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Letters Response

Global environmental priorities: making sense of remote sensing

Reply to TREE Letter: Satellites miss environmental priorities by Loarie *et al.* (2007)

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In a recent letter, Loarie *et al.* [1] raise an important concern. They suggest that future collection of remote sensing data should be better coordinated, distributed and funded to enable us to better address environmental challenges. We agree with their call but would like to note that their paper focused on the American Landsat satellite series and on some of the recent American commercial high spatial resolution satellites. A key point missed by Loarie *et al.* [1] is the increasing participation of additional countries outside the USA in large-scale Earth observation projects aimed at human and environmental issues, and efforts being made to coordinate these globally [2,3]. Substantial Earth observation programs outside the USA include those of the European Union (led by France and Germany), Canada, China, India, Japan and Russia. Recently, other countries such as Brazil, Israel, South Korea and Taiwan have developed civilian space programs with significant Earth resource-monitoring components, and with their own satellite imaging sensors [4]. These programs include both moderate spatial resolution (10–100 m pixels) and high spatial resolution (1–5 m pixels) multi-spectral imaging sensors.

For example, India launched its first operational remote sensing satellite for Earth observation (IRS-1A) in 1988. Its multi-spectral Resourcesat-1 (IRS-P6) was launched in 2003 and has four spectral bands equivalent to Landsat bands 2–5 with a spatial resolution of 5.8 m for three of its bands [5]. Additional programs in India's agenda include its Third World Satellite (TWSAT) [6], which will carry a multi-spectral camera providing images at a spatial resolution of 36 m. In contrast to other more expensive satellite imagery, its data will be provided at low cost or free of charge to research organizations and universities in developing countries.

An example for collaborative programs is the joint China-Brazil Earth Resources Satellite (CBERS) program, which began in 1999 with the launch of CBERS-1 [7]. The most recent satellites in this program, CBERS-2 and CBERS-2B, were launched in 2003 and 2007, respectively. Combined, they provide spectral bands equivalent to those of Landsat at a spatial resolution of 20 m in the visible and near-infrared bands and 80–160 m in the shortwave and thermal infrared bands. CBERS-2B also provides a panchromatic band at a spatial resolution of 2.7 m. Future launches of CBERS-3 and CBERS-4 in 2010 and 2012, respectively, will provide similar spectral bands at an even higher spatial resolution. An important aspect of this cooperative program is its data policy, which includes delivery of images free of charge to governmental agencies, non-governmental organizations, researchers and other users in Brazil and China. This program will provide in the near future free images to environmental organizations and researchers in additional countries in Latin America, Southeast Asia and Africa, where many biodiversity hotspots are located.

Vegetation indices that are based on visible and near-infrared bands have been shown to be positively correlated with species richness, vegetation cover and primary productivity in various ecosystems across the globe [8]. However, vegetation indices cannot inform about the vertical structure of forests and are less useful in the tropics, where cloud cover impedes the utilization of Landsat-like optical imagers [9]. Other sensors, such as radar and lidar, can be used to monitor biophysical properties and land cover changes to overcome these problems [1,10]. They also allow three-dimensional remote sensing of forest structure, which provides important ecological information for inaccessible biodiversity-rich areas. A new development in this area is Germany's TerraSAR-X, the first civilian radar satellite to provide images at high spatial resolution ranging between 1 and 16 m [11]. This satellite was launched in June 2007. Such programs will increase the availability of environmental data at multiple spatial scales.

In conclusion, better discussion and collaboration between space agencies [12], decision makers, remote sensing experts and ecologists across the globe would be useful in maximizing the gain from satellites for environmental and conservation-related purposes. Globally oriented governmental and non-governmental organizations can take part in these efforts by ensuring that imagery from

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biodiversity hotspots and from under-represented areas are acquired over time, and provided to scientists, conservation and environmental planners in both developing and developed parts of the globe.

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Letters Response

Landsat still contributing to environmental research

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Landsat data have enabled continuous global monitoring of both human-caused and other land cover disturbances since 1972. Recently degraded performance and intermittent service of the Landsat 7 and Landsat 5 sensors, respectively, have raised concerns about the condition of global Earth observation programs. However, Landsat imagery is still useful for landscape change detection and this capability should continue into the foreseeable future.

Loarie and colleagues [1] present important information about current problems in Earth observation. However, in our opinion, the environmental community has not been left 'blind' [1]. The Landsat archive is the longest-running and most comprehensive global land record ever created [2]. Loarie *et al.* incorrectly conclude that the Landsat era ended when the Landsat 7 Enhanced Thematic Mapper Plus (ETM+) Scan-Line Corrector (SLC) failed in 2003. Although it is true that the reduction in data quality has had an impact on the environmental remote sensing community, it has not been the deadly blow implied in the article. Seventy-eight percent of the data within each Landsat 7 scene are unaffected and continue to be valuable for many environmental applications. Approximately 300 scenes continue to be added to the US Geological Survey (USGS) Landsat data archive each day [3].

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The current Landsat operator, the USGS, does not delete Landsat 5 images 'from most of the rest of the world before they reach the ground' as indicated by Loarie and colleagues. The 24-year-old Landsat 5 experiences occasional technical problems. For instance, data collection was suspended in October 2007 because of battery issues. A solution is being developed and imaging is likely to resume soon (see http://Landsat.USGS.gov for status updates). Landsat 5 data must be transmitted directly to ground stations because the satellite does not have data recorders. Many of the international ground stations switched their regional collections back to Landsat 5 when Landsat 7 experienced the SLC problem. As a result, global Landsat 5 coverage, although not centralized in the USGS archive, is extensive and the US government retains full rights on behalf of the user community.

The long-term future of Landsat data continuity is improving. NASA and the USGS are currently developing the Landsat Data Continuity Mission, which should result in the launch of Landsat 8 in mid-2011. The administration has recommended formation of the National Land Imaging Program to make global Earth observation at Landsat scales operational far beyond Landsat 8 [4]. If this program functions as envisioned, stability of data collection, as called for by Loarie *et al.*, will be achieved and the environmental community will not be left 'blind to the ongoing changes in land-use patterns across key ecosystems.'

There is justifiable concern that the environmental community will see disruptions in coverage between today and mid-2011 should Landsat 5 and 7 fail. To mitigate possible disruptions, NASA and the USGS are developing