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Geography in Laser-light: Using Lidar to Map the Metroscape

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Chances are that at some point in your life, without even knowing it, you’ve been hit by a laser. It may have been mounted on an airplane, helicopter, or even a satellite. Your dwelling, your car or bike, perhaps even your pet may have also been hit. The fact that you’re still here to tell the tale is because the laser used was far too weak to damage you and was part of a system known as light imaging, detection, and ranging—“lidar” for short.

Whether orbiting the earth, circling the skies right above us, or just trundling down a road in the back of a pickup truck, lidar equipment has been put to use by engineers and scientists (and sometimes even artists) for projects ranging from the mundane to the monumental. Like almost all technologies, it’s hard to keep pace with the rate of improvements and changes to lidar, but every increase in its fidelity allows our region to know more about our resources, risks, and opportunities.

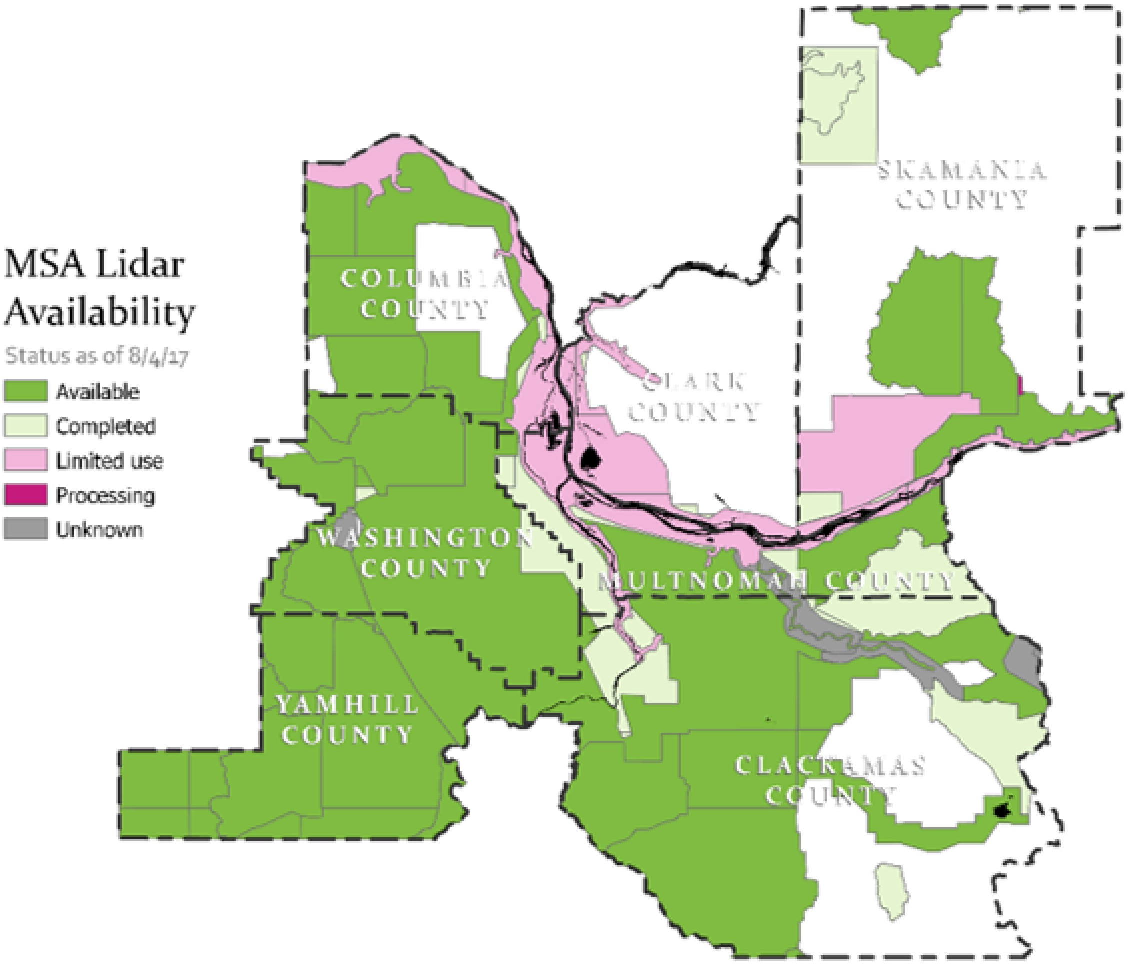

Figure 1. Source: BLM, Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

This issue of the Periodic Atlas will look at the rising prominence and capabilities of lidar, and how local researchers are using the technology to change the way we see, measure, and manage our region (figure 1).

