Tomoaki Miura displays his powerful computer server array that he uses for GIS work.

Tracking invasive weeds from space

CTAHR Student Research Symposium

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Remote sensing of vegetation dynamics from island, to continental, to global scales

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My research work is focused on the development and applications of spatial analysis technologies, including remote sensing, geographic information systems (GIS), and global navigation satellite systems (GNSS), to the management of natural resources. Most of my current research projects are on the development and validation of new remote sensing technologies that study vegetation dynamics and I would like to introduce some of those projects in this news article.

Remote sensing is defined as acquiring information about objects without being in direct physical contact with them. Our ears, eyes, and cameras are examples of remote sensors. More specifically, remote sensing is the science of collecting and interpreting electromagnetic (EM) radiation from the Earth using sensors on platforms on the ground (radiometric thermometer), in the atmosphere (balloons, airplanes), or in space (satellites). Depending on its chemical compositions and structures, every material reflects or emits EM radiation in different magnitudes with respect to wavelength. These “spectral signatures” are used to differentiate or even to identify surface objects either qualitatively or quantitatively. Land use and land cover maps are, for example, created based on differentiating spectral signatures. Please visit my website at [http://www.ctahr.hawaii.edu/miuralab/projects/makaha/intro_RS.html](http://www.ctahr.hawaii.edu/miuralab/projects/makaha/intro_RS.html) for a more detailed description of remote sensing.
Detection, mapping, and monitoring of invasive Species infestation in Hawaii

Exotic plant invasion is one of the most significant threats to various ecosystems all over the world. Oceanic islands are considered particularly susceptible to such invasion for several reasons: less exposure to different types of disturbances, a small number of species, taxonomic disharmony, and reduced aggressiveness of native biota due to less genetic variety. Approximately 90 plant species have become invasive in Hawaii, threatening native plant species, and the number is growing.

One of the important components in invasive plant management is to understand the spatial and temporal dynamics of the invading populations. Assessments over time and space are essential in detecting, mapping and monitoring spatial distribution, abundance, and population composition of invasive species when preventing the entries of new species is unsuccessful. Remote sensing is considered an effective technology that provides such spatial and temporal information of invasive species efficiently.

Fireweed is one of the highly invasive weeds in Hawaii and its ecological and economic impacts on range and pasture lands and livestock production is significant. I work with Drs. Mark Thorne (HNFAS), Jonathan Deenik (TPSS), Harold Keyser, Dale Gardner and Jim Phister (USDA-ARS Poisonous Plants Laboratory,
Utah), and county extension agents John Powley, Glen Fukumoto, and Matt Stevenson to characterize the invasion ecology and population dynamics of fireweed and to develop remote sensing methods to detect and map fireweed populations. Several past attempts to map fireweed using satellite imagery were unsuccessful because the spectral signatures of fireweed, although unique, were obscured by other ground materials at the spatial resolutions offered by existing satellite sensors.

In our project, we felt the need of a new system, and Roland Thompson (Ph.D. candidate in Department of Urban and Regional Planning) and I developed a cost-effective, high-resolution digital camera system that allowed us to image at spatial resolution as high as 5 mm. The system was deployed on a helicopter and flown across pastures in Maui. Alex Dale (NREM M.S. student) and I developed an image processing algorithm, processed the acquired digital air photos, and successfully detected and mapped fireweed flower covers. Our plan is to correlate these remote sensing estimates of fireweed flower cover with ground estimates of fireweed population density to advance our airborne digital camera system for automatic determination of fireweed population density.

Assessing tropical ecosystem dynamics in Hawaii

Scientific consensus indicates that global warming is occurring due to increased greenhouse gas concentrations in the atmosphere. Even if the concentrations of greenhouse gases had been stabilized in the year 2000, mean global temperatures are predicted to increase another 0.5°C during the 21st century. This temperature increase is expected to result in a higher intensity and frequency of extreme climate events such as El Niño events. It is generally accepted that significant drought occurs after an El Niño event in Hawaii. Recent rainfall data analysis indicates a long-term decreasing trend in rainfall in Hawaii. Response of tropical forests to such climate variability is not well understood despite its importance in the carbon and water cycles. Systematic, long-term observations are needed to monitor seasonal and inter-annual variability in tropical forest ecosystem functioning/services in response to climate events. Satellite remote sensing is an indispensable tool in this respect, as it allows for systematic, repeated observations of land surface conditions, including vegetation photosynthetic activities and seasonal dynamics.

Moderate Resolution Imaging Spectroradiometer (MODIS) is a NASA’s satellite sensor designed to provide consistent, well-calibrated data records at 250 m - 1 km spatial resolutions for the studies of Earth’s ecosystem processes. Launched in 1999, this sensor provides remotely sensed imagery of the major Hawaiian islands on a daily basis for the first time.

