Users, Uses, and Value of Landsat Imagery in the United States

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Survey Study Objectives

To better understand the uses, users, and value of moderate resolution imagery

- Identify and classify users
- Understand how and why imagery is being used
- Evaluate effects of “no cost” data policy
- Qualitatively and quantitatively measure societal benefits and value of this imagery
Challenges

• How do you study an unknown population or resource?
  – Wildlife—observation, mark/recapture, quad counts
  – Geography—surveying, mapping, modeling
  – People—census, birth records, vehicle registrations

Edrengiyn Nuruu, Mongolia
(http://eros.usgs.gov/imagegallery/index.php)
Study Components

- Phase I: User Assessment
  - ID potential users via online search
  - Refine through snowball sampling
  - Summer 2008

- Phase II: Online User Survey
  - Fall 2009
## Response Rates

### User Assessment

<table>
<thead>
<tr>
<th>Valid Emails</th>
<th># Agreeing to Participate</th>
<th>Users of MRI</th>
<th>Not Users</th>
<th>Don’t Know</th>
</tr>
</thead>
<tbody>
<tr>
<td>~22,000</td>
<td>4,753</td>
<td>~80%</td>
<td>~16%</td>
<td>~4%</td>
</tr>
</tbody>
</table>

### Survey

<table>
<thead>
<tr>
<th>Total Sent</th>
<th># Responded</th>
<th>Undeliverables</th>
<th>Response Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>4,753</td>
<td>2,523</td>
<td>19</td>
<td>53%</td>
</tr>
</tbody>
</table>
Overview of Results

- Emphasis on Landsat users
- Descriptives & comparisons
  - User profile
  - Uses
- Effects of Landsat imagery becoming available at no cost
- Value of Landsat imagery

Richat Structure, Maur Adrar Desert, Mauritania
(http://eros.usgs.gov/imagegallery/index.php)
Who Did We Sample?

Respondents

- MRI users
  - Past MRI users
  - Present MRI users

- Do not use sat imagery

- Other imagery users
  - High-res users
  - Low-res users

- Do not use sat imagery

- Past Landsat users

Current Landsat users

Path 1

Path 2

Path 3

Path 4
The Sample

Percent of respondents

Type of user

- Current Landsat user
- Current other MRI user
- Past MRI user
- High/low user
- Not a user
- Don’t know
- Past Landsat user
User Profile

- Education
- Gender
- Age
- Ethnicity
- Race
- Membership in professional organizations
- Sector

Farms, Komsomelets, Northern Kazakhstan
(http://eros.usgs.gov/imagegallery/index.php)
## Demographics

<table>
<thead>
<tr>
<th>Demographic</th>
<th>Current Landsat users</th>
</tr>
</thead>
<tbody>
<tr>
<td>Predominant sector</td>
<td>Academic institution</td>
</tr>
<tr>
<td>Median level of education</td>
<td>Masters degree</td>
</tr>
<tr>
<td>Member of RS/GIS org</td>
<td>51%</td>
</tr>
<tr>
<td>Gender</td>
<td>76% Male</td>
</tr>
<tr>
<td>Mean age</td>
<td>47</td>
</tr>
<tr>
<td>Ethnicity</td>
<td>3% Hispanic or Latino</td>
</tr>
<tr>
<td>Race</td>
<td>91% White/Caucasian</td>
</tr>
</tbody>
</table>
## MRI Used in Past Year

