National Geospatial Advisory Committee – Landsat Advisory Group[1]
The Value Proposition for Landsat Applications – 2014 Update

Landsat imagery provides the United States and the world with continuous, consistent inventory and monitoring of critically important global resources. Supplying an unprecedented record of global land cover status and change for over 40 years, Landsat imagery is an essential "national asset" which has made and continues to make critical "contributions to U.S. economic, environmental, and national security interests."[2] Because Landsat imagery is used most often by governmental and other non-commercial entities, the general lack of market forces makes estimating the economic value of Landsat data challenging. However, cost savings from operational efficiency improvements, avoided alternative replacement costs (assuming Landsat data were not available), and opportunity costs related to economic and environmental decision-support can be used to estimate the value of Landsat data.

To provide examples of the economic value of Landsat imagery, in 2012, the Department of the Interior requested that the Landsat Advisory Group (LAG) of the National Geospatial Advisory Committee (NGAC) provide advice to the Department "concerning the economic benefits of Landsat data."[3] The resulting paper, "The Value Proposition for Ten Landsat Applications,"[4] was well received and in 2014 the Department requested that the LAG review and update "the examples used in the 2012 paper, refining the list of user applications within and beyond government agencies, and enhancing the Landsat value summary."[5]

This paper first summarizes recent studies that estimate the total value of Landsat data. The second portion of the paper demonstrates the economic value of Landsat imagery by showcasing the economic value of Landsat imagery to 16 exemplary sustained programs within government agencies, NGOs and the private sector. **The paper establishes that the economic value of just one year of Landsat data far exceeds the multi-year total cost of building, launching, and managing Landsat satellites and sensors.**

1. Estimates of the Value of Landsat Data

In 2013, the National Research Council found that, "The economic and scientific benefits to the United States of Landsat imagery far exceed the investment in the system."[6] This finding echoes the results of studies done in 2007 by the American Society of Photogrammetry and Remote Sensing in support of the Office of Science and Technology Policy report[7] and in 2012 by Booz Allen Hamilton's work for a USGS study on Landsat.[8]

These studies were followed by a report by the USGS in 2013 with the results of their 2012 survey of 11,275 Landsat users on the uses and value of Landsat Satellite imagery.[9] The design and methodology of the study are more scientifically grounded than its predecessors. Key findings include:

- 43% of the respondents were new users of Landsat data who started using Landsat after the Department of the Interior made the imagery *available at no cost on the web* in 2008.
- 77% of the respondents stated they were *dependent on Landsat imagery to do their job*.
- The economic benefit of Landsat data for the year 2011 is estimated to be $1.70 billion for US users and $400 million for international users resulting in a ***total annual value of $2.19 billion***.

Not only has Landsat's overwhelming economic value been consistently established, its value relative to other civilian earth observing systems is also well recognized. In July of 2014, the Office of Science and Technology Policy identified 362 earth observation systems and had them ranked in order of impact by 300 Federal agency subject-matter experts. Landsat imagery was ranked as the 3rd highest, below only the GPS satellite constellation and the NEXRAD weather radar system. [10]

While Landsat's economic value is irrefutable, its non-quantifiable uses are often even more compelling:

- Several humanitarian groups including the US Holocaust Memorial Museum's Center for the Prevention of Genocide[11], Amnesty International[12], and the Satellite Sentinel Project[13] use Landsat imagery to document human rights violations. Because of its frequent revisit time, regional scale, and free access, Landsat imagery can support large-scale operational human rights monitoring campaigns. For example, Holocaust Museum personnel employed Landsat imagery to detect, where and when villages were burned during the Darfur conflict from 2002 to 2008.[14] Landsat imagery allows humanitarian organizations to monitor human rights violations at low cost and without incurring the burdens and risks of staff travel to inaccessible and dangerous regions of the world.

- To great media acclaim, Google released Landsat Timelapse in 2013 which allows anyone to easily zoom and browse through this interactive global animation, exploring phenomena such as urban growth in Las Vegas, the retreat of Alaska's Columbia Glacier, the deforestation of the Brazilian Amazon and mountaintop removal in Appalachia. This is perhaps the most comprehensive picture of our changing planet ever made available to the public. It receives 80,000 views per month, a year and a half after its release date. On May 5, 2014, Timelapse won the Webby People's Choice Award[15] for "Best Use of Video or Moving Images on the Web."

