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The 3D Elevation Program—Precision Agriculture and Other Farm Practices

Agricultural Productivity and High-Quality Terrain Information

A founding motto of the Natural Resources Conservation Service (NRCS), originally the Soil Conservation Service (SCS), explains that "If we take care of the land, it will take care of us." Digital elevation models (DEMs; see fig. 1) are derived from light detection and ranging (lidar) data and can be processed to derive values such as slope angle, aspect, and topographic curvature. These three measurements are the principal parameters of the NRCS Lidar-Enhanced Soil Survey (LESS) model, which improves the precision of soil surveys, by more accurately displaying the slopes and soils patterns, while increasing the objectivity and science in line placement. As combined resources, DEMs, LESS model outputs, and similar derived datasets are essential for conserving soil, wetlands, and other natural resources managed and overseen by the NRCS and other Federal and State agencies.

One of the largest privately held food and agribusiness companies in the Nation, J.R. Simplot assists small, medium, and large farms in carrying out production agriculture, including precision agriculture. J.R. Simplot relies on lidar for precision agriculture applications that improve terrain characterization for site-specific applications of seed, fertilizer, lime, pesticides, and water, which leads to increased farm yields, improved resource efficiency, and reduced chemical use.

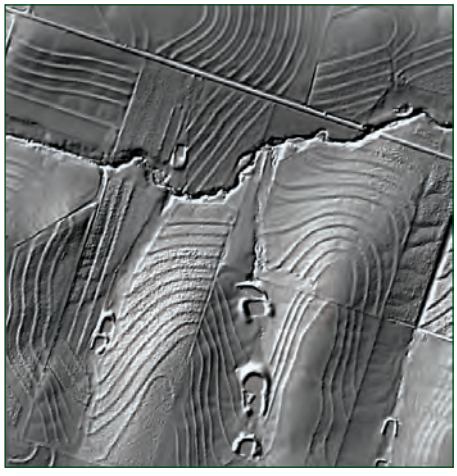

Image courtesy of Natural Resources Conservation Service.

Figure 1. The Natural Resources Conservation Service uses lidar to provide assistance to farmers for farm pond and contour farming practice design. This lidar-derived digital elevation model (DEM) shows field contours and several farm ponds.

Knowledge of relevant terrain information—soil type, soil wetness, drainage, and topographic variations within farm fields (slope, aspect, and curvature)—can improve crop yields. Awareness of these characteristics gives farms the opportunity to devise site-specific methods (fig. 2). Traditional, uniform treatment of crops such as wheat, corn, soybean, and cotton causes excessive costs in the form of fertilizers, pesticides, and herbicides, all of which can lead to excessive pollutant runoff.

The agriculture industry, including farmers who rely on advanced technologies, increasingly use lidar data for crop management to enhance agricultural productivity. Annually, the combination of greater yields and reduced crop losses is estimated to increase revenue by $2 billion for America's farmers when terrain data derived from lidar are made available for all high-quality croplands. Additionally, the NRCS estimates that the value of improved services provided to farmers through its farm assistance program would be $79 million annually if lidar-derived DEMs are made available for all farmlands (Dewberry, 2012).

The 3D Elevation Program (3DEP) (Sugarbaker and others, 2014; see sidebar) provides the programmatic infrastructure to generate and supply superior terrain data to the agriculture industry, thereby reducing costs and risks, which would allow farms to refine agricultural practices and produce crops more efficiently. The 3DEP infrastructure uses data acquisition partnerships that leverage funding; develop contracts with experienced private mapping firms; capitalize on technical expertise; maintain first-tier lidar data standards and specifications; and, most importantly, provide public access to high-quality 3D elevation data.

