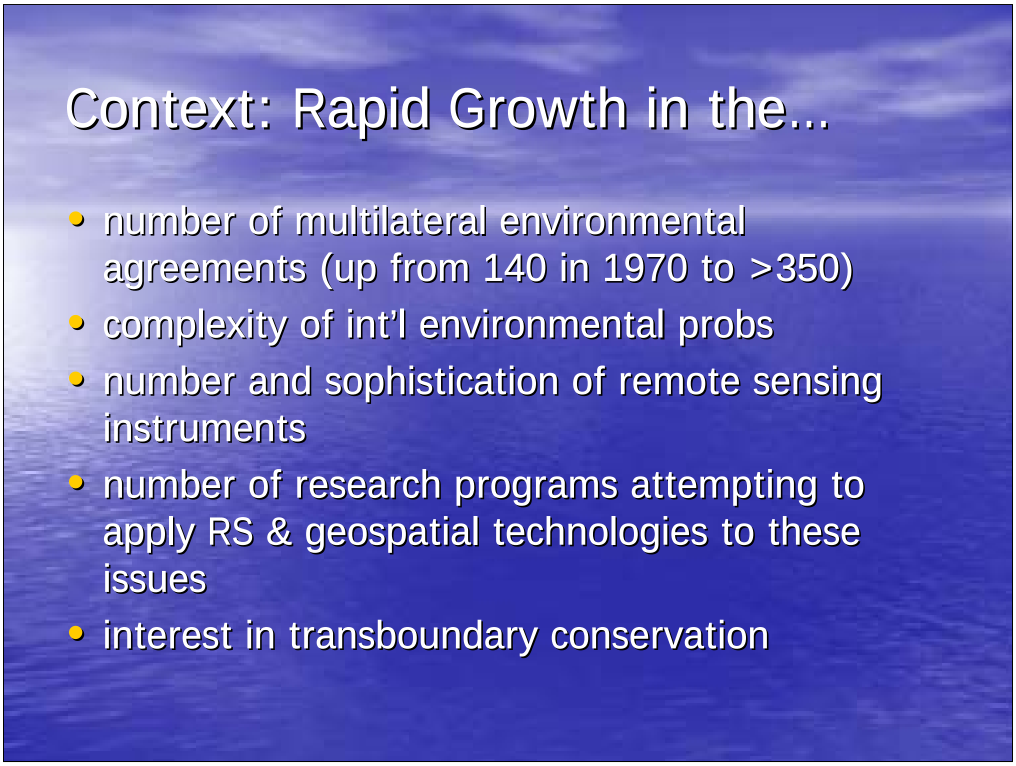
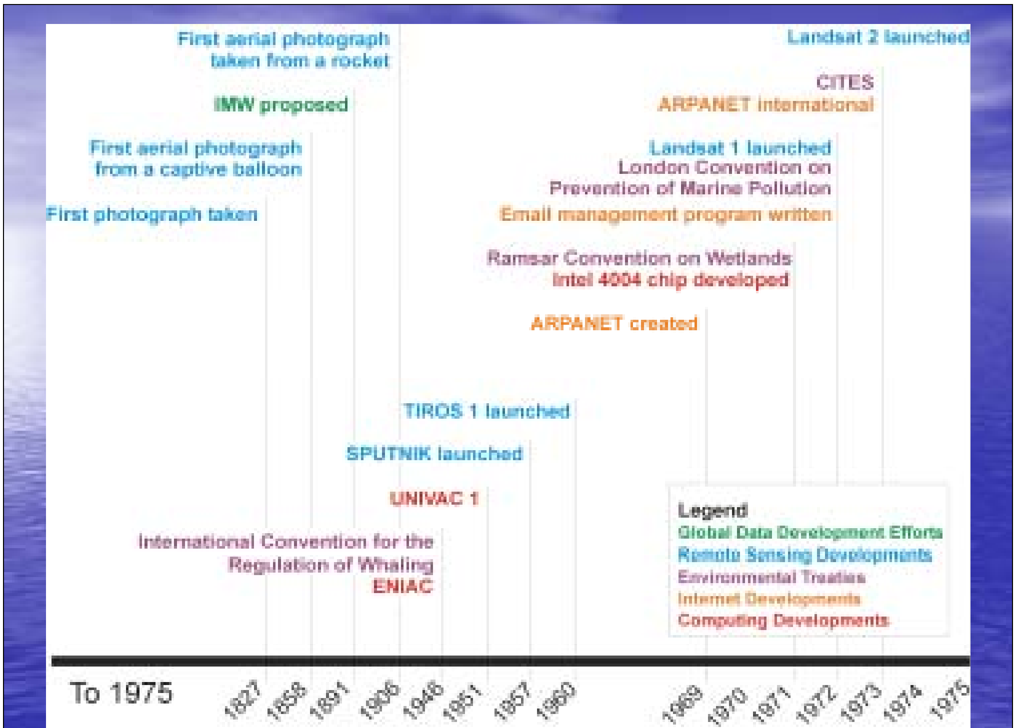
The subject of my talk is the application of remote sensing in support of multilateral environmental agreements. There is much that the conservation community has to gain by looking seriously at the contributions that remote sensing can make to environmental protection.

Acknowledgements

- Funding: United States Department of State, Bureau of Oceans and International Environmental and Scientific Affairs initiatives program (OESI)
- Collaboration:
  - The Remote Sensing Center (CSR) of the Instituto Brasileiro do Meio Ambiente e dos Recursos Naturais (IBAMA), Brazil
  - The Programa para la Conservación de la Biodiversidad y Desarrollo Sustentable de Los Bañados del Este (PROBIDES), Uruguay

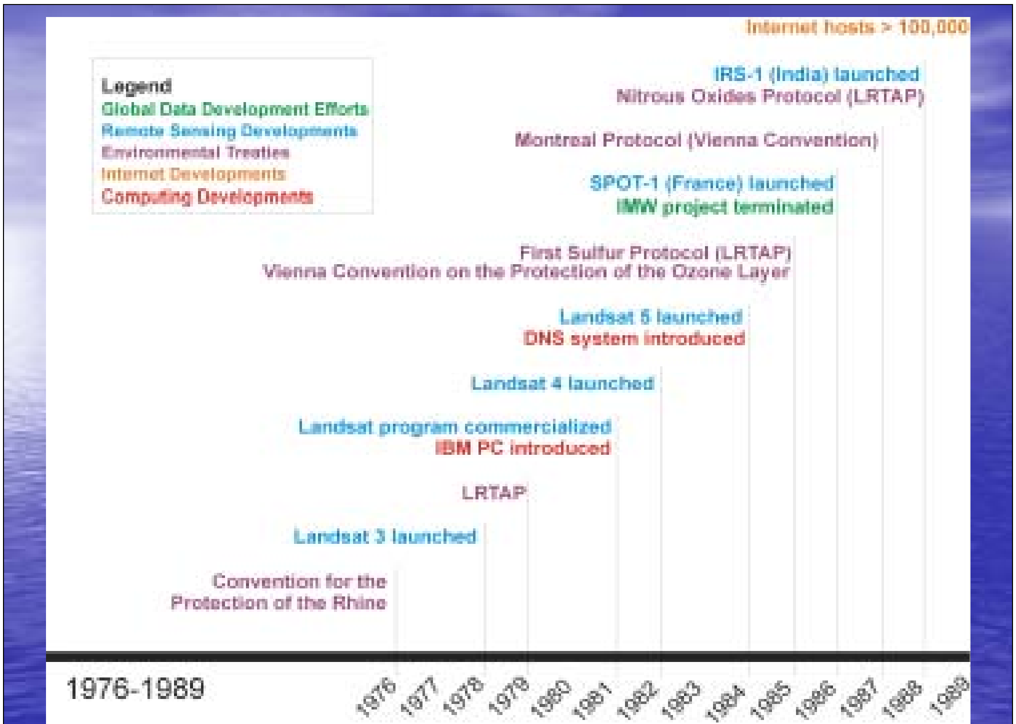


There has been an upsurge in interest over the past five years in the application of remote sensing to environmental treaties. This is related to a number of factors, including: an increase in the number of environmental agreements, from approximately 140 in 1970 to over 350 today; a the growing complexity of environmental problems; more and better remote sensing technologies; and a larger number of projects attempting to apply remote sensing and geospatial technologies to these complex environmental problems.