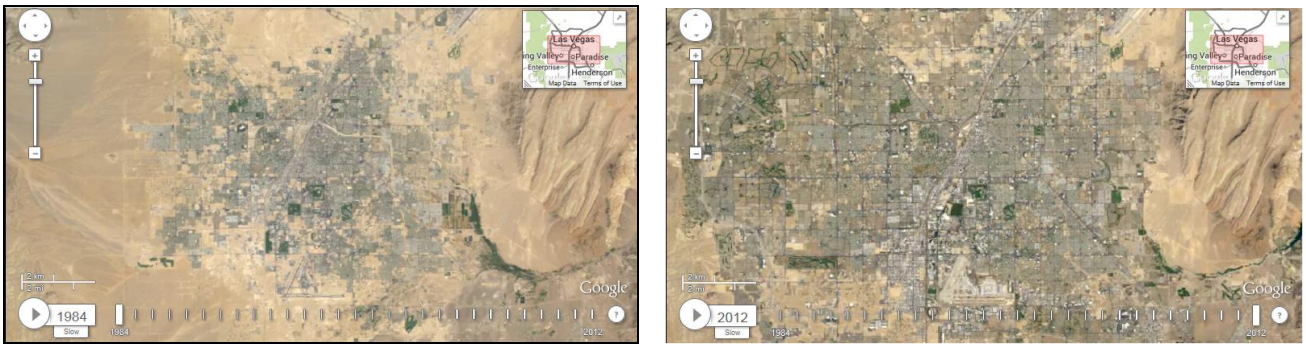

Figure 1. Landsat views of Las Vegas from 1984 and 2012.
View the animation at https://earthengine.google.org/#intro/LasVegas .

- Landsat's contribution to science is well documented and has sky-rocketed since the imagery has been freely accessible as shown on Figure 2. Since its first launch in 1972, over 22,384 scientific documents have referenced Landsat imagery.

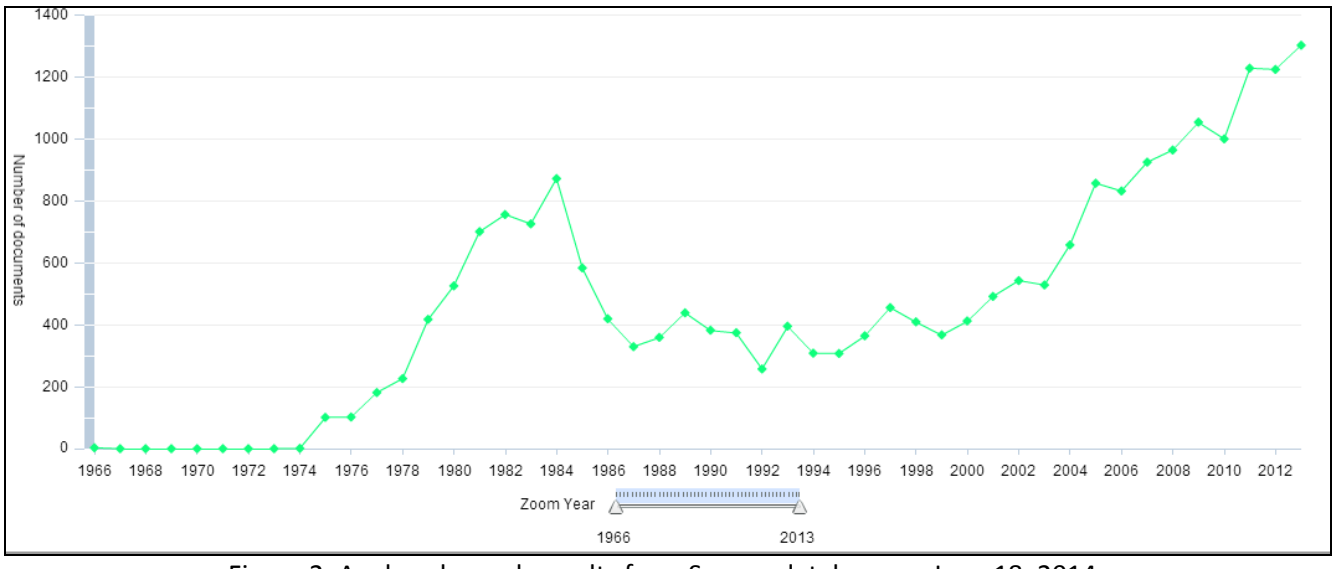

Figure 2. Analyzed search results from Scopus database on June 18, 2014.

