Chapter 14
The Value of Earth Observations: Methods and Findings on the Value of Landsat Imagery

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Abstract Data from Earth observation systems are used extensively in managing and monitoring natural resources, natural hazards, and the impacts of climate change, but the value of such data can be difficult to estimate, particularly when it is available at no cost. Assessing the socioeconomic and scientific value of these data provides a better understanding of the existing and emerging research, science, and applications related to this information and contributes to the decision-making process regarding current and future Earth observation systems. Recent USGS research on Landsat data has advanced the literature in this area by using a variety of methods to estimate value. The results of a 2012 survey of Landsat users, a 2013 requirements assessment, and a 2013 case studies of applications of Landsat imagery are discussed.

Keywords Landsat imagery • Value of information • Socioeconomic benefits • Remote sensing • Earth observations

14.1 Introduction

The US Geological Survey (USGS) provides a variety of Earth observation information to the public at no cost, such as data from the streamgage and Landsat programs. These data are used extensively in managing and monitoring natural resources, natural hazards, and the impacts of climate change. Given the budget difficulties and potential data gaps faced by Earth observing systems around the

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globe, understanding the socioeconomic and scientific value of these data will be useful to decision-makers for the next decade and beyond.

The process of valuing these data provides a better understanding of the existing and emerging research, science, and applications related to the information provided by these programs. In order to value information, the first step is to identify how the information is used and by whom. This information can be used to target user needs, communicate with users, and, ultimately, improve the provision of the information and identify which applications should be supported. Recent USGS research on Landsat data has advanced the literature in this area by using a variety of methods to estimate value.

Landsat satellite imagery has long been recognized as unique among remotely sensed data due to the combination of its extensive archive, global coverage, and relatively high spatial and temporal resolution. Since the imagery became downloadable at no cost in 2008, the number of users registered with USGS has increased tenfold to more than 50,000 registered users, while the number of scenes downloaded annually has increased more than a hundredfold to over 5 million scenes. It is clear that the imagery is being used extensively, and understanding the benefits provided by open access to the imagery can help inform decisions involving its provision.

While there have been some studies on the value of Landsat, it is not fully understood. To further this understanding, we have used a variety of approaches, both qualitative and quantitative, to evaluate the benefits obtained from the use of Landsat imagery. Three projects will be discussed in this chapter:

1. a 2012 online survey of Landsat users registered with USGS
2. a 2013 requirements assessment to identify operational or decision-supportive uses of Landsat
3. a 2013 case studies of the application of Landsat in water resources

14.2 Challenges in Valuing Landsat Imagery

There are a variety of challenges in assessing the value of Landsat imagery. Landsat is used in a wide variety of applications by hundreds of thousands of people, implying substantial value. For example, Landsat imagery is used extensively in Google Earth,[1] a program that has been downloaded over a billion times. However, a full valuation of the imagery would require a comprehensive knowledge of all the users and uses of the imagery. This knowledge is difficult to attain, given the public-good nature of the imagery.

Landsat imagery has characteristics of a public good because multiple users can use the same image at the same time, and, once an image is made publically available, there is little or no cost associated with providing that same image to additional users. Once the imagery is downloaded, it can be distributed to other users without

[1]Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the US Government.

attribution or incorporated into derived products then distributed to secondary users. The free and open data policy enacted in 2008 resulted in rapidly increasing use accompanied by new types of analysis and use of the imagery in new applications. New users and applications of the imagery are constantly identified (e.g., Miller et al. 2011, 2013), but it is impossible to identify all the downstream users.

In addition, USGS and other private and public entities are developing value-added products such as the LandsatLook Viewer, a full-resolution browsing tool, that make the data accessible to an even wider variety of users. These trends of increasing users, uses, and products indicate the value of Landsat is also increasing. Monitoring and assessing the constantly changing use and value of Landsat imagery represent a unique challenge. Another challenge stems from assigning dollar figures to the value of a public good such as Landsat imagery.

Frequently, monetary value is the most desired and requested type of value by policymakers, but estimating such a value can then be used to argue that the data should no longer be available at no cost. However, the enormous increase in use and applications (and subsequently, in the value generated by the use of the imagery) could not have occurred without the free and open data policy. Despite the barriers to assessing the value of Landsat imagery, the imagery is characterized by a number of positive attributes, which can be used to estimate or demonstrate the value. The more-than-40-year global archive of imagery is unique. When compared to other remotely sensed data, Landsat stands out as the only data available to perform time series analysis over decades almost anywhere in the world. Landsat is used by many people in many different applications (Miller et al. 2013).

