VQ5 – Ecosystems and Human Well-being

- Science Questions & Applications, Enabling Data Products, Science Traceability Matrix review

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Overarching Question

How do changes in ecosystem composition and function affect human health, resource use, and resource management?

Ecosystems and Human Well-Being

This is about *what affects humans*…..

- Water quality
- Resources availability and quality
- Invasive and undesirable plant species
- Exposure to factors in the environment related to disease
- All of which may ultimately impact social, economic and political behavior

Water Quality

- Direct measurement

- We are able to directly measure many components of water quality using hyperspectral imagery (especially in coastal water and larger lakes).

- Water quality is important for drinking supplies, food supply and human health.

    - A large body of literature/research on:
        * Chlorophyll concentration
        * CDOM
        * Particulate matter
        * Harmful algae blooms
    - Ability to capture *seasonal variations* is of significant importance

Water Quality

- Indirect measurement

- Measurement of ecosystem/watershed properties with direct bearing on water quality of receiving bodies of water.

- Stream water quality is important for drinking water supply, and its effects on downstream lakes or estuaries (eutrophication).

    - We know that all of the following affect WQ:

        * Species composition and functional traits
        * Disturbance
        * Foliar biogeochemistry

Resources Availability and Quality

- Plant stress and disease

- HyspIRI offers unprecedented capacity to detect stress in vegetation. This is highly relevant to resource management and human economic well-being.

    - Affects food and fiber.

    - An extensive body of literature on:

        * Forestry (pre-visual detection of infestations)
        * Agriculture (esp. disease, but also nutrient/water status)

- Important to repeat imaging (yearly) to track changes.

VQ5-3&4

Non-native and Invasive Plants

- Invasive species pose a significant threat to ecosystems worldwide:
  - Displacing native species used for food and fiber
  - Can change terrestrial or nutrient dynamics (because of differing functional and nutrient assimilation strategies)
  - Ultimately affect biodiversity and fauna
- Hyperspectral imagery is a critical tool for mapping:
  - Species composition
  - Nutrients
  - Leaf water content
  - All may be associated with changes due to invasives.
- Important to repeat imaging (yearly) to track changes.

VQ5. Ecosystems and Human Well-Being

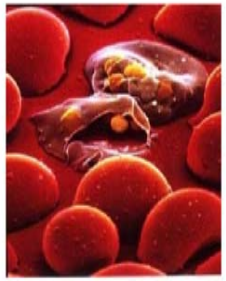
VQ5-1	How do changes in ecosystem composition and function affect the spread of infectious diseases and the organisms that transmit them? [DS 155, 160, 161]
VQ5-2	How will changes in pollution and biogeochemical cycling alter water quality?
VQ5-3	How are changes in ecosystem distribution and productivity linked to resource use and resource management?
VQ5-4	How will changes in climate and pollution affect the health and productivity of aquatic and agricultural resources?
VQ5-5	What are the economic and human health consequences associated with the spread of invasive species?
VQ5-6	How does the spatial pattern of policy, environmental management, and economic conditions correlate with the state and changes in ecosystem function and composition? [DS 155 (5-5), 230 (8-7)]
VQ5-7	What are the impacts of flooding and sea level rise on ecosystems, human health, and security? [DS 195, 224, 227, 348, 357]

VQ5-1

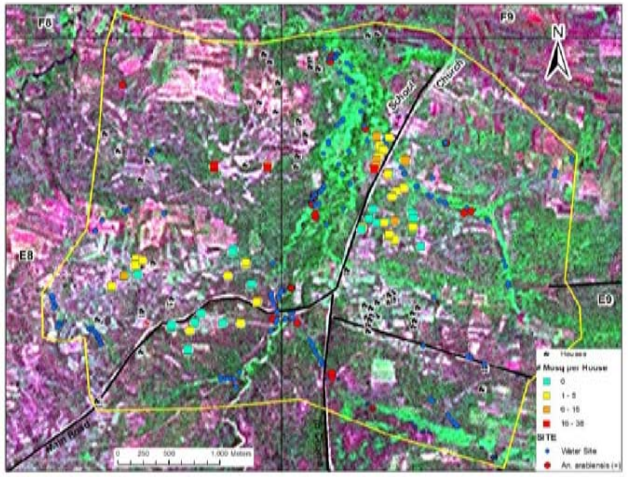
How do changes in ecosystem composition and function affect the spread of infectious diseases and the organisms that transmit them?

How do land characteristics such as vegetation state, soil moisture and land cover composition affect human health (e.g. vector- and animal-borne diseases?

VQ5-1



Vectors, such as mosquitoes transmit many deadly parasitic diseases such as malaria. Combinations of visible and IR bands are associated with areas where there are elevated likelihood of mosquitoes allowing targeted intervention and treatment.



MODIS image showing land cover with numbers of mosquitoes per house to indicate risk of malaria

Science Issue:

Land cover type and composition greatly influence the factors affecting vector- and animal-borne diseases. Because of its high spatial and spectral resolution, HyspIRI data will be able to provide more detailed data to better model the impact of land surface characteristics on human health, disease vector prevalence, persistence and spread.

Tools:

Synergy between VSWIR and TIR observations to identify globally areas of potential risk of disease incidences.

In situ measurements for assessments of presence and number of cariers.

Approach:

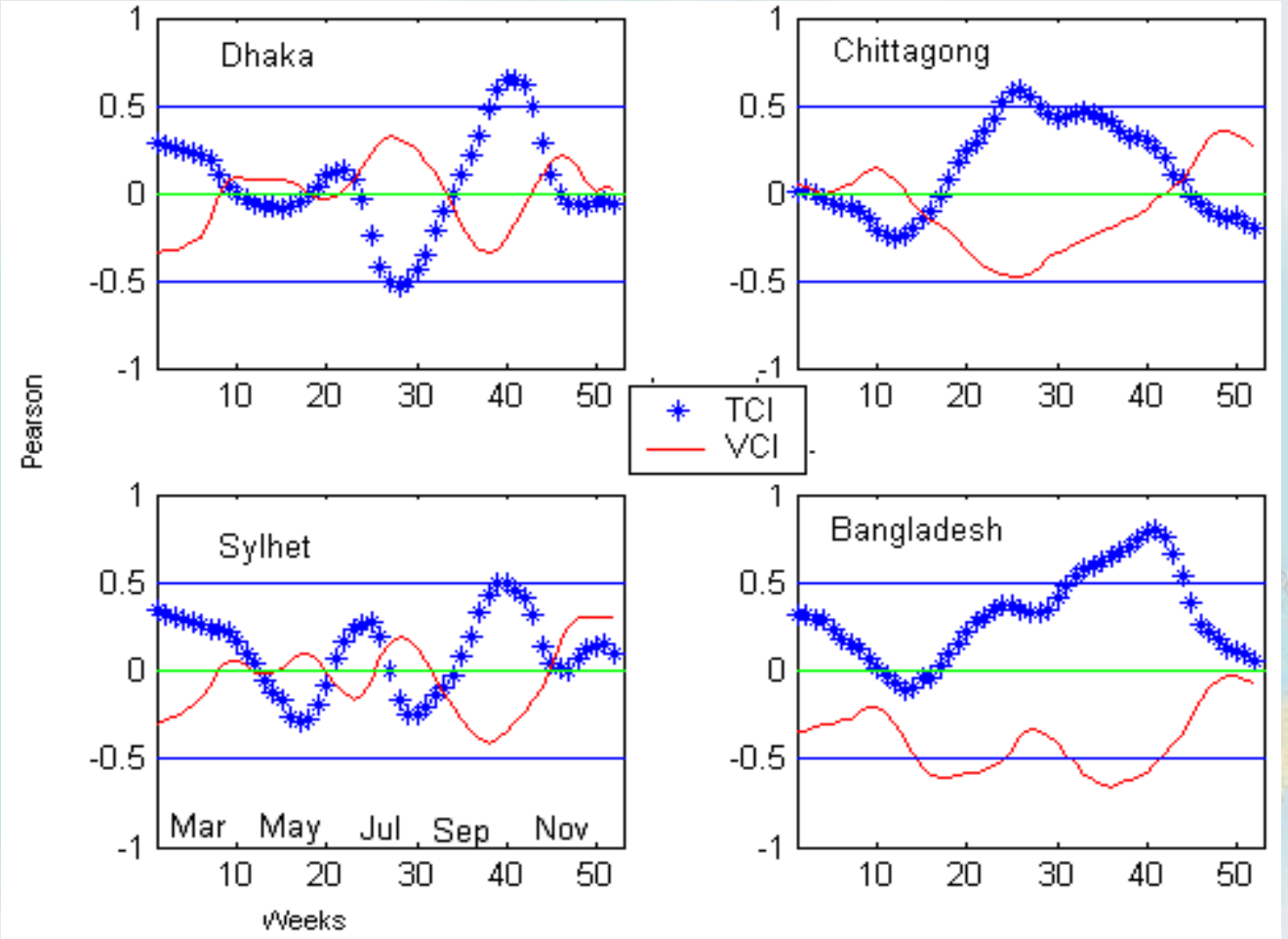
•Use HyspIRI hyperspectral VSIR/VNIR data to characterize landscape and vegetation state, extent, and condition as a measure of assessing prevalence of vector or animal disease carriers

