PIX4D

Drones in agriculture

Seeing beyond the surface with smart farming

November 2021

The challenges of modern farming

Farmers today face increasing pressure from all fronts: they are expected to meet rising food demand, with less space, whilst adapting to climate change and without using as many chemical treatments to be in line with strict regulations. It's a global challenge, and a major part of the Sustainable Development Goals for 2030, which promote more sustainable practices in agriculture and beyond.

Three of the major issues farmers face include:

1. Sustainable agriculture - using farming practices that are not wasteful, and reduce or adapt the treatments used to avoid affecting the local environment, including encouraging insect populations.
2. Increased yields - population projections expect 9.1 billion people by 2050, requiring overall food production to increase by almost 70%. Farmers need to be able to produce more food with extreme efficiency, which requires precision and consistency.
3. Cutting costs - farms need to be cost-effective in unstable conditions. This means finding a balance between identifying unchangeable factors, such as spacing between seeds in a field, and adaptable factors, such as volume of treatments required.

What solutions can farmers use?

Modern farming now involves new technologies that save time, effort, and money. Revolutions in agricultural tools are making it possible to adapt to the future. Practices such as precision agriculture techniques enhance this - and drones are a part of it. Explore this eBook to discover how drones and specialized software are helping agronomists and farmers worldwide save money, resources, and protect their local environment so they can adapt to modern agriculture.

What is precision agriculture?

Agriculture has evolved from passive, subsistence farming to using cutting-edge, modern technology to be more efficient and environmentally friendly. Precision agriculture is exactly what it sounds like: agriculture that takes advantage of modern data and machinery to make farming as precise, efficient, and productive as possible. Whether this is using a GPS to guide tractors or drones to gather crop information, precision agriculture is a diverse practice. In this eBook, we explore precision agriculture that uses UAVs and specialized photogrammetry software - specifically, PIX4Dfields and PIX4Dmapper.

Where is it?

Precision agriculture is in use all over the world, ranging from crops like oats to sugar cane. Using drones gives farmers and agronomists insights into the state of their crops on a large scale. Drones can be used all over the world, with some restrictions on the size and distance a drone flies in different countries. However, the benefits of using drones can be seen wherever drones are.

How do drones help?

Drones have evolved in the past decade to have capabilities we never could have imagined. Now, drones with specialized cameras can pick up heat signatures, light frequencies, and imagery feedback that provides incredibly helpful information about a field that is not available in the same way to the naked eye.

This is why they are helpful: they gather data that is incredibly precise and accurate that can be used to analyze how a crop is growing, areas of stress, and help implement treatment plans that are less resource expensive, which in turn helps agriculture move towards more sustainable practices.

The value of photogrammetry software

What does the software bring? Well, the drone only provides imagery - the software does the big stuff. With images from the right camera, the software can help analyze features such as how the plants reflect green light, which in turn gives insight into the state of chlorophyll in crops and thus, the health and vigor of the plants. Indices, which we will get into later, analyze the differences in spectral bands of light to look at the factors causing plant stress. This insight was previously unavailable at such an accessible, commercial scale, and yet it can now be used by any farmer in the field with a drone and a laptop. It has gained significant value in terms of providing new knowledge and in becoming accessible worldwide.

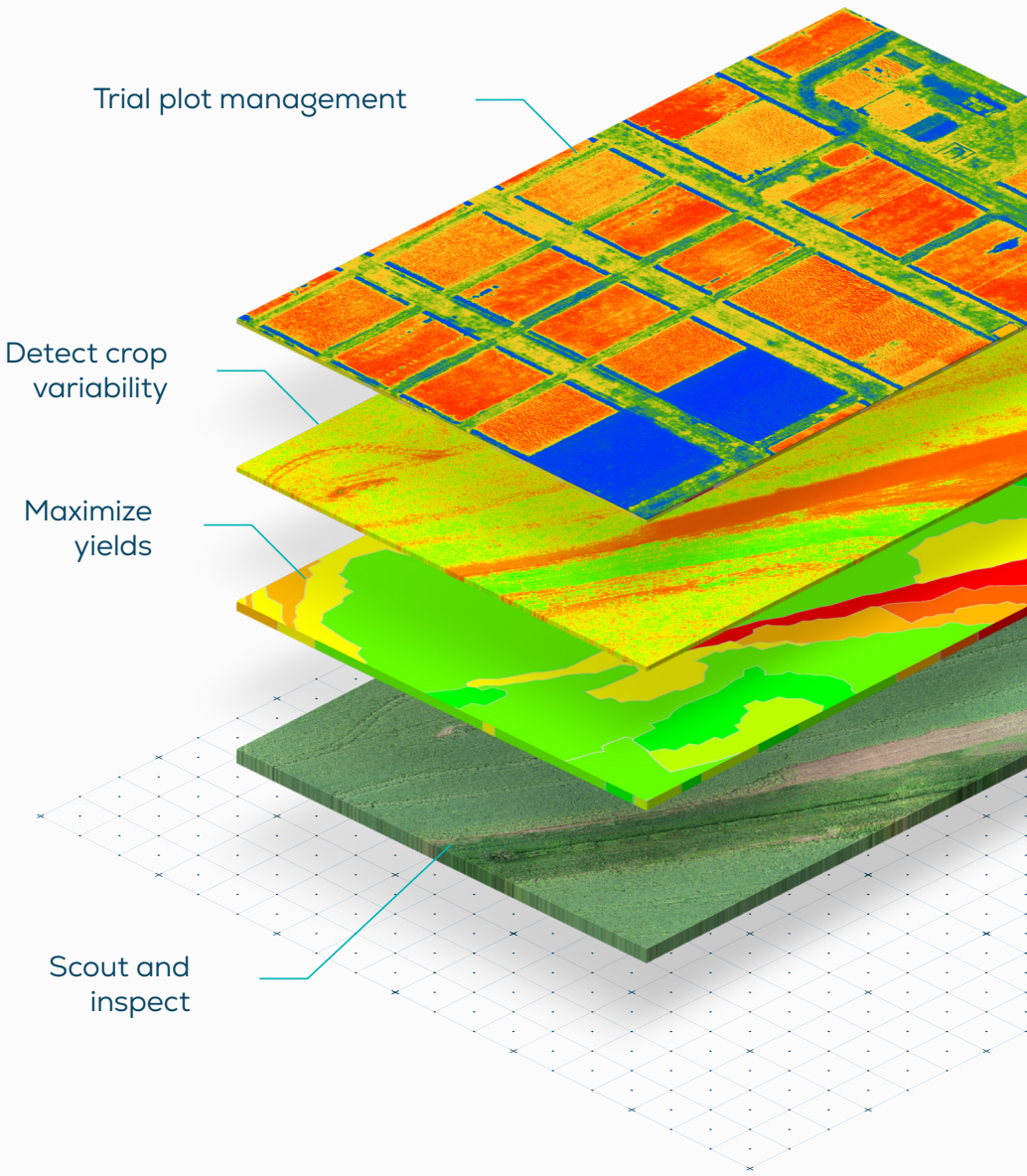
It sounds too good to be true. But it is true, as we have seen in use cases and examples around the world. This eBook will dive into these testimonials over the next few chapters. Our first chapter will discuss how drone mapping can help, looking at the decision circle and crop cycles. The next chapter explains how vegetation indices work, demonstrating precision agriculture in the field. Finally, we will share agricultural insights all year round and information about how drones in agriculture have a role throughout the agricultural cycle.

What does Pix4D do?

