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# OpTIS*: Operational Tillage Information System*

## *FAQs*

In 2019, Applied GeoSolutions, LLC (AGS), Dagan, Inc., the Conservation Technology Information Center (CTIC), and The Nature Conservancy (TNC) launched the Operational Tillage Information System (OpTIS), a geospatial tool that uses a proprietary software package to analyze satellite data and track the adoption of soil health practices, including tillage practices and cover crops, across the Corn Belt between 2005 and 2018. Data at the HUC-8 watershed and the USDA Crop Reporting District scales are available for free. A powerful online visualization tool enables users to interact with OpTIS data for tillage and cover crop usage trends. Online resources also include OpTIS data run through the DeNitrification/DeComposition (DNDC) model to simulate the impacts of land management decisions on nitrogen and carbon dynamics as well as changes in soil moisture holding capacity.

## ABOUT OPTIS & ITS APPLICATION

**1. What is OpTIS?**
New Hampshire-based Applied GeoSolutions (AGS) developed the Operational Tillage Information System (OpTIS), a geospatial tool that automatically analyzes data from several earth-observing satellites to map and monitor cover crop development and detect plant residue left on farmland to determine the tillage activities. This is combined with information on crop rotation to allow queries of combinations of practices related to user-defined soil health metrics. The OpTIS technology was transferred to Dagan, Inc. in 2019 as part of the spin-off from AGS.

**1a. What is the relationship between Dagan, Inc. and Applied GeoSolutions?**
Dagan, Inc. is a new soil health and ecosystem services company, working to be a leader in providing soil health and sustainable agriculture data insights to organizations who work with producers. Its mission is to make resilient agriculture ubiquitous for soil health outcomes, thriving people, communities, and the environment. Dagan was formed in 2018 as a spin-off from Applied GeoSolutions, LLC (AGS). The OpTIS and DNDC technologies were transferred to Dagan from AGS. Creating the Dagan spin-off has allowed much of the same team of scientists and engineers to continue to improve the technologies and provide data services to customers looking to understand and track soil health and environmental outcomes of agriculture

**2. What is the purpose of OpTIS?**

OpTIS enables the agriculture community to annually measure adoption of soil health practices in a standardized, systematic, and cost-efficient way across large-scale geographies. Specifically, this technology calculates the number of acres of winter cover (including wheat) and various tillage practices and tracks multi-year trends in the adoption of soil health practices across large areas. This technology represents a significant step in providing insight at a broader geographic and temporal scale with increased accuracy at a lower cost.

**3. What is DNDC modeling?**

The DeNitrification-DeComposition (DNDC) model is a soil biogeochemical computer model that tracks carbon, phosphorous and nitrogen cycling and GHG emissions in agroecosystems. When the OpTIS data are used as input to the DNDC model, DNDC can then provide an estimate of key environment performance metrics: nitrous oxide emissions, nitrate loss, soil organic carbon, and water holding capacity.

**4. How can OpTIS and DNDC data be used?**

OpTIS technology, coupled with the DNDC modeling, can help reinforce the value of soil health practices and increase their rate of adoption. Spatial analysis of OpTIS and DNDC results fills critical gaps in understanding trends in soil health practices, as well as set a baseline of adoption against which future progress can be tracked. The data give public and private stakeholders valuable insight for a range of uses, including targeting resources, tools and funding to locations most in need, as well as evaluating the success of existing conservation programs.

We foresee a range of public and private stakeholders—from universities to government agencies, from consumer goods companies to conservation organizations—using OpTIS data for a multitude of purposes, including:

- Tracking progress in meeting conservation goals
- Targeting technical service or incentive programs
- Comparing the success of conservation programs across large areas
- Validating compliance in ecosystem services markets
- Substantiating sustainability claims
- Analyzing markets for goods and services impacted by conservation trends
- Providing accurate data to validate models and analyze the success of conservation programs.

**5. How can OpTIS and DNDC data be accessed?**

Users can access available OpTIS data and an interactive visualization tool at www.ctic.org/OpTIS at no cost. A link to DNDC data is available at www.ctic.org/DNDC.

**6. What geographies are being mapped via OpTIS?**

Users can access information on the number of acres of no-till, reduced tillage, conventional tillage and winter cover crops across the Corn Belt—extending from eastern Ohio to eastern Kansas and Nebraska, and from the Missouri Bootheel to the Red River Valley of North Dakota—from 2005 to 2018 through CTIC's data portal.

Also available on the site are simulations created by running OpTIS data through Dagan, Inc.'s DeNitrification-DeComposition (DNDC) model.