• Use HyspIRI multi-temporal thermal IR data in conjunction with VSWIR/VNIR data to evaluate presence of water bodies and surface temperature conditions to support disease carriers.

Results:

Remote sensing data have shown good promise in applications in many aspects of public health, especially risk assessment related to infectious diseases caused by insect and animal pathogens. HyspIRI with its improved hyperspectral and multispectral capabilities will greatly increase our ability to monitor vector- and animal-borne diseases on a global scale.

Modeling and prediction of malaria, Bangladesh



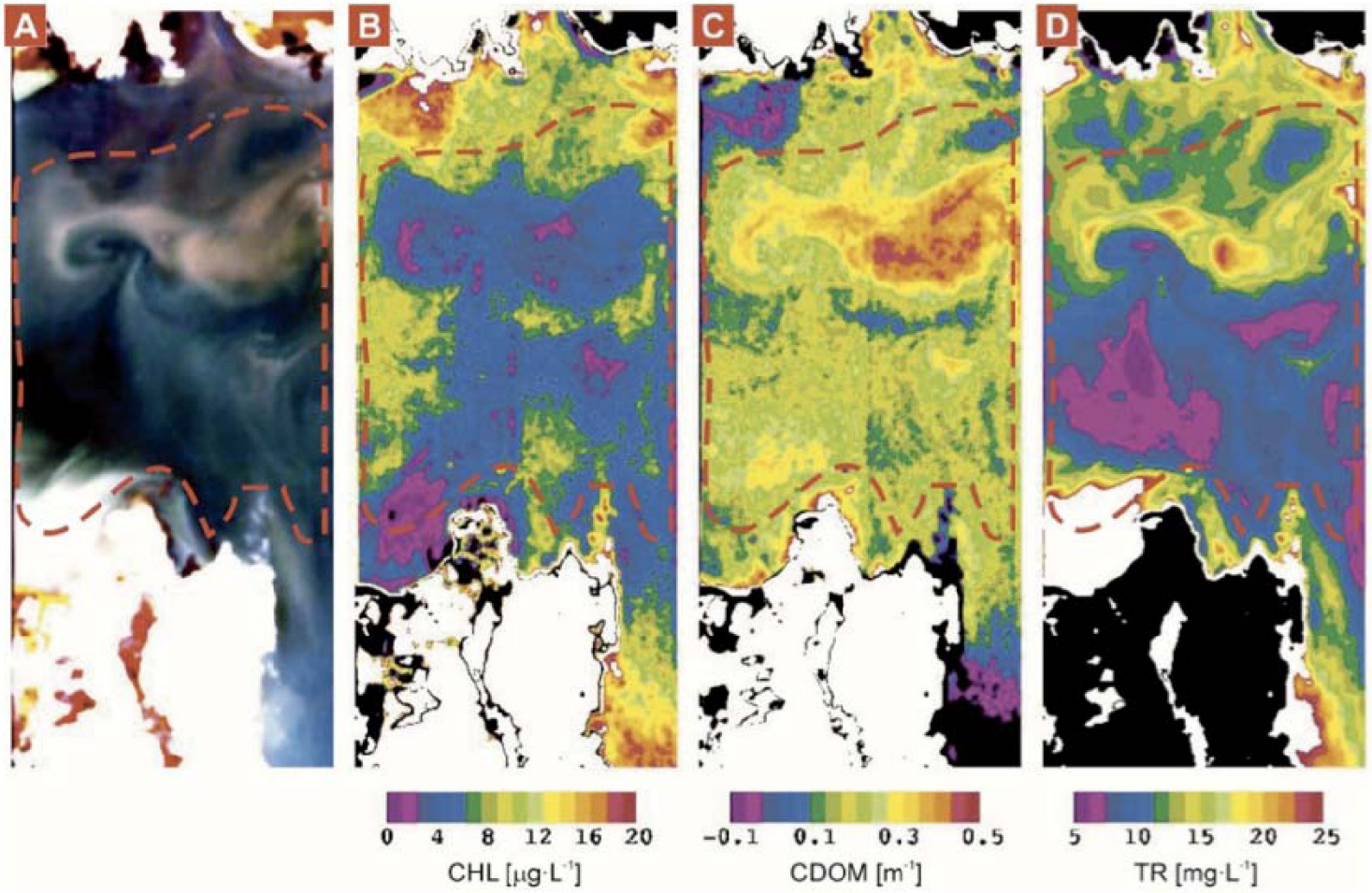
Pearson correlation coefficient dynamics of annual DY (percent deviation of malaria cases from trend) versus weekly area-mean TCI and VCI *(Rahman et al. 2008, IJRS).*

VQ5-2

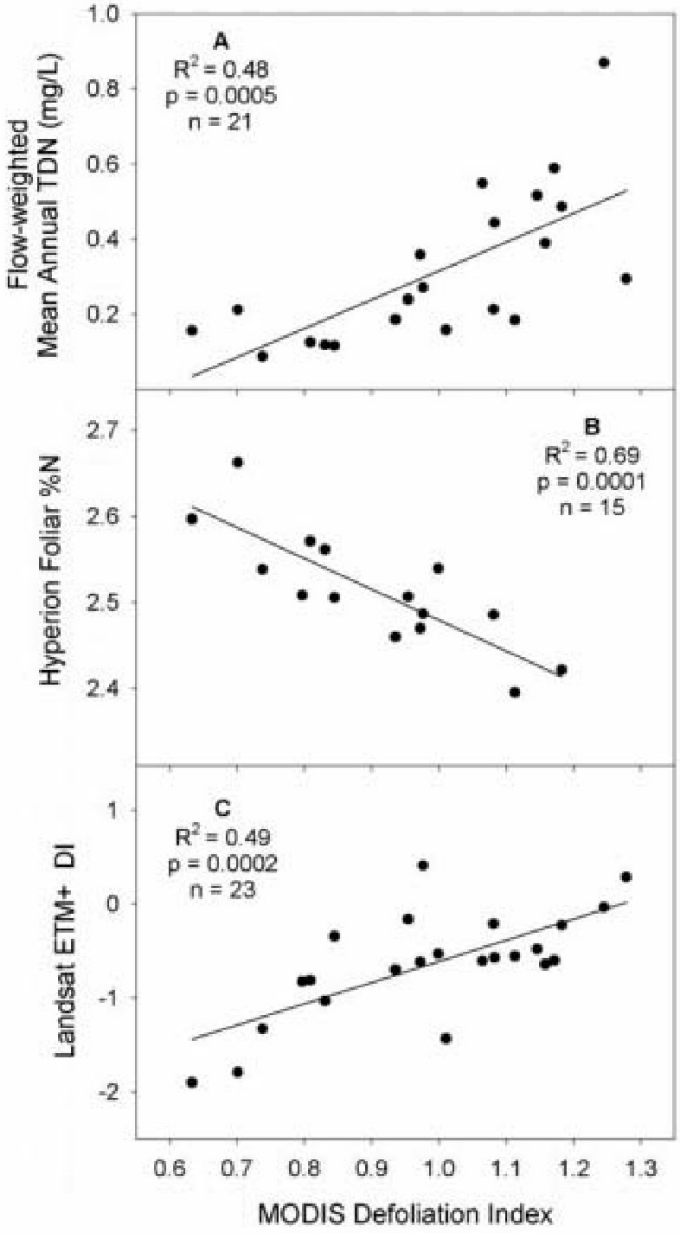
How will changes in pollution and biogeochemical cycling alter water quality?

