SIERRA NEVADA ADAPTIVE MANAGEMENT PLAN (SNAMP)

Study Plan and Inventory Protocol
User Field Guide

Sierra and Tahoe National Forests
Study Sites

UC Science Spatial Team

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Spatial Team Workplan

The spatial team will provide support for the other SNAMP science teams through spatial data acquisition and analysis.

PART 1: Spatial Data

Base Data
Base geospatial data were collected for each study area. Projection information: Northern site: NAD 83, UTM Zone 10N; Southern site: NAD 83, UTM Zone 11N. For layers with vertical data (both sites): NAVD 1988 in meters.

- Government:
  - City/town locations (CaSIL, ESRI, and geonames/geocities.org)
  - County boundaries (source: ESRI)
  - State boundaries (source: ESRI)
  - Ownership (private vs. public) (source: ESRI)
  - Federal lands (e.g. FS areas, etc) (source: FS)
  - Yosemite area (source: nps.gov)
- Other FS data:
  - Cedar Valley Project (source: FS)
  - Fishcamp project (source: FS)
  - Nelder Grove (source: FS)
  - SNAMP SPLATs (source: FS)
  - Fishcamp SPLATs (source: FS)
- Transportation:
  - Highways, roads, local roads (source: CaSIL)
  - Trails (source: NF)
  - Rail networks (source: ESRI)
- Hydrology:
  - Reservoirs and lakes (source: NHD)
  - Streams and rivers (source: NHD)
- Topo:
  - 30m and 90m DEM (source: CaSIL)
  - Mountain peaks (source: mountainpeaks.net)
- SNAMP:
  - Main study area boundaries (source: SNAMP)
  - Water study areas (source: SNAMP)
  - Owl and Fisher study areas (source: SNAMP)
  - Plot locations (source: SNAMP)
  - SNAMP base station (source: SNAMP)

LiDAR – Light Detection and Ranging
LiDAR data will be used to quantify forest structure and topography at high spatial resolution and precision. LiDAR will be collected for our two study areas: Sugar Pine and
Last Chance. As of January 2009, LiDAR has been collected and delivered for both sites. We contracted with the National Center for Airborne LiDAR Mapping (NCALM) for our data. They collected the data using the Optech GEMINI instrument at approximately 600 m above ground level, with 67% swath overlap. The instrument collected 4 discrete returns per pulse at 125kHz laser pulse repetition frequency; the delivered data has an average density of 9 points per m².

**LiDAR Specifications**

Our LiDAR survey used an Optech GEMINI Airborne Laser Terrain Mapper (ALTM) serial number 06SEN195 mounted in a twin-engine Cessna Skymaster.

**Sugar Pine Study Area**

- Collected Sept 13-15 2007
- Flew 600 m above ground level
- 117.5 km² covered
- 4 range measurements per pulse, including last
- 4 intensity readings with 12-bit dynamic range per measurement
- Pulse rate frequency: 100 KHz
- Laser wavelength: 1047 nanometers
- 6 points per m²
- ~1,000,000,000 points.
- Field Data Specs:
  - 130+ plots
  - 3,600+ trees surveyed

**Last Chance Study Area**

- Collected Sept 18, 19, 21, 22, 2008
- Flew 600 m above ground level
- 107.1 km² covered
- 4 range measurements per pulse, including last
- 4 intensity readings with 12-bit dynamic range per measurement
- Pulse rate frequency: 70 KHz
- Laser wavelength: 1047 nanometers
- 9 points per m²

**Technology and Basics**

LiDAR – Light Detection and Ranging - works by “sounding” light against a target in a similar way to sonar or radar. The actual concept that makes LiDAR work is quite simple. First, the system generates a short pulse of electromagnetic energy at a specific wavelength (i.e. a laser pulse) and directs it towards a target. In our case, the sensor is attached to the underside of an aircraft and the laser is directed towards the ground. The wavelengths used are typically in the visible or near infrared region of the electromagnetic spectrum, mostly because the production of such lasers is inexpensive. The laser pulse is emitted towards the earth, reflected back towards the airborne sensor where it is detected and
Because the speed of light is known, the roundtrip time for the pulse of light is converted to distance. Simultaneously, the aircraft’s exact position and orientation is measured by an attached global positioning system (GPS) and inertial measurement unit (IMU). The combination of all the above measurements allows us to backtrack and calculate the three-dimensional position where the light pulse was reflected (Dubayah and Drake, 2000; Lefsky et al., 2002; Roth et al., 2007; Vierling et al., 2008).