For some people, this widespread use clearly demonstrates value; others need more evidence. Landsat users are often willing to demonstrate the value of the imagery. Pursuing case studies and other qualitative work can be successful since the community already recognizes the importance of communicating the value of Landsat. While estimating the value of information from sources such as Landsat imagery continues to be a challenge, there is a range of existing qualitative and quantitative methods that can be used to communicate the value of data and information sources that do not have a market price. There is a growing interest among researchers, practitioners, and policymakers regarding the valuation of data and information sources such as Landsat. For example, the Socioeconomic Benefits Community is a recently formed community of practice focused on assessing the benefits of geospatial and environmental information (http://www.socioeconomicbenefits.org) and the theme of the 2013 Geospatial World Forum was '*Monetizing geospatial value and practices*.' The Socioeconomics Benefits Community and the Geospatial World Forum are not connected in any way

14.3 Valuations of Landsat in the Literature

There is a small but growing literature on the value of Landsat that utilizes a variety of approaches. Broadly, value can be assessed quantitatively or qualitatively. Quantitative methods use numerical units, which are measurable, comparable, and well defined, such as dollars, hours, or lives saved. Monetary values are easy to compare to the costs of the Landsat program, making a cost-benefit analysis potentially possible. Numerical values are also easy to understand, and the value is often immediately apparent. However, it is not possible to quantitatively estimate the total value of the Landsat program. The free and open data policy makes it difficult to track the users and uses of the imagery, which in turn makes it almost impossible to account for all of the benefits generated by Landsat. Additionally, quantitative values are not always the most effective way to engage an audience, particularly if the value was obtained using complicated analyses.

Qualitative value is typically demonstrated through narratives or stories that focus on difficult to quantify benefits, such as the provision of baseline information, the facilitation of decision-making processes, or the ability to ask and answer previously unsolvable research questions. Some may consider qualitative data more readily obtainable than quantitative data. For instance, a case study of a single organization or specific application can be achieved via a few in-depth interviews. This type of research can provide a good story and context for quantitative data. Numbers often mask a richer narrative that can be compelling on its own. However, qualitative data are harder to compare and often stand alone, though they can be presented in one package. It can also leave people asking for a more quantitative measurement of value. A good story can be useful for communication purposes, but for policy and funding purposes, a quantitative value is frequently requested as well.

There have been few quantitative valuations of Landsat imagery, but those that have been conducted have shown significant monetary benefits from the use of the imagery. The most common approach to valuing Landsat has been to demonstrate the cost savings that occur from using the imagery. The Mapping EvapoTranspiration at high Resolution with Internalized Calibration (METRIC) model was developed by the Idaho Department of Water Resources and uses Landsat thermal data, along with data from other sources, to measure agricultural water use as an alternative to traditional methods, such as power consumption coefficients. METRIC is used extensively by western states (Serbina and Miller 2014), either in lieu of or along with traditional water monitoring practices (e.g., measuring headgate flows, traveling to a location to see if it has been irrigated or not). METRIC was originally estimated to cost 80 % less than traditional methods (Morse et al. 2008), but the actual savings have been closer to 90 % (Landsat Advisory Group 2012).

The Landsat Advisory Group (LAG 2012) found substantial potential cost savings from the use of METRIC across the western United States, estimating that \$20–\$73 million could be saved annually. LAG found similarly large cost savings across a variety of Federal and State governmental applications of Landsat imagery. They estimated a savings of \$178–\$235 million annually over 10 applications, ranging from consumptive water use and forestry to agriculture and flood mitigation. Using this approach, costs are relatively easy to calculate and to compare, resulting in defensible numbers. This approach does not take into account any benefits created by the use of the imagery above and beyond that of the cost savings. For instance, an improvement in data quality could lead to a more accurate analysis and thus myriad resultant benefits.