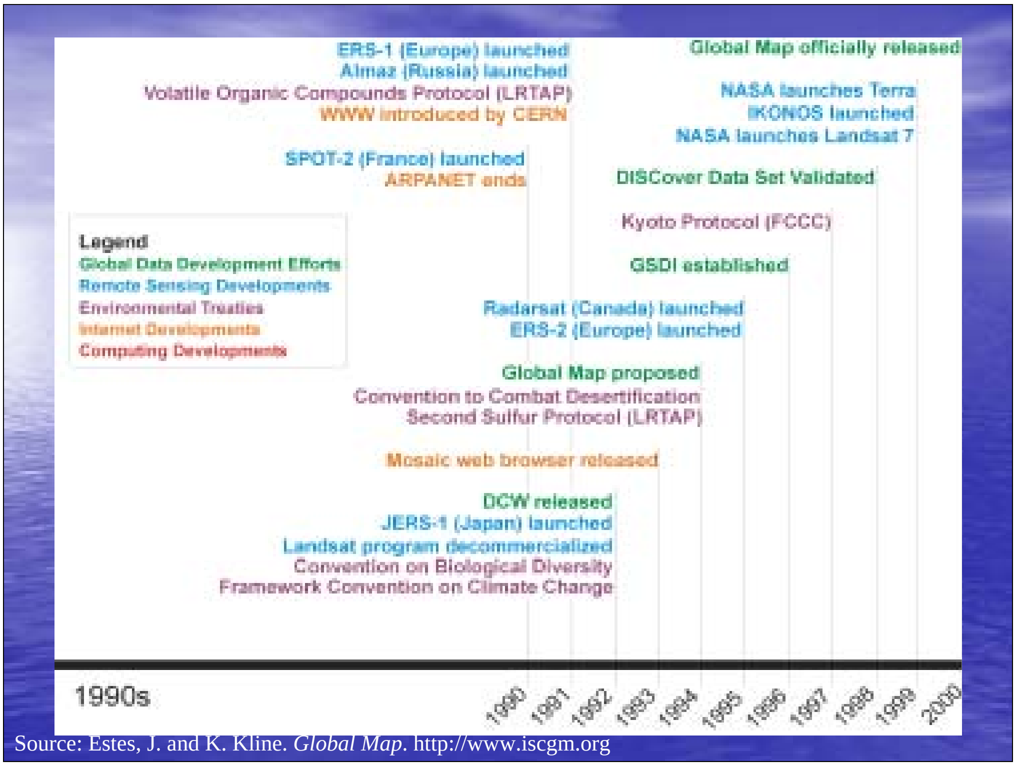
Source: Estes, J. and K. Kline. *Global Map*. http://www.iscgm.org

This and the following timelines show the parallel but separate development in remote sensing technology (light blue text) and environmental treaties (purple text). The proliferation in multilateral environmental agreements began in earnest after the Stockholm Conference on the Environment in 1972. This was the same year that the Earth Resources Satellite, later renamed Landsat, was launched. Prior to Landsat remote sensing was strictly the province of the military, the intelligence community and meteorologists. Landsat initiated a new era in civilian land remote sensing at moderate resolutions of 30-40 meters.



Source: Estes, J. and K. Kline. *Global Map*. http://www.iscgm.org

This chart shows the continued development of both environmental treaties and remote sensing instruments. It illustrates the point that treaties and remote sensing have developed on two parallel but similar tracks.

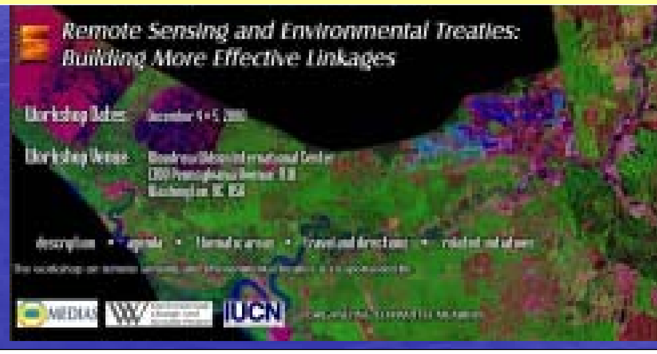


Source: Estes, J. and K. Kline. *Global Map*. http://www.iscgm.org

And this chart brings us up to the recent past, with the wave of post-Earth Summit treaties, and the launch of the first high resolution commercial satellite, IKONOS, in 1999. It has science been joined by QuickBird, with below 1 meter resolution.

Growing interest in the issue…

ISPRS workshop on RS applications in support of Kyoto Protocol – *October 1999*
AARS conference on RS and the Environment – *March 2000*
CIESIN, IUCN, Woodrow Wilson Center, and MEDIAS France workshop on RS & Environmental Treaties – *December 2000*
AIAA workshop on RS contributions to development & implementation of MEAs – *March 2001*
The European Space Agency's TESEO Initiative – *beginning 2001*
EURISY's conference on Space Applications for Heritage Conservation – *Nov 2002*
NASA NGO Group's Handbook on Remote Sensing for the CBD – *beginning 2004*

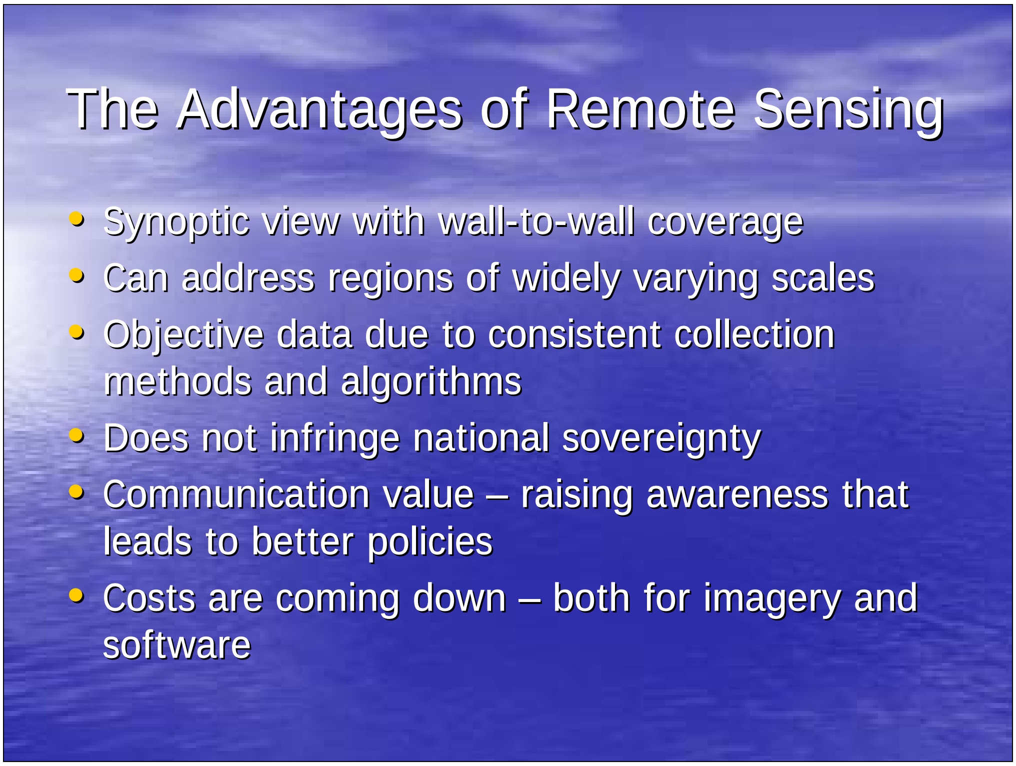


Remote sensing applications span a number of ecosystem types and environmental problems. Each of these has a number of agreements or frameworks for coordinated international action. Most of the remainder of this presentation will be a snapshot of applications in each area.

