Science Societies

Farm data layers for precision agriculture

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| September 16, 2025

Management zones created from real-time precision soil mapping.

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Farming today is not just about soil, seed, and sweat. It is also about data. Layering different types of farm data—such as yield maps, soil sampling, and remote sensing—can help producers and their advisers identify productivity trends, diagnose issues like nutrient deficiencies or water stress, and inform management decisions. By combining advanced sensors, satellite/drone imagery, and farm management software, producers can optimize inputs, improve yields, and increase sustainability.

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Kansas farmers are at the heart of feeding the world. The state is one of the largest producers of wheat, fuels the livestock industry with millions of bushels of grain, and leads in sorghum production, which is an important crop for biofuels and international markets. When a loaf of bread is baked in Europe or a shipment of beef reaches Asia, there is a good chance that Kansas farmers had a hand in it.

But farming today is not just about soil, seed, and sweat. It is also about data. As technology on the farm continues to advance and the amount of data being collected skyrockets, producers may ask, “How can I use all of these numbers for effective farming operations?” Or “What value can these numbers or data provide me?” There are many different types of data generated on the farm, but data is only valuable when they can be interpreted properly. The diverse landscapes of Kansas, with its uneven terrain, variable soil, and unpredictable weather, create challenges that are not unique to just this state. In fact, the solutions developed here can be applied to similar farming conditions worldwide, making Kansas a real-world testing ground for precision agriculture innovations.

Measuring crop performance and productivity

One of the most used and generated types of data in agriculture is measuring crop performance and productivity. This type of data depends on a wide range of factors like soil, climate, topography, and so on. Crop performance includes maps related to crop health, such as Normalized Difference Vegetation Index (NDVI). When measuring the crop performance and productivity, the crucial part is that the data is spatial, meaning it is tied to a location in the field. This allows you to evaluate how the performance and productivity of a crop changes across different locations in a field, which can be used to inform management decisions both in season and in future years.

Yield data is one of the most common types of farm data used to understand crop productivity. The yield map generated by the combine is important because it shows the final effect of every decision made throughout the growing season. Every preparation made following the last harvest, all the way to planting, through the entire growing season, and finally to harvest culminates in the yield. Think of it as your report card for the year. Certain year-to-year differences will occur in your field, but once you have collected multiple years of yields on that field, you can layer them together to find trends, as seen in Figure 1.

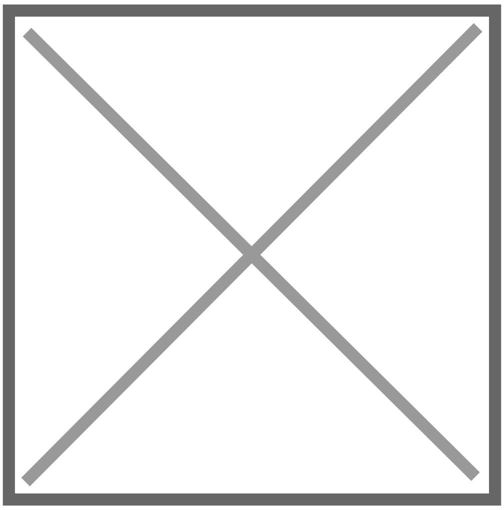


Figure 1. *Yield normalization for four years of corn yield data (green to red color indicates higher to lower*

yields).

To remove the effects of season-specific differences, yield maps are scaled to a similar range of values. This makes them comparable to each other. For example, say Year 1 is a great year with timely rainfall. Across the field, yields will be great, but there will still be areas that do better than others. Then, two years later when the field rotates back to corn, there is a drought. Across the field, yields will be worse, but there will still be areas that do better than others. Our goal with layered yield maps is not to represent yield directly, but the variability of yield in the field. We do not want the overall differences in conditions between the two seasons to show up in the layered yield map.

Yield values are scaled so that they fall between 0 and 1. The effect is that, on each map, the highest yield value in the field is represented by a 1, the lowest yield value in the field is represented by 0, and all other values fall proportionally between 0 and 1. This allows us to compare yield values from years with very different overall growing conditions, as well as the average performance of areas of the field across many years. This process of scaling values, so they are comparable is called normalization.

Yield maps can help to pinpoint the poor-yielding patches in the field, but they cannot explain the cause. Is it soil compaction? Nutrient deficiency? Poor drainage? To find the reason, we must look at other data layers that focus more on specific crop growth factors.

