The Earth Observing System and Forest Management
By Steven W. Running, Lloyd Queen, and Michele Thornton

Inexpensive, readily available, and frequently updated: These are the important characteristics of biophysical data coming from the first satellite launched as part of the Earth Observing System. For forest managers, the data can help detect and monitor fires, determine seasonal and annual productivity across ownerships, even estimate national carbon balances for environmental policy plans. Although the variables do not distinguish all forest cover types, processing modifications will soon allow more detailed calculations.

A new era of global remote sensing began with the launch of the NASA Terra satellite on December 18, 1999. The first major platform of the Earth Observing System (EOS), the Terra satellite has five sensors on board, of which the Moderate Resolution Imaging Spectroradiometer (MODIS) is the most useful for forestry applications. MODIS has 36 spectral bands (compared with five on AVHRR and seven on Landsat TM+) with three nested spatial resolutions—250 meters, 500 meters, and 1,000 meters. MODIS images the entire globe daily, and the most important products for forestry are computed every eight to 16 days.

Applications in Forestry
To an end user, the most significant advantage MODIS offers is an array of biophysical products (table 1) computed by NASA daily and made available at nominal cost to the public. This is a radical departure from current practice. If you order Landsat data, for example, you receive a tape of seven channels of radiometric data and must do all advanced processing yourself.

The most important advances MODIS offers over the current AVHRR sensor are continuous on-board calibration over the lifetime of the sensor and computation of an array of biophysical products immediately available for public use. Satellite sensors normally degrade with time in the hostile environment of space over their typical five-year lifetimes. This sensor degradation, which has made precise measurements almost impossible from AVHRR, will be remedied with the four calibration protocols built into MODIS.

Strengths and Limitations
MODIS data are globally available, produced every week, and distributed rapidly to scientists and managers. There are two important limitations of these MODIS data for foresters, however. First, the pixel size of 1 kilometer in some of these products is too coarse for many site-specific analyses. The best use of 1-kilometer data may be for regional policy and planning assessments and decisionmaking; the 250-meter data will give better local details.

Second, the global variables derived from MODIS may be too generalized for local use. For example, the weekly calculation of forest productivity from EOS does not distinguish between ponderosa pine forest and alpine fir forest; the global logic identifies only evergreen needle-leaf forest types in general. At the University of Montana we are developing an additional level of processing that makes more detailed calculations of, for example, forest productivity. These products will differentiate forest types

Table 1. Biophysical variables computed from MODIS data.

<table>
<thead>
<tr>
<th>Product</th>
<th>Spatial resolution</th>
<th>Temporal coverage</th>
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</thead>
<tbody>
<tr>
<td>Land cover</td>
<td>1 km</td>
<td>Seasonal</td>
</tr>
<tr>
<td>Surface temperature</td>
<td>1 km, 5 km</td>
<td>Daily</td>
</tr>
<tr>
<td>Snow cover</td>
<td>500 m</td>
<td>Every 8 days</td>
</tr>
<tr>
<td>Fires, burned areas</td>
<td>1 km, 10 km</td>
<td>Every 8 days</td>
</tr>
<tr>
<td>Vegetation indices</td>
<td>250 m, 500 m, 1 km</td>
<td>Every 16 days</td>
</tr>
<tr>
<td>Leaf area index</td>
<td>1 km</td>
<td>Every 8 days</td>
</tr>
<tr>
<td>Vegetation primary production</td>
<td>1 km</td>
<td>Every 8 days</td>
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</tbody>
</table>
and use local information on topography, microclimatology, and soils to compute stand growth.

**Cost-Effective Use**

Although conceived and developed as a global science program, since the mid-1990s NASA's EOS program has also emphasized research and applications to support regional objectives. The international science community has developed a system capable of characterizing and monitoring earth resources in a quantitative, calibrated fashion never before available. From the perspective of nonspecialists in remote sensing, the greatest benefit from EOS will be that biophysical variables of the land surface will be regularly and automatically produced. This includes not only global coverage once every eight days for EOS products but also an array of local products for the United States. Several programs are in place to provide Web-based, low-cost access to these products. For example, the University of Montana EOS Training Center Natural Resource Project is focusing on two areas of NASA's EOS Application Products for natural resource management—fire management and vegetation productivity.

