Lessons Learned on Border Area Projects

Douglas (Doug) Stow
Center for Earth Systems Analysis Research (CESAR)
Department of Geography
San Diego State University (SDSU)
Geography Water Management/RS/GIS Faculty

Richard Wright – GIS, cartography, Tijuana River Watershed Atlas, water resource policy

Trent Biggs – Watershed hydrology modeling, hillside erosion (e.g., Goat Canyon) and estuarine sedimentation processes (e.g., TJ Estuary), remote sensing

Kathleen Farley – land use change effects on ecosystem services (grasslands and shrublands), policy effects on watershed land use change (e.g., TJ River watershed)

Allen Hope – Watershed hydrology modeling, post-burn recovery of chaparral, invasive plants and their effects on stream hydrology, remote sensing
Piotr Jankowski – GIS, spatial decision support systems, sensor networks, water resource management

Lloyd (Pete) Coulter – remote sensing, image processing, survey GPS, habitat and fire management, urban water demand, border law enforcement

Doug Stow – remote sensing/image processing, habitat, fire fuel and invasive plant monitoring, land cover/land use change
SDSU Geography Border Water Projects

GIS Mapping Project for Bi-national Coordinated Land-Use Planning and Education in the Tijuana River Watershed
  Funding Agency: NOAA [collaboration w/ INEGI and COLEF]
  PI: Richard Wright, Co-Is: Profs. Allen Hope, John O’Leary, Doug Stow

San Diego County-Baja California Water Quality Prediction and Monitoring Program
  Funding Agency: California State Water Resources Control Board
  PI: Richard Wright, Co-Is: Rick Gersberg, Allen Hope, Doug Stow

Sediment and Erosion in Urban Tijuana: Socioeconomic Interactions with Sediment Budgets Under Rapid Urbanization of Marginal Lands
  Funding Agency: Southwest Consortium for Environmental Research and Policy
  PI: Trent Biggs

Particle Size and Accumulation Rates of Sediment Within Fluvial and Feeder Canyon Depositional Environments of the Tijuana Estuary Reserve
  Funding Agency: NOAA
  PI: Trent Biggs

Linking Land Use and Policy in the Tijuana River Watershed
  Funding Agency: U.S. EPA/Southwest Consortium for Environmental Research and Policy
  PI: Kathleen Farley
Other SDSU Geography Border or Water Remote Sensing Projects

Regional Hydrological Response of Semi-Arid Mediterranean Climate Watersheds to Land-Cover/Land-Use Variability
   Funding Agency: NASA LCLUC
   PI: Allen Hope, Co-I: Doug Stow

Fire, Land Cover and Climate Change: Impacts on River Flows in Semiarid Shrubland Watersheds
   Funding Agency: NASA LCLUC
   PI: Allen Hope, Co-I: Christina Tague

Spatial Decision Support System for Border Security
   Funding Agency: NASA REASoN
   PI: Doug Stow, Co-Is: Allen Hope, Piotr Jankowski, Ming Tsou, John Weeks

Spatial-temporal Patterns of Smuggling and Migration: National Center for Border Security and Immigration
   Funding Agency: DHS Science & Technology
   Center PI: Jay Nunamaker, U. Arizona, SDSU PI: Doug Stow
Lessons Learned: Bi-national Cooperative Projects

- Watersheds can span international borders
- Access to and sharing of new data sets
- Variable data standards and formats
- Protocols for cooperation and communication
- Cultural sensitivities
- Cross-border travel issues
- Transfer of funds
- Rewarding → Challenging
Lessons Learned: Resource Agency - University Cooperative Projects

- High expectations (e.g., accuracy, cost, etc.) by user agency personnel
- University driven by research and education; not always sensitive to user needs
- Agency funds limited for capital investments in remote sensing technology investments
- Difficult to achieve operational implementation of remote sensing technology
Role of Remote Sensing in Water Management

• Land cover/land use and topographic data for watershed modeling (quantity and quality)
  - vegetation cover, type, structure (ET, infiltration, streamflow)
  - impervious surfaces (runoff coefficients)
  - digital elevation data (slope gradient and aspect)
• Irrigated lands assessment
  - agriculture (water demand, unregulated usage)
  - urban (landscaping, parks)
• Vegetation mapping/monitoring
  - invasive plants (water demand)
  - wetland and riparian vegetation composition and condition
  - groundwater extraction/exploration (geobotanical indicators)
• Water quality mapping/monitoring
  - sediment/turbidity
  - chlorophyll/eutrophic status
  - pollutants (normally surrogate relationships with optical properties)
San Diego County-Baja California Water Quality Prediction and Monitoring Program