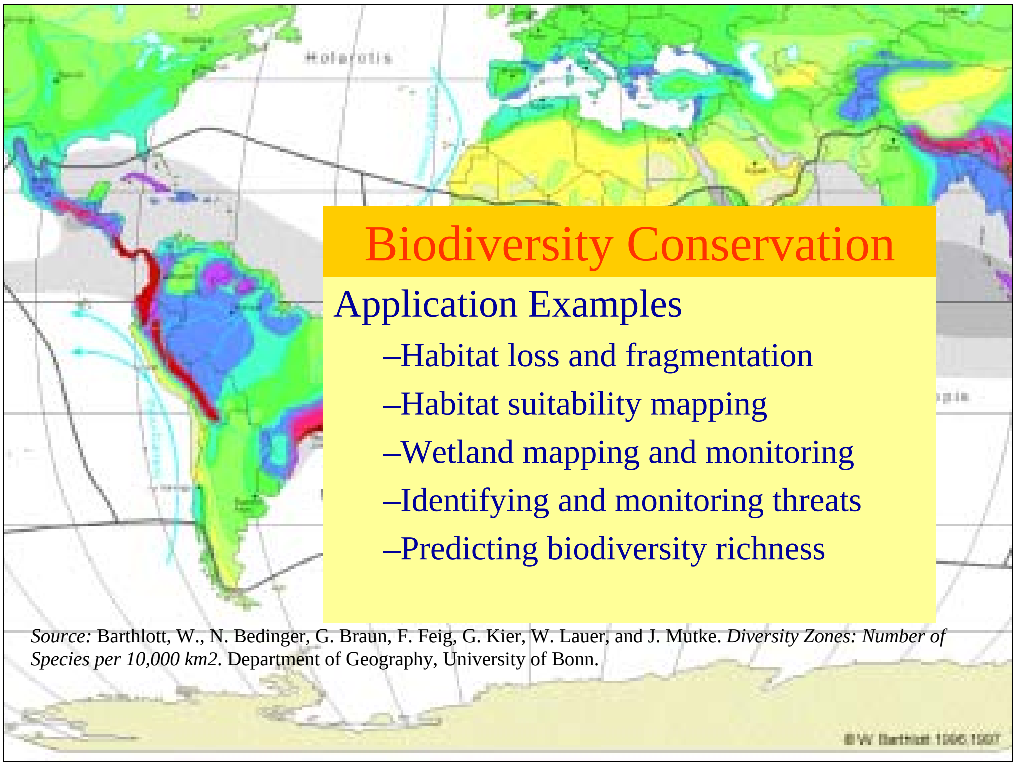
Current and Future Space-Based Earth Observation Systems	Related Monitoring Applications
Land Remote Sensing Systems: Landsat, SPOT, RADARSAT, IRS, CBERS, IKONOS, EROS-A1 **Future Systems:** RADARSAT-2, SPOT-5, Pleiades/Cosmos-Skymed, SMOS, QuickBird, OrbView-3/4, IRS-2C, VCL	Land cover/land use and conversions, mining activities, vegetation and forest cover, biomass, wetlands monitoring, pollution sources, deforestation/reforestation, desertification
Oceanic/Environmental Systems: Topex-Poseidon, OrbView-2/SEASTAR, EOS-TERRA, Quick-SCAT, ERS,TRMM, IRS-P4 Future Systems: JASON, EOS-AQUA, ICESAT, SMOS, CRYOSAT, GOCE, ADEOS-2	Ocean color/phytoplankton, ocean biota, ocean currents and circulation, surface winds, sea surface temperature, ocean dumping, ship pollution, fishing activities, oil spill detection, ice caps and sea ice characteristics
Atmospheric/Environmental Systems: NOAA/POES, METEOSAT, GOES, GMS, INSAT, ERS, TOMS, TERRA, **Future Systems:** NPP, NPOESS, METOP, ENVISAT, ADEOS-2, MEGHA-TROPIQUES, EOS-CHEM/AURA, AEOLUS, CLOUDSAT, PICASSO/CENA, PARASOL	Ozone mapping and profiling, atmospheric pollution, cloud cover, atmospheric CO_2, stratospheric aerosols, volcanic ash cloud tracking, tropospheric wind profiles

Source: American Institute of Aeronautics and Astronautics, Sixth International Space Cooperation Workshop Report, March 2001, P. 40.

This table provides a more detailed view of land, oceanic and atmospheric instruments, on the left hand side, and the specific applications for which they are useful on the right.



The advantages of remote sensing include: its synoptic view and regional application, which can situate environmental issues in their wider context; the objectivity of the data, though recognizing that there is some subjectivity in image interpretation; the fact that it does not infringe upon national sovereignty as just about any other monitoring effort would; and that it can raise public awareness of environmental issues which creates pressure for better environmental laws.



This is a small subset of applications that are useful to biodiversity conservation. The focus here is on those applications that are most relevant to biodiversity-related treaties. These include monitoring of habitat loss and fragmentation, habitat suitability mapping, wetland mapping and monitoring, and identifying and monitoring conservation threats such as timber concessions, pollutant sources, etc.

Ways in which remote sensing imagery can assist in ecosystem management and biodiversity conservation

1. Providing data for vegetation/land cover mapping to describe broad patterns of distribution of plant communities.
2. Providing data as a complement to field data for mapping and characterizing species habitats.
3. Assisting stratified random sampling strategies for field inventories by ensuring that different habitat types are adequately represented.
4. Identifying biodiversity 'hotspots' at broad spatial scales.
5. Facilitating GAP analysis assessing the distribution of suitable habitat and protected areas networks in order to determine the degree to which high biodiversity areas are protected.
6. Providing data for landscape fragmentation metrics such as patch size, edge length, connectivity, perforation, etc., in assessments of biodiversity richness, habitat loss, and population-habitat viability.
7. Providing data for leaf area and normalized difference vegetation indices as measures of biological productivity.
8. Establishing base-lines and ongoing monitoring data for deforestation, pollutant emissions, forest fires, the spread of invasive species, climate change impacts, and other threats to biodiversity conservation.