**7. Do OpTIS data violate farmers' privacy?**

Nothing in the OpTIS data release can be linked to individual farming operations. While OpTIS calculations are performed and validated at the farm-field scale using publicly available remotely-sensed data, the privacy of all individuals is fully protected by reporting only spatially-aggregated results at much larger scales (i.e., HUC-8 watershed and USDA Crop Reporting District).

**8. How do you know OpTIS works?**
Dagan, in collaboration with Conservation Technology Information Center (CTIC), conducted a pilot project to test, ground-truth and document the capability of OpTIS to consistently map tillage practices and cover crops in Indiana from 2005 to 2014.

The pilot project produced a searchable database of annual tillage practices and winter cover crop use for Indiana, county- and watershed-level maps of conservation tillage and cover cropping, and a comprehensive report (http://optis.ags.io) outlining the performance of the system.

For the Corn Belt data released in 2019, Dagan also contracted with trained technicians to validate OpTIS results in other states at hundreds of geo-referenced sites that were visited, assessed and photographed.

**9. How can OpTIS help bring positive change within the agriculture industry?**
With Dagan, CTIC and TNC each committed to agriculture, technology and conservation, the driving force behind OpTIS is the desire to create a tool that helps advance conservation farming systems on the landscape. By providing data that can be used free by farmers, crop advisors, academics, policy makers, market researchers and many others, OpTIS provides an accurate account of important land management decisions. Running the data through the DNDC model offers insight into their effects on nitrogen and carbon dynamics.

Those data can validate sustainability claims, guide policy, direct resources, influence the flow of products to areas where they can be most readily used, and inspire action. Stakeholders can use the data to create new revenue opportunities for farmers and substantiate eco-labeling throughout the supply chain. And by clearly illustrating trends and discrete data points, the data can help better inform the creation of effective conservation incentives and policies.

**10. How can external stakeholders ensure the OpTIS project continues? How can they become engaged?**
Given the scale and importance of these data to stakeholders in government, industry, and academia, it is clear that even greater levels of public and private collaboration will be required to operationalize and sustain this effort at the national scale. Plans are underway to expand the application of OpTIS beyond the Corn Belt, but additional funding is needed.

To keep the work going, let us hear from you. Tell us why you find OpTIS valuable. Consider partnering with us, either as a funder or a collaborator.

## ABOUT THE 2019 CORN BELT PROJECT

**11. Tell us about the 2019 Corn Belt project.**
Building on the success of the Indiana pilot project, Dagan and CTIC collaborated with The Nature Conservancy and others to apply OpTIS across the U.S. Corn Belt for the years 2005-2018, with plans to expand the application to other U.S. agricultural regions.
In addition to the OpTIS data, simulations of nitrogen and carbon dynamics influenced by tillage and cover cropping decisions analyzed through OpTIS were run through DNDC. Both datasets are available on the CTIC website.

**12. How was the project funded?**
The OpTIS project has received generous funding and support from the Foundation for Food and Agriculture Research, the U.S. Department of Agriculture and NASA, Bayer Crop Science, CF Industries, Corteva Agriscience, Enterprise Rent-A-Car Foundation, John Deere, The Joyce Foundation, J.R. Simplot Company, The Mosaic Company, Syngenta, the Walmart Foundation, the Walton Family Foundation and TNC.

**13. What is the visualization tool?**
Data users can access a free online visualization tool that presents OpTIS data in map and graph formats at the HUC-8 watershed and/or USDA Crop Reporting District scales. The tool enables users to access data for a specific year or over the study period, as well as isolate individual data points. Additionally, the visualization tool has been applied to OpTIS data run through the DNDC model, enabling users to study soil carbon change rate and nitrous oxide flux by geography, year and trend.

**14. Why now? What makes this project relevant today?**
The global population is estimated to exceed 9 billion people by 2050, placing unprecedented pressure on U.S. farmers to grow even more of the crops that feed, clothe and fuel the world. One way to help alleviate this pressure is to significantly improve soil health, which in turns helps to make the nation's cropland more productive, farmers more profitable and nature more resilient. In the U.S. alone, there are more than 200 million acres of row crops like corn, soybeans, wheat, cotton and rice. By adopting practices like planting winter cover crops and reducing tillage, farmers can improve productivity of their fields, reduce soil erosion, improve water quality and increase carbon storage. OpTIS provides trend and snapshot data on the adoption of soil health practices, which is vital to managing conservation incentives and markets for ecosystem services.

Knowledge is power, and OpTIS will help to empower a wide range of stakeholders with vital data to help improve farmers' productivity, safeguard our water and lands and ensure a sustainable future.