In the simplest case, light is reflected by the ground back to the airborne sensor where it is measured and converted to ground elevation. In a more complex situation, for example over a forest, the light can be reflected either by the ground, by the top of a tree, or it can be bounced around by the branches and leaves before returning to the sensor. In a more realistic situation, light can also undergo more convoluted behaviors such as scattering by the atmosphere and bouncing from a target towards a completely different direction, in which case it is never detected. The above process is repeated many times per second (the laser pulse repetition frequency) to map out the surface structure below. The collection method quickly leads to immense number of measurements over a relatively small area, and large file size is one of the challenges in processing and storing LiDAR data. This predicament is compounded by the fact that there are multiple possible measurements for any sensed light pulse, as described below.

Initially, laser systems were capable of simply detecting a returned pulse (or “a return”). Better understanding of the laser ranging system and improvements in technology led to more comprehensive measurements. Many commercial LiDAR systems are now capable of collecting four or more returns and their intensities for each sent pulse – that is eight recorded values for every sensed location. Although this significantly increases the size of data and slows down its analysis, the additional information is very valuable.

In a forest setting, multiple returns are fractions of the primary laser pulse reflected by the many parts of tree crown, branches, shrubs, or the understory. Their significance comes in the ability to describe forest structure as opposed to simply the average elevation of an area. The pulses intensity can also be recorded. The intensity of a pulse is related to the reflectance (i.e. albedo) of the target material – high intensity indicates a highly reflective material such as white paint or bright sand.

There are currently two common types of LiDAR systems: full waveform and discrete, small footprint pulse. Thus far, we have

Figure 1. Discrete return LiDAR System. Graphic modified from Lefsky et al. 2002 with tree from globalforestscience.org
only described a discrete pulse system. The major difference between waveform and discrete system can be attributed to their characterization of vertical structure of measurement – where a pulse system collects, four vertical points at a location, the waveform system completely describes the vertical characteristic. A discrete return system is demonstrated in Figure 1. Waveform LiDAR can provide a better description of forest structure than a discrete system. However, the footprint and spatial resolution of a waveform system is typically much larger and therefore does not provide as much detail about the forest system as a discrete system. The benefits and efficacy of a discrete system outweigh currently available waveform LiDAR for the purposes of the SNAMP project.

Another important aspect of LiDAR data is its point density, usually specified in number of points per unit of area. There are a number of aspects that influence the density of laser data. From the physical perspective, point density depends on the aircraft’s altitude or above ground level (AGL). The closer the sensor is to the ground, the higher the density of the data. On the contrary, as AGL decreases, the aircraft must stay in the air for a longer time to cover the same amount of area, which significantly increases the acquisition costs. Point density also depends on the technical aspects of the sensor. Earlier systems collected data at about one pulse per square meter, although this figure varies from project to project and on average increases over time. Our data has been collected at four to nine points per square meter.

Utilizing LiDAR

LiDAR data is typically delivered as a “point cloud,” a collection of elevations (x, y, z coordinates) and their intensities that can be projected in a three-dimensional space. These data are used to produce a number of valuable spatial information products. Good reviews of the system, data, and analyses can be found in (Gatziolis and Andersen, 2008).