Studies that sought to predict species presence/absence or richness using RS data

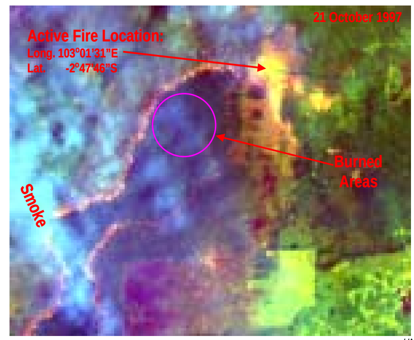
Location (Author)	Species/ Indicator	Summary of Methods	Degree of Prediction
Southwestern Finland (Luoto *et al.* 2002)	Vascular plant species richness	Nine different land cover types were derived from TM imagery; these were then compared with the Shannon Diversity Index values.	r values ranged from –0.76 to 0.9, p=0.0001
Kalahari Desert, southern Africa (Verlinden and Masogo 1997)	Ungulate presence and density	NDVI derived from AVHRR was used as a surrogate for grass greenness, which in turn was related to field data on presence/absence and densities of various ungulate species	NDVI predicted higher density of hartebeest, $p<0.05$
Islands in the Gulf of Maine, USA (Podolsky 1995)	Mammal richness	SPOT MS imagery for whole islands; the number of pixels of different colors was used as a surrogate for landscape richness; a complete mammal survey was conducted for each island.	r=0.990, p=0.0001
Cornwall, England (Griffiths *et al.* 2000)	Plant species richness (*Poaceae* taxon)	Landsat TM land cover data on landscape structure and plant species richness were compared for sampled tetrads in two classes – the top ten hotspots of richness and ten midspots. Of four biotopes, the coastal biotope provided the most significant results.	R^2 of 0.55 and 0.69 between mean patch size and total edge, respectively, and species richness
Greater Yellowstone Ecosystem, USA (Debinski *et al.* 1999)	Plant, bird, and butterfly species richness	Three forest types and six meadow types were classified using Landsat TM data. Presence/absence data were collected on birds and butterflies in 35 sites composed of three forest types and six meadow types. Plants were sampled at fine-grained (25 1m^2 plots) and coarse-grained scales (20 20m^2 plots).	20-30% of animal taxa and 65-100% of plant species were significantly correlated with RS-derived habitats
Great Basin, USA (Seto *et al.* 2004)	Bird and butterfly species richness	NDVI measures derived from a single Landsat TM image were used as a surrogate for vegetation productivity, and were related to field data on birds and butterflies collected using standard inventory methods.	R^2 of >.5, p<.01, for bird species richness and R^2 of >.23, p<.01, for butterfly species richness at the canyon level.

Forest Conservation

Application Examples

- Forest cover assessment and monitoring (e.g. FRA & TREES II)
- Forest fire monitoring
- Deriving forest parameters

LANDSAT - Zoom



UNEP EA

Sources: Global Observation of Forest Cover http://www.gofc.org, and UNEP Environmental Assessment Programme

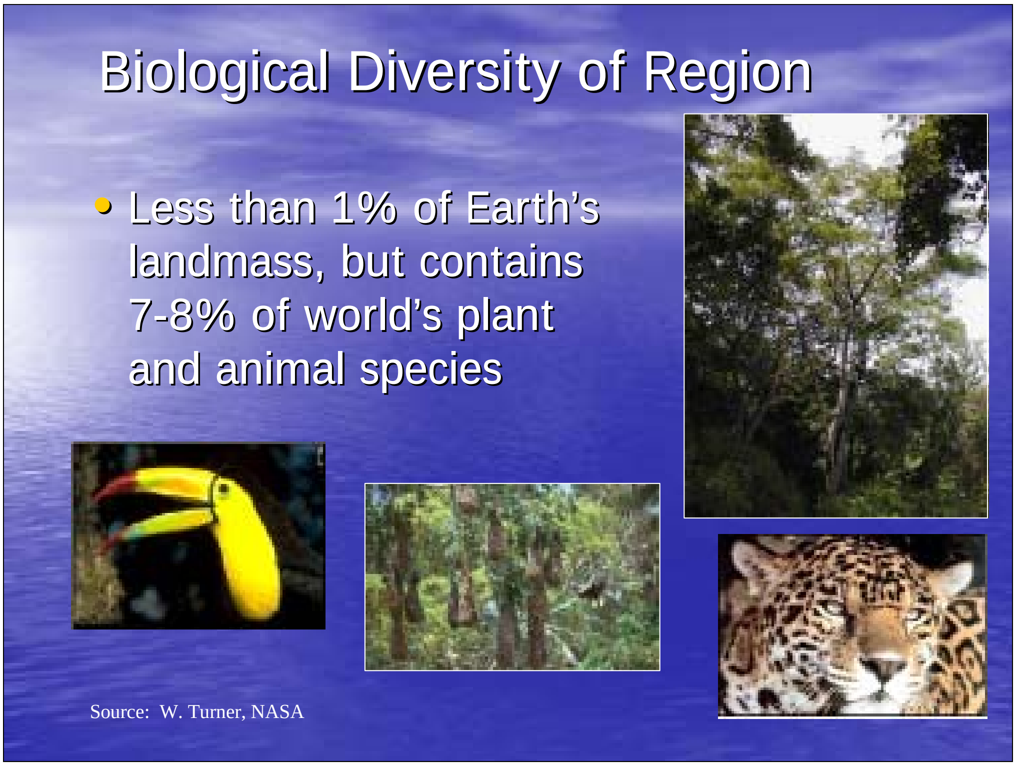
Applications in the area of forest conservation include forest cover assessment and monitoring, forest fire monitoring, and deriving forest parameters such as percent tree (or crown) cover.

Global Forest Watch is an initiative of the World Resources Institute and a number of national-level partners in Canada, Russia, Central Africa, Indonesia, and South America. This image is from their internet mapping service, and shows the forests of Central Africa. Global Forest Watch's primary focus has been on the monitoring of timber concessions in the last forest frontiers, largely in rainforests and boreal forests. They provide valuable and objective third party information, when needed, to refute claims of governments or logging companies that illegal cutting is not going on.

MesoAmerican Biological Corridor

Source: PROARCA/CAPAS

The MesoAmerican Biological Corridor is a multilateral environmental agreement overseen by the Central American Commission for Sustainable Development. It falls in both the ‘biodiversity conservation’ and ‘forest’ categories of applications. The objective is to create a corridor for wildlife migrations between protected areas from Mexico to Panama.

