Automated identification of natural and cultivated vegetation based on LiDAR-derived image texture

Randall (Sky) Jones

Faculty Adviser: Dr. Henrique Momm

Introduction

Natural vegetation is fundamental to the health of any watershed; it filters sediment and nutrients from runoff, stabilizes stream banks, controls sediment erosion, shades and cools water, and provides habitat and food for a diverse array of terrestrial organisms. On the other hand, cultivated vegetation can be a poor soil stabilizer, provides limited habitat and implies the application of potentially detrimental pesticides, herbicides and fertilizers. Because of this, rapid and accurate quantification of both the extent and character of vegetation in a watershed is of great interest to hydrologists, watershed planners, agronomists and other stakeholders.

The advent of aerial and satellite imagery has been crucial in allowing rapid characterization of vegetation strictly based on spectral information. However, the limited spectral characteristics of sensors with high spatial resolution have suboptimal ability to distinguish between natural and cultivated vegetation, which may have similar spectral signals despite having obviously different spatial arrangements. Some more comprehensive techniques use zonal properties to quantify “textural” (locally aggregated) information, allowing investigators to use incorporate spatial statistics into their land use predictions.

In this study, I propose a new vector-based method to distinguish natural and cultivated vegetation in a semi-automated fashion. By evaluating the linearity of clusters of vegetation, an “orderedness index” can be calculated and therefore used to classify whether vegetation is natural or cultivated. The purpose of this project is to explore the optimal implementation of this technique, its effectiveness compared to other techniques, and its general limitations. While natural vegetation is highly irregular, cultivated vegetation is expected to show a high degree of linearity due to the regular planting patterns preferred by producers. This strategy has the advantage of requiring only LiDAR datasets as input.

Background

Spectral methods have dominated landcover classification schemes ever since aerial and satellite imagery became widely available, and the bulk of published schemes are spatially and temporally agnostic. That is, the schemes consider only the pixel-based spectral signals received and ignore the variations surrounding those pixels. More recently, investigators have made attempts to integrate spatial variation (Momm, 2009), time variation (Bargiel, 2011) and both spatial and temporal variation (Zhai, 2018) in order to improve landcover classification, particularly vegetation classification. These techniques greatly improve landcover classification, but generally require high resolution multispectral imagery and training of supervised machine learning algorithms, which limits its general applicability beyond the study site.

While spectral methods are based on multi-channel raster grids, LiDAR data consists of three-dimensional point clouds usually collected from an airplane. Each point is described by a series of attributes in additional to spatial coordinates. LiDAR-based methods have been used for landcover classification (Helmer, 2008), and LiDAR-spectral composite methods have been proposed as well (Sturari, 2017). Like spectral methods, LiDAR methods typically require training a supervised machine learning algorithm.

Both LiDAR and spectral methods have difficulty in explicitly capturing spatial variation, particularly spatial entropy. Even image-based textural methods that create aggregate statistics based on neighboring pixels are agnostic to the arrangement of the pixels, and most contemporary measure of image entropy/disorder do not accurately capture spatial disorder (Razlighi, 2009). This presents a problem when attempting to differentiate natural and cultivated vegetation, which sometimes varies primarily based on spatial arrangement.

Because of this, a spatially-capable algorithm would be of great use for hydrologists, watershed planners, agronomists and anyone else interested in quantifying crop and vegetation impact in a watershed. Such an algorithm would only require inputting the locations of vegetation, rather than a multilevel array of data derivatives, allowing accurate classification of locations where high-resolution spectral data is unavailable or too costly to acquire. General vegetation identification is a well-studied problem, and herbaceous vegetation and even individual trees can be identified with simple color imagery or LiDAR (Chang, 2013).

It is interesting to note that at least some exploration of land use classification using lacunarity measures has been done (Myint, 2006). Lacunarity is variously described as a measure of "gappiness", rotational invariance or heterogeneity. Though lacunarity-only classification has mixed accuracy, its ability to quantify heterogeneity (order) may be of interest to this project. It has not been applied directly to differentiating natural and cultivated vegetation, and the measure is not spatially explicit, but it may be explored further in this project since measures of lacunarity are unopinionated about pattern shapes, while the proposed method is.