At Pix4D, we have two specific products for agriculture:

PIX4Dfields - PIX4Dfields is the precision agriculture mapping software. Use images taken from drones to generate reliable maps that tell you about the state of your crops and stress hotspots in your fields, with photos captured by specialized multispectral cameras or normal RGB images. Results are generated in-field with no need for an internet connection, making everything more efficient.

PIX4Dmapper - PIX4Dmapper is a desktop software that also has the ability to interpret both RGB and multispectral imagery to get insights into a field before anything is visible to the human eye.



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Contents

01 How drone mapping can help in your fields

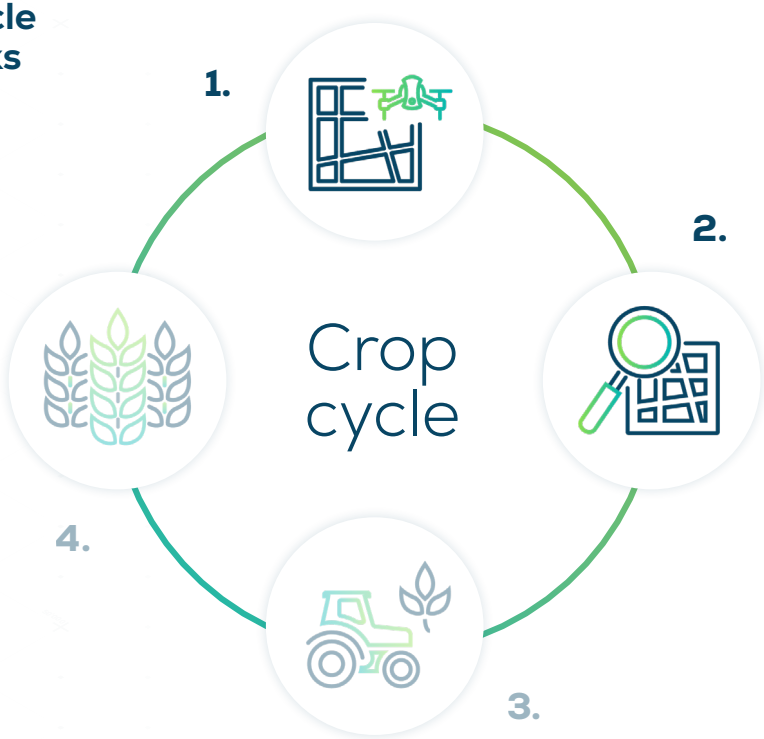
Decision cycle and crop cycle – Fast crop scouting – Sustainable agriculture

Decision cycle vs crop cycle

Drones provide more information to growers before they make a decision that might affect the crop. As a result, the impact of the decision - or decision cycle - is made more effective by being based on more data. This, in turn, means the crops are better taken care of which improves the crop cycle.

Drones enter the agricultural cycle as part of a decision cycle. It looks like this.

1. **Surveying/scouting**
   a. The drone will be used to collect data about the site. The data collected is imported to PIX4Dfields or PIX4Dmapper.
   b. The software rapidly processes the data offline, and provides results where anomalies can be highlighted with vegetation indices and shared via share-to-PIX4Dcloud.



2. **Interpret findings**
   a. Once the data has been processed, farmers and service providers can analyze the data, looking at factors such as.
      i. Using machine learning and AI for crop counting, row detection, and weed management.
      ii. Areas of stress or general status of their field and crops - e.g. affected by pests, diseases, nutrient deficiency, animals or weather.
      iii. Land topography - flood prone areas, elevation, soil characteristics, etc.
      iv. Determine field boundaries - locate and create records of field areas.
      v. Planning targeted operations or variable rate mapping to have specialized treatment plans for minimal resource use to cut costs and treatments.

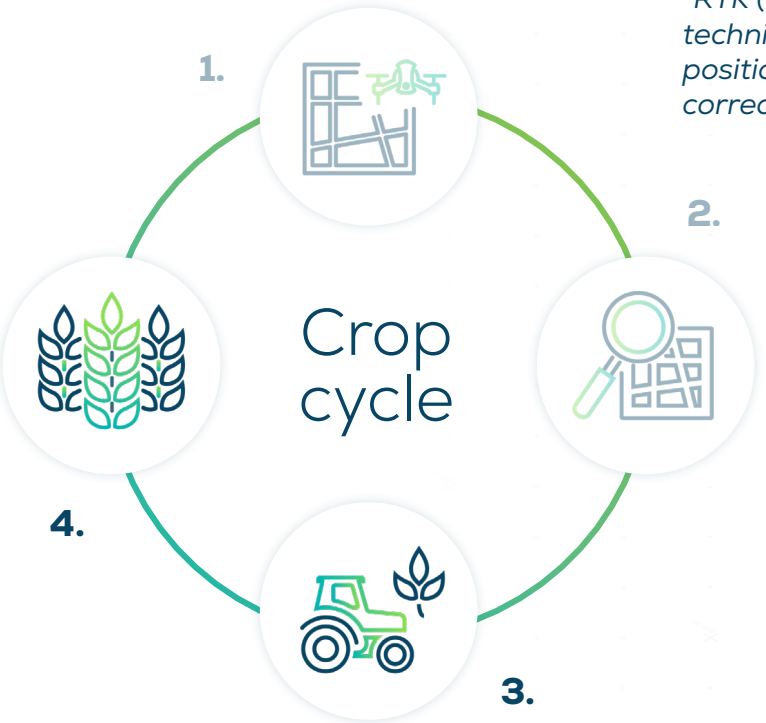
3. Make a decision

a. Farmers and agronomists can then decide on how best to use the information they have been provided. They can plan for localized pesticide application on their crops or trial plots, new irrigation techniques, and store their data as a record of work done, success, and improvements.

