Sustainable Chesapeake

Innovations in Controlled Traffic Farming: *Building Resilient, Sustainable and Smart Cropping Systems: Final Report*

By John Shepherd, Michael Flessner, Kristen Hughes Evans and Lydia Taylor*

Project Summary

Sustainable Chesapeake, in partnership with John Shepherd of Shepherd Grain Farms, Virginia Tech, and conservation agronomy partners, received funding through the Virginia Conservation Innovation Grant program to demonstrate and evaluate controlled traffic farming (CTF) innovations aimed at improving soil health, reducing compaction, and managing weeds on over 3,000-acre grain farm (typically a 50:50 corn soybean rotation) spanning the James and Chowan River basins.

Building on prior experience with GIS-based CTF systems that proved challenging for custom applicators to follow, the project focused on implementing tramlines to improve consistency and ease of adoption. To support tramlining, John audited existing machinery and invested in equipment that aligned base widths. He also purchased a Horsch planter equipped with software that automatically created tramlines every third pass, while increasing seeding rates in adjacent rows to avoid yield loss. Once established, tramlines provided clear visual guidance for all operators and substantially simplified implementation of the CTF system. Soil compaction data collected from three project fields indicated reductions in compaction relative to baseline conditions.

In parallel, the project piloted chaff lining in collaboration with Virginia Tech to explore its potential to reduce weed pressure. Chaff lining concentrates weed seeds and crop residue into narrow bands during harvest rather than distributing them across the field. While alignment of chaff lines with tramlines was not fully achieved during the project period, the demonstration showed that chaff lining can be implemented using relatively low-cost modifications. Follow-on research is currently underway to further evaluate performance on Shepherd Grain Farms.

The project also supported farmer-to-farmer learning through the Virginia Innovation Roundtable, a network of producers committed to advancing soil health, resilience, and farm profitability. Project lessons were shared through farmer meetings and professional conferences, including the 2026 Virginia Crop Producers Association annual meeting, with additional outreach planned. Collectively, the project demonstrated practical pathways for improving CTF adoption and laid the groundwork for continued research and knowledge transfer across Virginia.

**John Shepherd is the owner of Shepherd Grain Farms, Dr. Michael Flessner is a professor and weed extension specialist with Virginia Tech, Kristen Hughes Evans is the Executive Director of Sustainable Chesapeake, and Lydia Taylor serves as a Virginia Tech/Virginia Natural Resources Conservation Service Integrated Conservation Agronomist.*

Project Goals and Objectives

The primary goal of this project was to successfully implement controlled traffic farming (CTF) using physical tramlines that all equipment operators could follow consistently. Additionally, the project team wanted to explore chaff lining as a complement to CTF systems.

Specific objectives included:

- Establish permanent tramlines that help confine equipment traffic to the same wheel tracks year after year.
- Reduce soil compaction by minimizing heavy equipment traffic over most of the field.
- Improve operational efficiency and ease of use compared to GPS-only, CTF system.
- Evaluate the feasibility of chaff lining as a weed seed management strategy within a CTF system.
- Generate on-farm data and experience that and share results with other producers.
- Establish the Virginia Innovation Roundtable as a valuable networking opportunity for leading farmers, with the long-term goal of increasing adoption of regenerative farming practices across the Commonwealth.

Project Methods

Tramline Implementation

Thanks to a previous contract via EQIP, John Shepherd had aligned wheel base widths of most equipment on the farm to implement the CTF system. The key remaining piece was a planter capable of creating tramlines. CIG funding to implement an improved CTF system allowed him to purchase a Horsch Maestro SV

John Shepherd's Perspectives.

John Shepherd is the owner of Shepherd Grain Farms LLC

I've been trying to do the right thing agronomically for a long time—no-till since 2007 and paying attention to soil health. In my region, we routinely experience drought, which makes moisture retention and soil health essential for my farm's financial viability. Controlled traffic farming made sense to me because minimizing compaction across the field improves water infiltration. This allows the crop to take full advantage of a heavy rainfall event that may last only a few minutes by drastically reducing run off.

Before this project, I had already tried to implement controlled traffic farming using GPS guidance alone. The idea made sense, but in practice it was frustrating and unreliable. Transferring GPS tramlines to custom applicator equipment was particularly challenging.