<table>
<thead>
<tr>
<th>Imagery</th>
<th>Current Landsat user</th>
<th>Academic institution</th>
<th>Federal gov</th>
<th>State gov</th>
<th>Local gov</th>
<th>Private business</th>
<th>Non-profit org</th>
<th>Other MRI user</th>
</tr>
</thead>
<tbody>
<tr>
<td>Landsat</td>
<td>54%</td>
<td>65%</td>
<td>57%</td>
<td>49%</td>
<td>31%</td>
<td>48%</td>
<td>57%</td>
<td>NA</td>
</tr>
<tr>
<td>Terra</td>
<td>11%</td>
<td>15%</td>
<td>12%</td>
<td>7%</td>
<td>5%</td>
<td>10%</td>
<td>11%</td>
<td>10%</td>
</tr>
<tr>
<td>SPOT</td>
<td>8%</td>
<td>7%</td>
<td>8%</td>
<td>9%</td>
<td>8%</td>
<td>7%</td>
<td>9%</td>
<td>7%</td>
</tr>
<tr>
<td>Resourcesat</td>
<td>3%</td>
<td>2%</td>
<td>7%</td>
<td>2%</td>
<td>2%</td>
<td>3%</td>
<td>4%</td>
<td>2%</td>
</tr>
<tr>
<td>ALOS</td>
<td>1%</td>
<td>&lt;1%</td>
<td>1%</td>
<td>1%</td>
<td>&lt;1%</td>
<td>2%</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>CBERS</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
<td>1%</td>
<td>&lt;1%</td>
<td>&lt;1%</td>
<td>1%</td>
<td>1%</td>
<td>&lt;1%</td>
</tr>
<tr>
<td>Other</td>
<td>6%</td>
<td>5%</td>
<td>6%</td>
<td>5%</td>
<td>10%</td>
<td>8%</td>
<td>3%</td>
<td>26%</td>
</tr>
<tr>
<td>Unknown</td>
<td>16%</td>
<td>5%</td>
<td>8%</td>
<td>26%</td>
<td>43%</td>
<td>21%</td>
<td>13%</td>
<td>53%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
<td><strong>100%</strong></td>
</tr>
</tbody>
</table>
Uses of Landsat Imagery

• Scales
• Locations
• Applications
  – Primary
  – Secondary
• % work using Landsat
• How using MRI?

Von Karman Vortices
(http://eros.usgs.gov/imagegallery/index.php/)
Scales of Projects

Percent of respondents

0% 10% 20% 30% 40% 50% 60% 70% 80% 90% 100%

Local State/Province Regional National Continental Global

All sectors Academic Federal gov State gov Local gov Private Non-profit org

Percent of respondents
Land Use/Land Cover: Secondary Applications

Percent of respondents

- Ecosystems
- Water resources
- Urbanization
- Education: univ/college
- Forestry
- Biodiversity conservation
- Climate science/change
- Urban plan & dvpnt
- Rural plan & dvpnt
- Agriculture

USGS science for a changing world
Which describes your work with moderate-resolution imagery?

- Use imagery to answer questions
- Process imagery
- Make decisions based on imagery
- Develop algorithms
- Provide or sell imagery
- Develop commercial software

Percent of respondents by sector:
- All sectors
- Academic
- Federal gov
- State gov
- Local gov
- Private
- Non-profit org
Level of Landsat Use in Work

Percent of respondents

- 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%

All sectors
Academic
Federal gov
State gov
Local gov
Private
Non-profit org
“Local Users”

- Working in local or state gov applying imagery in projects at local scales in the U.S.
  - More likely to be applying imagery in planning & development and transportation
  - Less likely to process imagery, provide/sell imagery, or develop algorithms
  - More likely to be a light Landsat user

Parana River Delta, Argentina
(http://eros.usgs.gov/imagegallery/index.php/)
Changes in Landsat Use

• Current Landsat users
  – Past 10 years
  – Next 5 years

• Non-Landsat users
  – Likelihood of use in the future

Ganges River Delta
(http://eros.usgs.gov/imagegallery/index.php/)
Changes in Landsat Use Over Time

- Increase use
- Use stays the same
- Decrease use
- Cannot characterize use

Past 10 years
Next 5 years
“Increase is dependent on the assumption of availability of a new Landsat sensor”
Reasons for Increasing Use in Past 10 Years

- Work required more imagery
- More affordable imagery

Percent of respondents

- 0%
- 10%
- 20%
- 30%
- 40%
- 50%
- 60%
- 70%
- 80%
- 90%

All sectors
Academic
Federal gov
State gov
Local gov
Private
Non-profit org

USGS: Science for a Changing World
Reasons for Decreasing Use

Percent of respondents

- Spatial resolution
- Other imagery attractive
- Work required less imagery
- SLC-off impacted usability
- Landsat not available
- Data quality
- Temporal resolution
- Spectral bands
- Availability
- Accessibility
- Cost
- Licensing/dist restrictions
- Other