Soil variability

Even looking at bare-soil imagery can tell us a lot about the productivity of a soil. Color can be indicative of the organic matter content, texture, or saline or sodic status. Figure 2 shows just how much variability we can see just with our eyes. There are also a few ways to obtain soil data. General soil properties can be obtained from the USDA Web Soil Survey. This free database contains soil data for nearly the entire country. This data is good to get general idea not as useful in helping you make management decisions due to limited sampling points per field. To obtain more specific information about the soil in your field, two main methods exist: Traditional soil sampling (pulling cores and sending them to a lab) from grids of 1 to 2.5 acres in a field and real-time precision soil mapping.

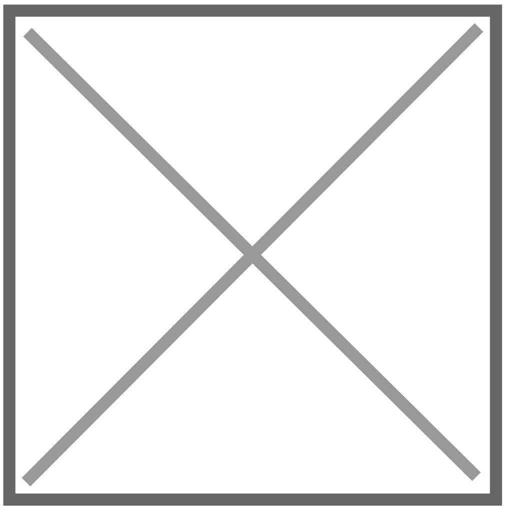


Figure 2. *Imagery of bare soil, illustrating variability of soils across space even to the naked eye. Source: Web Soil Survey.*

Soil sampling

For row crops, it is recommended that soil tests be taken every three to five years. There are two main strategies for traditional soil sampling, zone and grid soil sampling.

Zone sampling. This strategy is typically cheaper and less intense than grid sampling but can give deceiving results if you do not divide the field into zones properly. The field is divided into zones of similar soil and management practices. The number of zones depends on the variability within the field. Samples are taken within each zone to be representative of that zone. Multiple samples can be taken in each zone, and the number of samples taken in a single zone should correspond to the size of the zone.

For zone sampling to be successful, the soil within a single zone must be very similar in terms of fertility, texture, structure, porosity, topography, organic matter content, productive capability, etc. If the zones are not consistent in these factors, the sample sent to the lab will not be representative of the zone, but rather, just of the soil in the area sampled.

Grid sampling. This strategy is more labor and cost intensive, but it is not as susceptible to misrepresentation as zone sampling. This is due to the higher density of samples taken. A grid is laid over the field, typically with the cells of the grid being 2.5 acres. Cores are then pulled either surrounding the intersections of the grid lines or within a single cell of the grid. Grid-sampling results allow for more detailed and accurate soil maps to be produced.

A typical strategy for utilizing the advantages of both types of soil-sampling methods is to use grid sampling initially to obtain a better understanding of the field and to allow for proper management zones to be delineated. Once accurate management zones have been established, a farmer can switch to zone sampling based on the established management zones. This balances the cost of soil sampling with maintaining useful accuracy.

Real-time precision soil mapping

New technologies and advanced sensors allow for mechanized precision soil mapping. These machines employ one of two methods: electrical capacitance using direct-contact sensors or electromagnetic induction using non-contact sensors. The two accomplish similar results. Both methods are unable to test the nutrient content of the soil as traditional soil sampling does. However, the advantage is the increased density of data points.

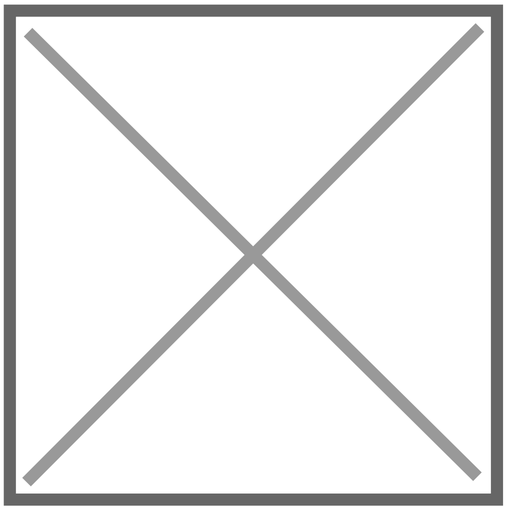


Figure 3. *Veris system.*

Electrical capacitance is sensed using pairs of coulter disks in the ground. One of the disks carries an electrical current into the ground, and the other disk measures the electrical field induced by the other disk. This yields the apparent electrical conductivity of the soil (EC_a). This metric can be used to determine soil texture. These platforms also typically measure pH and organic matter with a separate sensor. An example of these machines would be a Veris system (Figures 3 and 4).