One of the most common uses of laser altimetry and typically the first step in analyses is to transform the data into a bare earth model, or digital elevation model. As defined by the U.S. Geological Survey, a grid Digital Elevation Model (DEM) is the digital cartographic representation of the elevation of the land at regularly spaced intervals in x and y directions, using z-values referenced to a common vertical datum (Aguilar et al., 2005; Raber et al., 2007). A DEM is essential to various applications such as terrain modeling, soil-landscape modeling and hydrological modeling (Anderson et al., 2005). Consequently, the quality of a DEM and derived terrain attributes become important in spatial modeling (Anderson et al., 2005; Thompson et al., 2001). LiDAR has emerged as an important technology for the acquisition of high quality DEM due to its ability to generate 3D data with high spatial resolution and accuracy. Compared to traditional DEM derived from photogrammetric techniques such as a widely used DEM within the United States produced by the U.S. Geological Survey (USGS), LiDAR-derived DEM has much higher resolution with high accuracy and precision.

Another typical step in processing LiDAR data is to extract individual trees, or to derive stand-level forest characteristics (Dubayah and Drake, 2000; Henning and Radtke, 2006; Jeanne E. Anderson a and Marie-Louise Smith b 2008; Leckie et al., 2003; Naesset, 2004; Popescu and Wynne, 2004; Popescu et al., 2004; Popescu and Zhao, 2008; Radtke and Bolstad, 2001; Zhao et al., 2009). Chen and colleagues (2006) used discrete return LiDAR
data to isolate individual trees with 64% absolute accuracy. The project was located near Ione, CA, in a savannah woodland mostly composed of blue oaks (Chen et al., 2006). Naesset and Bjerknes (2001) developed regression models between field and LiDAR data for mean canopy height and tree density of stands in a young forest in Norway. Their tree height model was explained 83% of the variability in field mean tree height (Naesset and Bjerknes, 2001). Airborne LiDAR data has also been used to map course woody debris volumes in a forest (Pesonen et al., 2008), and biomass (Naesset and Gobakken, 2008). Other research shows that it may be more accurate to isolate trees by combining laser altimetry with remotely sensed imagery. For instance, Leckie and colleagues were able to separate trees with 80-90% correspondence with ground truth by combining LiDAR data with multispectral imagery (Leckie et al., 2003).

The vertical structure of forests is also an important driver of forest function, affecting micro-climate, controlling fire spread, carbon and energy balance, and impacting the behavior of species. But there are no standard metrics of preferred data format to capture vertical structure of forests. The analysis of LiDAR data holds promise for the theoretical development of functionally-relevant metrics that capture the vertical structure in forests. For example, Zimble and colleagues (2003) demonstrated that LiDAR data could be used to classify a forest into single-story and multistory vertical structural classes. Their landscape-scale map of forest structure was 97% accurate (Zimble et al., 2003).

The intensity of the return pulse has also been used to assist the classification of tree species in some cases. Ørka and colleagues (2007) discriminated between spruce, birch, and aspen trees using the return intensity from a multiple return LiDAR system with overall classification accuracies from 68 to 74% (Ørka et al., 2007).

Where aerial photography and optical remote sensing once provided the inputs to fire models, LiDAR data is increasingly being used alone or fused with remote sensing imagery to derive parameters used in fire modeling (Mutlu et al., 2008; Riano et al., 2003). For example, stand height, canopy cover, canopy bulk density, and canopy base height have been correlated with ground truth data based on height quintile estimators of the laser data (Andersen et al., 2005). The reported accuracies ranged between $r^2=0.77$ and $r^2=0.98$, with canopy height being most accurate and canopy base height the least accurate. This study is particularly interesting because its objective was to derive input parameters for the FARSITE wildfire model (Finney, 1995; Finney, 1998).

Figure 2. Vertical structure of forests.
Field Plan
Ground control for airborne LiDAR data is critical to correctly map individual trees, and to scale up forest parameters to stands. The process involves inventory and survey.

FFEH plot inventory
The inventory spatial data procedure involves the following steps. First, the FFEH plot center is located and the plot center marked using a metal rebar and surrounding trees flagged. The rest of inventory procedures can be found in the FFEH field procedures; they include establishing a 12.6m radius area from the plot center (“the plot”), tagging all trees above DBH=15cm, identifying and measuring the tagged trees, and running linear transects to collect fuel information.