Past 10 years
Next 5 years

USGS science for a changing world
Responses to SLC-Off

- Replaced L7 imagery with L5 imagery
- Replaced L7 imagery with other MRI
- Use gap-filled L7 imagery
- Still use some SLC-off L7 imagery
- Replaced L7 imagery with other kinds of data
Effects of “No Cost” Imagery

• Before and after
  – Where users acquire imagery
  – Number of scenes
  – $ dollars spent (or saved)
Sources of Landsat Acquisitions

*Other sources include universities, federal government agencies (besides USGS), state governments, commercial entities, and international entities. This category also includes respondents who did not obtain any imagery during that year.
2009 Sources of Landsat Acquisitions

Percent of respondents

All sectors
Academic
Federal gov
State gov
Local gov
Non-profit org
Private

Percent of respondents

USGS EROS
Internet in general
Global Land Cover Facility
Landsat.org
AmericaView
Int coops/grnd sts
Other
Don't know

[Graph showing the sources of Landsat acquisitions with various sectors represented by different colors and bars showing the percent of respondents for each source.]
### Changes in Landsat Acquisitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>2008 Means</th>
<th>2009 Means</th>
<th>F</th>
<th>p</th>
<th>eta²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of scenes acquired</td>
<td>91</td>
<td>168</td>
<td>290.16</td>
<td>&lt;.001</td>
<td>.992</td>
</tr>
<tr>
<td>Percent of scenes acquired from EROS</td>
<td>42%</td>
<td>46%</td>
<td>25.18</td>
<td>&lt;.001</td>
<td>.459</td>
</tr>
<tr>
<td>Dollars spent on imagery</td>
<td>$5,117</td>
<td>$1,040</td>
<td>128.37</td>
<td>&lt;.001</td>
<td>.913</td>
</tr>
<tr>
<td>Percent dollars spent on imagery from EROS</td>
<td>31%</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
</tbody>
</table>

“Making the archive freely available is by far the best decision made regarding remote sensing in this country in the 10 yrs I've been working in the field.”

“States are currently extremely cost constrained. This has affected use of all types of data and the ability of states to purchase imagery. The new availability policy for LANDSAT could not have come at a better time.”
Value of Landsat Imagery

- Importance/satisfaction
- Environmental and societal benefits
- Impacts on work and costs/revenues if no longer available
- Willingness to pay for replacement imagery
Value of Landsat Imagery: Importance/Satisfaction

- Importance of MRI products
- Importance of Landsat to work
- Importance of MRI attributes
- Satisfaction with Landsat attributes

Alluvial fan, Xinjiang Province, China (http://eros.usgs.gov/imagegallery/index.php)
Importance of MRI Products

- Derived product
- Basic processed product adjusted for surface reflectance
- Basic processed product
- Raw unprocessed imagery

- Very unimportant
- Somewhat unimportant
- Neither important nor unimportant
- Somewhat important
- Very important
Overall Importance of Landsat

Percent of respondents

0% 10% 20% 30% 40% 50% 60%

All sectors
Academic
Federal gov
State gov
Local gov
Private
Non-profit org

Percent of respondents

Very unimportant Somewhat unimportant Neither important nor unimportant Somewhat important Very important

USGS
Landsat User Importance/Satisfaction

- Accessibility
- Area/footprint of individual scene
- Cost
- Delivery time
- Global coverage
- Spatial resolution
- Temporal resolution/frequency of coverage

- Archive/continuity
- Availability
- Data quality assessments
- Ease of use
- Licensing/distribution restrictions
- Spectral resolution

Importance

- Very Important
- 5
- 4
- 3
- 2
- 1

Satisfaction

- Very Dissatisfied
- 5
- 4
- 3
- 2
- 1

“Concentrate Here”

“Low Priority”

“Too Much Effort Here”

“Keep Up the Good Work”
Value of Landsat Imagery: Qualitative Responses

• Open-ended questions:
  – Landsat effect on decision-making
  – Environmental and/or societal benefits of Landsat
  – Why Landsat?
  – New and unique uses in the next 5 years
Value of Landsat Imagery: Qualitative Responses

• Effects on decision-making
  – Establishing policy (349)
  – Planning and management (222)
  – Modeling (128)

“We have been able to come up with evidence to change small town policy and challenge politics. Good science is hard to beat.”