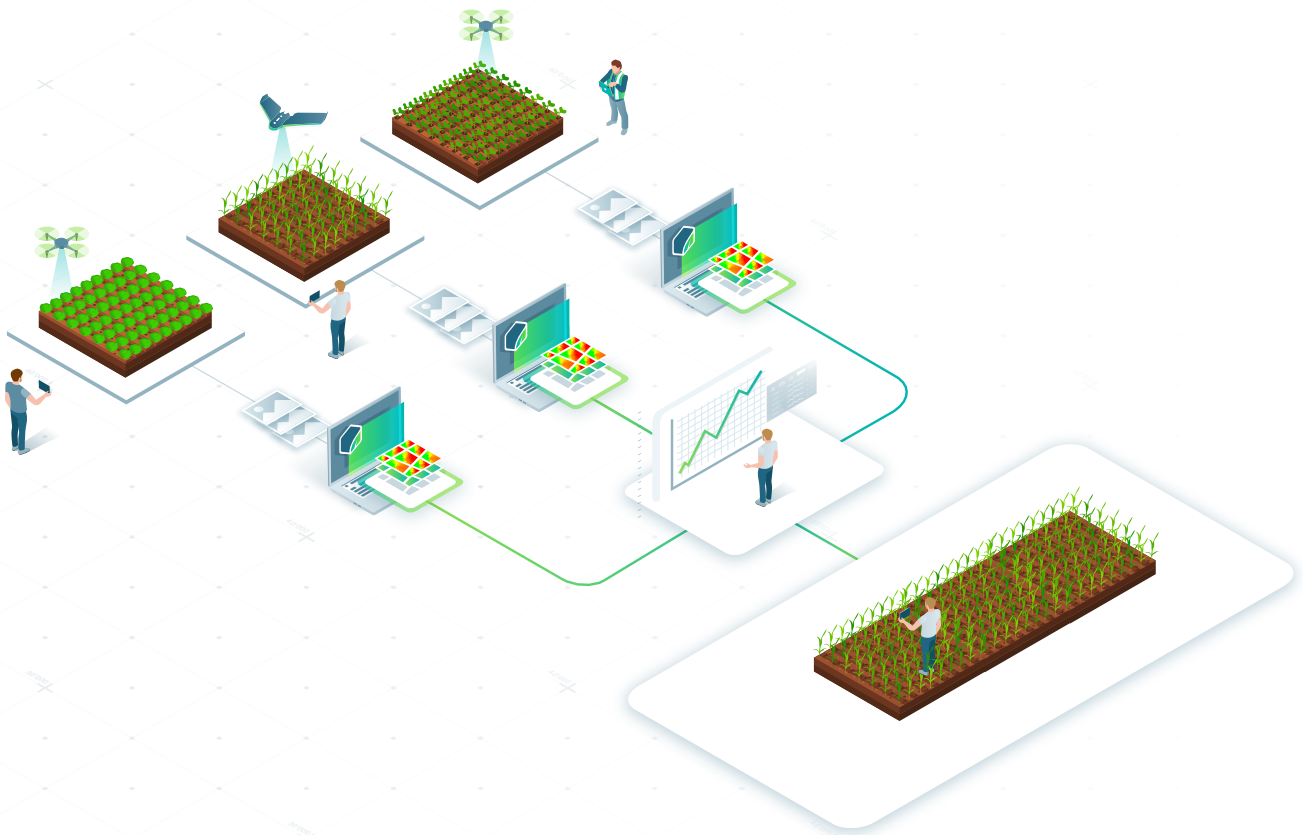
4. Implement plan

a. After a decision has been made, all that is left is to take action. A grower/farmer can upload a prescription map to precision agriculture compatible machinery for site-specific application, using GPS positioning or more accurate alternatives such as *RTK** to enact treatment plans or new application techniques.

**RTK (Real-Time Kinematic) is a technique used to ensure higher positional accuracies by providing corrections to common errors.*



Common Agriculture Workflow



1. Fly/Map
2. Digitize
   Analyze
3. Plan
4. Execute
   Validate
   Review

When should you do it?

This process can be repeated throughout the year, regardless of where you are in the crop cycle. Regular updates about the status of your crop will actually enable you to get better overall results by tending to the needs of a field before a problem becomes widespread. The insight analytics of using different indices empower farmers to identify potential issues before they're really a problem.

Why should you use drones?

What's the point of more information? If you've coped fine without it beforehand, why would you be interested in a change of technology? What are the benefits?

1. Identify problems early - plan a solution before your crops are affected.
2. Comprehensive view of a crop - actually see all of the plants, even if they're in the middle of the field.
3. Apply inputs more effectively - use fewer pesticides or treatments, and practice more environmentally friendly practices whilst saving money and resources.
4. Minimize unintended impacts on the local environment.

02 Vegetation indices: a key tool in precision agriculture

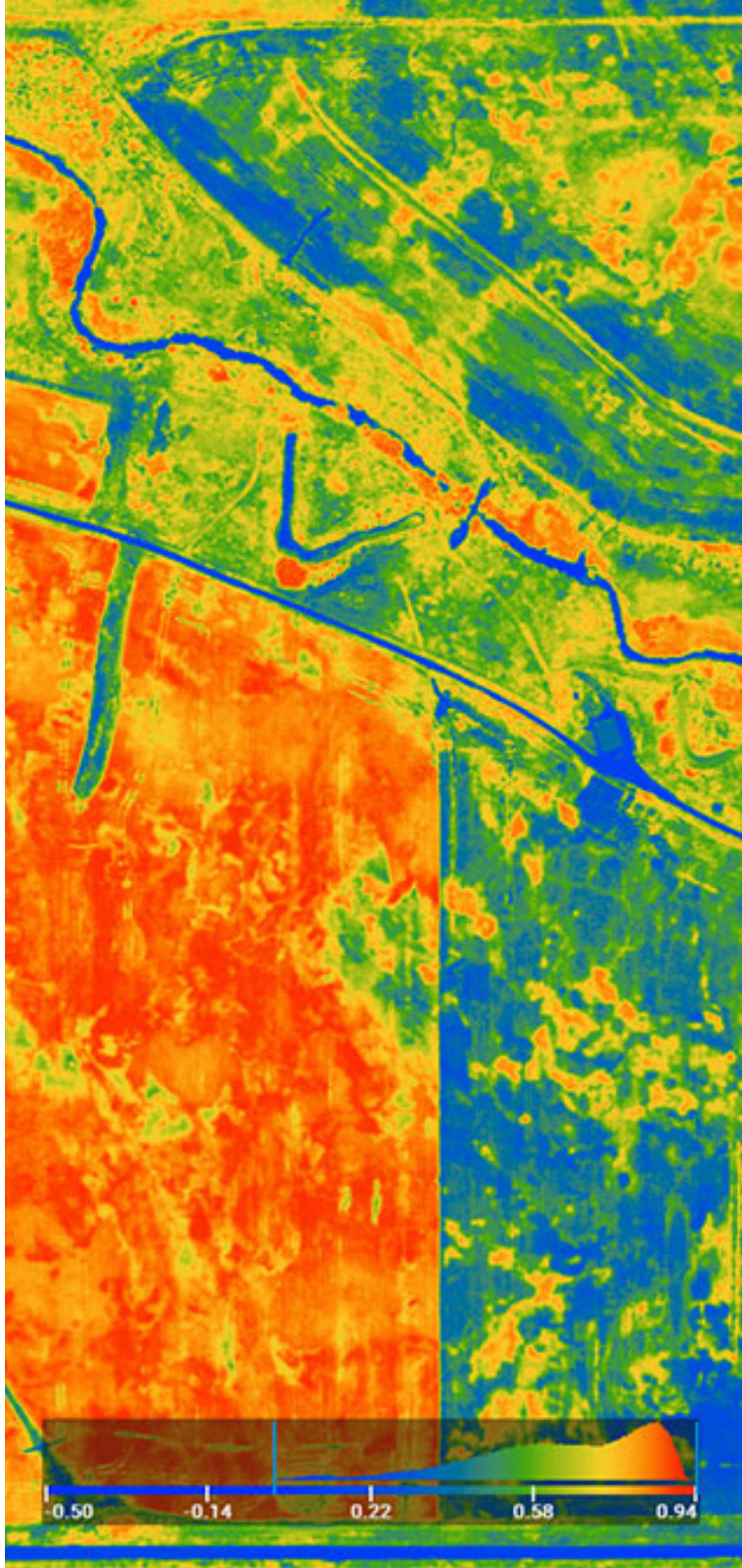
What are they and how they work – Examples of most commonly used indices
When to use NDVI and NDRE – How custom indices work

Making a difference in precision agriculture: vegetation indices

What is a vegetation index?

Let's first look at light. The light we can see around us is just part of a wider spectrum, where there are different wavelengths that we cannot perceive with a naked eye. How objects around us interact with that light affects how we see them - plants reflect green light, making them green to us. Everything has a specific spectral signature, which is the collection of wavelengths it absorbs, transmits, and reflects. This signature can be affected by several factors, including changes of the object itself - in this case, a plant. If you can look at this signature and analyze changes or deviances from the norm, you could find out about the health of a crop before your eyes even see anything on the plant.

A vegetation index is the combined surface light reflectance measured on at least two wavelengths that highlight a particular property of a plant or crop. Vegetation indices are calculated according to the reflectance properties of vegetation. It's done with multispectral imaging. You can use vegetation indices to investigate several features about a plant, including the stage of its growth cycle, water stress levels, or even nutrient deficiencies.



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What does this matter with drones?

Drones can now carry multispectral cameras that capture all the data necessary to generate vegetation index maps of fields, giving farmers an unparalleled level of understanding of their crop. There are several different indices they can use to get different types of information.