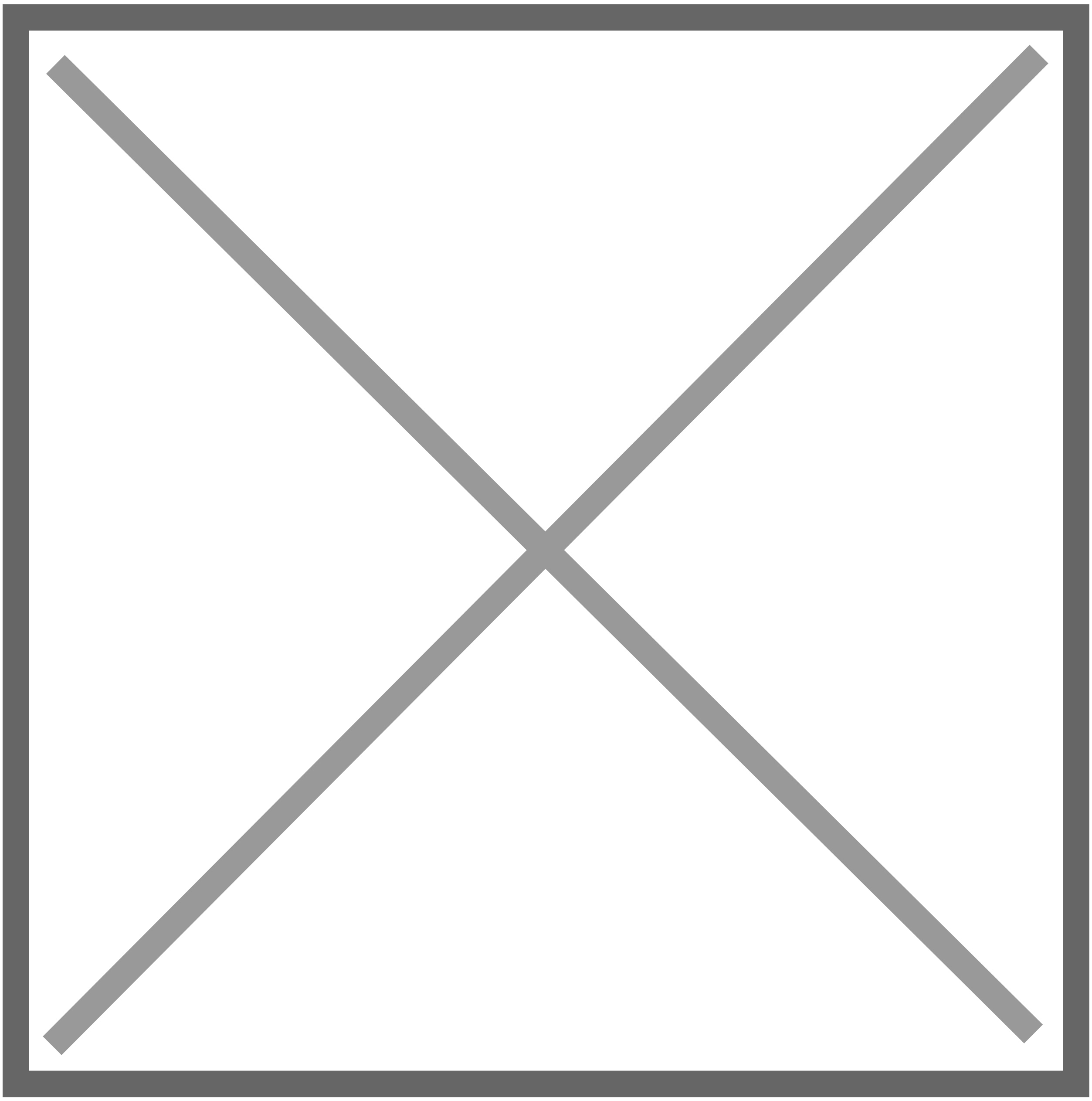


Figure 4. *Electrical conductivity maps generated from Veris. Data represent the shallow portion of the soil profile and the deep portion.*

Electromagnetic induction is accomplished by a non-contact sensor with two coils. The first induces an electromagnetic field in the soil, and the second measures the induced field. This also yields the apparent electrical conductivity of the soil (EC_a). An example of this type of sensor would be DualEM or EM38.