Next, an area with relatively open canopy for the GPS signal as close to the plot center as possible (max=40m) is identified; ideally this is directly over the plot center but that is often not the case. The GPS equipment is set up and stabilized the GPS equipment. The inventory GPS equipment consists of: a lightweight tripod for the GPS antenna (expands to approx. 3.3m); a Trimble Hurricane external antenna; a Trimble Recon unit for data recording; and a Trimble XH Receiver. A point feature is collected using TerraSync software with the following specifications: measure and input the exact vertical distance between the antenna and the ground; collect at least 10 points at PDOP≤6; note whether the antenna is on plot center or offset; use 1-second point collection interval; and use UTM NAD83 coordinate system.

Once the center point is marked, we record the bearing and distance from directly below the antenna to the plot center in degrees. A compass is used to measure the bearing (according to true north), and the horizontal distance is measured using a Vertex hypsometer.

SURVEY spatial data procedure
The survey data collection procedure includes collecting GPS points, generating a stand-map of the plot, taking photographs, and, in special cases, taking hemispherical photographs.

Plot stand-map procedure involves the following steps. First two points for the laser rangefinder near the plot center (here referred to as L1 and L2) but not necessarily within the plot are established such that L1 is visible from L2 and L2 is visible from L1, the plot center is visible from L1 and L2, the GPS location is visible from L1 and L2, the maximum number of tagged trees are visible from L1 and L2, and L1 and L2 are approximately at 90° angle in relation to the plot center to minimize the positioning error. Both points, L1 and L2 are marked temporarily. The surveying equipment is setup at point L1. The surveying equipment consists of: a Laser rangefinder, connected to an electronic compass, which is connected to the GeoExplorer XM; a reflector is used for the laser rangefinder to eliminate distance error. Setting up the equipment requires: leveling the tripod and calibrating the electronic compass. The points are collected in the “filter” rangefinder setting. A shapefile is created in ArcPad 7 with an L1 point at coordinate (50,50,0) and set as a reference point.
Points are collected using the following procedure: the plot center is collected three times (three points to minimize positioning error); the GPS location is collected three times; L1 and L2 locations are collected three times from L2 and L1, respectively; tree locations are collected once and Step 7 and 8 is repeated for L2.

Plot photographs are taken to have a general idea of the terrain after the field season. They are also used as an indicator of the site fuel type for fire simulation input (the most important variable). No pictures of the plots were taken prior to this effort. Plot photographs procedure involves the following steps. Five photographs are taken in the following order: from north towards the plot center; from east towards the plot center; from south towards the plot center; from west towards the plot center; and from plot center directly up towards the sky (Figure 3).

![Plot Photography Example](image)

**Figure 3.** Example of plot photography. Photo directions from left to right: from north, east, south, west, toward sky.

Hemispherical photos are only acquired in special circumstances when the equipment is available and on selected dates. This procedure is still at an experimental stage. Hemispherical photograph equipment may consist of: a Tripod and stabilizing mechanism, Nikkor 8mm lens, film camera, light meter, compass, film; or Tripod and stabilizing mechanism, Nikkor 8mm lens, digital SLR camera, compass; or both.

The equipment is stabilized and positioned consistently so that the same side of the camera always points towards north. The picture is taken using a timer to avoid blurring; pictures must be taken in low light conditions (dawn). When a digital camera (Nikon D80): three photographs at 60° increments around the z-axis (directly up) are taken to cover the entire 180° hemisphere. The pictures are taken using the timer to avoid blurring. Suitable acquisition time is still unknown. The position of the camera is taken three times using the rangefinder from points L1 and L2.
PART 2: LiDAR-Derived Data Products

The main protocol for deriving terrain and forest variables from airborne LiDAR data is to separate the ground returns from the vegetation returns. This process involves first extracting the digital surface model (DSM) from the first return data and then extract the digital terrain model (DTM) or elevation model from the last return data. The canopy height model (CHM) is:

\[ \text{CHM} = \text{DSM} - \text{DTM} \]

and can be used with field data to map some forest attributes over space (e.g. canopy height, canopy cover, etc.). The accuracy of the LiDAR product will be verified with field plot data. Other forest variables make use of the multiple returns, and calculate metrics based on the density of returns at specific heights from the ground. Determination of canopy base height and canopy bulk density for example require analysis of the vertical structure of multiple returns.