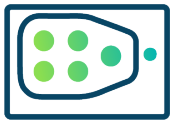
TYPES OF CAMERA AND INDICES

An RGB camera
aka a red-green-blue camera

- The most standard camera carried by drones
- Captures all the standard visible colours and wavelengths - or all visible light

What indices can it generate?

- Visible Atmospherically Resistant Index (VARI) VARI works with RGB imagery rather than infra-red alternatives. Simply, it detects how much greenery is present and can **help detect plant stress**.
- Triangular Greenness Index (TGI) - The TGI looks at chlorophyll sensitivity to **provide insights into nitrogen levels in leaves**, which helps inform how farmers apply fertilizers.



A multi-spectral camera

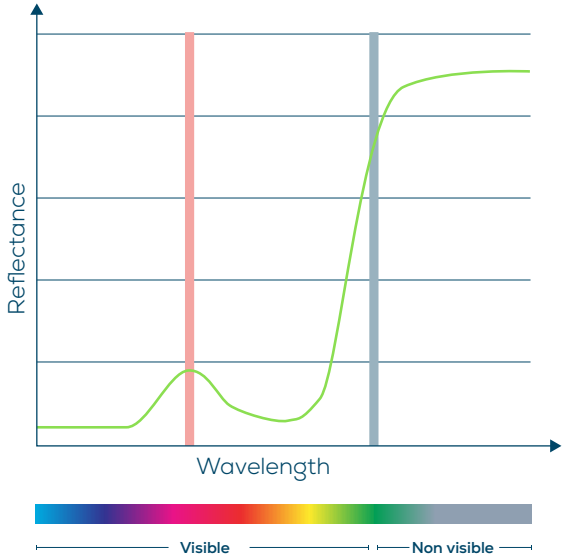
- Detect light waves and behaviour outside of the visible spectrum
- Gather near infrared imagery and light
- More varied vegetation indices from these specialized cameras

What indices can it generate?

- Normalized Difference Vegetation Index, or NDVI - this is the most common vegetation index. It uses the red band of light and the near-infrared light to calculate reflectance values. The index results in providing an estimation of the amount of chlorophyll in plants. The deterioration of chlorophyll is symptomatic of a plant's declining health, so the NDVI is critical to **identifying problems early**.
- Green Normalized Difference Vegetation Index (GNDVI) - similar to the NDVI index, this index gives information about the rates of photosynthesis which **informs growers about plant stress**. Instead of using red light like NDVI, this index uses green.

How plants reflect light is an indicator of their health. Multi-spectral cameras capture light we cannot see, provides more data for analysis.

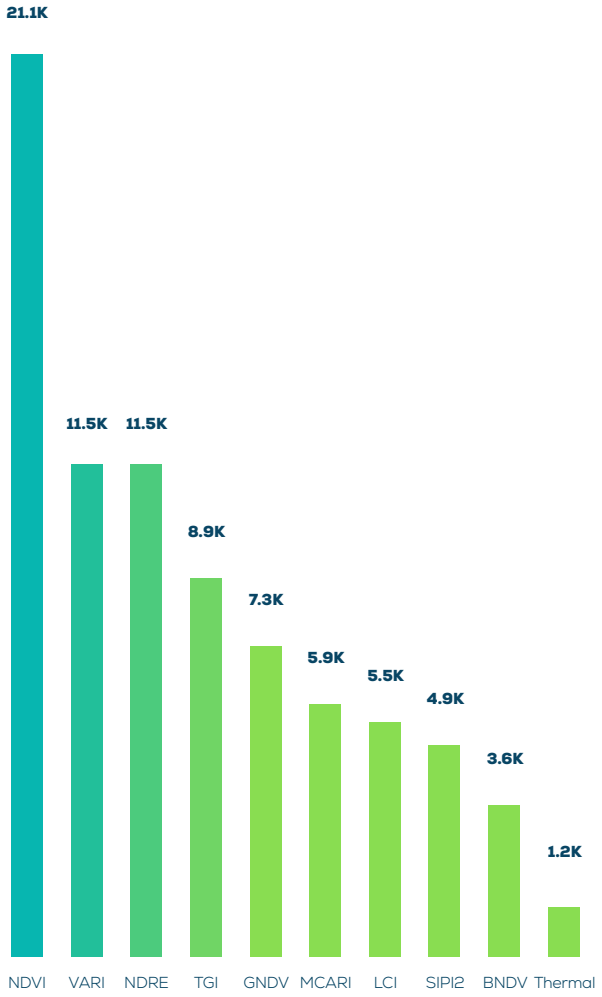
- Normalized Difference Red Edge Index (NDRE) - this index uses near-infrared light to **look at plant conditions for middle and late season crops** that already have significant levels of chlorophyll due to having already grown.
- Leaf Chlorophyll Index (LCI) - this index will assess chlorophyll content in areas with high or total leaf coverage, **helping assess nutrient deficiencies**.



Why am I using a drone for this, not a satellite image?

1. A drone can provide immediate information on the day you need it, and are easy to update - unlike a satellite which uses fixed sensors for years.
2. UAVs are ideal for on-demand work and provide high-resolution imagery that is not impacted by cloud coverage, unlike satellite imagery.
3. The Ground Sample Distance (GSD) represents how many centimeters a pixel represents in an image. Satellites range from a GSD of 10 meters to 0.5 meters, whereas drones can be reliable from 0.5cm up to 10cm, depending on the operator and accuracy of the geolocational system used (eg RTK or GPS).
4. PIX4Dfields: You can have your results in the field with PIX4Dfields, as it is designed to work on a laptop without an internet connection. You can have detailed information about your crop before you even get back to the office.

These are the different vegetation indices typically used by precision agriculture specialists.



Which indices do I need?

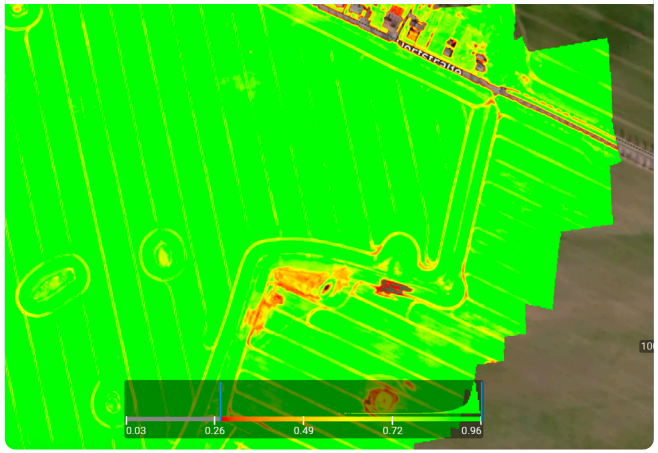
Well, the key thing is to be clear on is what you want to find out. Do you want a holistic assessment of the field, or are you investigating water stress? When you know that, it narrows down your choices. PIX4Dfields comes with an index generator and index calculator tools to do the work for you or empower you to use your own formulas, getting the results needed about a field.

Two of the most commonly used indices are NDVI and NDRE. They help analyze the health of plants. For instance, in the NDRE image on the right, low chlorophyll content is shown in areas colored in red and high chlorophyll content in areas with more green, following the spectrum at the bottom of the image. This will help a farmer identify plant stress and plan treatment.