Interpreting soil-sampling data

It is important to layer soil fertility maps with yield data, as well as other data layers, in order to determine a course of action. For example, say a producer was to soil test their field and found the southwest region of the field has much lower levels of fertility across many tested nutrients. The farmer may assume that region of the field is just tougher ground, with lower yields, and thus tested lower. However, these low test values could be a result of a very high yield in that region of the field taking higher levels of the tested nutrients out of the soil. It is important to know which situation you are dealing with as each requires a different course of action. In the first situation, there may be no remedy if the lower fertility and lower yields are caused by unchangeable soil properties. In the second situation, the farmer simply needs to fertilize to support next year's crop.

In-season crop monitoring

Remote sensing has allowed data collection without destroying growing plants or intense labor. Since bushels are made or lost during each day of the growing season, data that can evaluate performance and condition of the crop during the growing season is valuable in the decision-making process.

Stress maps

When plants are stressed, bushels are lost. But stress often occurs before symptoms are visible. In-season remote sensing allows us to see beyond the human eye to detect stress before it is visible; allowing us to take corrective measures before more bushels are lost. There are a few common types of stress maps in use:

Vegetation indices. The most common index is NDVI, which is an indicator of "greenness" or plant health (Figure 5). It is a mathematical comparison of the reflectance of red and near-infrared light and can be acquired with handheld sensors, satellites, or drones. A key feature of NDVI is that it can see plant stress before the farmer. The values of NDVI range from –1 to +1 with 0 to –1 being essentially no vegetation, and values near 1 being perfectly healthy vegetation. Other vegetation indices also exist for more specialized purposes, but NDVI is the most common in agriculture.