I have an extensive background with environmental modeling, with projects that range from a fuzzy-logic based sedimentation model to a Python package for analyzing and designing stream restoration projects. I also worked for three years at an environmental consulting firm where I designed and implemented a machine learning models to predict locations and qualities of potential stream and wetland restoration projects.

Purpose

The goal of this project is to develop a set of instructions (an algorithm) that can be used to distinguish natural vegetation from cultivated vegetation <u>purely on the basis of its spatial relationship to other vegetation.</u> Thus, the project will entail testing different aspects of the proposed methods, quantifying its predictive power, and comparing the results to spectral-based techniques. If possible, it would be desirable to produce a Python package the implements this algorithm, making it available to a wide audience.

Methods

Identifying vegetation using LiDAR-derived digital height models (DHMs) is well-studied, and not the focus of this project. Rather, this project is focused on using the relative spatial arrangement of vegetation to classify it as natural or cultivated. To explore this, a study area in middle Tennessee has been selected. The study area encompasses an apple orchard, a natural forest, and an area of cultivated coniferous trees. By using a digital height model derived from a LiDAR dataset, individual tree canopies can be identified.

Once tree locations are identified, the proposed method to identify a given tree as natural or cultivated is as follows: find all other trees within a certain radius. Then, use a clustering algorithm to identify natural groups of trees. Finally, find the line that best fits each cluster, and use each tree's deviation from its cluster's line to determine if the cluster is irregular or linear. Linear clusters imply the tree is cultivated (rows of trees in an order), while irregular clusters imply that the tree is natural. Techniques such as hierarchical clustering and stochastic optimization may be used within the model and to adjust model parameters.

The proposed method is noteworthy because it takes into explicit consideration the spatial arrangement of vegetation, in contrast to the non-spatial spectral methods that currently dominate landcover classification schemes. If this method proves successful in the proposed study area, then it might also be applied to herbaceous vegetation, which shows a similar spatial dichotomy between row crops and natural herbaceous vegetation. Other methods such as spatial entropy and lacunarity-based analyses may also be explored as they are currently understudied for the purpose of vegetation classification.

Mentor Collaboration

Dr. Henrique Momm will be my mentor for this project. We are already collaborating together on a project that is focused on the identification of riparian vegetation using LiDAR-derived datasets. While working on this project, we realized that our model was unable to differentiate natural and cultivated vegetation which limited the model's effectiveness. This proposed project, though separate from our ongoing work, would be able to address this limitation. Dr. Momm and I already have ongoing weekly meetings where we discuss the status of our work. Because Dr. Momm had a critical role in developing the texture-base methods discussed elsewhere in this proposal, he is well-suited to advise on the proposed project.

Previous URECA Projects

This proposal differs significantly from past URECA projects. No previous URECA projects have involved the analysis of remotely sensed data, and projects in the earth and environmental science have been scarce in past years. Of the past earth and environmental science projects, none investigated land use classification schemes or spatially explicit algorithms.

Citations

Bargiel, Damian, and Sylvia Herrmann. "Multi-Temporal Land-Cover Classification of Agricultural Areas in Two European Regions with High Resolution Spotlight TerraSAR-X Data." *Remote Sensing*, vol. 3, no. 5, 2011, pp. 859–877., doi:10.3390/rs3050859.

Chang, Anjin, et al. "Identification of Individual Tree Crowns from LiDAR Data Using a Circle Fitting Algorithm with Local Maxima and Minima Filtering." *Remote Sensing Letters*, vol. 4, no. 1, 2013, pp. 29–37., doi:10.1080/2150704x.2012.684362.

Helmer, Eileen H. "Mapping Land Cover and Estimating Forest Structure Using Satellite Imagery and Coarse Resolution Lidar in the Virgin Islands." *Journal of Applied Remote Sensing*, vol. 2, no. 1, Jan. 2008, doi:10.1117/1.3063939.

