# Arupa Agronomy Platform

*A precision agriculture tool for grains and oilseeds.*

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## Abstract.

Remote sensing indices are used in many applications, including agriculture. Many of the mainstream vegetation indices (VIs) in use today were developed years ago as generalist plant health indicators that could be used in any vegetated land cover. We propose a new framework for building indices that are specifically optimized for agriculture; we call these Crop Vigor Indices (CVIs). Arupa AG suite of CVIs, including our version of common metrics like NDVI and EVI as well as a proprietary metric called the Arupa Crop Vigor Index (A-CVI), representing a novel set of tools for assisting with crop-specific decision support with precision throughout the season. We do this by using crop masks to focus our attention on where crops are growing, we improve our CVIs correlations with ground truth by on-field sensing and end of season outcomes. In introducing our offering, we propose that CVIs (Including our own NDVI & EVI) have the potential to make significant improvements over traditional VIs and will contribute value at many scales - field, regional and national. We see a dramatic range of industry applications, including index-based insurance (IBI), crop management, commodities trading, supply chain risk and food security.


## Problem Statement: Optimizing Vegetation Indices for Precision Agriculture.

### Background.

VIs rely on the physics of photosynthesizing plants; healthy, green leaves absorb and reflect specific wavelengths of light (Figure 1), and remote sensing scientists are able to observe these relationships from space. Scientists can graph the measurements, examine the unique patterns of absorption and reflection of visible and infrared energy, and use this information to identify specifics stress & types of plants. Since the 1970s, VIs have been designed to maximize the correlation with plant health by using mathematical combinations of image spectral channels (for example, NDVI: Rouse et al. 1974), and thanks to satellites, we have global, high cadence coverage with a long historical archive and consistent calibration.

