

Satellite imagery activism: Sharpening the focus on tropical deforestation

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Since the first land remote sensing satellite was launched in the early 1970s, government agencies, private companies and research institutions have used satellite imagery data for a growing range of civil and commercial applications focused on natural resource management and exploitation, and environmental monitoring. The global diffusion of remote sensing expertise, along with growing public access to satellite images, has created conditions for improving levels of global transparency. One aspect of this global transparency is the advent of new users of imagery data – or ‘imagery activists’ – including, among others, issue-oriented nongovernmental organizations (NGOs), media groups, multinational organizations and academic researchers who now are able to access satellite imagery in order to draw domestic and international attention to particular public policy concerns. This paper broadly surveys the contemporary phenomenon of satellite imagery activism and outlines the main challenges facing imagery activists, particularly in relation to deforestation and other forest monitoring issues.

Keywords: tropical deforestation, remote sensing, imagery activists, Indonesia, nongovernmental organizations, forest monitoring

Introduction

Since the first Landsat satellite was launched by the USA in 1972, satellite remote sensing has become an important source of data for better understanding the nature and sustainability of the earth’s natural resources, and particularly the impact of human activities at the local, regional and global levels. Whereas traditional users had comprised state agencies (civil and military), natural resource-related businesses and scientific research institutes, today a broad spectrum of actors, who include various issue-oriented nongovernmental organizations (NGOs), multinational organizations and independent researchers, use satellite imagery data for a wide range of civil and commercial applications. For example, those focused on natural resource management and exploitation, environmental monitoring and preservation, disaster monitoring and humanitarian responses, international security and, increasingly, coverage of all these by the news media.¹

The growth in remote sensing expertise worldwide, along with the recent advent of high-resolution commercial observation satellites, has enabled more detailed observations of environmental changes resulting from major human activities on the earth’s surface, thus also engendering the conditions for improved transparency in policymaking. The wider availability of remotely sensed data, together with the spread of geospatial expertise, has underpinned applications of satellite imagery data by a group of newer users, specifically to support involvement in and contributions to public policy debates. In the main composed of NGOs, the news media, academic researchers and multinational organizations, these ‘imagery activists’ help focus domestic and international attention on problematic issues such as environmental degradation, international security and human rights abuses in closed societies.

This paper broadly surveys the contemporary phenomenon of satellite imagery activism with particular emphasis on those concerned with deforestation and related aspects in forest monitoring. It also outlines the main challenges and opportunities for imagery activists in acquiring the necessary expertise, resources and access to imagery data in order to bring public policy decisions into open forum.

Global transparency and satellite remote sensing

An unanticipated result of the diffusion of remote sensing expertise has been the increased public availability of high-resolution commercial observation satellite data. This is emblematic of a broader trend towards global transparency brought about by the convergence of new information and communication technologies with political economic developments such as the spread of market economies and the concomitant demand for popular access to a range of information sources (Baker & Williamson, 2001). Satellite information technologies, given their global coverage, are key drivers encouraging data and information flows to cross national boundaries. New civil (i.e. state-owned) and commercial (i.e. privately owned) observation satellites, along with communication and space-based PNT (position, navigation and timing) satellites, are providing both governments and other users with an unprecedented potential to locate and monitor major developments occurring almost anywhere in the world, and then share this data and information over global communication networks such as the Internet or other electronic and digital means. The growing global market for geospatial technology and information products only serves to bolster this trend toward worldwide accessibility of satellite imagery data and other information products.

Commercial and civil observation satellites produce overhead images that contain accurate and detailed geospatial data. Unlike aerial photography (which has its advantages),² satellite imaging does not depend on prior approval from governments or private landowners. Instead, satellite remote sensing has the ability to collect images of large areas, covering sites located almost anywhere in the world and on a routine basis. Images collected of the same location at different times provide comparative geospatial information that helps analysts identify and accurately characterize or measure physical features of the terrain (e.g. riparian systems) as well as human impacts (e.g. deforestation). Not only major changes but also subtle distinctions can be discerned. Furthermore, continuing advances in computer capabilities and user-friendly software allow imagery analysts to process and display digital imagery data, patterns and trends that are not obvious to ground-based observers. Satellite and aerial imagery data are important inputs to Geographic Information Systems (GIS), wherein complex layers of socioeconomic and other types of geospatial databases can be integrated.