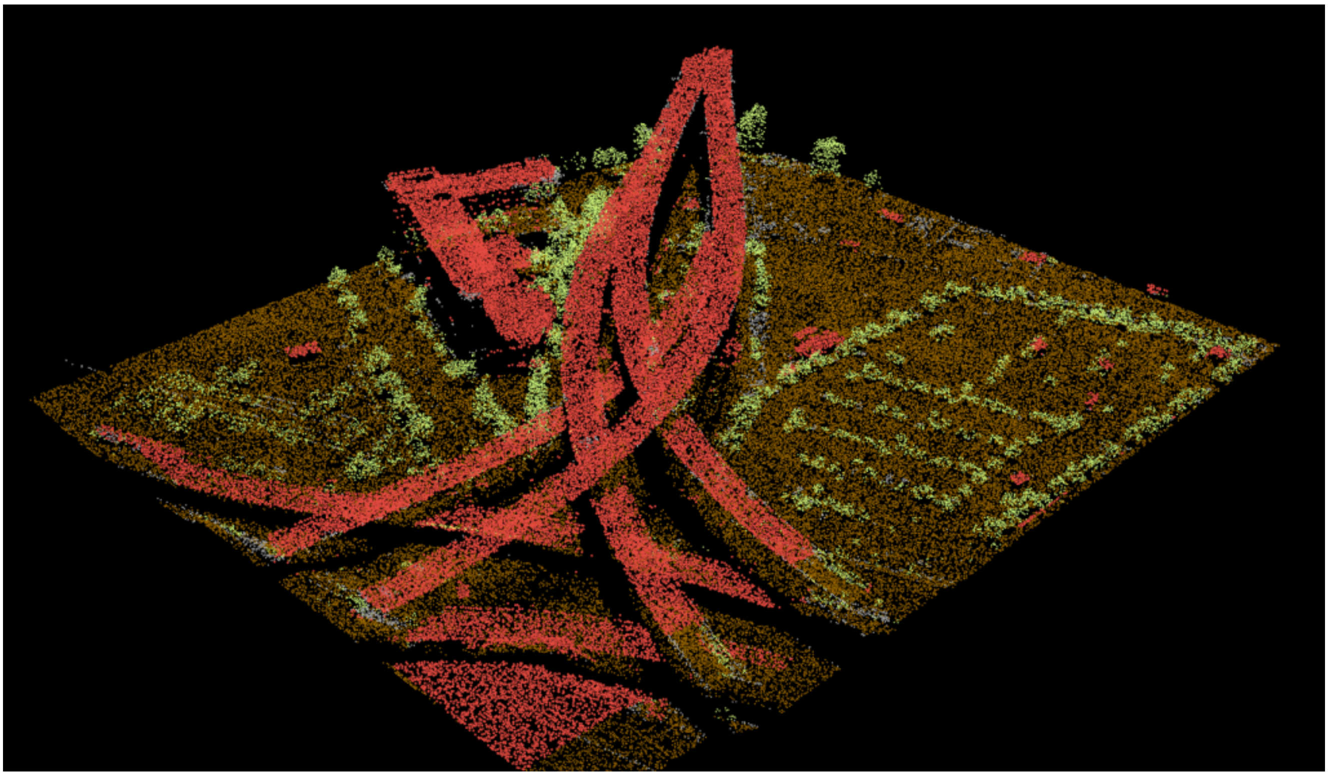

Figure 2. A 3D rendering of a lidar point cloud, here looking at the western end of the Marquam Bridge. Flat surfaces such as roadway and rooftops are rendered in red, while likely tree locations are in green.

First developed in the 1960s in conjunction with the invention of the laser, lidar is an active sensing system that functions on the same principle as its cousins, sonar and radar, firing a pulse of energy in the form of radar waves, sound, or light, and measuring the time it takes to bounce back. If you know the speed of that pulse of energy, then measuring the time it took to bounce back to you will give you the distance to your target of interest.

In lidar’s case, a laser operating in the infrared, visible, or ultraviolet spectrum is fired at the target. (In reality, thousands of beams are pulsed at the target.) A sensor unit mounted with the laser detects the reflected beams, measures their time of flight along with their energy intensity, and returns what is called a point cloud (figures 2 and 3).

This point cloud represents the first, rawest form of lidar-derived data, containing millions, or even billions, of points, each one representing the three-dimensional coordinates of laser reflections. With current technology, the accuracy of a given point is usually within fifteen centimeters vertically, and forty centimeters horizontally.

However, from their raw form, point clouds are often far too large and complex to be used by anyone but specialized analysts or engineers. Most often, the point cloud is simplified into a raster or pixelated image. Each pixel of this image represents an averaging of hundreds or even thousands of individual lidar points, depending on its resolution. The most common of these rasters are “digital ground models” used for measuring the elevation of the natural or built environment (figure 4).