Momm, H.g., et al. "Evaluation of the Use of Spectral and Textural Information by an Evolutionary Algorithm for Multi-Spectral Imagery Classification." *Computers, Environment and Urban Systems*, vol. 33, no. 6, 2009, pp. 463–471., doi:10.1016/j.compenvurbsys.2009.07.007.

Myint, Soe W., et al. "Urban Textural Analysis from Remote Sensor Data: Lacunarity Measurements Based on the Differential Box Counting Method." *Geographical Analysis*, vol. 38, no. 4, 2006, pp. 371–390., doi:10.1111/j.1538-4632.2006.00691.x.

Razlighi, Q. R., and N. Kehtarnavaz. "A Comparison Study of Image Spatial Entropy." *Visual Communications and Image Processing 2009*, 2009, doi:10.1117/12.814439.

Sturari, Mirco, et al. "Integrating Elevation Data and Multispectral High-Resolution Images for an Improved Hybrid Land Use/Land Cover Mapping." *European Journal of Remote Sensing*, vol. 50, no. 1, 2017, pp. 1–17., doi:10.1080/22797254.2017.1274572.

Zhai, Yongguang, et al. "Land Cover Classification Using Integrated Spectral, Temporal, and Spatial Features Derived from Remotely Sensed Images." *Remote Sensing*, vol. 10, no. 3, Jan. 2018, p. 383., doi:10.3390/rs10030383.

Department of Geosciences
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MIDDLE TENNESSEE STATE UNIVERSITY

September 4, 2019

RE: URECA Fall 2019 Application

Dear Sir or Madam,

I have known Sky Jones since May 2019 as a student worker in an ongoing research project. Sky and I worked closely over the summer in developing algorithms and methods for classify and characterize riparian vegetation in a semi-automated fashion with the ultimate goal of supporting watershed modeling of non-point source sources and sinks. Over this short period of time, Sky has demonstrated he has strong skillset in computer programming, data analysis, and has developed understanding of machine learning methods and techniques.

This undergraduate research experience will further develop his skillsets in computer programming, GIS, remote sensing, and data analysis. I believe Sky has also the opportunity to present findings of this project in scientific/professional conferences and potentially document it as peer-reviewed manuscript depending on the outcome.

I truly enjoyed my interactions with Sky as a student worker. Sky has a positive attitude, demonstrated critical thinking, and strong work ethics. I strongly recommend Sky for this funding opportunity. If you require any further information with regards to Sky's suitability for this project please do not hesitate to contact me.

Sincerely,

Henrique Momm
Associate Professor & Interim Chair
Department of Geosciences
Middle Tennessee State University
henrique.momm@mtsu.edu and 615-904-8378

Timeline

9/9/19: Download study area data, generate canopy model, vectorize tree locations and type

9/16/19: Build prototype model, explore effectiveness

10/14/19: Explore alternate methods (lacunarity)

11/11/19: Compare new models against existing models

1/13/20: Formal validation, begin working on paper for publication and Python package

2/13/20: Explore integration of new method with existing (spectral, LiDAR) methods

3/30/20: Publish Python package, send paper for review

5/15/20: Project finished, including URECA documentation

Sky Jones

416 2nd Avenue, Murfreesboro, TN, 37130
rsajones94@gmail.com • +1 (919) 621-9137 • linkedin.com/in/RandallSAJones

PROFESSIONAL EXPERIENCE

Remote Sensing Research Assistant

- Middle Tennessee State University, Department of Geosciences — Jun 2019 – Present
  - Conducted research related to the automated characterization of riparian vegetation using LiDAR

Environmental Scientist II

- KCI Technologies, Inc. — Dec 2018 – May 2019
  - Managed interns during field data collection
  - Created technical designs and plans for stream restoration and bank stabilization projects

Environmental Scientist I

- KCI Technologies, Inc. — Oct 2016 – Dec 2018
  - Planned and performed field work for stream and wetland restoration, dam removal and stormwater design projects
  - Prepared technical reports for clients
  - Designed computational models to analyze stream morphology and surface hydrology and provided CAD and GIS support
  - Developed scripts and software in R and Python to automate data analysis and aid stream design