• Why Landsat?
  – Accessibility (486)
  – Cost (429)
  – Archive (228)

“They are free now!”

• Environmental and/or societal benefits
  – Assessing impacts and change over time (216)
  – Habitat/Land conservation (130)
  – Improving the environment/Reducing impacts (123)

“The issuance of water rights are commonly dependent upon Landsat evaluations. These water rights provide economic value to the community at large.”

• New and unique uses in the next 5 years
  – Time series analyses (181)
  – Integration with other programs (108)
  – Climate change monitoring/Awareness (106)

“...mostly will come from the power of comparing the long catalog with new observations, especially associated with urbanization and global warming induced changes.”
Value of Landsat Imagery: Impacts to Work If No Longer Available

• Impacts to work
  – Substitute other information or imagery
    • field work
    • other data sets (not imagery)
    • other imagery
  – Discontinue some or all of work
  – Continue work “status quo”

Dasht-e Kevir desert, Iran
(http://eros.usgs.gov/imagegallery/index.php)
If Landsat Was No Longer Available…

<table>
<thead>
<tr>
<th>At least 1% of work would be...</th>
<th>Yes</th>
<th>No</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>...substituted with other imagery or info</td>
<td>76%</td>
<td>4%</td>
<td>20%</td>
</tr>
<tr>
<td>...discontinued</td>
<td>51%</td>
<td>28%</td>
<td>21%</td>
</tr>
<tr>
<td>...continued without substituting other imagery or info</td>
<td>46%</td>
<td>30%</td>
<td>24%</td>
</tr>
</tbody>
</table>
## Substituting Imagery and Information

<table>
<thead>
<tr>
<th>Users who would substitute (76%) would use...</th>
<th>Yes</th>
<th>No</th>
<th>Don’t know</th>
</tr>
</thead>
<tbody>
<tr>
<td>...other imagery</td>
<td>89%</td>
<td>1%</td>
<td>10%</td>
</tr>
<tr>
<td>...other data sets</td>
<td>69%</td>
<td>15%</td>
<td>16%</td>
</tr>
<tr>
<td>...fieldwork</td>
<td>63%</td>
<td>25%</td>
<td>12%</td>
</tr>
</tbody>
</table>
Substitute Imagery

- Preferred imagery (no budget constraints) vs. imagery most likely to acquire (within budget constraints)
  - 55% would choose same imagery regardless of budget constraints
    - Terra, SPOT, and Resourcesat
  - 40% would choose different imagery
Substitute Imagery

Percent of respondents

- SPOT
- Terra
- Resourcesat
- High res
- ALOS
- Other MRI
- CBERS
- Other
- Don't know
- Low res
- Free/cheapest
- None

Preferred imagery

Imagery most likely to acquire
Value of Landsat Imagery: Impacts on Costs

- Increases in costs
- Changes in revenue/funding

Lena River Delta, Russia
(http://eros.usgs.gov/imagegallery/index.php)
Value of Landsat Imagery: Impacts on Costs if No Longer Available
Impact on Costs/Revenues

• Costs
  – Half of Landsat users believed their costs would increase at least 1%
  – 41% didn’t know how much their costs would increase
  – Average total percent increase in costs was 30%

• Revenues/funding
  – 20% believed revenue/funding would decrease
  – 33% believed there would be no impact
  – 43% didn’t know what would happen to their revenues/funding
Value of Landsat Imagery: Willingness to Pay for Replacement

Economic benefits are measured by how much the user would pay over and above their existing costs.

Contingent Valuation Method (CVM) - uses a simulated or hypothetical market to measure what users would pay for nonmarket goods

- Realistic scenario - increase in taxes or costs
- Established method
- Thousands of applications

This net willingness to pay is the standard measure of benefits in benefit cost analysis.
WTP Question

“If Landsat 5 and 7 became inoperable before the next Landsat satellite is operational (scheduled to launch in 2012), you may have to obtain imagery elsewhere during the interim. Assume that you are restricted to your current project or agency budget level and that the money to pay this cost would have to come out of your existing budget. If such a break in continuity did occur and you had to pay for imagery that was equivalent to the Landsat standard product now available, would you pay $___ for one scene covering the area equivalent to a Landsat scene?”