Funding Agency: California State Water Resources Control Board

PI: Richard Wright, Co-Is: Rick Gersberg, Allen Hope, Doug Stow
Investigate Utility of TM and IKONOS Satellite Data to Map and Identify Land Use for Water Quality Modeling

Determine utility of classifying land use and land cover (LU/LC) with several remote sensing imagery types in the context of providing LU/LC inputs to water quality models such as BASINS and the core hydrologic model in BASINS, HSPF (Hydrologic Simulation Program-Fortran).
Campo Creek Watershed

Study Area

United States

Mexico
LU/LC Classification System

- Commercial
- Industrial
- Agriculture
- Rangeland
- Domestic livestock
- Barren land
- Mixed urban or built up
- High-density residential
- Low-density residential
Landsat Thematic Mapper (TM) satellite imagery with 30 m spatial resolution
IKONOS multispectral with 4 m spatial resolution
• IKONOS panchromatic with 1 m spatial resolution
Fusion of IKONOS multispectral 4 m spatial resolution and panchromatic 1 m spatial resolution images
Color infrared digital orthophotography (DOQQ) image data with 2 ft. (0.6 m) resolution
LU/LC for Tecate Creek Watershed
Landsat TM (30 m)
Accuracy Assessment Results

• Landsat TM (30 m) land cover/use classification product yielded an overall accuracy of 61%.

• IKONOS (4 m) product yielded an overall accuracy of 85%
HSPF has not been extensively applied in arid or semi-arid shrubland ecosystems and only recently in southern California.

Neither calibration software tool has been tested in river systems dominated by intermittent flow.
Three-Dimensional Visualization of Bacterial Indicators at Shore and Ocean Stations of the International Treatment Plant Monitoring Program

Rick Gersberg & H. Johnson
3-D Visualization of Bacterial Indicators at Shore and Ocean Stations of the International Treatment Plant Monitoring Program
Land Use/Cover Change Tijuana River Watershed: 1994 - 2005

Lina Ojeda, COLEF
Kathleen Farley, SDSU
### Land Use/Cover Transitions TJ River Watershed: 1994 - 2005

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<thead>
<tr>
<th>Land cover/use</th>
<th>Juniper Scrub</th>
<th>Chaparral</th>
<th>Coastal Sage Scrub</th>
<th>Riparian vegetation</th>
<th>Mountain Meadows</th>
<th>Grasslands</th>
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Lina Ojeda, COLEF and Kathleen Farley SDSU
Irrigated Vegetation Assessment in Urban Environments

Ikonos

ADAR 5500
Irrigated Vegetation Assessment in Urban Environments

**Irrigated Grass**
- Low stature veg.
  - Homogeneous veg.
  - NDVI

**Tree/Shrub**
- High stature veg.
  - Heterogeneous veg.
  - NDVI

**Modeling with the Knowledge Engineer**

**Urban landuse**
- Unsupervised classification
  - GV shade
  - Texture
  - NDVI

**Knowledge Engineer**
- Irrigated Grass
- Tree/Shrub
- Low stature veg.
- Homogeneous veg.
- Heterogeneous veg.
- Urban landuse
- Unsupervised classification
  - GV shade
  - Texture
  - NDVI
Irrigated Vegetation Cover from Ground Observations and 1 m NDVI Threshold Image

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Integration of Fieldwork, Remote Sensing and Modeling for Sediment Studies
PI: Trent Biggs
Regional Hydrological Response of Semi-Arid Mediterranean Climate Watersheds to Land-Cover/Land-Use Variability

Funding Agency: NASA LCLUC, PI: Allen Hope, Co-Is: Doug Stow
Watershed Similarity Based on NASA MODIS Products

- SOM
- All Products
- EVI
- NDVI
- LAI
- fPAR
MODIS LAI Predicted ET vs. Watershed ET = P-Q for 66 Gauged Watersheds in Southern/Central California
Hydrologic Process Modeling
Spatially Explicit Process Modelling Experiments

Parameters
Equations
Linkages

Streamflow

Examples: MIKE-SHE Pitman
           RHESSys      ACRU     IHACRES
Chaparral Recovery Curve

![Graph showing LAI (Leaf Area Index) over years with a fire event in 1994.](image)
Uncertainty Bounds