Example 1: Direct measurement of water quality in coastal waters.

VQ5-2



From Brando and Dekker (2003). (a) Image derived from filtered Hyperion scene over Deception Bay and processed to estimate concentrations of (b) Chlorophyll, (c) Chromophoric Dissolved Organic Material (CDOM), and (d) tripton (TR). The dashed red line delimits the clear-sky, optically deep water pixels in this scene.



Example 2: Variability in forest foliar nitrogen concentration, and its relationship to stream water quality.

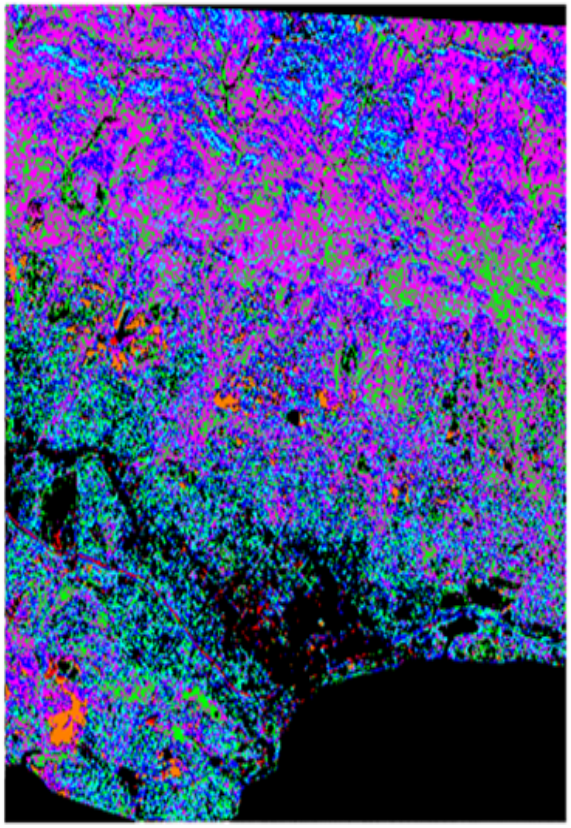
VQ5-2

From McNeil et al. (2007). Watershed-scale ecosystem responses to disturbance, specifically related to stream water quality (Panel A: TDN = Total dissolved nitrogen concentration). Disturbance is measured using MODIS imagery (X-axis) and Landsat (panel C), illustrating an inverse response stream nitrogen (A) and foliar nitrogen (B), as derived from Hyperion.

VQ5-3

How are changes in ecosystem distribution and productivity linked to resource use and resource management?

Wild Fires: Forestry practices control the type and amount of fire fuel on the forest floor and limit the risk and can prevent wild fires



Fire Fuel Condition

Red = Senesced, Green = Live

Tools:

Using continuous spectral information selectively, as illustrated with AVIRIS, one can assess the species composition and monitor the amount of senesced and green vegetation.

The continuous high spectral resolution of the VISNIR instrument on HyspIRI is required for spectral analysis to answer the questions.

Approach:

Monitor vegetation composition and condition of areas at risk of fire, to detect changes and provide warnings and notify the forest service. Pair with field checks for validation.

VQ5-3

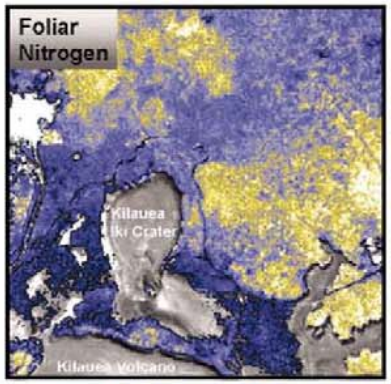
Expected Results:

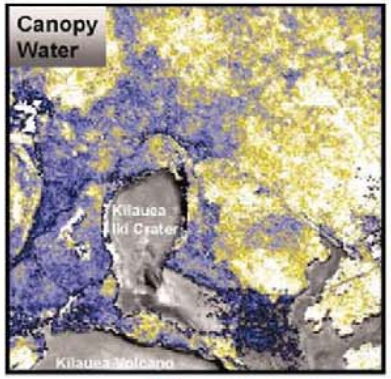
Warning capability for decision support, detection of changes in areas under risk, tool for prediction and prevention. Timely management decisions could alter the path of ecosystem succession and control the occurrence and severity of natural fires.

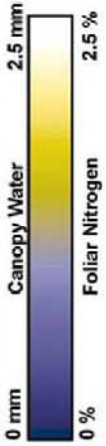
Roberts et al.

VQ5-3
VQ5-5

VQ5: How do changes in ecosystem composition and function affect human health, resource use, and resource management? (DS 152-153)

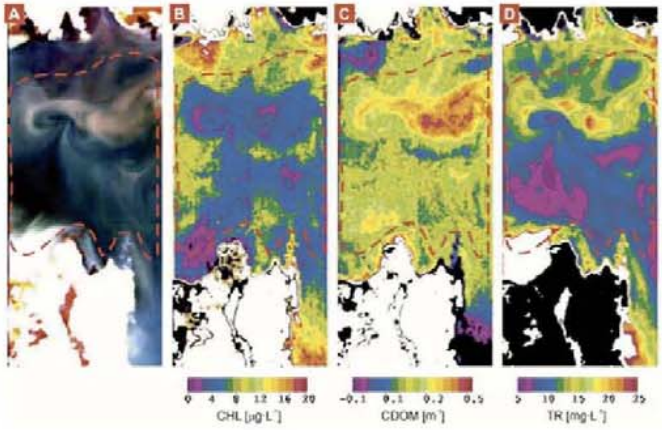






Left: Detection of foliar nitrogen and water concentrations derived for areas with the invasive Myrica faya (high N, high water content) in Hawaii (from Asner & Vitousek, 2005: PNAS 102:4383-4386).

Below: Hyperion derived estimated concentrations of chlorophyll, chromophoric dissolved organic material (CDOM), and (d) tripton (TR) (from Brando and Dekker, 2003: TGARS 41:1378-1387).



Science Issue:

• Ecosystem condition affects the humans dependent on those ecosystems for life and livelihood. How do changes in ecosystem composition and function correlate with famine, exposure to harmful biotic growth, the spread of infectious disease, and disease vectors and other causal agents? What are the implications of ecosystem changes such as invasive species for sustained food production, economic infrastructure, water supplies, and other ecosystem services? Can ecosystem changes be used to anticipate regions for targeted interventions to reduce adverse outcomes?

Tools:

• Satellite observations from HyspIRI. Requires measurements from 0.4 – 2.4 µm at 5-10 nm resolution for water quality measurements, to detect vegetation stress related to pests and pathogens, and to quantify foliar nutrient concentration related to invasive species and other ecosystem changes.