**15. What cover crop and tillage trends did the OpTIS data reveal for the Corn Belt?**
Available data document the level of adoption of soil health practices for the Corn Belt —an area extending from eastern Ohio to eastern Kansas and Nebraska, and from the Missouri Bootheel to the Red River Valley of North Dakota—show that soil health practices across the region are steadily moving in the right direction.

- Adoption of winter cover crops planted after corn and soy is increasing.
    - 2006: 2.03 million acres (1.7%)
    - 2018: 3.94 million acres (3.2%)

- Cover crop use on all cropland across the Corn Belt went from 23 million acres (1.8%) in 2006 to 4.7 million acres (3.7%) in 2018.

- Based on OpTIS data from 2006 to 2018, scientists anticipate that cover crop adoption after corn and soy harvests will be around 5.4 million acres (4.5%) within the next five years across the Corn Belt.

- The use of conservation tillage practices after planting corn or soy has remained relatively steady:
    - 2006: 55.1 million acres (45.5%)
    - 2018: 54.2 million acres (44.4%)

**16. Does the data shows progress is too slow?**
OpTIS promises to be an extremely useful tool for tracking the progress of conservation systems such as no-till and winter cover crops. Data from OpTIS may be used in a wide variety of applications, from ecoservices markets to establishing incentives, that may help speed the rate of adoption. However, the trends from OpTIS

are not unexpected. We already knew that we need to work across the agriculture supply chain, with many partners, to help support farmers in the transition to adopting these practices at a higher rate.

**17. The OpTIS data is different from the data reported in the last ag census. Why are there discrepancies?**
The Census of Agriculture is a detailed survey of farmers and landowners across the country. OpTIS is an automated analysis of remote sensing imagery. Differences can occur due to the differences in methodologies and the inherent errors in both systems. For instance, self-reporting surveys have limitations due to human error and bias, while OpTIS will have errors in the algorithms, interpretations of imagery, cloud cover, etc.

There is no single best data source. Each methodology is different and useful for different purposes. For example, OpTIS is great for low-cost and broad-scale information, while a survey-based approach can dig into how and why farmers are doing what they're doing. Also, spatial information from OpTIS provides added information on frequency of use of conservation practices and spatial patterns that could inform an understanding of barriers to adoption of conservation.

## TECHNICAL DETAILS ABOUT OPTIS

A detailed paper on how OpTIS works and how the data were ground-truthed is available online at https://www.ctic.org/files/Final_Report_CTIC-TNC.pdf. The OpTIS team is also preparing a paper for a peer-reviewed journal.

**18. How often are the remote sensing images gathered? At what time of the year?**
The remote sensing images analyzed by OpTIS were gathered primarily by the Landsat and Sentinel 2 sensors. Landsat is operated jointly by NASA and the US Geological Survey and has been in operation since the 1970s. The Sentinel 2 series of sensors have been operation since 2015 and are operated by the European Space Agency.

Landsat images of an individual location are captured every 8 to 16 days, while the Sentinel 2 repeat frequency is 5 to 10 days. OpTIS integrates all cloud-free data captured from these sensors into a single information stream.

Field boundaries are estimated using historical information from the Cropland Data Layer, a geo-referenced, crop-specific land cover map of the continental U.S. funded by the USDA National Agricultural Statistics Service, which is also based primarily on Landsat data. That public database allows OpTIS to use USDA data on the specific crops planted on each parcel, which is very important to qualifying a field for analysis and knowing how much residue cover is expected for various tillage practices.

OpTIS is analyzed at a 30-meter scale and reported at the HUC-8 watershed or USDA Crop Reporting District scales to ensure grower privacy.

**19. How does the timing of the data work? What does the year mean?**
OpTIS data cover a period of interest beginning at fall harvest (around November 1). The system analyzed remote sensing images captured during the spring to evaluate the amount of residue before planting, and during the winter to evaluate the presence of cover crops or other ground cover. An area that was determined to be in cover crop in 2017 data would have had its cover crop planted in fall, 2016.

**20. How does OpTIS deal with cloud cover?**
Cloud cover obscures many of the images fed into OpTIS, and the algorithm automatically discards cloud-covered fields. But, because Landsat and Sentinel satellites pass over a site roughly every two weeks in the mid-2000s and every 3-5 days in 2017 and 2018, the odds are good that at least one or two of the images of a particular field can be captured without cloud cover during the six-month period of interest. In fact, AGS reports that OpTIS has been able to make a determination of tillage practice or cover crop on 85 to 90 percent of the land area that has been analyzed to date.