Engineering Intern

- KCI Technologies, Inc. — May 2016 – Oct 2016
  - Collected and evaluated environmental data for stream and wetland restoration sites and prepared reports
  - Created R scripts that increase data analysis accuracy and cut up to 10 hours from report preparation per project

EDUCATION

Middle Tennessee State University

- Post-Baccalaureate Undergraduate, Biochemistry — Jun 2019 – Present

The University of North Carolina at Chapel Hill

- Bachelor of Science in Geology – with Distinction — Sep 2012 – May 2016
  - Cumulative GPA: 3.67

SELECTED PROJECTS

pyfluv

- Independent Project — Dec 2018 – May 2019
  - Designed a Python package for the analysis of fluvial geomorphology with a focus on stream restoration
  - Implemented both standard analyses as well as novel algorithms designed to facilitate metanalyses of previously collected data as well as the processing of data that is collected remotely (e.g., via LiDAR)

KCI Geoengine

- KCI Technologies — Feb 2018 – May 2019
  - Designed a web mapping application that automatically identifies potential stream and wetland restoration projects across North Carolina using remotely collected data
  - Acquired $27,000 in internal funding
  - Hired and managed an employee to assist with project
  - Provided multi-department training in the use of the final application

Quantitative Prediction of Clastic Sequence Stratigraphy

- Undergraduate Research — Fall 2014 – Summer 2016
  - Overhauled and maintained a fuzzy logic based MATLAB program used to simulate deltaic deposition
  - Added over 40 major features that improve quality of output, runtime and ease of use
  - Presented at the 2016 Anadarko Research Symposium and 2016 UNC Climate Change Symposium

SKILLS

- Software and Programming Languages
  - Python, R, Microstation, AutoCAD, ArcGIS (including ArcPy and Model Builder), SQL, MATLAB, ENVI, Advanced Excel (including VBA programming)
- Technical
  - Stream and wetland assessments (morphology, hydrology, hydraulics and biology), remote sensing, CAD drafting, GIS, watershed analysis, cartography, scientific programming and modeling, surveying, GPS data collection

PRESENTATIONS

PYFLUV: A Python Module for Subwatershed Scale Fluvial Analysis

- Professional oral presentation, TN Water Resources Symposium — Mar 2019

Modeling the Geologic Response of Climate Belt Migration with Fuzzy Logic

- Student poster, UNC Climate Change Symposium — Apr 2016

Semiquantitative Prediction of Deltaic Sequence Stratigraphy Using fuzzyPEACH

- Student poster, UNC Anadarko Research Symposium — Apr 2016

ACADEMIC AWARDS

- Martin L. Stout Scholar (*Association for Environmental and Engineering Geologists*) — 2016
- Roy L. Ingram Field Camp Scholar (*UNC*) — 2015

LICENSES & CERTIFICATIONS

- TN Geologist-in-Training
- TN Qualified Hydrologic Professional In-Training
- Rosgen Level I

VOLUNTEERING

Animal Therapy

- Vanderbilt and St. Thomas Rutherford Hospitals — Jun 2019 – Present
  - Visited adult and pediatric patients in multiple departments with my registered therapy dog

Adult Inpatient Visitation

- Vanderbilt Hospital — Oct 2018 – Jun 2019
  - Visited patients in the surgical and neurological units
  - Distributed reading materials, board and card games, and other small items
  - Played games and chatted with patients who wanted to

Animal Obedience Instruction and Ring Stewarding

- Nashville Dog Training Club — Jun 2018 – Present
  - Assisted with beginner obedience, Canine Good Citizen and therapy dog training classes
  - Set up, broke down and helped run rally, obedience and agility trials

Academic Transcript

This is not an official transcript. Courses which are in progress may also be included on this transcript.