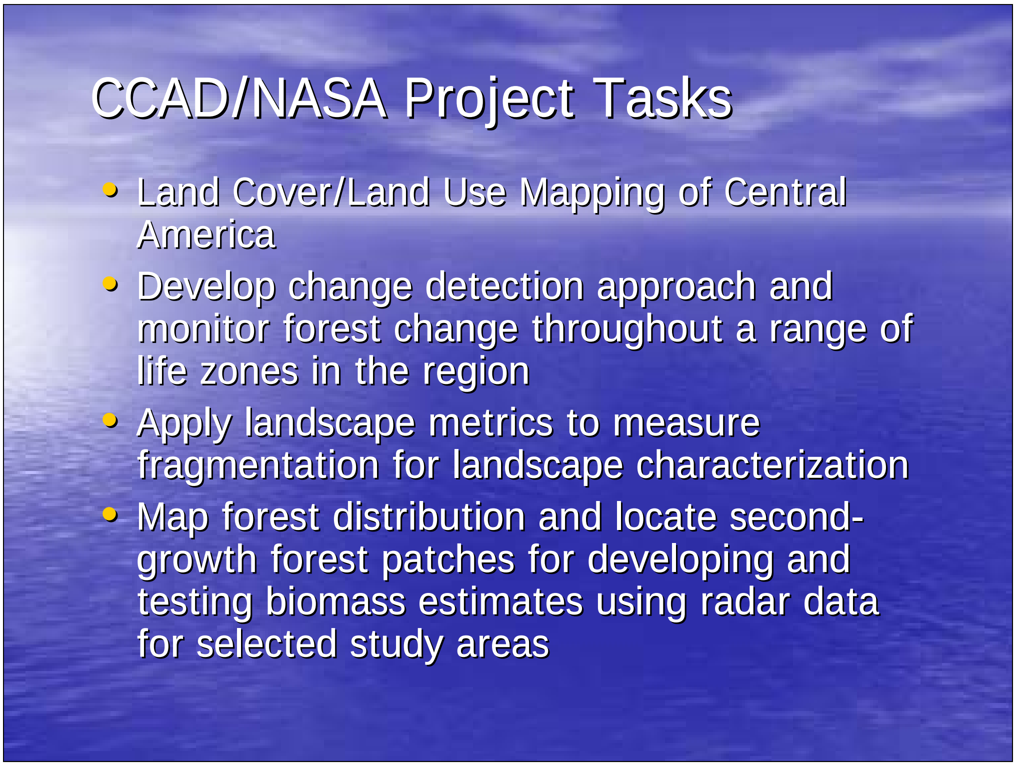


Mesoamerica contains ecosystems ranging from wet Caribbean lowlands, to its central mountains, to the hot, arid Pacific coast produce spectacular veins of wildlife. Jaguars hunt tapirs and peccaries in its tropical forests. Quetzals and toucans forage in the canopy shared by black howler monkeys, while giant tarpon swim in its rivers.

The forests of Mesoamerica are subject to many threats, including: slash and burn agriculture; cattle ranching; illegal logging; poor enforcement of protected areas; massive immigration of landless farmers; large-scale use of pesticides and insecticides; large-scale industrial development; oil and gas exploration and drilling; refugee migration; road construction.

Deforestation rate for Central America

The landsat imagery of the Mexico-Guatemala border region helped to prompt concern about the future of Mesoamerican forests that lead to the Biological Corridor proposal. In 1996 the Commission approached NASA, and in 1998 an MOU was signed which led to a partnership between a number of NASA centers, the University of Maine, and the CCAD.



NASA and CCAD agreed to work together towards a number of the tasks described in this slide.

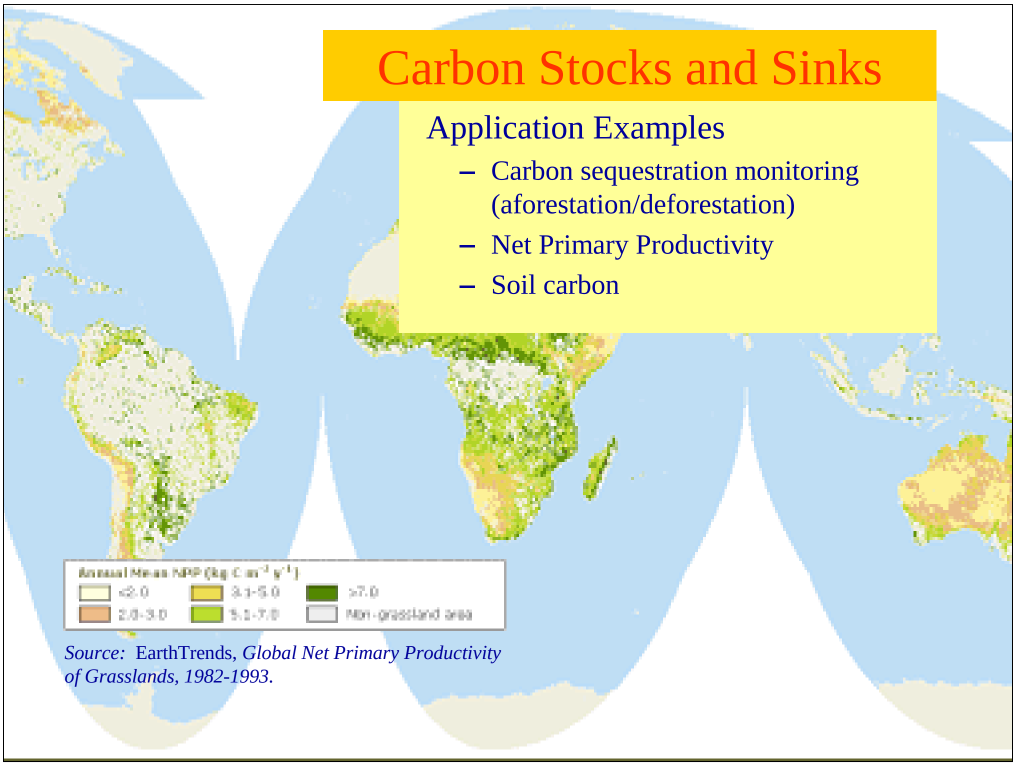
•Land Cover/Land Use Mapping of Central America

•Forest cover change detection throughout a range of life zones in the region

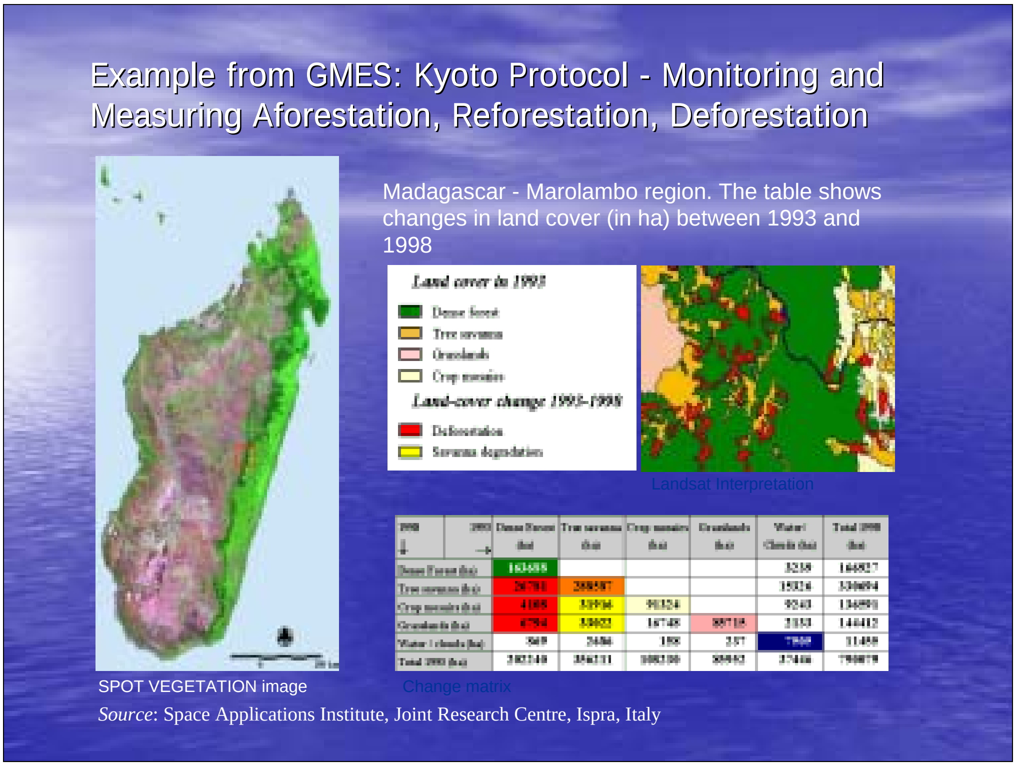
•Measurement of fragmentation for landscape characterization

•Technical assistance to improve estimates of carbon sequestration using radar data for selected study areas

