

Dedication

This work is dedicated to my family, whose support, patience, and understanding have facilitated my achievement of this academic hallmark in my Army career.

Biography

Brent Dunford Fogleman is originally from Palouse, Washington. He is the son of Dr. Richard and Nancy Dunford of Raleigh, NC. He is married to Elicia and they have two sons, Brandon and Austin. Brent is a Major in the U.S. Army, serving on active duty at North Carolina State University.

Upon graduation from North Carolina State University in 1997 with a Bachelor of Science in Parks, Recreation and Tourism Management, Brent was commissioned a Second Lieutenant in the United States Army. He attended and graduated from the Field Artillery Officer's Basic and Advanced courses and the Combined Arms and Services Staff School. He is a graduate of the U.S. Army's Ranger school, Basic Airborne Course, and the Jumpmaster Course. Brent has served at many duty stations around the world including the Republic of Korea; Fort Sill, OK; Fort Lewis, WA; Fort Leavenworth, KS; Fort Wainwright, AK; and Fort Richardson, AK. He was deployed to Afghanistan in support of Operation Enduring Freedom IV-V where he served as the Task Force 1-501st PIR Fire Support Officer. Upon return to Alaska, he successfully commanded three separate units over the span of four years.

Brent's awards and decorations include the Bronze Star Medal, the Meritorious Service Medal, the Army Commendation Medal with one oak leaf cluster, the Army Achievement Medal, the Global War on Terrorism Expeditionary Medal, the Global War on Terrorism Service Medal, the Korean Defense Service Medal, and the Overseas Service Ribbon with numeral four. He earned the Ranger tab and the Senior Parachutist badge. Upon graduation from NC State, Major Fogleman will attend his Intermediate Level Education at the Command and General Staff School, Fort Leavenworth, Kansas.

Acknowledgements

I thank my advisor, Dr. Hugh Devine, who facilitated my transition from the Chief of Current Operations in a U.S. Army airborne brigade stationed in Alaska, to a graduate student pursuing a master's degree at a premier institution. He successfully guided me through a dynamic program, which despite its infancy, was demanding, challenging, and rewarding. I am especially grateful of Dr. Helena Mitasova for giving me the opportunity to become a member of her Tangible GIS research team. Her commitment to her students' success is unparalleled. The simulation and modeling knowledge she has imparted on me will remain ever-relevant in my Army career as a Simulation Operations Officer. I thank Dr. Heather Cheshire for imparting on me a firm base of knowledge in the areas of geography, geospatial hardware and software, and remote sensing. I thank Dr. Laura Tateosian for her superb programming instruction, for it has saved me countless hours. I owe her credit for helping me turn my rudimentary georeferencing equations into those understood by academics.

I am proud to be the first student at North Carolina State University to graduate with a Masters of Geospatial Information Science and Technology.

Table of Contents

List of Tables	viii
List of Figures	ix
Chapter 1 Introduction	1
1.1 Objectives	3
1.2 Significant Prior Research	3
Chapter 2 Study Location	5
2.1 Fort Bragg	5
2.2 Falcon Airstrip	5
Chapter 3 Data	7
3.1 LIDAR Data	7
3.1.1 Bare Earth LIDAR	7
3.1.2 Multiple Return LIDAR	8
3.2 Scanner Data	8
3.3 Soil Data	9
3.4 Ancillary Data	9
Chapter 4 Methodology	10
4.1 Tangible Geospatial Modeling System	10
4.1.1 Graphics Hardware	10
4.1.2 Physical Setup	11
4.1.3 Software	11
4.2 Workflow	12

4.2.1 Step 1: Scan	12
4.2.2 Step 2: Scale and Georeference.....	12
4.2.3 Step 3: Import into GIS	13
4.2.4 Step 4: Create a DEM.....	13
4.2.5 Step 5: Conduct Analysis	14
4.2.6 Step 6: Produce Feedback	14
4.2.7 Step 7: Modify.....	14
4.3 Model Construction	14
4.3.1 Current Method	15
4.3.2 Alternative Method	15
4.3.3 Preserving Scale	16
4.4 Simulated Processes.....	16
4.4.1 Digital Elevation Model	16
4.4.1.1 Processing Bare Earth LIDAR	17
4.4.1.2 Processing Multiple Return LIDAR.....	17
4.4.2 Flow.....	19
4.4.2.1 <i>r.watershed</i>	19
4.4.2.2 <i>r.flow</i>	20
4.4.3 Erosion	20
4.4.3.1 Runoff Erosivity Factor <i>R</i>	21
4.4.3.2 Soil Erodibility Factor <i>K</i>	21
4.4.3.3 Length/slope Steepness Factor <i>LS</i>	21
4.4.3.4 Cover Factor <i>C</i>	23
4.4.3.5 Conservation Support Practice Factor <i>P</i>	23

Chapter 5 Results	25
5.1 Model Construction Accuracy	25
5.2 Evaluating the Models	25
5.3 Parameterization	26
5.3.1 Flow Parameters	26
5.3.2 Cover Factor Parameters	27
5.3.3 Exponents m and n	27
Chapter 6 Implications to Future Research	28
6.1 Multi-scale Computations.....	28
6.2 Military Operational Application.....	28
6.3 Instructional Environments.....	29
Chapter 7 Conclusion	30
Bibliography	56