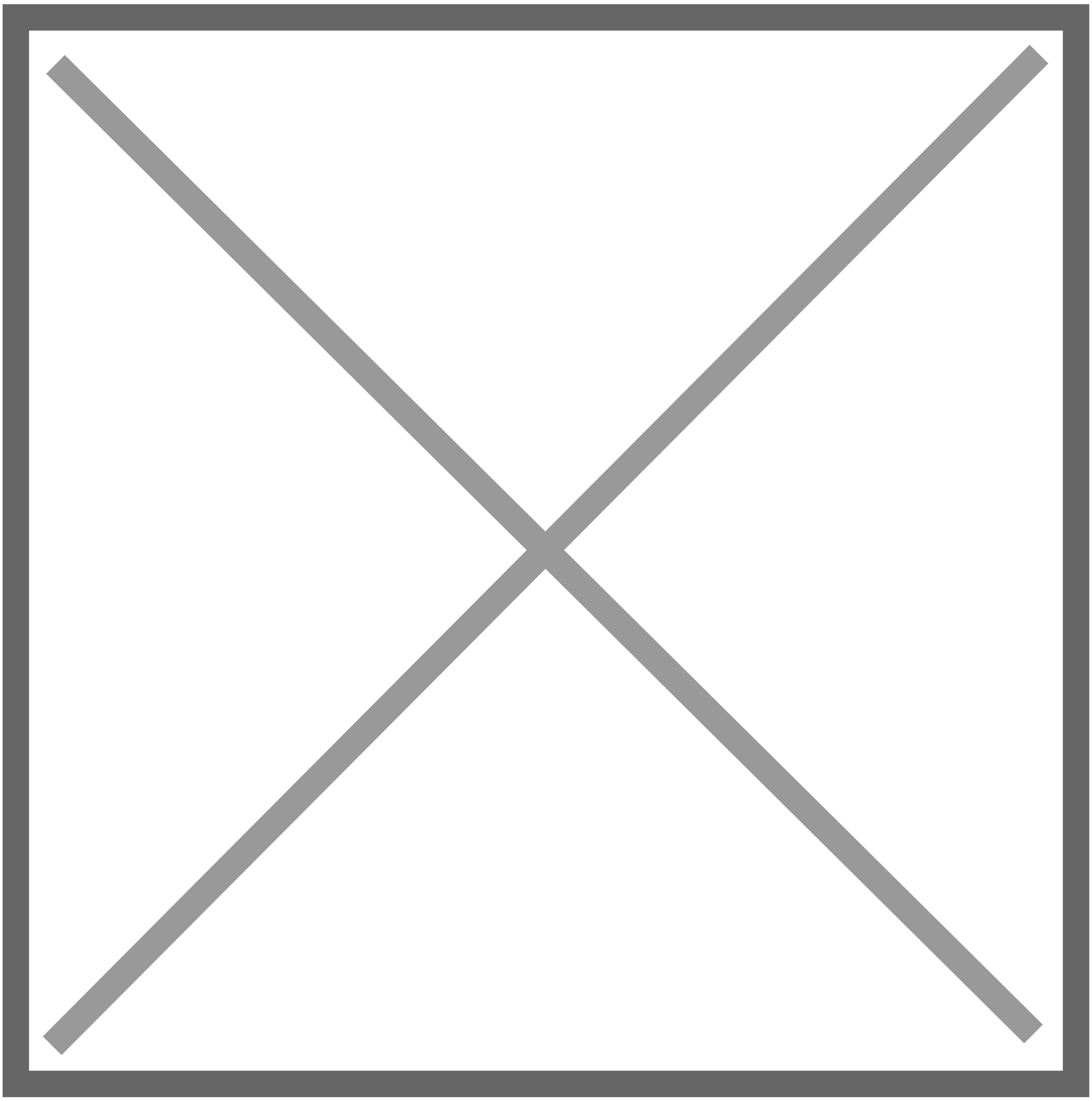


Figure 5. *Split view of thermal (left) and NDVI (right).*

Thermal. Temperature of the crop canopy can also be an indicator of plant health. When plants become water or heat stressed, they heat up. So, thermal maps can show which areas of the field are stressed before there are visible symptoms. Think of taking a sick person's temperature. Just as we may run a fever when we are sick, crops do as well. Thermal data is typically acquired through satellites or drones but can also be acquired with handheld sensors (Figure 6).

Water stress. Water stress is one of the most common types of stress in Kansas. In remote sensing, Normalized Difference Moisture Index (NDMI) can be used to measure moisture stress in the field and show how it varies across the field. This index is a mathematical comparison of the reflectance of near-infrared and short-wave infrared light. An NDMI map can be used to detect water stress before visual symptoms occur.

Many more indices have been developed for specific purposes. An extensive list can be found at Index Database.

Advanced uses for stress maps

All vegetation indices, but more specifically NDVI, can have a wide variety of uses in crop management. Some of the more common are nitrogen management, yield estimation, and disease outbreak detection. Because nitrogen is a common limiting factor, especially in irrigated settings where water is not as limiting, NDVI can be used to develop variable-rate application prescriptions for nitrogen. It can be used to locate areas of insufficient nitrogen. While NDVI does not directly measure nitrogen supply, it does measure plant health. Areas with low NDVI tell us something is deficient, and scouting can help determine the source of lower health.

Yield estimation can also be done based on NDVI. Accuracy may not be sufficient to get an actual bushel estimation, but the NDVI map is a good indicator of which areas will be higher yielding, and which will be lower yielding. High NDVI values are typically strongly related to high yields. Disease outbreaks can also be detected with NDVI maps. Patches of lower NDVI near the edge of the field that follow a general radiating pattern can be indicative of a disease outbreak. Once an outbreak has occurred, its spread can be tracked using NDVI.

Handheld sensors like GreenSeeker can measure NDVI on the fly. These NDVI values can be used to create variable-rate nitrogen prescriptions. This Michigan State University Extension article is a great guide on how to use the GreenSeeker for a variable-rate nitrogen application (Costa, 2019).

Comparing drones and satellites

Table 1 highlights the important differences between drones and satellite systems. The most obvious difference in data output is the resolution. The effect of this difference on the output data is seen in Figure 6. Drones typically collect data with resolutions in the range of 1 to 2 inches per pixel while satellite data resolutions will be feet or even miles per pixel (Joyce, 2022). A satellite has a coarser resolution due to the great distance between sensor and ground. However, certain paid (example: PlanetScope satellites) satellite services have a finer resolution of around 1 ft per pixel.

