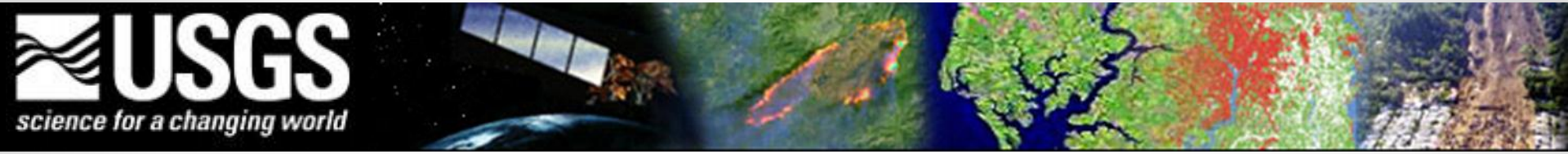

Users, Uses, and Value of Landsat Imagery: 2012 User Survey and 2013 Case Studies

Holly Miller, Larisa Serbina, and Leslie Richardson
Policy Analysis and Science Assistance Branch (PASA)
Fort Collins Science Center
U.S. Geological Survey

Stephen Koontz and John Loomis
Department of Agricultural and Resource Economics
Colorado State University

Landsat Science Team Meeting
July 22, 2014
Corvallis, OR

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Projects

- Online surveys of Landsat users
  - 2009 (~1,400 current Landsat users)
  - 2012 (~11,000 current Landsat users)
  - 2014 (~11,000 current Landsat users)
- Case studies to determine value of Landsat in specific application areas
  - 2013 (water resources)
  - 2014 (agriculture)

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2012 Landsat User Survey

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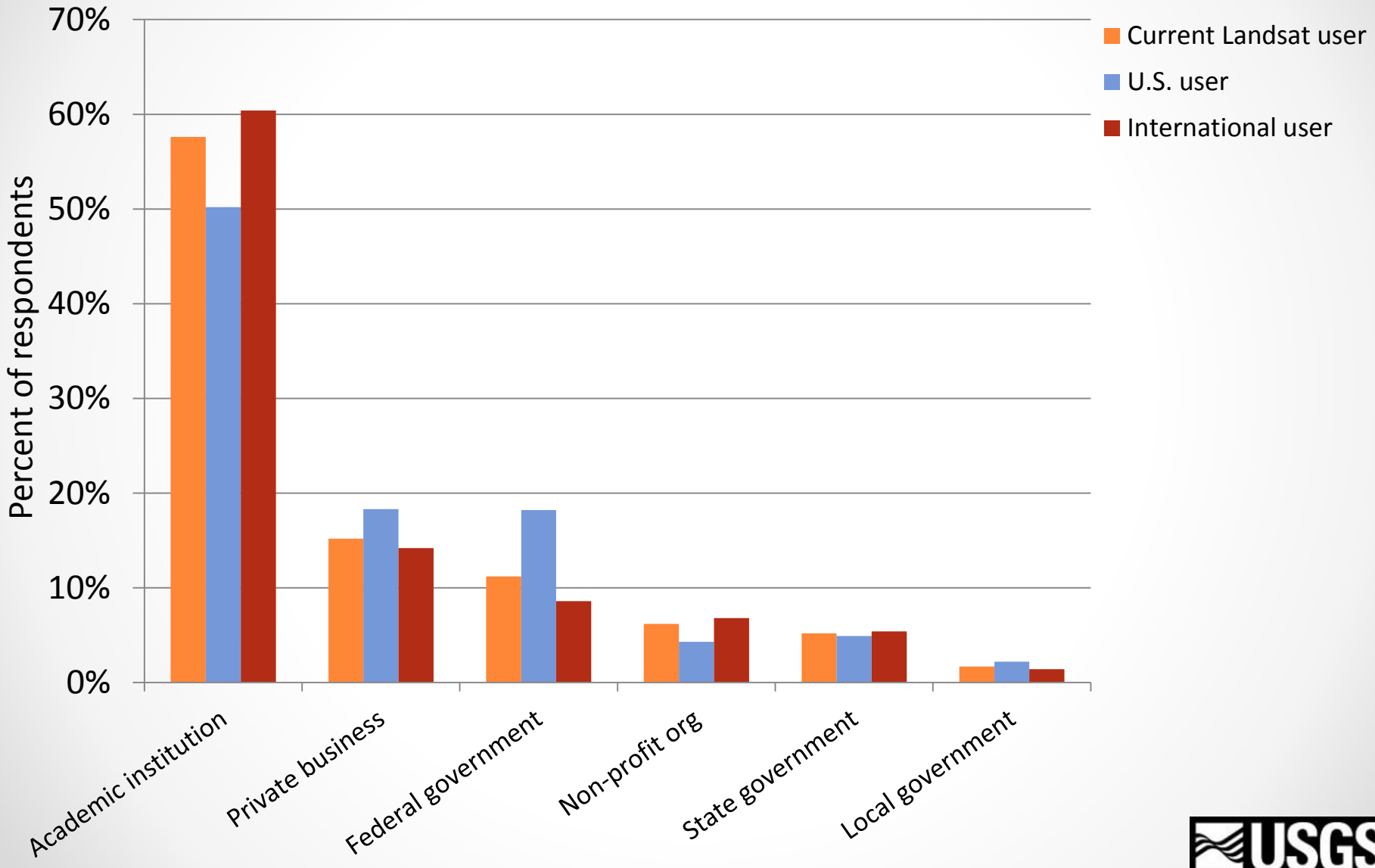
2012 Response Rate

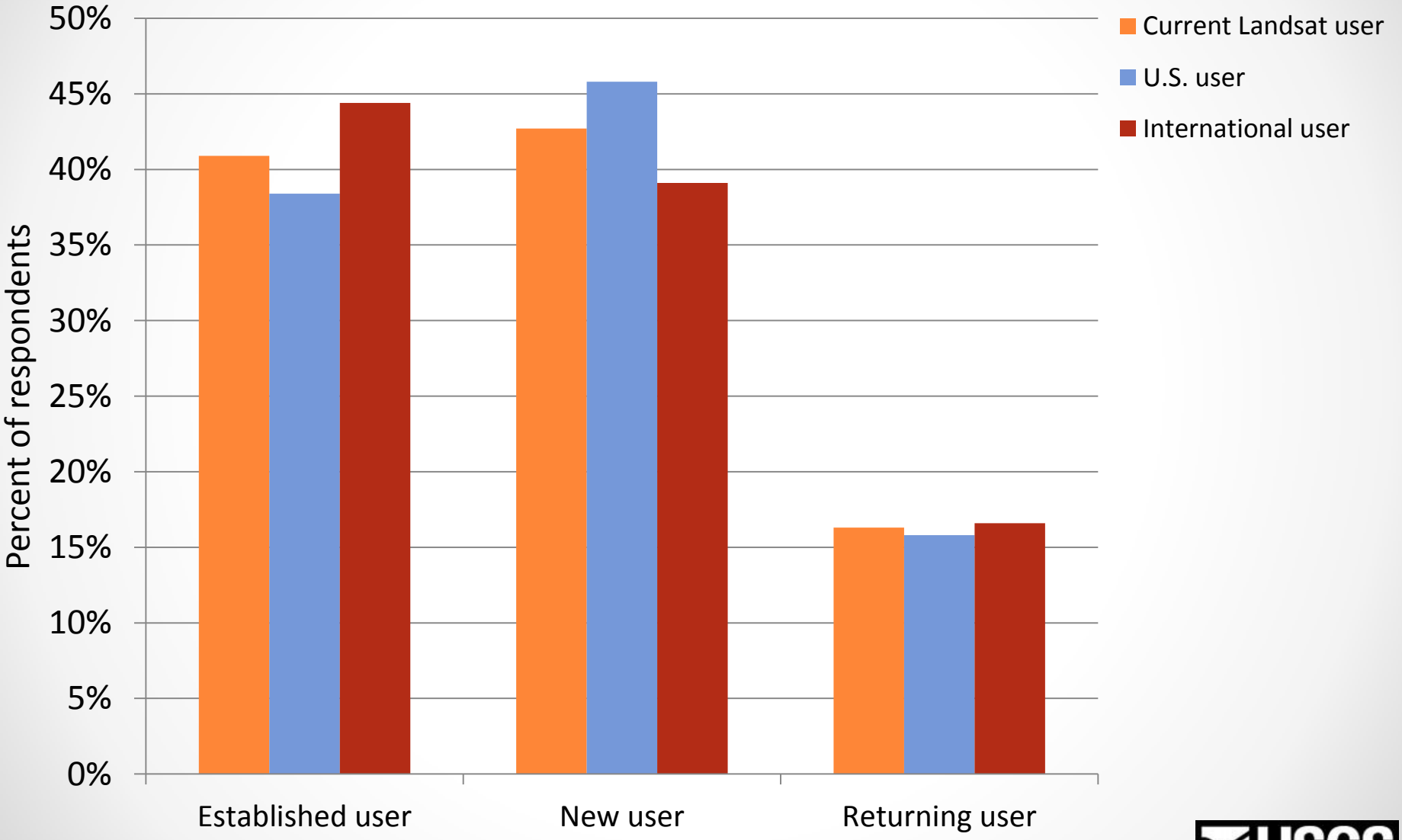
Total Sent	# Responded	Undeliverables	Response Rate
44,731	13,473	87	30%

- 11,275 respondents were current Landsat users (used Landsat imagery in the year prior to the survey)
- 27% were U.S. users and 73% were international users

Sector


70%
60%
50%
40%
30%
20%
10%
0%
Percent of respondents
Current Landsat user
U.S. user
International user
Academic institution
Private business
Federal government
Non-profit org
State government
Local government

New, Established, or Returning User



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Satellite Imagery Used in Past Year

Imagery	Current Landsat users	U.S. users	International users
Landsat	64%	69%	62%
MODIS	8%	8%	8%
ASTER	6%	5%	6%
SPOT	4%	2%	5%
Quickbird	3%	3%	3%
IKONOS	2%	2%	2%
GeoEye-1	2%	2%	2%
WorldView-2	2%	2%	2%
ALOS	2%	1%	2%
Other*	7%	6%	4%
Total	100%	100%	100%

*Contains 1% or less from each of the following: AVHRR, CBERS, Envisat, EO-1, Formosat 2, RapidEye, Resourcesat-1/IRS, and other imagery.

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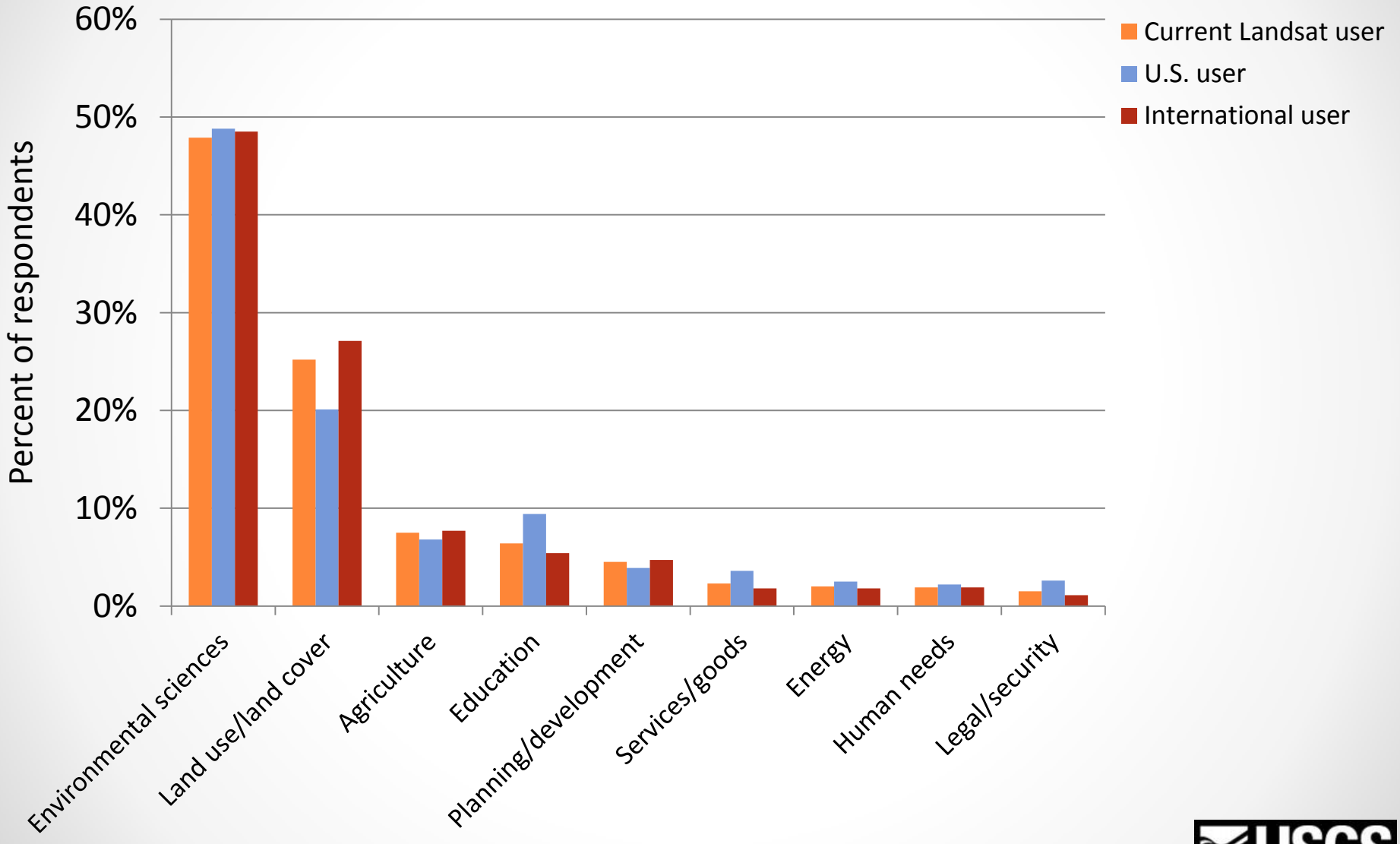
Use of Landsat in Work

- On average, current users used Landsat imagery in 46% of their total work
  - U.S. users used it in 38% of their work
  - International users used it in 49% of their work

Of work that used Landsat…	Current Landsat users	U.S. users	International users
Percent operational work	35%	30%	35%
Percent nonoperational work	65%	70%	65%
Total	100%	100%	100%

Primary Applications



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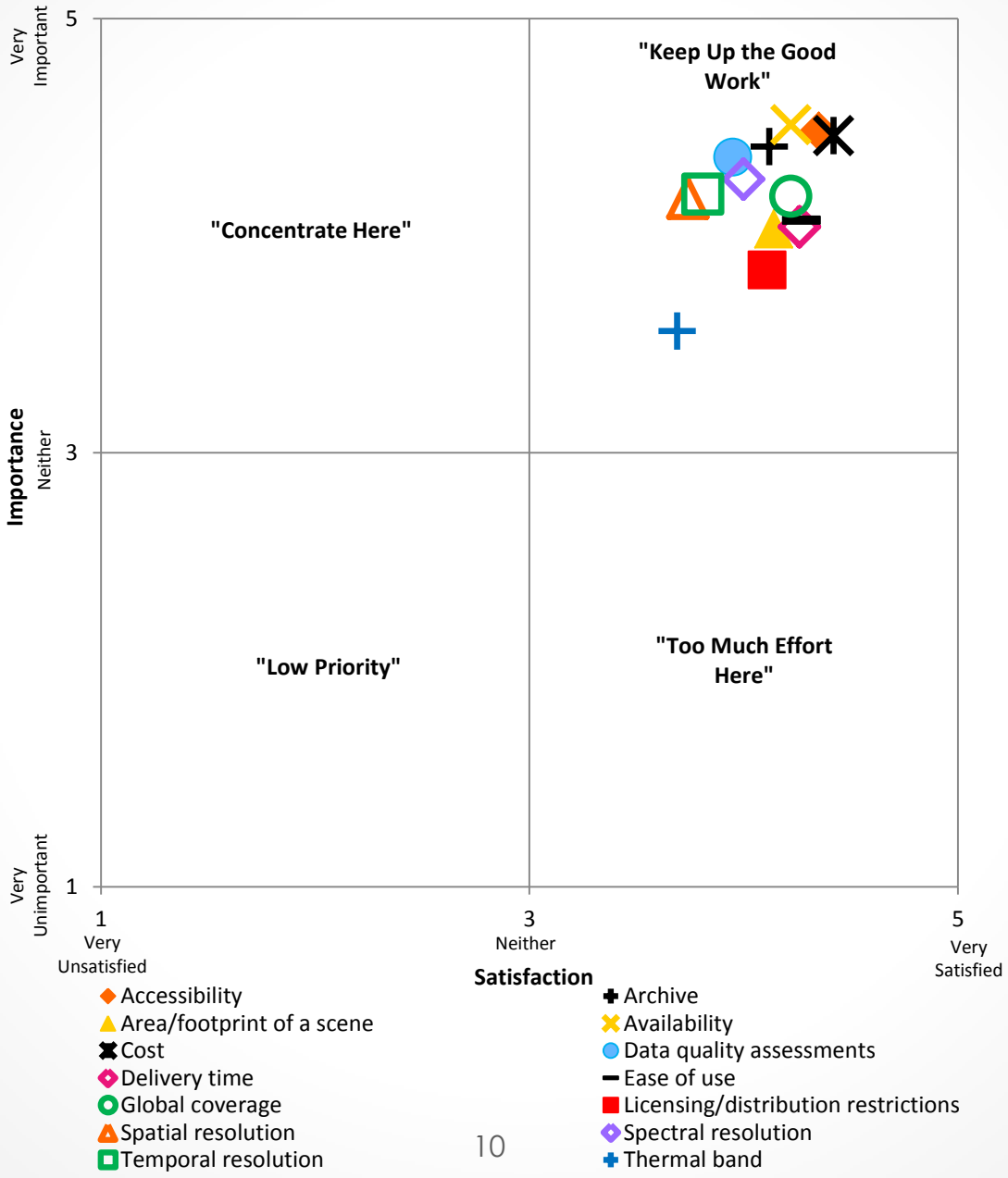
Importance of and Satisfaction with Landsat Attributes



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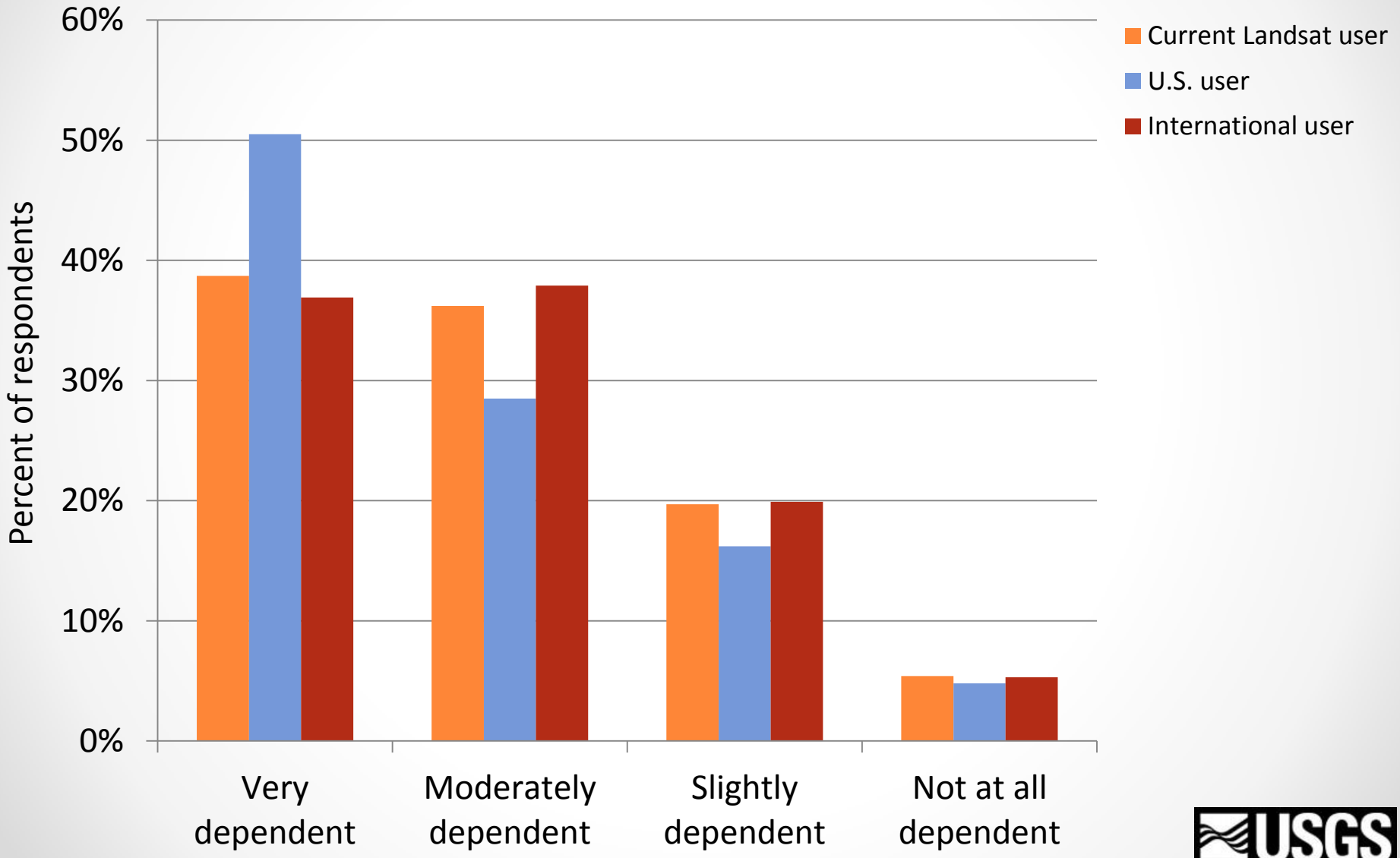
Dependence on Landsat



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If Landsat Was Not Available…

Action taken if Landsat was not available	Current Landsat users	U.S. users	International users
Average percentage of work that uses Landsat that would…			
…be discontinued	49%	55%	48%
…use substitute information	57%	59%	56%
…be continued without substitute information	40%	41%	40%
Average percentage of work using substitute information that would use…			
…different imagery	71%	77%	69%
…other data sets	32%	33%	32%
…on-the-ground fieldwork	29%	28%	29%

Economic Benefits from Landsat Imagery

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Economic Value of Landsat Imagery

- Economic benefit (consumer surplus) is 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 a nonmarket good

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

- This net willingness to pay (WTP) is the standard measure of economic *benefits* in benefit cost analysis

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The CVM Question

"At the moment, current Landsat 5 imagery is not available (expected to be available again in spring of 2012) and you may have already obtained imagery elsewhere to replace Landsat 5. If both Landsat 5 and 7 became permanently inoperable before the next Landsat satellite is operational (scheduled to launch in early 2013), you may have to obtain imagery elsewhere again. 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 typically available (which assumes both Landsat 5 and 7 imagery are available), would you pay $X for one scene covering the area equivalent to a Landsat scene?"

Choose one: YES NO

- The blank was filled in with 1 of 20 different dollar amounts that ranged from $10 to $10,000.

Double bounded follow-up question - If the cost was $(0.75x/1.25x the *original)*, would you pay this amount for one scene covering the area equivalent to a Landsat scene?