Another approach to valuing Landsat is a cost-benefit analysis. Booz Allen Hamilton (BAH 2012) conducted a cost-benefit analysis using a variety of case studies from many applications of Landsat imagery. Each case study addressed a major use of the imagery and used existing data to calculate the benefits provided by Landsat in that use. A cost-benefit analysis using a Bayesian network approach was used to estimate benefits. BAH determined the return on investment for Landsat to be more than $119 billion over a 15-year period (2003–2018). Cost-benefit analysis is a common approach that tends to be well understood. It covers a lot of different application areas but still results in an aggregate value and can be an efficient approach if existing data are used to determine the benefits of Landsat. There is no available estimate of the contribution of the value of information provided by Landsat to existing economic activity. This analysis used the 1 % rule based on an estimate by Nordhaus (1986), but there has been no research to determine if this is appropriate to apply to the use of Landsat imagery in multiple applications.

The potential revenue from the use of Landsat can also be valued. Bernknopf and his colleagues (2012) used a variety of data, including Landsat thermal data, to determine where the greatest risk of nitrate contamination of drinking water wells was in northeast Iowa. They then used this information to determine the optimum pattern of crop distribution (soybeans and corn) to avoid well water contamination and maximize yield. The integrated assessment approach incorporated models for agricultural production, nitrate leaching, groundwater nitrate dynamics, groundwater protection, and economic optimization. They found that if the optimum crop distribution was applied, the maximized yield would result in an increased profit of $858 (±197) million annually, with a net present value of $38.1 (±8.8) billion into the indefinite future. This approach demonstrates the relative value of Landsat imagery when it is combined with other data, which is most often how Landsat is used. It provides multiple levels where economic benefit could be accrued. For instance, the value of a map that assesses the probability of well contamination could also be quantified based on its contribution to the prevention of health problems. In order to realize the economic benefits of the crop distribution application, new policy would have to be enacted to encourage farmers to plant certain crops (e.g., incentives for planting corn instead of soybeans or leaving land fallow). As the authors state, it is difficult to know the extent to which crop optimization could be obtained, but it will most likely not be perfect, thus reducing the estimated benefits.

In addition to estimating the benefits created by the use of Landsat, the impacts of the loss of Landsat can also be used to assess value. In 2006, the American Society for Photogrammetry and Remote Sensing (ASPRS) conducted a survey of remote sensing professionals (Green 2008). ASPRS estimated an annual loss to respondents of $936 million if Landsat imagery were not available. It is often easier for people to estimate losses rather than calculate benefits, though the value questions asked may have been difficult for some users to answer due to their broad nature.

In addition to the quantitative valuations of Landsat imagery, there are myriad examples of qualitative approaches. These typically are case studies focusing on a specific use or user of Landsat. AmericaView, an organization that supports the use of Landsat through research and education at the state level, produces fact sheets describing the use of and benefits from Landsat (find examples at http://www.americaview.org/downloadable-fact-sheets). A recent NASA (2013) publication describes the benefits of using Landsat in fire, land use and land cover change, water, agriculture, ecosystems, and forestry applications. Qualitative benefits include providing baseline data, increasing accuracy, improving long-term mitigation and planning, and detecting change over time. These qualitative case studies are useful in communicating the applications and direct benefits of Landsat relevant to individual decision and policymakers, as well as providing context to quantitative data.

14.4 Recent USGS Studies of the Value of Landsat

In a continuing effort to assess the value of Landsat imagery, the USGS has undertaken several different projects. The three projects described here each take a different approach to estimating the value of Landsat and provide a mix of qualitative and quantitative data. They each have their advantages and disadvantages and provide different types of complementary valuations, which can be used in diverse policy situations.

14.4.1 Survey of Landsat Users

In April 2012, a survey was sent to 44,731 Landsat users registered with the USGS Earth Resources Observation and Science (EROS) Center (Miller et al. 2013). The response rate to the survey was 30 % with 11,275 current (having used Landsat in their work the year prior to the survey) and 2,198 past Landsat users responding. The results reported here apply to current users registered with USGS. The value of Landsat imagery was measured in a variety of ways. The importance of, dependence on, and impacts of the hypothetical and actual loss of the imagery were explored. The monetary value of Landsat was estimated using the contingent valuation method, a nonmarket approach to valuing public goods.