Uses of 3D Elevation Data for Agriculture

Uses of 3D elevation data in agriculture investments (Dewberry, 2012) include:

- Prescription application of seed, fertilizer, water, pesticides, and herbicides
- Farm pond design
- Farm contour design
- Tribal, State, and local government farmland program management

3D Elevation Program (3DEP)

The 3D Elevation Program (3DEP) is a national program managed by the USGS to acquire high-resolution elevation data (Sugarbaker and others, 2014). It produces point clouds, bare-earth digital elevation models (DEMs), and other products.

The 3DEP is backed by a comprehensive assessment of lidar, interferometric synthetic aperture radar (ifSAR), and related elevation data requirements (Dewberry, 2012) and is now an operational program. The goal of this high-priority cooperative program is to have complete coverage of quality level 2 (QL2) lidar data for the conterminous United States, Hawaii, and the U.S. territories, and ifSAR data for Alaska, by the end of 2023.

Reduced Acquisition Costs and Risks

A funded national program will provide:

- *Economy of scale* by acquiring data for larger areas and reducing acquisition costs by 25 percent.
- *Predictable, efficient, and flexible Federal investments* that reduce costs for and allow better planning by Federal, State, Tribal, U.S. territorial, and local government partners, including the option of "buying up" to acquire higher quality data.
- *Consistent, high-quality, national coverage* that (1) provides data ready for applications that span project, jurisdictional, and watershed boundaries, (2) meets multiple needs, and (3) increases benefits to citizens.
- *Simpler data acquisition* that provides contracts, published data-acquisition specifications, and specialized quality assurance and information technology expertise. Partners reduce their risks and can concentrate on their business activities.

3DEP can conservatively provide new benefits of $690 million per year and has the potential to generate $13 billion per year in new benefits through applications that span the economy (Dewberry, 2012). The shared lidar, ifSAR, and derived elevation datasets would foster cooperation and improve decisionmaking among all levels of government and other stakeholders.

High-Quality Data

For the conterminous United States, Hawaii, and the U.S. territories, the USGS and its partners acquire QL2 or better lidar data. The QL2 data have a minimum nominal pulse spacing of 0.7 meters and a vertical error

- Farmland suitability analysis
- Drainage analysis
- Conservation planning
- Mapping of floodplains, cultural resources, wetlands, grasslands, forests, and wildlife habitat

Benefits of 3D Elevation Data

The benefits (table 1) realized by the agriculture industry, through improved cropland management and farming practices, can include:

- Increased crop yield
- Decreased crop losses due to flooding or poor site design
- Improved compliance for the application of regulated chemicals
- Reduced design costs for farm ponds and other farm infrastructure
- Conservation of critical natural resources and habitats

Table 1. Conservative annual national benefits of 3DEP data related to precision agriculture, other farm practices, and associated business uses (derived from Dewberry, 2012).

Business use	Conservative annual benefit (million dollars)
Agriculture and precision farming	122
Natural resources conservation	159
Forest resources management	44
River and stream resource management	38
Wildlife and habitat management	2
Total	**365**

Maximize Benefits and Minimize Risks

3DEP presents opportunities for users to maximize the benefits and minimize the risks associated with mapping terrain. Data that meet the needs of the user's project may already be available through 3DEP. As such, users may benefit by taking advantage of previously derived product data, or the standardized point cloud, to ease the learning curve associated with processing raw lidar data. The user can then begin project work immediately.

When data must be acquired, 3DEP offers:

- Reduced unit collection costs by pooling funding with other partners, resulting in an economy of scale that 3DEP coordination provides.
- Access to vetted, qualified, and experienced contract firms that acquire and process aerial lidar data.
- USGS programmatic infrastructure that issues and manages data acquisition contracts, and inspects, accepts, and distributes point cloud and derived data products.
- Opportunities to "buy up" to higher quality data for specialized applications.
- Opportunities to receive direct 3DEP cost-share funding to acquire lidar data

References Cited

Dewberry, 2012, Final report of the National Enhanced Elevation Assessment (revised 2012): Fairfax, Va., Dewberry, 84 p. plus appendixes, accessed October 5, 2016, at http://www.dewberry.com/Consultants/GeospatialMapping/FinalReport-NationalEnhancedElevationAssessment.