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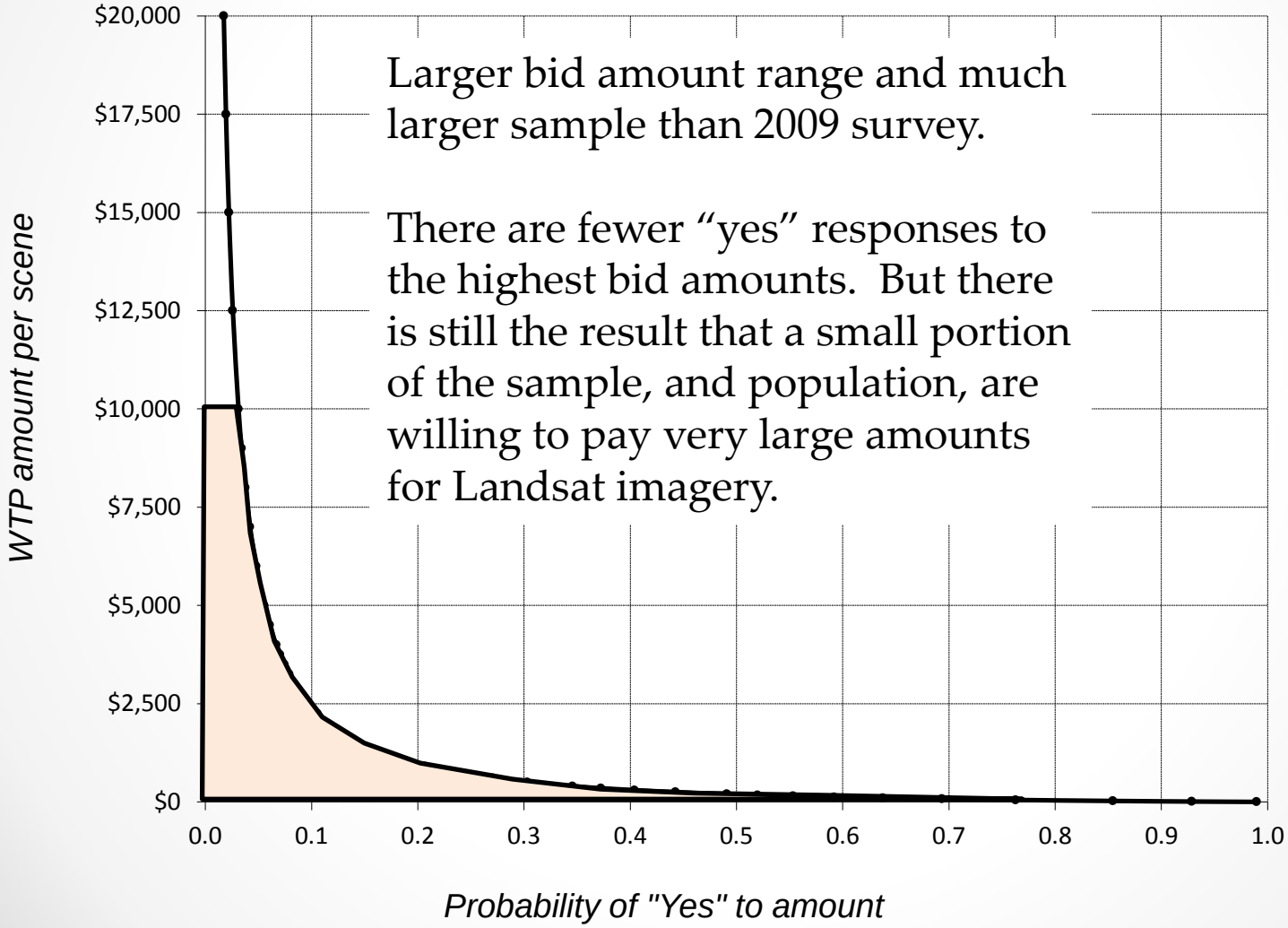
2012 User Value Results



Larger bid amount range and much larger sample than 2009 survey.

There are fewer "yes" responses to the highest bid amounts. But there is still the result that a small portion of the sample, and population, are willing to pay very large amounts for Landsat imagery.

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2012 User Value Results

	Sample		User Values Per Scene			
	Number	Percent	Average	CI Lower	Median	CI Upper
U.S. Domestic Users	1,914	28.9%				
Established Users	732	11.1%	$912	$157	$182	$207
New & Returning Users	1,182	17.9%	$367	$42	$49	$55
International Users	4,705	71.1%				
Established Users	2,138	32.3%	$930	$146	$171	$205
New & Returning Users	2,567	38.8%	$463	$54	$59	$64

The double-bounded models performed very well under the new bid design – relative to the traditional bid design – and relative to the very commonly used and published single-bounded approach.

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Annual Aggregate Economic Value

	Number of scenes obtained in 2011 from EROS	Average economic benefit per scene	Annual economic benefit (millions)	Lower bound (millions)
U.S. Domestic Users				
Established Users	1,687,600	$912	$1,539	$1,399
New & Returning Users	692,508	$367	$254	$236
U.S. total	***2,380,108***		***$1,793***	***$1,635***
International Users				
Established Users	377,749	$930	$351	$318
New & Returning Users	160,969	$463	$101	$68
International Total	***538,718***		***$399***	***$386***
TOTAL	**2,918,826**		**$2,192**	**$2,021**

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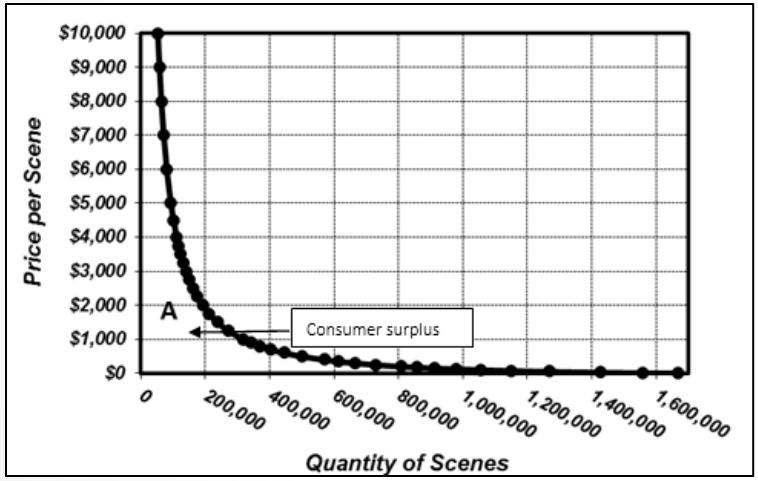
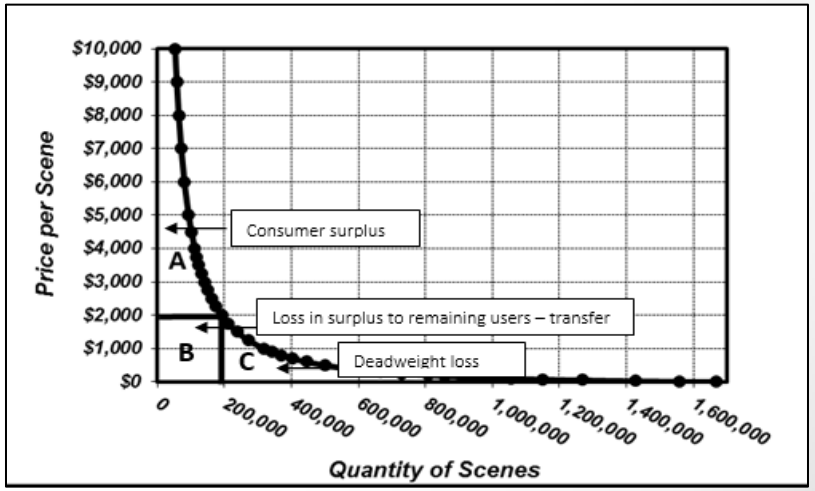
Economic Rationale for Continuation of No Cost Policy

When Incremental Cost = $0, Price Set at $0 is Economically Efficient



Price Set > $0 is Economically Inefficient



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Public and Private Landsat Applications in Water Monitoring and Measuring

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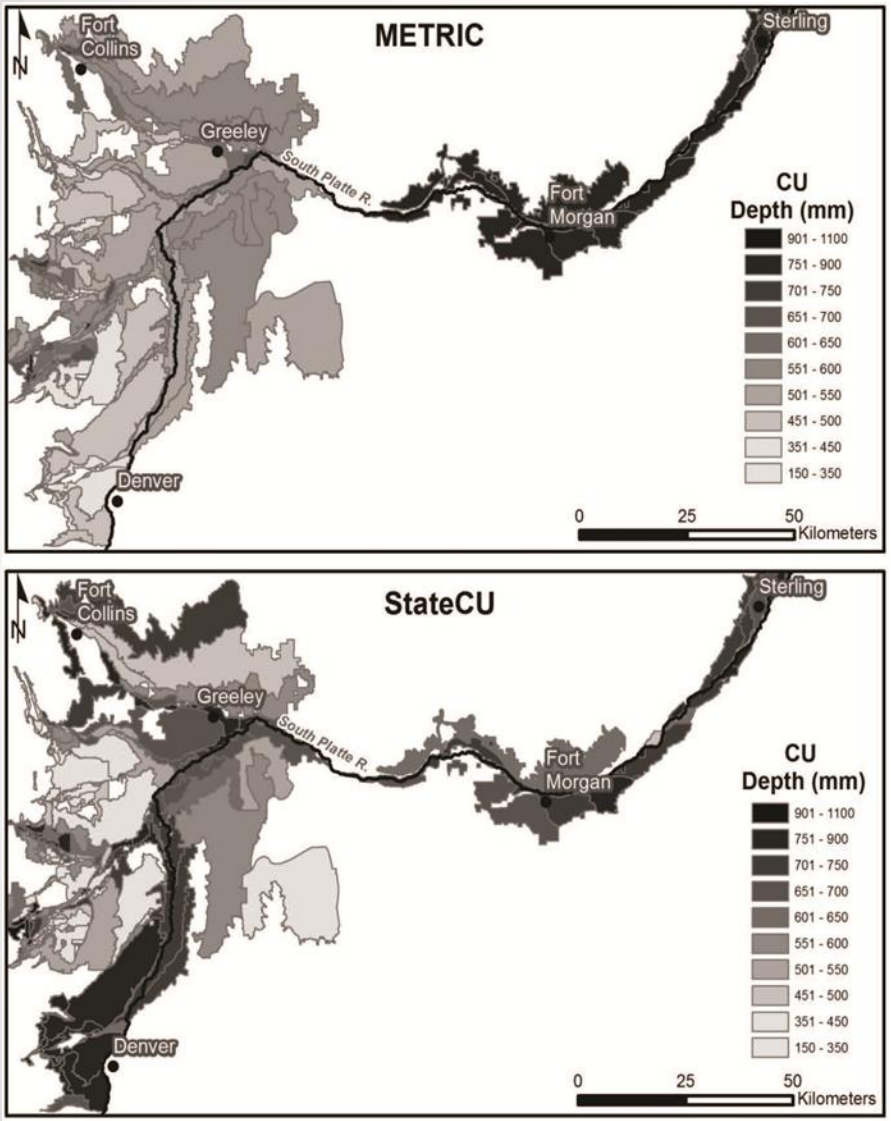
Colorado Water Conservation Board



South Platte River, Colorado, Riverside Technology, Fort Collins, CO and Colorado Water Conservation Board

Considering a switch from the historical StateCU to Landsat and METRIC

- Benefits include:
  - Increase in accuracy
  - More consistent output
  - Crop specific CU measurement
  - Able to identify CU variation along the river reach … generally not estimable with the StateCU model

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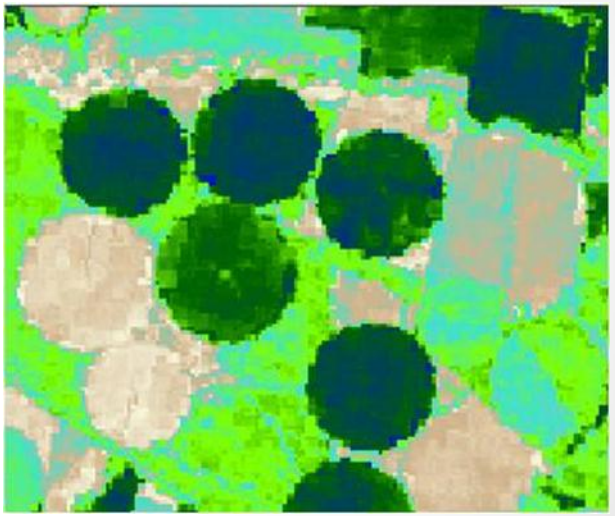
Wyoming State Engineers Office

Landsat and METRIC for CU measurement

- Green River Basin:
    - 2,000 headgates spread over 17,000 mi^2
- Used to calculate CU for compliance with Upper Colorado River Compact
- Benefits:
    - Savings of 1/3 compared to on-the-ground methods using headgates
    - Time savings
    - Cost savings
- Challenges with Landsat force continuation of expensive measurements at the headgates
    - Necessary until operational Landsat program is guaranteed
    - Return time, cloud cover, scan line corrector on L7 present limitations



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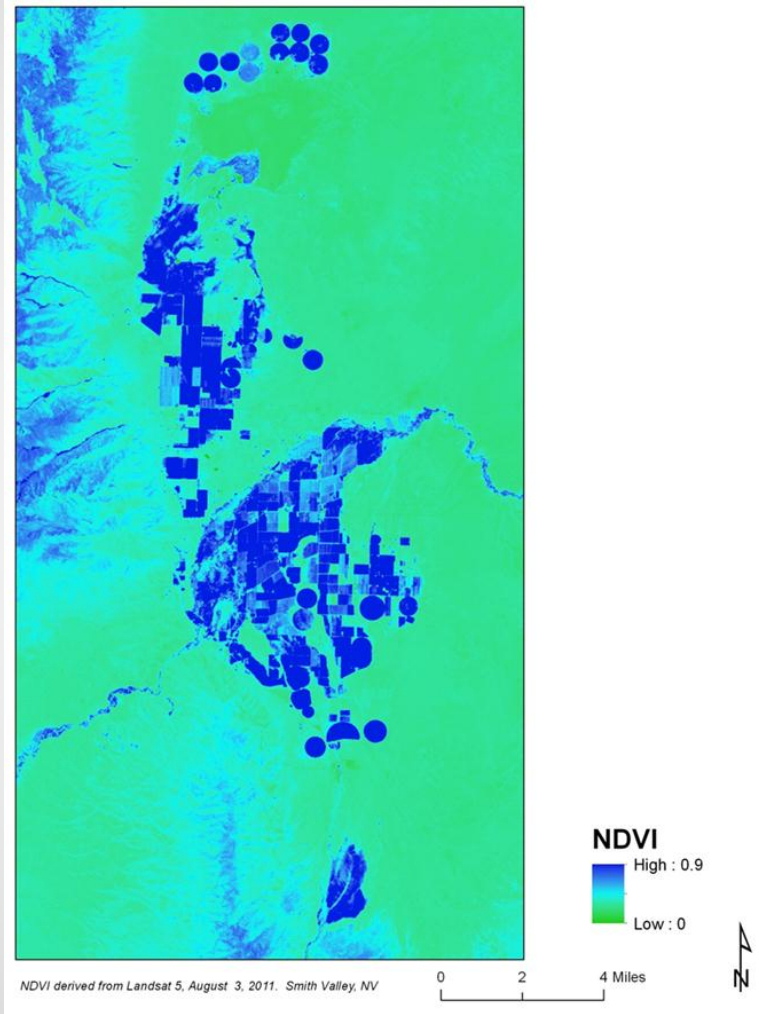
Nevada State Engineers Office



Smith Valley, Nevada

Landsat imagery is used as independent data source for CU measuring

- Used by:
  - Applicants and protestants of water rights application for purpose of quantifying water use
  - State engineers at least once a month to refute or support claims regarding water use
- Benefits:
  - Accuracy
  - Defensibility of historical use
  - Consistency
  - Time savings
  - Labor savings
- Currently working with Desert Research Institute to quantify annual CU at state level with Landsat and METRIC

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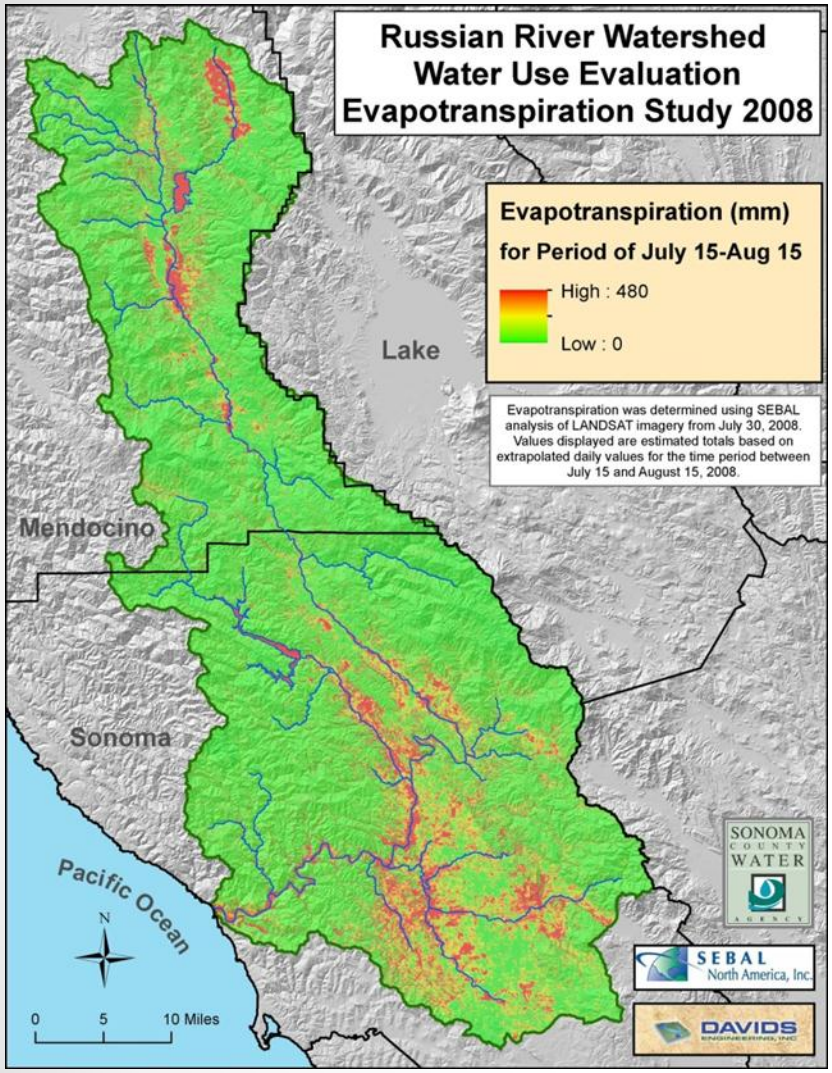
Use of Landsat Imagery in Sonoma County, California



Evapotranspiration in the Russian River watershed determined using SEBAL analysis of Landsat, Sonoma County Water Agency

Landsat imagery in conjunction with SEBAL are used to understand the water supply and demand on the Russian River:

- Predicting demand on the river while maintaining minimum required flow
- Improving current river condition
- Establishing long-term planning for water allocation
- Conducting field level assessments of consumptive water use

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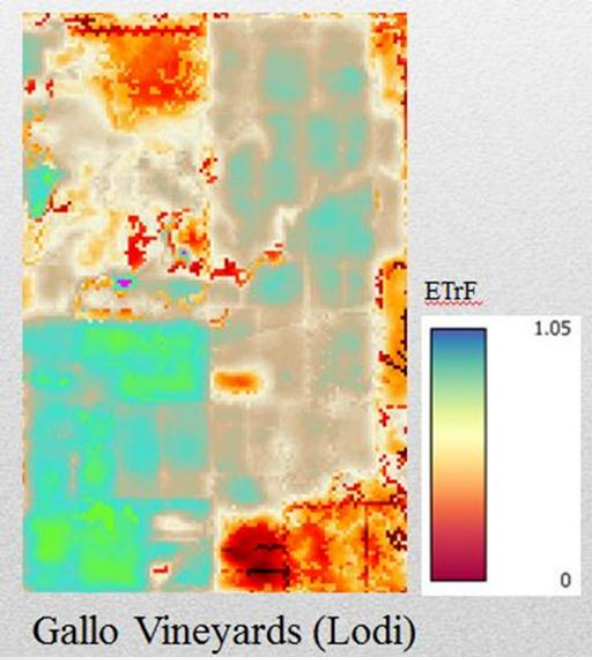
Industry Use of Landsat Imagery

E. & J. Gallo uses Landsat and METRIC to scan 20,000 acres, looking to increase to 150,000 acres of vineyards



Viticulture and Enology, E. & J. Gallo Winery, California

Observations of Landsat use benefits include:

- Improved water management and water budgets
- More efficient seasonal irrigation schedules
- Decrease in water applied by 20-30%
  - Water remains instream for environmental, recreational, industrial, municipal, and agricultural uses
  - Decrease in irrigation cost due to energy savings
- Grape quality improvement
  - Upward movement in the wine program
  - Increase in price per bottle
- Reduce trimming of excess foliage
  - Labor savings
- Using current year's allocation to estimate and plan for next year's allocation

Dr. Martin Mendez-Costabel, E. & J. Gallo

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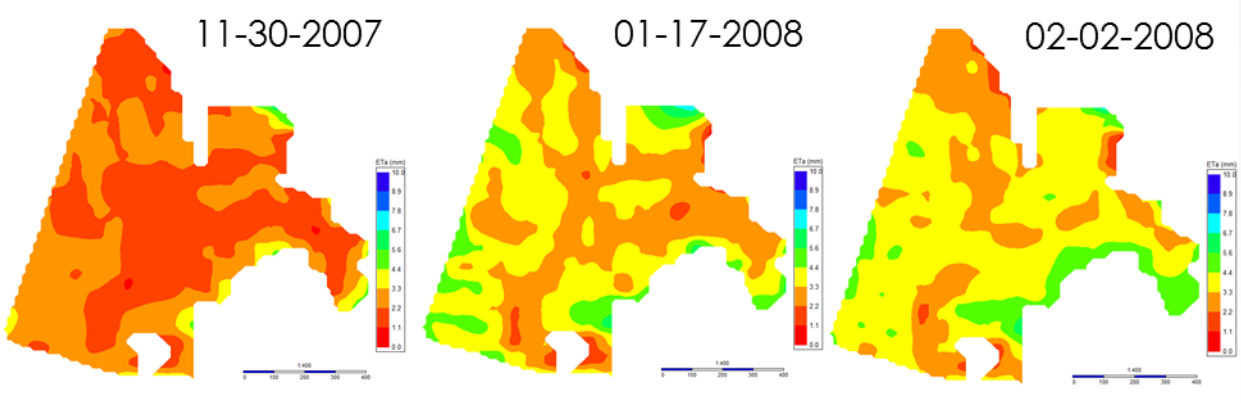
International Landsat Use in Viticulture



ET mapping of drip irrigated vineyards in Chile using Landsat 7 and METRIC

Landsat imagery and METRIC are used on vineyards, apple and olive orchards in Chile's agricultural research

- Observed benefits include:
  - $80/acre cost savings in energy used for irrigation for 3,700 acres of olives per year
  - 30-60% reduction of water applied to grapes
  - 30-35% increase in grape quality
  - Increase in price per bottle due to intentional deficit irrigation for quality improvement on selected sites

Dr. Samuel Ortega, Universidad de Talca, Talca, Chile

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Water Exploration using Landsat, West Darfur