On average, respondents used Landsat in 46 % of their work. Three-quarters of the users stated that Landsat imagery was somewhat or very important in their current work, and three-quarters also indicated that they were somewhat or very dependent on Landsat to complete their work (Miller et al. 2013). Importance and dependence were found to be related to the level of use of Landsat imagery in work. More than 60 % of heavy users of the imagery (using Landsat in 71 % or more of their work) were very dependent on the imagery, compared to a quarter of light users (using Landsat in 30 % or less of their work; see Fig. 14.1). More than 65 % of heavy users considered Landsat to be very important to their work, compared to a quarter of light users. Dependence also correlated to the percentage of work using Landsat that was operational (continuous or ongoing work that either relies on the consistent availability of Landsat imagery or is mandated). Very dependent users

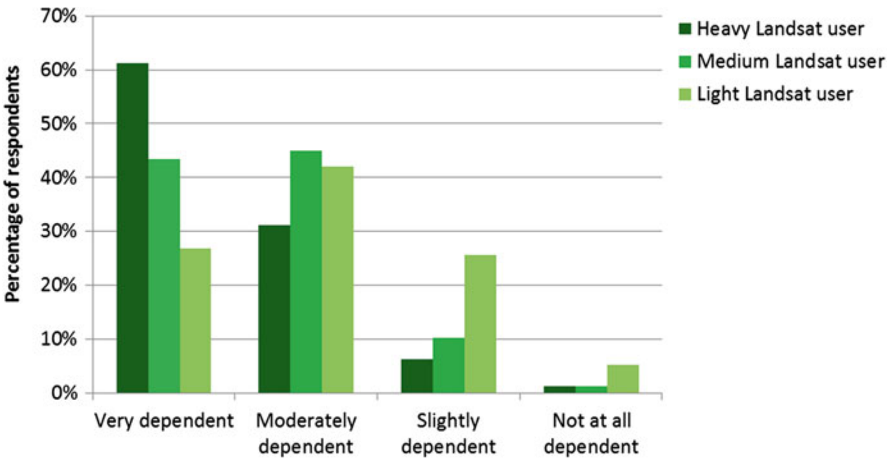

Fig. 14.1 Dependence on Landsat imagery among users with varying levels of use of Landsat imagery (Reproduced from Miller et al. 2013, p. 22, Fig. 14)

estimated a higher percentage of their work to be operational (40 %) compared to users who were not at all dependent (24 %).

Users were also asked to respond to a hypothetical situation in which all Landsat imagery (new and archived) was no longer available. More than 65 % of the users reported that they would have to discontinue at least some of their work; on average, these users would discontinue half of their work, indicating a strong dependence on the imagery (Miller et al. 2013; see Table 14.1). The majority (86 %) would use substitute information for some of their remaining work. Satellite imagery was the most common substitution, but other data sets and fieldwork would also be used by more than half of those who would use substitute information. The use of often expensive and time-consuming fieldwork as a substitute data source seems to indicate that fieldwork might be the only viable alternative for certain types of data.

During the time the survey was being administered, one of the two Landsat satellites, Landsat 5, was not acquiring new imagery. Landsat 7 was acquiring new imagery at the time but delivering images with missing data due to a technical issue. This unique situation provided an opportunity to determine the actual responses of users to the loss of one segment of Landsat imagery. The majority of users (79 %) had used Landsat 5 imagery in the year prior to the survey, and more than two-thirds of Landsat 5 users (69 %) believed their work had been impacted negatively by the loss of Landsat 5 imagery, whether due to reduced quality or scope of work or more time spent on work (Miller et al. 2013). A quantitative measure of the loss was the amount spent on imagery or other data to replace Landsat 5 data. Though only 8 % of the Landsat 5 users spent money on substitute information in the 30 days prior to the survey, they spent an average of $3,765. The population of users registered with EROS spent an estimated $9.4 million in the 30 days prior to the survey to obtain imagery or other data to replace Landsat 5 data.

The contingent valuation method (CVM) was used to estimate the economic value derived from the use of Landsat imagery, known as consumer surplus.

Table 14.1 Percentages of current Landsat users who would take certain actions if Landsat imagery were no longer available

Action taken if Landsat was no longer available	Current Landsat users	US users	International users
For work that uses Landsat, percentage of users who would…	*n≥5,903*	*n≥1,703*	*n≥4,200*
…discontinue some of work	66 %	66 %	66 %
…use substitute information in some of work	86 %	83 %	87 %
…continue some of work without substitute information	57 %	46 %	61 %
For those who would use substitute information, percentage of users who would use…	*n≥4,779*	*n≥1,301*	*n≥3,478*
…different imagery	98 %	97 %	98 %
…other data sets	59 %	49 %	63 %
…on-the-ground fieldwork	57 %	46 %	61 %