In this paper, we consider imagery data acquired by electro-optical sensors (essentially, very sophisticated digital cameras) operating in the visual and infrared portions of the electromagnetic spectrum and, to a lesser extent, on radar imagery acquired by using SAR (synthetic aperture radar) technology.³ Briefly, electro-optical sensors gather light reflected and radiated from the earth's surface, converting it to digital intensities before transmitting the information in bits and bytes; using sophisticated image processing software, this is converted into imagery that can be analysed for detailed information (Lillesand & Kiefer, 2000). Multispectral satellite imagery often seems easy to interpret when relatively familiar details can be displayed at sufficient spatial resolutions to discern imaged objects; however, in the absence of detailed processing and analysis, even this can be deceptive as objects near the limit of a spatial resolution may be difficult to identify with any amount of certainty. Also, in the absence of precise ground measurements made

with a global positioning or PNT receiver, position determination may be faulty. If it is necessary to identify plant or tree species in a complex environment, analysis may produce identification errors if there are no comparisons with *in situ* measurements and positions determined using PNT devices. The complexity of image processing programmes, thus, does require substantial training and practical experience, both in the computer laboratory and in the field.

Because they are acquired in the microwave spectrum, SAR images reveal glints emanating from metallic surfaces, presenting interpretative challenges. Moreover, SAR technology is much more expensive and SAR imagery present more technical challenges to achieve a level of sharpness comparable to that of multispectral imagery. Nevertheless, SAR is a powerful observational tool that is not affected by the dark of night or by cloudy weather (Jensen, 2000) and, hence, is often used in combination with multispectral imagery in the same area to provide additional information.

Thus, depending on the sensor systems that they carry, civil and commercial satellites can produce several types of imagery data, including panchromatic, multispectral and radar, each of which have particular advantages and limitations, depending on the specific needs of the user. Multispectral imagery data are particularly useful for land cover assessments that seek to identify different types of vegetation, including forests and crops, as well as to assess their status over time. However, as electro-optical sensors that collect panchromatic and multispectral data depend on favourable sunlight conditions to collect radiation reflected from surface objects, radar imaging systems are often used to collect imagery data on tropical forests in parts of the world like Southeast Asia, where smoke and haze from burning and cloud cover are common.

Table 1 provides a list of currently operating satellites capable of imaging land areas at medium and relatively high spatial resolutions and at varying spectral resolutions. Resolution refers to the limit of sharpness that the sensors aboard provide for distinguishing between signals that are spatially near or spectrally similar (for an in-depth discussion of spatial and spectral resolution for overhead images see Jensen, 2000). The distinction indicated between research and operational satellites is of some importance because research satellites may not be replaced after the primary research mission is completed; the information supplied is therefore more useful for the initial reconnaissance of an area because it cannot be depended upon for longer-term monitoring.

In sum, civil and commercial imaging satellites are adding to global transparency in imagery data. Whereas the earlier civil observation satellites such as the USA's Landsat, the European Space Agency's ERS satellites and France's SPOT satellites could only provide users with imagery data of moderate spatial resolution, now users have access to relatively high-resolution spatial imagery data produced by (largely USA) commercial observation satellites as well as other more recent imaging systems, such as India's ResourceSat and the Israel-led consortium ImageSat's EROS satellites. With this scenario, the distinction between civil and commercial observation satellites is increasingly becoming blurred as state agencies can easily turn to private corporations that offer their satellite imagery data for sale in the global market to recoup their costs; at the same time, commercial observation satellite companies, in particular USA companies, are increasingly dependent on large government contracts to generate revenue, at least until they can muster a sufficiently large commercial client base (for further details on current and planned imaging satellites see Stoney, 2005).

Table 1. Selected civil and commercial observation satellites.