2. Productivity Savings from Landsat

People use Landsat because it is more efficient than any other technology to accomplish the same decision support requirement. The remainder of this document outlines sixteen (16) decision processes that would be significantly more expensive without an operational Landsat-like program. Many of these processes are associated with the US government and save significant amounts of money compared to other methods of accomplishing the same objective. They also include non-governmental science applications where scarce research dollars cannot be wasted on inefficient technologies. The estimates of annual efficiency savings are conservative and can be substantiated upon request. These sixteen Landsat applications alone produce savings of $350 million to over $436 million per year for Federal and State governments, NGO's and the private sector.

Summary Table: Estimated Productivity Savings from Uses of Landsat

Landsat Application	Estimated Annual Efficiency Savings
1. USDA Risk Management Agency	over $100 million
2. U.S. Government Mapping	over $100 million
3. Monitoring Consumptive Agricultural Water Use	$20 - $80 million
4. Monitoring Global Security	$70 million
5. Landsat Support for Fire Management	$28 - $30 million
6. Forest Fragmentation Detection	over $5 million
7. Forest Change Detection	over $5 million
8. World Agriculture Supply and Demand Estimates	over $3 - $5 million
9. Vineyard Management and Water Conservation	$3-5 million/year
10. Flood Mitigation Mapping	over $4.5 million
11. National Agricultural Commodities Mapping	over $4 million
12. Waterfowl Habitat Mapping and Monitoring	$1.9 million/year
13. Coastal Change Analysis Program	$1.5 million
14. Forest Health Monitoring	$1.25 million
15. NGA Global Shoreline	over $90 million (one time)
16. Wildfire Risk Assessment	$25-50 million (one time)

1. USDA Risk Management Agency

The USDA RMA provides crop insurance to US growers. Over 1.2 million policies are issued resulting in premiums exceeding $6 billion per year. About 20% of the policies are in areas subject to flooding and higher premiums are accordingly charged. Prior to using Landsat the crop flood zones were very broad. Some growers with little potential for flooding were paying the same premiums as those with higher probably of flooding. The RMA Insurance Services Unit uses the Landsat archive to get a much more detailed picture of how flooding is distributed. They could see what areas had good levees and others with little protection. There was no other source for a systematic survey of agriculture flooding with sufficient historical evidence to refine the actuarial tables. With the Landsat evidence, RMA under took a program (FCI-33) to create much more detailed flood rate maps based of the true risk of flood damage. This allowed many growers to have a lower rate. These flood maps are constantly being updated based on new Landsat observations reflecting changes in water course, levee protection and other mitigating factors. The provision of more detailed zones reduced the premium cost by over $300 million annually. Without Landsat it is conservatively estimated RMA would have to raise premiums for more than 200,000 policies equal to $300M annually.
See also: http://gcn.com/articles/2013/10/18/usda-gis.aspx

Result: Annual efficiency saving with Landsat: over $100 million

2. U.S. Government Mapping

U.S. Government defense mapping agencies are estimated to spend over $300 million annually to create digital maps of roads, buildings, airports, foreign military sites and other defense-related mapping applications. Until recently, the method of updating these maps was to simply redo them or to manually scan high resolution images for new features. Because of the very large areas (global) and associated high costs involved, it is conservatively estimated less than 5% of these maps were updated annually meaning most were more than 20 years old (average of 10 years). This situation created a significant problem in supporting overseas military activities with maps of this age. Consequently only the most urgent areas were updated. Recently a new technology called Correlated Land Change (CLC) has been developed by a U.S. company which locates these new features at a few pennies per sq. km. The primary input to CLC is new and archive Landsat images. With CLC, the analyst is targeted only to areas of recent change, where high resolution imagery is then used to identify and extract new features. Using this process, it is conservatively estimated that analysts can update 10 (ten) times the area in the same labor time, a 1,000% efficiency improvement. Agencies are adapting their map updating approach to take advantage of this process. Over 100,000 Landsat scenes going back 14 years and covering 2/3rd of the Earth's land area will be processed this year. Annual consumption of Landsat will be 20,000 scenes per year. It is expected that over time the average age of DoD/IC digital maps will decrease from over 10 years to just 1 year. To accomplish the same feat without Landsat would cost over $1 billion annually; a fiscal improbability in the current economic climate. More likely the average age would stay or increase beyond 10 years. See also:
http://issuu.com/kmi_media_group/docs/gif_10-4_final?mode=window&pageNumber=24