**Fire Management.** We have developed a surface moisture index for use in fire danger and drought monitoring. Using both vegetation index and surface temperature data, the index monitors surface and vegetation moisture stress every eight days. Index data are posted to a website in both browse image and actual data formats. Users may review maps of the surface moisture index online, or they may download the data files for incorporation into a local geographic information system (GIS). Departure indices, which show deviations in surface moisture condition from "normal," are calculated by applying the index algorithm to a 10-year historical database. Derivatives of the surface moisture index are currently being evaluated for drought and live fuels moisture mapping, in support of programs like the USDA Forest Service's Wildland Fire Assessment System.

Fire detection and monitoring products are also calculated from MODIS data (fig. 1). Global observations of fire occurrence will be available on a daily basis and include diurnal images for fire detection. These products also show burn scars, enabling fire managers to assess regional fire activity and behavior. Work to date has demonstrated that modifications may be needed to optimize performance in specific situations or biomes.

Several applications being developed will enable value-added processing of the global fire product so that detection accuracy is optimized for those areas. Remote areas such as Alaska or the Great Basin would benefit from operational satellite fire detection and monitoring, thereby alleviating the need for repeated flyovers. Fire managers in regional coordinating centers, concerned with broad-scale wildfire occurrence, will be able to assess the spatial and temporal distribution of these fires. Given a regional picture of wildland fire, managers may be better able to schedule logistics, such as workers and vehicles, and assess the timing and distribution of prescribed fire programs.

**Vegetation Productivity.** Global estimates of weekly vegetation productivity and annual net primary productivity are other MODIS products of interest to forest managers who require estimates of primary production (i.e., stand growth) to manage forests for long-term sustainability (fig. 2). These estimates are easy to make at permanent growth plots but are almost impossible to derive across the entire landscape without the aid of remote sensing. The EOS-MODIS net primary productivity variable permits observed stand growth data to be extrapolated to the entire management unit. These estimates will not only be available as a consistent product across all ownerships but will also be recalculated regularly—every eight days. Seasonal or annual productivity maps can then be used to assess regional patterns of growth across climate, disturbance, and management regimes. If historical growth rates are known, a departure index can monitor seasonal trends in growth relative to long-term conditions. Applied to rangeland settings, this index can be used to assess differences in the seasonal timing and development of rangeland vegetation and to compare this year's growth with last year's. Such departure indices can also help determine range readiness and stocking rates and assess grazing allotments or reforestation. Because seasonal primary productivity of forest and rangeland vegetation is an important component of wildlife habitat requirements, the data are useful for monitoring wildlife population dynamics, too. Finally, terrestrial carbon sources and sinks can be computed.
Users can apply direct biophysical variables to their applications and assessments of forest resources. Access to the information is through the EOS data and information system (EOSDIS) (http://spossun.gsfc.nasa.gov/NewEOSDIS_Over.html), whose purpose is to make the earth science data easily available to the widest community of users.

Within EOSDIS, distributed active archive centers (DAAC) have been established to distribute data products and user-support services. The EROS data center DAAC (http://edcimswww.cr.usgs.gov/landdaac) provides the primary entry point to MODIS terrestrial science products as computed from the global algorithms. Full background and documentation for each product are also provided, and users may access documentation of the models and algorithms used to compile the data on NASA websites. Additionally, numerous centers are being established to enhance users' access to EOS data, specifically to value-added products and services. Examples of these centers include regional earth science applications centers (www.crsp.ssc.nasa.gov/resac/resacmain.htm), earth science information partners (http://esipfed.org), and projects such as the EOS Training Center Natural Resource Project at the University of Montana (http://eostc.umt.edu).

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Figure 2. MODIS vegetation productivity data are used to illustrate annual net primary productivity for three national forests in western Montana.

Online Access and Sources
EOS provides foresters and allied scientists unparalleled access to low-cost remote sensing data and products.