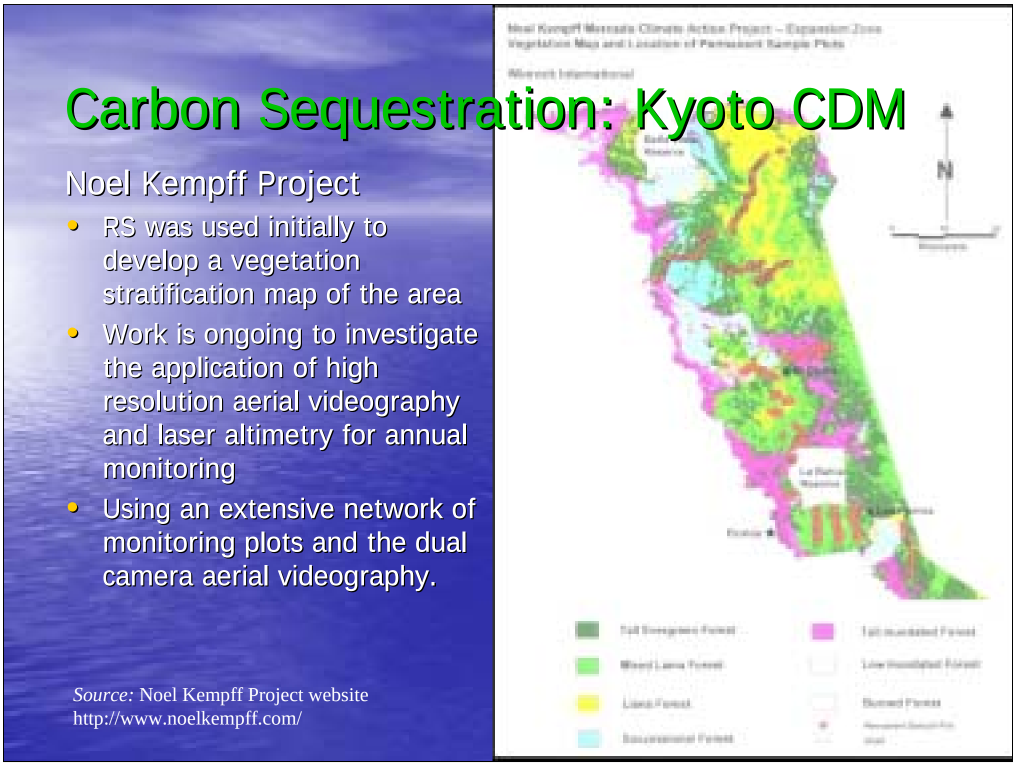
The study has utilized Japanese radar data as the baseline for mapping, in conjunction with digital elevation data and optical remote sensing imagery for nine intensive study areas.



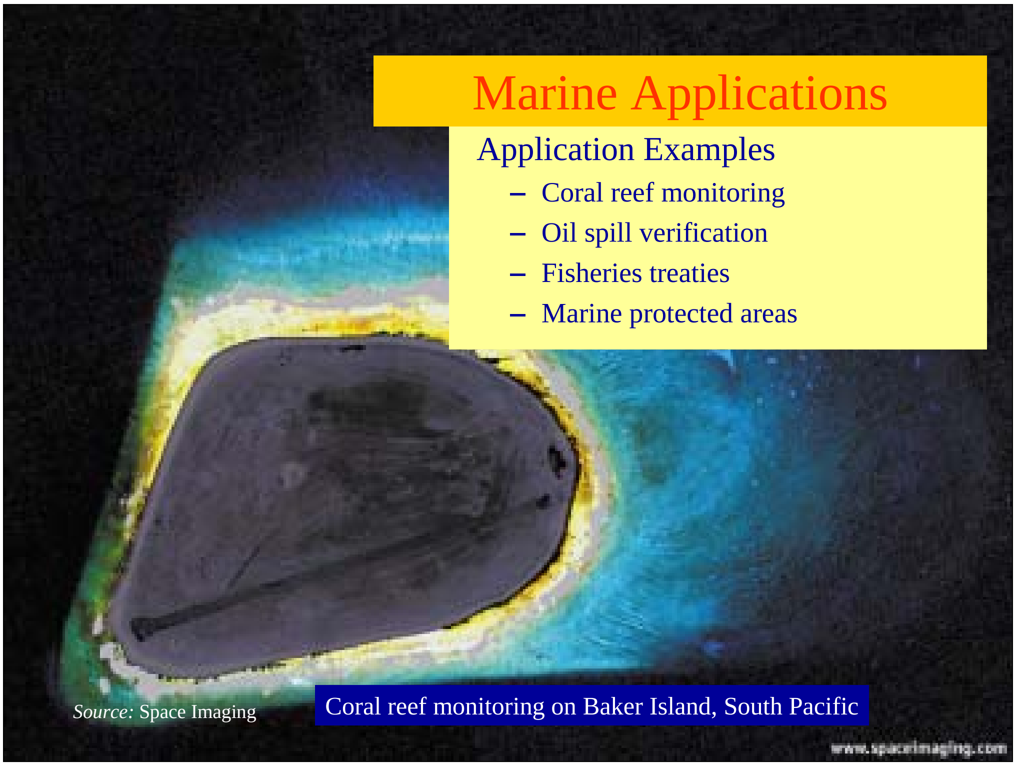
Although less well developed than in the biodiversity and forest conservation arena, climate change agreements can also make use of remote sensing imagery. The monitoring of some greenhouse gas emissions such as carbon monoxide is possible using remote sensing, though most emissions inventories are compiled from fossil fuel consumption data. Carbon sequestration monitoring has also been attempted.



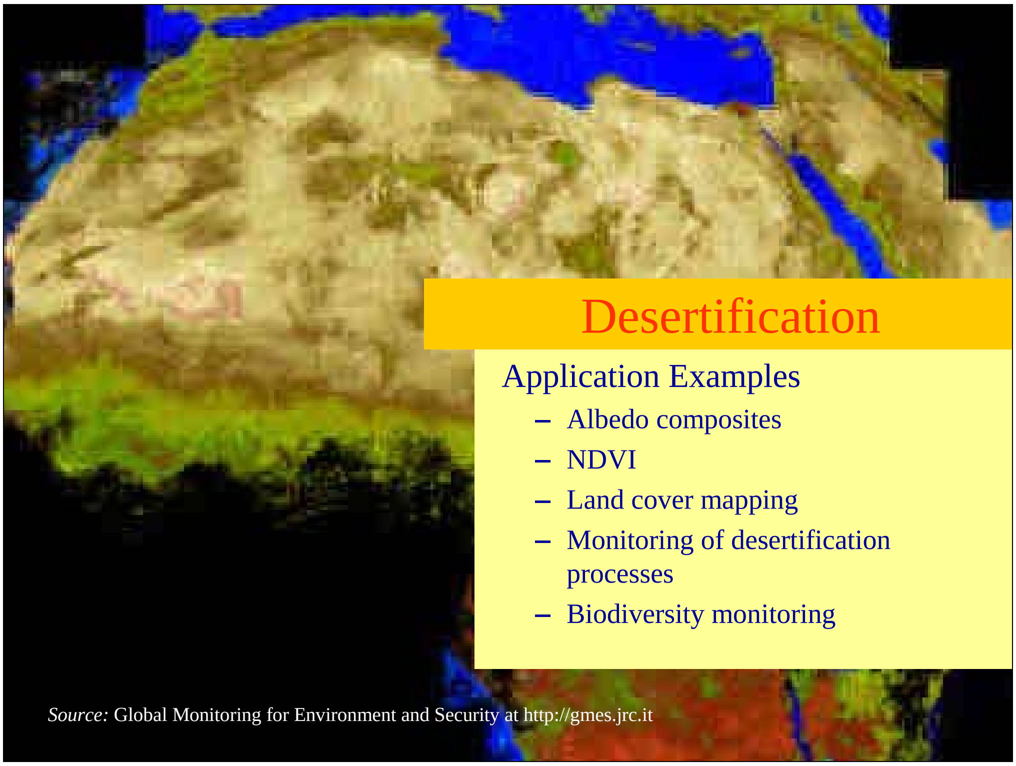
This example of a GMES project in Madagascar shows land cover change monitoring in Madagascar utilizing SPOT VEGETATION and Landsat imagery. The change matrix in the lower right hand corner shows net deforestation in red, and savanna degradation in yellow.