Reproduced from Miller et al. 2013, p. 24, Table 8

Consumer surplus provides the best measure of societal benefits resulting from government programs (Office of Management and Budget 1992). CVM is a survey-based stated preference or intended behavior technique recommended for use by Federal agencies (US Environmental Protection Agency 2000; US Water Resources Council 1983). Users were presented with a hypothetical, though probable, scenario in which both Landsat 5 and 7 became inoperable before Landsat 8 was launched, creating a data gap. As mentioned previously, Landsat 5 was, at the time, not acquiring new imagery, so this situation had already partly come to pass. If a data gap were to occur, users may have had to obtain imagery elsewhere. Users were asked if they would be willing to pay a certain dollar amount (each respondent received a predetermined amount ranging from $10 to $10,000) for a scene equivalent to a Landsat scene in the event of a data gap. They were instructed to assume they were restricted to their current budget, and the money to pay for this imagery would have to come out of that budget.

Differences between certain user groups in the benefits they received from the imagery were hypothesized. A similar user survey conducted in 2009 (Miller et al. 2011) revealed significant differences in benefits among sectors, and similar differences were expected for this survey. Many users were new users (43 %), or those who had never used Landsat before it became available at no cost in 2008, and these users were expected to receive fewer benefits than established users (41 %), or those who used Landsat consistently both before and after the no-cost data policy was enacted (Miller et al. 2013). There was also a group of returning users (16 %) who were similar to the new users; the two groups were combined for the CVM analysis. Lastly, the users were divided into US and international users to better understand the benefits accrued by each group.

The analysis looked at four groups (US and international established and new/returning) to determine the economic benefits for each one. The differences in

Table 14.2 Annual aggregate economic benefits to Landsat users registered with the US Geological Survey from Landsat imagery distributed by the Earth Resources Observation and Science (EROS) Center in 2011

Landsat user group	Number of scenes obtained in 2011 from EROS	Average economic benefit per scene	Annual economic benefit (millions)	Lower bound (millions)
US users				
Established	1,687,600	$912	$1,539	$1,399
New/returning	692,508	$367	$254	$236
US total	*2,380,108*		*$1,793*	*$1,635*
International users				
Established	320,522	$930	$298	$270
New/returning	218,196	$463	$101	$93
International total	*538,718*		*$399*	*$363*
Total	**2,918,826**		**$2,192**	**$1,998**

Reproduced from Miller et al. 2013, p. 36, Table 13

benefits among sectors were accounted for in each group. The annual economic benefit from Landsat imagery obtained from EROS in 2011 was just over $1.79 billion for US users and almost $400 million for international users, resulting in a total economic benefit of $2.19 billion (see Table 14.2; Miller et al. 2013). This estimate does not represent the entire societal benefit from Landsat imagery because it accounts only for the benefits received by direct users (i.e., those that download scenes directly from USGS). Any benefits that users receive from derived or value-added products that include Landsat imagery were not estimated. This estimate is also a reflection of economic value received by users under the free and open data policy. If a price is charged, it is expected that the number of users will decrease, as well as the number of scenes each remaining user obtains. This decrease in the number of users and the amount of imagery used would reduce the societal benefits of the imagery while not creating any additional benefits, resulting in a net loss of benefits.

14.4.2 Requirements Assessment

In 2012, under the direction of the White House Office of Science and Technology Policy (OSTP), a National Earth Observations Task Force conducted an assessment of 362 Earth observation systems (space, air, land, and sea platforms) with regard to their contributions within a framework of 13 societal-benefit areas (National Science and Technology Council 2014). Among 132 satellite systems considered, Landsat ranked second highest in impact, surpassed only by the Global Positioning System. Findings from this assessment informed the National Plan for Civil Earth

Observations (National Science and Technology Council 2014), which was released from the White House on July 18, 2014.

In a related 2013 effort, a USGS National Land Imaging Requirements Pilot Project elicited 151 distinct, representative Federal-agency applications where Landsat data are used routinely to produce consistent services or information products. The study identified operational or decision-supportive uses of Landsat in a broader variety of fields than was previously recognized. The associated USGS report (Vadnais and Stensaas 2014) highlights key requirements such as the need for an eight-day (or fewer) satellite site-revisit cycle, 30-m pixel resolution, and simultaneous Visible to Short Wavelength InfraRed (VSWIR) and thermal measurements. For example, the assessment found that 60 % of elicited threshold user requirements call for eight-day or more frequent revisit.