Choose one:  YES  NO

- The blank was filled in with 1 of 21 different dollar amounts that ranged from $5 to $5,000.

Double bounded WTP - If the cost was $(half/twice original), would you pay this amount for one scene covering the area equivalent to a Landsat scene?
  - $ amounts ranged from $2.50 to $10,000

Asked about level of certainty of WTP
Performance of the Double Bounded Dichotomous Choice CVM

• In concept, the DB is intuitively appealing as statistical theory & past studies have shown that asking the 2nd follow-up WTP Question does reduce the variance of WTP estimates & gives more precision.

• But like other studies found, we too found the respondent behavioral response to the 2nd bid amount is somewhat different than the response to the first bid amount
  – For example, respondent #2329 said NO to the bid amount of $150 and ranked their certainty as 40% and then said NO to the bid amount of $75 and ranked their certainty as 60%
Performance of the Double Bounded Dichotomous Choice CVM

• **In practice**, respondents don’t like the follow up question – they do not like that the bid amount changes.
  – The information they are giving us in answering the second question is not as good as the information in answering the first question.
    • Strategic behavior
    • Noncooperative
    • Changed preferences

• In both cases, the higher the $ amt asked to pay, the Prob of Yes goes down, but at *somewhat* different rates in response to the first and second bid.
Single Bounded WTP Results

- The graph illustrates the per-scene willingness-to-pay amounts in relation to the percent of "yes" answers.
- The x-axis represents the percent of "yes" answers ranging from 0% to 100%.
- The y-axis represents the per-scene willingness-to-pay amounts ranging from $0 to $5,000.
- The data points are shown as dots, with a downward trend indicating a decrease in willingness-to-pay as the percent of "yes" answers increases.
Single Bounded WTP Results

![Graph showing the relationship between Percent of "Yes" Answers and Per Scene Willingness-to-Pay Amounts. The graph plots increasing willingness to pay as the percentage of "Yes" answers decreases.](image-url)
Single Bounded WTP Results

Median - $218/scene
Mean - $760/scene
SB & DB Results

• DB improves efficiency but has problems with the second question.
  – has value but not as much as first question.

• Reasonable sector results are not present in the DB results.
  – sector variables were very insignificant. The standard errors on those variables were larger than the parameter estimates so t-statistics were less than one and the variables can reasonably be removed from the model.
Why we relied upon the Single Bounded rather than Double Bounded Dichotomous Choice CVM

- We did not expect this difference in behavior with Landsat users, as the respondents are experienced Landsat data users and know the good being valued.

- We hypothesize that the difference in respondent behavior may be related to the large increases & decreases in the second $ bid amount.

- Given our results, at this time we believe the std binary dichotomous choice CVM results are statistically the best in terms of statistical significance of independent variables and goodness of fit (percent correct predictions is about 70%).
Median & Mean WTP by Sector

Average across all groups - Median $256  Mean $751
Lessons learned for Improving the Double Bounded in Future Surveys

To attempt to obtain the added statistical precision with the DB without the “behavioral shift” between 1st & 2nd bid amount we plan to:

- Reduce the magnitude of the 2nd bid
  - step up from 2X used in the past literature to 1.25X
  - step down from one-half X to 0.75X

- Increase the number of initial high bid amounts since these high bid amounts are essential to accurate & precise estimates of mean WTP (which involves integration across the entire demand function).

- Try using other statistical modeling techniques such as ordered logit models which would allow for one category for each of 4 responses (YY, YN, NY, NN).
Next Steps

• This Survey (Summer/Fall)
  – Project report
  – Web visual representation
  – Journal articles
    • Remote Sensing and the Environment
    • PERS/ASPRS Highlight

• Building On (2011/2012)
  – Survey EROS customers
  – 1-2 Case Studies
    • Landfire, NLCD, Google, NGA, Foreign Ag Service, Carbon Monitoring

• Future
  – Other Case Studies
  – International users
  – Repeat of initial survey post LDCM-launch
Acknowledgments

- Tom Loveland
- Eric Wood
- John Dwyer

EROS Data Center

Volga River Delta
(http://eros.usgs.gov/imagegallery/index.php)