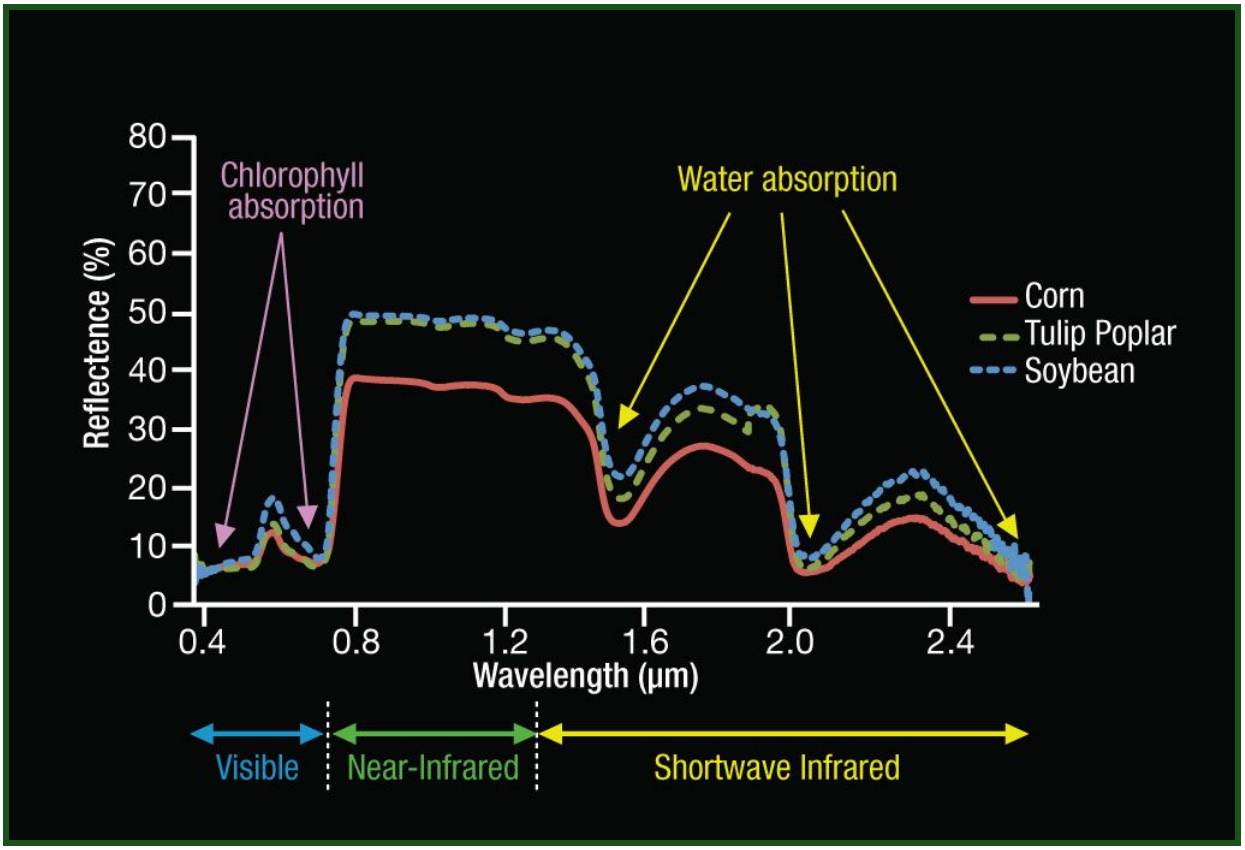


**Figure 1**. In this figure, the 'red edge' is clearly evident as a sharp spike in reflectance on the boundary between visible (RGB) and near-infrared light.

## Motivation.

The potential of vegetation indices has been noted by many commercial actors and they are considered standard for market intelligence products (e.g. Bloomberg, Reuters) and crop insights (Farmers Edge, Trimble) at a variety of scales. However, these indices were largely developed to reflect plant health in general - from grasslands to forests - and have not been adequately tailored for precision agriculture.

## Our Approach.

We propose 'Crop Vigor Index' (CVI) as a more suitable term for a specific type of vegetation index that has been optimized for use in agricultural decision making. A Crop Vigor Index refers to a product or suite of products that are tightly coupled to the geography and phenology associated with particular crops or crop types.

## Why CVIs? Making the case.

We propose that Arupa AG is positioned to add value in this area because our CVIs specifically **1)** utilize our domain knowledge of where the crops are, **2)** are focused formulae - both existing and homegrown - that are intended to specifically assess crop health, as opposed to the health of all types of green vegetation on earth, and **3)** respect that crops are on a clock that doesn't necessarily follow the date on the calendar.

By incorporating weather, seed technology and ground truth data, we are able to track crops in different regions based on the plant's own cycle and specific to the conditions experienced by the plant in-season. These qualities help us prescribe precision corrective measures to boost the quality and yield of crops.

## How do we measure success?

A well-functioning CVI should provide a better basis for making decisions related to the crop in question. Based on feedback from agronomy, entomology and environmental professionals, our conclusion is that any candidate CVI should excel in the following dimensions:

- **Accuracy:** The index should be reliably correlated with outcomes that matter for the specific crop.
- **Consistency:** The index should correlate to outcomes consistently through time and across geographies. In temporal space, stability is important seasonally as well as over a decadal time span in order to capture the rapid pace of change in agriculture. Given the scope of the food balance sheet, the index should also perform well across regions.
- **Complementarity:** Given the utility of weather indexes, a viable CVI should also prove itself complementary to these and other long-standing measurement tools.
- **Simplicity:** Much like weather indices, a strong CVI should be simple enough to explain, to allow for reproducibility and clarity.
- **Quality:** A useful CVI must be produced with the lowest latency, highest frequency, and highest reliability possible.

## The challenges.

Most of our limited-testing of individual crop index approaches to date have focused on accuracy, including some testing of complementarity and consistency. Simplicity is a constant challenge, as there is often a trade-off with achieving the absolute highest accuracy. Quality decisions are made at the platform level - latency, frequency, and reliability would be the attributes of our data flow system.

In our experience, several challenges are associated with building useful CVIs that support agricultural decision-making:

**1**. **Reflectance (remote sensing):** Despite the availability of high resolution data, remote sensing has operational challenges stemming from Polar-orbiting satellites, look angles, atmospheric correction, clouds, decay of sensors and calibration, and multi-sensor needs are some potential impediments.
**2**. **Crop maps (masking):** Vegetation indices are often developed and monitored without respect to distinct geographies. Knowing where the crops are matters, both at regional and finer scales.
**3**. **Index design (formula):** The formula for the index matters. Common VIs were not specifically designed for crops; we can further tune the algorithms to make them more useful for agricultural applications.
**4**. **Crop phenology (timing):** The growing season is not uniform through time. When making comparisons over wide areas, plant timing is a confounding factor; we are exploring techniques to identify and weight the right moments.
**5**. **Technology:** High quality near-real-time information is paramount for good decision-making. CVIs must be developed on a platform that fights latency, maximizes frequency, minimizes errors, and achieves the best overall availability possible.

Over the next sections, we will share where we are in the journey with our Arupa CVIs.