THE TWO MOST COMMONLY USED INDICES ARE NDVI AND NDRE:

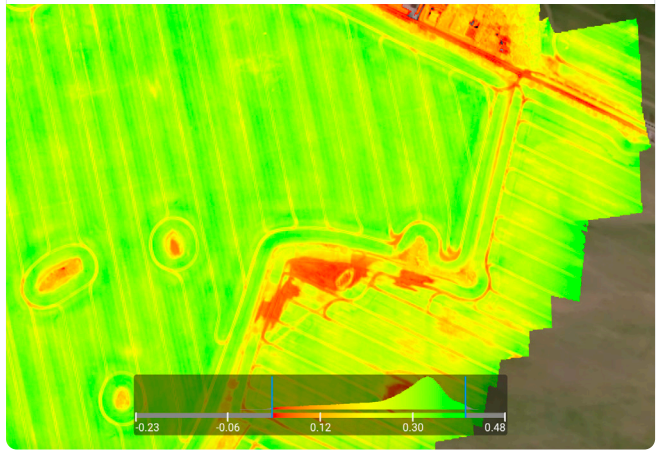
NDVI

- Indicates crop health from early to medium stages of growth , so is used earlier in the growing season.
- Requires a multi-spectral camera.
- Used to measure biomass, and in forestry, it can quantify forest supply and leaf area.



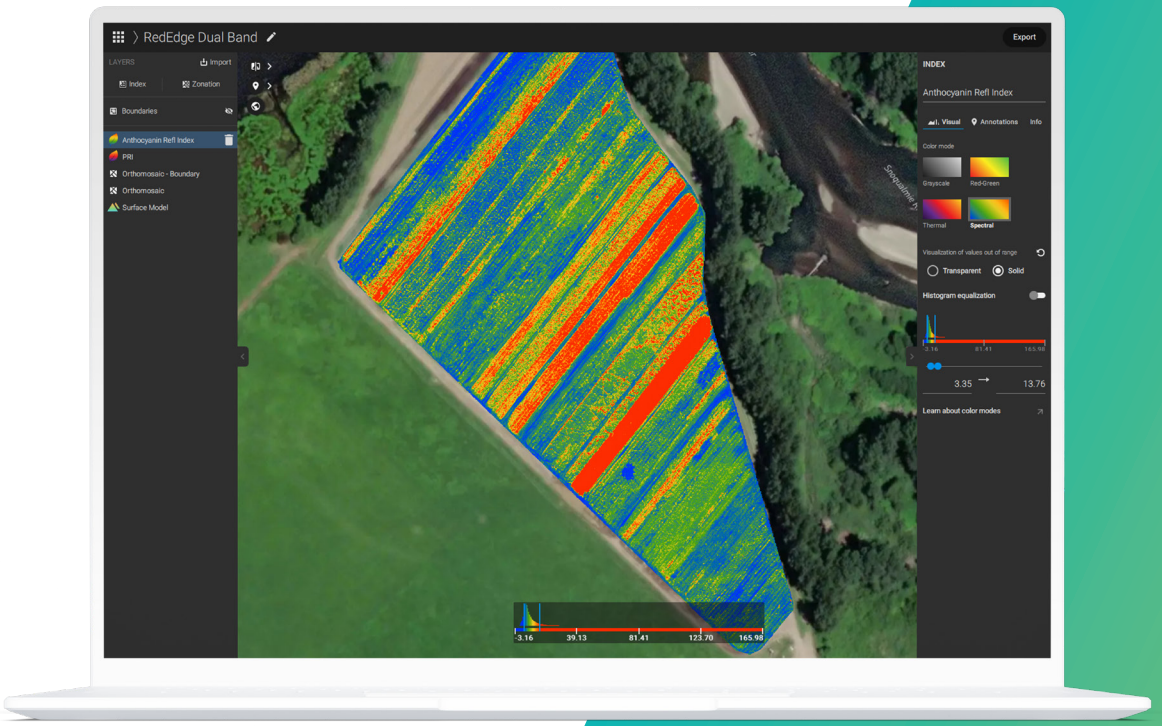
NDRE

- Better for later stages of growth, especially for cereals, high biomass or dense crops, and permanent tree crops.
- Requires a multi-spectral camera.
- It analyzes chlorophyll content in leaves without disruption from the soil in the background. Only used when red and near infra red light can be compared, as in late stage or permanent crops, known as the red band.



How can I specify what I am looking at?

You can in fact customize indices for your own work and farm. As an example, custom indices can be used for masking soil or vegetation from the map to get more focused results. One example of a custom index is the Anthocyanin Reflectance Index. Anthocyanins are specific pigments found in new leaves or ones going through senescence. Plants that are weakening will have higher concentrations of anthocyanins, so this index is adept at identifying stressed vegetation.



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USE CASE 1

Indices in action:
spot spraying invasive species

An invasive species can be threatening to crops and the local environment. Treating them, however, can be difficult in widespread, rural areas. In this case, a wildlife conservation zone needed spot spraying to solve the problem - they made a treatment plan with PIX4Dfields.

LOCATION
Turtle Valley Wildlife Area, Wisconsin

SOFTWARE
PIX4Dfields

USER
Rantizo

HARDWARE
eBee SQ
Spray drone: DJI AGRAS MG-1
Camera: Parrot Sequoia camera

USE CASE 1

PROBLEM

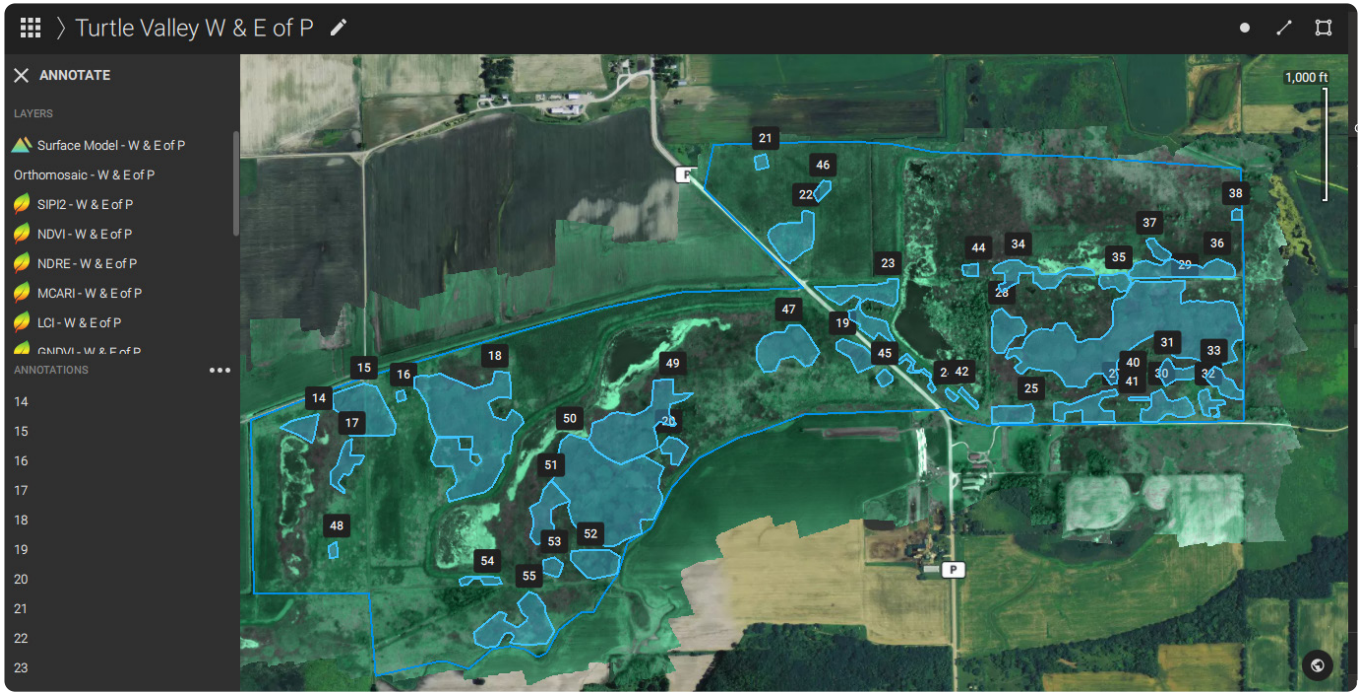
Invasive phragmites were spotted in a wildlife area in Wisconsin, USA.