Satellites	System	Launch	Imagery/resolution (m)
Civil			
USA	Landsat 7 [O]	1999	Pan: 15; MS: 30
	EO-1 [R]	2000	Pan: 10; MS: 30; HS: 30
France	SPOT 4 [O]	1998	Pan: 10; MS: 20, 1150
	SPOT 5 [O]	2002	Pan: 25, 5; MS: 10, 1150
European Space Agency	ERS 2 [O]	1995	SAR (C-band): 30
	Envisat [O]	2002	SAR (C-band): 30, 150, 1000
Canada	Radarsat 1 [O]	1995	SAR (C-band): 8-100
India	IRS-1C and -1D [O]	1995, 1997	Pan: 6; MS: 23, 188
	ResourceSat [O]	2003	Pan: 6; MS: 6, 23, 56
Japan	ALOS [P]	2006	Pan: 25; MS: 10; SAR (L-band): 10 to 100
China/Brazil joint venture	CBERS 2 [O]	2003	Pan: 20; MS: 20, 160
Singapore	X-Sat	2006	MS: 10
Commercial			
Space Imaging (USA)	IKONOS [O]	1999	Pan: 0.8; MS: 3.3
DigitalGlobe (USA)	QuickBird [O]	2001	Pan: 0.6; MS: 2.5
	WorldView [P]	2006	Pan: 0.5; MS: 2.0
Orbimage (USA)	OrbView-3 [O]	2003	Pan: 1 to 2; MS: 4
	OrbView-5 [P]	2007	Pan: 0.4; MS: 1.6
ImageSat International (Israel-led consortium)	EROS A [O]	2000	Pan: 1.8
	EROS B [P]	2006	Pan: 0.7
MacDonald Dettwiler (Canada)	Radarsat 2 [P]	2006	SAR (C-band): 3 to 100
Rapideye (Germany)	Rapideye [P]	2007	MS: 6.5

HS, hyperspectral; MS, multispectral; O, operational; P, planned; Pan, panchromatic; R, research; SAR, synthetic aperture radar.

Rise of satellite imagery activism

The initial civil remote sensing satellites largely focused on providing data for technology development and scientific research, environmental monitoring and natural resources management. Access was confined mainly to state agencies, businesses concerned with natural resources and scientific researchers. Several developments have contributed to the now worldwide accessibility of imagery data. First, more powerful but relatively inexpensive computing technologies and computerized databases have significantly broadened the range of consumers that can access and work with satellite imagery data (Williamson, 2001). Imagery processing that once required computer mainframes or workstations now can be run on higher-end personal computers, for instance. Second, the advent of user-friendly software for image processing and analysis has made imagery analysis much less the purview of remote sensing specialists. Graduate and undergraduate students in geography departments around the world are gaining experience with at least the basics of imagery data processing and analysis. Third, the cost of imagery data has been significantly reduced within the past decade with the supply of cheaper Landsat and SPOT images, declassified USA and Russian intelligence satellite images and various forms of less expensive commercial satellite images. Finally, the Internet and CD-ROMs have greatly facilitated the spread of and interest in overhead imagery data, while data providers, such as Google, now offer consumers convenient access to maps and satellite imagery data (*New York Times*, 2005).

Taken together, the rising levels of global transparency and hardware developments have created many opportunities for citizens to raise debates on public policy issues – as has occurred most notably in the USA (Litfin, 2001). For instance, remotely sensed data have been used to raise concern over human rights related conditions (labour and prisoner camps) and security concerns.⁴ To more practical effect, satellite images have been used by the United Nations High Commissioner for Refugees, together with GIS databases including the Reuters Foundation's AlertNet, to coordinate its humanitarian work in disaster situations around the globe (Bjorgo, 2002). Along with the imagery activists concerned with monitoring forest conservation and deforestation that are discussed specifically below, several environmental monitoring organizations in the USA that have made use of satellite remote sensing to support their work include the Nature Conservancy, the Natural Heritage Network and the Coral Cay Conservation (Litfin, 2001). Environmental groups in particular have developed a symbiotic relationship with news media organizations, which in a sense also function as imagery activists by illustrating and providing evidence for 'breaking news' stories or investigative reporting with, quite often, the imagery and disciplinary expertise of NGOs (Corbley, 2004). By so doing, the work of NGOs receives greater public attention while media groups compete to find novel and credible information to attract audiences for their products (Livingston, 2001). Once a relative rarity, satellite imagery is regularly carried by newspapers (e.g. *New York Times* and *Washington Post*), as well as by televisual and electronic news media (e.g. *CBS News*, *BBC News* and *CNN*), although some critics contend that the news media seem more content to include these as 'eye candy' rather than providing insightful analysis (Corbley, 2004). Nevertheless, the visual appeal of satellite imagery in inviting greater public as well as expert interest in the work of NGOs in environmental concerns cannot be denied.