This project was really about making controlled traffic farming work in the real world. With support from the Conservation Innovation Grant (CIG) program, we installed physical tramlines using a planter designed to create permanent wheel tracks. That one change made a big difference. With a physical marker, everybody knows where to drive. You're not staring at a screen, counting rows, or hoping the lines transferred right.

We also explored chaff lining as a complementary practice to manage weed seed distribution at harvest. As Dr. Michael Flessner explained, *"When we harvest conventionally, we're very good at spreading weed seeds around. If one weed goes into the combine, we might spread those seeds 30 feet wide and 20 feet long. That's how we make the problem worse."*

While the chaff lining component required adaptation, the tramline system itself has been a clear success. It simplified operations, improved consistency across operators, and allowed us to truly implement controlled traffic farming across the operation. We tested compaction in several fields and CTF with tramlines has made a difference in just three years. Over the last three years we have been implementing CTF, we've had the best yields during two of those three years that we have ever had. I'm confident we are heading in the right direction with this approach. CTF paired with other practices to promote healthy soil such as cover crops and poultry litter applications are building a more resilient and more productive soil.

1820 planter with tramline software (**figure 1**). Every third pass, the planter automatically shuts off specific rows to create a 40-inch-wide tramline, approximately every 90 feet.

Figure 1. John Shepherd with the new Horsch planter with software installed to implement tramlines.

Once installed, the tramlines served as permanent, visible traffic lanes for sprayers, applicators, and other equipment. This eliminated the need to rely solely on GPS guidance or row counting (**figure 2**). As John describes it, *"Instead of watching a monitor and the rows and the monitor and the rows, you just look forward. You can see where to turn in. It actually makes farming easier."*

Custom applicators quickly adapted to the system. John explained that *"Before tramlines, getting buy-in to use a GPS-based CTF system from custom applicators was almost impossible. Once the tramlines were there, everybody loved it because it was so much easier."*

Figure 2: Once established, tramlines make it easy to see where to place equipment wheels, concentrating compaction due to heavy equipment in the tramlines, reducing soil compaction over the rest of the field.

Chaff Lining Research (Led by Dr. Michael Flessner)

The chaff lining component of this project was led by Dr. Michael Flessner, professor and extension weed science specialist with Virginia Tech. He focused on addressing the growing challenge of herbicide-resistant weeds. *"As herbicide resistance numbers have gone up and up, it's pretty clear we've got to do something beyond herbicides,"* Dr. Flessner explained.

At harvest, weed seeds that escape in-season control are typically spread across the field by the combine's residue spreaders. *"Everything that comes out the back of the combine gets spread evenly—and that's great for residue, but terrible for weeds,"* he noted.

Chaff lining changes this dynamic by separating the finer chaff fraction—where most weed seeds exit the combine—from the larger straw residue. Instead of spreading weed seeds across the full width of the header, the chaff is concentrated into a narrow band (**figure 3**). *"Rather than spreading seeds across 30 or 40 feet, you're putting them in a band maybe 18 inches wide. That's an 80 to 90 percent reduction in area."*

The original vision paired chaff lining with controlled traffic farming by proposing to deposit weed seeds directly into tramlines. *"The idea is that if we're going to concentrate weeds, let's put them in areas where there isn't a crop competing with them,"* Dr. Flessner said. *"And if those tramlines stay in the same place year after year, we keep putting seeds right back where they came from."*

Initial attempts to implement chaff tramlining used conveyor belts to move chaff from the center of the combine to the wheel tracks. Under commercial conditions and rolling terrain, this system proved unreliable. As Dr. Flessner summarized, *"We were asking the combine to do something it wasn't designed to do."*

The team pivoted to a simpler funnel-based chaff lining system. *"Moving from conveyor belts to just dumping it in one line was really about simplicity—fewer moving parts, fewer headaches,"* he said. After several design iterations, the system operated reliably for multiple seasons.

Additional support was received, in part from the USDA Agricultural Research Service Areawide program and the Virginia Soybean Board. Field trials evaluating chaff lining performance on weed pressure are ongoing on Shepherd Grain Farms.

Figure 3. Chaff lines created during soybean harvest at Shepherd Grain Farms.
Photo: Claudio Rubione, GROW. The inset photo features the chaff line distribution system mounted on the back of the combine.

Project Results

Controlled Traffic Farming with Tramlines

The tramline system worked exactly as intended. Having a physical marker in the field made controlled traffic practical and repeatable. Operators no longer had to watch screens constantly or count rows. Custom applicators immediately understood where to drive and consistently stayed in the tramlines.