PLAN

Use PIX4Dfields to map the field and identify the phragmites with the LCI index. They then loaded a spray drone, with the map used to target spray treatments to the phragmites.

WORKFLOW:

The team used PIX4Dfields to map the field and identify the phragmites with the LCI index. They then loaded a spray drone with the map and used it to target spray treatments to the identified spots.



Treatment applied exactly where needed to the invasive species.

OUTCOME

Specialized spray treatment, with great precision, and less manual treatment applied exactly where needed to the invasive species.

03 Agriculture insights – all year round

Planning stage / emergence – Nutrient inputs, zonation, and precision spraying
Crop scouting and yield estimates – Crop monitoring and harvest
Crop protection and insurance

Drones (at work) in different stages of the crop cycle

Step 1

Planning stage and emergence
As you look at planting your crop, you can plan how to best use your field to maximize efficiency. Check out our use case for how it works on the next page.

Step 2

Nutrient inputs, zonation, and precision spraying
Applying treatments to the crop helps protect it. Precision spraying solutions prevent unnecessary pollution or damage to the local environment. See Use Case 3 for an example.

Step 3

Yield estimations
How do you plan the yields of a crop? How can drones help estimate what your field will produce? See Use Case 4 to see how the process works.

Step 4

Crop monitoring and harvest
Stay up to date with your crops and fields as you go along. As you try different treatment and growing techniques, measure your results with more than the naked eye. See how farmers in Mexico used PIX4Dfields for just this in their own fields.

Step 5

Crop protection and insurance
The worst can happen - you can face crop damage or need to insure your plots against the unexpected. Drones can map your field to assess damage quickly to get the proof you need to make your case. Check out Use Case 6 for an example.

USE CASE 2

Seedling rate optimization

Soil surveying is an important part of agriculture. It can reveal soil properties and help plan for optimized farming and crop treatment. This farm used drones and photogrammetry to analyze the soil, compare it to existing yield maps, and generate management plans for seeding.

LOCATION
USA

SOFTWARE
PIX4Dmapper

USER
Anez Consulting LLC

HARDWARE
eBee drone and Canon IXUS camera

TOTAL IMAGES
274

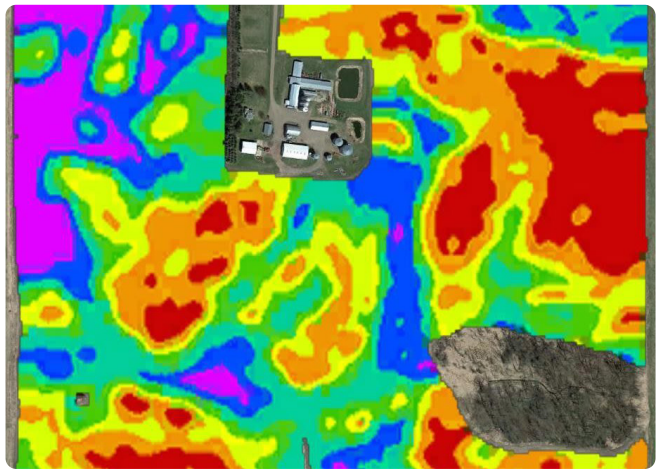
GSD
3.75 cm

USE CASE 2

PROJECT CONTEXT

A corn farm wanted to optimize its seeding rate across 500 acres.

Analyzing how soil pH, salinity, and texture change helps farmers plan optimized crop seeding - a field can have varied soil conditions, as seen in the image on the right.



Workflow

- Divided area into 80 acre sections.
- Images acquired with an eBee and an RGB camera.
- Created an orthomosaic with PIX4Dmapper.
- Analyzed the imagery with precision software (PIX4Dfields, PIX4Dmapper).
- Generated management zones based on bare-earth analysis.
- Set seeding rate to each zone and exported file to the tractor.

Key benefits

- Able to gather data on-demand
- Actionable results in use from the first use of software
- Precision agriculture used to improve the seeding rate

USE CASE 3

Spot-spraying:
optimizing sugarcane production in Colombia

For their valuable sugarcane crop, one company decided to use multispectral imagery and the NDVI index to investigate how they could optimize their yields.

LOCATION
Valle del Cauca, Colombia

SOFTWARE
PIX4Dfields

HARDWARE
Parrot Bluegrass drone with Sequoia camera for data capture, DJI Agras MG-1P drone for spraying

USE CASE 3

CONTEXT

The growers wanted to reduce the use of ripening agents and improve sugarcane production. They worked at a large scale, gathering over 30,000 images over 600 hectares.

Key benefits

- Reduced the costs of ripening agents by 20%
- Potential savings of up to $1 million USD for the entire region in sugar-cane production
- **93% accuracy** rate in forecasting sugarcane production

Workflow

- Data was gathered and imported to PIX4Dfields
- Vegetation indices generated with PIX4Dfields using the NDVI index
- The users planned a forecasting algorithm, identifying the spec-tral signature of each sugarcane variety and its relationship with the tons of sugarcane per hectare (biomass production), including variables such as age and variety of sugarcane being analyzed.

USE CASE 4

Estimating rice yield in China

How do you plan the yields of a crop? How can drones help estimate what your field will produce? By using the right vegetation indices, you can analyze how crops are growing, collate that information with local weather data, and create a realistic estimate.

LOCATION
Zhijiang City, Hubei Province, China

SOFTWARE
Pix4Dmapper

AREA SURVEYED
14 km^2

HARDWARE
DJI Matrice 200
Cameras: Parrot Sequoia camera & MicaSense RedEdge-MX

USER
Survey office of the National Bureau of Statistics in Hubei Union Space

USE CASE 4

CONTEXT

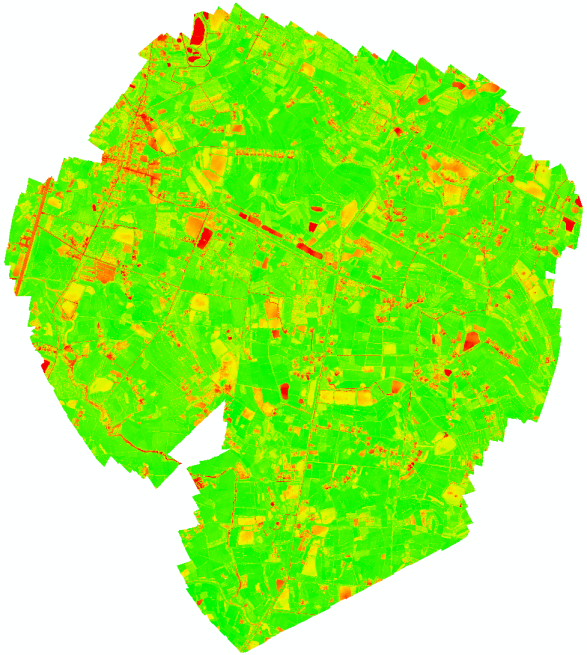
- With growing populations, the need to predict food supply is increasing
- Tillering (the gradual increase of plant height and growth at regular intervals) can give an accurate insight into how rice is growing and the height of the final crop and harvest.