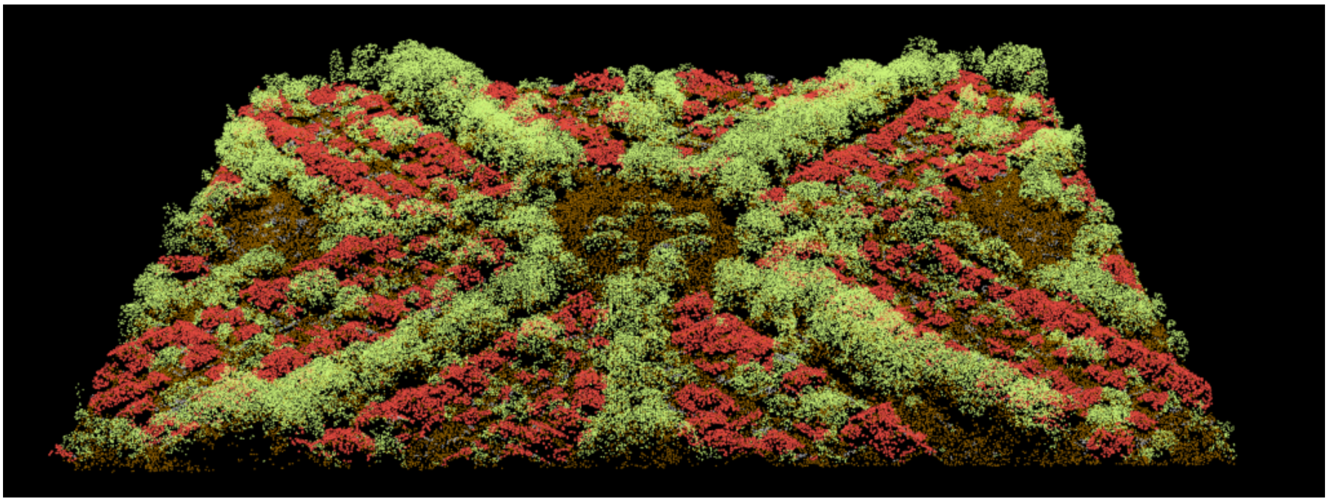

Figure 3. A 3D point cloud rendering of Ladd’s Addition, with treetops in green and rooftops in red.

Given the high labor and material costs of collecting lidar data, public sector users have tended to pool their resources into consortiums to purchase large, high-resolution data sets. In Oregon, the Oregon Department of Geology and Mineral Industries (DOGAMI) has led the Oregon Lidar Consortium since

2007, managing procurement, establishing and maintaining quality standards for the data, and hosting the final products on the web for all members of the public to use.

Here in the region, lidar data has been an essential component of an ever-expanding spate of research projects, many of them focusing on sustainable solutions for managing climate change and new development