Of course, there are still some constraints to the potential for public access to satellite imagery data. First, it is still relatively expensive for most NGOs and interested individuals to acquire timely satellite imagery data of a high spatial or spectral resolution, particularly if numerous images are required covering large areas, which might also entail frequent revisits to monitor and detect changes on the ground. Second, accurately interpreting satellite imagery data still requires some degree of expertise and experience beyond the most obvious forms of change detection. Third, full public access to satellite imagery may be restricted because of security concerns, such as the US government's restrictions on sales of commercial imagery of the Afghanistan region several weeks following the initiation of its *Operation Enduring Freedom* in October 2001. Finally, the future viability of the commercial satellite firms that have been the forefront of encouraging a broader consumer base for satellite imagery data is uncertain as they struggle to keep afloat against stiff competition in the global market for geospatial information products and services. Despite all these constraints, however, the widening public access to satellite imagery data with improved spatial and spectral resolution is only likely to continue as civil imaging satellite data becomes increasingly available in the market or is released into the public domain without charge.

Imagery activism and tropical forests

Satellite imagery, such as the broad coverage and moderate resolution of Landsat and SPOT satellites, coupled with their multispectral characteristics provide critical data for analysing regional changes in vegetation, biological stress and habitat characterization. These data collection attributes are particularly useful for an inventorying of tropical rainforest worldwide and monitoring trends in deforestation. Besides forest degradation,

satellite imagery can be used to monitor growth as well as the effects of human activity and exploitation, including the damage caused by fire, on the surrounding ecosystems.

In recent years, human disturbance in the tropical rainforests of Brazil (Moran & Brondizio, 1998) and Indonesia have been in the limelight. Satellite imagery of these regions has provided government bodies and scientists with a medium to convey useful information to a broader, non-expert audience. As Litfin (2001:466) notes:

Perhaps the greatest asset of satellite imagery is its visual character. As one individual working to stop deforestation in British Columbia's Clayoquot Sound – the world's last remaining expanse of temperate rain forest declared, 'Satellite images are totally convincing. You show people a map, and they can see clearly what's left.'

A workshop held by the World Resources Institute (WRI, 2002) on promoting transparency in the forestry sector identified several best practices on detecting and monitoring illegal and destructive logging, which included the use of satellite remote sensing. The workshop concurred that satellite imagery is efficient and necessary for widescale monitoring of forests at national and regional levels to support government enforcement and to focus stakeholder activities in high-priority areas. Moreover, satellite images can provide objective documentation of potential logging infractions, which are consistent and can be replicated by others. Finally, given that satellite images and resulting datasets are becoming readily available, to promote transparency and accountability the workshop noted that time series of satellite images could be used to build a data and information base for long-term monitoring of rainforests. These observations on the use of satellite remote sensing for forest monitoring are confirmed in other studies (e.g. Peterson *et al.*, 1999; Jensen, 2000). At the same time, organizations seeking to rely on satellite imaging for forestry monitoring and assessment must anticipate the need to invest in expertise for acquiring relevant remote sensing data, as well as processing, interpreting and analysing the data to produce information and insights. In addition, remote sensing seldom obviates the requirement for complementary data sources, including *in situ* ground data and geolocation information (WRI, 2002). In some situations, satellite monitoring may be considered appropriate only for large-scale monitoring and characterization of forests, while more detailed assessments are made using aerial platforms and on-the-ground surveys (Peterson *et al.*, 1999).