METHOD

- Flew a DJI Matrice 200 with the Parrot Sequoia and MicaSense RedEdge-MX cameras over the fields at 3 stages of growth
- They flew between 10am and 2pm, as that would have the smallest possible change in shadows and light which would mitigate image distortion
- Gathered 8,000 RGB images and 30 - 40,000 multispectral images
- Generated NDVI maps with PIX4D software

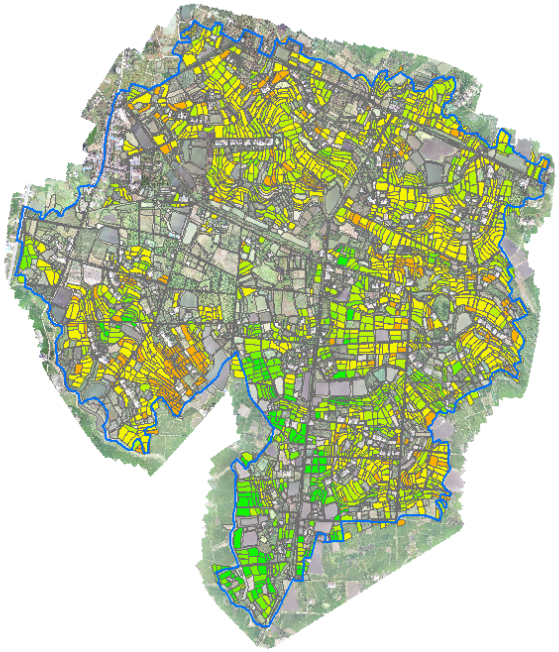
The NDVI maps were imported to a rice yield model by Union Space, which analyzed factors including:

- Temperature
- Precipitation
- Fertilizer



FINAL OUTPUT

Rice yield distribution map based on specialized software for optimal accuracy



USE CASE 5

Crop monitoring and harvest

Stay up to date with your crops and fields as you go along. Employ different treatment and growing techniques and measure your results with more than the naked eye. Check out this use case and the astonishing return on investment.

LOCATION
Veracruz, Mexico

SOFTWARE
PIX4Dfields

CROP
Pineapples

AREA SURVEYED
11.7 hectares

GSD
1.28 cm

IMAGES CAPTURED
500

HARDWARE
DJI Phantom 4 Pro, Parrot Sequoia camera

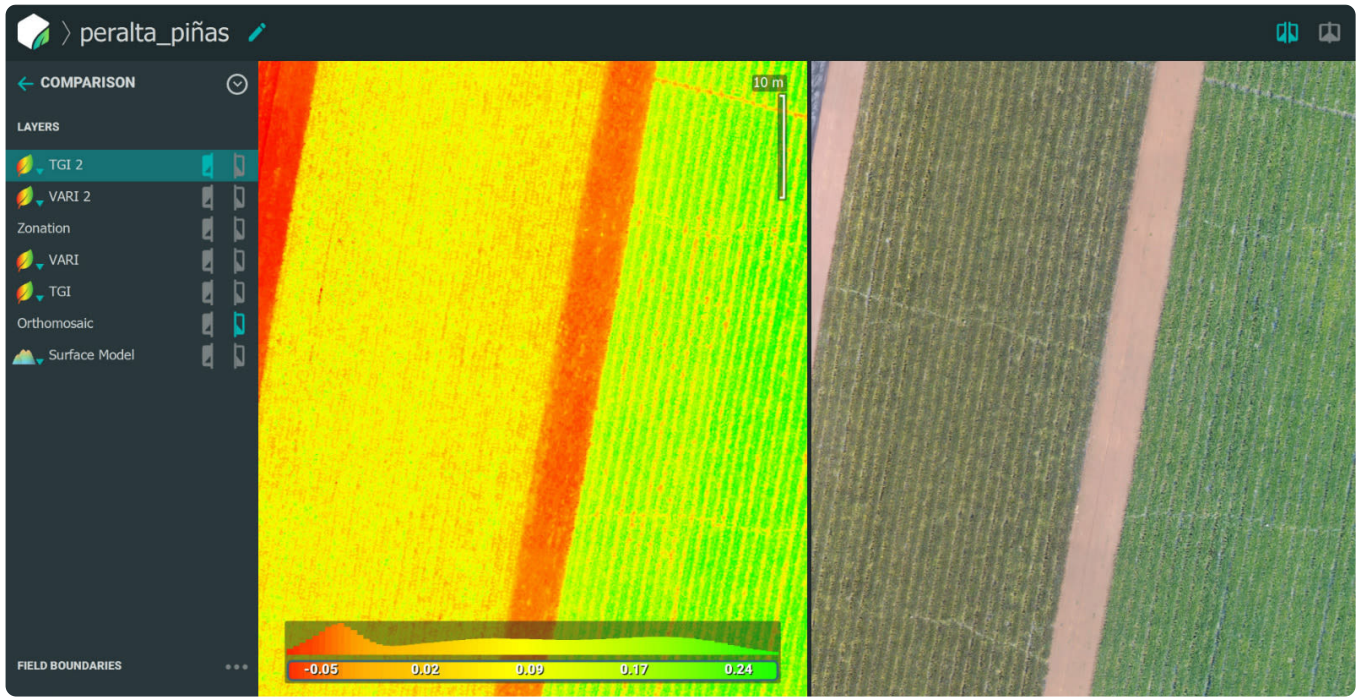
USE CASE 5

CONTEXT

Pineapples are a difficult crop to access when in the middle of a field, which can mean farmers or growers miss potential problems with the plants. PIX4Dfields was used for scouting and crop analysis to help solve this issue. Pineapples are very important in this region, which accounts for 65% of pineapple production in Mexico.

BENEFITS

- Helped prevent damage and scorching of the plants with early problem identification.
- Reduced operational costs by 30% thanks to the drone inspection saving time, resources, and money.
- The changes have resulted in an increase in gains by 15 - 20%.



> "By implementing precision agriculture, ***Piñas Peralta*** estimates that by the end of year they will have a harvest of **70 tons** insured per hectare and will increase their gains by **15-20%**"

WORKFLOW

1. The data was collected with the DJI Phantom 4 Pro.
2. Images were imported to PIX4Dfields, processing in 10min.
3. Generated an orthomosaic.
4. Analyzed the orthomosaic with TGI and VARI indices.
5. They identified hot spots in the fields that were at risk of heat damage and protected the affected plants.

USE CASE 6

Crop protection and insurance

The worst can happen - you can face crop damage or need to insure your plots against the unexpected. Drones can map your field to assess damage quickly, for use by you or your insurance agency. Get the proof you need to make your case.