Result: Annual efficiency saving with Landsat: over $100 million

3. Monitoring Consumptive Outdoor Water Usage

In the West and the Nation, water is in short supply, requiring reductions in consumptive uses. Further, water and water rights are increasingly valuable commodities being bought and sold, based on Landsat thermal imagery that is essential for determining past and present water use and evapotranspiration (ET) at scales that reveal patterns of land use and water consumption to inform decision making. Western state water managers and others are increasingly turning to Landsat's thermal infrared sensor (TIRS) imagery to measure and monitor consumptive outdoor water uses. This data is used in hydrologic modeling, water planning, comparing water use when cropland is converted to urban uses, measuring agricultural water use, monitoring aquifer depletion, administering water rights (legal findings of fact, ensuring compliance with administrative orders, court decrees, and interstate compacts, as well as water right buy-back programs), Native American water rights settlements, and riparian endangered and invasive species monitoring.

The Idaho Department of Water Resources (IDWR) and the University of Idaho have partnered to pioneer these uses of TIRS data, which have been recognized with an award from the Harvard Kennedy School of Government. One of those uses is adjudicating, measuring and monitoring consumptive irrigation use by wells on the Snake River Plain Aquifer. IDWR used a power consumption coefficient method to estimate extraction and water use at an annual cost of about $500,000/5,000 wells or $100/well – before beginning to use Landsat TIR data through a process called METRIC (Mapping EvapoTranspiration with high Resolution and Internalized Calibration) to measure actual crop evapotranspiration on a field-by-field base. IDWR annual costs dropped to approximately $53,500/year for the same 5,000 wells or less than $11/well. These two options have also been compared with requiring installation of flow meters on each and every well at a capital cost of hundreds of dollars to over a thousand dollars per well.

Given IDWR's cost experience and extrapolating the cost savings compared to using the Power Consumption Coefficient (PPC) measurement method ($100/well) or installing flow meters ($1,000/well) for monitoring

groundwater use from unmetered irrigation wells in the 17 western waters, the potential cost savings from using METRIC could mean annual cost savings of nearly $20 million annually to measure irrigation from groundwater extraction alone (with 219,013 unmetered irrigation wells). If similar savings could be achieved for measuring irrigation water use on surface water supplied acreage (77.5% of total irrigated acreage in the West), then total potential saving could be closer to $80 million/per year.

These figures represent a conservative estimate using unpublished IDWR cost figures and West-wide unmetered irrigation well numbers, as well as total irrigated acreage estimates from USDA's 2007 Census of Agriculture, 2008 Farm and Ranch Irrigation Survey).

Idaho has also used Landsat thermal imagery in its water rights administration. In 2007, the A & B Irrigation District made a "call" on the Snake River, asking that IDWR curtail more junior uses in order to protect its senior surface water rights and diversions. Using Landsat thermal imagery and METRIC, IDWR evaluated those fields the district claimed were water-short, and found that the crops were not stressed. The findings averted the possible shut off of water to some 1000 farms and approximately 214,000 irrigated acres, with a potential loss of over $314 million in direct farm sales. IDWR's decision was appealed all the way to the Idaho Supreme Court, and was upheld without the METRIC analysis and use of Landsat thermal data ever being challenged.

Similarly, in a 2012 case involving quantification of Wood River Valley water rights, IDWR used the same technology to demonstrate that only 20.2 acres of a 104-acre farm had been continuously irrigated as required *by law to establish a vested right*. IDWR was able to access the Landsat archive and compare land and water uses from 1984 to 2012. In the face of the evidence, the land owner withdrew his challenge seeking more water than his historic use. The value of the additional water claimed was $2,514,000 ($30,000/acre x 83.8 additional acres).
See also: http://www.westernstateswater.org/wp-content/uploads/2014/04/Morse_wswc-landsat-talk-san-diego3.pdf
http://www.agcensus.usda.gov/Publications/2007/Online_Highlights/Farm_and_Ranch_Irrigation_Survey/fris08_1_14.pdf.