14.4.3 Case Studies

Serbina and Miller (2014) examined 25 applications of Landsat imagery in water resources to shed more light on the benefits accrued from the imagery and to gain a better understanding of the program's value in water resources applications. The users included Federal, State, and county governments; private companies; and non-governmental organizations. Users applied Landsat in consumptive use mapping, water budgeting and accounting, irrigation improvements, resolving water rights cases, humanitarian aid, flood mapping and monitoring, and land cover mapping. The case studies tell a more descriptive story of how Landsat imagery is used and what its value is to different private and public entities, but include quantitative valuations where possible. A few case study findings are outlined below.

In the private sector, E. & J. Gallo, the largest winery in the world, is using Landsat imagery in a modified METRIC model to improve yield and grape quality while decreasing the amount of water applied by 20–30 %, depending on the region (Serbina and Miller 2014). More precise water monitoring and application has enabled Gallo to increase the quality of the grapes and thus improve the quality of its wine. Gallo has also spent less money on irrigation and pruning (too much water causes excess foliage which must be removed). In Chile, the use of Landsat and METRIC (see Fig. 14.2) has led to cost savings of $80/acre in 3,700 acres of olive orchards, and a 30–60 % reduction in water applied to 6,000 acres of vineyards. Grape quality has also improved by 30–35 %.

The US Bureau of Reclamation uses Landsat extensively in estimating evapotranspiration and evaporation, as well as identifying types, locations, and acreages of crops, irrigated lands, and riparian vegetation (Serbina and Miller 2014). The agency saves approximately $40,000 each year by using Landsat instead of traditional methods for estimating evapotranspiration on agricultural and riparian lands. Unlike traditional on-the-ground methods, Landsat is able to provide complete coverage of the lands, which need to be monitored; if this was to be replicated through fieldwork, it would cost around $580,000 each year. Aside from the cost savings to

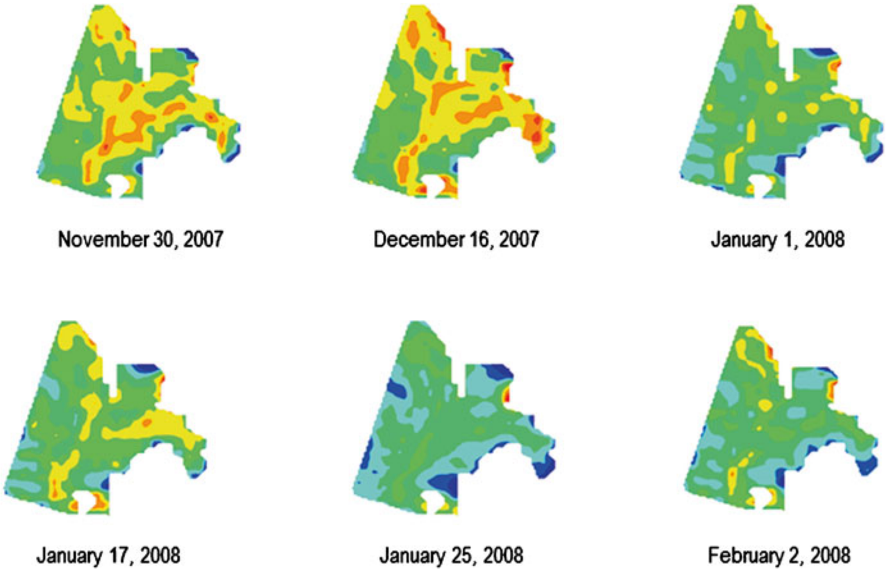

Fig. 14.2 Crop coefficient mapping of a drip-irrigated vineyard in Chile using images from Landsat 7 ETM+. *Blues* and *greens* indicate more evapotranspiration and *yellows*, *oranges*, and *reds* indicate less evapotranspiration (Courtesy of Universidad de Talca. Reproduced from Serbina and Miller 2014, p. 28, Fig. 20). From L-R, top to bottom: 30 Nov 2007, 16 Dec 2007, 1 Jan 2008, 17 Jan 2008, 25 Jan 2008, 2 Feb 2008

the agency, the reports and data sets they produce are used by myriad other entities, including Federal and State agencies, universities, and private businesses. Without this information derived from Landsat imagery, these organizations would have to spend money to produce or find alternative data.