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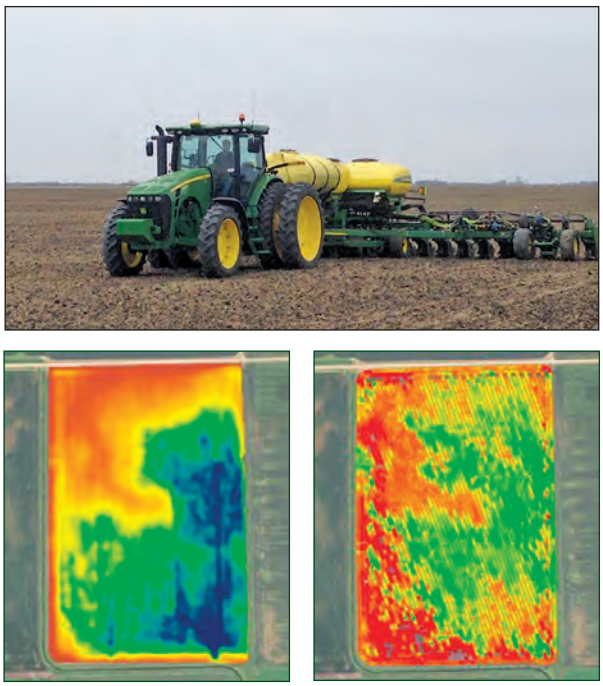

Figure 2. The image on the lower left shows field elevations, as determined by lidar survey, and the image on the lower right shows farm yield. The top photograph shows a tractor equipped with a Global Positioning System (GPS) and precision agriculture equipment, allowing for the precise application of seeds and chemicals. Images courtesy of J.R. Simplot Company. Any use of trade, firm, or product names is for descriptive purposes only and does not imply endorsement by the U.S. Government.

3D Elevation Program—Continued

of 10 centimeters, measured as root mean square error in the elevation (z) dimension ($RMSE_z$). Statewide for Alaska, quality level 5 ifSAR data are acquired that have a vertical error of 185 centimeters $RMSE_z$.

The data must have been acquired during the previous eight years. For more information see the Lidar Base Specification available at http://pubs.usgs.gov/tm/11b4/.

Point Cloud and Derived Products

Lidar data products include the all-return classified point clouds and derived bare-earth DEMs. Each DEM dataset is identified by its horizontal resolution and is produced to a consistent set of specifications. All DEMs represent the topographic surface of the Earth and contain flattened water surfaces. Nationally seamless DEMs are produced by blending only the highest quality project data into a continuous terrain surface for the United States, and are published at resolutions of 1/3 arc-second, 1 arc-second, and 2 arc-seconds. The standard 1-meter DEM dataset is seamless within collection projects but not across projects.

IfSAR data in Alaska include digital surface models, orthorectified intensity images, and 5-meter-resolution hydro-flattened DEMs.

The USGS integrates the elevation model data into its national elevation data coverage, as a component of The National Map. All 3DEP products to include an elevation-point query service and bulk-point query service are components of The National Map. Data are available, free of charge and without use restrictions. To download 3DEP products visit http://viewer.nationalmap.gov/basic/.

Ways to Participate

Partners may contribute funds toward data acquisition projects managed by the USGS, or they may receive cooperative funds to manage their own acquisition projects. The Broad Agency Announcement process is the primary mechanism used to establish agreements between partners. For more information see the 3DEP Web site at http://nationalmap.gov/3DEP/index.html. Organizations may also access the geospatial products and services contracts and quality control services managed by the USGS to acquire 3DEP data. Organizations may contribute existing elevation data that meet 3DEP specifications. More information about using USGS contracts or about other ways to contribute is available by request through http://nationalmap.gov/3DEP/3dep_feedback.html.

Learn More About 3DEP

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