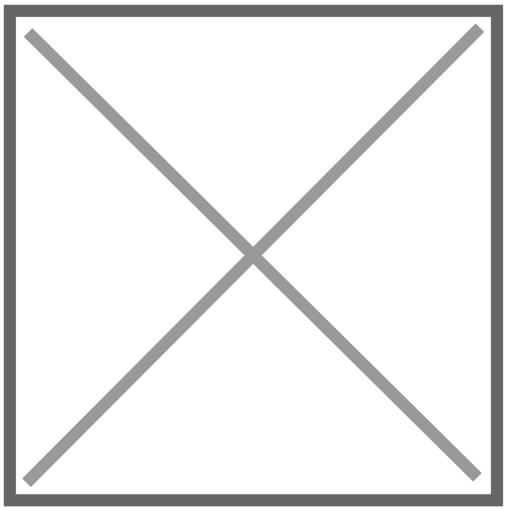


Figure 6. *Comparison of resolution between unmanned aircraft systems (UAS) and satellite systems.*

Another major difference is the cost to use. Data from unmanned aircraft systems comes at a fee, which can be more expensive than paid satellite subscriptions. The reason for the high costs associated with UAS is that the flight mission is specific to your field. A satellite in the air, although it is much more expensive to put into orbit, covers many customers in the same pass, while a UAS pilot must travel to your field and fly it specifically.

Table 1. Basic pros and cons of unmanned aircraft systems (UAS) and satellite systems.

	UAS	Satellite
Resolution	Very fine	Coarse
Typical cost	$$$	Free or $$
Timing	Whenever you want	When the orbit passes
Weather restrictions	Cannot fly in bad weather, cloud cover affects results	Images blocked by clouds

Smaller, yet still important, differences between the two systems exist in timing and weather restriction, too. A UAS flight can occur whenever you order it, pending weather restrictions. During bad weather, UAS flights will likely be cancelled for the safety of the drone. Flights also may be cancelled because partial cloud cover can skew the results. This can limit the time frames in which drone flights can occur. Satellites, on the other hand, are unaffected by weather and make their scheduled passes no matter what. The images captured by the satellites, however, may be blocked by cloud cover, and thus rendered useless. Satellites also orbit on regular intervals, which gives them a dependability, but also means if there is cloud cover on the day the satellite passes, you may have to wait multiple days for it to pass again.

Accessing satellite data

There are free online sources for satellite data that farmers can use to generate data layers for their fields (Box 1). A common source would be Sentinel imagery, which can be accessed online via the Copernicus Browser. The Copernicus Browser offers standard true-color images as well as NDVI and NDMI.

Box 1. Satellite data sources

Sentinel (Free)

Landsat 8 (Free)

PlanetScope (subscription)

Software used for management zone creation

Nowadays, there are so many different software packages available for farm data management that it can be very hard to navigate when choosing one. For Kansas farmers, choosing the right software means selecting tools that can handle diverse soil types, unpredictable weather, and the need for precision input applications. To decide on which software will best suit your operation, it can help to define the purpose you hope for the software to fill on your farm (Table 2).

Table 2. Different software types, functions, and some examples.

Software type	Functions	Examples
Farm management systems	Field mapping, crop planning, financial management, inventory tracking	Granular, Trimble Ag Software, John Deere Operations Center

Software type	Functions	Examples
Data collection and analysis tools	Sensor integration, yield mapping, soil sampling analysis, remote sensing	Climate FieldView, AgLeader SMS, AgVerdict
Variable-rate technology software	Prescription mapping, variable rate application of inputs	Raven Slingshot, AgFiniti, SST Summit
Mobile apps for farmers	Field scouting, crop monitoring, weather forecasting	FarmLogs, AgriSync, CropX

Management zones can be created using a wide variety of data layers. Layers should be chosen based on the data available, the quality of data, the goals of the farmer, the specific challenges faced in that field, and the preference of the farmers. For farmers who are just getting started in management zones, the easiest place to start is by building productivity-based management zones using yield data, as seen in Figure 7.