• *In situ* and lab measurements of ecosystem properties as well as spectral libraries from validation activities are necessary to derive and validate scaling relationships between ground and spectral data.

• A time series of ground data and imagery are required to identify and track changes in ecosystem properties.

• Published models relate spectra to hyperspectral imagery.

Approach:

• Use systematically collected HyspIRI images to develop baseline measurements of importnant ecosystem properties such as water quality, community composition (including terrestrial and aquatic vegetation), and nutrient status.

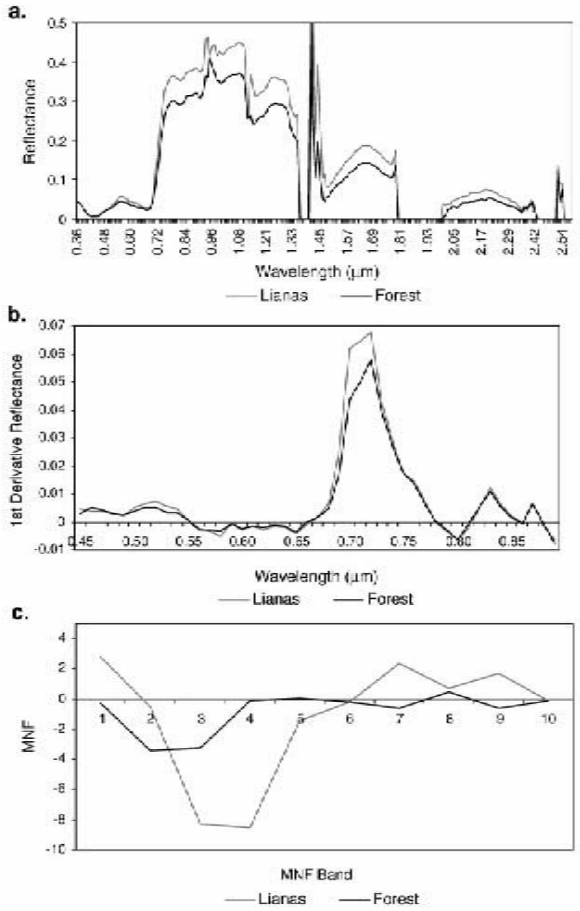
• Field campaigns to collect baseline measurements (including spectra) of key ecosystem properties across the range of ecosystem types.

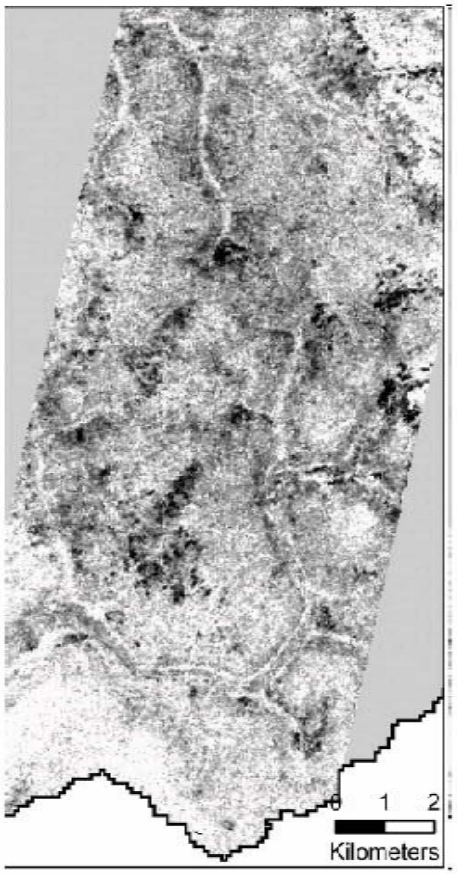
•.Elucidate linkages between ecosystem properties measured with HyspIRI and resources important to human health and well-being.

Example 5. Liana invasion of tropical forests.

From Foster et al. (2008). Replacement of canopy trees by lianas affects long-term carbon accumulation and water relations in tropical forests. Left: Mean reflectance (a), 1st derivative reflectance (b), and minimum noise fraction (c) from EO-1 Hyperion lianas (gray) and tropical forest (black). Right, contrast between lianas (black) and forest (light) mapped from Hyperion MNF in Noel Kempff NP, Bolivia.