LOCATION
Czech Republic

SOFTWARE
PIX4Dfields

CROP
Rapeseed

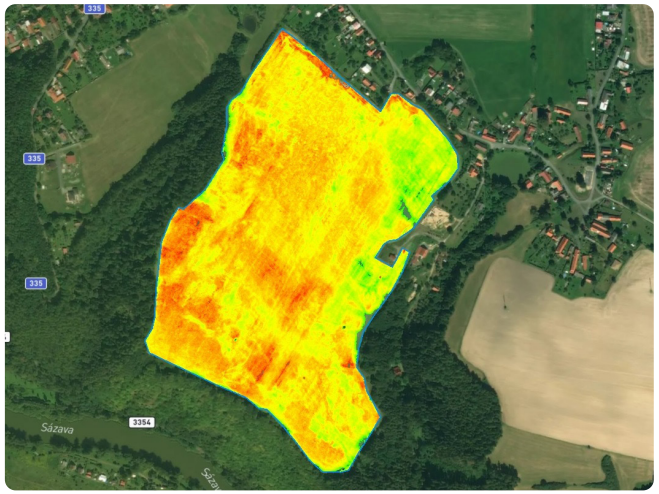
HARDWARE
DJI Phantom 4 RGB

AREA SURVEYED
26.1 hectares

USE CASE 6

Benefits of using drones

1. Fast data collection
2. Easy analysis of imagery and maps
3. Can identify damage more accurately using indices
4. Full picture - get the status of the whole field with all of the information

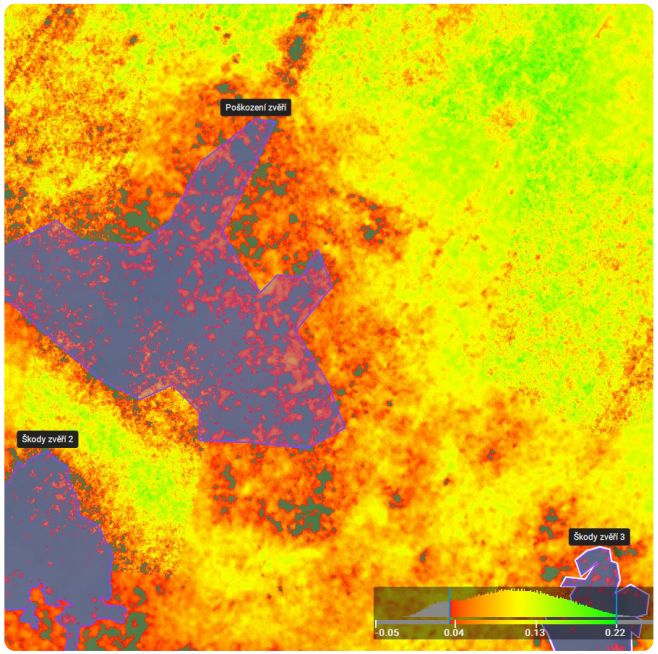


Method for assessment:

1. Gathered data with the DJI Phantom 4 drone
2. Data imported to PIX4Dfields, with orthomosaics ready within 30 minutes
3. Created a field boundary for visual assessment
4. VARI and TGI indices used to identify the damage
5. Zonation map generated with color gradient to show areas of high or low damage

DAMAGE CAUSE

Animals passing through field and grazing/knocking down stalks



The prescription tool was used to summarize the map as it calculated the areas of different damaged zones from the zonation map. This was used as the evidence for the overall damage claim

04 Proving it works: more use cases

We've explained the products and techniques that can be used, and proven it with use cases. But you want to know - is it worth it? Is there really a return on investment? We've had use cases in Chapter 3 that prove the ROI of using UAVs and photogrammetry software, but here are two final examples of how drones have contributed to optimized processes in agriculture.

USE CASE 7

Precision agriculture and bananas

Banana is a popular crop that is relatively vulnerable to disease. Some of these diseases can be detected with the right vegetation indices - in this use case, they used TGI and VARI.

LOCATION
Teapa, Mexico

SOFTWARE
PIX4Dfields

AREA SURVEYED
20.6 hectares

USER
CoatzaDrone, Advan Mexico

IMAGES CAPTURED
1,770 multispectral images, 885 RGB

HARDWARE
DJI Phantom 4 Pro, Parrot Sequoia camera

USE CASE 7

PROBLEM

1. Bananas can be susceptible to disease, so careful care is needed for the crops.
2. The best region for growing bananas in Mexico is the south-southeast part of the country, where the climate is good but the area can be difficult to access.
3. Lack of access to crops means sickness or crop stress can be missed.
4. Bananas are typically grown in wetland gleysol, with excess humidity. These conditions can promote fungi and bacteria. Diseases like Black Sigatoka can decrease the leaf area and affect how the plant grows. This overall affects the quantity of flowers, number, and weight of hands (banana clusters), which can reduce the production of bananas overall.

AIM OF USING PIX4DFIELDS

Monitor water stress using digital scouting to analyze Degree Brix (aka Brix), a scale for measuring soluble solids in liquids. The Brix measurement approximates the sugar content of a sample; a higher Brix level means higher sugar and a better flavor. 16 degrees Brix is the best for bananas. Using PIX4Dfields to monitor this enabled early intervention for crop damage.

OUTCOME

Improved crop production by

30%

USE CASE 8

Fungicides and NDVI

How can you use vegetation indices to plan crop treatments? This team wanted to create a prescription map based on data collected with a drone and processed in PIX4Dmapper. Find out how it worked in their use case.

LOCATION
Ontario, Canada

SOFTWARE
PIX4Dmapper

USER
Deveron

IMAGES CAPTURED
5,968

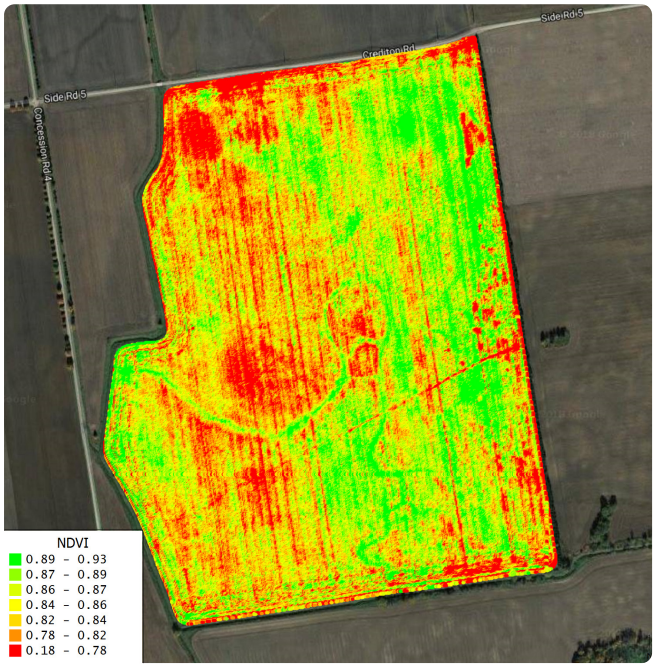
AREA SURVEYED
257 acres

HARDWARE
senseFly eBee drone, Parrot Sequoia camera

USE CASE 8

PROBLEM

- White mold damaging soybean crops, which can reduce yield by as much as 10%.
- Treatment is necessary but expensive.



Workflow

1. Mapping from 10 - 16:00 during the day, avoiding light distortion which happens if shadows move too much during data collection.
2. Ensured 75 - 80% overlap between images to ensure they got a full picture.
3. Generated an NDVI map with PIX4Dmapper (PIX4Dfields has automated prescription maps, and PIX4Dmapper was used to out-source the prescription mapping to a third-party organization).
4. Prescription map ready within 48 hours.
5. The maps were used to track the efficacy of treatment plans and prepare ones for the future.

ROI benefits

- New treatment plan reduced the overapplication of fungicide with an integrative pest management (IPM) strategy.
- Prescription maps mitigate the risk of yield loss that can occur if a grower cannot justify the upfront cost of spraying for high-risk acres.
- Drone imagery gave more detail than satellite imagery of a specific area.
- Field scouting indicated that disease incidence was not increased by reducing the areas where the fungicide was applied.
- Drone imagery was captured under cloud level and therefore on-demand, which provided results faster than a satellite alternative.

What's next?

If you want to find out more about how to include drones and **PIX4Dfields** or **PIX4Dmapper** in your own workflows, get in touch! Pix4D is on LinkedIn, Instagram, and Twitter, or you can contact us directly at **pix4d.com/contact**

Our blog pix4d.com/blog has constant updates about exciting new use cases of how drones are making a difference in agriculture. Check it out to find out more about how people all over the world are getting the whole picture for half the effort.