A US initiated project is the Noel Kempff Project in Bolivia. This project on the eastern slope of the Andes aims to measure the amount of carbon that can be sequestered by reforesting certain areas of the Noel Kempff national park, and by insuring that new areas do not become deforested. RS was used initially to develop a vegetation stratification map of the area. The project is also investigating the application of high resolution aerial videography and laser altimetry for annual monitoring. And the project is also using an extensive network of monitoring plots and the dual camera aerial videography. Although the results will be useful for further efforts to monitor carbon sequestration, should the CDM ever become operational, it is clear that the cost of monitoring at Noel Kempff has been in excess of the actual value of the carbon sequestered.

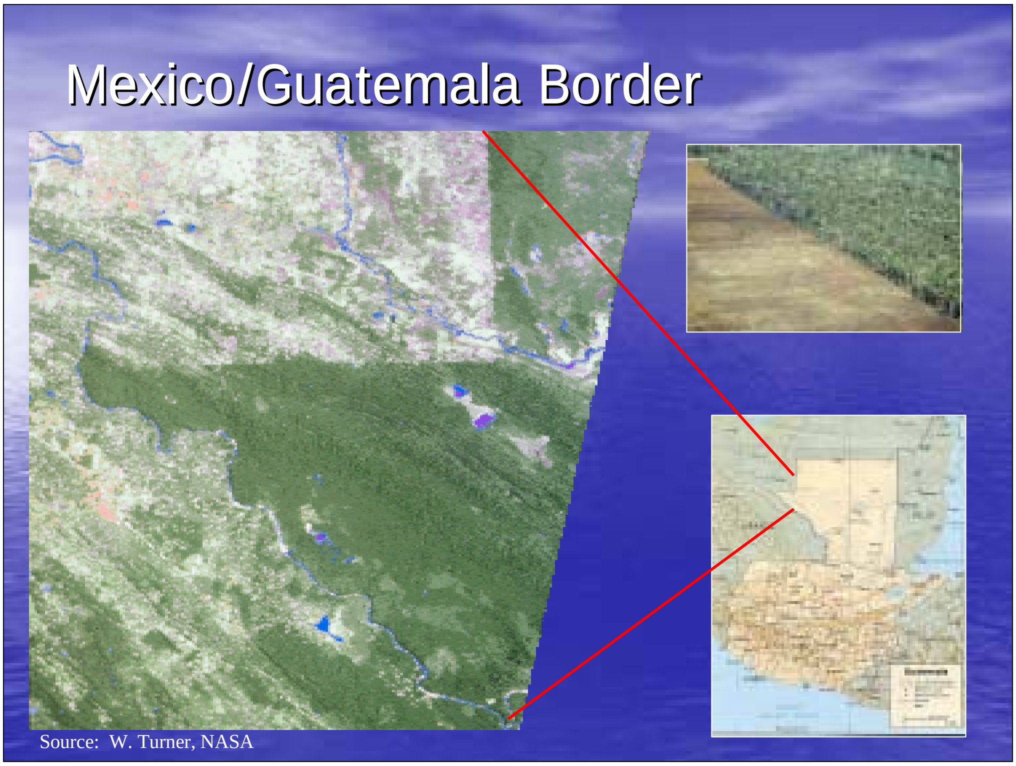


Marine applications are also relatively under-represented – at least in terms of applications relevant to marine treaties. Another satellite technology – Global Positioning Systems or GPS – has tended to have wider applications for marine biodiversity conservation, with tagging of large marine mammals, amphibians and fish now becoming coming practice. Still, the potential of remote sensing for monitoring of coral reefs, oil spills, and fisheries treaties is potentially great.



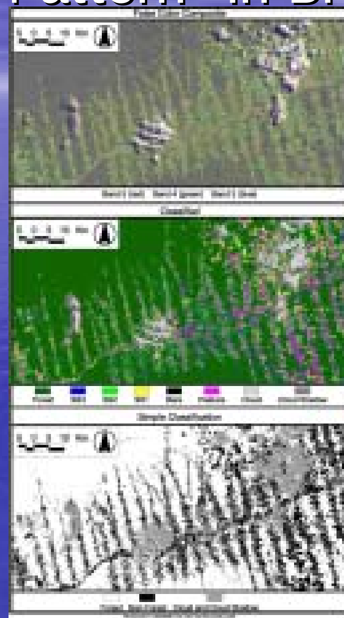
Desertification and habitat degradation can also be monitored from space through albedo composites, normalized difference vegetation indices, land cover mapping, and monitoring of ‘desertification fronts’.

Finally, it is worth reiterating the overarching ability of remote sensing to raise awareness of global environmental issues such as the ozone hole (the disappearance of which was confirmed by the Troposopheric Ozone Mapping Spectrometer), deforestation or other significant land cover changes in tropical countries, and climate change.

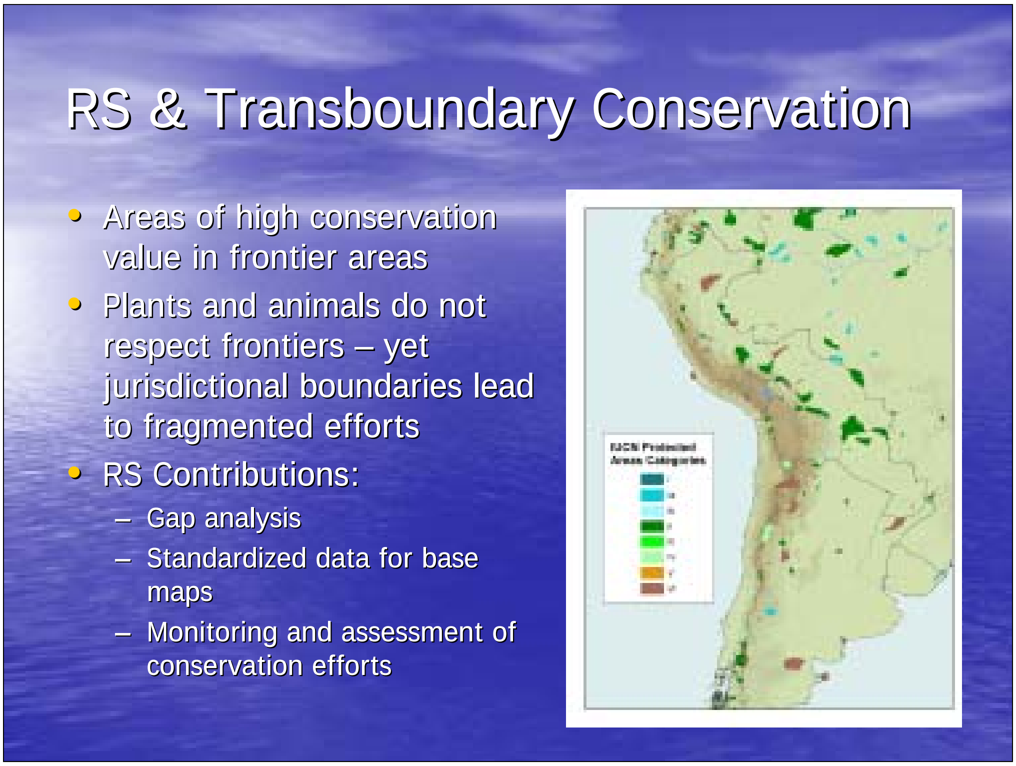


A 1988 Landsat image of the Mexican and Guatemalan borders near Guatemala’s Petén region showed that the Mexican side was largely deforested, but the Guatemalan side held largely intact forest cover. The stark contrast at the border was a catalyst in promoting one of the first meetings in decades between the Mexican and Guatemalan presidents to discuss management of borderlands. This development demonstrated the potential for remote sensing to monitor large-scale changes in the regional environment and to create a situation conducive to regional environmental planning. Remote sensing is now being used to provide a land-cover baseline for the entire region and is viewed by NASA’s Central American partners as a vital tool for developing the corridor.