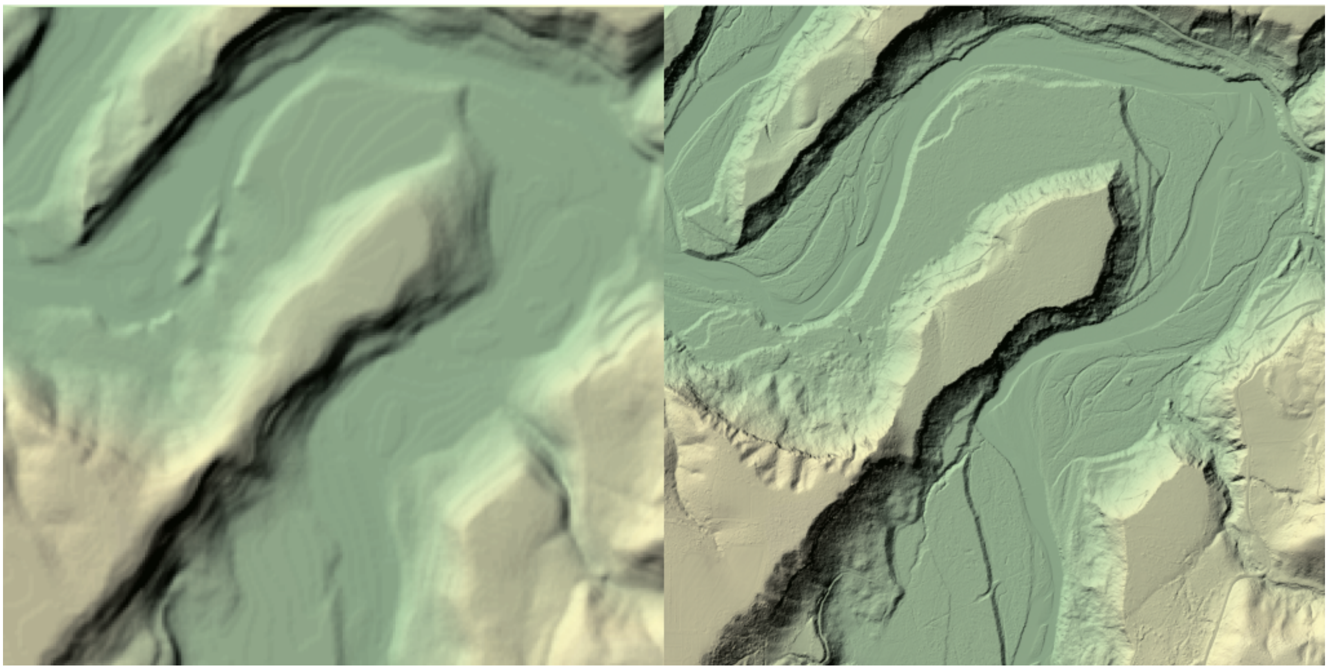

Figure 4. Lidar digital ground models (right) is a massive improvement over older, usually radar-derived elevation models (left). For years, the usual resolution for digital elevation models was 10 m. x 10 m. With lidar, that resolution is now improved to 3’ x 3’. That means being able to see ever more detailed features of the landscape, like being able to see individual oxbows of the Sandy River that give their name to Oxbow Regional Park.

Landslides

One of lidar’s most common uses has been the study and prediction of landslides. According to DOGAMI, tip-offs include “scarps, tilted and bent (‘gun-stocked’) trees, wetlands and standing water, irregular and hummocky ground topography, and over-steepened slopes with a thick soil cover.” With finer resolutions and improvements in the ability to interpolate terrain beneath forest canopies, geologists and environmental engineers are using lidar to spot those tip-offs, as well as evidence of historic landslide activity that may not be immediately visible to the naked eye

Earlier in 2018, DOGAMI released a report and accompanying data sets detailing the landslide risks faced in western Multnomah County (Figure 5). Using lidar along with existing tax lot and census data, DOGAMI determined that $1.65 billion in land and buildings and almost 6,700 people are located on existing landslides, twenty-nine thousand residents are at direct risk of a shallow landslide, and eight thousand at risk of a major deep landslide. The majority of those at risk are located in and around Forest Park, where elevation, soil, runoff, and vegetation health all combine as determinants of landslide risk.

