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Using a Low-Cost Unmanned Aircraft System and Structure-From-Motion for Hillslope Gully Modeling

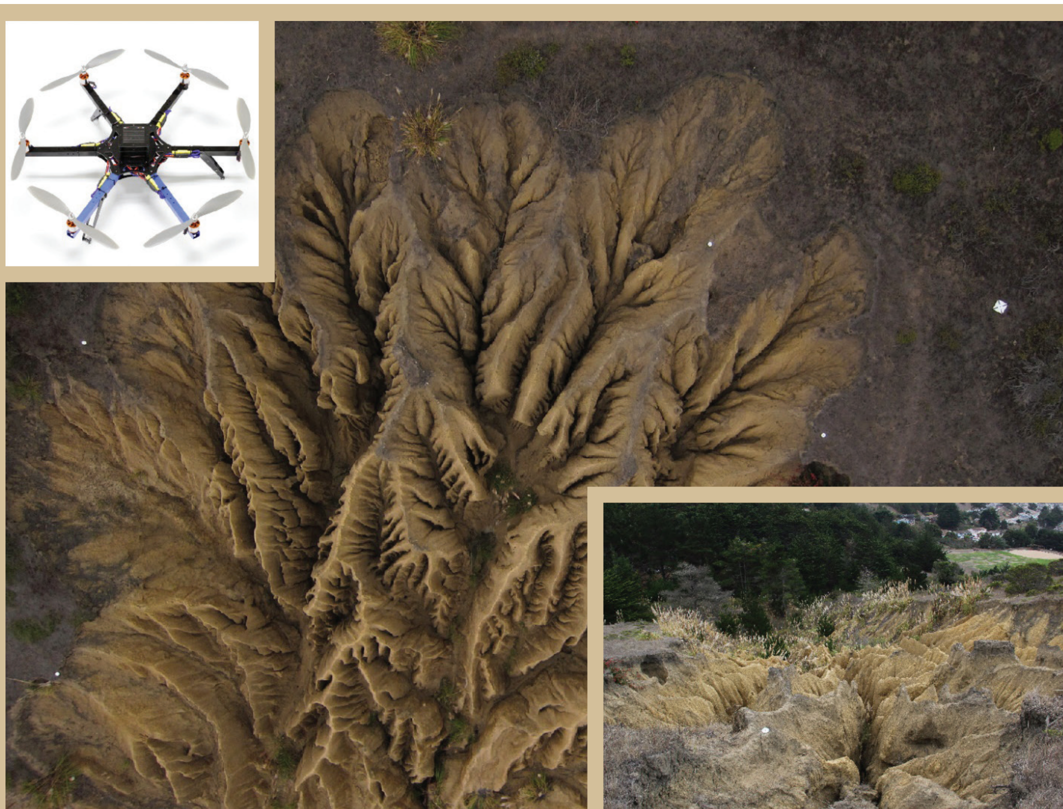

Figure 1.
Upper left:
3Drobotics hexacopter.
Lower right:
Looking down slope from head of gully. One CD used as a surveyed ground control point (GCP) is visible.
Main image:
Raw image captured from 20m above gully. CDs and ceiling tiles used as surveyed GCPs are visible as white dots

Geomorphologists often use three-dimensional data products to model stream flow, predict slope failure, or determine sediment accumulation and loss. Currently, the common methods of acquiring these data (laser scans or field survey) at fine spatial or temporal resolution are expensive, with high costs either financially or in person hours. A low cost method for 3D data collection would reduce the dependency of cost-concerned researchers on preexisting datasets, allowing them to choose study areas based on scientific importance rather than data availability. This study seeks to determine the feasibility of 3D surface model creation using a very low cost multi rotor unmanned aircraft system (UAS) and a consumer point and shoot camera.

BACKGROUND

In late 2012, funded by the SFSU Center for Computing for Life Sciences, the Geography & Environment Department at SFSU acquired a low-cost UAS in order to evaluate it as a platform for a diverse range of research. The system comprises a 3D Robotics hexacopter, Ardupilot automated flight hardware and software, cameras, and a field laptop for mission planning. Other ancillaries include a flight simulator, a quadcopter for pilot training and a license for Agisoft's Photoscan 3D modeling and photogrammetry software. To date, flights over hillslope gullies have been used to create digital elevation models. Future applications for the UAS include recording and monitoring stream channel formation in montane meadows, landslide scars, vegetation, and archaeological sites.

TECHNOLOGY

This research used a new method of photogrammetry

continued page 6

INSIDE

SAVE THE DATE
Please join us at the 2014 ESRI International User Conference in San Diego, California, July 14–18.