Digital Surface Model

These products are made from “first return” data (see figure above). The method involves classifying the highest reflections, and interpolating the missing points to create a smooth surface. This is often expressed as a raster grid of a chosen cell size (e.g. 1m).

Digital Terrain or Elevation Model

The LiDAR derived DEM product are made from “last return” data (see figure above). The method involves filtering out the false ground, and interpolating to a continuous surface of a chosen cell size. Interpolation methods can vary, and might include Kriging, nearest neighbor, inverse distance weighted, and spline. Our DTM is a 1-m grid from which slope and aspect grids have also been created. We have systematically evaluated the impact of slope variation and LiDAR density on different interpolation methods (see figure below). Our result indicated that the Kriging-based methods consistently outperformed the other interpolation methods in all different elevation conditions in the Sugar Pine study area.

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**Figure 4.** Impact of slope variation on interpolation accuracy for the LiDAR data in the Sugar Pine study area. CV: elevation coefficient of variation, RMSE: root mean square error, IDW: inverse distance weighted interpolation, NN: natural neighbor interpolation, Spline: spline.
DTM Products
- Digital Elevation Model (DEM) at 1-m
- Slope and Aspect at 1-m
- DEM, slope and aspect resampled at user-defined scales (e.g. up to 30m)

Canopy Height Model

The canopy height model is the difference between the DSM and the DTM, and can be used to map tree height, canopy cover, and individual trees over space. Other forest attributes require more processing of the multiple return data. Variables such as canopy bulk density, canopy base height and canopy height for each plot will be derived using the field data-set and LiDAR metrics in a stepwise multiple regression to develop models relating the canopy fuel parameters to a subset of lidar metrics. The regressed lidar metrics will be extrapolated to each grid cell across the study area to generate an estimated value of each canopy fuel parameter at each grid cell, resulting in a set of maps at variable scales (from 5m up).

Forest Structure Products
- Canopy Bulk Density at 10m-scale
- Canopy Base Height at 10m-scale
- Canopy Height at 10m-scale
- Canopy Cover at multiple scales 10m – 300m.

Figure 5. Conceptual diagram of LiDAR data processing flow.
PART 3: Inter-team Analysis

Forest inventory over the last 100 years has concentrated on the determination of the volume of logs, trees, stands, and a calculation of increment and yield. These efforts have recently expanded to include measurement and evaluation of habitat characteristics.

Forest Attributes

Tree attributes such as height, dbh (diameter at breast height), height to live crown, species, age, location, basal area, volume, biomass growth and leaf area index have been measured in the field in forest plots for over 100 years. Many of these attributes can be measured directly using LiDAR data, and some can be inferred from lidar data. Stand attributes such as age, trees per hectare, mean diameter and height, dominant height, volume per hectare, form factor, annual increment per hectare and growth have also been estimated from individual plot data for some time. Again many of these can be measured from processed LiDAR data.

Fire and Forest Health Team.

The FFEH team is interested in understanding treatment effect on fire behavior and forest health. The FFEH team needs the following data from SPATIAL Team.