- Over 250,000 refugees in the desert
- Dire need for water resulting in hundreds of daily deaths
- Options:
  - Trucking water
    - Millions of U.S. $ and safety concerns
  - Send in ground crew for survey
    - High cost, safety concerns and length of time required
  - Use Landsat imagery to assess potential well drilling sites
- Radar Technology International with the support from UN and U.S. uses Landsat in conjunction with its own WATEX (RTI) to locate potential drilling sites

- Benefits of Landsat use:
  - Successful identification and drilling of 1,800 wells since 2005
  - 98% success rate
  - Water delivery to the region saved lives
  - Timeliness

Dr. Alain Gachet, Radar Technology International (RTI), France

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Current Case Study Work

- **Agriculture**
  - USDA use of Landsat Imagery for national and international reports
  - Private agricultural producers defining zone maps with Landsat
- **Economic Activity**
  - Startups or new product development: Mapbox, Silviaterra
  - Landsat as a tool: DigitalGlobe, PlanetLabs, BlackRidge, DMCii, ESRI
- **Public Goods**
  - Global Forest Watch: World Resource Institute
  - EEFlux: Google, University of Idaho, Dessert Research Institute, University of Nebraska
- **Water Resources**
  - Western US
  - Survey

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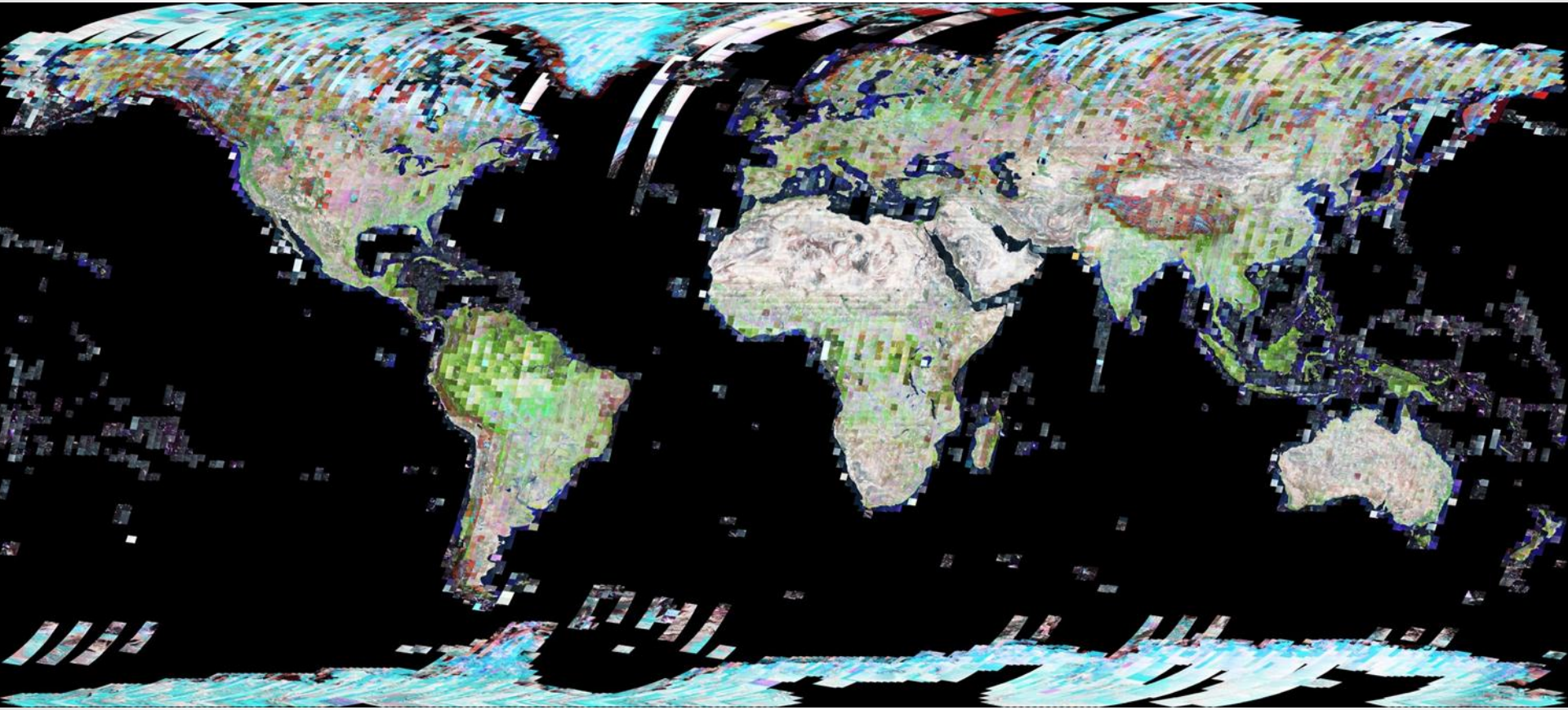
Questions?



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Additional Slides

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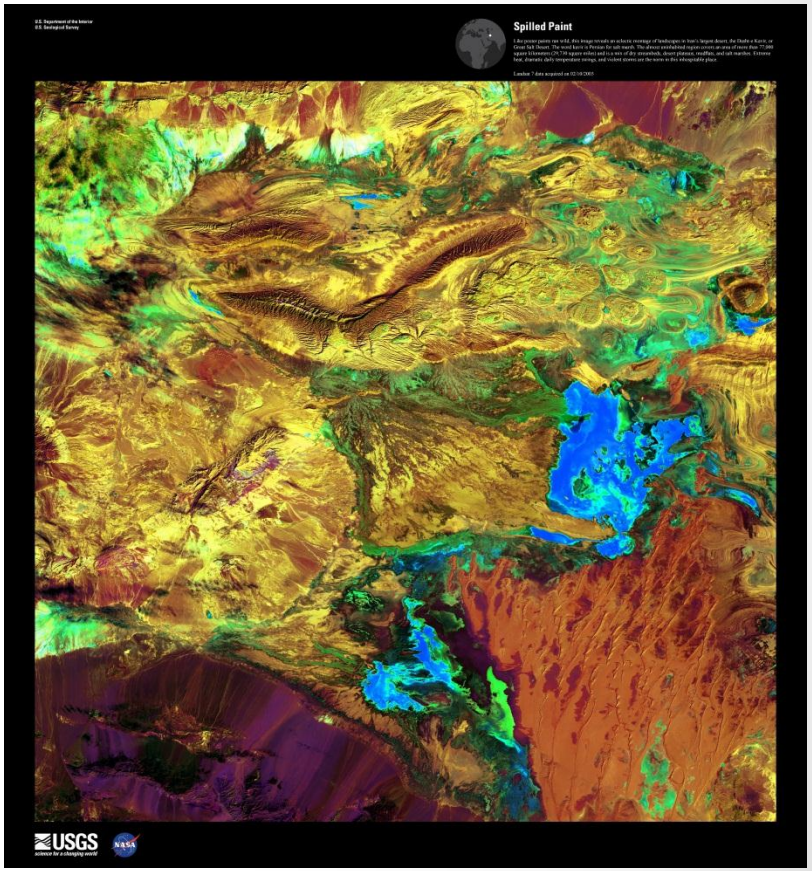
Survey Administration

- Online survey
- All contact via email
- Emails sent in waves between 2/29/12 and 4/27/12



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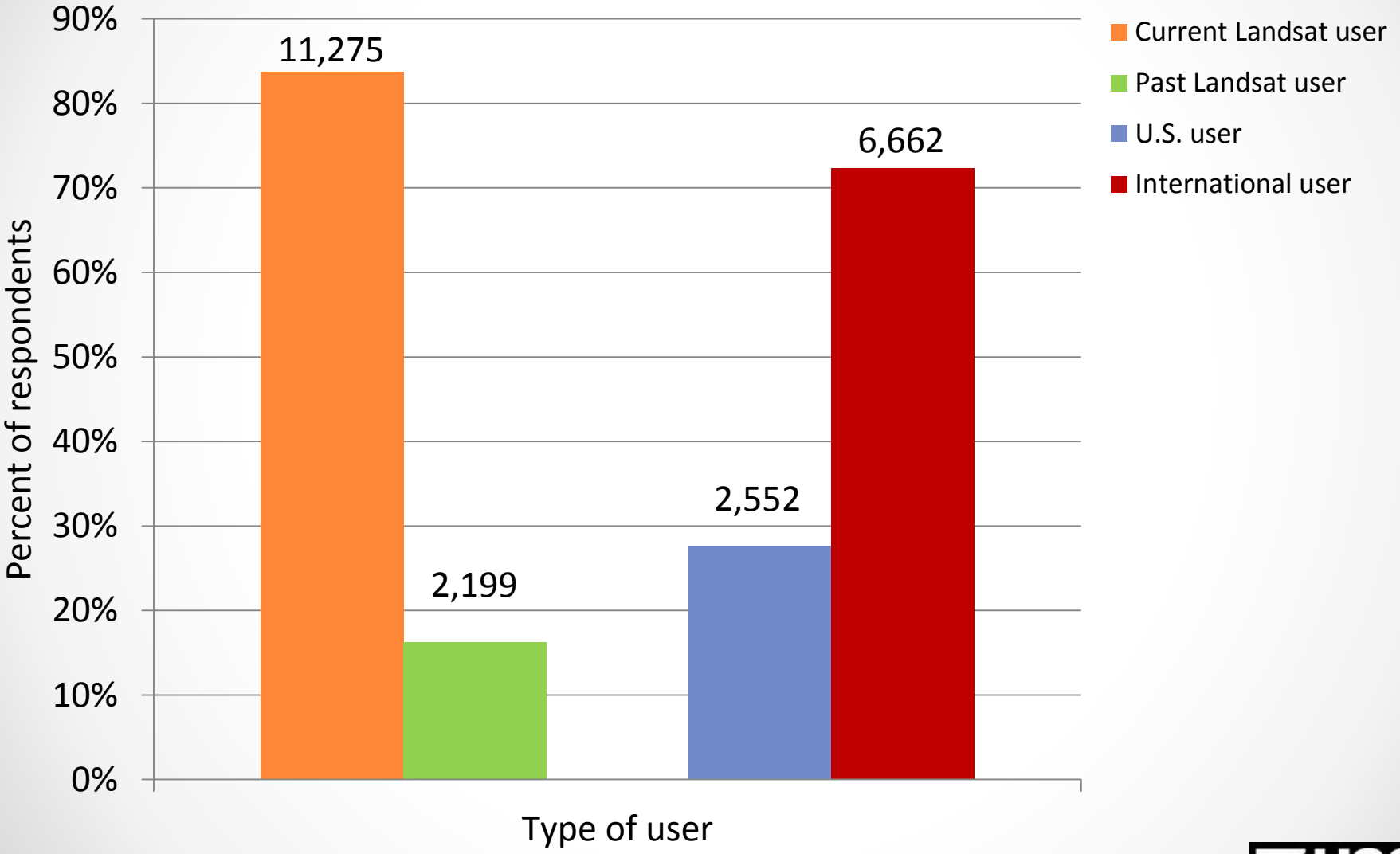
Response Rate

Total Sent	# Responded	Undeliverables	Response Rate
44,731	13,473	87	30%

- # responded includes both completed surveys (11,749) and some abandoned surveys (1,724)
  - Abandoned surveys were only included if surveys were completed through a designated question

The Sample



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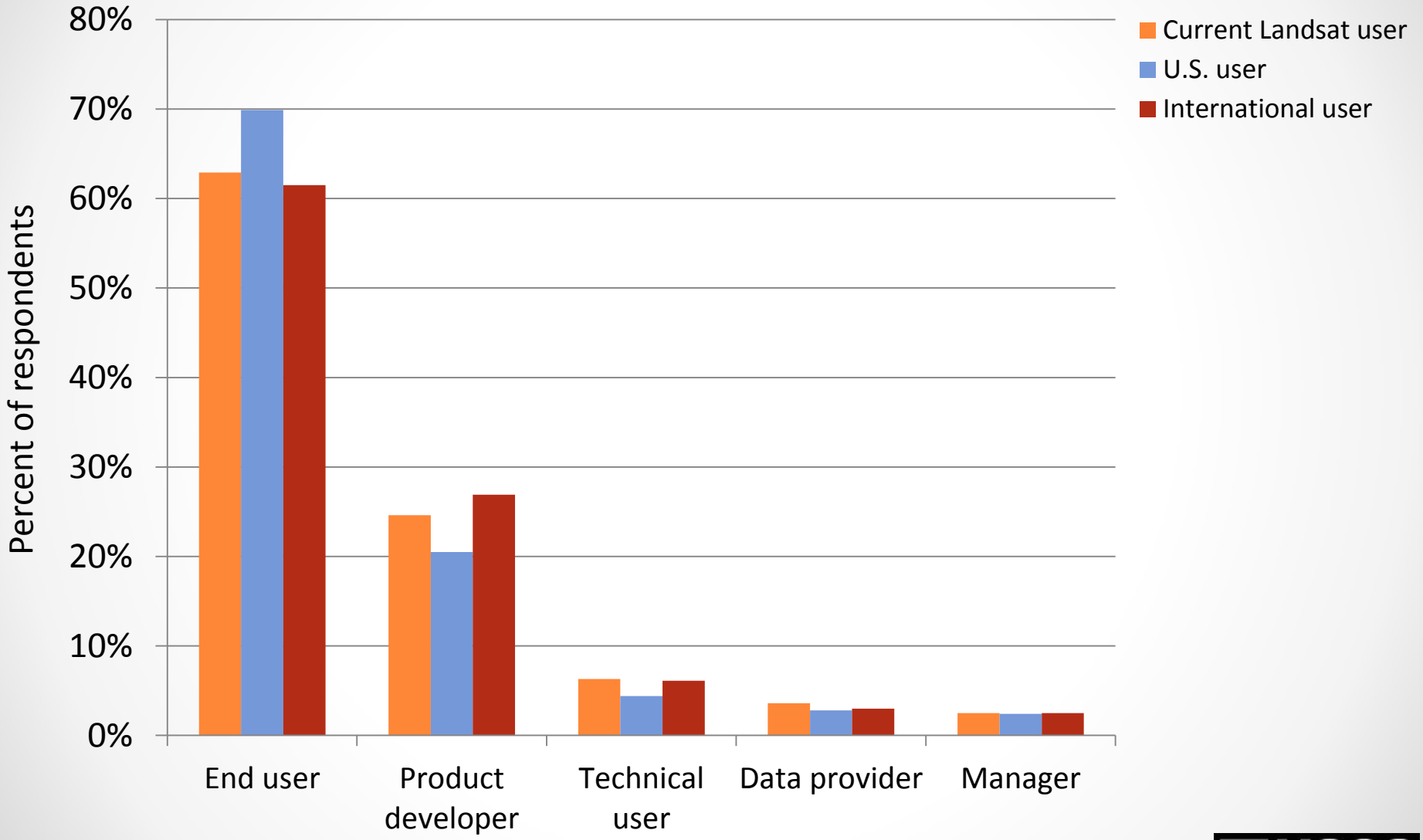
Demographics

Demographic	Current Landsat users	U.S. users	International users
Median level of education	Graduate or professional school	Graduate or professional school	Graduate or professional school
Gender	78% male	73% male	80% male
Mean age	38	41	37
Member of RS/GIS organization	32%	48%	26%
Mean years using satellite imagery or GIS software	10	11	9

Type of User



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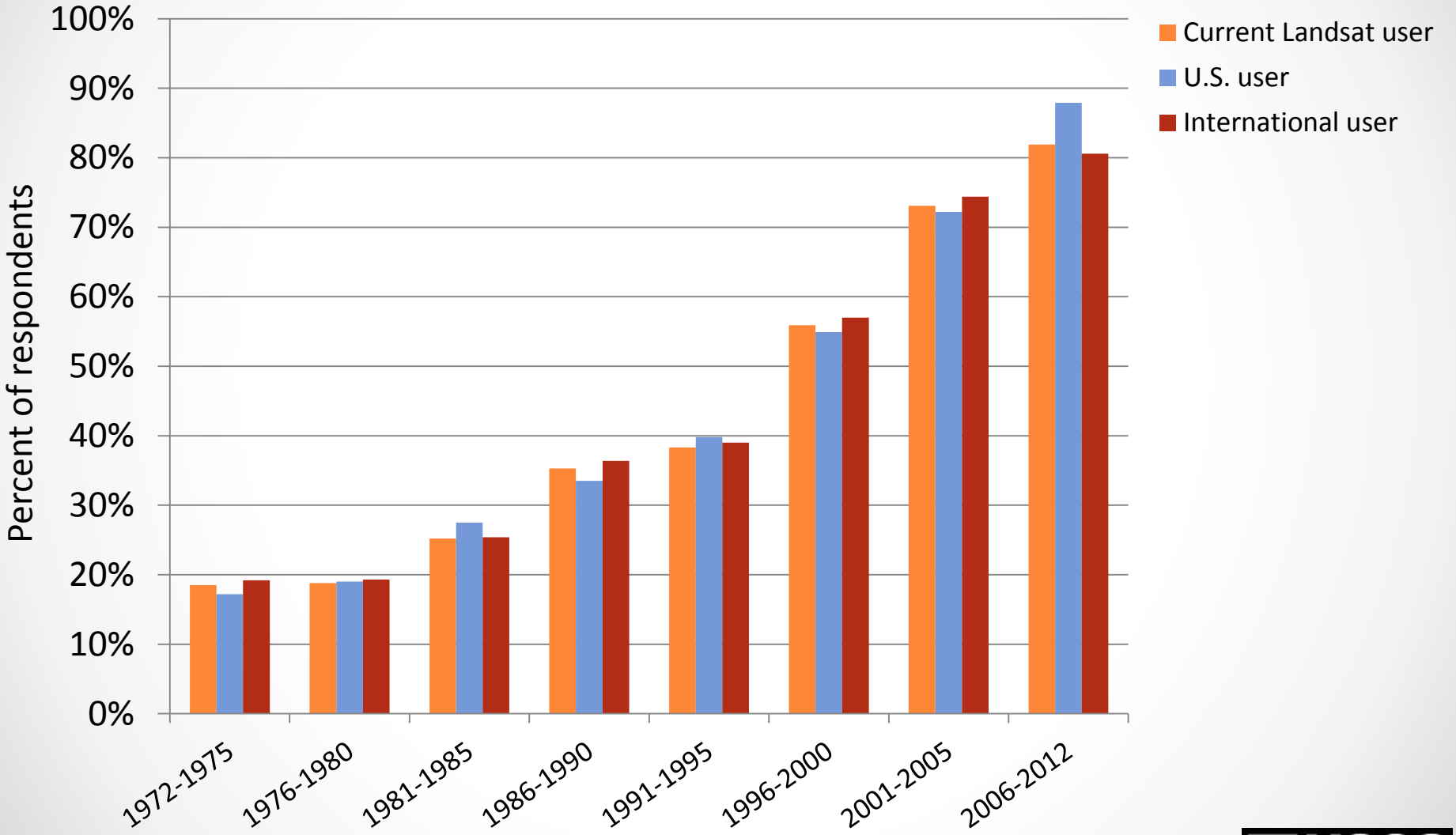
Landsat Imagery Used in Past Year

Landsat sensor	Current Landsat users	U.S. users	International users
ETM+ (Landsat 7)	44%	40%	45%
TM (Landsats 4 and 5)	44%	46%	44%
MSS (Landsats 1 thru 5)	7%	6%	7%
Unknown sensor	5%	8%	4%
Total	100%	100%	100%

Scenes Used by Year Acquired



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Use of Landsat in Work

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  - U.S. users used it in 38% of their work
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Of work that used Landsat…	Current Landsat users	U.S. users	International users
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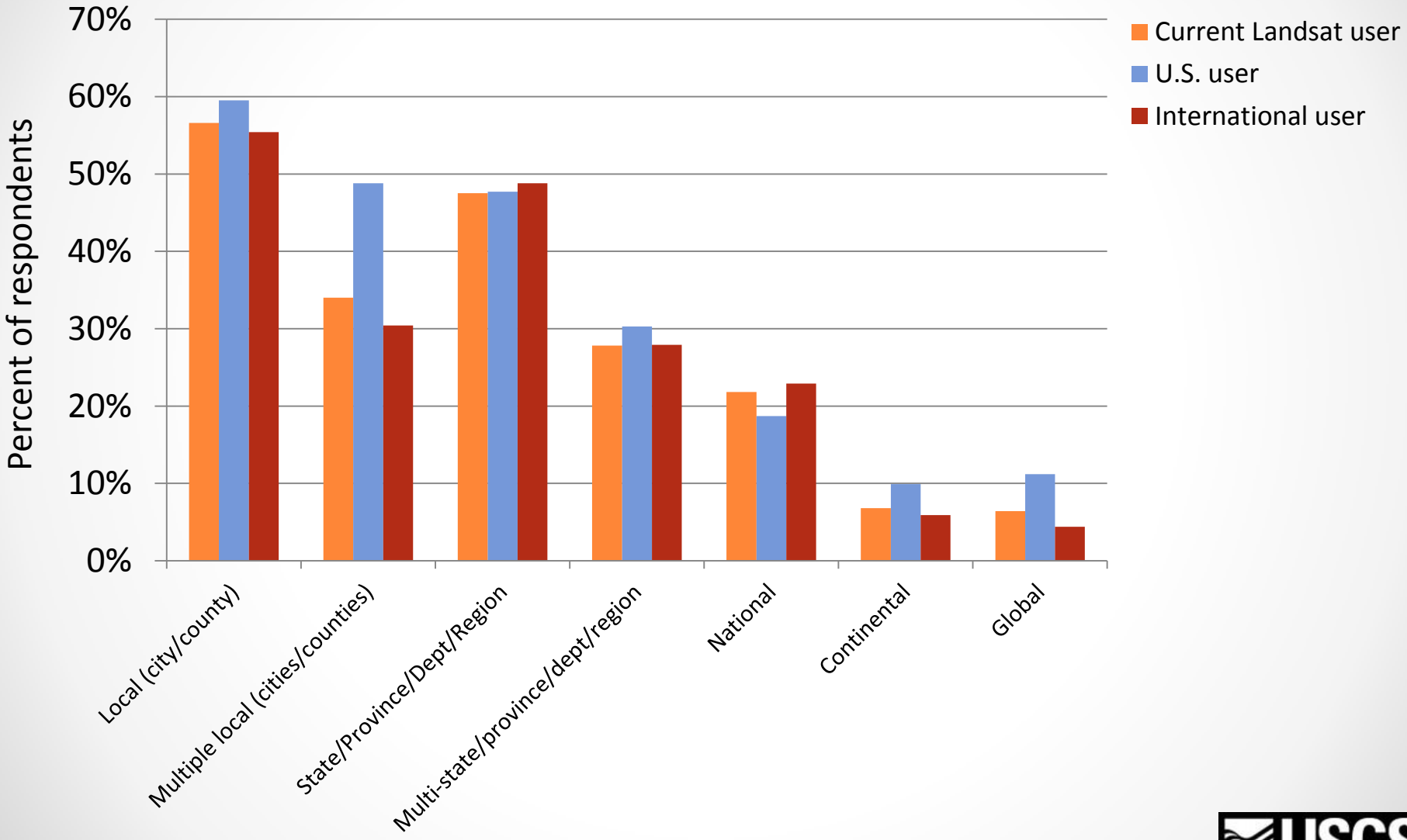
Percent nonoperational work	65%	70%	65%
Total	100%	100%	100%