The Geography of Water Resources

The current drought in California is yet one more reminder of the importance of understanding water resources in our state. Not surprisingly, our GIScience colleagues throughout California have been studying the effects of climate change and developing methods to better understand water resources and model hydrologic systems. The annual issues of this publication over the last ten years have documented some of this in reports on water quality and hydrologic simulation (Wang 2006), mapping streamflow measurements from stream gauges (Keyantash 2011), volumetric analysis of lakes (Steinberg 2009), modeling streamflow from object-based satellite image analysis (Burgett et al. 2012), climate spatial variability (Sato 2013), GIS tool sets for mapping water resources (Nelson 2008), and water management planning (Slobodian 2009).

This issue includes two water-related articles, documenting student projects on remote sensing methods applied to climate change and its effects on snowpack (Cox & Yetter 2014), and the hydrologic effects of a fire in the southern Cascade Range (Larson & Fairbanks 2014). We will certainly see more in the coming years as the demand for water resources continues to increase while the supply is increasingly threatened by the effects of climate change on snowpack and anomalies in weather systems.

Larson, DC, and DH Fairbanks (2014). The impact of episodic land cover change on ecosystem services. *CSUGR* 12: 2-3.

Burgett, D, M Benedetti, and L Blesius (2012). Measuring river geometry for automatic discharge estimation using GOBIA. *CSUGR* 10: 1, 4.

Cox, HM, and L Yetter (2014). Student activities in climate change using NASA satellite data. *CSUGR* 12: 7-8.

Keyantash, J (2011). Using GIS to map streamflow measurement in remote mountain watersheds. *CSUGR* 9: 1, 6-7.

Nelson, C (2008). CalWaterMap: a GIS tool for small water agencies.

Sato, N (2013). Geographic analysis of climate variability in climate divisions of California. *CSUGR* 11: 2-3.

Slobodian, RP (2009). GIS in Integrated Water Management Planning. *CSUGR* 7: 3.

Steinberg, SJ (2009). Bathymetric mapping. *CSUGR* 7: 4.

Wang, Z (2006). Watershed Monitoring and Hydrologic Simulation using GIS. *CSUGR* 4: 1.

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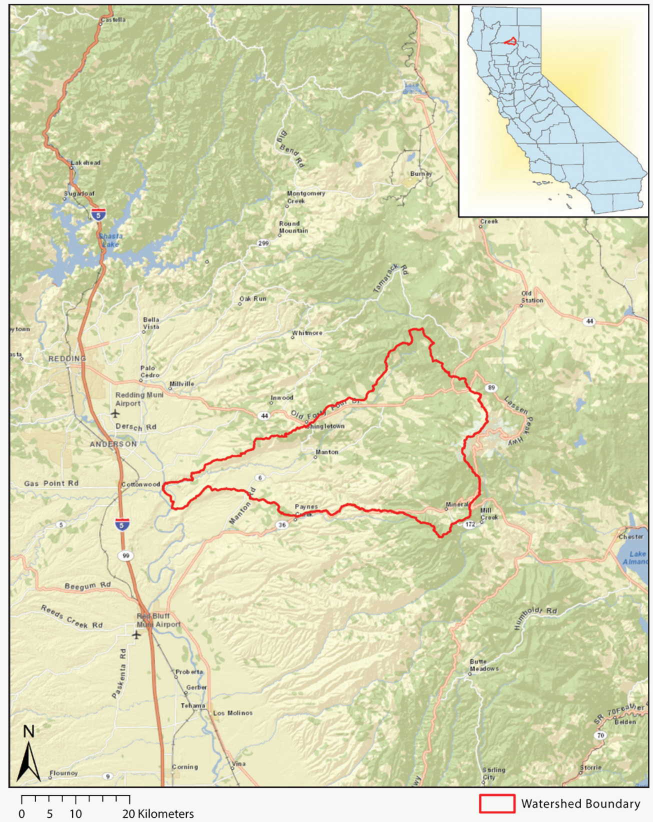

Figure 1. The Location of Battlecreek Watershed in Shasta and Tehama County, CA.

The Impact of Episodic Land Cover Change on Ecosystem Services

A Case Study in Shasta and Tehama County California

Ecosystem services are goods and services that sustain and enhance human life (Daily 1997). Humans have degraded ecosystems due to land use or land management practices favoring more profitable land use scenarios at the expense of other valuable ecosystem services (Polasky et al. 2011).

Natural hazards (i.e. floods, fires, earthquakes) pose a threat to ecosystem service provision (Wang and Xu 2012). There is ample evidence of ecosystems regulating natural hazards, but little mention of the loss or alteration of services due to hazards. It is necessary to determine not only how human activities influence ecosystem services, but how natural events influence them as well.

The purpose of this study was to address the following questions: Is the InVEST Water Yield model sensitive to a large fire disturbance on water supply in a catchment? Will model outputs accurately correspond to observed stream gauge data?