Fire behavior model (FlamMap) inputs

These are calculated for individual pixels, optimal size: 5-10m:

- Canopy Bulk Density – mass of available canopy fuel per unit volume (e.g. kg/m3)
  - include the following as available fuel (Scott and Reinhardt, 2005): live and dead foliage, 0-3mm live branchwood, 0-6mm dead branchwood
  - Calculate by running each field plot through Fuels Management Analyst (Carlton, 2005) then scale to landscape using least-squares regression (Valiant, 2007).
- Canopy Base Height – the lowest height above the ground at which there is sufficient available canopy fuel to propagate fire vertically through the canopy
  - Calculate based on the lowest height at which there is at least 0.011 kg/m3 of available canopy fuel
  - Can be calculated at plot level using Fuels Management Analyst, then scaled up by interpolation (Valiant, 2007).
- Canopy Height – average height of the dominant and co-dominant trees in a stand
  - Need to determine global threshold from which to compute average (e.g. upper 20 % of LiDAR hits)
  - Threshold can be determined using plot-level data
- Canopy Cover - horizontal percentage of the ground surface that is covered by tree crowns
  - Can be calculated in bins (1: 1-20, 2: 21-50...) or percent (0-100)
  - Can be based on density of LiDAR hits and/or plot-level measurements
- Slope (%)
- Aspect (degrees)
- Elevation (m)
• Shrub cover – horizontal percentage of understory covered by shrub crowns
  - Not critical for running fire models, but used to determine fuel model
  - Can be calculated in bins or percent

**Estimate of standing carbon**
Ultimately we would like this pre- and post-treatment.

**Wildlife Team**
Geospatial data are used in wildlife research in many ways, including 1) to characterize vegetation and animal habitat, 2) as inputs in environmental niche models or species distribution models, and 3) as a check on existing habitat data. Mapping important habitat characteristics such as canopy cover, forest type, topographic roughness, patch connectivity, etc. can all be done at a finer spatial resolution than with many conventional data. These environmental niche models (ENM), are increasingly recognized as important tools that can support our understanding of biodiversity and speciation mechanisms, as well as aid in setting natural resource, conservation and species management priorities (Graham et al., 2004; Guo et al., 2005; Kelly et al., 2007).

**Fisher**
According to the fisher team, 300 m resolution is the appropriate scale for Fisher research. The Fisher team needs the following parameters as inputs to their species distribution model:

- Number of tree, tree size, class, species composition, biomass, topography variability, stem density, canopy closure & a range of landscape indices (derived from FragStats) at the 300m scale.
- These variables can also be examined across different scales and provided at different resolutions.

**Owl**
According to the owl team, the appropriate resolution for the owl work is likely 50m. There are about 80 owl home ranges that need to be characterized by environmental features such as vegetation and topographical variability. However, our current LiDAR footprint only covers 3 owl nesting trees. There is no current LiDAR acquisition plan to extend the current study area to cover all owl study areas, but we will evaluate the NextMap product (an alternative solution, 5 meter resolution, first and last return from Radar data) for feasibility. Note that this will only provide an average result within a 5 by 5 meter grid.

LiDAR can also be used to assess the accuracy of the vegetation and forest cover types used to classify vegetation, and habitat metrics used to model variability in spotted owl demographic rates, in the central Sierra Nevada, California, 1990-2004. Previously, the following metrics were estimated within a 400 ha circle at each site, and the LiDAR data can be used to verify some of these.

**Cover Type**

1. Hardwood forest (>10 % hardwood canopy cover and <10% conifer canopy cover)
2. Brush and/or sapling conifer (<15.2 cm dbh)
3. Pole conifer forest (15.2 to 30.3 cm dbh)
4. Medium conifer forest (30.4 to 60.9 cm dbh) low canopy cover (30-69%)
5. Medium conifer forest (30.4 to 60.9 cm dbh) high canopy cover (>70%)
6. Large conifer forest (>61 cm dbh) low canopy cover (30-69%)
7. Large conifer forest (>61 cm dbh) high canopy cover (>70%), and
8. Water or barren rock.

**Water**
The water team will be using the Distributed Hydrology Soil Vegetation Model (DHSVM) in their research. Required variables for the DHSVM that can be derived from LiDAR products and high -spatial resolution images are:

1. Vegetation type
2. Fractional coverage of overstory
3. Radiation attenuation by the overstory
4. Clumping factors of overstory vegetation
5. Overstory LAI
6. Understory LAI
7. High resolution DEM

**Public Participation**
Spatial data and visualizations are used in all public meetings; we have developed a spatial component to our web-based discussion board; and spatial data is used at SNAMP Integration Team meetings.