Where cloud cover has obscured a field at all critical times during a year, OpTIS extrapolates from the land use around the obscured area and applies the percentage of land use types to the field. This approach is commonly used and has been validated in the scientific community.

**21. What are the algorithms that are used to process the remote sensing data?**
OpTIS is a proprietary algorithm developed by AGS and owned by Dagan that automatically analyzes land use, tillage type and the presence of cover crops or other ground cover.

**22. How are each of cover crops and tillage data determined?**
OpTIS does not discern among various species of winter cover crops—it simply registers the presence or absence of a winter cover crop. Using differences in signature among various vegetation types, the timing of greenness, and information from other data sources such as CDL, OpTIS can differentiate among winter cover that's primarily used just as a cover crop, a winter cash crop such as winter wheat, a perennial crop such as alfalfa and a weedy field without cover crops.

OpTIS can estimate the amount of residue cover on the soil surface during the fall, winter, and spring and, based on the previous cash crop, identify the tillage system that was used on the field.

It is important to note that only fields that were planted to commodity crops for the entire reporting period—2005 to 2018—have been counted in OpTIS data. In some cases, there are fields that were taken out of CRP or planted into alfalfa that were disqualified from analysis, leading to discrepancies with survey/census data.

**23. How were the satellite images verified in the field? How does the validation of the current project compare to the CTIC/AGS pilot in Indiana?**
Ground truthing of the OpTIS results was conducted by a team of paid technicians using an app that supplemented their geo-located visual observations with photos. In all, there were 736 field observations for verification in Illinois, Indiana and Iowa, and nearly 300 total observations in other Corn Belt states. Though the study reporting period extends back to 2005, in-field verification only occurred in 2017 and 2018.

The pilot study in Indiana was verified by transect survey results provided by the USDA Natural Resources Conservation Service covering the period 2005-2014.

**24. How does the satellite imagery differentiate between cover crops and pasture land? Cover crops and weeds?**
In the course of this project, AGS relied on information from the Cropland Data Layer and analysis of imagery to differentiate between cover crops, pasture or permanent crops, and weedy fields. Pastures are not included in OpTIS analysis, so areas with that visual signature were excluded from the system's acreage reports.

**25. What's the difference between DNDC and COMET or DayCent?**
There are several peer-reviewed models that assess soil quality parameters, including DNDC, COMET (Carbon Management Evaluation Tool) and DayCent. In the current project, we are running OpTIS data through DNDC,

due to its long history in the peer reviewed literature and ability to calculate uncertainty. Future analyses may be run through other models.

**26. Where can people go if they want field-scale data?**
We designed this project to report data at a scale that protects individual farmers' data. OpTIS data are currently being reported at the HUC-8 watershed or USDA Crop Reporting District scales. For finer resolution data, contact Dagan (optis@daganinc.com) to see what may be available for specific needs.

**27. Will data continue to be collected in future years?**
Yes. Efforts are underway in additional states to continue data collection, and there are ongoing conversations with partners to extend the temporal and geographic range of the data set.

**28. When will data for other regions be available? Will new field verification be needed for other regions?**
There is no timeline yet for the release of data from other regions. However, we expect to continue validation efforts to ground-truth the system in other geographies. Other regions and other crops will likely require modifications to OpTIS.

**29. Does OpTIS look at land conversion?**
Because OpTIS only tracks rotation among row crops for the entire study period, it is not reporting on land conversion in this project.

**30. Why are Landsat images being used, when there are so many newer technologies to do remote sensing?**
Landsat is a remarkably rich, robust and publicly accessible database that allows OpTIS to analyze land use dating back to 2005. It ideally suits our need for more than a decade of consistently acquired imagery, resolution that allows a detailed look at ground cover without invading the privacy of people on the land, and free public access. Landsat data is complemented by the addition of Sentinel 2 imagery, beginning in 2015.

**31. What are the sources of error in the OpTIS data? What is its accuracy?**
Because it is an algorithmic analysis of imagery, OpTIS is free from human response bias such as social desirability, which could cause survey respondents to over-report the level of their conservation practices, or errors in memory or calculating acreage. The algorithm correlates closely with ground-truthing reports from trained verifiers. Read a report that includes results from the verification.

**32. What are future plans for OpTIS?**
Dagan, CTIC, and TNC are working with partners to expand OpTIS to other regions of the country (e.g., Chesapeake, Mississippi Delta, Far West, Great Plains, Southeast, etc.) and conduct annual updates of the Corn Belt for 2019 and beyond.