InVEST is a commonly used, open-source, spatially explicit, GIS application developed by the Natural Capital Project. InVEST assesses the output of services based on an ecosystem's composition and structure. The models are raster-based and conducted on an annual time step. The InVEST Water Yield model provides estimates of water available for consumption at the mouth of the catchment in m³/year, after accounting for in-catchment consumption. These values can then be directly compared to observed annual runoff values from available stream gauges located at the mouth of the catchment. Model outputs are predictive maps and numeric data tables of biophysical or monetary values (Bagstad et al., 2013).

Our study site was the Battle Creek Watershed (BCW) located in Shasta and Tehama County, California (Figure 1). The BCW is a major water supplier to the Sacramento River, contains the Coleman Fish Hatchery, and has a PG&E hydropower operation. Its water source is Lassen National Park. In August-September 2012 the BCW was affected by the Ponderosa Fire that burned 27,676 acres, including a large amount of forest and riparian cover. The significant change in land cover due to this event was the impetus for an analysis of how ecosystem services are affected by episodic changes in land cover. The model uses data on land cover, annual precipitation, annual reference evapotranspiration, plant available water content, effective soil depth, root depth, and a seasonal rainfall constant. Water supply was assessed for 1992, 2001, 2006 and 2012 to establish a baseline. We then assessed conditions after the fire in 2013 (Figure 2).

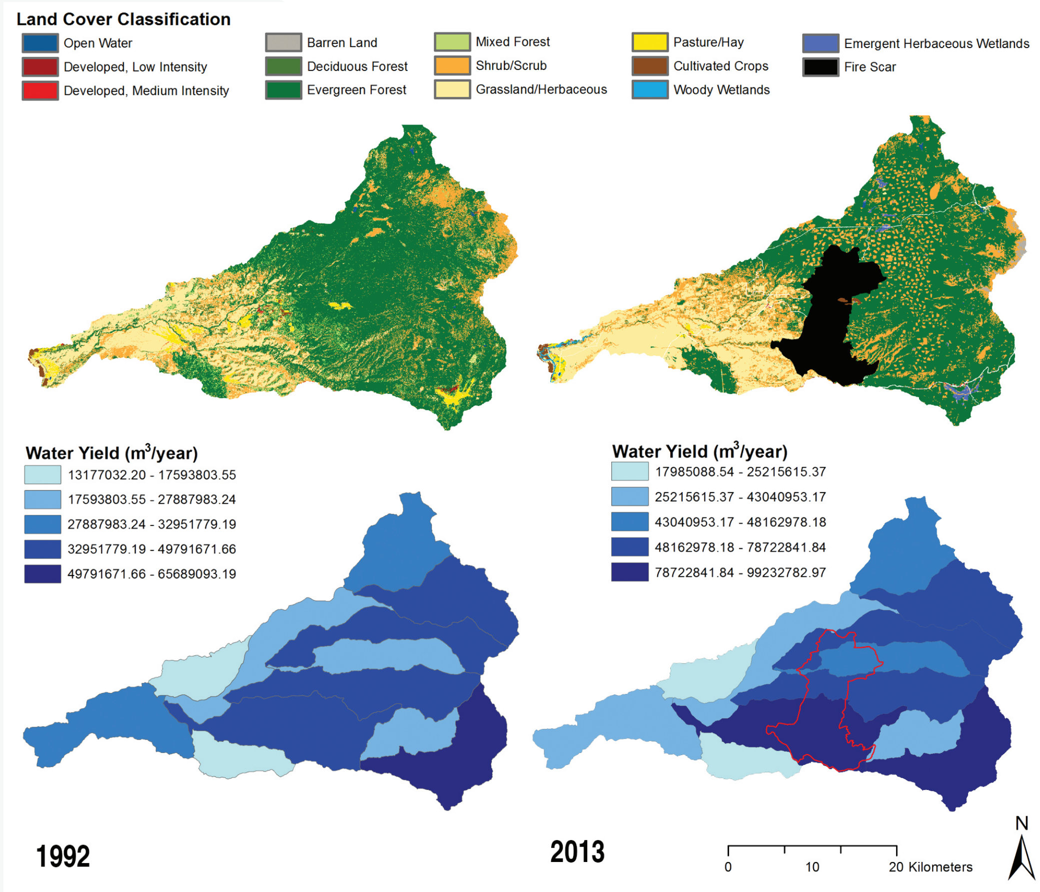

Figure 2. Land Use/Land Cover and InVEST Annual Water Yield for 1992 and 2013.

The InVEST model did not show a statistically significant difference in water supply pre- and post-fire, despite a 12% reduction in forest cover due to the fire. After removing water extracted by water consuming infrastructure from the water balance based on available data, the InVEST model results for annual water supply were compared with observed USGS measured annual runoff gauge data. The model estimated water supply values at 10.5% more than that observed. Reasons for this over-reporting could be the distribution of precipitation (rain and snowpack) in relation to the fires impact and lack of consideration of surface-groundwater interactions.