VQ5-3
VQ5-5

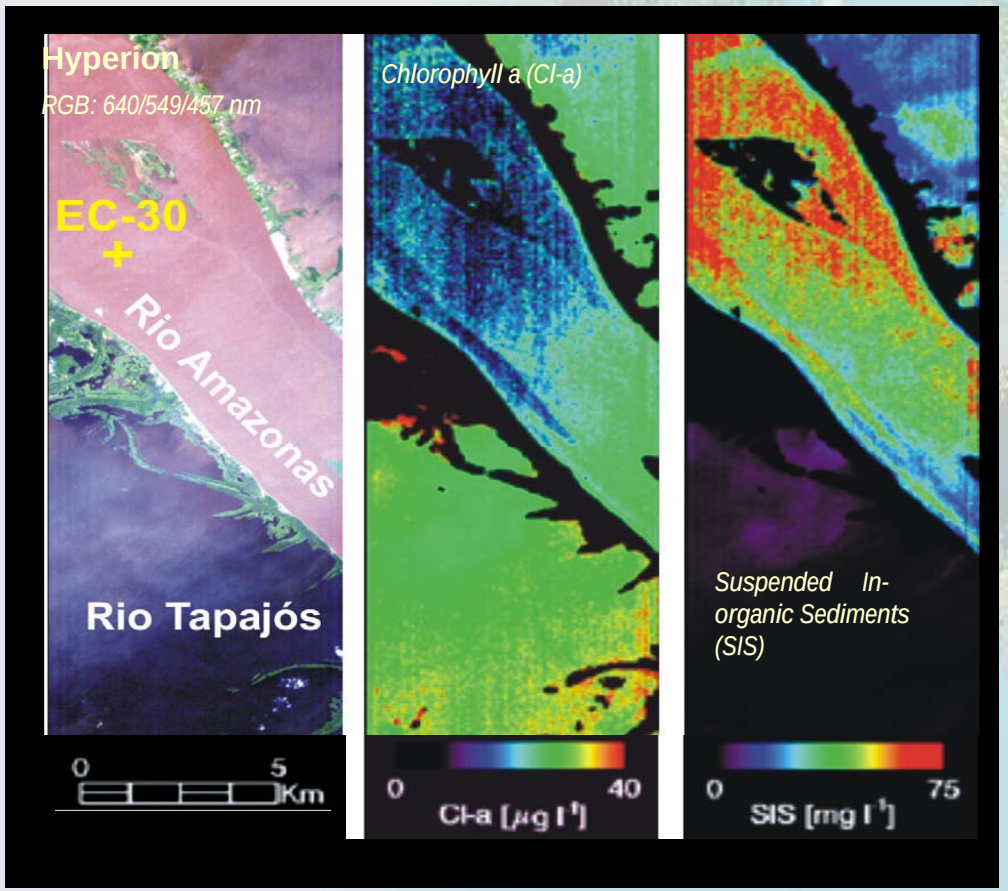




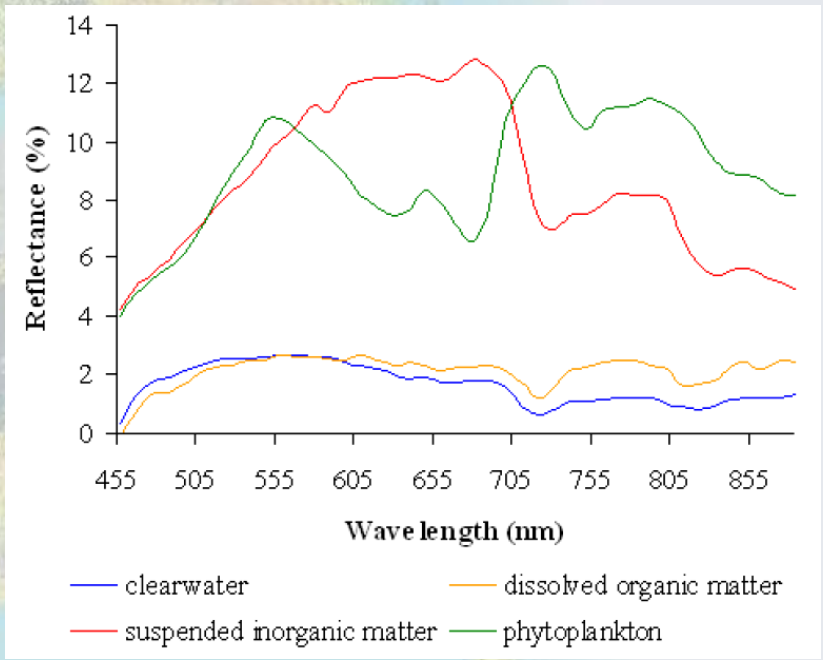
VQ5-4

How will changes in climate and pollution affect the health and productivity of aquatic and agricultural resources?

Composition of Inland Tropical Amazon Floodplain Waters Using Hyperion Derivative Analysis



Hyperion end-members spectra of waters dominated by optically active substances



VQ5-4

(Rudorff et al., 2007)

Volcanoes and earthquakes are frequently accompanied with fire, ash, smoke and various debris, which present a treat to human health, urban communities, transport and aviation.

EO-1: Eruption of Mt. Etna
July 22, 2001

ALI Pan Enhanced RGB: 3-2-1

Hyperion RGB: 213,152, 32

The clouds and smoke can obscure the debris and path of the lava flow and present difficulties assessing the extend and precise location of the disaster events.

Tools:
Using continuous spectral information selectively, as illustrated with EO-1 Hyperion, one can assess the composition and monitor the clouds, and also "see" under the clouds to identify the direction of the lava flow and assess its temperature. The continuous high spectral resolution of the VISNIR instrument on HyspIRI is required for spectral analysis to answer the questions.

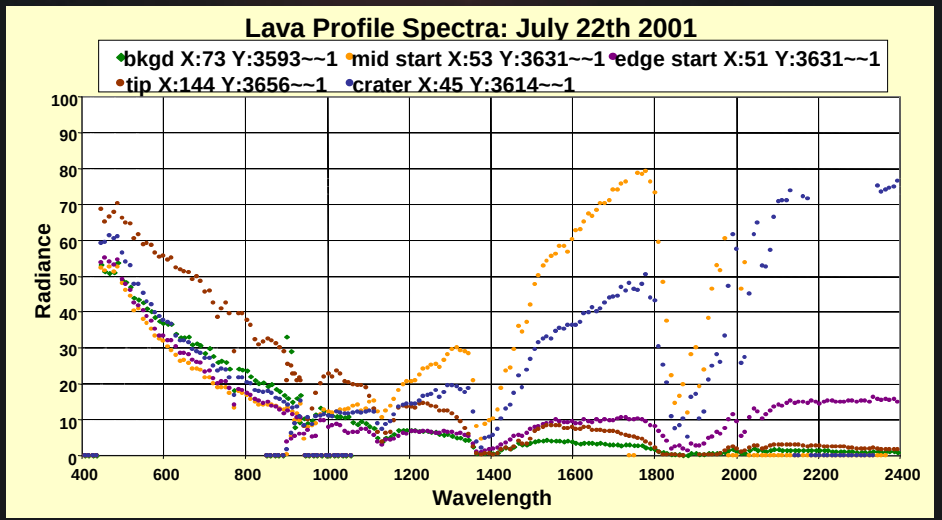
Approach:
Monitor areas designated as environmental risks, to track the direction, characteristics and amounts of lava, ash and smoke to detect changes and provide warnings. Pair with airborne spectrometers for short term monitoring.

Expected Results: Early warning capability for decision support, detection of changes in areas under risk, identifying the location of fires and debris.

VQ5-4

Spectrum	Crust Temp	Hot Temp	Area Hot
J 13 - CTB	346 C	994 C	0.0025
J 13 - MM	874 C	876 C	0.45
J 13 - CTS	976 C	978 C	0.47
J 13 - TipX	210 C	900 C	0.00034
J 22 - MS	726 C	1075 C	0.090
J 22 - CX	487 C	1075 C	0.022
J 22 - RS*	1054 C	1058 C	0.690

Flynn et al., 2001

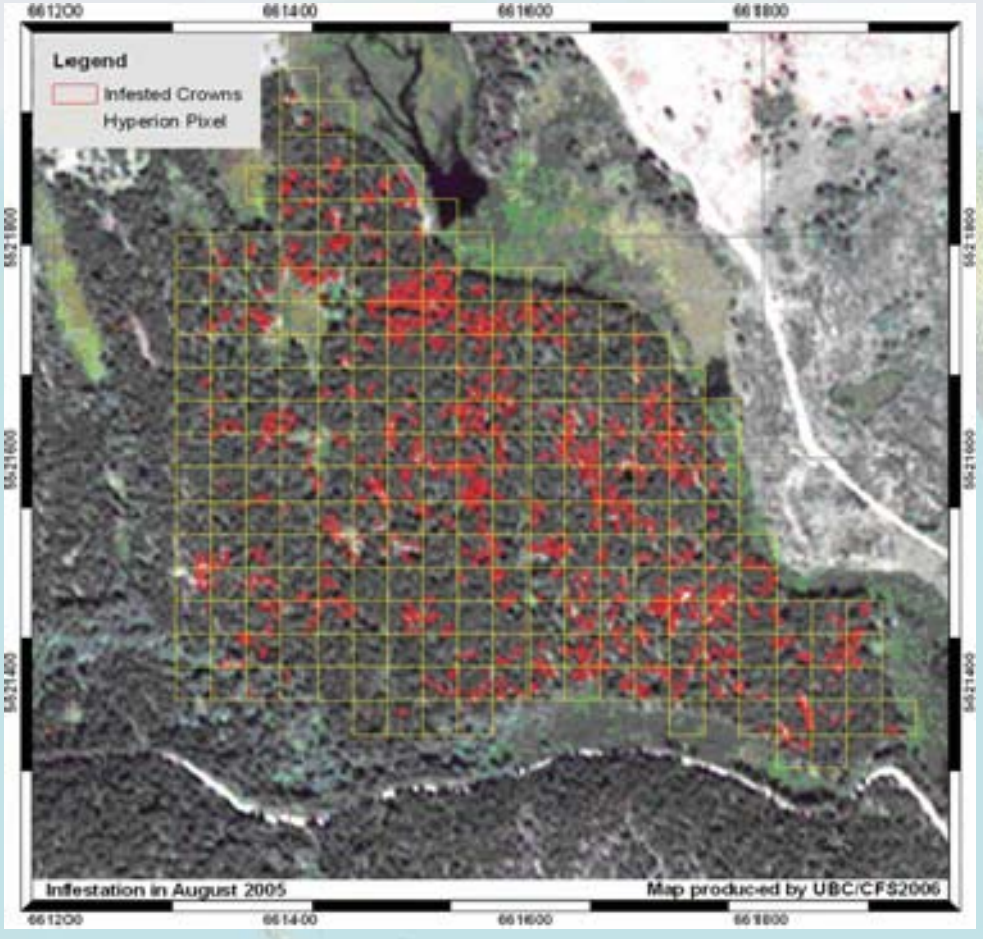


VQ5-5

What are the economic and human health consequences associated with the spread of invasive species?