Together with Dr. Chris Lepczyk (NREM), Michele Harman (NREM M.S. student), and Dr. Sun Park (UH Hilo), I am working to characterize tropical forest seasonal dynamics and their inter-annual
variability using high temporal resolution satellite data records from MODIS. The project objectives are to: 1) quantify spatial and temporal patterns in cloud cover occurrences at the moderate spatial resolution of 1 km for the whole state of Hawaii, and then to recommend and develop a temporal compositing scheme for the generation of “cloud-free” MODIS time series data over the main Hawaiian islands, and, 2) develop a quantitative methodology to extract seasonality in vegetation photosynthetic activities, or “phenological metrics,” from the MODIS time series data for tropical forest ecosystems. We are also conducting seasonal field campaigns at the recently established Hawaii Experimental Tropical Forest in support of refining and validating our MODIS-derived phenological metric algorithm. Results obtained through this proposed study will provide a significant step toward the establishment of a regional-scale monitoring and analysis program of tropical vegetation with moderate resolution remote sensing.

Cross-Calibration of satellite products for the U.S. National Drought Monitoring System

I also work on continental scales. One of the most widely-used satellite products is spectral vegetation indices (VIs). VIs have operationally been used to monitor temporal and spatial variations of vegetation photosynthetic activities and biophysical properties on regional to global scales. Such VI data records originated from a sensor series, NOAA Advanced Very High Resolution Imaging Spectroradiometer (AVHRR) developed in the 1980s, which is now transitioning to MODIS and to a new future sensor series, Visible Infrared Imager Radiometer Suite (VIIRS). These
long-term VI observations have been used in a variety of applications, including crop yield prediction, early famine warning, and drought monitoring. These long-term observations, however, require much effort to ensure continuity and compatibility due to various engineering- and science-related issues.

I have been addressing this satellite product continuity issue with Drs. Hiroki Yoshioka (Aichi Prefectural University, Japan) and Alfredo Huete (University of Arizona), and Drs. Jeff Eidenshink, Brad Reed, Jess Brown, and Yingxing Gu (U.S. Geological Survey). Our on-going activities involve the development of cross-calibration methodologies and inter-sensor translation equations that will allow for interchangeable, seamless uses of VI products from various satellite sensors. Initial results have been obtained and we are currently evaluating accuracy and precision of the derived translation equations. The final translation equations will be used in the U.S. continental-scale drought detection system developed by the U.S. Geological Survey’s Earth Resources Observation and Science (EROS) Center.

**Development of global vegetation phenology and vegetation index products**

Vegetation phenology is a characteristic property of ecosystem functioning and predictor of ecosystem processes. Shifts in phenology depict a canopies’ integrated response to environmental change and influence local biogeochemical processes, including nutrient dynamics, photosynthesis, water cycling, soil moisture depletion, transpiration, and canopy physiology. Recent findings indicate that the effects of climate change are first detected in landscape phenology, hence this has emerged as a key area of research in biosphere-atmosphere interactions, climate change, and global change biology. Knowledge of phenologic variability and the environmental conditions controlling their activity are a further prerequisite to inter-annual studies and predictive modeling of land surface responses to climate change. Satellite phenology encompasses the analysis of the timing and rates of vegetation growth, senescence, and dormancy at seasonal and inter-annual time scales. VIs, which capture the aggregate functioning of a canopy, are the most robust and widely used measurements for extracting phenology information.

As a member of an interdisciplinary, multi-institutional group consisting of Drs. Kamel Didan, Jeff Czapla, and Wim van Leeuwen (University of Arizona); Dr. Mark Friedl (Boston University); Dr. Xiaoyang Zhang (NOAA); and Dave Myers and Calli Jenkerson (U.S. Geological Survey), I also work to develop long-term data records of global vegetation phenology and vegetation index products. This project is in its first project year and we are currently adapting the existing phenology and VI generation algorithms to generate preliminary data records.

In relation to global vegetation dynamics studies, I am also a science team member of a Japanese satellite,
the Greenhouse Gases Observing Satellite (GOSAT), or “IBUKI” (meaning the Earth’s breath) launched on January 23, 2009. IBUKI is a collaborative project by Japan Aerospace Exploration Agency (JAXA), the National Institute for Environmental Studies (NIES), and the Ministry of the Environment (MOE) to provide the world’s first satellite to observe global greenhouse gasses from space. Data acquired by the “IBUKI” will be utilized to learn the “current” status of the Earth concerning global warming and to contribute to a better future for all mankind. My specific contribution to the IBUKI project is to validate its VI product generation algorithm and assure compatibility of IBUKI VI product with those from other sensors, including MODIS and AVHRR.

Yes, this is a lot of technical information, but the bottom-line is this: keeping invasive plant species at bay and being able to track plant changes on a global scale is important to the future of the planet; and that is a very good thing!


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Languages Spoken: English, Japanese

Recent Publications

Recent Grants
Vegetation Phenology and Vegetation Index Products from Multiple Missions and Satellite Sensors; $385,715 Subcontract Amount; NASA, Subcontracted through University of Arizona.
Development of Best Management Practices for Control of Madagascar Fireweed (Senecio madagascariensis Poiret) in Maui; $54,056; Maui County.
Multi-sensor Translation of EOS Reflectance and Vegetation Index Products for Long Term Continuity with AVHRR; $657,353; NASA.