The unevenly distributed, strongly orographic precipitation regime suggests that the fire occurred in areas less responsible for water supply. There are five dams and other water infrastructure in the study area making it difficult to determine the exact amount of water removed from the watershed, consumed on-site, or allocated elsewhere.

Model results closely resembled observed water discharge data, improving confidence in the model's precision. This study was a valuable exercise in testing the efficacy of a widely used ecosystem service assessment tool for the southern Cascades region. Future studies should strive for transparency and validation as more robust models are developed.

REFERENCES

Bagstad, K. J., D. J. Semmens, S. Waage, and R. Winthrop. (2013). A comparative assessment of decision-support tools for ecosystem services quantification and valuation. *Ecosystem Services* 5: 27-39.

Daily, G. (Ed.). (1997). Nature's services: societal dependence on natural ecosystems. Island Press.

Polasky, S., E. Nelson, D. Pennington, and K. A. Johnson.(2011). The Impact of Land-Use Change on Ecosystem Services, Biodiversity and Returns to Landowners: A Case Study in the State of Minnesota. *Environmental Resource Economics* 48: 219-242.

Wang, Y.K., B. Fu, and P. Xu. (2012). Evaluation the impact of earthquake on ecosystem services. *Procedia Environmental Sciences* 13: 954-966.

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Spatial Analysis of Distressed Residential Property Sales in the Fresno/Clovis Metro Area

The housing market crash of 2007 was the worst housing price crash in U.S. history. It caused the 2008 financial crisis. This housing bubble burst almost sent the U.S. economy into another depression like the Great Depression of the 1930s. It caused the collapse of several large financial institutions, the bailout of banks by national governments, and downturns in stock markets around the world.

The bursting of the U.S. housing bubble caused real estate prices to plunge in many parts of the country. As a result of high unemployment rates caused by the financial crisis, significant numbers of homeowners were unable to pay their mortgages. Banks and other lenders then repossessed the distressed properties and tried to sell them on the open market in order to recoup their initial financial outlay. These distressed properties were either labeled as foreclosures or short sales.

Fresno and Clovis are two adjacent cities in Fresno County, California, located in the Central Valley (Figure 1). The two-city metro area, which is defined as the study area in this research, covers 136 square miles with a total population over 600,000. The metro area does not have a robust economy; it is largely an agricultural community. The housing market bubble in the metro area followed the national trend from 2003 to 2012. However, the bubble in the Fresno area inflated at a much faster pace between 2004 and 2008 compared to the rest of the nation. As a consequence, the number of distressed properties in the area has risen steeply since 2007.

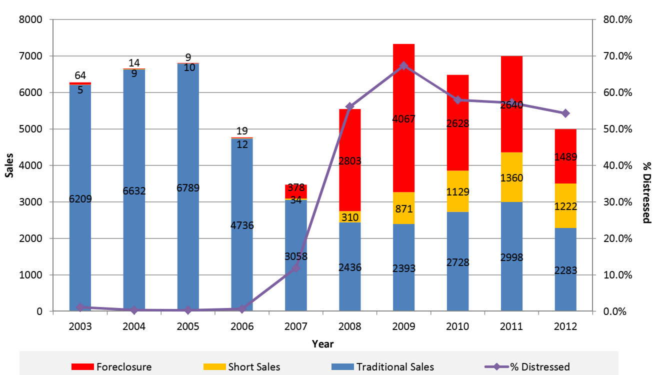

Figure 2. Numbers of Samples in the Study Area by Year and Type.

As displayed in Figure 2, distressed residential property sales were only a very small fraction of the total residential property sales before 2007, less than 1.1%. Starting in 2008, distressed residential property sales rose to more than 50% of total residential property sales and peaked at 67.4% in 2009.

The primary objective of the study is to investigate, using spatial statistical methods, the spatial distribution of distressed sales in the study area and the spatial distribution changes of the distressed sales over time. More specifically, the study

Figure 1. The Fresno-Clovis metro area, Fresno County, CA.

attempts to answer two questions. Are there any patterns in the distressed sales? If there are patterns, where are they?

The study uses brokered residential sales data from 2003 to 2012, a total of 61,287 transactions. Based on the status of each sale, transactions were classified as a traditional sale or a distressed sale. Out of all sales, there were 19,981 (32.6%) distressed sales.

To help us understand how distressed sales progressed across the study area and over time, we used an analyzing pattern method called Average Nearest Neighbor (ANN) (Mitchell, 2005). This method provides inferential statistics that quantify broad spatial patterns as dispersed, random, or clustered. It determines if distressed sales in the study area were spatially clustered. It also provides indices that show the intensity of the clustering over time.