Within this context, it is pertinent to briefly acknowledge how satellite imagery has actually been made use of in relation to the concerns surrounding deforestation in the well known cases of the Brazilian Amazon and the activities of WRI's Global Forest Watch (GFW) initiative, and in the impetus for the nascent – and therefore perhaps little known – Indonesian Forest Monitoring Network (IFMN).

Perhaps the best known use of satellite imaging in monitoring tropical forest sustainability are the periodic official assessments of the rate of deforestation for the Amazon rainforest undertaken by a government agency and publicized by NGOs. Over the past several years, satellite imagery has been applied to assess forest loss in the Brazilian Amazon resulting from the construction of road networks, from establishing farms, plantations and pastures, and from illegal logging (Moran & Brondizio, 1998). Growing international and domestic concern has put pressure on Brazil's government to assiduously monitor and publicly release its estimates of such losses based on its analysis of satellite images and other geospatial data sources. In mid-2003, Brazil's National Institute for Space Research (INPE) released satellite images and analyses estimating that over 25 000 km² of the Amazon had been cleared in 2001–02, mainly for farming –

a 40 per cent increase in the annual rate of deforestation over the previous year (*BBC News*, 2003; *New York Times*, 2003). The moderate-resolution imagery data from civil remote sensing satellites used for detecting changes in forest land cover in this instance had specifically identified the telltale herringbone pattern characteristic of new road construction and accompanying land clearings associated with new farming, cattle ranching, or logging activities (Anonymous, 2004).

On the global front, a good example of NGO imagery activist activities is the GFW programme sponsored by WRI (<http://www.wri.org>). Drawing on a worldwide network of local forest groups linked through the Internet, this programme urges better forest management by monitoring and publicizing what is occurring in major forests around the world, and highlighting deforestation in the USA, Canada, Central Africa, Chile, Indonesia, Russia, Brazil and Venezuela (Hammond, 2001). Combined with reports from ground observers, GFW experts make use of satellite imagery data and GIS to provide independent verification of how different national forests are faring. In terms of satellite imagery, the GFW project relies on moderate-resolution (15–30 m) satellite imagery, along with other geospatial data sources. For example, GFW Canada made use of data from over 1000 such images, generated by Landsat 5, Landsat 7 and the ASTER sensor on NASA's Terra satellite, to highlight that Canada's protected areas accounted for only about 2 per cent of the nation's large, intact forests (Lee *et al.*, 2004).

Indonesian Forest Monitoring Network

The third example of imagery activism, the IFMN, was started off only in mid-2004 with a group of environmental NGOs and individuals concerned with threats to the sustainability of the Indonesian tropical forest resources from unauthorized land-clearing fires and rampant illegal logging activities (see <http://www.ifmn.org>). Indonesia's tropical forests are a natural resource that have come under stress from population growth and questionable transmigration policies. The lowland forests of Sumatra and Kalimantan are sources of substantial biodiversity and yield both timber and non-timber forest products. Fires have long been used by local populations for land-clearing, but this practice has been adopted by plantation owners and ever-growing numbers of small farmers (Barber & Schweithelm, 2000). Besides hastening deforestation, these annual fires made the headlines in the international news media when they coincided with the drought conditions associated with the periodical El Niño phenomenon, such as in 1982–83 and 1997–98, when the smoke from fires caused a persistent regional haze over large areas of Sumatra and Borneo, extending to neighbouring Singapore and Malaysia. This resulted in widespread health problems, transportation hazards and lost tourism revenue in Indonesia, Malaysia and Singapore (Glover & Jessup, 1999).