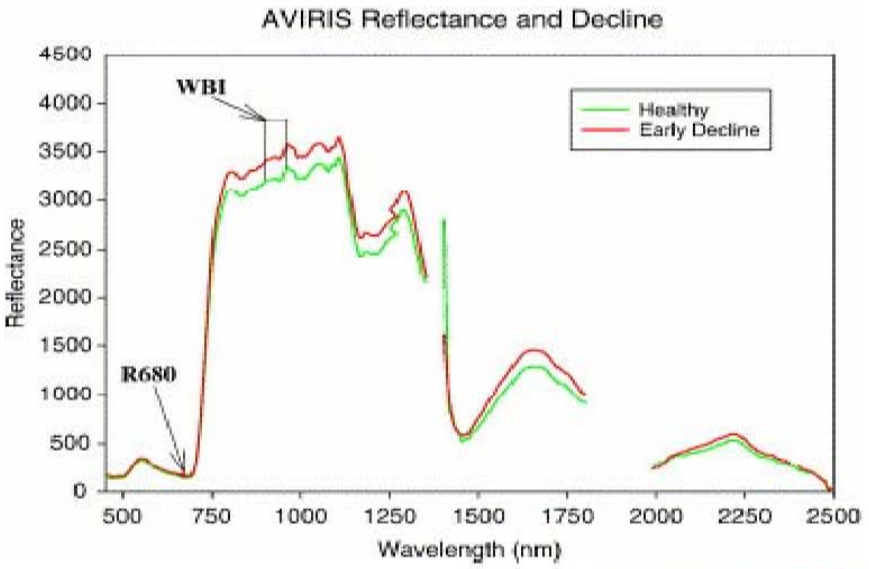
Detection of mountain pine beetle red attack damage, using Hyperion moisture stress indices (MSI)

VQ5-5



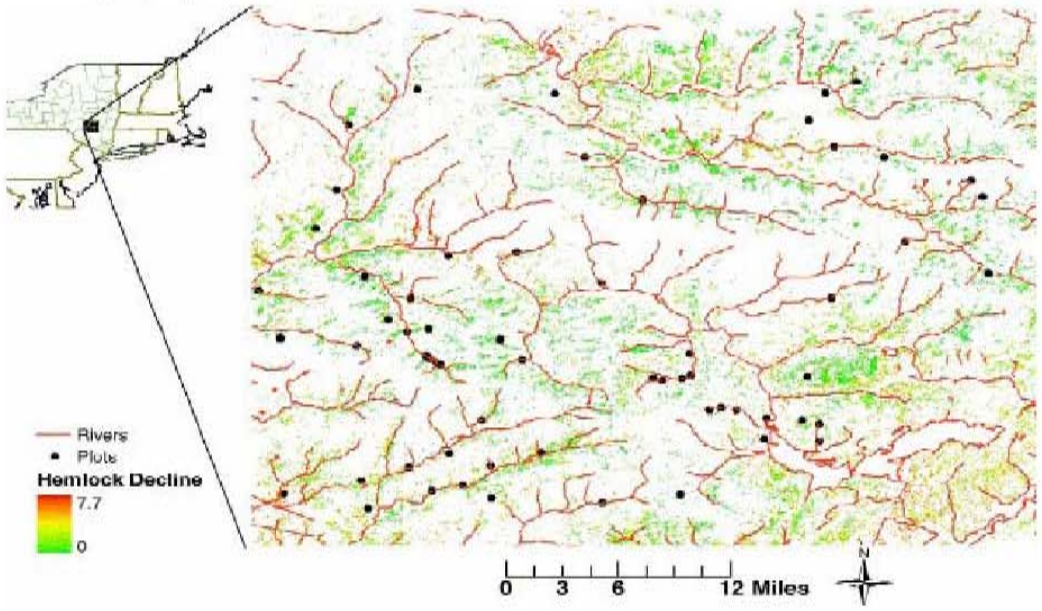
Individual tree crowns with mountain pine beetle red attack damage were identified using the Hyperion spectra then overlaid on a QuickBird image and are delineated in red.

(White et al. 2007)



Example 3. Pre-visual detection of hemlock wooly adelgid infestation.

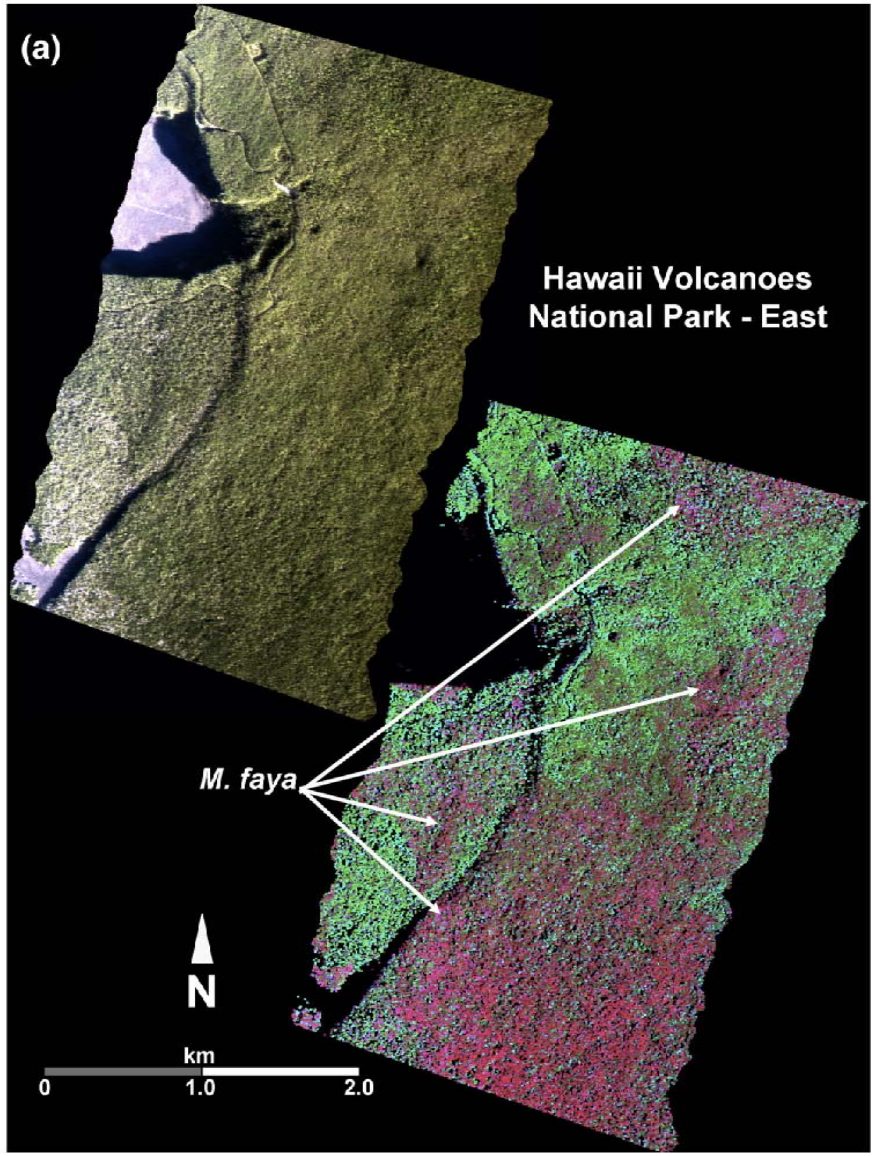
From Pontius et al. (2005). Differences in AVIRIS reflectance for healthy hemlock and hemlock in early decline, and a resulting map of hemlock decline derived from AVIRIS for the Catskills.