From an operational standpoint, farming became easier and more efficient. Turning into rows, lining up equipment, and verifying proper traffic patterns were all simpler with visible tramlines.

Equipment Challenges

The initial challenge implementing a CTF system with tramlines was to ensure the wheel base of all equipment used on the farm aligned with the tramline spacing. Additionally, a setback occurred in the first year when the planter's hydraulic system, developed for flat terrain common in the Midwest, could not respond quickly enough to rolling terrain characteristic of many farms in Virginia. This resulted in shallow seed placement in some areas and reduced corn stands during the first season. To address the problem, Horsch sent a team of equipment specialists to Shepherd Grain farms. They modified the hydraulic system, which completely resolved this issue. Since then, the Horsch planter has been operating exactly as John had envisioned.

Impact on Yields

Farms in John's area of Virginia had some rough weather over the project timeframe including both record breaking droughts and heavy rainfall events, making improvements in soil compaction even more important for moisture retention and drought resiliency. Because CTF with tramlines was widely adopted across the farm, the team doesn't have field trial data. However, John won second place in the 2025 Virginia Corn Yield Contest, No-till and non-irrigated class, at 328.6 bu/a. John also won first place in the 2023 Virginia Corn Yield Contest, No-till and non-irrigated class, at 314.4 bu/a. These contest results were from field J03_5, highlighted in figures 4 and 5 below. For reference, the Nottoway County corn yield average in 2023 was 140 bu/a and the Virginia average was 157 bu/a.

Soil Compaction Improvements

Sustainable Chesapeake contracted with EarthOptics, a soil mapping and data company, to evaluate the impact of CTF on soil compaction in three fields (**Alt Field 1**, **J03_5**, and **FR1**). EarthOptic's GroundOwl sensor suite and Automated Digital Cone Penetrometer were used to measure compaction.

Field J03_5 demonstrates strong improvement between 2023 and 2025, particularly at 3 and 6 inches (**figures 4 and 5**). The dominant mid-depth compaction layer observed in 2023 is substantially reduced and broken up in 2025. While deep compaction persists, its continuity appears diminished. Overall, soil conditions in J03_5 show meaningful recovery at agronomically important depths.