Project Scales



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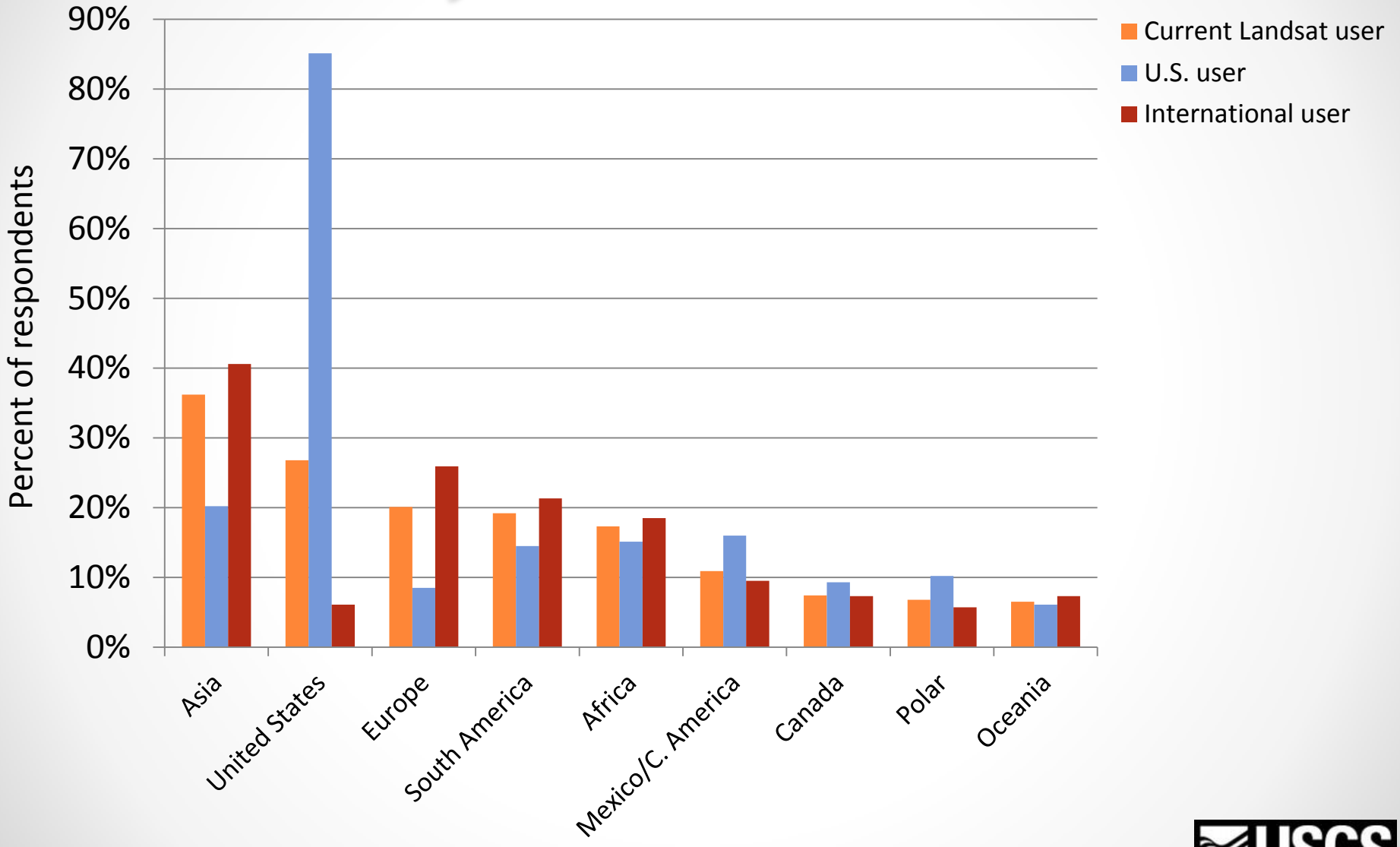
Project Locations



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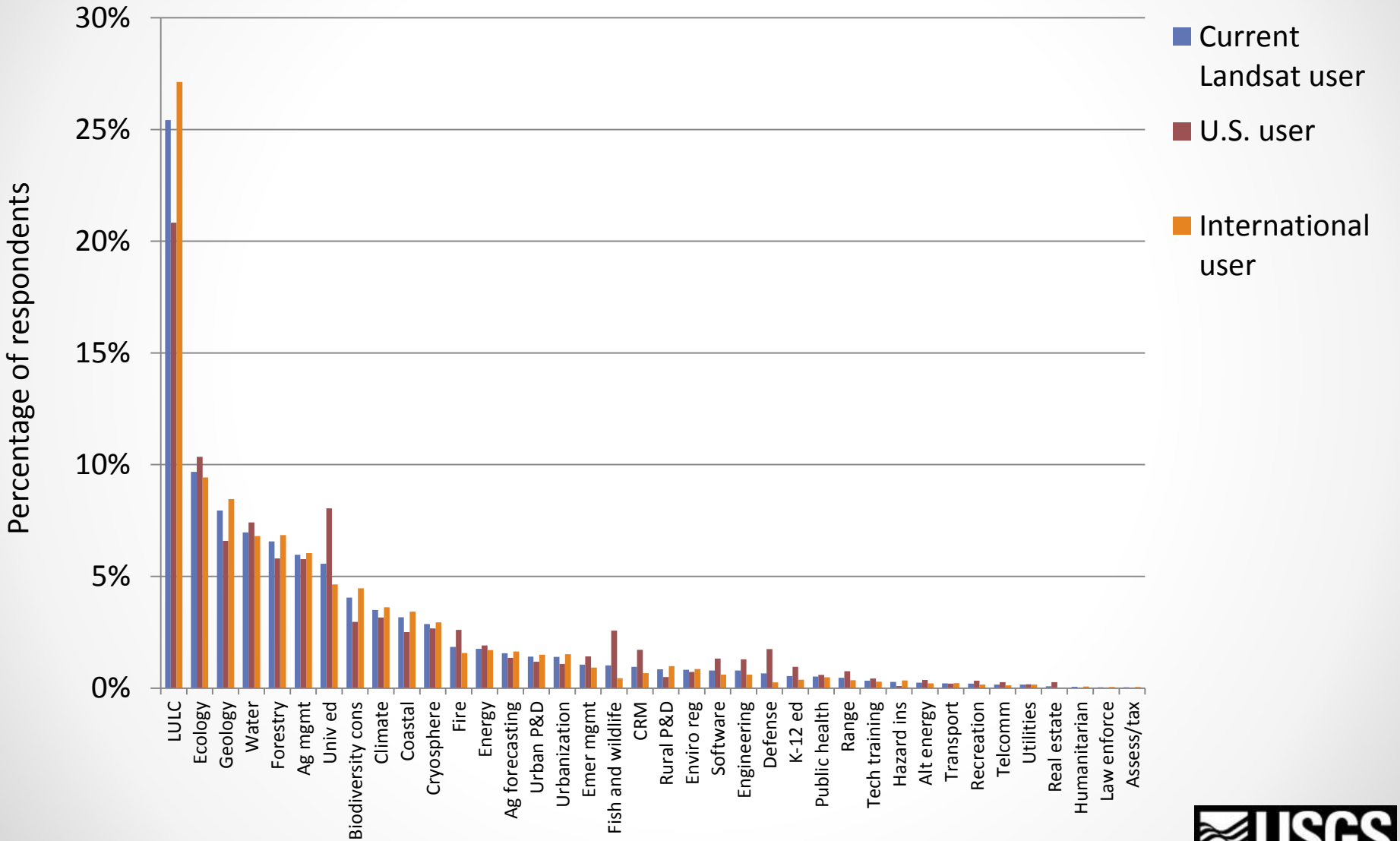
Primary Applications



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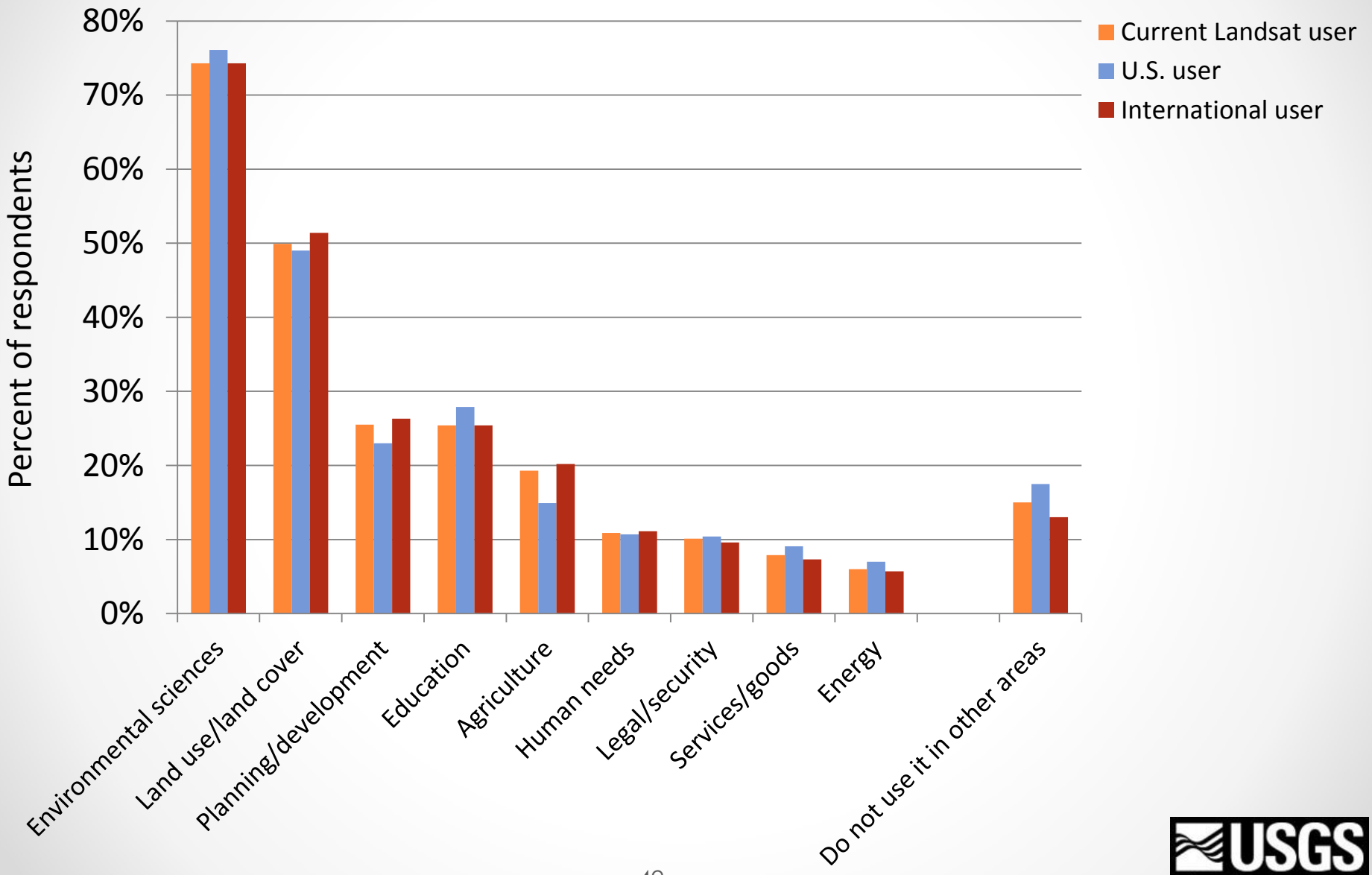
Secondary Applications



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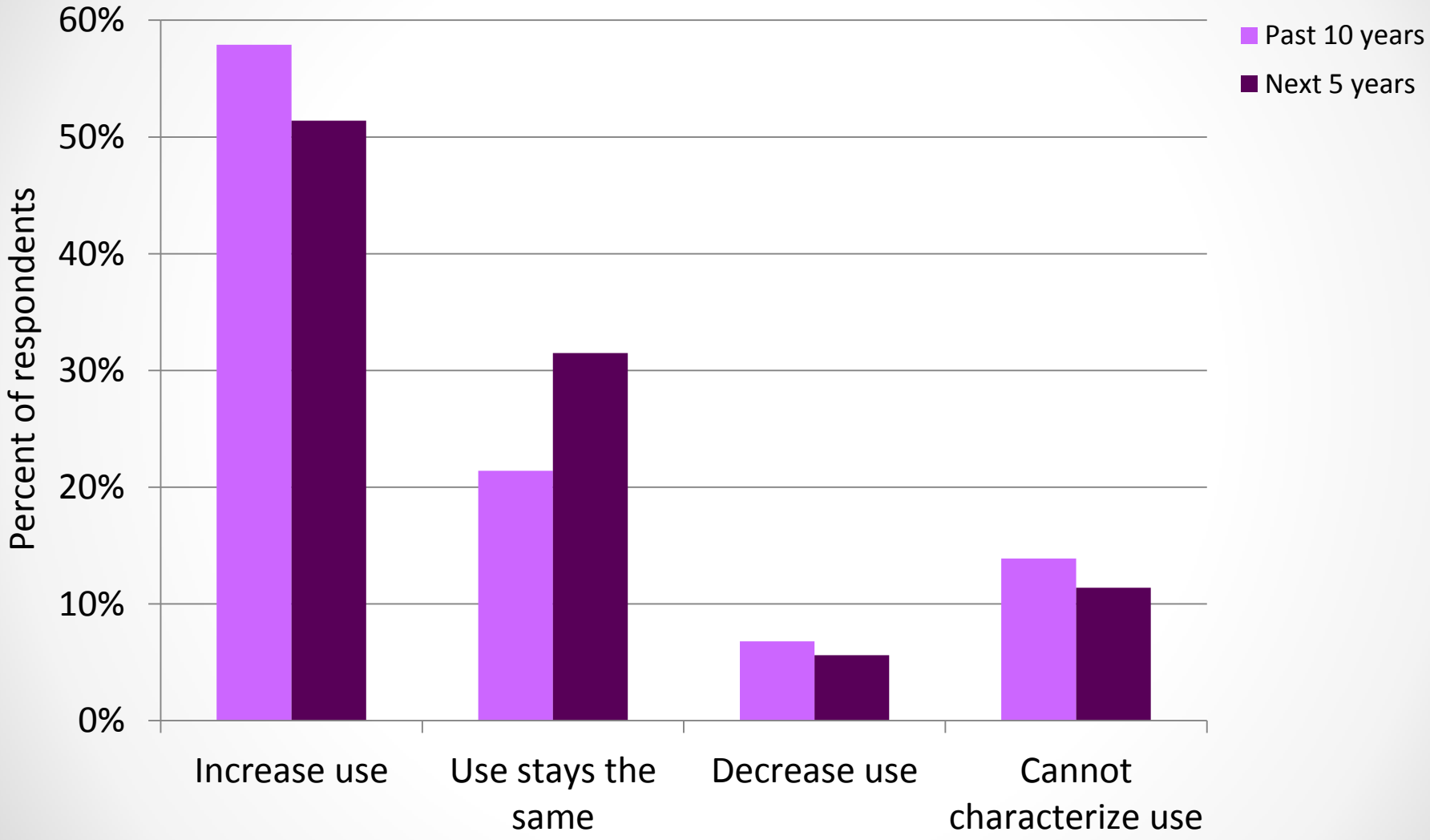
Change in Use Over Time



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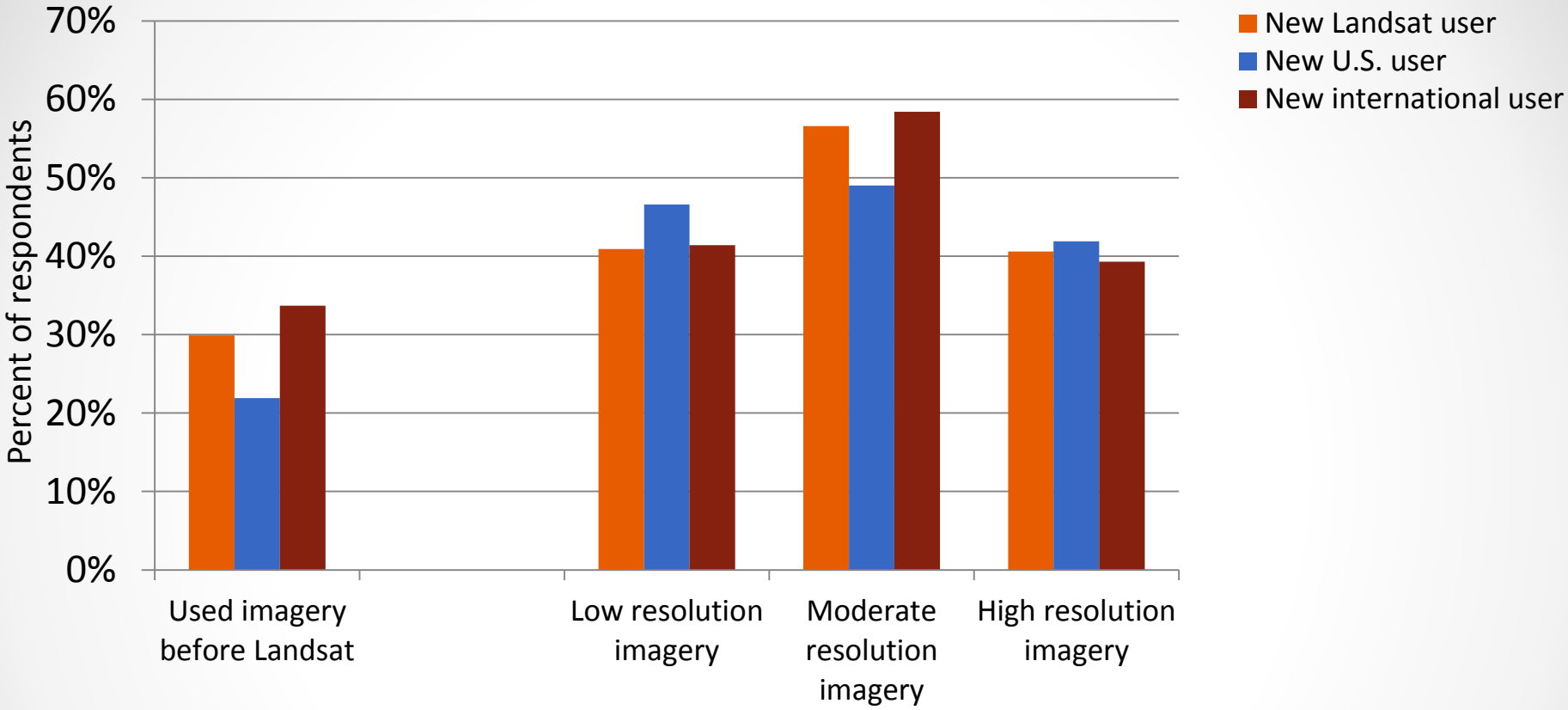
New Users: Imagery Used Before Trying Landsat



Average percent of existing imagery replaced by Landsat among new users:

- All new users = 49%
- New U.S. users = 44%
- New international users = 51%

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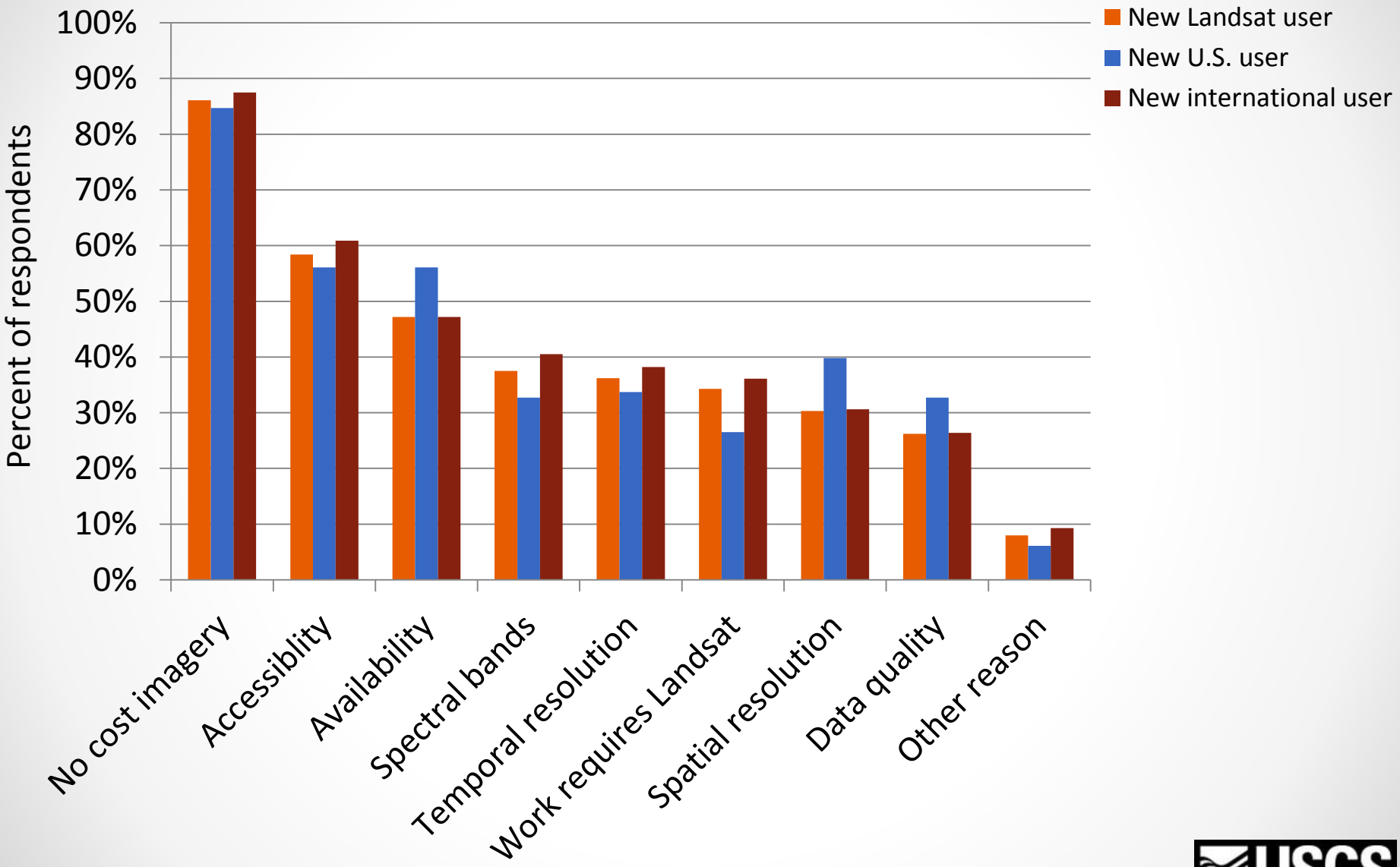
New Users: Why Landsat as Replacement?