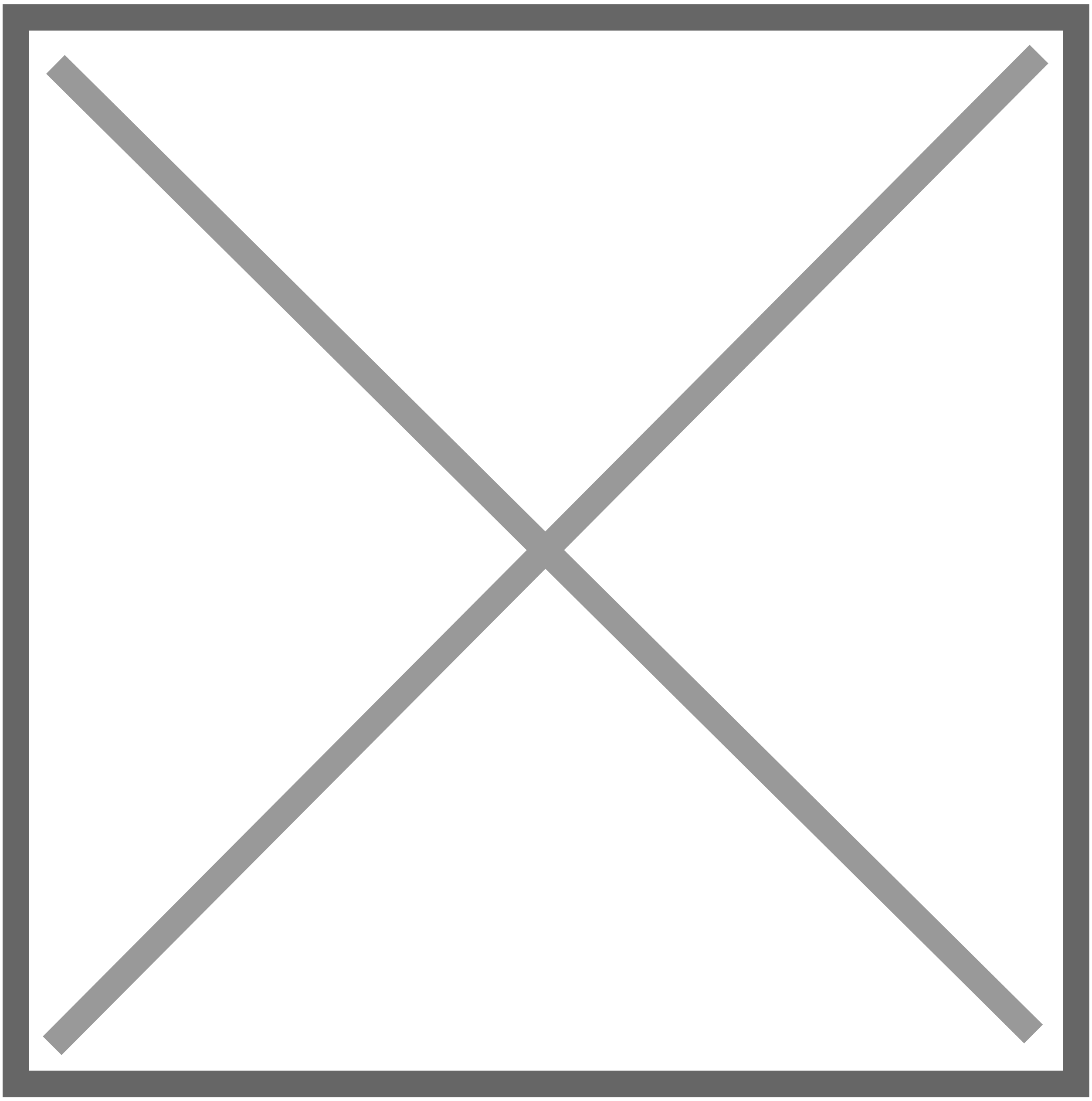


Figure 7. *Management zones based on soybean yield.*

If you only have one year of quality yield data for the crop that will be in the field this growing season, that is sufficient. However, the accuracy of the management zones will increase when you incorporate more years of yield data for that crop using normalization, as discussed before. Areas of the field with similar yields can be grouped into management zones such as high productivity, medium productivity, and low productivity. When making zones, keep it simple. Less complex and larger zones with smoother edges are preferable. An easy place to start implementing your productivity-based management zones is in variable-rate planting. Higher productivity zones can accommodate a higher population than lower-yielding areas. Planting prescriptions can be created using one of two philosophies:

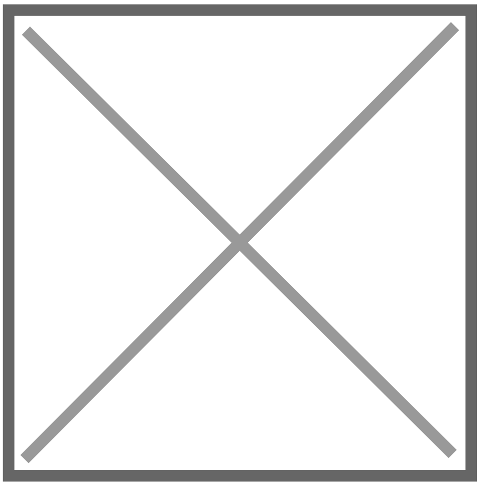
1. Keep the standard planting rate in lower productivity zones and increase the population as you move to more productive zones. This will increase the overall amount of seed you need to plant that field.