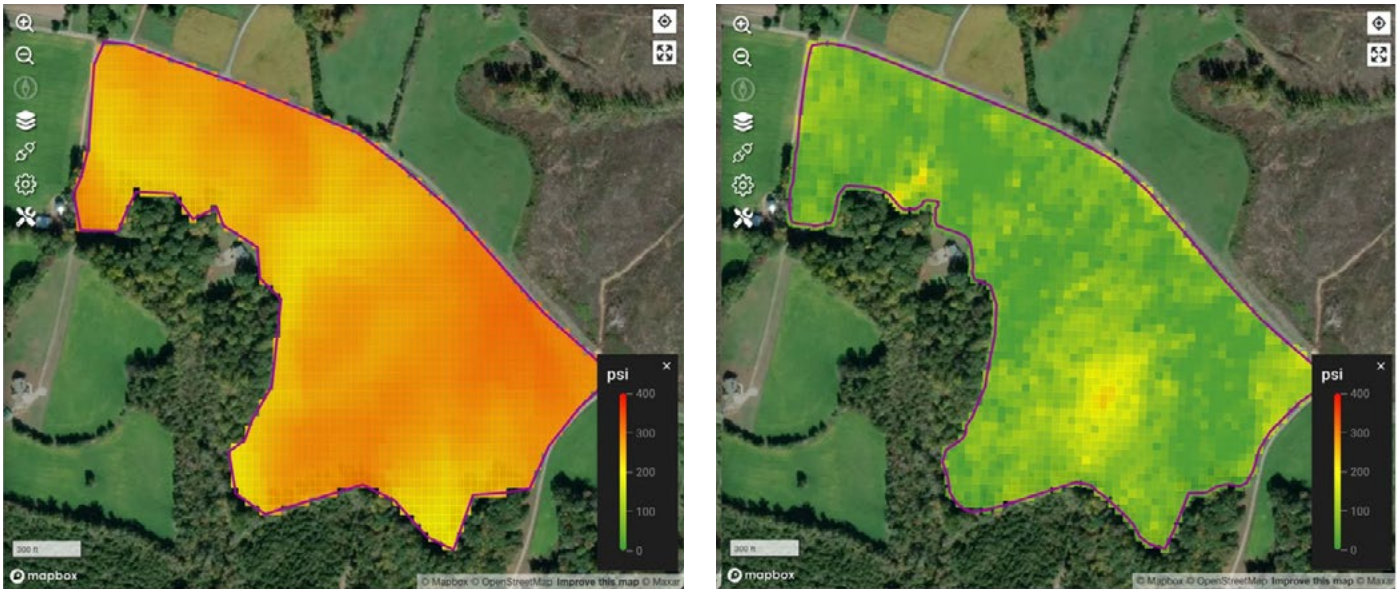

Figure 4. Soil compaction at 3 inches in J03_5 in 2023 (left) and 2025 (right).

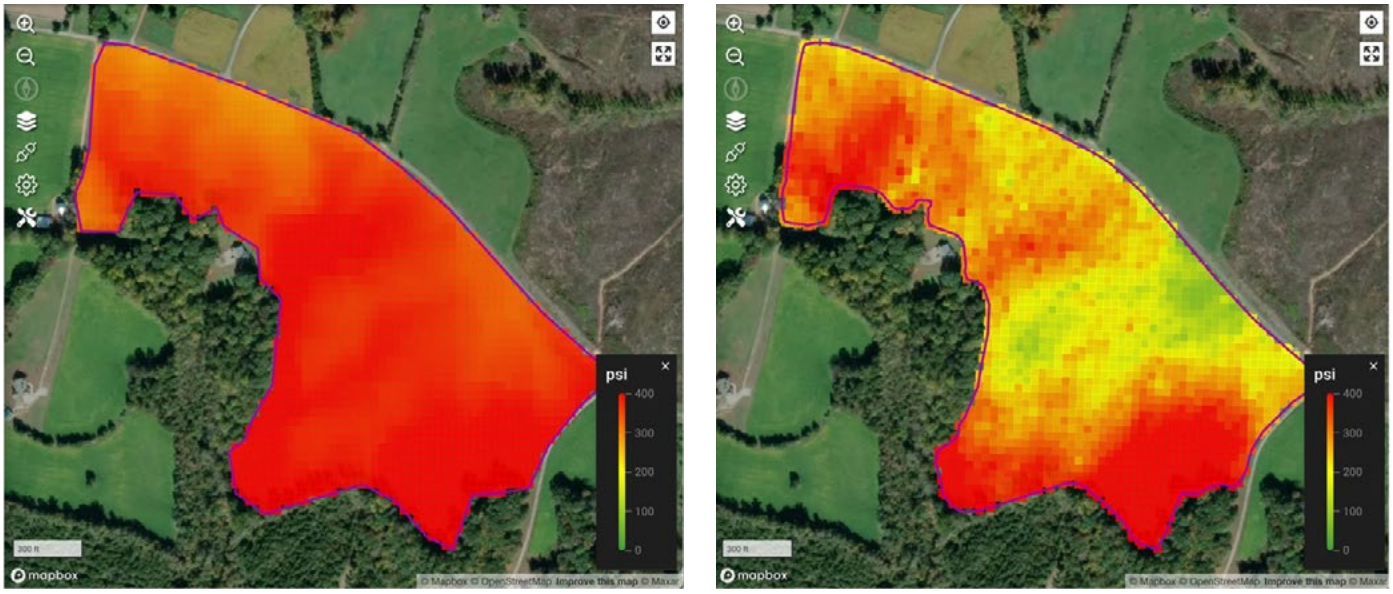

Figure 5. Soil compaction at 6 inches in J03_5 in 2023 (left) and 2025 (right).

Alt Field 1 shows clear improvement from 2023 to 2025 (**figures 6 and 7**), most notably at 3 and 6 inches. Shallow subsurface compaction is substantially reduced, and the mid-depth compaction layer appears weaker and less continuous. Deep compaction remains a constraint but shows signs of reduced uniformity. Overall, soil structural conditions are trending positively, particularly in the depths most critical for root development.