Result: Annual efficiency saving with Landsat: potential of $20 - $80 million for groundwater monitoring, as well as avoided loses of hundreds of millions of dollars from surface water management and water rights administration

4. Monitoring Global Security

Landsat data provides the required image quality, spatial resolution, and temporal periodicity needed to support the analysis of macro-scale food and water security issues to aide in NGA's forecasting potential civil unrest and nation-state instability in support of national security issues (or US foreign security interests). The 42-year record of global Landsat observations and sustainable land imaging (SLI) program provides an enduring monitoring capability by establishing a long-term, time-series, baseline that contributes to effective detection of land use and land cover change. Landsat-based change detection not only supports natural resource assessments and disaster relief monitoring, but facilitates anomalous activity discovery that can provide further focusing for the collection of complimentary imagery sources. This capability could potentially serve as a tipping and cueing mechanism that augments collection strategies, potentially saving both time and human resources. Furthermore, Landsat is open source/unclassified data that allows for technical exchange of unclassified expertise via developed methodologies and/or Landsat-derived products to unclassified customers. Additionally, no other sensor has the spatial or consistency of coverage that Landsat provides. The estimated annual cost savings for using Landsat data vs other comparable information sources is roughly $70 million dollars/year.

Result: Annual efficiency saving with Landsat: $70 million

5. Landsat Support for Fire Management

Landsat images are used for developing vegetation and wildland fuel data used in wildland fire management decision support systems. Currently 15 Western States are using a Landsat derived product called LANDFIRE to develop a wildfire risk assessment and planning system. Nine southern states already have a similar system in place fed by LANDFIRE data. Landsat is also commonly used in post-fire burn severity mapping.

Landsat data are also used to perform immediate post fire assessments of soil burn severity and vegetation mortality, usually by Burned Area Emergency Response (BAER) teams. The restoration work performed by BAER teams mitigates effects on hillslope stability, water quality and supply, and the spread of invasive species, as well as other ecosystem services, such as habitat for fish and wildlife. BAER teams use Landsat data as a geospatial foundation for plans that address emergency stabilization where post-wildfire effects pose immediate and significant threats to human life and property. This information helps define the short-term and possibly longer-term management needs of burned areas, such as erosion control, re-vegetation or seeding, and pasture deferment.

Both current and archived Landsat data are used to develop wildland fire atlases across the United States by evaluating differences in pre-fire and post-fire Landsat imagery. A national database of Landsat derived fire information is maintained by the Monitoring Trends in Burn Severity (MTBS) project, a joint DOI and U.S. Forest Service activity. The MTBS database allows a national level evaluation of vegetation management practices used to mitigate hazardous fuels. These evaluations occur in two primary ways. First, wildland fires in treated areas are expected to have relatively lower burn severities. This can be determined for specific fires, over time, from MTBS data. Secondly, the effective duration for a hazardous fuel treatment can be determined by monitoring vegetation vigor indexes as surrogates to fuel condition (biomass accumulation and growth) and comparing this with untreated areas or areas with alternative treatment approaches. The Landsat archive is the only comprehensive and consistent data stream that provides this monitoring potential for the United States.

Landsat imagery is the foundation for the vegetation and fuels information in the LANDFIRE database. LANDFIRE data products are a foundational element used in the Federal Government's Wildland Fire Decision Support System (WFDSS). WFDSS is used to model fire behavior and is used to make tactical decisions during specific wildland fire incidents. LANDFIRE is also critical for the Interagency Fuels Treatment Decision Support System, a web-based software and data integration framework that organizes previously existing and newly developed fire and fuels software applications to make fuels treatment planning and analysis more efficient and effective. See also: http://www.landfire.gov/version_comparison.php

Result: Annual efficiency saving with Landsat: $28-$30 million

6. Forest Fragmentation Detection

The University of Maryland is tracking worldwide forest fragmentation through time for biodiversity applications. Loss of forest has the effect of isolating some species from natural habitats leading to significant biodiversity issues. For this effort, global forests are being mapped at 5 year intervals involving a total of over 50,000 Landsat scenes. Lower resolution satellite imagery is too inaccurate. Higher resolution satellite imagery is orders of magnitude more expensive to acquire and process. Landsat provides the most efficient data for mapping global deforestation. See also: http://glcf.umiacs.umd.edu/library/pdf/rse78_p118.pdf

Result: Annual efficiency saving with Landsat: over $5 million

7. Forest Change Detection

The University of Maryland is developing an annual data set for the US to track forest disturbance (fire, insect, harvest, etc.) through the lower-48 states for each of the last 26 years in an effort called North American Forest Dynamics (NAFD). This effort will ultimately require 25,000+ Landsat scenes. NAFD supports the North American Carbon Program and is funded through NASA Terrestrial Ecology. Landsat is the most cost efficient means to quantify forest changes covering the entire USA. See also: http://www.geog.umd.edu/projectprofile/US%20forest%20disturbance%20history%20from%20Landsat%3A%20North%20American%20Forest%20Dynamics%20(NAFD)%20-%20Phase%20III