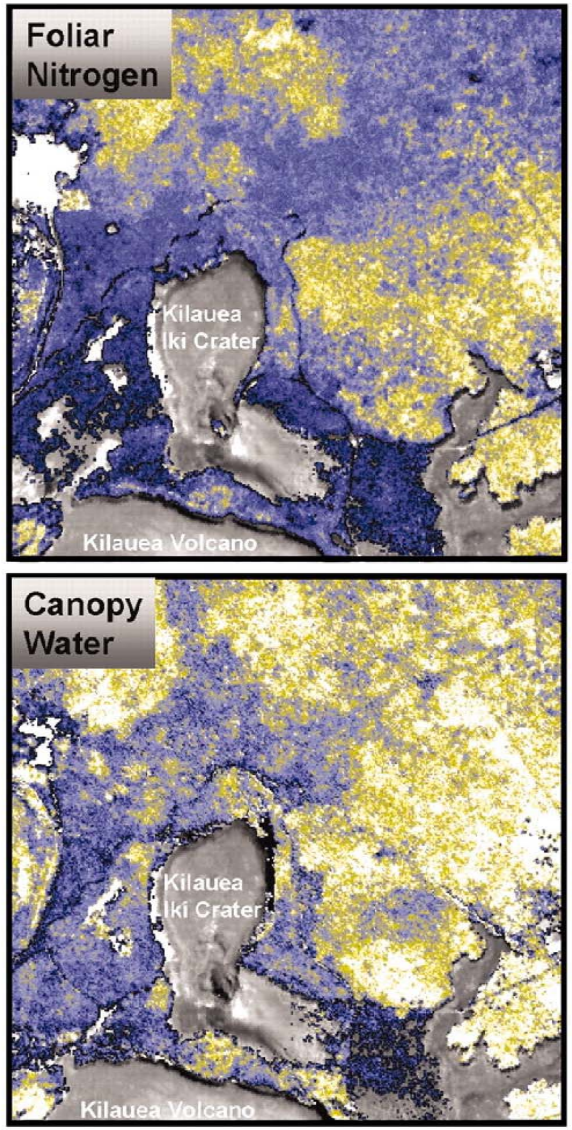


VQ5-5

Example 4. Invasion of the N-fixing *Myrica faya* in Hawaii

Detection of *Myrica faya* using AVIRIS-lidar fusion (left, Asner et al. 2008) and foliar nitrogen and water concentrations derived for areas with the invasive Myrica faya (rig high N, high water content, Asner & Vitousek 2005).



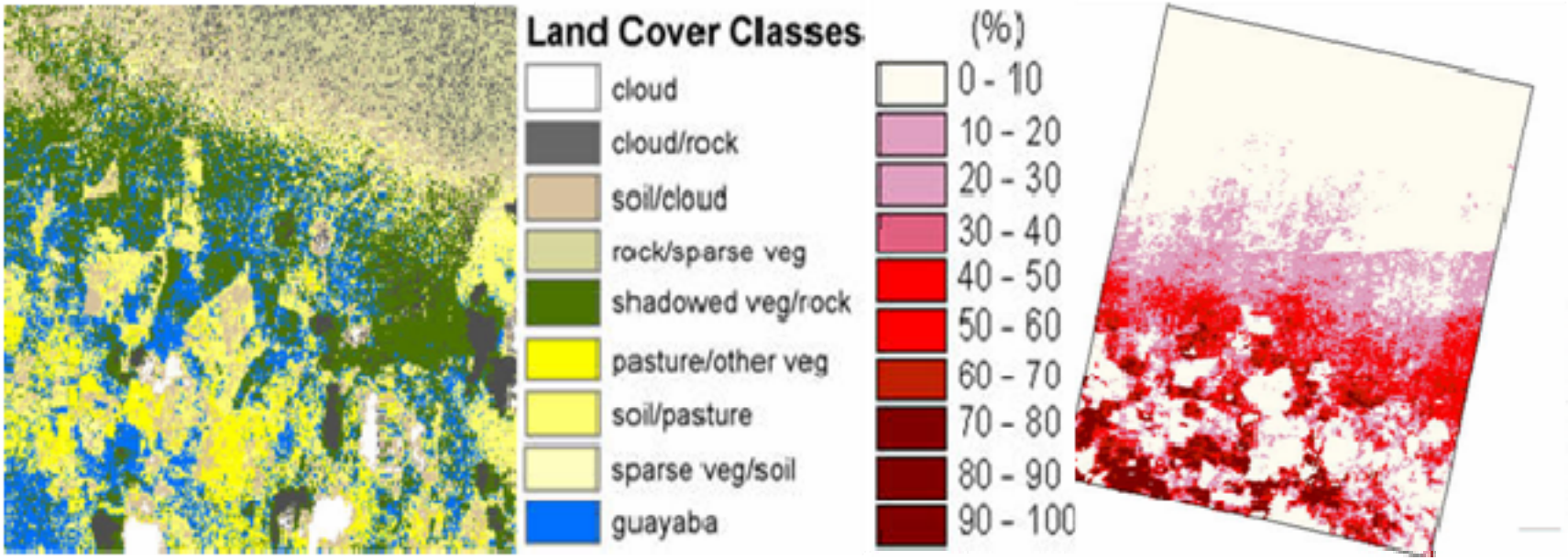


VQ5-5

Detection of Invasive Plants in the Galapagos National Park and Archipelago, Ecuador by merging Hyperion and *QuickBird*

Classification of guava (blue) and other land cover types

Spectral un-mixing of Hyperion data for the characterization of guava (%)