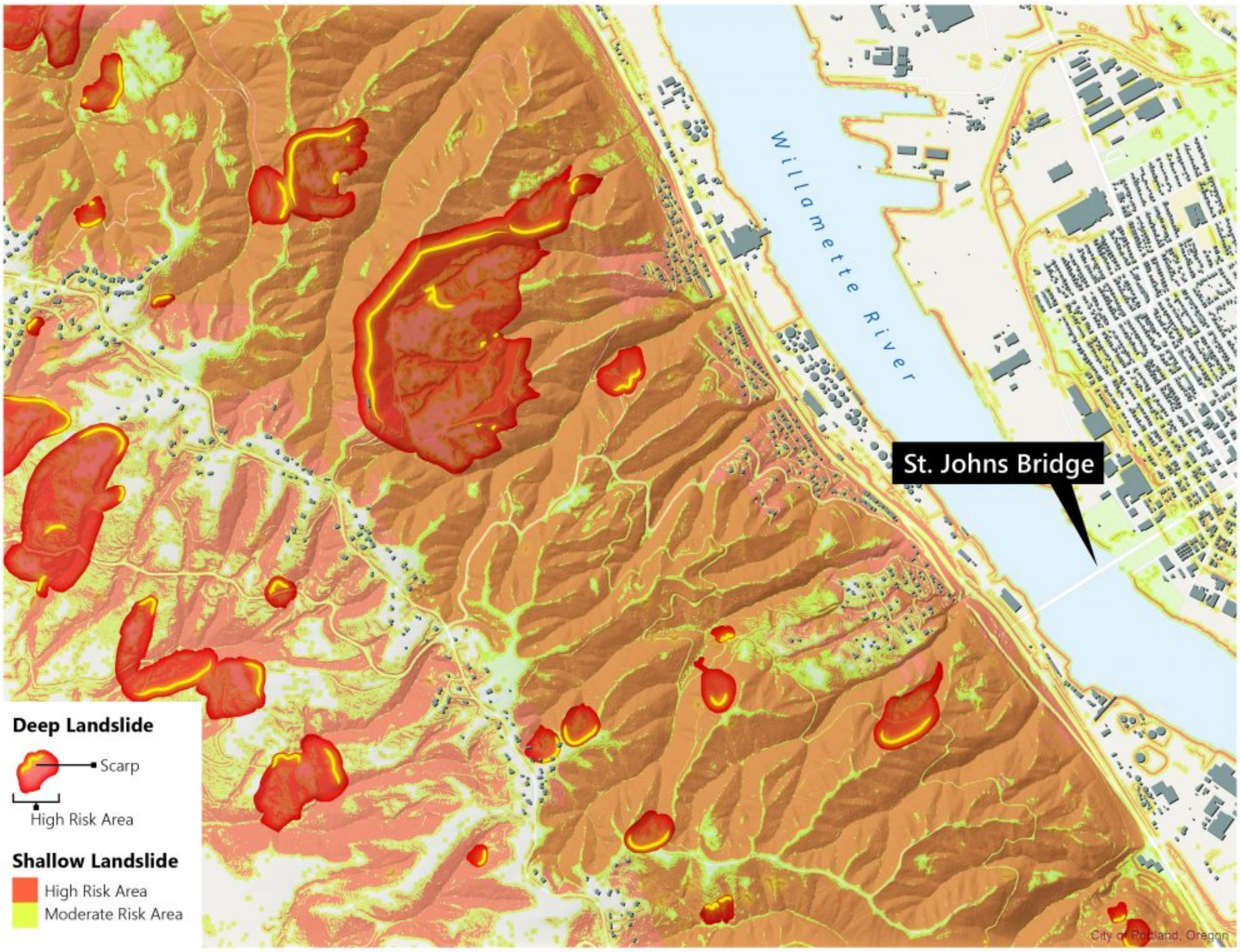

Figure 5. DOGAMI's 2016 landslide risk assessment for central and western Multnomah County. DOGAMI estimates that 21 percent of the surveyed area is at moderate risk of a shallow landslide, while 16 percent is at high risk. Deep landslides (those likely to be triggered by an earthquake) are more damaging than shallow, but cover a smaller area—around 7 percent of the study area is at high risk of a deep landslide. (Data source: DOGAMI)

Canopy

While the Portland region has long enjoyed the reputation and benefits of being one of the most verdant urban areas in the nation, measuring the health of urban tree canopies has either relied on aerial observation and a lot of guesswork, or tedious on-the-ground investigation. With the introduction of lidar, researchers have gained a powerful tool that opens the door to new ways of measuring the health and density of trees across the region.