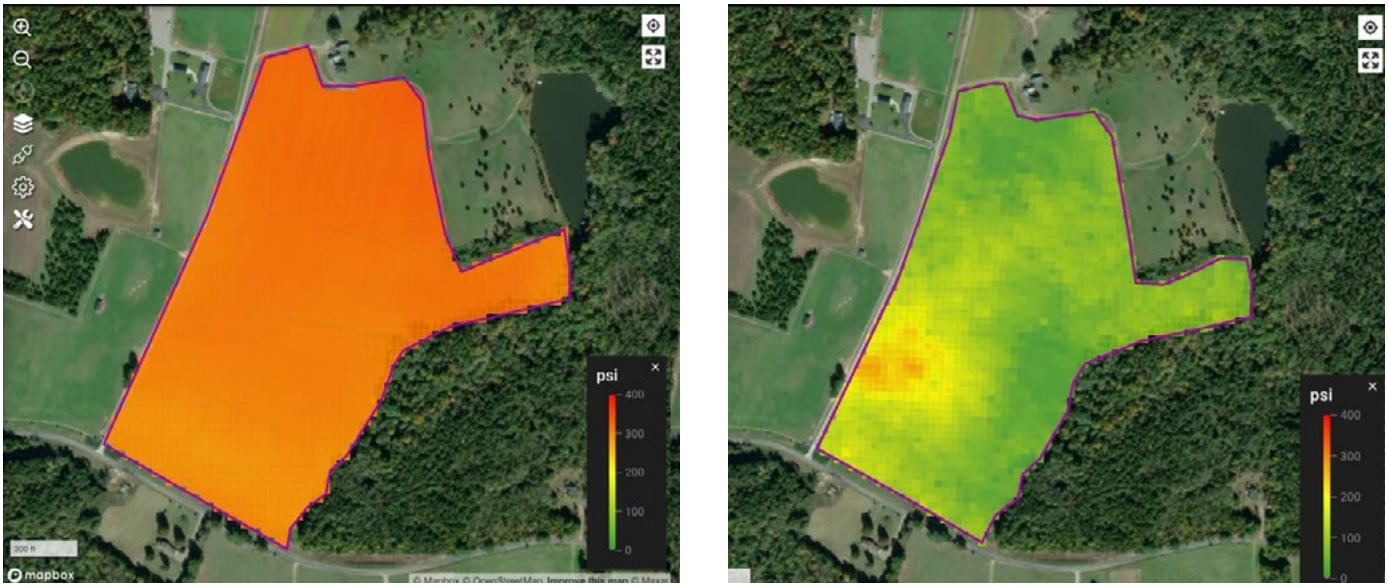

Figure 6. Soil compaction at 3 inches in Alt Field 1 in 2023 (left) and 2025 (right).

