills that I learned in those courses. Especially, I learned the theory about MLP which is the main methodology I used.

It was also a good opportunity to deepen the understanding of how to use our knowledge to solve problems and learn some new functions in Terrset and ArcGIS. Because our task was to predict global deforestation, due to an excessive number of features displaying was a problem. For example, there are more than 20 thousand features in protected area image. Therefore, I used a function that exists in both ArcGIS and Terrset to create pyramid which helps in increasing the speed a lot.

I did not have much working experience before. Although I had GIS related knowledge and skills, I did not know what I could do for a real task. This internship gave me a chance to solve specific problems and let me realize what will I do in the future. I really enjoyed the process of discovery and learned new things that finally helped me solve the problem.

For those who want to practice GIS and RS skill within Terrset and ArcGIS environment, I really recommend this internship. And people is Clark Labs are really nice. They will answer any questions you ask. We also have International Food Festivals during the summer where in you can try food from all over the world. Clark Labs allows students to schedule their own stable working time too.

4.2 Yashee Joshi

The internship in Clark Labs has been a great journey. It varied from doing a hard core raster GIS related project to making great relations with staff. A happy place is always a better place to work, and Clark Labs is one happy place. With everybody well immersed into GIS, there were so many ways to approach a problem. This gives me a broader perspective of troubleshooting.

Since we were dealing with various datatypes, I believe I have gotten better in data handling. Since I already am skilled with GIS and Remote Sensing, what was to learn was specifics of modeler and tool that we were working with. The Advanced Raster GIS class taken during the second semester proved to be of great help. I learned data extraction and processing. Our instructor Stefano Creama was a great resource. He taught us the specifics of the system when dealing with bulky data as we had to georefernce, resample and reclass a number of times. As our software of choice was TerrSet, we did not learn anything new about other softwares but did perfect the skills in TerrSet. We had to constantly recheck our results. This is because we were dealing with different variables for different levels. There was a constant back and forth with eliminating variables if there was any doubt on the results. There were many occasions when we would find our results wrong days after. We went back and corrected and re-ran the modeler from the start. This internship has also taught a lot of patience!

Skills that came handy in the internship were raster data handling and GIS that we had learned in class.

I would surely recommend this internship to other IDCE/GISDE students. The internship requires independent work and brainstorming about the projects. Students interested in land change can keep looking for internships here. They have great projects with great companies and institutes. There is a freedom for students to work as they like, bring up their own ideas and set their own working schedule. They will be exposed to multi -cultural environment which is something to cherish. Professor Eastman and the people working in the lab are extremely warm.

5. Conclusions

Our internship with Clark Labs this semester was really a great experience. We learned a lot of troubleshooting tricks. Prior knowledge of the software and GIS as a subject came handy in this period. We got an opportunity to deepen our understanding about TerrSet and its Land Change Modeler. We acquired an important skill, that is dealing with data transfers between Terrset and ArcGIS. This is confusing for many GIS people. The results of our internships were finally presented by our supervisor, Stefano Crema, in a meeting with Conservation International in Washington-DC. This is really exciting and makes us proud. We also had (and continue to have!!) a fantastic social life there. So many professional and nice people helped us not only for our work but also for our daily life and future career plans. We are very thankful to Professor Eastman for providing us with this great opportunity and we recommend this internship opportunity to future students as well.

6. Literature

[1] Clark Labs, 2015. Clark Labs | Geospatial Software for Monitoring and Modeling the Earth System [online]. Clark Labs. Available from: http://www.clarklabs.org [Accessed September 2016].

[2] Ron Eastman (2015). Terrset Help Document. Clark Labs. (https://clarklabs.org/)