Result: Annual efficiency saving with Landsat: over $5 million

8. World Agriculture Supply and Demand Estimates

The USDA Foreign Agriculture Service (FAS) Production Estimates and Crop Assessment Division (PECAD) has used satellite imagery to assess agriculture in foreign countries since 1975 to support the USDA World Agriculture Supply and Demand Estimates (WASDE). The numbers produced by WASDE are critical to decision making by the USDA and US farmers/growers on when and at what price to sell crops for export. With the recent failure of Landsat 5, the effective ground observation increases from 40 to 60 days, an unacceptable level. USDA has estimated it will take $1.5 to $2.5 million per year to purchase foreign data to replace Landsat 5. If Landsat 7 fails, it would take $3 to $5 million per year to purchase replacement satellite imagery. See also: http://www.usda.gov/oce/commodity/wasde/

Result: Annual efficiency saving with Landsat: over $3-$5 million

9. Vineyard Management and Water Conservation

E&J Gallo Winery, the world's largest family-owned winery and the largest exporter of California wine, uses multi-temporal Landsat imagery to closely manage its vineyard irrigation schedules and its water use, and to monitor California vineyard production statewide. “At Gallo, everyone understands the value of Landsat in their operations, from the vineyard manager up to the Vice President level,” states Martin Mendez-Costabel, Gallo’s Manager of GIS and remote sensing.

During the grape growing season, Gallo downloads every available Landsat image captured over California’s agricultural lands. While all Landsat bands are important to Gallo’s efforts, it is the thermal bands that have the greatest value because they can be used to monitor evapotranspiration. “With grapes, we want to impose water stress because there is a strong correlation between water stress and good wine quality,” states Mendez-Costabel. The thermal bands, Landsat’s 8 day revisit time, and the high quality of Landsat image calibration are critical to supporting the fast paced and high precision management decisions made at Gallo.

Because only Landsat imagery provides weekly revisits of region-wide thermal imagery, Gallo would be unable to conduct their detailed water management and conservation efforts without creating a separate company to develop, build and collect airborne thermal imagery – an endeavor estimated to cost at least $3-5 million/year.

Result: Annual efficiency saving with Landsat: of $3-5 million/year

10. Flood Mitigation Mapping

FEMA spends over $200,000,000 annually to update flood maps to mitigate losses from future flood events. Less than 3% of these maps are updated per year. While flood plain contours don’t often change, the impervious surface adjacent to flood plains regularly increases due to new home and business construction. Increased impervious surface increases runoff into the flood plain and will increase the size of the flood zone near these new developments, and possibly put new homes at risk. Having an accurate, consistent, and cost-

effective method to assess impervious surface change going back decades will help DHS/FEMA to target areas of highest potential flood zone change. FEMA has begun using a recently developed process called Correlated Land Change (CLC) to consistently map the lower 48 States for new construction going back over 25 years. FEMA calls the dataset the National Urban Change Indicator (NUCI). NUCI is completely compiled with over 12,000 Landsat images and will consume 1,500 Landsat images each year going into the future. The alternative to NUCI is a much more costly and time-consuming manual interpretation of historical aerial images. It is estimated that manual interpretation would cost in excess of $5,000,000 per year. Not doing the prioritization based upon consistent empirical data could mean lower flood insurance premiums in potentially new flood zone extent. The cost to create NUCI for ½ CONUS is $550,000 annually. See also: http://www.fgdc.gov/participation/coordination-group/meeting-minutes/2011/july/excom-liaison-report-dan-cotter.pdf

Result: Annual efficiency saving with Landsat: over $4.5 million

11. National Agricultural Commodities Mapping

The USDA National Agricultural Statistics Service (NASS) creates a Cropland Data Layer (CDL) for the Contiguous U.S. (CONUS) identifying crop type by farm field. "The purpose of the CDL is to (1) provide acreage estimates to the Agricultural Statistics Board for the state's major commodities and (2) produce digital, crop-specific, categorized geo-referenced output products." Major commodity acreage is used by farmers and manufacturers to better estimate crop yields to help in planting and selling decisions. Landsat is used because of its ability to identify crop type with sufficient accuracy at low-cost. With the demise of Landsat 5, the USDA must acquire supplemental imagery from foreign sources costing an additional $1.2 million in FY12. Should the foreign sources fail, the accuracy of the CDL will plummet with consequences that are difficult to measure. Efficiency savings from Landsat are estimated at $4 million per year. See also: http://calval.cr.usgs.gov/JACIE_files/JACIE11/Presentations/TueAM/1135_Reynolds_JACIE2011.pdf