“Fishbone Pattern” in Brazil



Source: Anthropological Center for Training and Research on Global Environmental Change (ACT), Indiana University, in de Sherbinin et al. (2002a).



in Africa approximately 45% of existing protected areas are located on national borders, and the worldwide preponderance of protected areas on borders will inevitably lead to a dramatic increase in transboundary projects in the next 10-20 years. However, the limited synchronicity and communication between nations on protected area management requires the application of tools, such as RS, that have minimal political baggage, and that provide a wealth of information on assets, risks and opportunities in a format that can be easily understood by ALL stakeholders, from the grassroots to international donors and decision-makers.

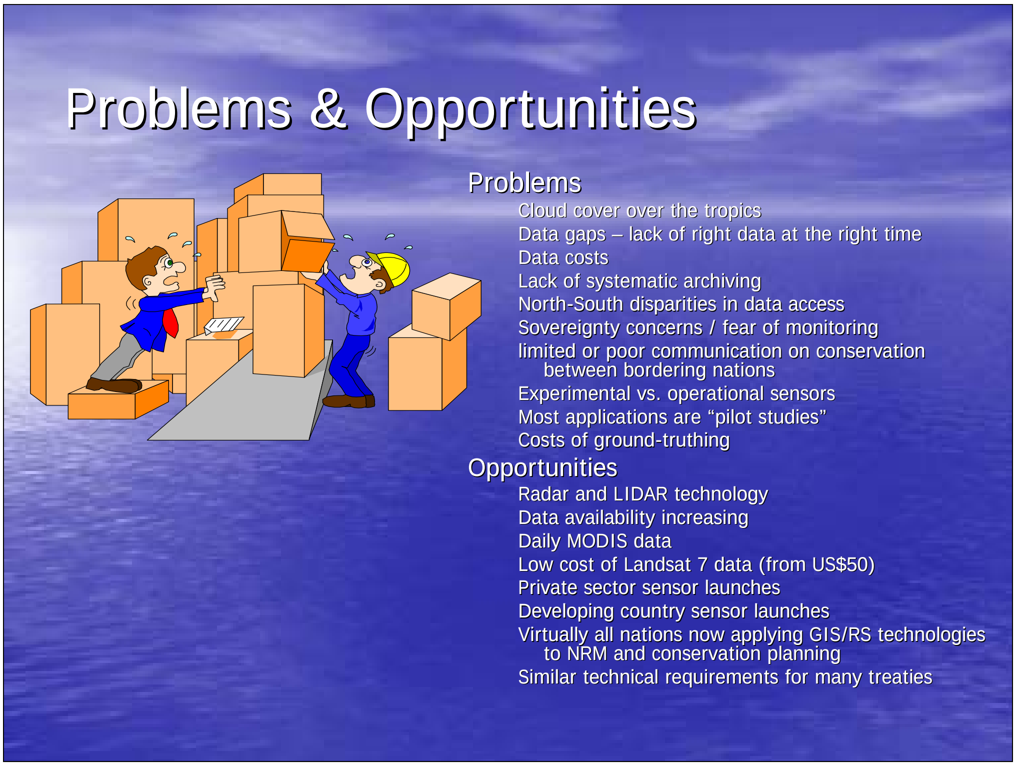
Peace Parks Foundation

Vegetation Productivity

Elephant Migration Corridor

RS has the potential to ...

- change minds
- build consensus
- enhance understanding
- enable monitoring of change over time
- bring people together across boundaries to address common problems
- provide a powerful tool for international cooperation



There are a number of problems and opportunities in the use of remote sensing for environmental treaty negotiation, monitoring, and enforcement. The problems include everything from persistent cloud cover over some of the most biodiverse spots in the world to data gaps and data costs, lack of consistent archiving (for historical analysis), and North-South disparities in data access that could lead to power imbalances in international environmental diplomacy. Other problems include the cost of ground-truthing, which can be non-trivial, and the fact that most instruments are developed for scientific research and not operational applications. These problems will need to be resolved before remote sensing becomes operational for treaty enforcement or monitoring. On the other hand, there are new opportunities brought about by the availability of new technologies such as radar, high resolution sensors, and declining costs of the most commonly used moderate resolution imagery. There is also increased developing country capacity to process and analyze imagery, which may offset some of the geopolitical concerns.

Looking towards the future, the CIESIN-sponsored workshop in December 2000 resulted in a number of recommendations for future action. These include:

•Development of an international institution coordinate among space agencies, value-added companies, and MEAs for technology & applications development

  •Integrated Global Observing Strategy's Caron Theme

  •Group on Earth Observations' GEOSS: Its architecture will incorporate sensors and data processing, archiving, exchange and dissemination, under principles of open exchange and assured availability.

•Awareness-raising and training in developing countries for *trust* and *capacity*

•Long-term commitment to providing medium-resolution satellite imagery at low costs

•Development of a constellation of operational environmental monitoring instruments more specifically tailored to the needs of specific agreements.

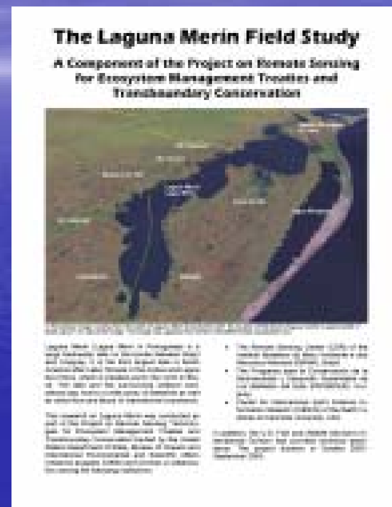
In conclusion, remote sensing ...

- creates demand for better environmental policies through awareness-raising
- provides a synoptic view over time
- complements national data collection
- contributes to global assessments
- is a tool for international collaboration and transboundary conservation
- has the potential to contribute to compliance verification and enforcement

In conclusion, remote sensing holds significant promise for environmental treaties. Remote sensing creates a demand for better environmental laws and national and international levels through awareness raising. It provides a synoptic view, with global coverage that extends back to 1972. It complements other forms of ground-level data collection. It contributes to global environmental assessments such as the IPCC and the Millennium Ecosystem Assessment. And it has the potential to contribute to compliance verification and enforcement once the “problem areas” are addressed.

Take a copy...


Remote Sensing in Support of Ecosystem Management Treaties and Transboundary Conservation


The Laguna Merin Field Study

A Component of the Project on Remote Sensing for Ecosystem Management Treaties and Transboundary Conservation

... and visit http://sedac.ciesin.columbia.edu/rs-treaties/laguna.html