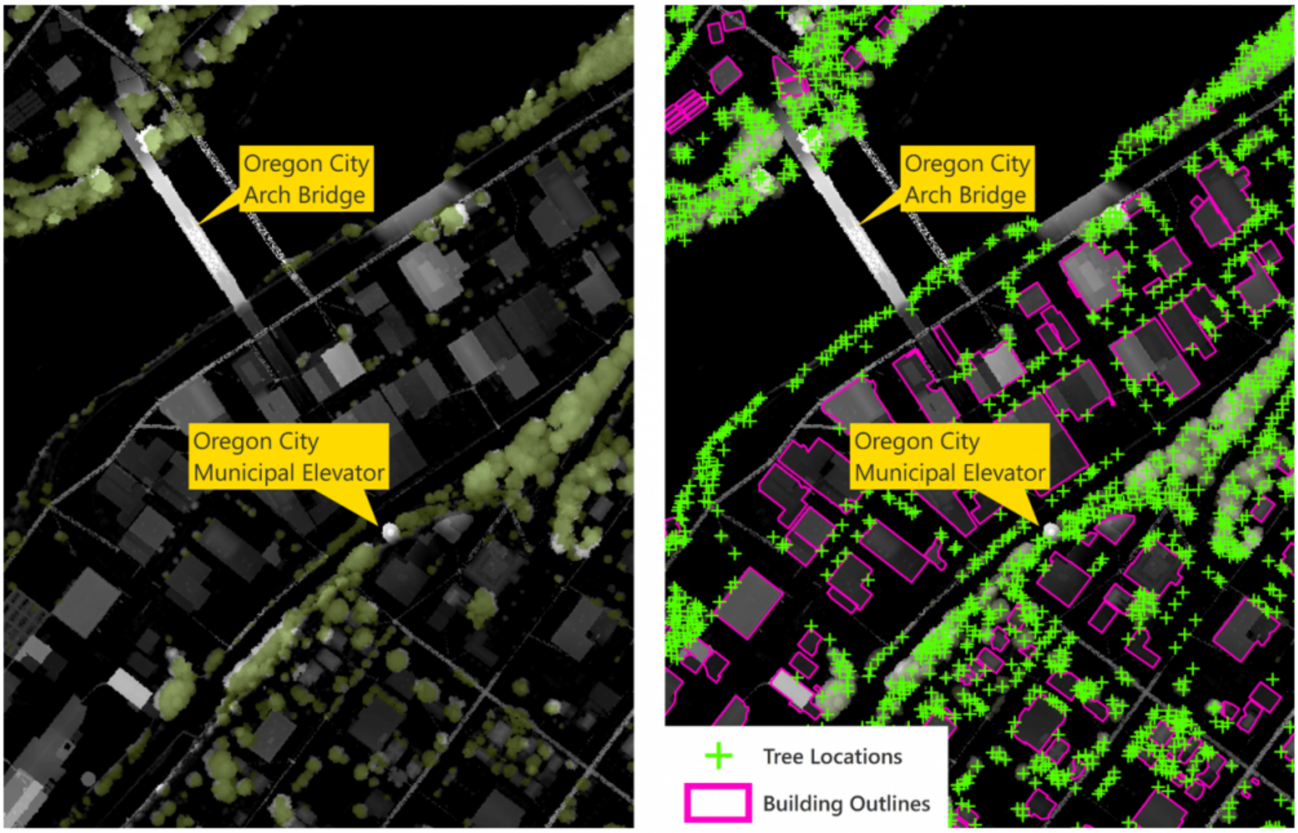

Figure 6a. A high-resolution lidar raster of downtown Oregon City, with tree biomass colored green.
Figure 6b. The same section of Oregon City, but overlaid with tree-top points and building footprints. Spatial analysts can use advanced statistical algorithms to sift through lidar data and spot the abrupt changes in height other patterns that indicate a tree or a rooftop.

Researchers from PSU's Sustaining Urban Places Research Lab and Metro's Data Resource Center have used canopy height data from lidar in conjunction with spectrum data from aerial imagery to produce new datasets that can estimate the total biomass of the region's trees (Figure 6). Going further, researchers used statistical analysis of the lidar data to identify individual tree crowns, which in turn allowed for the identification of particularly tall, old-growth trees around the region. Going forward, this data could allow local tree-preservation advocates and agencies to more accurately allocate their limited resources.

Ecoroofs

Ecoroof development has taken on greater importance in the region, especially in light of Portland’s recent inclusion of an ecoroof mandate and targets in the Central City 2035 Plan. While specific incentives have yet to be decided, the city plans to add 408 acres of ecoroofs to the city by 2035. Portland State researchers and faculty took part in analyzing current regional lidar data to determine which existing buildings may already be good candidates for adding ecoroofs (figure 7a and 7b). Using high-resolution lidar, researchers were able to identify candidate buildings across the region, analyzing not only the overall aspect and slope of roofs, but their flatness as well (e.g., building roofs without excessively bulky HVAC units on them).