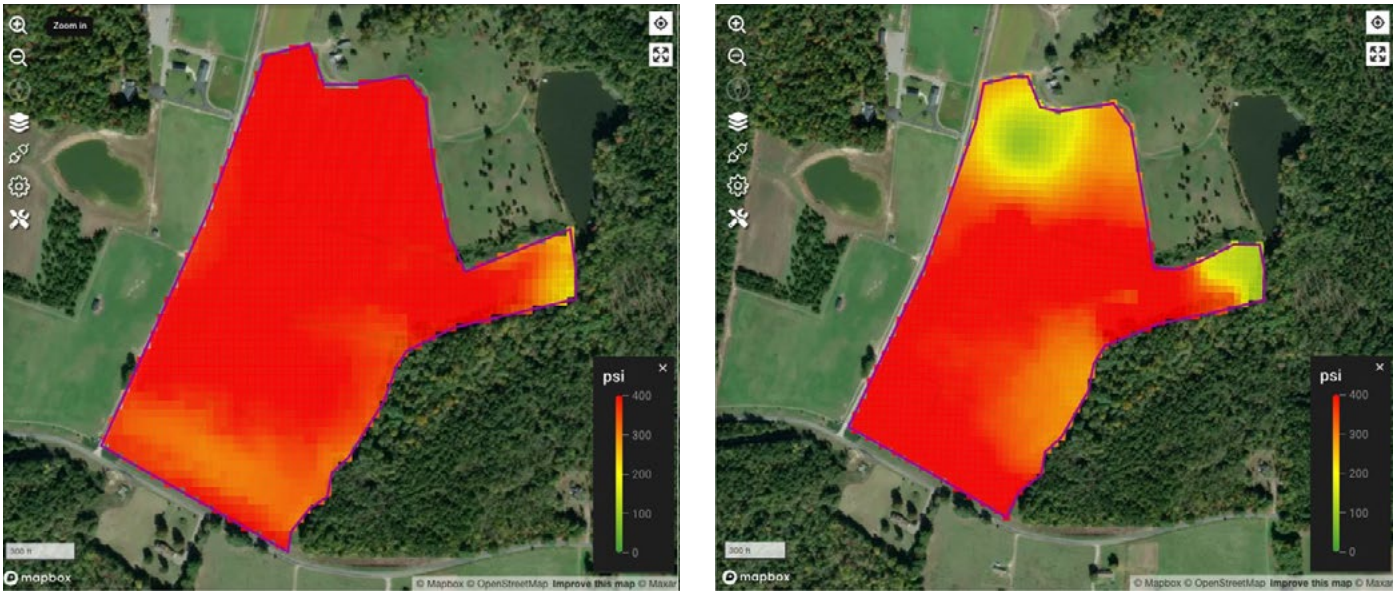

Figure 7. Soil compaction at 6 inches in Alt Field 1 in 2023 (left) and 2025 (right).

FR1 shows substantial improvement from 2023 to 2025 (figures 8 and 9), especially at 6 inches, where a previously continuous compaction layer becomes significantly weaker and less extensive. Shallow subsurface conditions also improve, while deep compaction remains but shows reduced uniformity. Overall, FR1 exhibits strong evidence of structural recovery at critical rooting depths.

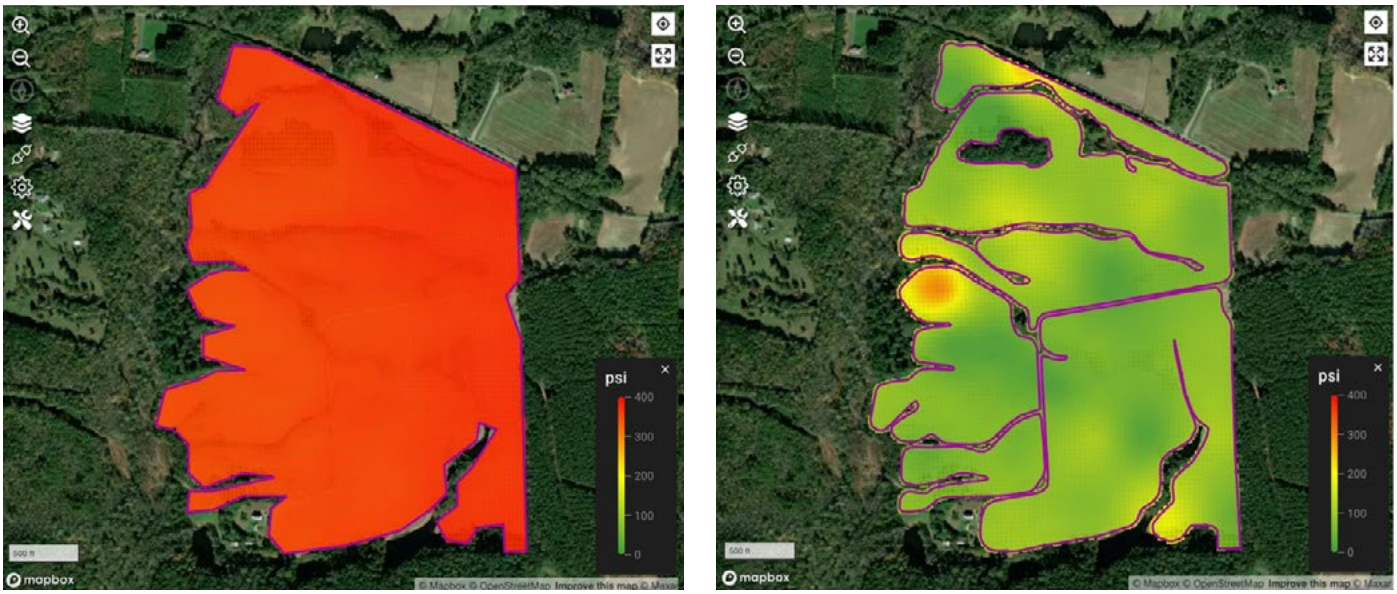

Figure 8. Soil compaction at 3 inches in FR1 in 2023 (left) and 2025 (right).

Figure 9. Soil compaction at 6 inches in FR1 in 2023 (left) and 2025 (right).