**Team integration and data sharing**
All the spatial and non-spatial data from the UC science teams will be stored and maintained in a digital library developed by the spatial team. The data will be stored according to their data levels. Example definitions of the data level are as follows: (definitions may vary depending on the need of each UC science team):

- **Level 0:** raw data (e.g. flat files off data logger or field book, instrument manuals, instrument descriptions, raw LiDAR)

- **Level 1:** data cleaned & formatted: CSV or TXT files (e.g. delete NaN/-999 missing data points & outliers, convert LiDAR LAS file into ESRI GRID file, reprojecion).

- **Level 2:** Calibrations applied to yield usable measurements: processing algorithms (e.g. Date, EC-temperature corrected).

- **Level 3:** Correction if needed – i.e. stage to staff gauge: processing algorithms

- **Level 4:** Discharge of calculated values: processing algorithms, other value added products/data analysis (e.g. Discharge using rating curve).
Level 5: value added product with model: processing algorithms, and other value added products/ data analysis.

Data Sharing
SNAMP project is committed to data sharing within the UC science team as well as with the public. Our digital library includes the following data sharing levels:

1. share only with individual science team;
2. share with UC science teams; or
3. share with public.

Detailed descriptions on our data sharing policy & agreement can refer to the SNAMP data sharing agreement at the SNAMP website: http://snamp.cnr.berkeley.edu.

References


Valiant, N.M., 2007. Sagehen Experimental Forest past, present, and future: an evaluation of the fireshed assessment process, University of California, Berkeley, Berkeley, CA USA.


Appendices

Appendix A: First Spatial Team Newsletter

2008 FALL EDITION SPATIAL TEAM VOL. 2 NO. 3

A Newsletter from the SNAMP Public Participation Science Team - Volume 2, Number 3, November 2008

SNAMP HIGHLIGHT: SPATIAL TEAM

The spatial team has two leads: Dr. Maggie Kelly at UC Berkeley and Dr. Qinghua Guo at UC Merced. At UC Merced, staff researcher Hong Yu is developing a bare earth model from the LIDAR data with Wenkai Li, PhD student. The UC Berkeley group will concentrate on research and support for the wildlife and public participation teams, and the UC Merced team will support the water team. Both groups will support the fire and forest ecosystem health team.

the SIERRA NEVADA Adaptive Management Project newsletter

Welcome to our newest SNAMP newsletter! This issue focuses on the Spatial Team. To read other newsletters and for more information, please visit our project website at: snamp.cnr.berkeley.edu.

THE SNAMP SCIENCE TEAMS

As directed by the US Forest Service’s 2004 Sierra Nevada Forest Plan Amendment, vegetation management treatments that remove flammable natural materials from national forests are planned or being implemented at many sites in the Sierra Nevada where fire risk is high. How do these treatments affect fire behaviors, wildlife, forest health and water? A team of university scientists is monitoring the effects of vegetation management treatments in two Sierra Nevada locations: Sugar Pine (in the Sierra National Forest) and Last Chance (in the Tahoe National Forest). The SNAMP science teams are made up of researchers from University of California Berkeley, UC Merced, UC Cooperative Extension, and the Univ. of Minnesota. The science teams study fire and forest health, wildlife (focusing on fisher and spotted owl), water, and public participation. All science teams are supported by spatial analysis and GIS.

SPATIAL DATA IN SUPPORT OF FOREST ECOLOGY

Geospatial data, or data that is linked to a place on the surface of the earth, is increasingly a part of our daily lives. We commonly use digital maps to navigate, we use GPS (Global Positioning Systems) to capture our routes through the forest and the city, and we look at aerial imagery from websites like Google Maps showing our neighborhoods from above. These and other tools are also being used in environmental sciences, and they play a large role in the SNAMP project. We are mapping the forest before and after vegetation management treatments and measuring forest habitat characteristics across our treatment and control sites. One of our datasets, called LIDAR, is a new source of data that shows great promise for mapping forests.