List of Tables

Table 2.1 Fort Bragg 30-year monthly average precipitation.....	31
Table 2.2 Fort Bragg 30-year Normal Monthly Mean Temperatures, Mean Daily Temperatures and potential evapotranspiration	31
Table 4.1 Vegetation height map recoding values to simulate weighted runoff	32
Table 4.2 Cover factor recoding values to simulate surface types	32
Table 5.1: Modeled results of spatially variable <i>Factor C</i> with weighted and non-weighted flow	33
Table 5.2: Modeled results of variable erosion based on flow concentration with spatially variable <i>Factor C</i>	34
Table 5.3: Modeled results of uniform <i>Factor C</i> = 0.1 with weighted and non-weighted flow	35
Table 5.4: Soil loss potential for each modeled scenario.....	36

List of Figures

Figure 2.1 Fort Bragg installation boundaries	38
Figure 2.2 Falcon Airstrip and Fort Bragg Drop Zones.....	39
Figure 2.3 The erosion seen in these images are typical of the dirt roads in and around Falcon Airstrip. (a) failed attempts were made to reduce the erosivity of the road, (b) a gully is forming along the airstrip, (c) vehicular traffic on the airstrip is disturbing the vegetation and further loosening the sandy soil.....	39
Figure 2.4 Orthophotograph of the project site from 2007	40
Figure 2.5 The concentrated flow in this eroded gully resulted in depths up to four meters.....	41
Figure 4.1 TanGeoMS hardware configuration	41
Figure 4.2 TanGeoMS offers “plug-in-play” for analysis and visualization.	42
Figure 4.3: The scanner laser beam makes three passes over the model collecting nearly 300,000 points and stores them as xyz tuples	43
Figure 4.4: TanGeoMS promotes collaboration.	44
Figure 4.5 Projecting 3-meter contour intervals on the foam work surface.	44
Figure 4.6 Contour levels are cut, stacked and pinned in place.....	45
Figure 4.7 Plasticine is placed over the contours to create a malleable surface	45
Figure 4.8 Proto-type cutting station was developed to cut contour levels	46
Figure 4.9 The real world DEM in (a) 2D and (b) 3D images.....	46
Figure 4.10 (a) The raster map produced with the multiple-return data contains large block segments on the airstrip. (b) Sampled points have overlain the image.	47
Figure 4.11 (a) 2,168,992 bare-earth points were returned in the region and (b) only 193,032 multiple-return points were returned	47

Figure 4.12 Simulated high flow accumulation values calculated with <i>r.watershed</i> overlain an orthophotograph. Darker areas indicate higher concentrated flow.....	48
Figure 4.13: <i>R-Factor</i> was visually interpolated from an isoerodent map.	49
Figure 4.14 A spatially-variable <i>K-factor</i> raster map was created to more accurately assess soil loss potential in the area of interest.....	49
Figure 4.15 A weighted flow accumulation (<i>U</i>) raster map was calculated as a function of cover factor <i>C</i>	50
Figure 4.16 A spatially-variable <i>C-factor</i> was applied to the erosion models.....	50
Figure 4.17 A 3D view of the vegetation. Brown indicates little to no vegetation	51
Figure 5.1 The real-world DEM (a), the initial model scan (b), and the difference between the two (c)	52
Figure 5.2 Real world DEM (a), with flow accumulation (b), soil loss potential with standard flow accumulation (c), and soil loss potential with weighted flow accumulation (d).....	52
Figure 5.3 Initial model scan (a), with flow accumulation (b), soil loss potential with standard flow accumulation (c), and soil loss potential with weighted flow accumulation (d).....	53
Figure 5.4 Fill Dam 1 simulates filling in the gully and constructing a large dam (a), with flow accumulation (b), soil loss potential with standard flow accumulation (c), and soil loss potential with weighted flow accumulation (d).....	53
Figure 5.5 Fill Dam 2 simulates filling in the gully, constructing a large dam, and diverting some flow from the airstrip to the dam (a), with flow accumulation (b), soil loss potential with standard flow accumulation (c), and soil loss potential with weighted flow accumulation (d)	54

Figure 5.6	Fill Dam 3 simulates filling in the gully, constructing a small dam, and diverting some flow from the airstrip to the dam (a), with flow accumulation (b), soil loss potential with standard flow accumulation (c), and soil loss potential with weighted flow accumulation (d)	54
Figure 5.7	Grade 3 simulates filling in the gully, constructing a small dam, and grading the airstrip(a), with flow accumulation (b), soil loss potential with standard flow accumulation (c), and soil loss potential with weighted flow accumulation (d)	55
Figure 5.8	Rip rap simulates placing rip rap in the gully and in the low ground where significant concentrated water flows (a), with flow accumulation (b), soil loss potential with standard flow accumulation (c), and soil loss potential with weighted flow accumulation (d)	55