In this context, the importance of civil and commercial observation satellites have a much needed role in detecting and identifying locations where fires are being set or are raging, as well as in understanding the extent of resulting deforestation (Fuller *et al.*, 2004). During the 1997–98 protracted fires, researchers, such as those at the Centre for Remote Imaging, Sensing and Processing (CRISP) at the National University of Singapore, used several different sources of remotely sensed data including timely (but relatively low-resolution) imagery data from the AVHRR (Advanced Very High Resolution Radiometer) sensor on the US NOAA's (National Oceanic and Atmospheric Administration's) weather satellite to generate maps of hotspots and moderate resolution satellite imagery (e.g. SPOT or Landsat) to more accurately determine the locations and extent of individual fires (Liew *et al.*, 2001).

The initial impetus for IFMN originated from the workshop held in 2004 at the Center

for International Forestry Research (CIFOR) in Bogor, which had brought together local conservation groups and international experts on remote sensing and forest management issues to look at how remotely sensed data from satellites and airborne systems could be harnessed for monitoring the state of Indonesia's tropical forests. One outcome of the Bogor workshop (from which this paper derives) was a group consensus to proceed with creating a structured network for sharing remote sensing data, best practices and other relevant information relating to the threats to the forest in Indonesia posed by fires and illegal logging. IFMN members have since been sharing information via the Internet and developing a database of satellite imagery and information on Indonesian forests. The prospects for this group of satellite imagery activists influencing government policies to curb unauthorized deforestation activities have been reinforced by President Susilo Bambang Yudhoyono's widely reported pledge to crack down on illegal logging and timber smugglers in order to preserve Indonesia's natural resources (*Jakarta Post*, 2004). However, muting these entrenched interests is not likely to be an easy task, even if the central government becomes more proactive about putting a halt to destructive practices. Nevertheless, as already noted, information derived from satellite imagery can be disseminated to serve policy targets for enforcement and public education on the need to protect the forest.

Challenges and opportunities for imagery activism

Although some imagery activists can claim to possess unrivalled expertise, many lack the formal training and experience in remote sensing disciplines found among imagery analysts and geospatial experts in state agencies, industry and academia. Thus, most require on-the-job training as few nonprofit groups, or media organizations for that matter, are large enough to afford to have dedicated imagery specialists on their payroll. Therefore, environmental NGOs are faced with the continuing challenge of gaining the necessary expertise and experience for producing credible satellite imagery analysis, without which they run the risk of adding more noise than light to important policy debates (Litfin, 2001). What they do have, however, is the capacity to gather considerable ground truth information, which is equally necessary for undertaking accurate analyses.

It is thus ideal that NGOs seek collaborations on several fronts including sharing information, equipment and expertise; other types of cooperation could involve industry and professional organizations. The satellite remote sensing industry also can benefit from having imagery activists as customers because of the broad, if not worldwide, attention that these users bring to the diverse applications of overhead imagery. To ensure that their products are not associated with erroneous interpretations, commercial firms have a vested interest in working with imagery – to encourage NGOs to gain greater hands-on experience, they can provide discounts on imagery data, support training courses, provide discounts on needed imagery processing software or even produce affordable learning materials tailored to non-expert users of satellite imagery. Professional associations, such as the International Society for Photogrammetry and Remote Sensing (ISPRS), also have an important role in bridging the gap between the new users and remote sensing professionals by recognizing the work of NGOs engaged in imagery activism and by facilitating their professional training in the skills of imagery data handling, interpretation and analysis.

Finally, even governments have an interest in encouraging NGOs to improve their imagery interpretation and analysis skills to minimize the nuisance factor for government agencies resulting from public claims that are erroneous. Governments are in a position

to encourage and permit more regular and open engagement between their expert imagery analysts and the less-experienced imagery activists in NGOs and the news media (Baker, 2001).

Conclusion

Satellite imagery activists are fast becoming a significant source of insight on a broad range of human concerns, including human-environmental interactions, humanitarian and disaster emergencies, and worrisome weapons development or abuses occurring in closed societies. As a result of the considerably broadened public access to civil and commercial satellite imagery data, nontraditional imagery activist users have made considerable progress in the last decade in using satellite imagery to advance their public policy agendas.