LIDAR (LIGHT DETECTION & RANGING)

Environmental sciences are inherently spatial, and geospatial tools such as Geographical Information Systems (GIS), Global Positioning Systems (GPS) and remote sensing (collecting imagery using a sensor that is not in direct contact with the target, as we do with a camera) are fundamental to these research enterprises. Remote sensing has been used for forest and habitat mapping for a long time, and new technological developments such as LIDAR (light detection and ranging) are making this field even more exciting. Here we briefly describe LIDAR’s basic principles and show some preliminary analyses completed for the SNAMP Project. We are using this data to model detailed topography to help the water team understand runoff in the SNAMP watersheds, to map forest canopy cover and vegetation height as inputs to the fire and forest health team’s detailed fire models, and to derive important forest habitat characteristics for the spotted owl and fisher teams.

For More Information: http://snamp.cnr.berkeley.edu
LIDAR TECHNOLOGY & BASICS

LIDAR systems work by “sounding” light against a target in a similar way to sonar or radar. First, a laser illuminator generates a short pulse of electromagnetic energy at a specific wavelength (a laser pulse) and directs it towards a target. In our case, the sensor is attached to the underside of an aircraft, and the laser is directed towards the ground. The wavelengths used are typically in the visible or near infrared region of the electromagnetic spectrum. The laser pulse moves towards the earth, and when it meets an object like a leaf or the ground, the light can be reflected, absorbed or transmitted by that object. Different materials interact with light in different ways. The portion of the light that is reflected moves back towards the airborne sensor where it is detected and recorded (see “First Return” in Figure 1). The time between sending the pulse out and its collection is measured and converted to distance by using the speed of light. Simultaneously, the aircraft’s exact position and orientation is measured by an on-board GPS and inertial measurement unit (IMU). The combination of all the above measurements allows us to backtrack and calculate the elevation at which the light pulse was reflected. Some LIDAR instruments, like the one we use in SNAMP, collect multiple signals from one initial pulse, and so we can get information about the tops of trees, the structure of the trees, and the ground (see “Multiple Returns” and “Last Return” in Fig 1).

LIDAR DATA ANALYSIS

Raw Data: LIDAR data is typically delivered as a “point cloud,” a collection of elevations and their intensities that can be projected in a three-dimensional space. In Figure 2 (right) we show this “point cloud” concept. There are thousands of individual points in the image, each colored according to its height (magenta and red are high; orange and yellow are low; figure 2 shows three trees on a gradual hillside).

Bare Earth: Once the data is collected, the first step is to transform the data into a “bare earth” model, which is an approximation of the ground if all objects above surface are removed. We use the “Last Return” data (see Figure 1 above) to generate this model of the bare earth. These are typically very detailed products (with a small footprint on the ground) and provide much more topographic information than from Digital Elevation Models (DEMs) that were derived from topographic maps. See the example of a DEM derived from LIDAR data at right (Figure 3). Our DEM has a ground resolution of under 1m.

Forest Structure: Another typical step in processing LIDAR data is to examine individual trees and forest structure. An example of a forest stand is shown in Figure 4. These and other products help us understand how the forest influences surface hydrology, how a patch of forest might provide habitat for a fisher and how a forest might burn given certain weather and wind patterns.

Future Analyses: We are in the process of linking the forest parameters gathered by the Fire & Forest Ecosystem Health Team in summer 2008 with the LIDAR-derived data to help scale-up forest variables to the fireaged scale. For example, tree height, tree breast-height and canopy cover have been successfully modeled using LIDAR data in other studies, and there is active research linking field-based and LIDAR-based fire-related measures such as canopy base height and ladder fuels, and wildfire-related measures such as vertical structure. We are still in very preliminary stages of data analysis, so please stay tuned to the SNAMP website for more information.