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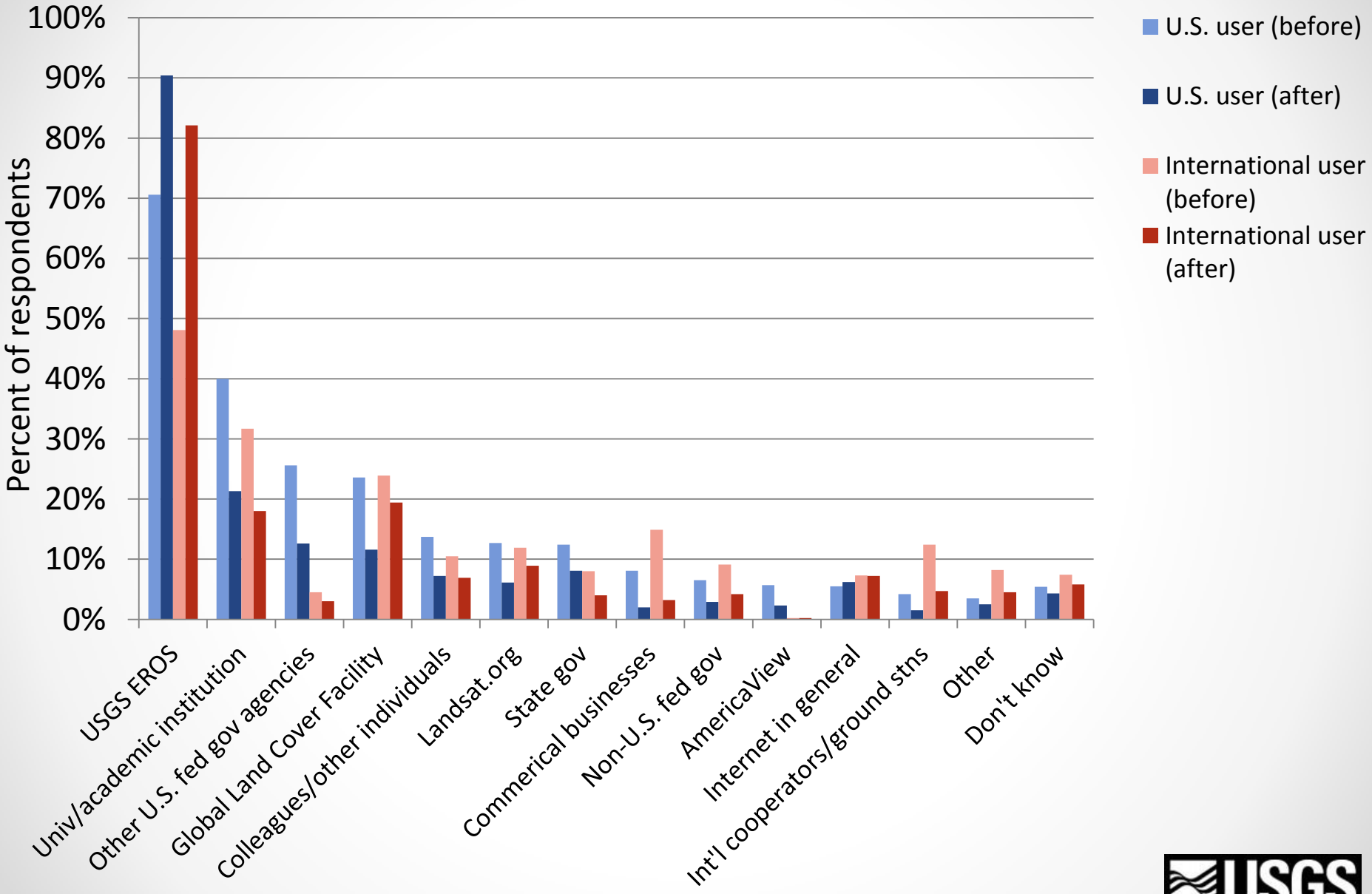
Landsat Sources Before and After No Cost Data



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Value of Landsat Imagery

- Importance of the imagery and its attributes
- Benefits of the imagery
- Impacts to work if no longer available
- Contingent valuation method (CVM)

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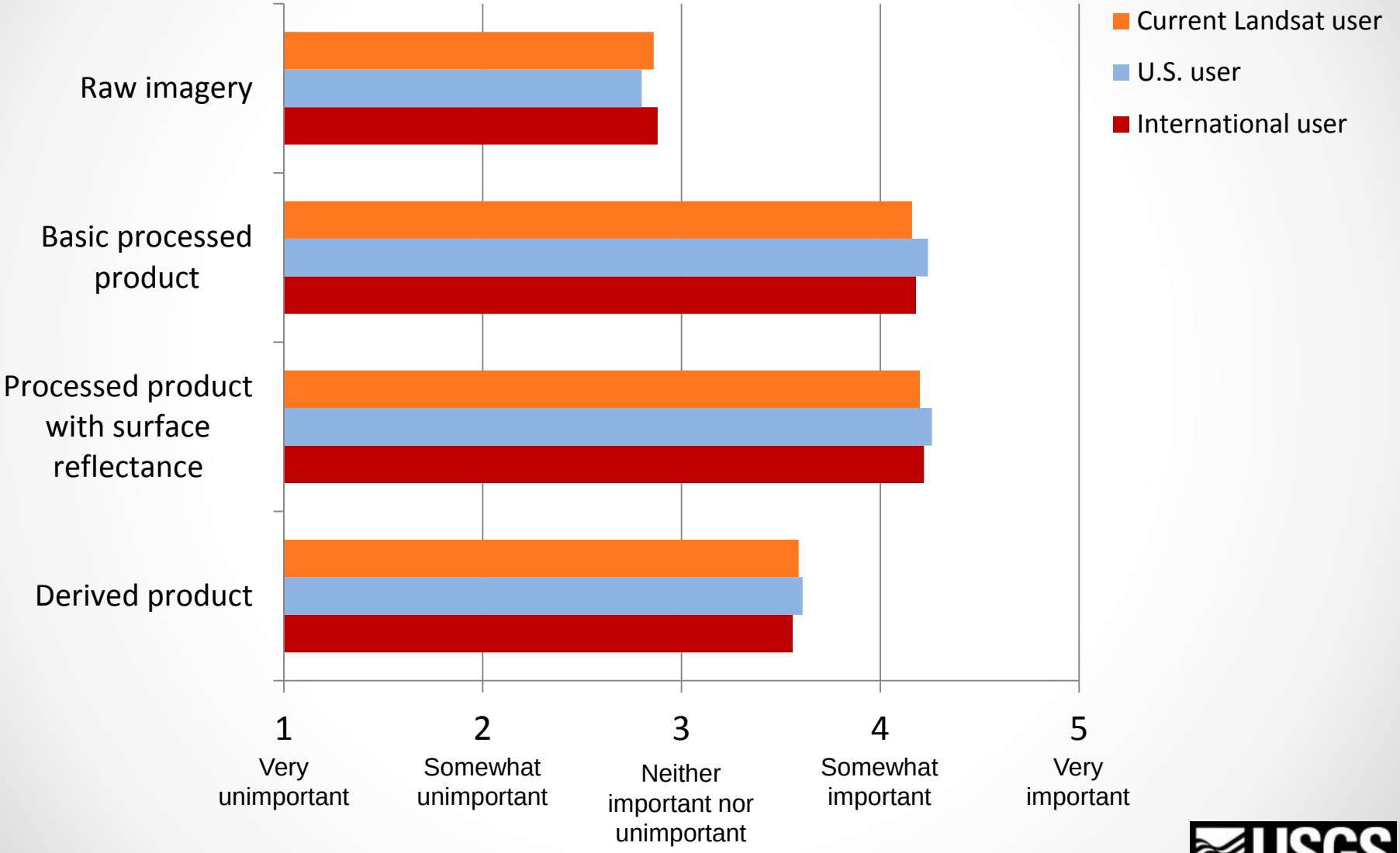
Importance of Processed Imagery



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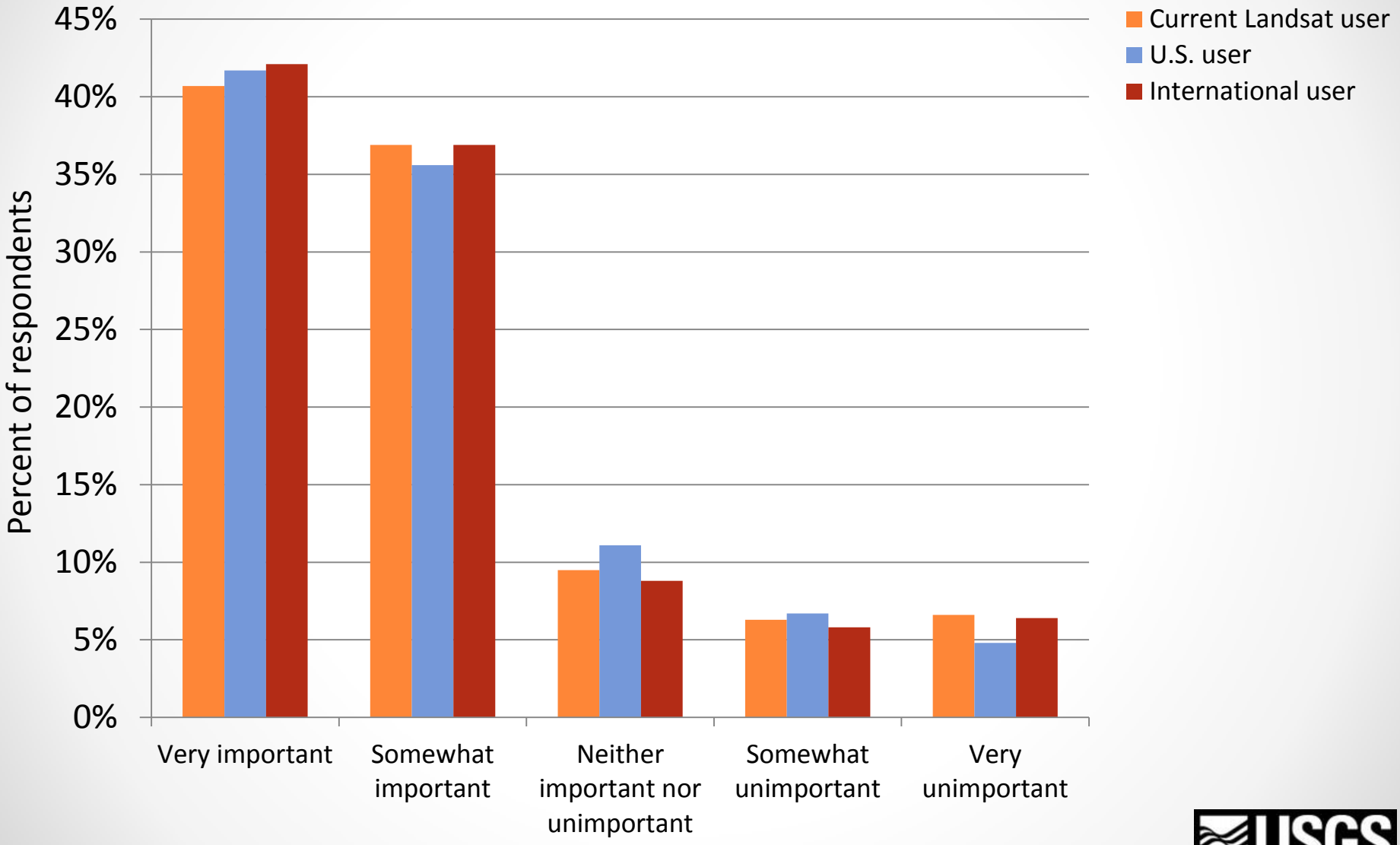
Overall Importance of Landsat



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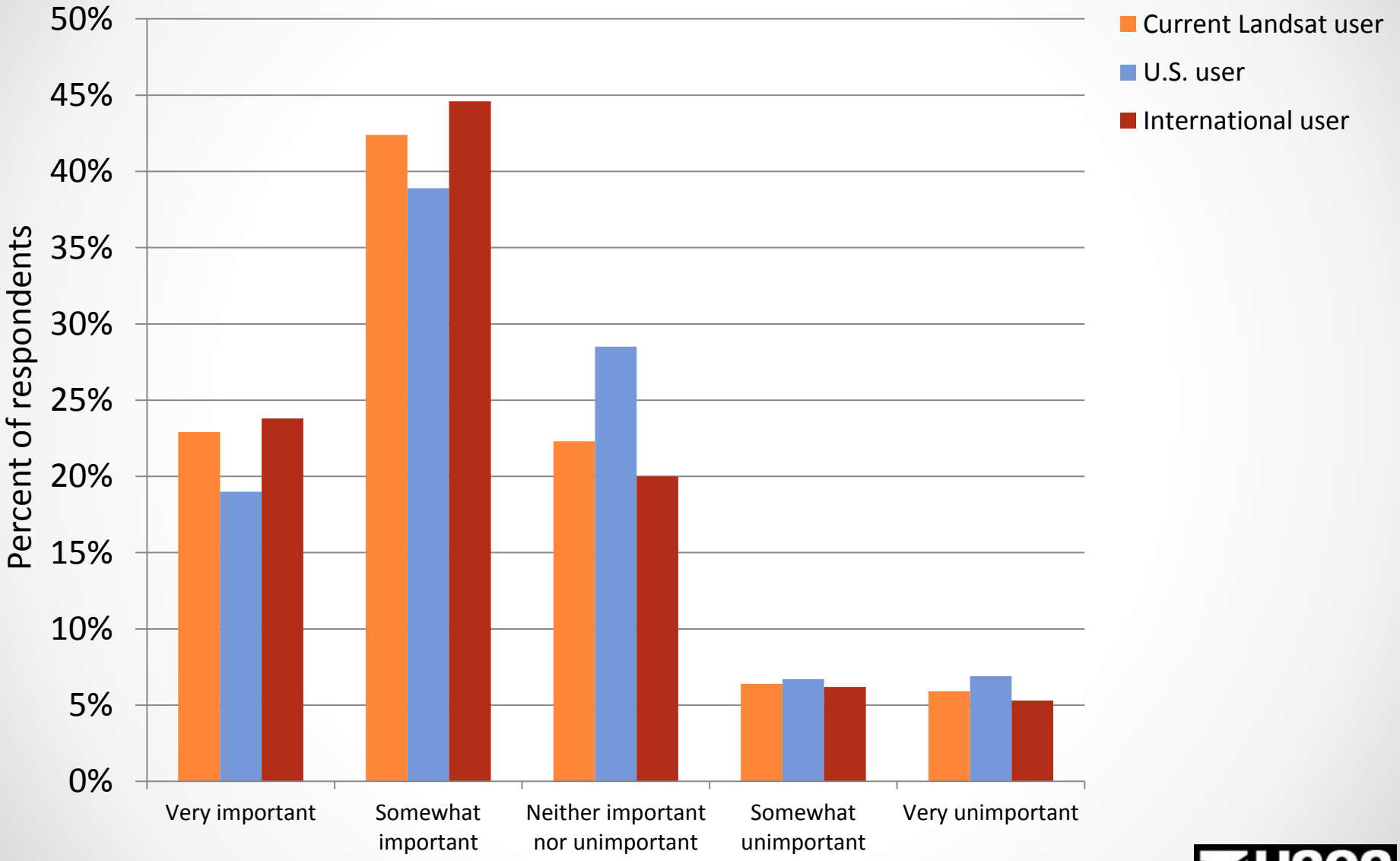
Importance of Landsat in Decision Making



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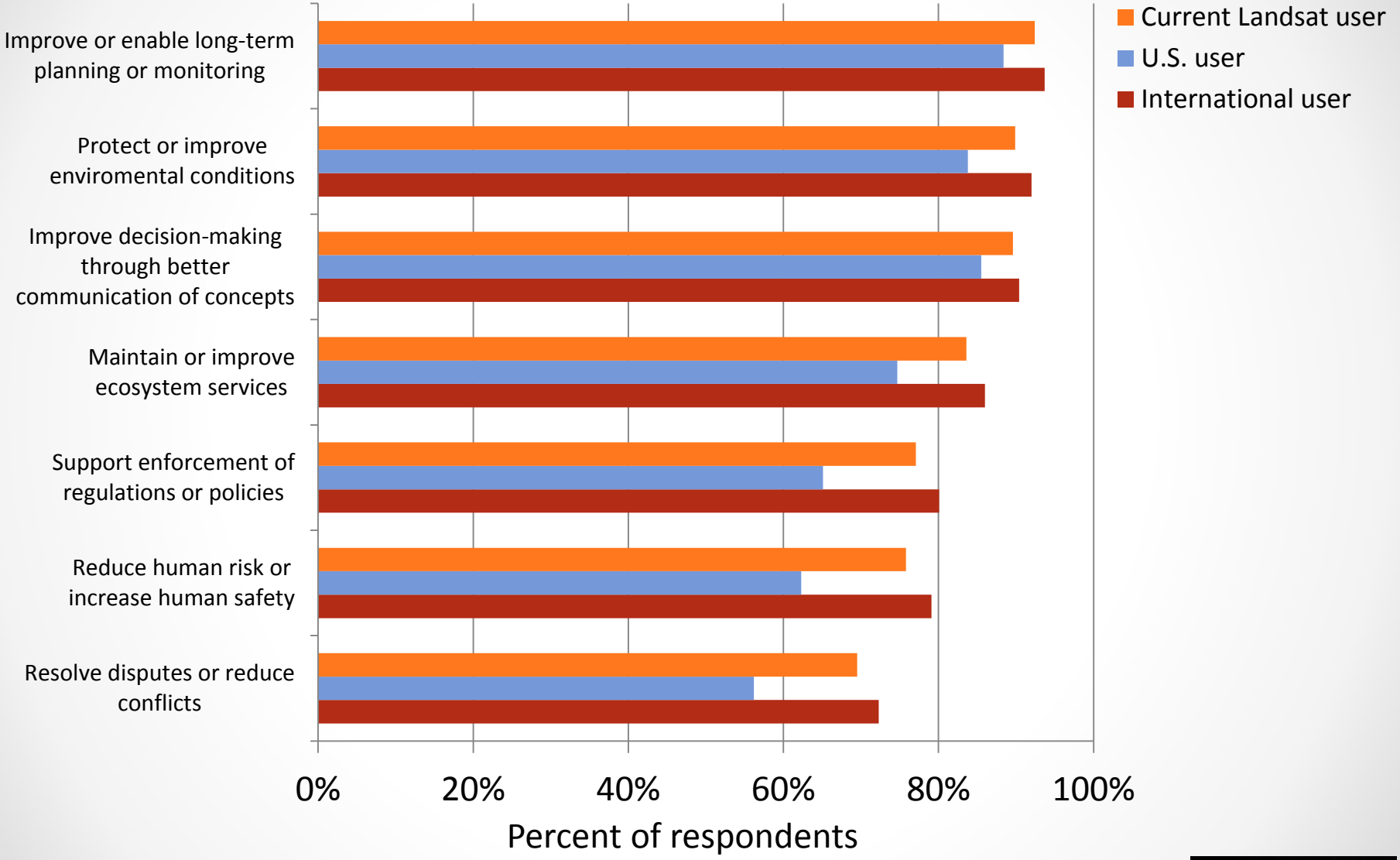
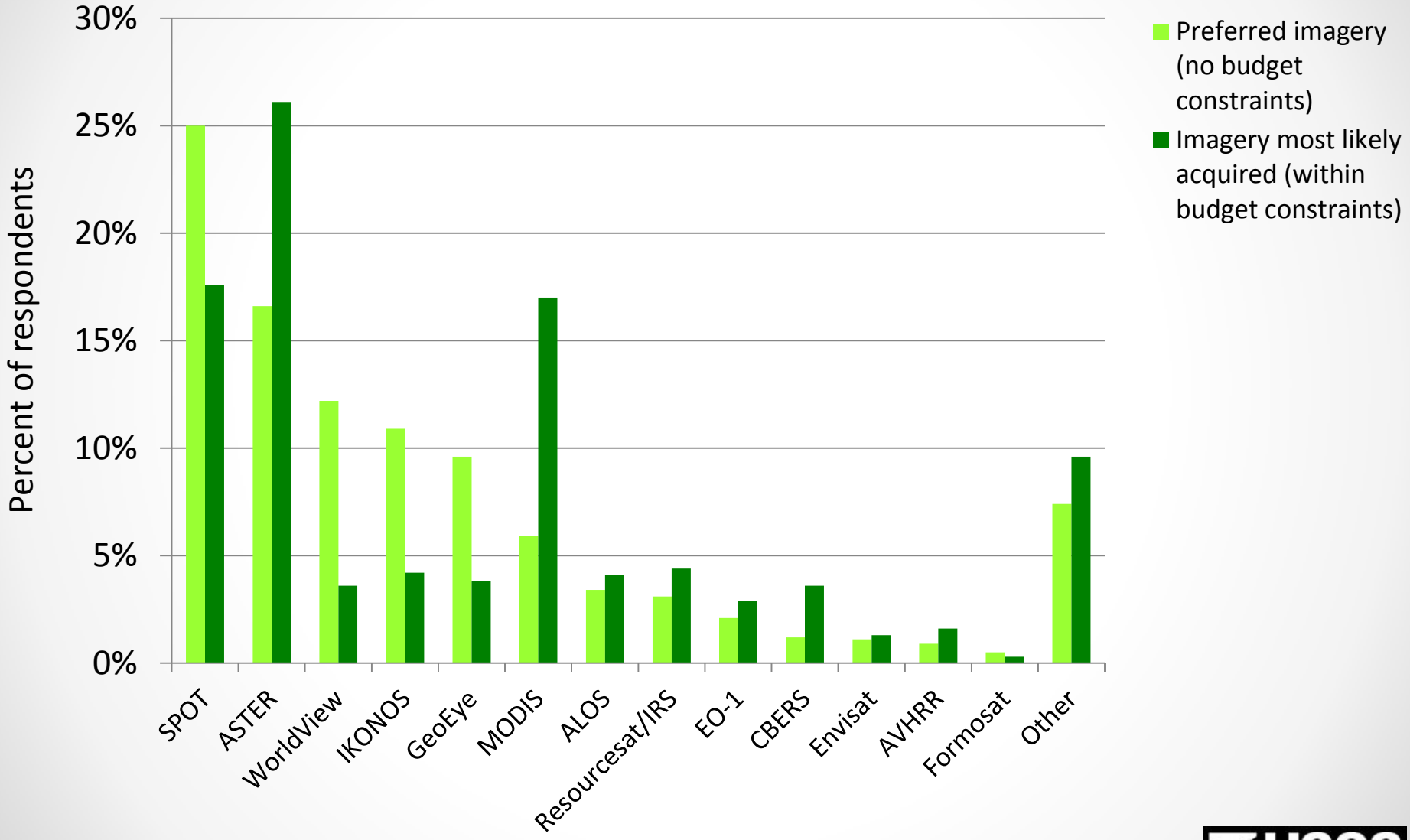
Observed Benefits from Landsat Projects