Walsh et al., 2008

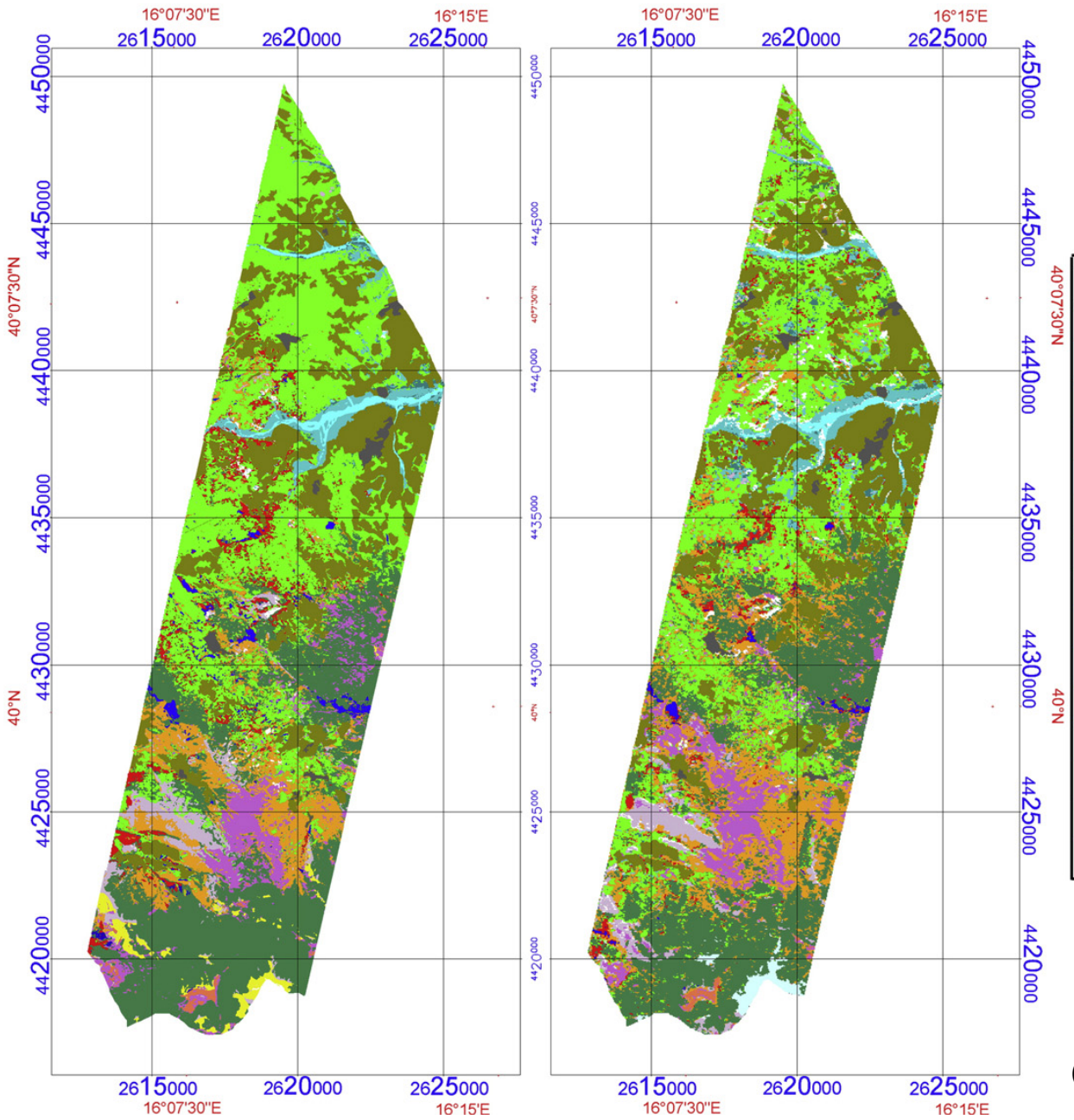
VQ5-5

VQ5-6

How does the spatial pattern of policy, environmental management, and economic conditions correlate with the state and changes in ecosystem function and composition?

Mapping land cover and vegetation diversity in a fragmented ecosystems

VQ5-6



Ability to map up to the 4th level of the CORINE legend (CORINE Land Cover 2000)

(Pignatti et al., 2009)

VQ5-7

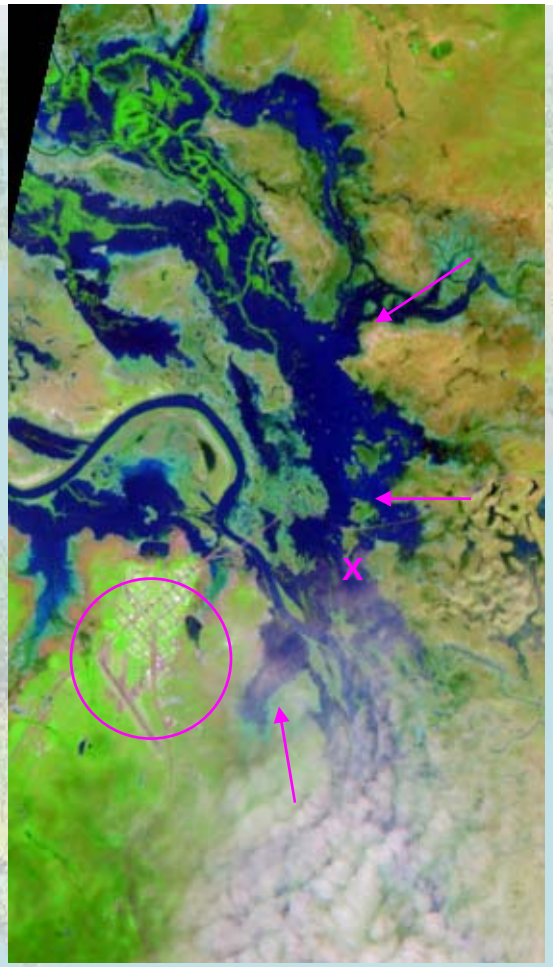
What are the impacts of flooding and sea level rise on ecosystems, human health, and security?

VQ5-7

ALI Imagery of Australian Flood (March 2009)

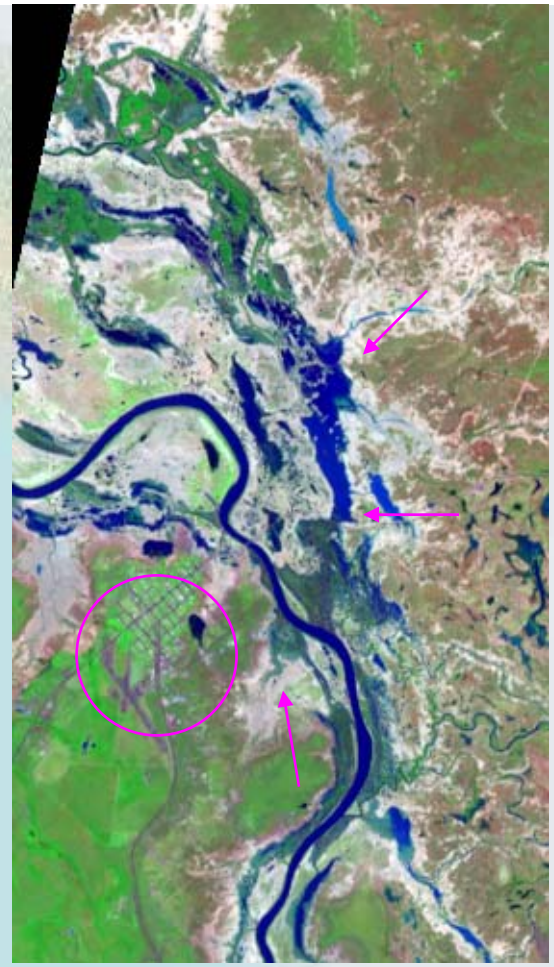
March 12, 2009
True-Color Image
EO-1 ALI Image

In this true-color image, note how the water color is so muddy that it makes discerning the extent of the flooding difficult



March 12, 2009
False-Color Image
EO-1 ALI Flood Product

This false-color image combines infrared and visible light, which makes the extent of the flooding far more obvious. Water is dark blue, while plant-covered land is green, and bare earth is rosy tan.



March 25, 2009
False-Color Image
EO-1 ALI Flood Product

Two weeks later, the flood waters have receded even more, which the EO-1 Flood Product makes evident.

Level 3 Products

- **Maps of species composition/Plant Functional Types**
- **Ecosystem maps, including invasive species mapping**
- **Seasonal spectral libraries of species/PFT**
- **Estimates of fractional cover**

  PV, NPV Water fraction (aquatic) PFT/Species
- **Standard suite of biophysical/physiological narrow-band**
- **indices (i.e. PRI, EVI, MCARI, EWT)**
- **Time series for all parameters above, directly from measurements, and from model outputs**

- **Possible L4 products:**
  - **Infection/transmission rates and distribution**
  - **Monitoring vector habitats**
  - **Ecosystem degradation**

Tools for Product Validation

- Leverage existing core validation sites
  - LTERs
  - Flux networks (i.e. Euroflex, Ameriflux)
  - EOS Validation Core Sites
- FIA/USFS/International LC databases
- CEOS/GEOSS
  - Coastal/marine
- Supporting sub-orbital missions/field Campaigns
- International collaborations

Precursor Science

- **Spatial/Spectral/Temporal requirements must be determined:**
  - **for discriminating PFT & Species in terrestrial, coastal and marine environments, and**
  - **for sub-pixel mixing**
- **Evaluation/development of current/new approaches for invasive species mapping in marine, coastal and terrestrial ecosystems**
- **Classification/algorithm development and assessment across a diversity of ecosystems, leveraging phenological/seasonal information**
- **Evaluate and adopt a globally applicable vegetation and coastal classification and validation scheme**
- **Temporal compositing and classification of hyperspectral data**
- **Fully integrated terrestrial/coastal/marine campaigns across latitudes gradients, ecosystems with stages of succession, and contrasting similar ecosystems on different continents, using suborbital assets**

Summary

- **Information derived from HyspIRI will facilitate mapping components of ecosystems that are important to long-term human well-being.**
- **Seasonal and multi-year measurements will enable tracking changes through time.**
- **Ultimately, early detection using HyspIRI may provide the opportunity to develop management plans to reduce risks to human populations.**