Result: Annual efficiency saving with Landsat: over $4 million

12. Waterfowl Habitat Mapping and Monitoring

Ducks Unlimited, Inc. (DU), Ducks Unlimited Canada, and Ducks Unlimited de Mexico have been mapping and tracking land cover and land use patterns to identify, monitor and manage waterfowl habitats throughout North America for more than 20 years using Landsat products. DU's Landsat-derived map products cover more than 500 million acres throughout the 48 conterminous states, Alaska, Canada, and Mexico and coincide with the primary breeding and wintering grounds for a large majority of the North American waterfowl population. Their efforts include the first ever nation-wide wetland inventory in Mexico, which allows for long-term tracking of wetland gains and losses. In the U.S. and Canada the map products help guide the placement of protection, restoration, and enhancement of wetlands and associated upland habitats. They provide a basis for conservation planning efforts that result in protection of key habitat areas, and in collaboration on and implementation of improved Best Management Practices for wetlands by the industry and agricultural partners in working landscapes. The activities include partnerships and collaboration with Federal and State agencies, industry and agriculture partners, other NGOs and private landowners to restore and enhance thousands of acres of wetlands annually. DU's current efforts utilizing Landsat imagery include wetland mapping throughout the boreal forest of Canada and Alaska; reforestation modeling based on forest breeding bird habitat requirements in the Mississippi Alluvial Valley; annual mapping of water extent across large landscapes of the southern U.S. and Gulf coast region; mapping of winter-flooded rice agriculture in California's Central Valley, and mapping the availability of flooded habitats during drought conditions in California's Central Valley. DU processes an average of 80 to 90 Landsat scenes annually. The cost to acquire a similar footprint of moderate or high resolution satellite imagery to replace Landsat is estimated to be over $1,900,000 annually. As a non-profit organization, that cost would preclude them from performing the

majority of their currently active Landsat-based work and significantly reduce their ability to monitor and track landscape level trends in waterfowl and wetland habitats throughout North America.

Result: Annual efficiency saving with Landsat: of $1.9 million/year

13. Coastal Change Analysis Program

The National Oceanic and Atmospheric Administration (NOAA) monitors land cover and land cover changes in the coastal regions of the United States, as part of its Coastal Change Analysis Program (C-CAP). This data is provided to coastal managers in order to better understand the effects of past management decisions, document recent trends, and provide a better baseline of current conditions to which they can consider impacts of future planning decisions. This change analysis is often also used as a screening-level tool to provide other, more detailed mapping initiatives and information on where changes to their own products may have occurred and are likely to be in need of updating. C-CAP products are updated every five years.

Landsat is used because of its systematic collection of larger footprint imagery, the larger number of spectral bands it provides, and the historic archive of complimentary data available. This provides NOAA with a consistent, reliable source of image data that can be processed and classified in a consistent, repeatable, cost-effective way. This cannot be said of more commercial sensors that are tasked to acquire some areas and not others. Not only does this reduce the cost in creating C-CAP land cover, it improves the accuracy in several of the classes mapped, such as the improved discrimination of wetland features seen due to the infrared bands Landsat supplies (and that are not available elsewhere).

The 30 meter resolution of this imagery is about the coarsest that mangers tasked with tracking changes in these coastal environments can utilize. NOAA spent $3,200,000 on the original baseline mapping and currently spends approximately $1,300,000 on each update cycle. Production of an equivalent C-CAP product using a smaller footprint sensor with fewer spectral bands are estimated to more than double these existing costs ($4,000,000 over the same 5 year period) or would require that NOAA would decrease the specifications associated with these maps (i.e. coarser resolution, fewer categories, less accuracy), which would potentially impact their availability and/or usefulness. See also:
http://www.cop.noaa.gov/stressors/resourcelanduse/past/lu-ccap.aspx

Result: Annual efficiency saving with Landsat: $1.5 million

14. Forest Health Monitoring

The U.S. Forest Service (USFS) of the U.S. Department of Agriculture (USDA) uses an average of over 500 Landsat scenes per year to evaluate potential risk due to insects and diseases on forest lands in the U.S. Based upon this risk assessment, the USFS can allocate resources to mitigate the overall effect of the insect and disease losses. An alternative to Landsat would be more expensive high resolution imagery costing at least $30,000 or more per Landsat equivalent area. The additional analysis cost of higher resolution images would add over $5,000 per Landsat equivalent area. With an average of over 500 Landsat scenes analyzed per year the increased cost to the U.S. Government without Landsat source data would be conservatively estimated at $1,250,000 annually. See also: http://www.fs.fed.us/rm/analytics/about/history/remotesensingafim.pdf