Imagery Acquired if Landsat Was Not Available



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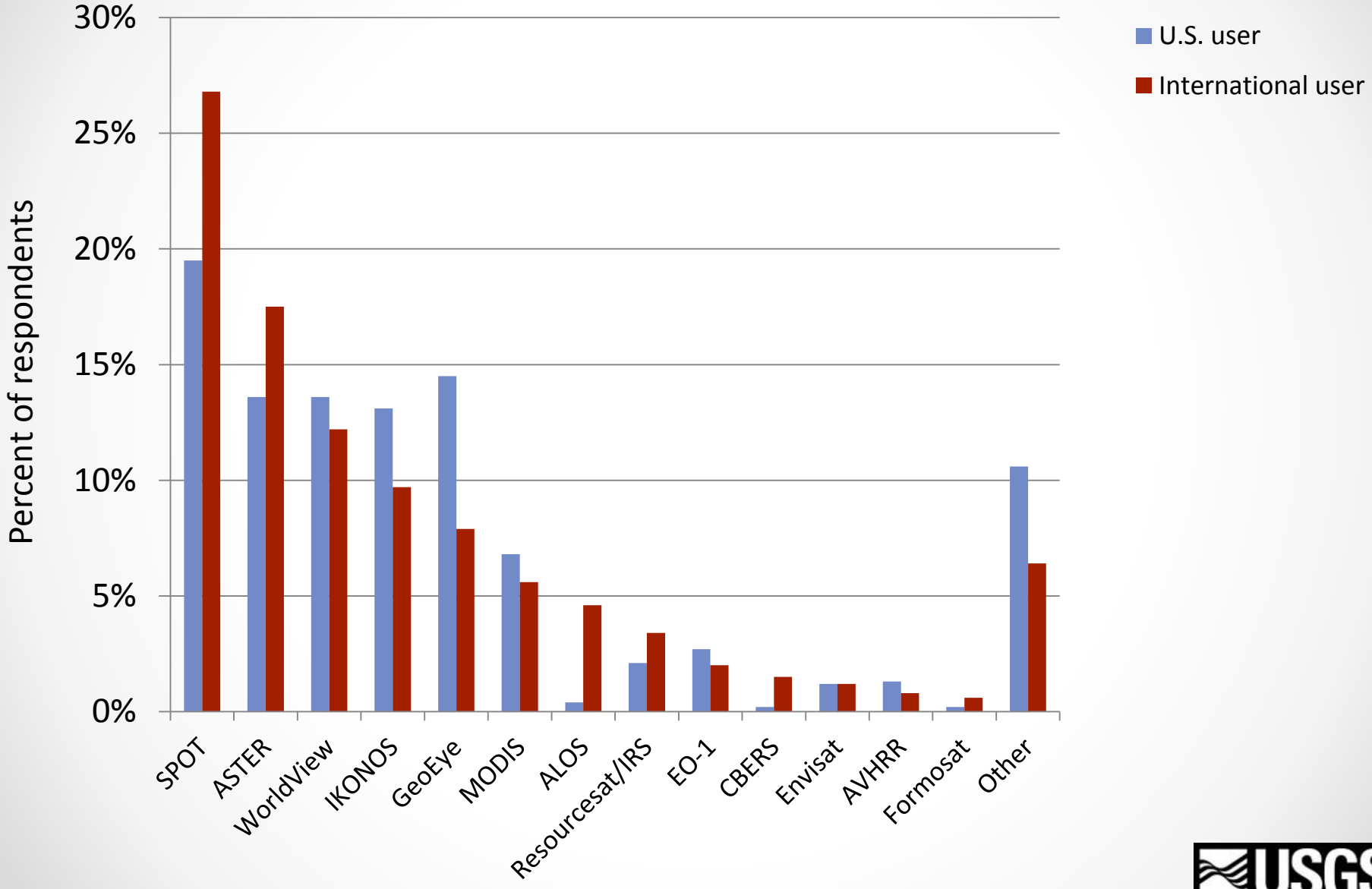
Preferred Imagery if Landsat Was Not Available



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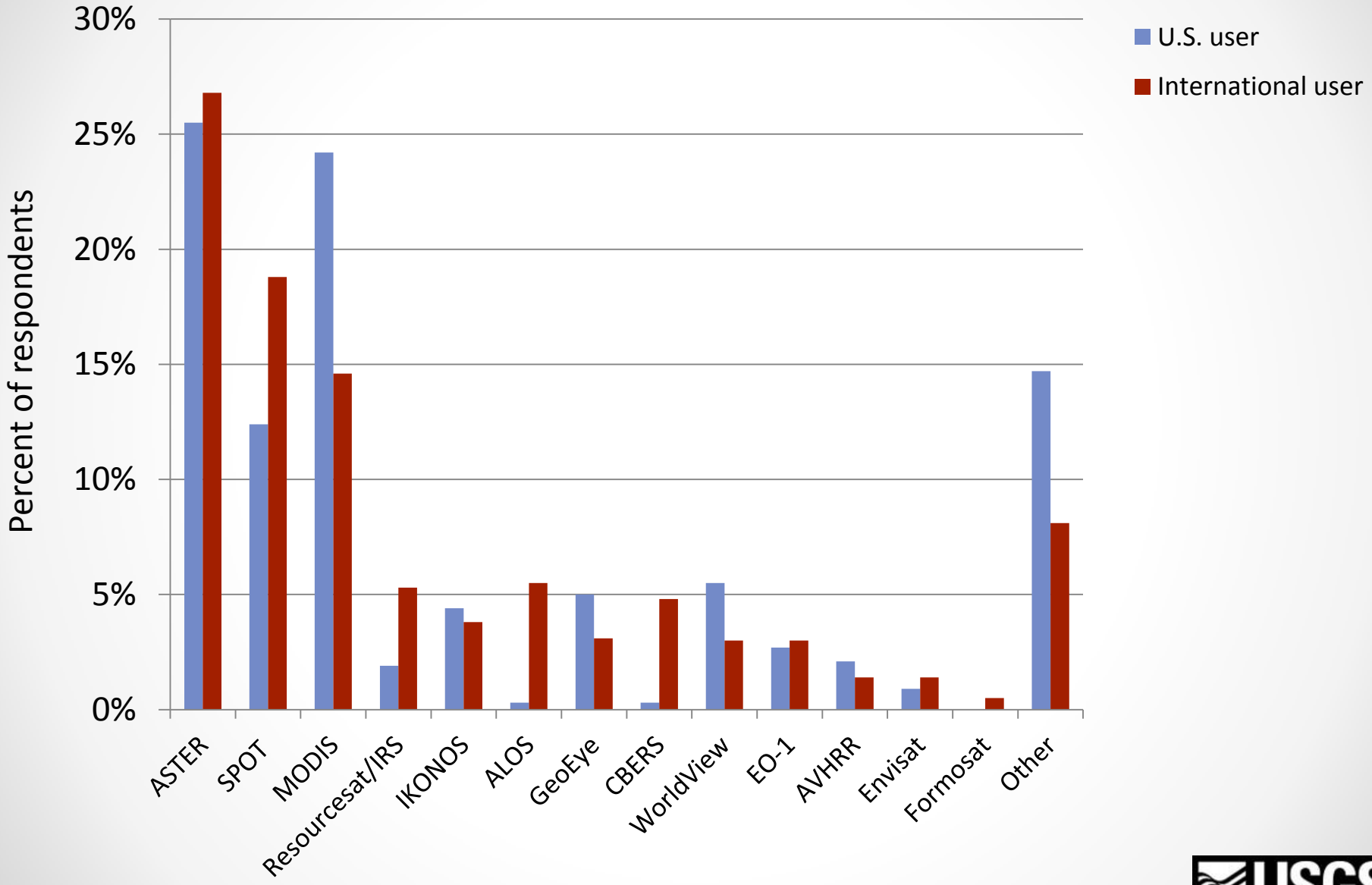
Imagery Most Likely Acquired if Landsat Was Not Available



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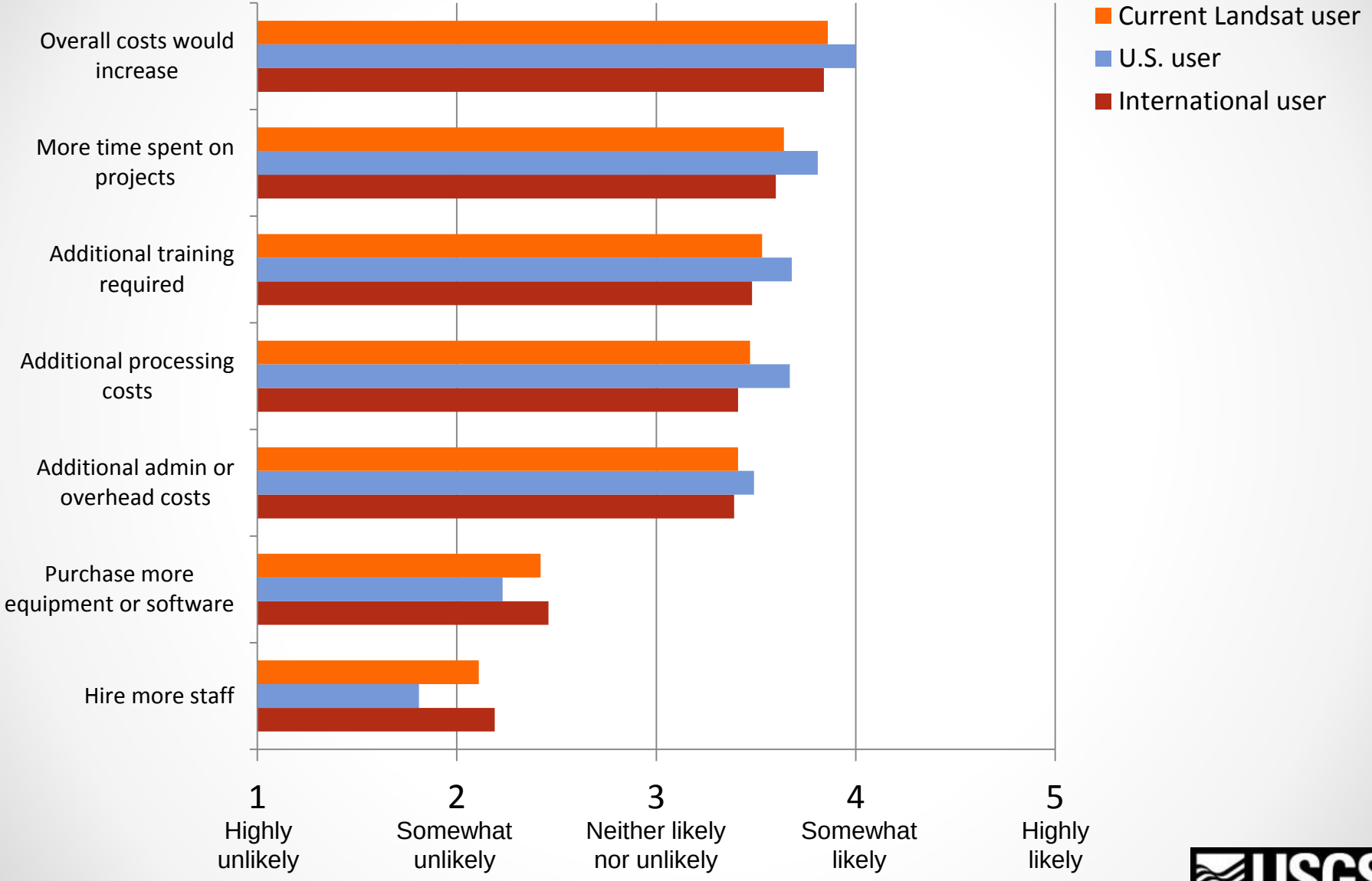
Likelihood of Cost Increases if Landsat Was Not Available



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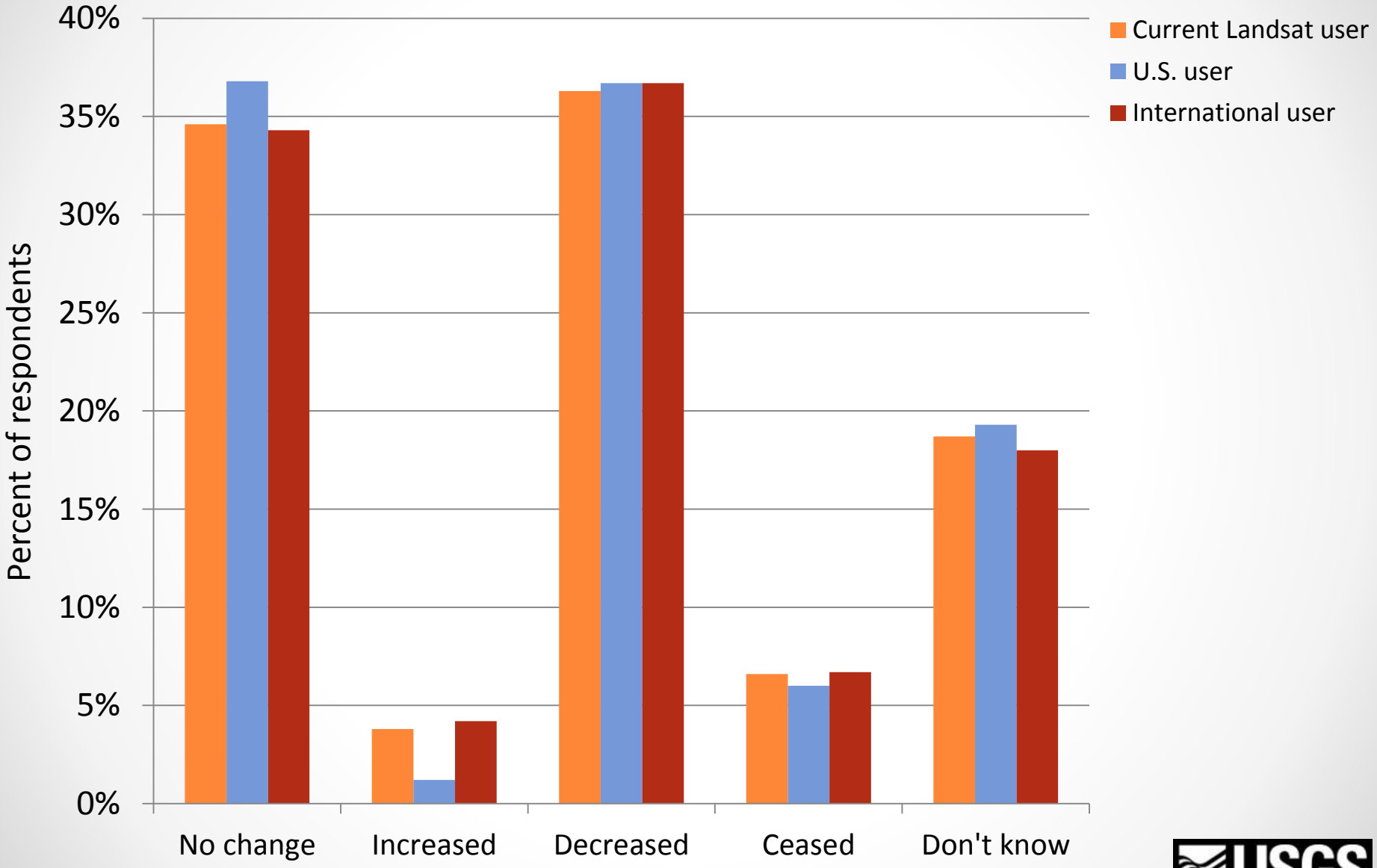
Change in Amount of Imagery Used Due to Loss of Landsat 5 Data



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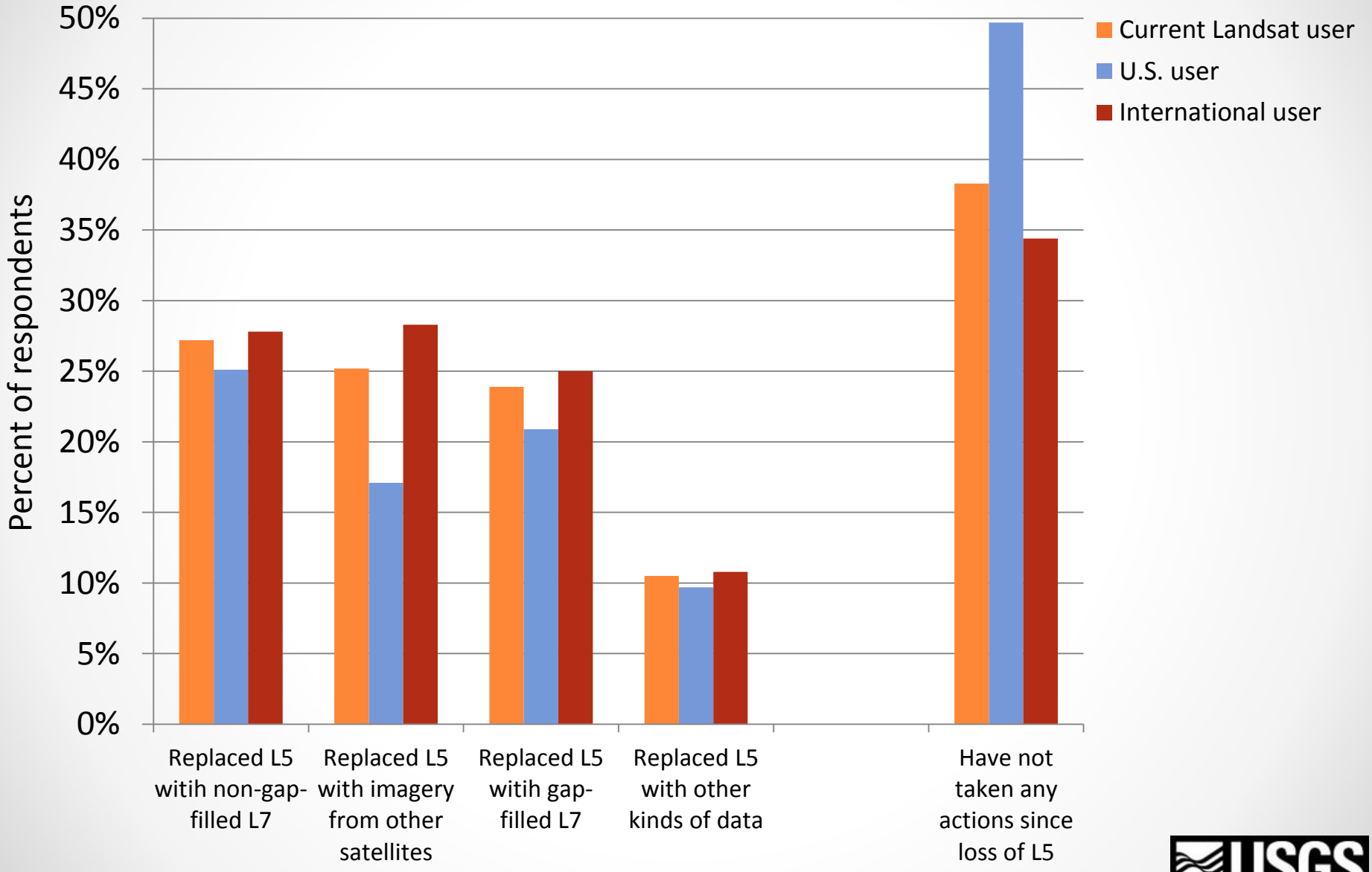
Responses to Loss of Landsat 5 Data



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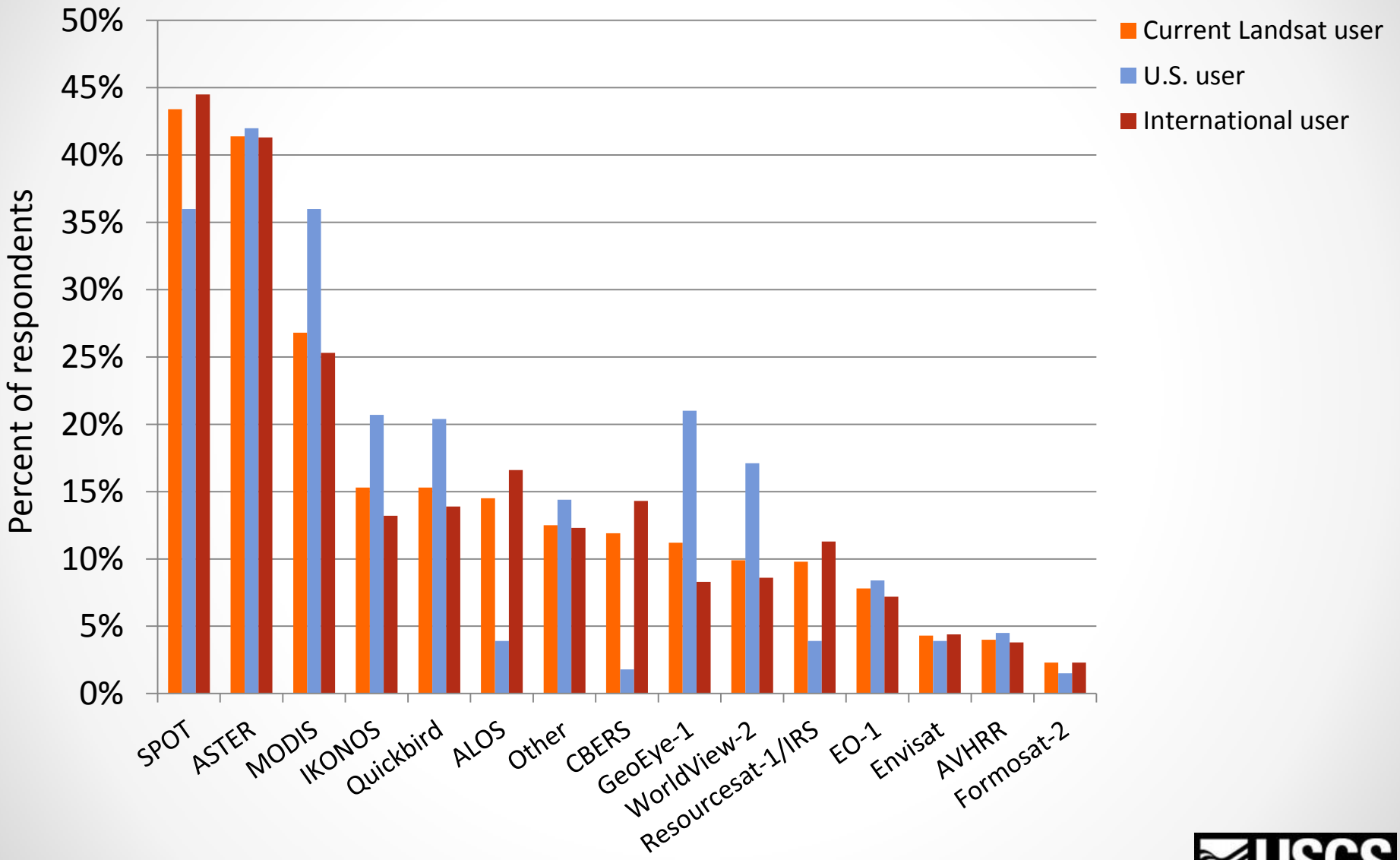
Imagery Used to Replace Landsat 5 Data



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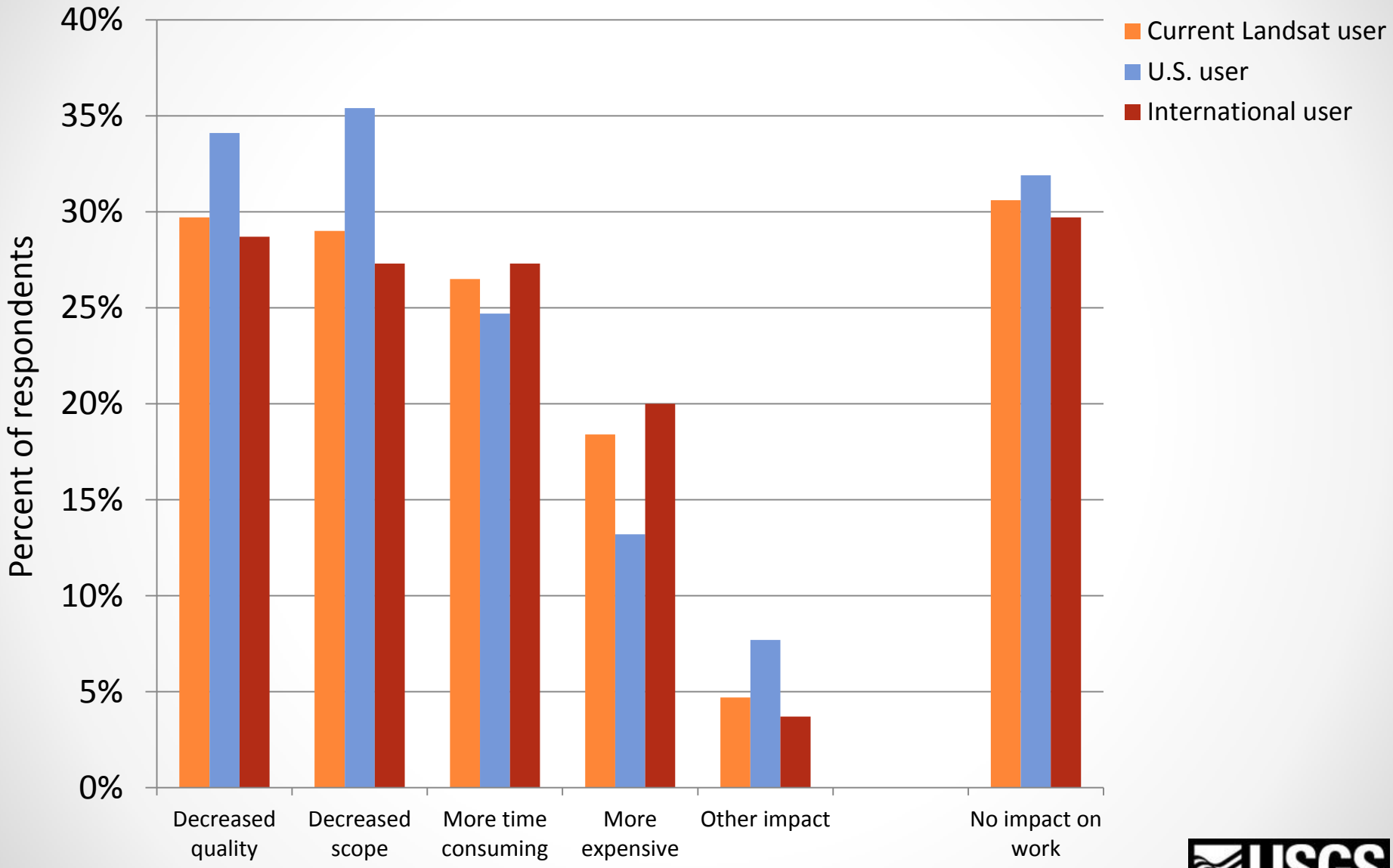
Work Impacts Due to Loss of Landsat 5 Data