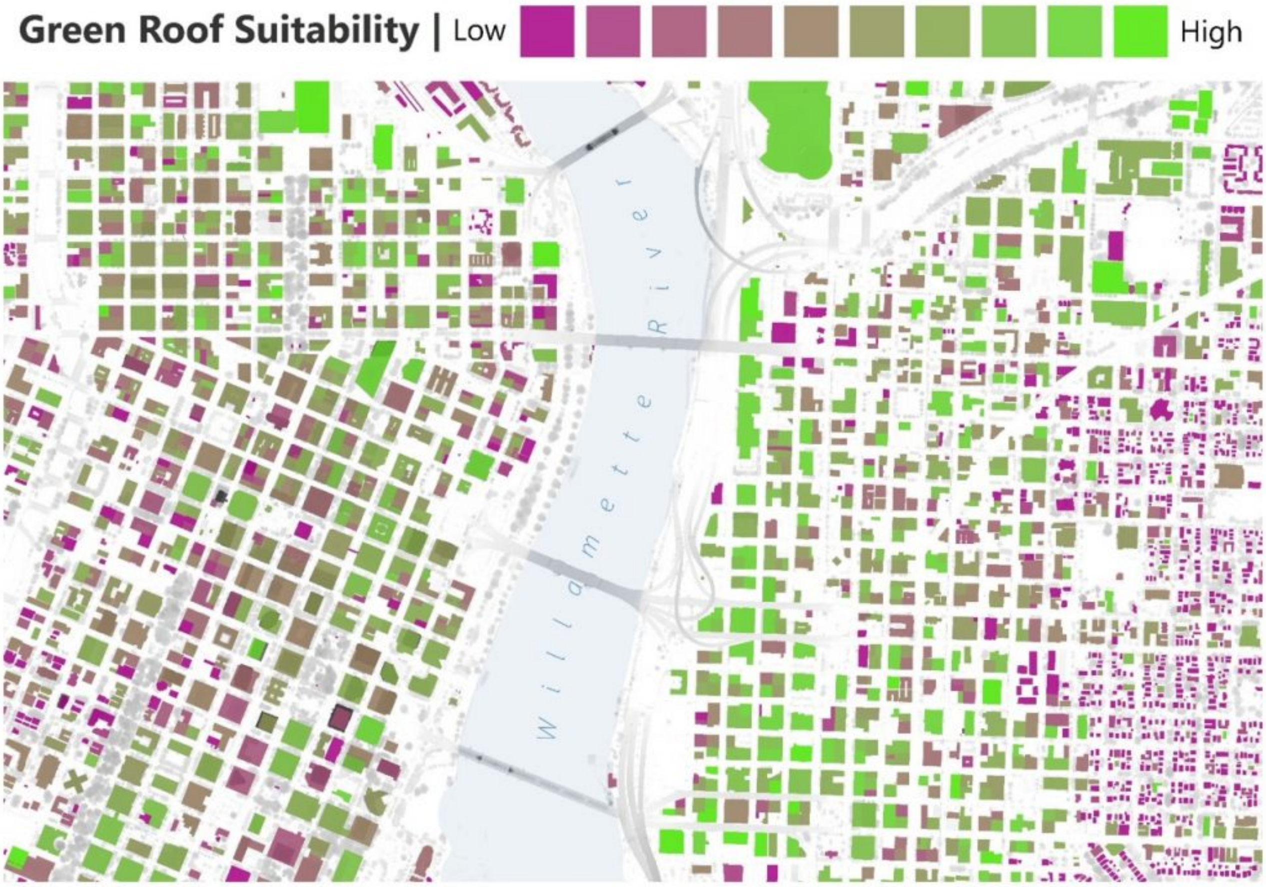

Figure 7a. For an investment in a green roof to pencil out, let alone be feasible, the planting area needs to be big enough and free of obstacles like large HVAC units elevator winch housing that lidar is perfect for identifying. Above is a green roof suitability analysis of buildings in Portland’s city center. Suitability has been calculated using a combination of rooftop area, angle and evenness. (Data source: City of Portland, Lone Fir Labs)

The projects discussed in this issue of the Periodic Atlas represent just a glimpse of what lidar data has allowed researchers to do so far. Moreover, these projects exist in the growing area of overlap between lidar data and sustainable policies and investments. As the capabilities of lidar become more known among local decision-makers, entirely new ways of analyzing and planning for a sustainable region could be quick to follow.