Multiple western states use Landsat imagery to monitor consumptive water use (Serbina and Miller 2014). The State of Wyoming is using Landsat imagery in the METRIC model to assess evapotranspiration so they can more efficiently meet their annual consumptive use reporting requirements under the Upper Colorado River Basin Compact. The use of Landsat and METRIC has yielded consistent savings from a third to as much as one-half of the total costs compared to on-the-ground methods. Colorado, Idaho, and Nevada (see Fig. 14.3) are also using Landsat for water management.

Landsat imagery has proven critical in preserving minimum needed stream flows, as well as settling water rights disputes (Serbina and Miller 2014). In the Klamath Basin in Oregon, Landsat and METRIC were used to determine which water rights were being used to their fullest extent. The Klamath Basin Restoration Agreement Water Use Retirement Program could then make offers to purchase water rights which would result in the largest increase in in-stream flows. In Idaho, the A&B Irrigation District, a senior groundwater user, claimed that junior groundwater users were pumping too much water. Landsat and METRIC analysis of the

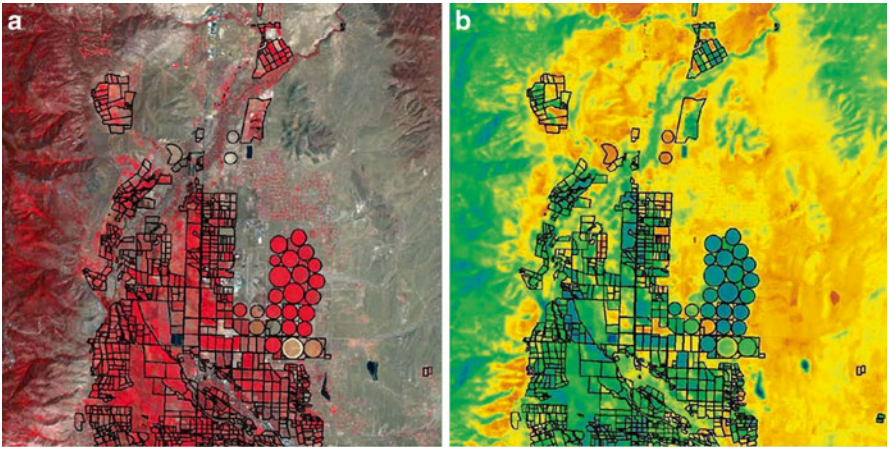

Fig. 14.3 Images of Northern Mason Valley, Nevada, showing irrigated and nonirrigated lands (Courtesy of Desert Research Institute. Reproduced from Serbina and Miller 2014, p. 12, Fig. 7). From left to right: (**a**) Landsat false-color infrared image showing irrigated lands in *red*, Northern Carson Valley, Nevada, August 3, 2009. (**b**) Landsat image showing evapotranspiration using energy balance (irrigated lands in *blue*), Northern Carson Valley, Nevada, August 3, 2009

current evapotranspiration in the district did not show a water shortage in the area (see Fig. 14.4), and A&B's claim was dismissed.

Landsat has also been used for water exploration in developing nations. Amid the Darfur Crisis in 2004, more than 250,000 Sudanese refugees were forced to relocate to camps in the desert landscape of eastern Chad (Serbina and Miller 2014). Many refugee camps did not have access to water on site. Every passing day without an adequate supply of water meant the loss of 200 children's lives in the camps, and water trucking cost millions of US dollars per day. Radar Technologies International used Landsat imagery in their WATEX System to help identify and drill 1,800 water wells, with a drilling success rate of 98 %, contributing to the survival of hundreds of thousands of people (see Fig. 14.5).

14.5 Conclusions

Landsat satellite imagery is highly valued by users in a wide range of application areas and sectors. Many users would be negatively impacted by the loss of Landsat imagery; some were already affected during the gap in Landsat 5 provision. The value of Landsat can be measured monetarily, but it can also be measured by lives saved, by improvements in accuracy or quality, and by advancements in scientific research. Though valuing a public good such as Landsat imagery can be difficult, using a variety of methods provides different types of valuations. The valuations can