Special grades to note are:
FA = Failure and stopped attending
T_ = Transfer grades with leading "T" are not calculated in the overall and overall combined GPAs, but do count in the lottery GPA. Leading “T” grades were started Summer 2015 for new undergraduate transfer credits regardless of the term the course was completed.
X = Grade not submitted by course instructor and not used in calculating grade point average until final grade submitted by instructor

The repeat indicator column denoted by an "R" after the Quality Points column translates as follows:
E = Excluded from GPA and Earned Hours
A = Included in GPA, but not Earned hours
I = Included in GPA and Earned Hours
F = Frozen and exempt from repeat processing (i.e., repeatable courses)
. = Excluded from GPA and Earned Hours – Academic Fresh Start

Note: Additional information about all grades and repeats are available in the University Catalog

Click here to Print Unofficial Transcript (Chrome and FireFox Only)

Institution Credit   Transcript Totals   Courses in Progress

Transcript Data

STUDENT INFORMATION

Student Type:	Continuing

Curriculum Information

Current Program

Bachelor of Science	
College:	Basic and Applied Sciences
Major and Department:	Biochemistry, Chemistry

***Transcript type:Advising-Unofficial Transcript is NOT Official ***

PRE-SYSTEM TRANSFER SUMMARY HOURS -Top-

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Total:	132.000	132.000	141.000	132.000	485.400	3.677

Unofficial Transcript

INSTITUTION CREDIT -Top-

Term: Summer 2019

College:	Basic and Applied Sciences
Major:	Biochemistry
Student Type:	New Transfer
Academic Standing:	Good Standing

Subject	Course	Level	Title	Grade	Credit Hours	Quality Points	R	CEU Contact Hours
BIOL	1120	UG	General Biology II	A	4.000	16.000		
CHEM	3010	UG	Organic Chemistry I	A	4.000	16.000		

Term Totals (Undergraduate)

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Current Term:	8.000	8.000	8.000	8.000	32.000	4.000
Cumulative:	8.000	8.000	8.000	8.000	32.000	4.000

Unofficial Transcript

TRANSCRIPT TOTALS (UNDERGRADUATE) -Top-

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Total Institution:	8.000	8.000	8.000	8.000	32.000	4.000
Total Transfer:	132.000	132.000	141.000	132.000	485.400	3.677
Overall:	140.000	140.000	149.000	140.000	517.400	3.696

	Attempt Hours	Passed Hours	Earned Hours	GPA Hours	Quality Points	GPA
Institution Combined:	8.000	8.000	8.000	8.000	32.000	4.000
Transfer Combined:	132.000	132.000	141.000	132.000	485.400	3.677
Overall Combined:	140.000	140.000	149.000	140.000	517.400	3.696

Unofficial Transcript

COURSES IN PROGRESS -Top-

Term: Fall 2019

College:	Basic and Applied Sciences
Major:	Biochemistry
Student Type:	Continuing

Subject	Course	Level	Title	Credit Hours
CHEM	3020	UG	Organic Chemistry II	4.000
CHEM	4500	UG	Biochemistry I	3.000
PHYS	2021	UG	Physics Problems Laboratory II	4.000
PSY	1410	UG	General Psychology	3.000

Unofficial Transcript

RELEASE: 8.7.1 PROD - SSBPROD1

Seq Nbr: 1

ID: 720331195 RANDALL JONES

Internal Unofficial Transcript - UNC Chapel Hill

```
Name       :  RANDALL JONES
Student ID:  720331195
Print Date   :  2016-06-23
```

- - - - - Degrees Awarded - - - - -

```
Degree        :  Bachelor of Science
Confer Date   :  2016-05-08
Degree Honors :  Distinction
Plan          :  College of Arts and Sciences
                 Geological Sciences (BS)
Sub-Plan      :  Geological Sciences (BS): Earth Science
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- - - - - Transfer Credits - - - - -

Transfer Credit from East Carolina University

Applied Toward AS Bachelor of Science Program

2015 Fall

```
GEOL      601      SUMMER FIELD COURSE IN GEOLOGY    3.00     3.00 TR
GEOL      602      SUMMER FIELD COURSE IN GEOLOGY    3.00     3.00 TR
  Course Trans GPA:     0.000  Transfer Totals :      6.00     6.00           0.000
```

- - - - - Test Credits - - - - -

Test Credits Applied Toward AS Bachelor Program

2012 Fall