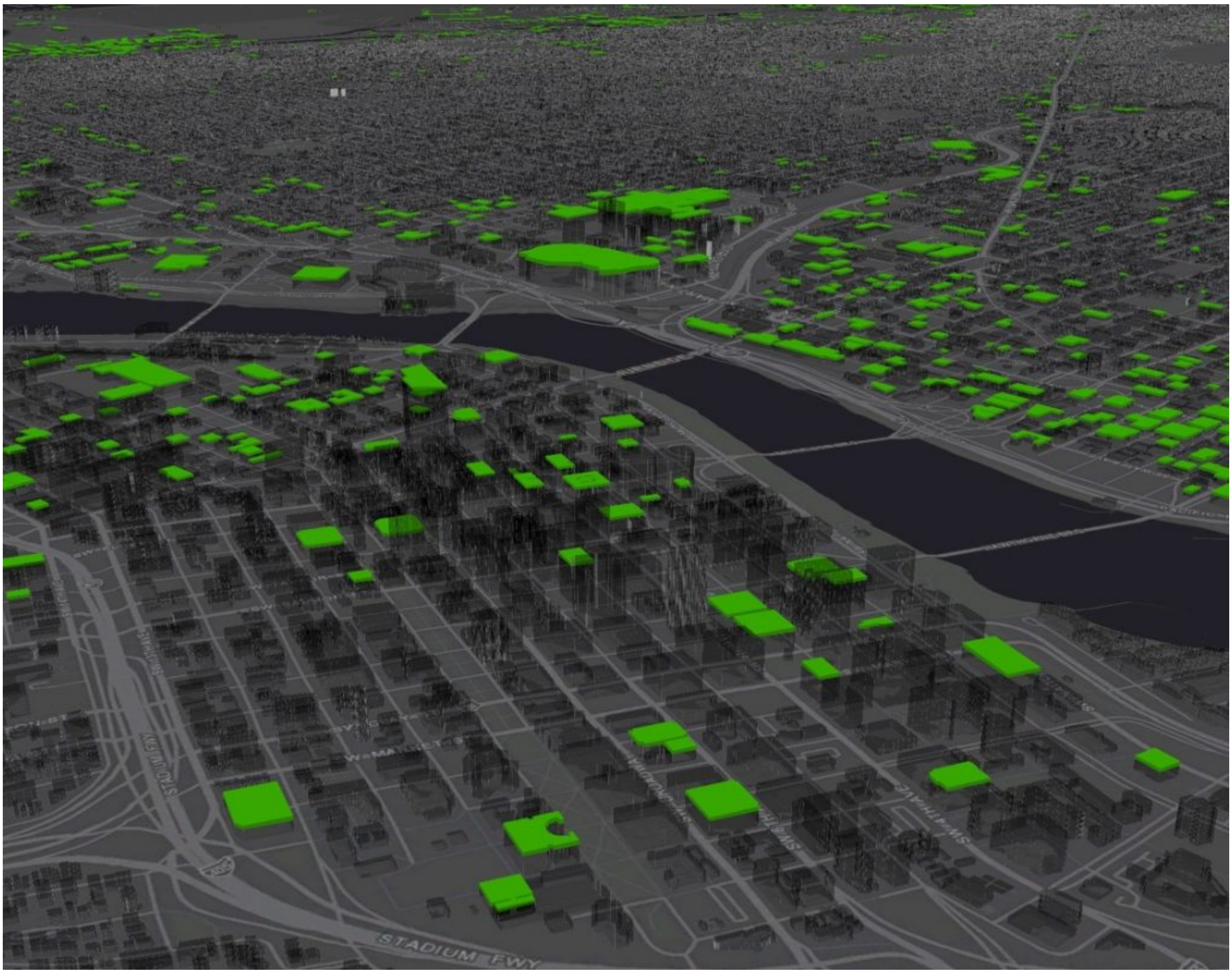

Figure 7b. Oblique view of potential green roofs along the Willamette River near downtown Portland. (Data source: Metro, Lone Fir Labs)

Researchers within IMS and PSU are increasingly depending on lidar data to improve our understanding of the region, but the data still have limits. First among these is the static nature of the data—with the rapid growth and change occurring within the region, every day that passes means the most recent lidar survey from 2014 loses a little bit of its relevance. The scope of the data is also limited as it does not include complete coverage, often leaving out rural areas and small towns. While there is certainly interest among researchers in procuring a more exhaustive survey of the entire MSA region, and the benefits of lidar data are becoming more and more evident, local elected officials and agencies will have to find a way to share in the investment and management of future surveys.

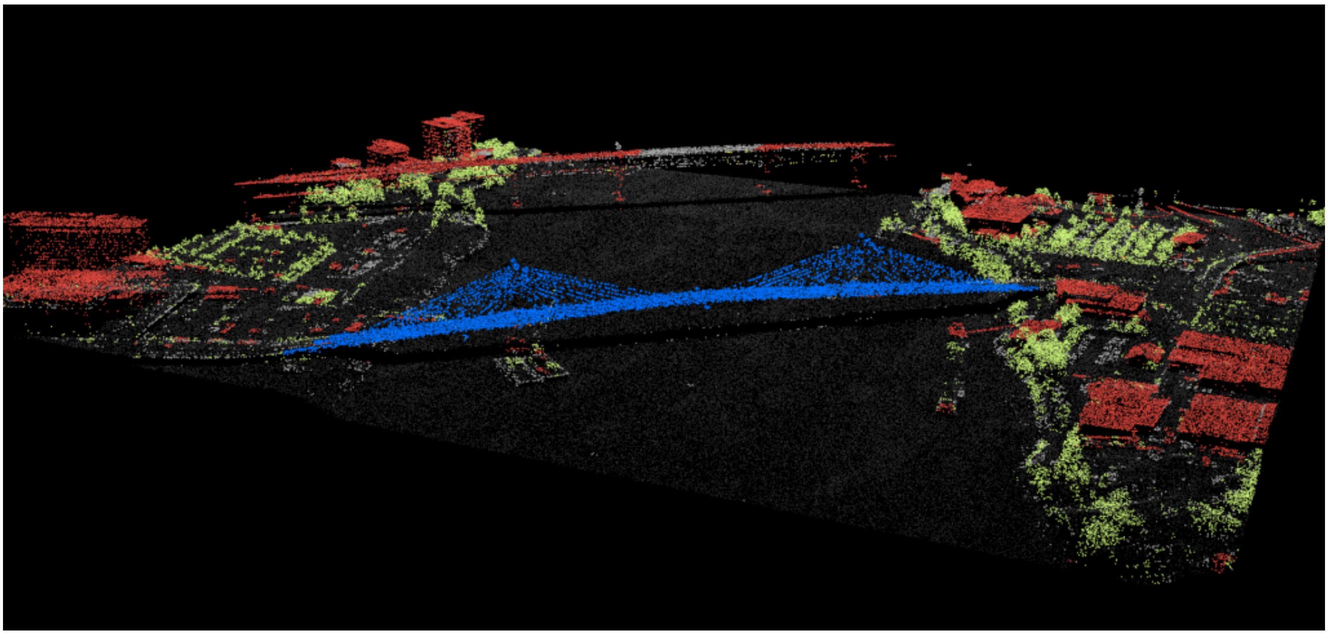

Figure 8. A 3D point cloud rendering of the Tilikum Bridge (in blue) from a lidar survey taken during construction. The crane barge is visible in the lower left, at the foot of bridge’s western tower.

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