Streamflow (mm)

5% bound  95% bound  * Observed


Water Year

Fire

(a)
Border Security: Decision Support System

**MODELS**
- Terrain
- Visibility
- Vehicle/Foot Trafficability
- Origination/Destination
- Vegetation Structure/Condition
- Wildfire Risk
- Weather Severity
- Tunnelability

**MEASUREMENTS**
- Terra (ASTER/MODIS)
- AQUA (MODIS)
- Landsat-7 (ETM+)
- LIDAR / SRTM
- Aircraft multispectral
- Aircraft hyperspectral

**DETECTION SUPPORT**
- Information Products, Predictions, and Data from NASA ESE Missions and Models:
  - Trails and illegal crossings
  - Transborder trafficking
  - Weather/humanitarian safety (freeze/dehydration)
  - Land cover change
  - Wildfire risk
  - Transborder hideouts
  - Clandestine runway locations
  - Potential tunnel locations
  - Border susceptibility
  - Critical habitat impacts
  - Hazard/bio-terrorism risks

**Analysis:**
- Monitor route changes
- Track smuggler speed and direction
- Immigrant origination and destination maps
- Resource assessment
- Predict weather-related risk
- Forecast wildfire risk
- Map apprehension locations
- Map illicit crops and drug laboratories

**Management Decisions:**
- Rescue/recovery plans
- Tactical/strategic plans
- Resource allocation
- Counter-drug intelligence
- Plan sensor locations
- Multi-agency cooperation
- Habitat mitigation response

**Additional factors:**
- Improves border agencies relations/cooperation
- Link SDSS to field via real-time communications

**VALUE & BENEFITS**
- Improve border security
- Reduce loss of life
- Reduce drug traffic
- Improve siting of border personnel/sensors/assets
- Reduce threats to US agents/citizens near border
- Increase confidence in border security agencies and policies
- Minimize impacts to endangered habitat and wildlife
- Reduce negative economic impacts upon local law enforcement agencies, judicial systems, and local economies
- Improve trans-border relations/cooperation
- Expand technologies to other border locations

Adapted from NASA's Earth Science Applications Network: http://www.esanetwork.org
High Resolution Image-based Monitoring

Imagery Specifications

Trail Mapping

Advanced Imagery Methods

Change Detection

Registration

Automated Feature Extraction

REASoN Project

San Diego State University
Large Format Digital Imaging Systems & U.S. Land Border Imagery Collection

NGA, USGS, USBP 2008/2009 Imagery

- Nationwide land borders
  - 30 miles into US
  - 10 miles into Mexico/Canada
- 1 ft spatial resolution
  - 6” for ports of entry
- 3-band true color (RGB)
- Separate near-infrared (NIR) band
- Currently collecting/processing
- 3001, Inc. leading effort, many subs
  - DMC and ADS40 systems
NGA - U.S. Land Border Imagery Collection

Large Format Imagery
- large area coverage
- high resolution
  (10-100 cm)
Spatial Coverage
100 - 10000 km²

National Center for Border Security and Immigration, RESEARCH LEAD: University of Arizona.

ADS40  DMC42
U.S. Border Imagery Collection – ADS40 Imagery

1 Ft Resolution
Low-cost, flexible and mobile aerial platforms

Micro-UAS

Light sport aircraft (LSA)

NEOS GT500 "MOSQUITO"
LOUIS
The Low Cost Unmanned Imaging System
Minimize and Automate Pre-processing of LOUIS UAS imagery
Low-cost autonomous imaging systems for resource reconnaissance and calibration/validation of satellite RS data

Potential Tunnel Entrance

Spoil Piles
LOUIS UAV Color Imagery – Dos Palmas Preserve, Salton Sea Recreation Area
NEOS Mosquito – MS/4100 CIR Digital Camera
SOC-700 Hyperspectral Imagery
Invasive Plant Mapping -- Lake Hodges Site

#80 (779 nm), #60 (694 nm), #25 (548 nm)
Classification Products (*Tamarix spp.*)

Scene Specific Optimal Bands & Indices

Reference Map
How can we help water managers/agencies?

Research/development and technology transfer pertaining to:
- Optical remote sensing/image processing
- GIS data base development (web and mobile GIS)
- Sensor networks
- Spatial decision support systems
- Land use/land cover mapping and change analysis
- Watershed modeling
- Sedimentation studies
- Water resources policy