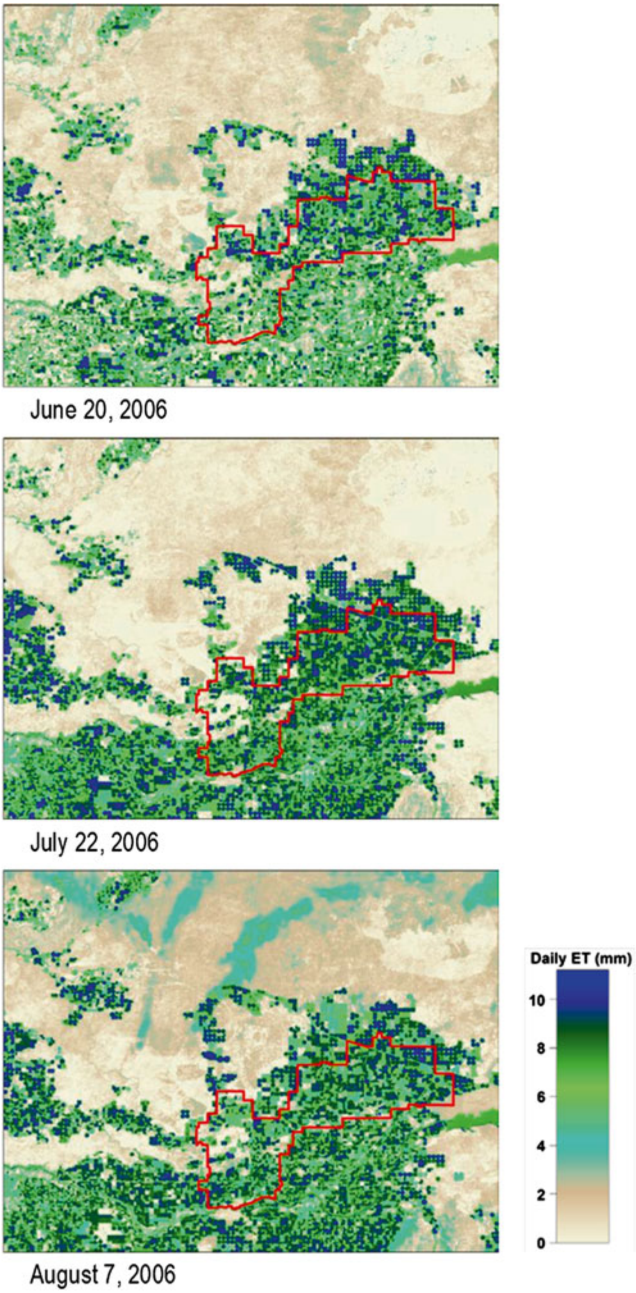

Fig. 14.4 METRIC evapotranspiration images of A&B Irrigation District (outlined in *red*), Idaho. Courtesy of Idaho Department of Water Resources. *ET* evapotranspiration, *mm* millimeters (Reproduced from Serbina and Miller 2014, p. 40, Fig. 29). From top to bottom: 20 June 2006, 22 July 2006, 7 August 2006

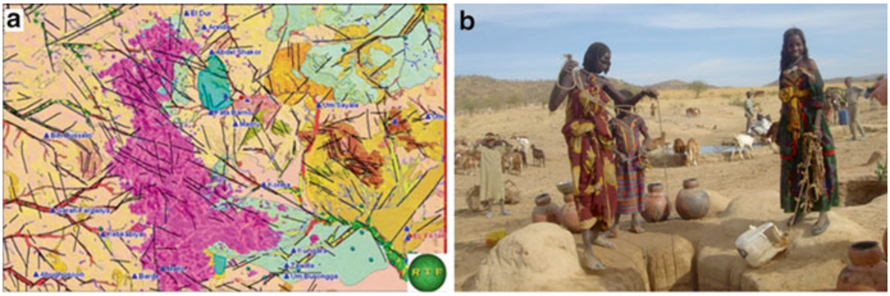

Fig. 14.5 Successful water well drilled in Eastern Ouaddai, Chad, located based on information provided by Landsat images processed in the WATEX model (Courtesy of Radar Technologies International. Reproduced from Serbina and Miller 2014, p. 42–43, Figs. 34 and 35). From left to right: (**a**) Potential water drilling sites map for West Darfur, Sudan, produced by WATEX. (**b**) Successful water well in Wadi Gaga Campsite, Eastern Ouaddai, Chad

then be tailored for use in varying communication situations with different audiences. The approaches used for valuing Landsat imagery can also be used to estimate the value of other Earth observations and information with public-good characteristics. While determining the full value of Landsat imagery and similar data sources may not be possible, the use of multiple valuation approaches can provide ample evidence of the benefits accrued from such information.

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