```
MATH      110P     ALGEBRA                                     0.00 BE
MATH      110P     ALGEBRA                                     0.00 BE
     Repeated     : Repeat
MATH      130P     PRECALCULUS MATHEMATICS                     0.00 BE
MATH      231      CALC FUNC ONE VAR I                3.00     3.00 BE
    Test Trans GPA:     0.000  Transfer Totals :      3.00     3.00           0.000
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- - - - -   Academic Program History   - - - - -
Program     :  AS Bachelor
2012-05-30  :  Active in Program
               2012-05-30 : Undecided Major
2013-07-17  :  Active in Program
               2013-07-17 : Environmental Sciences Major
               2013-07-17 : Philosophy Second Major
               2013-07-17 : Physics Minor Minor
Program     :  AS Bachelor of Science
2014-01-08  :  Active in Program
               2014-01-08 : Environmental Sciences Major
               2014-01-08 : Philosophy Second Major
               2014-01-08 : Physics Minor Minor
2014-03-26  :  Active in Program
               2014-03-26 : Environmental Sciences Major
               2014-03-26 : Geological Sciences (BS) Second Major
2014-09-11  :  Active in Program
               2014-09-11 : Geological Sciences (BS) Major
               2014-09-11 : Geological Sciences (BS) Second Major
2014-09-11  :  Active in Program
               2014-09-11 : Geological Sciences (BS) Major
2015-10-05  :  Active in Program
               2015-10-05 : Geological Sciences (BS) Major
               2015-10-05 : Philosophy Minor Minor
2016-04-04  :  Active in Program
               2016-04-04 : Geological Sciences (BS) Major
```

- - - - - Beginning of Undergraduate Record - - - - -

2012 Fall

ANTH	92	UNITAS	3.00	3.00	A	12.000
BIOL	101	PRINCIPLES OF BIOL	3.00	3.00	A	12.000
BIOL	101L	INTRO BIOLOGY LAB	1.00	1.00	B	3.000
ENGL	105	ENG COMP & RHETORIC	3.00	3.00	A-	11.100
GERM	101	ELEMENTARY GERMAN	4.00	4.00	A	16.000
PHIL	110	INTRO: GREAT WORKS	3.00	3.00	B+	9.900
	TERM GPA :	3.765 TERM TOTALS :	17.00	17.00		64.000
	CUM GPA :	3.765 CUM TOTALS :	17.00	20.00		64.000

Dean's List
Good Standing

2013 Spr

ANTH	93	UNITAS	3.00	3.00	A-	11.100
COMP	110	INTRO PROGRAMMING	3.00	3.00	A	12.000
GERM	102	ADV ELEMENTARY GERMAN	4.00	4.00	B	12.000
LFIT	107	LIFE FITNESS: INT JOGGIN	1.00	1.00	A	4.000
PHIL	155	INTRO MATH LOGIC	3.00	3.00	A-	11.100
POLI	130	INTRO TO COMP POLI	3.00	3.00	B	9.000
	TERM GPA :	3.482 TERM TOTALS :	17.00	17.00		59.200
	CUM GPA :	3.624 CUM TOTALS :	34.00	37.00		123.200

Good Standing

2013 Sum I

CHEM	101	GEN DESCRIP CHEM I	3.00	3.00	A-	11.100
CHEM	101L	QUANT CHEM LAB I	1.00	1.00	A-	3.700
	TERM GPA :	3.700 TERM TOTALS :	4.00	4.00		14.800