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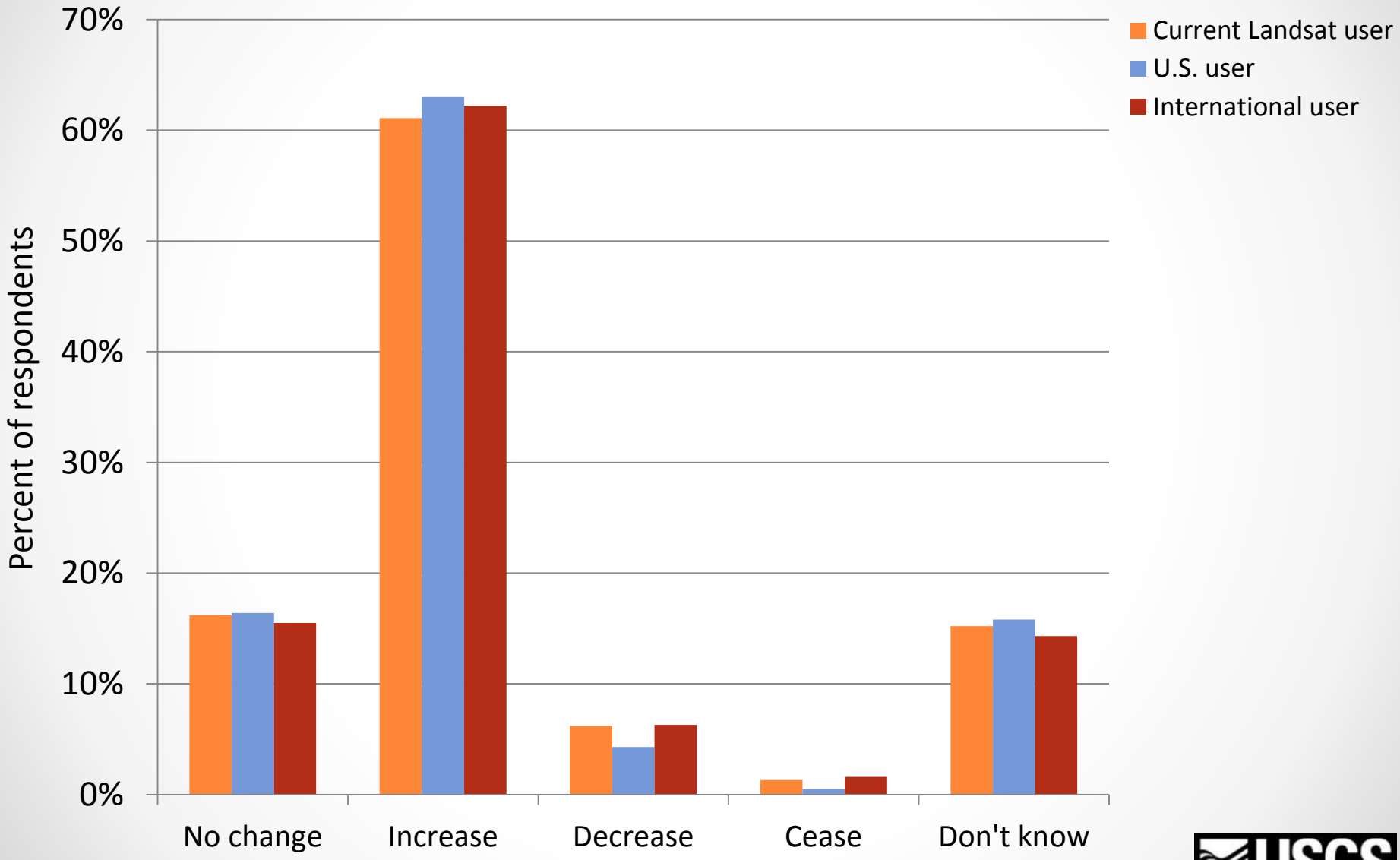
Expected Landsat Use with LDCM Data



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2012 WTP Sample Size

Respondents	Sample size
All	11,275
Responded to WTP questions	8,742
Responded to 2009 WTP design	2,123
Responded to 2012 WTP design	**6,619**

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Double Bounded Analysis

Statistical theory & past studies have shown that asking the 2nd follow-up question reduces the variance of user value estimates & gives more precision.

2009

- Bid amounts were half/twice initial amount – Traditional Bid Design
- All respondents answered questions based on this design

2012

- Bid amounts were .75x/1.25x initial amount – New Bid Design
- ¼ respondents answered questions based on 2009 design
- ¾ answered questions based on 2012 design

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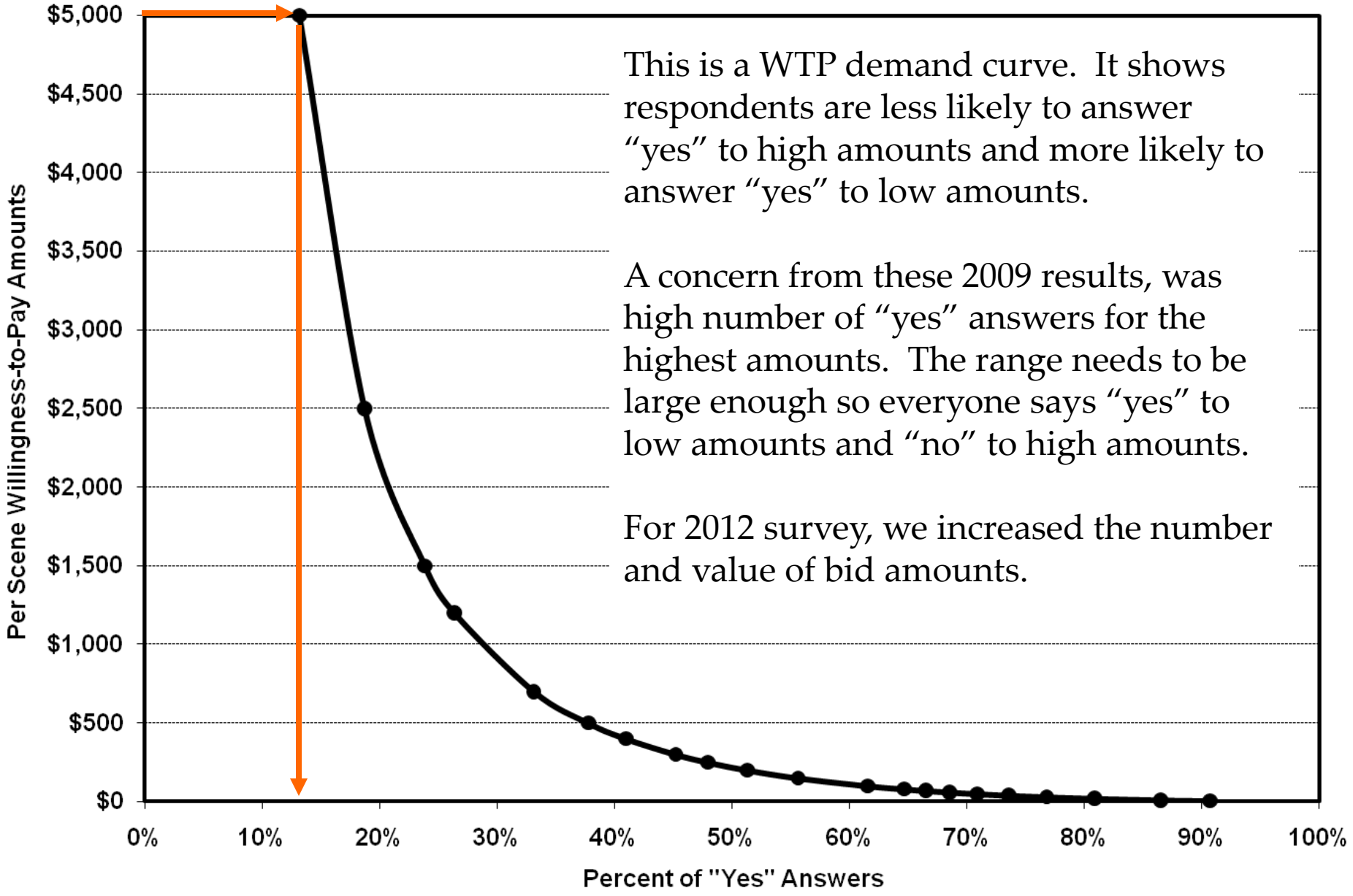
2009 WTP Results

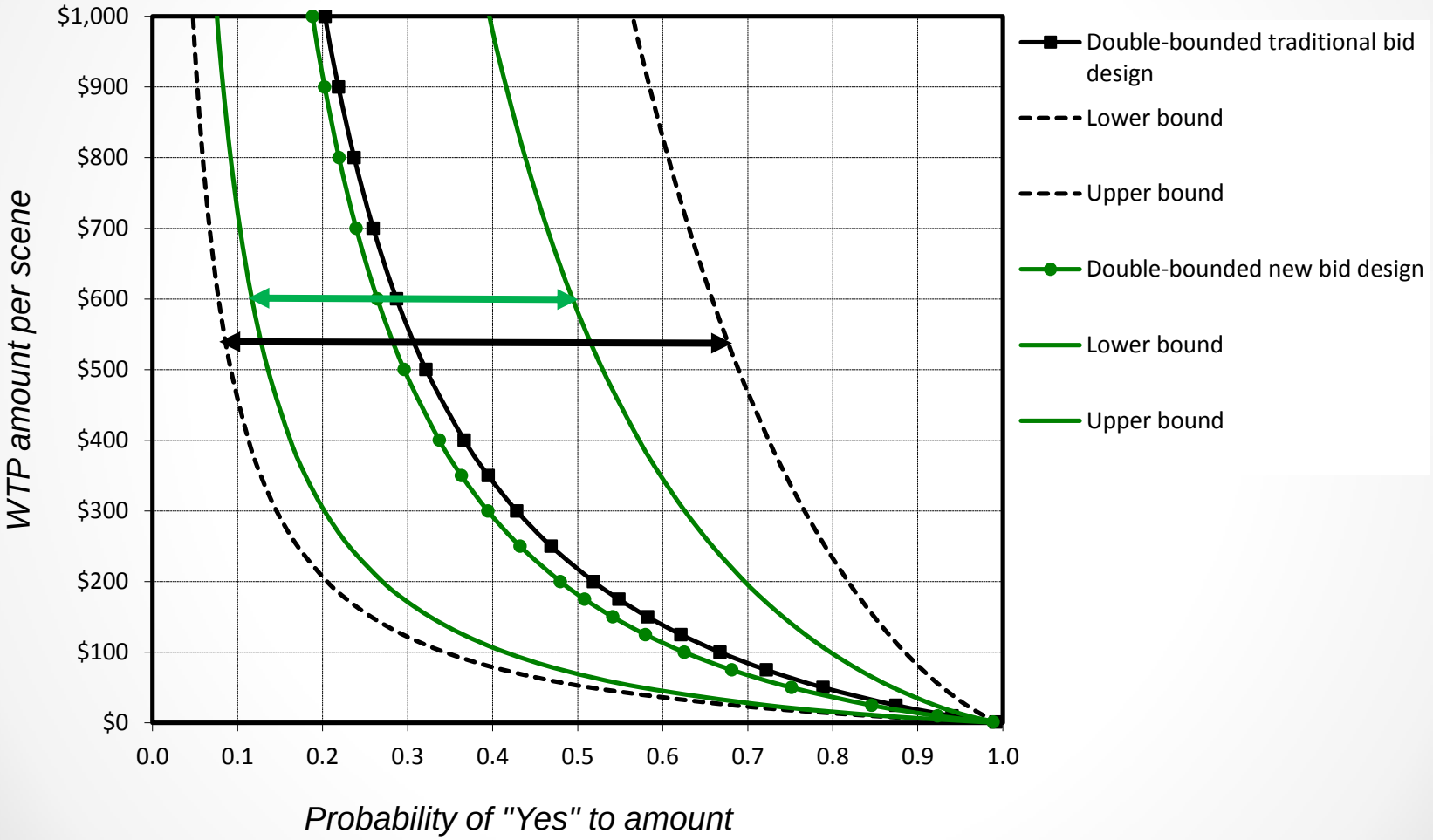


This is a WTP demand curve. It shows respondents are less likely to answer "yes" to high amounts and more likely to answer "yes" to low amounts.

A concern from these 2009 results, was high number of "yes" answers for the highest amounts. The range needs to be large enough so everyone says "yes" to low amounts and "no" to high amounts.

For 2012 survey, we increased the number and value of bid amounts.

Double Bounded Analysis



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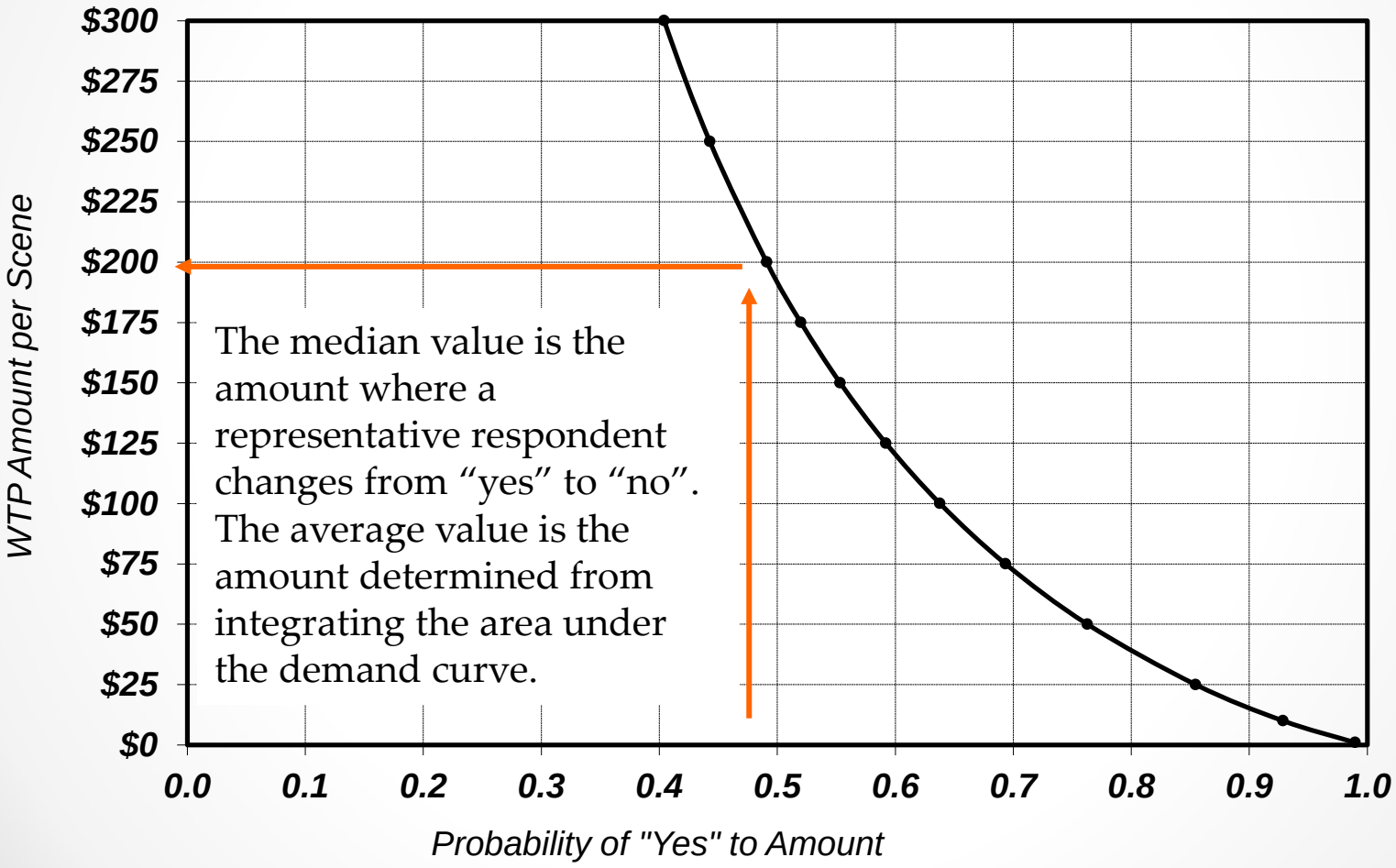
2012 User Value Results



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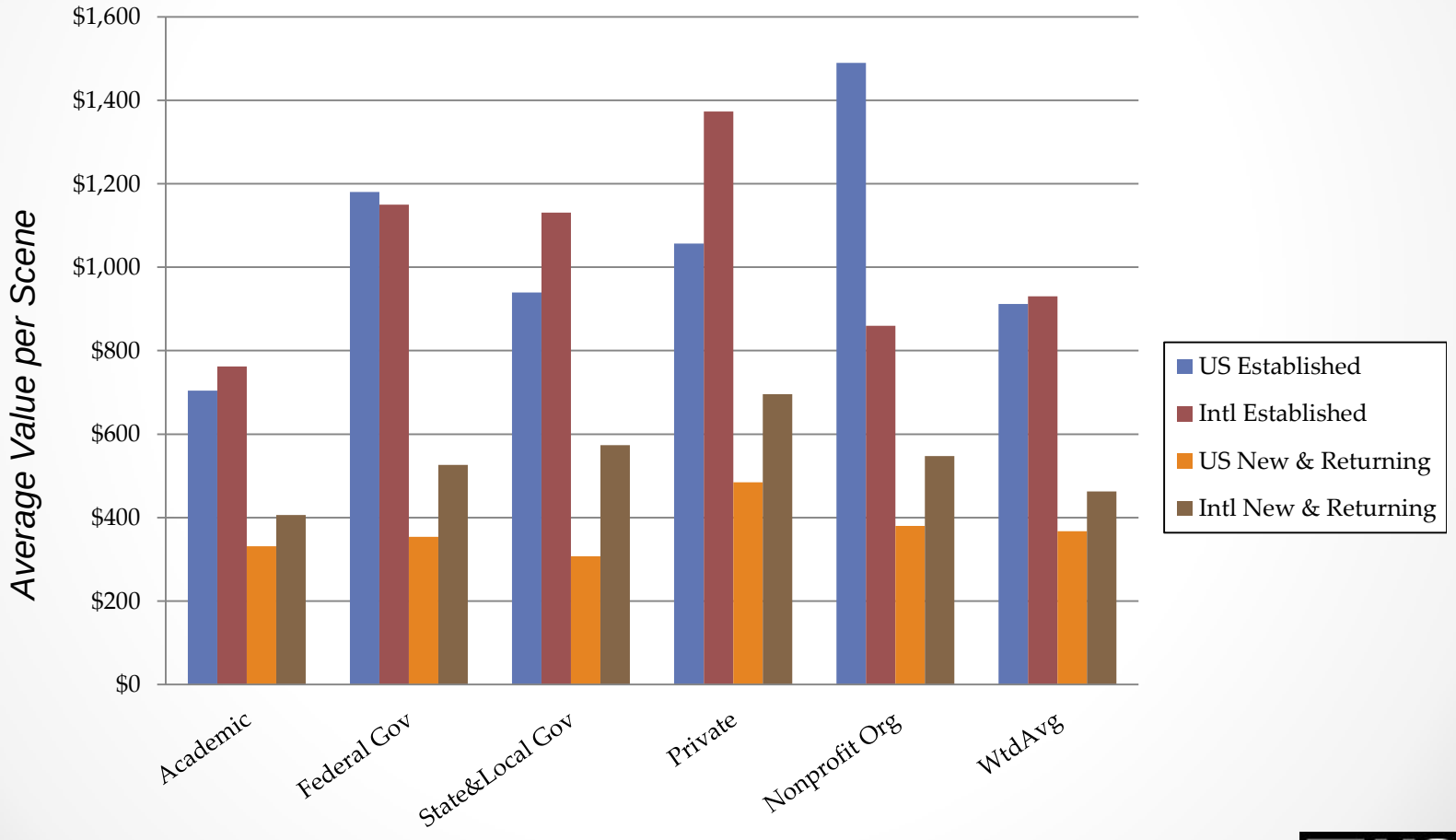
Average Values by Sector



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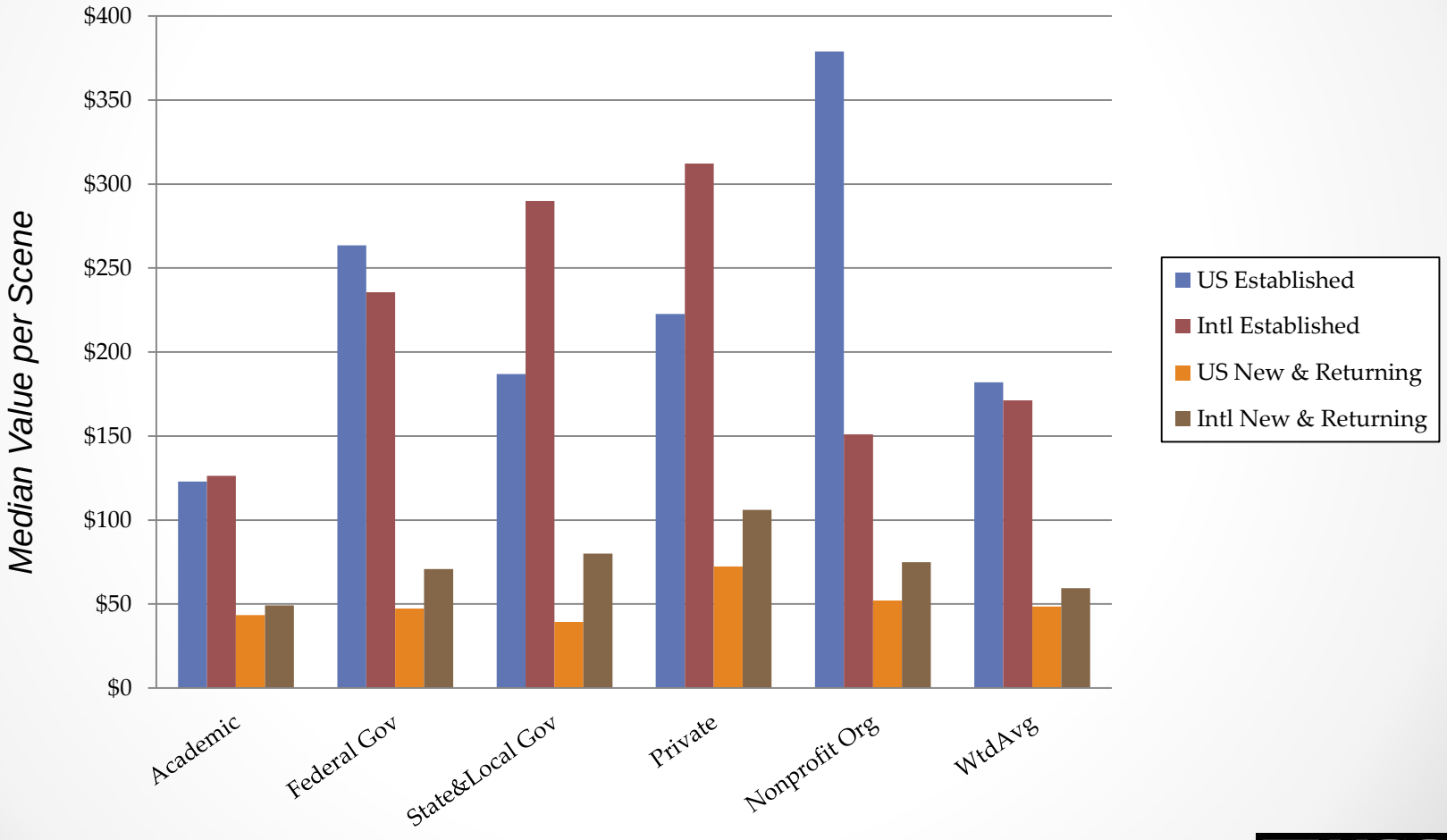
Median Values by Sector