2. Keep the standard planting rate in the middle or average productivity zones. Lower populations in lower productivity zones and raise populations in higher productivity zones by the same amount. This will result in the same amount of seed being planted in the field, but the seeds are allocated more efficiently.

Both philosophies have the same goal: to work the more productive areas of the field a little harder in order to extract more yield out of it while taking it easy on the poorer regions of the field so that the yield quality is maintained.

Conclusion

While navigating the plethora of data that can be collected on the farm can be confusing, valuable information can be obtained from the data. Data collection on the farm has come a long way in recent decades. Monitoring crop performance is no longer based on subjective observations but can be quantified. Soil variability can be understood to a level never seen before. Managing this variability can help farmers maximize the output from their fields while saving money and having less environmental impact. New sensors allow farmers to see beyond the capabilities of their own eyes and spot crop stress before it is even visible. Today's farmer has access to both satellite and drone data and can choose which is a better fit for their operation. Ag software programs can help farmers use data in a way that benefits your operation. Data-driven decision making allows you to solve issues on your farm and increase your bottom line.



The use of trade names for software and hardware products is for informational purposes and example only. It does not imply endorsement of the product, nor does exclusion imply non-approval. Individuals should conduct their own research on ag software to choose the product that will work best for them. This article was prepared by the K-State Digital Agronomy Research Team (DART). Further information on their work can be found on the DART website.

References

Costa, R. (2019, August 19). *GreenSeeker tool might help reduce your nitrogen costs.* Michigan State University Extension. https://www.canr.msu.edu/news/greenseeker-tool-might-help-reduce-your-nitrogen-costs

Joyce, K. (2022, February 9). *What is the resolution of drone mapping?* GeoNadir. https://geonadir.com/drone-resolution/

Self-study CEU quiz

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1. What is the main purpose of normalizing yield data?

a. Eliminate weather forecasts.

b. Determine exact nutrient deficiencies.

c. Remove weeds from data.

d. Compare spatial trends across years with different conditions.

2. Which index detects early signs of plant stress through red and near-infrared reflectance?

a. NDMI.

b. NDVI.

c. SWIR.

d. RGBI.

3. What does the Veris system primarily measure?

a. Soil nitrogen.

b. NDVI.

c. Apparent Electrical conductivity (EC_a).

d. Canopy temperature.

4. Grid soil sampling uses more sampling points and is less prone to misrepresentation than zone sampling.

a. True.

b. False.

5. Which condition would make zone sampling less accurate?

a. Consistent soil properties.

b. Well-delineated zones.

c. Variability within zones not captured properly.

d. Use of drones.

6. What technology is used for real-time NDVI readings while driving across a field?

a. Veris.

b. GreenSeeker.

c. Landsat.

d. EM38.

7. Which system uses electromagnetic induction for soil mapping?

a GreenSeeker.

b. Veris EC sensor.

c. DualEM.

d. Trimble.

8. Satellite imagery is always higher resolution than drone imagery.

a. True.

b. False.

9. A satellite sensor may be rendered useless on a given day due to

a. cloud cover.

b. low battery.

c. crop rotation.

d. no internet.

10. Which data source is free and available through the Copernicus Browser?

a. Sentinel.

b. PlanetScope.

c. AgVerdict.

d. Trimble Ag.

11. What is a key limitation of traditional soil sampling?

a. High resolution.

b. Instant results.

c. Cannot detect nitrogen.

d. Sparse data points.

12. What causes plants to appear hotter in thermal imagery?

a. High fertility.

b. Water stress.

c. Early planting.

d. Soil salinity.

13. A good strategy for creating management zones is to start with

a. an NDMI map.

b. single-year yield data.

c. normalized multi-year yield data.

d. soil pH readings only.

14. Satellites pass over the same location only once every few months.

a. True.

b. False.

15. What is one advantage of using drones for imagery?

a. Works better in clouds.

b. Scheduled pass at any time.

c. Higher spatial resolution.

d. Free to use.

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