Figure 3 shows the results of the ANN analysis. The 90% confidence interval is for the null hypothesis that the distressed transactions are randomly distributed in the study area. The z-score represents standard deviations. It shows the number of standard errors of an observed average nearest neighbor distance from the expected average nearest neighbor distance given a random pattern. A positive z-score indicates that the observed average distance is larger than the average distance of random distribution, meaning the distribution of the sample data tends to be dispersed. A negative z-score indicates that the observed average distance is shorter than the average distance of random distribution, meaning the distribution of the sample data tends to be clustered. The magnitude of a z-score expresses the intensity of disperse/cluster. As indicated in the figure, the clustering of distressed sales became statistically significant in

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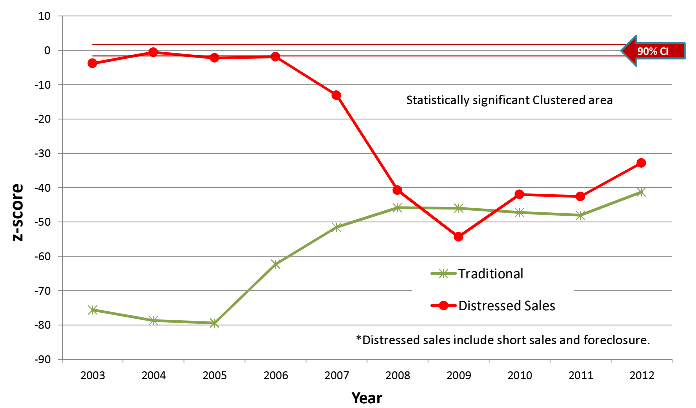

Figure 3. Results of the Average Nearest Neighbor Analysis.

2007 and the clustering intensity sharply increased until 2009. From 2009 to 2012, the clustering intensity gradually leveled out, but the figure still shows a very strong clustering.

The ANN analysis only provides a numerical index to exhibit if any spatial pattern exists. When there are patterns, it does not show where those clusters are located. To map out these clusters, Hot Spot Analysis or Getis-Ord G* statistics were employed to identify statistically significant hot spots and cold spots (Getis and Ord, 1992). The analysis calculates a Getis-Ord G* statistic for each distressed sale location with respect to nearby distressed sales at a defined distance. A distressed sale hot spot is defined as a distressed sale that not only itself has a high Getis-Ord G* statistical value, but is also surrounded by other high Getis-Ord G* statistical value distressed sales. A distressed sale cold spot is defined as a distressed sale that has a low Getis-Ord G* statistical value and is also surrounded by other low Getis-Ord G* statistical value distressed sales.

Figure 4 shows the results of the Hot Spot Analysis from 2007 to 2012. It clearly illustrates where the hot and cold spots are clustered. Generally speaking, the hot spots were distributed in the west and southeast regions of the study area, while the cold spots were found mostly in the north.

In conclusion, applying spatial statistics to the distressed residential property sales not only provides a measurement of spatial patterns of the data, it also reveals the spatial distribution of the patterns. By identifying the locations of the clusters, it permits researchers to investigate underlying population characteristics in terms of demographics and socioeconomic factors.

REFERENCES:

Getis, A. and J.K. Ord. (1992). The Analysis of Spatial Association by Use of Distance Statistics. *Geographical Analysis* 24(3): 189-206.

Mitchell, Andy. (2005).The ESRI Guide to GIS Analysis, Volume 2. ESRI Press.

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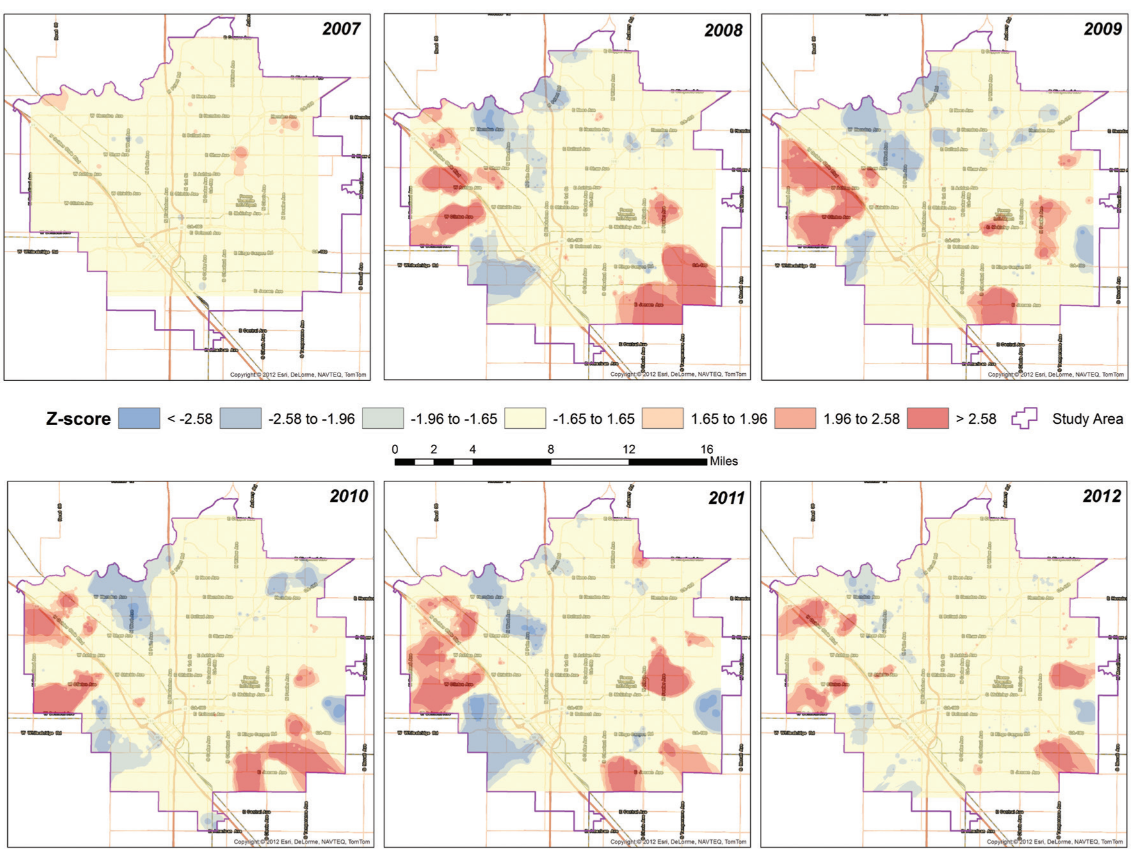