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Issues & Conclusions

- New bid design results in robust double-bounded model results
- Average values reflect the impact of a small number of users with very high valuations
- There remains the conceptual issue of how to summarize the value of a public good where most of the users associate a modest value but where some users attach a very high value to that good

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Economic Rationale for Continuation of a No-Cost Policy

- Landsat imagery has characteristics of a public good, meaning it will not be efficiently allocated through private markets
  - Non-rival – more than one person can use the imagery at the same time, and once the imagery is made publically available, the cost of allowing an additional person to use it is $0

- One often cited role of government is to promote economic efficiency in the use of resources to obtain maximal benefit for society

~Musgrave (1959)

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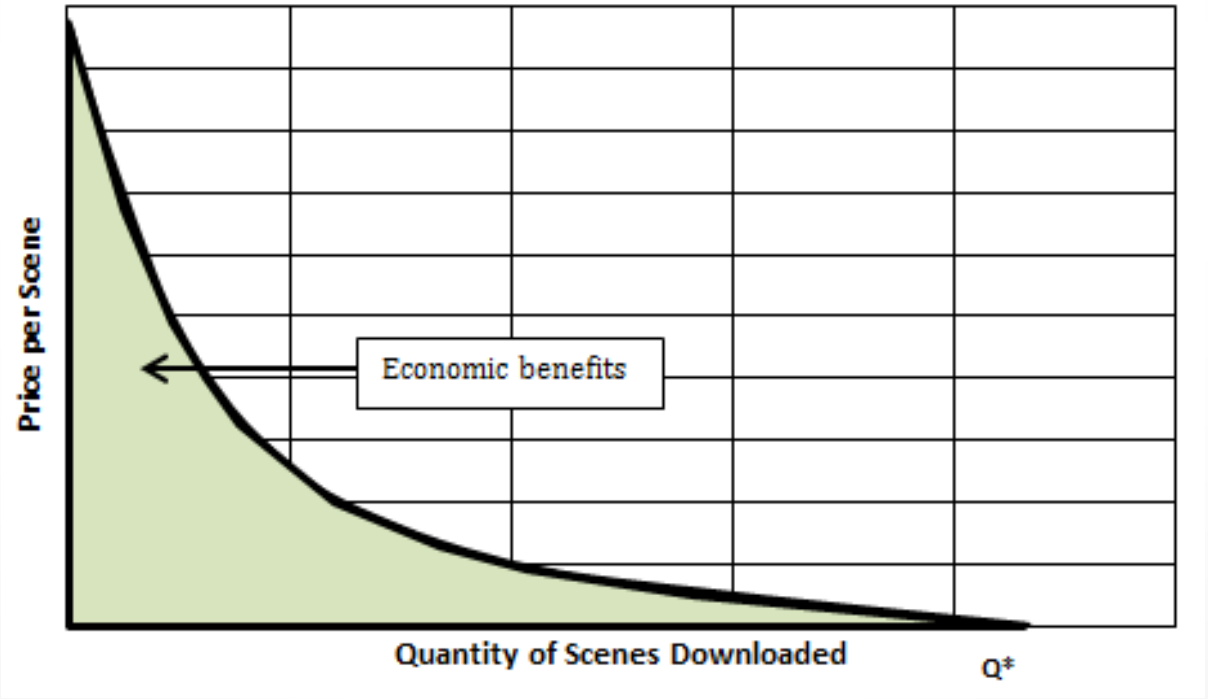
Economic Rationale for Continuation of a No-Cost Policy

When Incremental Cost = $0, Price Set at $0 is Economically Efficient



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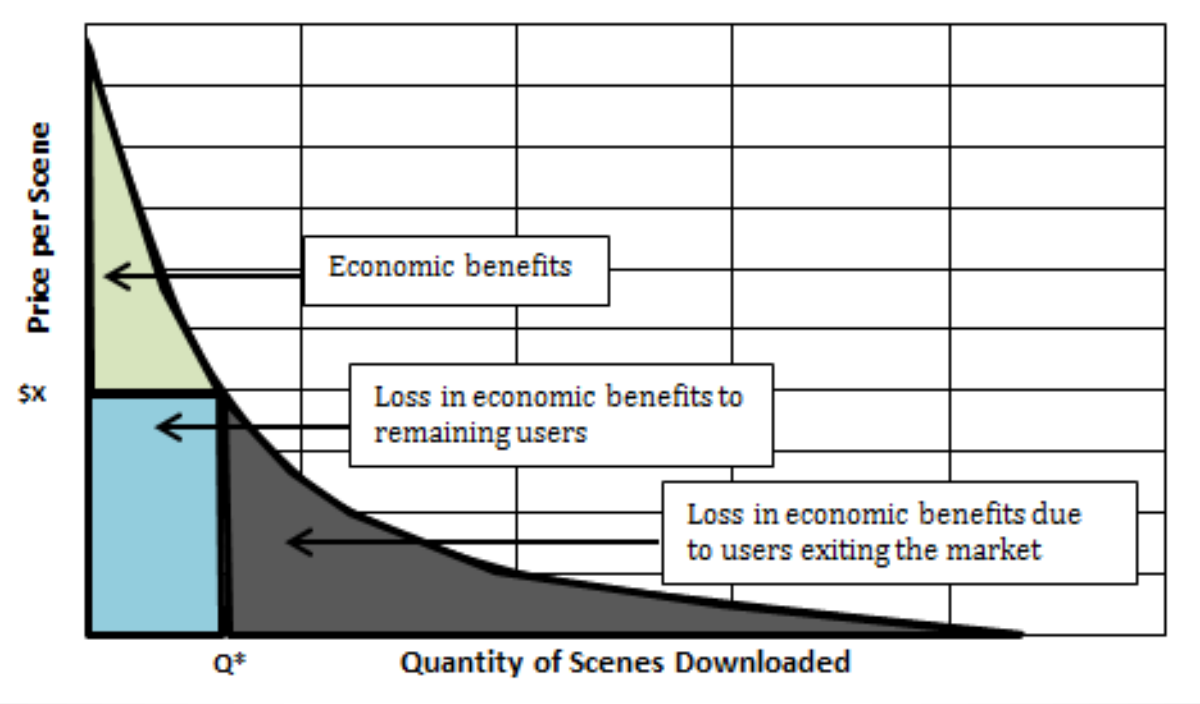
Economic Rationale for Continuation of a No-Cost Policy

When Incremental Cost = $0, Price Set > $0 is Economically Inefficient



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Economic Rationale for Continuation of a No-Cost Policy

- Similar rationale put forward by NOAA:
  - NOAA Information Systems have high "Public Goods" characteristics
  - Difficult to exclude users, making it difficult for private sector to recoup capital costs and therefore supply the service
  - Once produced, data can be provided to additional users at zero marginal cost; to charge would be economically inefficient
  - NOAA therefore provides capital infrastructure (satellites, observing stations, distribution systems, etc.)
  - Policy is for private "value added" industries to provide forecasts and information tailored for their customers, as appropriate

~Weiher, R., NOAA Chief Economist, NAS/OECD Conference
http://www.oecd.org/sti/interneteconomy/40066192.pdf

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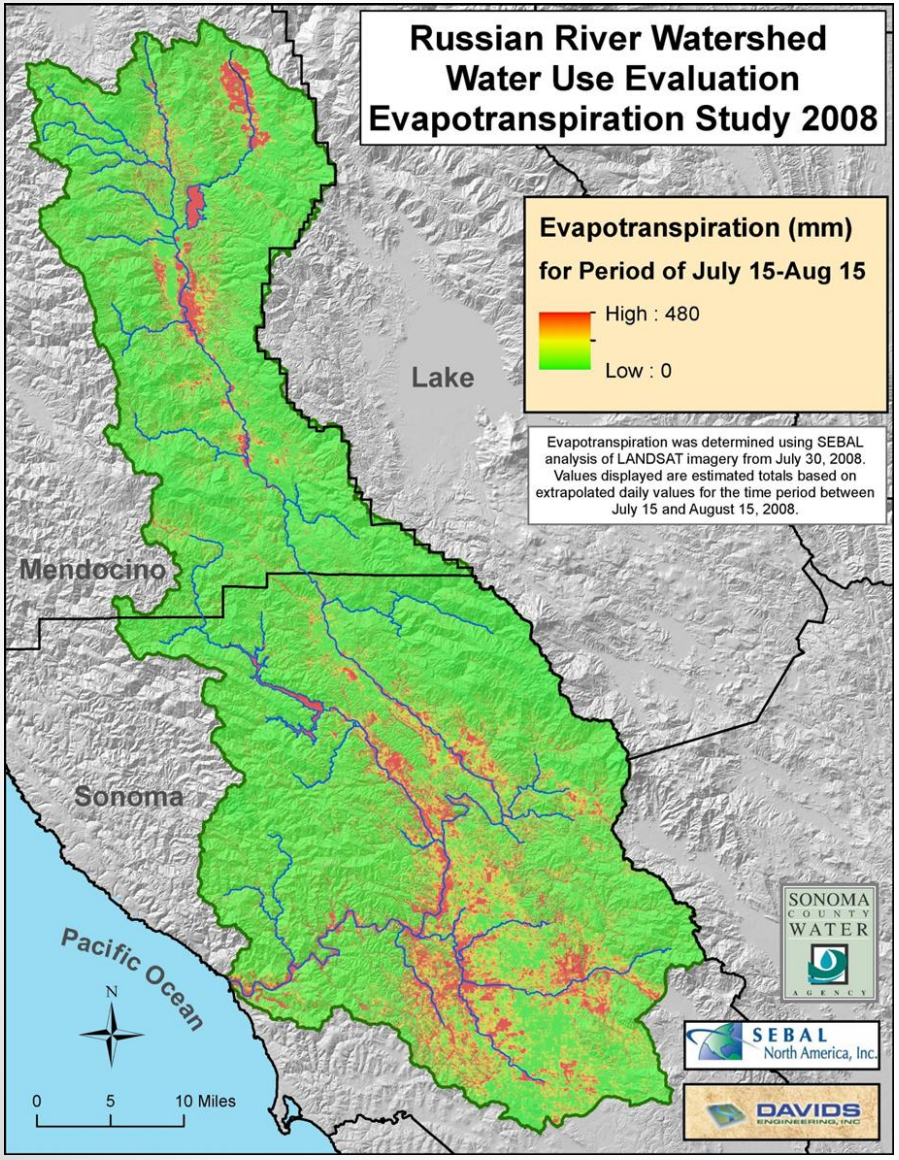
Sonoma County, California



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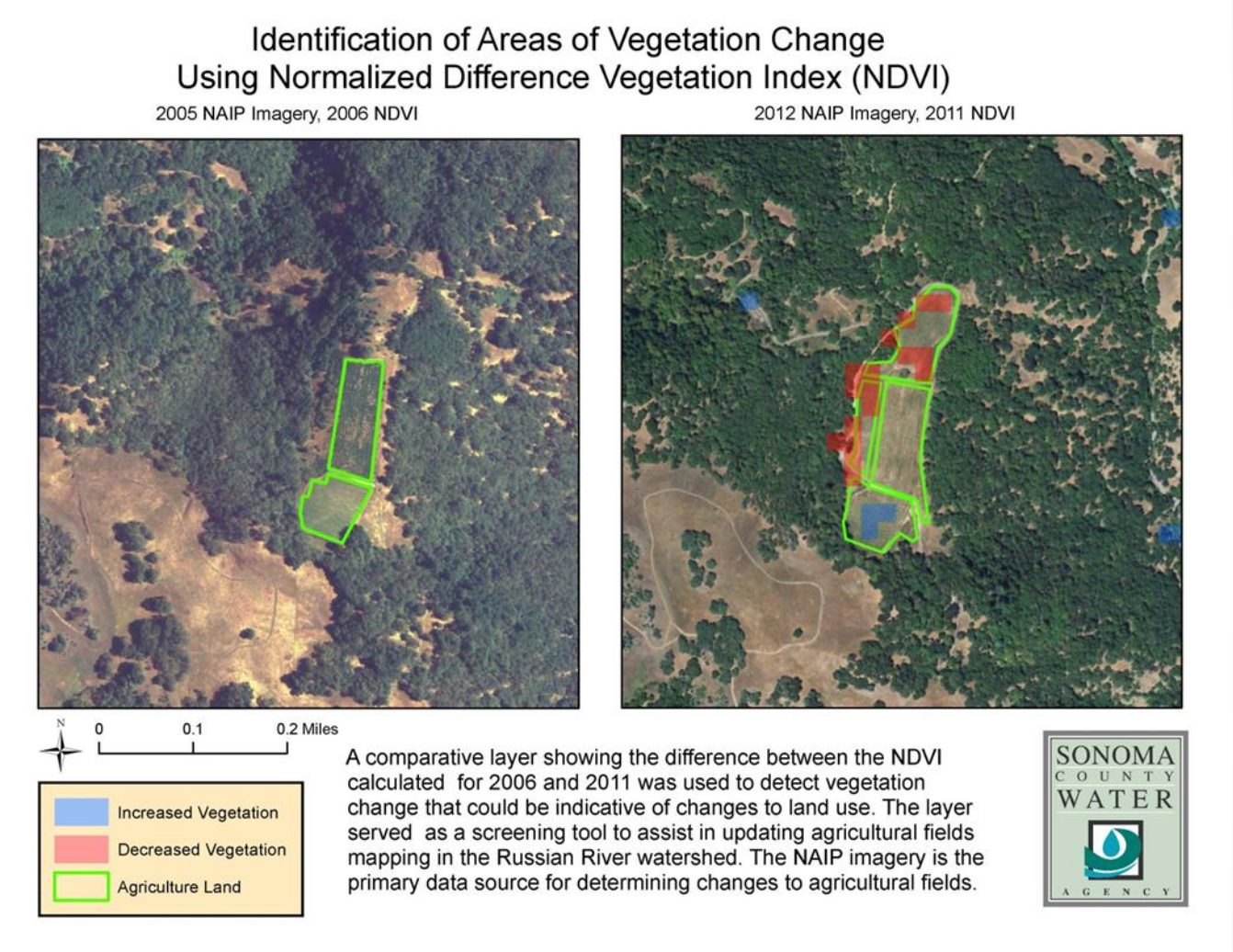
Sonoma County, California



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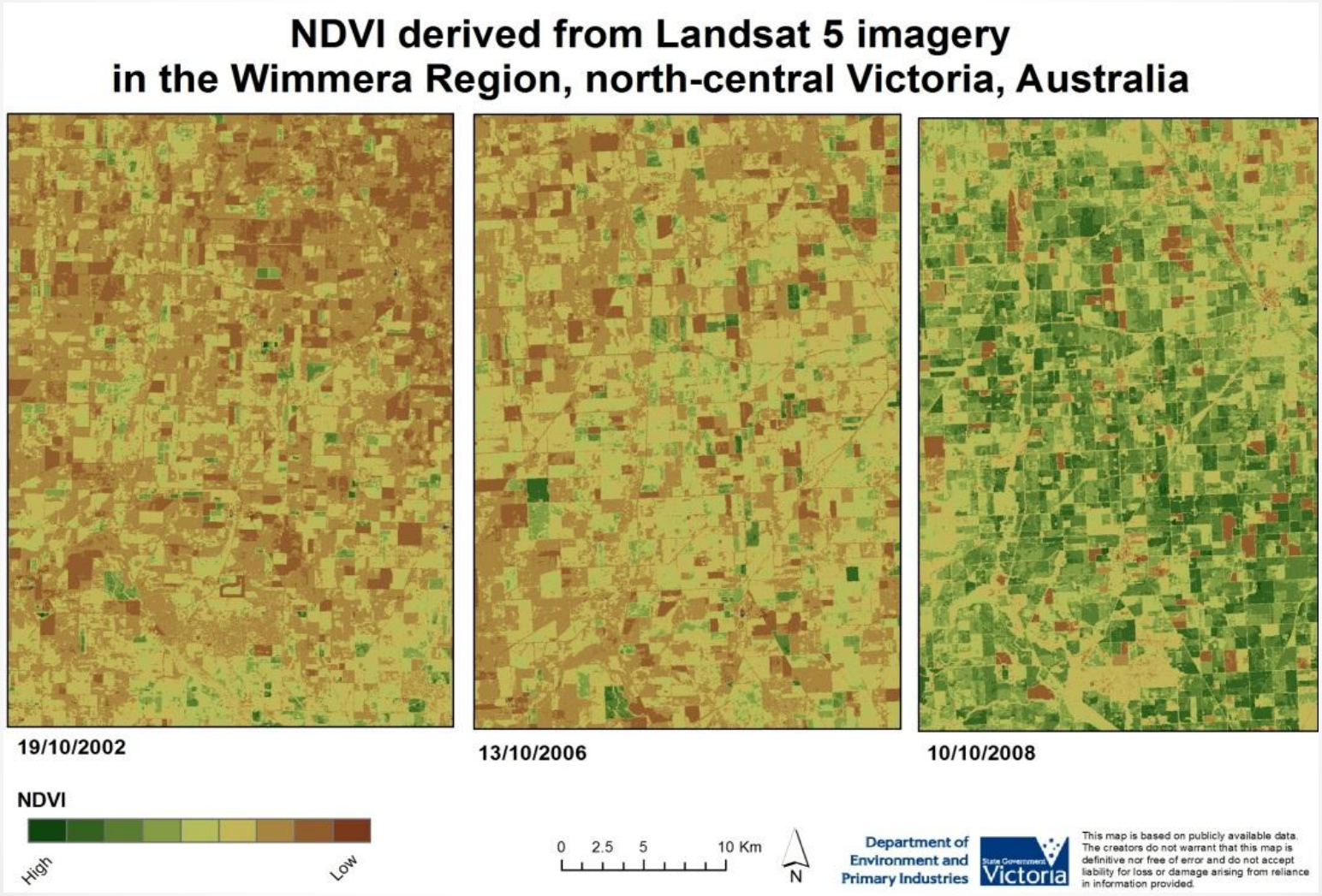
North Central Victoria, Australia



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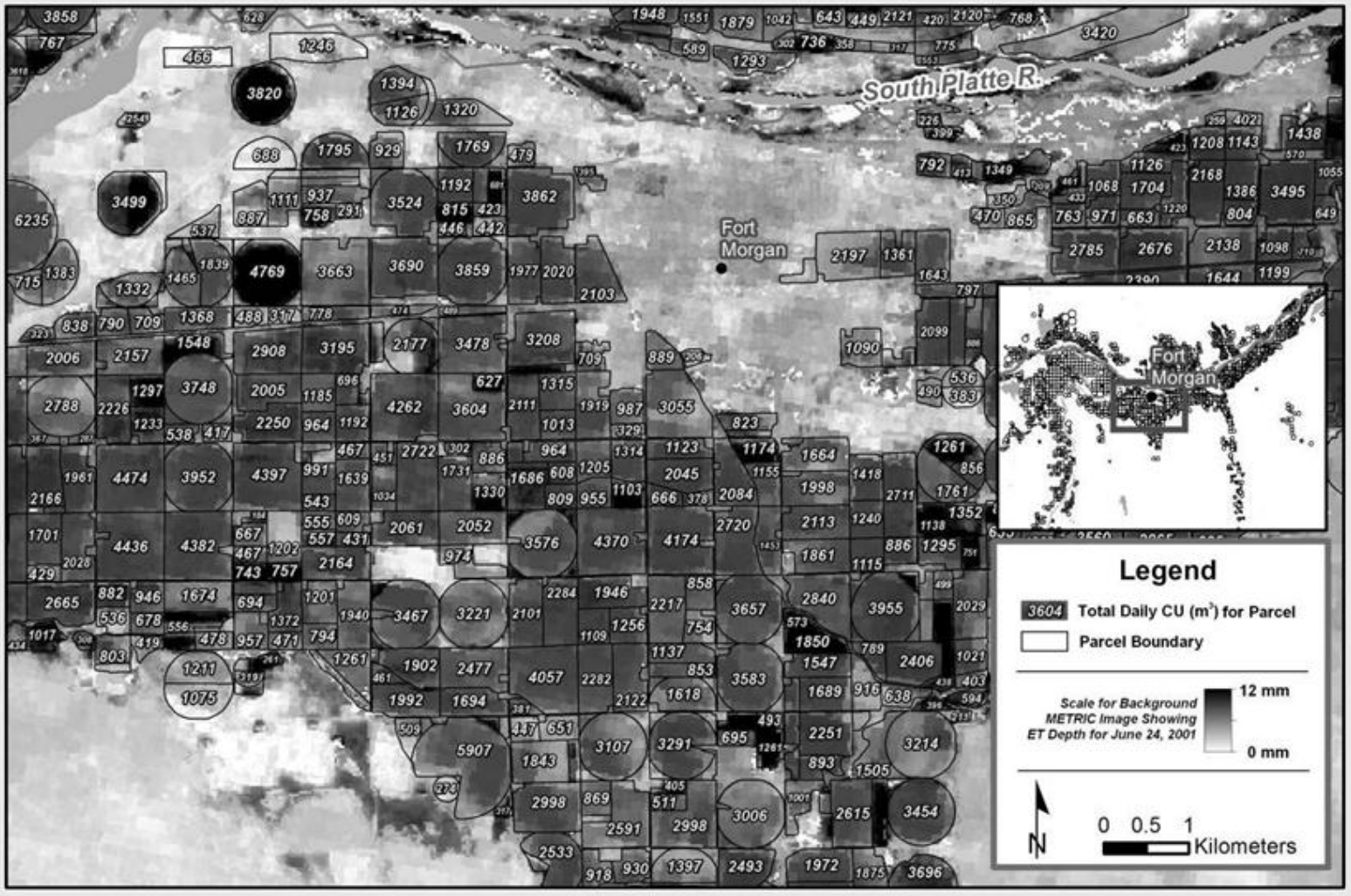
South Platte River, Colorado



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