Result: Annual efficiency saving with Landsat: $1.25 million

15. NGA Global Shoreline

From the NGA website: Prototype Global Shoreline Data (Satellite Derived High Water Line Data). "NGA developed the current version of World Vector Shoreline® through digitization of a variety of hard copy map and chart products. The limited accuracy of these products resulted in a WVS® product at an accuracy of about 250-meters, which in this era of accurate satellite positioning is of limited utility. The Global Shoreline Data set

(satellite derived High Water Line) compiled by NGA has been acquired from orthorectified NASA, 2000 era, LANDSAT GeoCover (multi-spectral imagery). … The result of testing of the SWIR band approach showed that the resulting accuracy of shoreline derived in this manner is about 50-meter (RMS)."[16] The resulting shoreline is the highest resolution continuous global shoreline. To date there is no other satellite which has complete coverage with the Short Wave Infrared detector which is essential to mapping the distinction between water and land sufficient to identify the high water line at low tide. To produce a similarly accurate continuous shoreline from other sources has been estimated to cost in excess of $100 million. The production cost was less than $10 million. Compared to all the nautical charts, the NGA Global Shoreline is the most authoritative map for more than 50% of the world's shoreline. See also:
http://msi.nga.mil/NGAPortal/DNC.portal?_nfpb=true&_pageLabel=dnc_portal_page_72
http://wiki.openstreetmap.org/wiki/PGS_whitepaper

Result: Efficiency saving with Landsat: over $90 million (one time)

16. Wildfire Risk Assessment

Verisk Analytics, working in association with the insurance industry, developed and deployed a wildfire risk assessment solution, FireLine™, used for underwriting tens of millions of homes and businesses in 10 Western states (CA, NV, NM, AZ, UT, CO, ID, OR, WA and TX). The product scores individual addresses based on timely evaluation of factors underlying wildfire risk: vegetative fuels, topographical features, long-term weather patterns, and road networks in a geospatial framework. Landsat data are a key data source used in the assessment of fuels on a regular basis, typically every 1 to 2 years. The process uses Landsat scenes covering 10 states to update fuel assessments based on evaluation of areas of change, e.g. new developments in the wildland urban interface/intermix, changes due to past wildfires, and vegetation re-growth. FireLine has helped insurers in both the proper selection of risks and appropriately pricing, which in turn ensures that consumers pay a fair price consistent with the wildfire exposure of their respective properties. Over the past decade wildfires have caused over $5 billion in losses to the insurance industry. For instance, in California alone, which is considered the prime market for wildfire insurance, FireLine has identified some 2 million properties to be at high to extreme wildfire risk. Analysis has shown that in California over 90% of wildfire losses have been historically associated with properties at high or extreme risk. It is estimated that conservatively the economic value of FireLine is $50-100 million, and the Landsat contribution to this value is about 25% - $25-50 million. See also: http://verisk.com/underwriting/property/wildfire-risk.html

Result: Landsat value of $25-50 million (one time).

3. Conclusion

These sixteen Landsat applications alone produce savings of $350 million to over $436 million per year for Federal and State governments, NGOs, and the private sector. It can be expected that these savings, and others not addressed here, will continue to accelerate.

[1] This paper was approved by the NGAC Landsat Advisory Group on October 6, 2014 and will be considered for final approval by the NGAC as a whole in December 2014. The members of the Landsat Advisory Group are: Kass Green, Kass Green & Associates (Co-Chair); Roger Mitchell, MDA Information Systems, Inc. (LAG Co-Chair, NGAC Member); Peter Becker, Esri; John Copple, Sanborn Mapping Company; Joanne Gabrynowicz, University of Mississippi (NGAC Member); Jack Hild, Digital Globe (NGAC Member); Rebecca Moore, Google; Michele Motsko, U.S. National Geospatial-Intelligence Agency (NGAC Member); Tony Spicci, State of Missouri (NGAC Member); Cory Springer, Ball Aerospace & Technologies Corp.; Julie Sweetkind-Singer, Stanford University

(NGAC Member); Darrel Williams, Global Science & Technology, Inc.; Tony Willardson, Western States Water Council.

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