Figure 4. Hot Spot Analysis: Fresno-Clovis Area Distressed Sales 2007-2012.

called Structure from Motion (SfM). Designed to create 3D data from unstructured collections of images (Snavely et al., 2007), this method does not rely on a priori camera parameters to produce 3D data. Unlike traditional photogrammetry which derives its elevation data from image stereo pairs, SfM finds matching features across large numbers of highly overlapping images from which it derives all camera parameter and location information for each image. Because the process uses so many pictures and derives all camera parameters, lower quality, consumer grade cameras are suitable for producing 3D models. Although the majority of the SfM process is automated, the point cloud created is in relative coordinates which must be translated to real-world using ground control points (GCPs) and then interpolated to create a DEM. Because the final elevation data can only be as accurate as the GCPs used, a highly accurate GPS receiver or total station is require (Westoby et al, 2012).

While LiDAR can produce highly accurate spatial data, vegetation density estimates, and bare-ground detection through vegetation, SfM can readily compete in some environments. Low altitude SfM products can produce a point cloud far denser and more accurate than what is produced by the first returns of a conventional aerial LiDAR scan, although it cannot provide the information that accompanies aerial LiDAR's multiple returns in vegetated areas (i.e., canopy height, canopy density). However, this same SfM point cloud will not compare favorably to the density and accuracy of a terrestrial LiDAR scan (James and Robson, 2012).

METHODS

Due to their small size and extreme relief, gullies are poorly represented in most available elevation datasets. The SfM process has the potential to deliver the surface models needed to monitor gully growth. In our study, SfM methods were applied to images taken of a gully on a coastal terrace in Pacifica, CA. The flights were at altitudes of 10, 20, and 70m and the average resolution was approximately 0.3cm, 0.6cm and 2cm respectively. A Canon S95 point-and-shoot camera took > 80 images at one second intervals running an intervalometer script using the firmware hack CHKD (Canon Hack Development Kit). The gullies were primarily bare soil, an ideal environment for SfM.

The gully location was covered by the Golden Gate LiDAR Project (GGLP) (Hines, 2011), an aerial LiDAR survey flown in 2010 for USGS 1/9 arc-second NED, which allowed us to compare our product with an existing LiDAR dataset (Figure 2). The most immediate difference was the lack of gully features included in the LiDAR bare earth DEM caused by the returns from vertical features being classified as medium vegetation. Additionally, the SfM point cloud is 100 times denser than the GGLP point cloud and 10 times more horizontally accurate.

The results of the study indicate this low-cost approach can be used to gather relevant research data, but that there are significant downsides to using equipment designed for hobbyists rather than for research. Specifically, the repurposing and maintenance of the low-cost equipment greatly increases the time needed before quality data can be obtained. The method is also unable to collect points through vegetation, in contrast to LiDAR. However, in sparsely vegetated areas, this method has many advantages, especially in cost.

REFERENCES:

Agisoft LLC. Photoscan [software]. Available at www.agisoft.ru.

CHKD. [software]. Available at http://chdk.wikia.com/wiki/CHDK.

Hines, E. (2011). Final report: Golden Gate LiDAR project. San Francisco State University.

James, M. R., and S. Robson. (2012). Straightforward reconstruction of 3D surfaces and topography with a camera: Accuracy and geoscience application. *Journal of Geophysical Research: Earth Surface (2003–2012)* 117(F3): 1-17.