	CUM GPA :	3.632 CUM TOTALS :	38.00	41.00		138.000

Good Standing

2013 SumII

CHEM	102	GEN DESCRIP CHEM II	3.00	3.00	A-	11.100
CHEM	102L	QUANT CHEM LAB II	1.00	1.00	A-	3.700
	TERM GPA :	3.700 TERM TOTALS :	4.00	4.00		14.800
	CUM GPA :	3.638 CUM TOTALS :	42.00	45.00		152.800
		Good Standing				

2013 Fall

ENST	201H	ENVIRONMENT AND SOCIETY	4.00	4.00	B+	13.200
ENST	222	ESTUARINE PROCESSES	4.00	4.00	B+	13.200
GERM	203	INTERMEDIATE GERMAN	3.00	3.00	A-	11.100
MATH	232	CAL FUNC ONE VAR II	3.00	3.00	C	6.000
PHYS	116	MECHANICS	4.00	4.00	B	12.000
	TERM GPA :	3.083 TERM TOTALS :	18.00	18.00		55.500
	CUM GPA :	3.472 CUM TOTALS :	60.00	63.00		208.300
		Good Standing				

2014 Spr

ENST	203	ENVIRON PROBLEM SOLVING	3.00	3.00	A-	11.100
GEOL	101L	INTRODUCTORY GEOL L	1.00	1.00	A	4.000
GEOL	110	EARTH/CLIMATE SCI MAJORS	3.00	3.00	A	12.000
HIST	107	MEDIEVAL HISTORY	3.00	3.00	A	12.000
MASC	460	ENVIRON FLUID DYNAMICS	3.00	3.00	A	12.000
MATH	233	MULTI VARI CALC I	3.00	3.00	A	12.000
	TERM GPA :	3.944 TERM TOTALS :	16.00	16.00		63.100
	CUM GPA :	3.571 CUM TOTALS :	76.00	79.00		271.400
		Dean's List				
		Good Standing				

2014 Sum I

MATH	383	1ST COURSE DIFF EQUATION	3.00	3.00	A-	11.100
	TERM GPA :	3.700 TERM TOTALS :	3.00	3.00		11.100
	CUM GPA :	3.576 CUM TOTALS :	79.00	82.00		282.500
		Good Standing				

2014 SumII

Withdrew : 2014-06-23

2014 Fall

GEOL	301	EARTH MAT: MINERALS	4.00	4.00	A-	14.800
GEOL	395	RESEARCH IN GEOLOGY	3.00	3.00	A	12.000
GEOL	401	STRUCTURAL GEOLOGY	4.00	4.00	A	16.000
GEOL	520	DATA ANALYSIS	3.00	3.00	A	12.000
	TERM GPA :	3.914 TERM TOTALS :	14.00	14.00		54.800
	CUM GPA :	3.627 CUM TOTALS :	93.00	96.00		337.300
		Good Standing				

2015 Spr

GEOL	402	INTRO SED AND STRAT	4.00	4.00	B	12.000
GEOL	404	PETROL & PLATE TECTONICS	4.00	4.00	A	16.000
GEOL	512	GEOCHEMISTRY	3.00	3.00	B	9.000
MUSC	142	GREAT MUSICAL WORKS	3.00	3.00	A	12.000
	TERM GPA :	3.500 TERM TOTALS :	14.00	14.00		49.000
	CUM GPA :	3.610 CUM TOTALS :	107.00	110.00		386.300
		Dean's List				
		Good Standing				

2015 Fall

ENGL	146	SCIFI/FANTASY/UTOPIA	3.00	3.00	A-	11.100
GEOL	483	APPLICATIONS OF GIS	4.00	4.00	A	16.000
GEOL	517	SEQUENCE/SEISMIC STRAT	3.00	3.00	A	12.000
PHIL	261	ETHICS IN PRACTICE	3.00	3.00	A	12.000
	TERM GPA :	3.931 TERM TOTALS :	13.00	13.00		51.100
	CUM GPA :	3.645 CUM TOTALS :	120.00	129.00		437.400

Dean's List
Good Standing

2016 Spr

ENEC	350	ENV LAW & POLICY	3.00	3.00	A	12.000
GEOL	509	GROUNDWATER	3.00	3.00	A	12.000
GEOL	525	INVERSE THEORY	3.00	3.00	A	12.000
MATH	547	LINEAR ALGEBRA FOR APPL	3.00	3.00	A	12.000
	TERM GPA :	4.000 TERM TOTALS :	12.00	12.00		48.000
	CUM GPA :	3.677 CUM TOTALS :	132.00	141.00		485.400

Dean's List
Good Standing