Chaff Lining Outcomes

Although the original goal of placing chaff directly into tramlines was not fully achieved, the simplified chaff lining system functioned reliably for multiple seasons. Weed sampling suggested that concentrating chaff altered weed seed distribution, with higher densities in the chaff line and lower densities across the rest of the field.

Dr. Flessner noted that research elsewhere shows promise: *"What we've seen in other studies is 50 to 80 percent reductions in some problematic weeds in chaff lines compared to spreading them out."* On this commercial farm, however, overall weed pressure varied widely by year. Some years we just didn't have many weeds to measure. That's a good problem to have from the farmer's perspective, but it makes research and data collection more challenging.

Crop-specific observations were also important. Chaff lining fit well behind soybeans, where residue decomposed quickly. *"With soybeans, I really don't see a lot of downside,"* Dr. Flessner said. In corn, many weed seeds never reach the back of the combine, limiting the effectiveness of chaff lining after corn harvest.

The experience and process of modifying the combine for chaff lining, including photos and video, were reported by GROW, a national collaboration of weed scientists: **https://growiwm.org/making-chaff-lining-work-on-shepherd-grain-farms/**

Virginia Innovation Roundtable

This grant also helped Sustainable Chesapeake and our partners launch the Virginia Innovation Roundtable. While innovators make up a small percent of the population, they are key drivers for technology adoption (figure 10).[1,2] While innovative farmers often partner with NRCS and land grant university extension specialists to try promising new techniques on their farms, they may feel isolated in their immediate farming communities and find value in networking with likeminded peers. Theories of change suggest that strategies to reach a "tipping point" in technology or conservation practice adoption can be facilitated by maximizing innovator success and equipping innovators to counter skepticism. The Virginia Innovation Roundtable serves this purpose.

Figure 10: Rogers' Innovation Curve adapted for regenerative agriculture. Virginia Innovation Roundtable farmers are not only innovators, but many also serve as soil health mentors who lead efforts to expand the adoption of regenerative agricultural methods to farmers throughout Virginia.

[1]*Rogers, E.M. (1962). *Diffusion of Innovations*. Free Press, New York.*

[2]*Moore, G.A. 2014. Crossing the Chasm: Marketing and selling disruptive products to mainstream customers, 3rd Edition. Harper Business: New York*

With support from the Virginia Soil Health Coalition and the Virginia Tech/NRCS Integrated Conservation Agronomist, many of the Innovation Roundtable members also serve as soil health mentors and leaders in the Virginia No-till Alliance, a farmer-led effort to expand the adoption of regenerative agricultural practices that improve farm profit and resiliency throughout the Commonwealth.

Project Outputs

- Installation and successful operation of a full-field tramline system using commercial-scale equipment.
- On-farm trials of chaff lining equipment and harvest modifications.
- Multi-year weed population sampling across crop rotations (corn and soybeans).
- Soil compaction and traffic pattern data collected for ongoing analysis.
- Demonstration of controlled traffic farming under real-world conditions, including use by contract applicator farm partners.
- Networking for innovative farmers is well established, and is in the early stages of replication in Maryland and Delaware.

Project Impacts

This project demonstrated that controlled traffic farming becomes significantly more practical when physical tramlines are used. According to John Shepherd, *"Once you get your equipment matched, it's a no-brainer. I don't really see any drawbacks once it's set up."*

Operational benefits included improved efficiency, reduced stress, and greater consistency across operators. John noted *"You know if somebody messes up because you can see it. And most of the time, they don't mess up because the system makes sense."*

The chaff lining research added an important weed management dimension to the project. Dr. Flessner emphasized its role as a complementary tool: *"We're not killing weed seeds, but we're changing where they end up—and that alone can make a big difference over time."*

While additional research is still needed to understand long-term weed seed survival, this project showed that chaff lining can be implemented at low cost. *"If a farmer's willing to put in a day or two and a few hundred dollars in materials, they can make this work,"* Dr. Flessner noted.

Together, the tramline and chaff lining components illustrate how farmer-led innovation and applied research can intersect. By combining practical experience with targeted research, this project offers a realistic pathway toward more resilient cropping systems that protect soil health, improve operational efficiency, and prepare farms for a future with fewer weed management options.

USDA United States Department of Agriculture
Natural Resources Conservation Service

VT College of Agriculture and Life Sciences
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Sustainable Chesapeake

Bridging the gap between agriculture and conservation in the Chesapeake Bay watershed.

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