Snavely, N., S.M. Setiz, and R. Szeliski. (2008). Modeling the World from Internet Photo Collections. *International Journal of Computer Vision* 80(2): 189-210.

Westoby, M. J., J. Brasington, N.F. Glasser, M.J. Hambrey, and J.M. Reynolds. (2012). 'Structure- from-Motion' photogrammetry: A low-cost, effective tool for geoscience applications. *Geomorphology* 179: 300-314.

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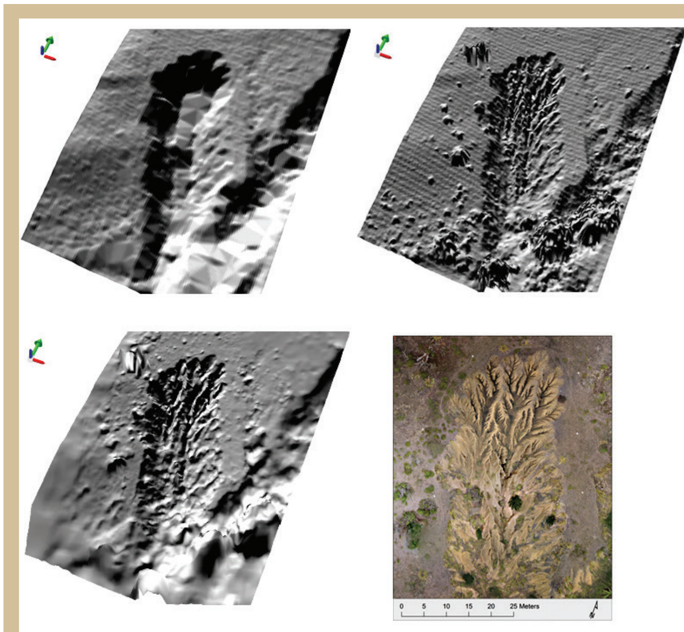

Figure 2. Clockwise from top left: GGLP bare earth DEM, GGLP all returns DTM, Project Area Orthophoto, SFM DTM

Nasa Satellite Data *from back page*

would be a Level 1 product. In these exercises students work with Level 1, 2 and 3 data helping them to understand the differences in these product levels.

Snow mapping using MODIS data: Snow cover is an important component of the climate system. Its presence or absence can be used to monitor climate change; it has an important feedback on climate in that it is a good reflector of sunlight; it plays a vital role in providing freshwater storage for much of the world's population. Students generate a snow cover map for a single day from MODIS data (Level 2) in Yosemite National Park (Figure 1). They verify their map by comparing it to a finished product snow cover map (Level 3). The MODIS instrument provides daily global coverage at a moderate spatial resolution of 250 m to 1 km coverage per pixel.

Sea ice mapping using passive microwave data: Sea ice concentrations are important to monitor because ice is sensitive to changes in temperature and thus is a strong indicator of climate change. In addition sea ice reflects sunlight keeping the planet cool, and thus influences climate through the albedo effect. If ice melts, more heat from the sun will be absorbed and the planet will warm causing more ice to melt, perpetuating a positive feedback loop. These changes have important ramifications for all life on earth especially Arctic and Antarctic ecosystems and Arctic people who depend on sea ice for hunting and wildlife. Microwave data is useful for monitoring sea ice because it is capable of collecting data through clouds and at night. This is important because during the winter the poles are in darkness. Because there is a large emissivity difference between ice and the ocean at microwave wavelengths it is possible to distinguish sea ice from water, and even first year from multi-year ice. The Special Sensor Microwave Imager/Sounder (SSMIS) instrument on board the DMSP F-17 satellite collects passive microwave data, and provides daily coverage at 25 km spatial resolution. Students download brightness temperature data for the 19, 22, and 37 GHz channels of SSMIS and perform analysis to construct a map of sea ice which they are able to compare to a NASA product.

Mapping atmospheric gases using AIRS: Carbon dioxide, ozone and carbon monoxide are important in studying climate change, stratospheric ozone depletion, and air pollution. Together with other atmospheric variables such as temperature and humidity, they can also be important components of broader environmental studies. In this set of exercises, students learn how to download, import and incorporate global monthly maps (Level 3) of data from the AIRS instrument for use in environmental studies, spatial analyses, and to monitor global change. (See back cover for examples of other exercises.)

Other exercises: These include use of ASTER data to map burn severity associated with wildfires (Figure 2); analysis of changes in the mass of Greenland ice sheet; mapping of deforestation in Brazil (Figure 3); and use of the normalized difference vegetation index (NDVI) from SPOT and MODIS to study the phenology of crops.