By way of a broad overview, this paper looked at how both governments and NGOs are increasingly using satellite remote sensing for monitoring deforestation. In the case of Brazil, official periodic reports on deforestation rates for the Amazon rainforest reflect an institutionalized process for forest monitoring that has been encouraged by external scientific and NGO studies using satellite imagery and other geospatial information sources. Satellite imagery has also been harnessed by global activist NGOs such as WRI's Global Forest Watch, a fairly mature effort that has succeeded in building an international network that links local forest groups interested in monitoring deforestation worldwide. While aimed at attracting international public attention to deforestation problems, this initiative also works with both governments and wood products companies to improve forest management practices, and makes prominent use of satellite imagery data and other geospatial technologies in assessing deforestation trends in several different countries. Focused at a different scale, the originators of IFMN, a relatively nascent effort in satellite imagery activism, are striving to build linkages between local and international groups and individuals who are dedicated to using remote sensing and field survey methods for monitoring and evaluating forest developments in Indonesia, including deforestation resulting from land-clearing fires and illegal logging practices. One of its aims is to share widely imagery data and other information on Indonesian forestry activities.

In each of the cases highlighted, satellite imagery offers an emerging source of data for analysis and a novel medium to attract greater government and public attention to domestic and international problems such as deforestation. Satellite imagery activists could play an increasingly important role in the coming years in focusing policymakers' and public attention on a range of key issues of sustainability. However, their long-term effectiveness in public policy debates will depend on whether or not they can meet the challenges of developing sufficient analytical proficiency in handling imagery data to ensure that imagery activists carve a reputation for being a credible source of data and public knowledge.

Endnotes

- 1 A good example of emerging international interest in taking advantage of growing satellite remote sensing capabilities is the fact that over 60 countries and 40 international organizations have agreed to create the Global Earth Observation System of Systems (GEOSS), which will include an intergovernmental organization to facilitate international access to satellite imagery and other data needed for monitoring the earth's surface, atmosphere and oceans as a unified whole (see <http://earthobservations.org/>).
- 2 The advantages of aerial imagery over satellite imaging include potentially higher imagery

resolution, the ability to fly under cloud cover and flexibility in formulating flight plans to fit the user's area of interest for obtaining imagery data.

- 3 Most remote sensing imagery satellites orbit in a so-called sun-synchronous orbit that crosses the poles either from north to south or the reverse. This orbit, maintained in a single plane while Earth rotates beneath, allows such satellites to cover the entire planet over a period of time that depends directly on the swath width of the imager and the orbital altitude. For example, the Landsat satellites are designed to achieve full earth coverage every 16 days. The sun-synchronous nature of the orbit assures that each satellite crosses the equator at the same time every day so that the illumination is the same except for seasonal changes each time the satellite passes overhead. Constant orbital conditions when collecting imagery of particular surface locations makes it much easier to compare data gathered on different days (Jensen, 2000:186–88). Other remote sensing satellites carry radiometers and other types of sensors that collect data on the chemical composition of the atmosphere, the height of the oceans, and weather conditions (e.g. temperature, humidity and rainfall). These may operate in nonpolar orbits and generally do not collect imagery data.
- 4 For example, commercial satellite images have been used to monitor topical concerns in international security by the Federation of American Scientists and GlobalSecurity.org (Brown & Pike, 2004). Similarly, both the US Institute for Science and International Security (ISIS) (<http://www.isis-online.org>) and the Natural Resources Defense Council (NRDC) have effectively presented data from high-resolution commercial satellite imagery to question official assessments and draw public and policymakers' attention to weapons proliferation, such as the current high interest cases involving the nuclear programmes of Algeria, Iran or North Korea (Albright & Hinderstein, 2001; Cochran & McKinzie, 2005). In the area of human rights, in 2003 the US Committee for Human Rights in North Korea released a report that used commercial satellite images revealing the deplorable conditions in North Korean prison camps, drawing on assistance from NRDC imagery analysts (Hawk, 2003). Also directed at conditions in North Korea, the then Hong Kong-based *Far Eastern Economic Review* (2002) had used satellite images, coupled with defector testimony, to highlight the existence of slave-labour camps that the government attempted to keep out of sight.

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