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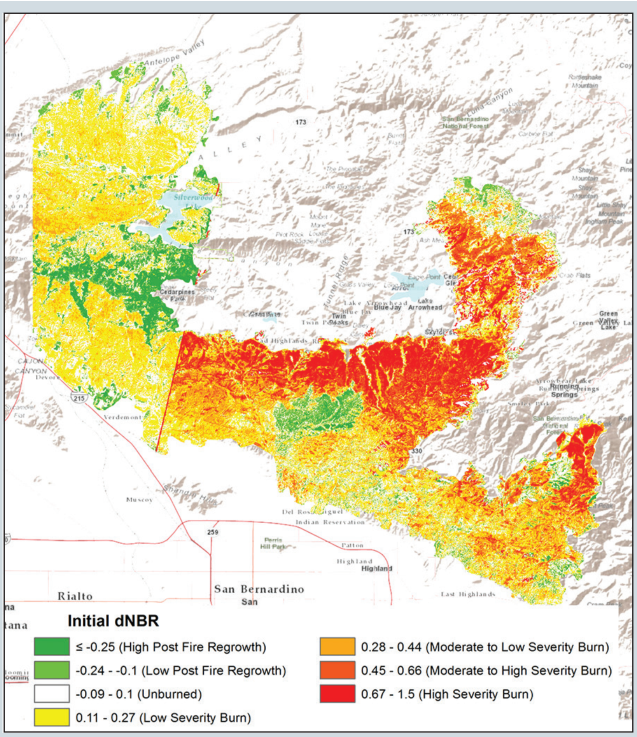

Figure 2. Burn severity assessment (difference in Normalized Burn Ratio) for the Old Fire, which occurred in October 2003 in southern California. ASTER data (bands 3 and 6) were used to construct the NBR.

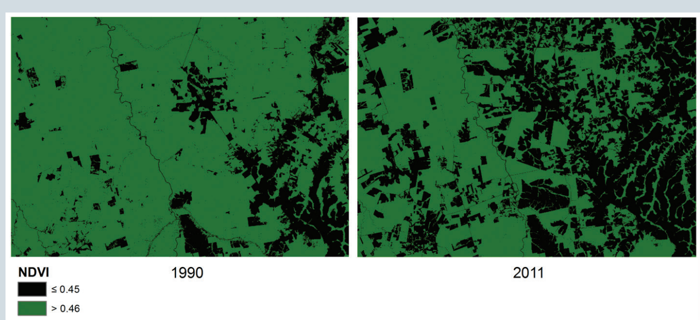

Figure 3. Normalized Difference Vegetation Index images computed from Landsat data (bands 3 and 4) for the Mato Grosso region of Brazil for 1990 and 2011. Green shows forested land, black un-forested.

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Student Activities in Climate Change using NASA Satellite Data

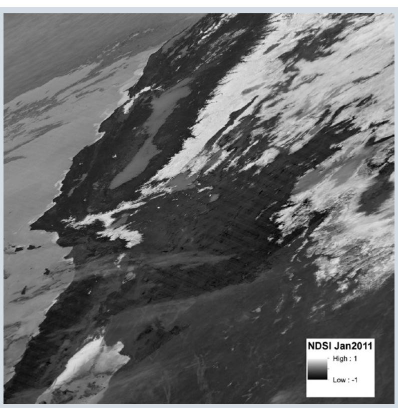

Figure 1. Gray scale raster of the Normalized Difference Snow Index (NDSI) for Yosemite National Park in the Sierra Nevada Mountains on January 4, 2011 generated from MODIS data (bands 4 and 6). Raster values are between -1 and +1 where high values (light areas) indicate snow.

Under a NASA grant, students in the Geography Department at California State University, Northridge are integrating GIS, remote sensing, and satellite data technologies to study global climate change. Exercises (1) help students acquire skills in understanding, downloading and processing satellite data, (2) integrate remote sensing technology and data with GIS, (3) expose students to data and methods that they can incorporate in their own research projects, (4) prepare students to use GIS to solve real world problems, (5) raise awareness about climate change.

The series of multi-part exercises utilize data from six different satellites to teach students how remote sensing data can be applied to study the concentration of atmospheric gases such as carbon dioxide and ozone, air temperature, snow cover, sea ice, glaciers, fires, deforestation, crop growth and other elements of the earth system affected by climate change. These exercises (at http://www.csun.edu/climate/Links_Resources.html) utilize ArcGIS and ERDAS Imagine software, are free, and provide instructions for downloading (free) NASA data.

Satellite instruments are designed to detect a larger part of the spectrum than that to which the human eye is sensitive. By measuring reflected sunlight across a range of wavelengths researchers are able to discern differences and distinguish objects that appear similar to the human eye. NASA has launched many satellite instruments to monitor global environmental change over the past four decades. Included in these exercises are six of these—MODIS, ASTER, SSMIS, AIRS, Landsat and GRACE.

Satellite data is available in a range of levels from 0 to 4. Low level data is unprocessed raw data, whereas high level data has been processed and formatted into finished products. For example, composite global cloud-free maps of land cover derived from multiple instruments would be available as Level 4, whereas measured reflected sunlight in each individual band

continued page 7