## Arupa Crop Vigor Index (A-CVIs) Processing Overview.

Our process for delivering crop vigour indices, including our own proprietary Arupa Crop Vigor Index (A-CVIs), is outlined in Figure 2. We begin with a highly processed set of satellite images, measurements that have undergone atmospheric correction, cloud screening, look angle adjustments, and a host of quality assurance protocols (steps 1 - 2). We then calculate A-CVIs and extract distinct values for specific crops (steps 3 - 4). The crop-specific masks that make this process possible will be updated seasonally, resulting in seasonal A-CVI offerings based on revised views of crop locations. Finally, Arupa AG delivers those crop-specific index values at the field, regional, and national levels (steps 5 - 6).

 

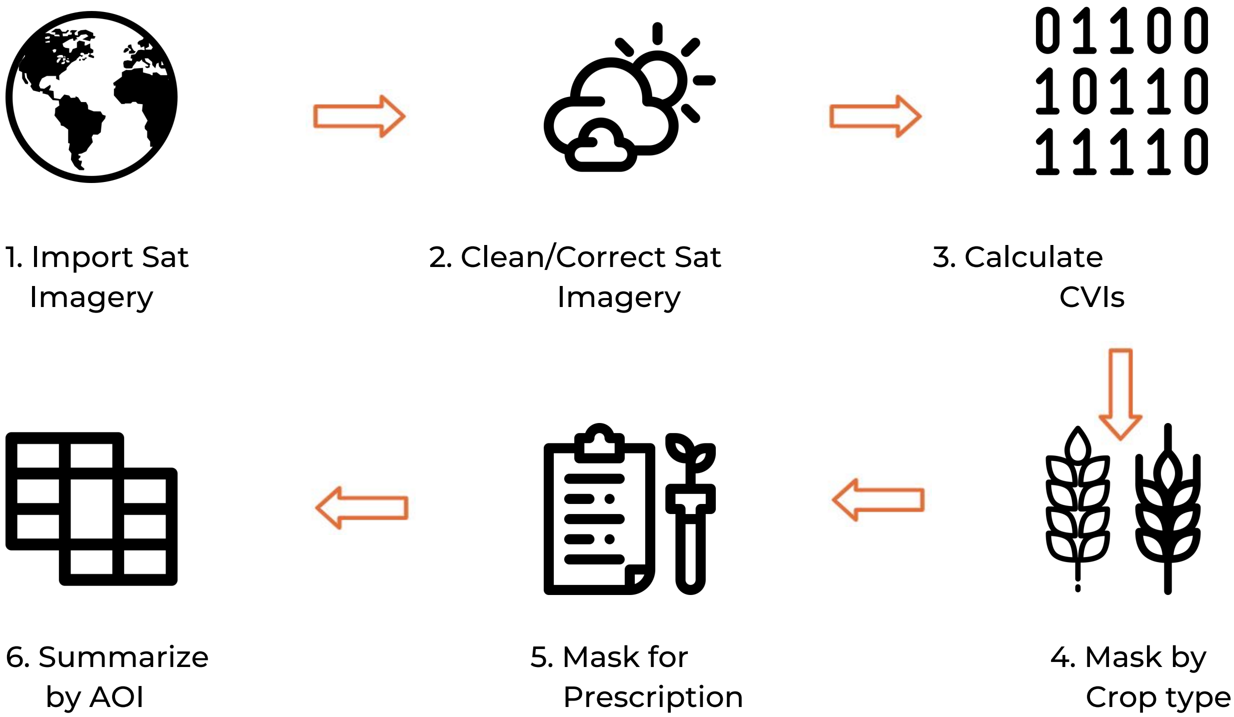


**Figure 2.** The six key steps in creating Arupa CVIs.

## Data Source

There are hundreds of satellites in orbit, and on the back of the most scientific satellites are hundreds of products and offerings. A thorough understanding of remote sensing is required to choose the right sensors and the right products. Each decision point is crucial in producing quality agricultural observations at enough locations, often enough, over a long enough period of time to provide meaningful insights.

We use (currently limited access) the Planet Explorer RapidEye constellation of 5 Satellites within a specified AOI that has minimal cloud cover (< 5 %), maximum overlap (> 99 % with the AOI). Each RapidEye image has five spectral bands that represent blue, green, red, red edge, and near-infrared spectral values. We get valid images at fifteen-time stamps over the scene, with at least one image per month (Revisit time: Daily; off-nadir / 5.5 days; at nadir). The scene below is a sample dataset from RapidEye, see Figure 3.

 

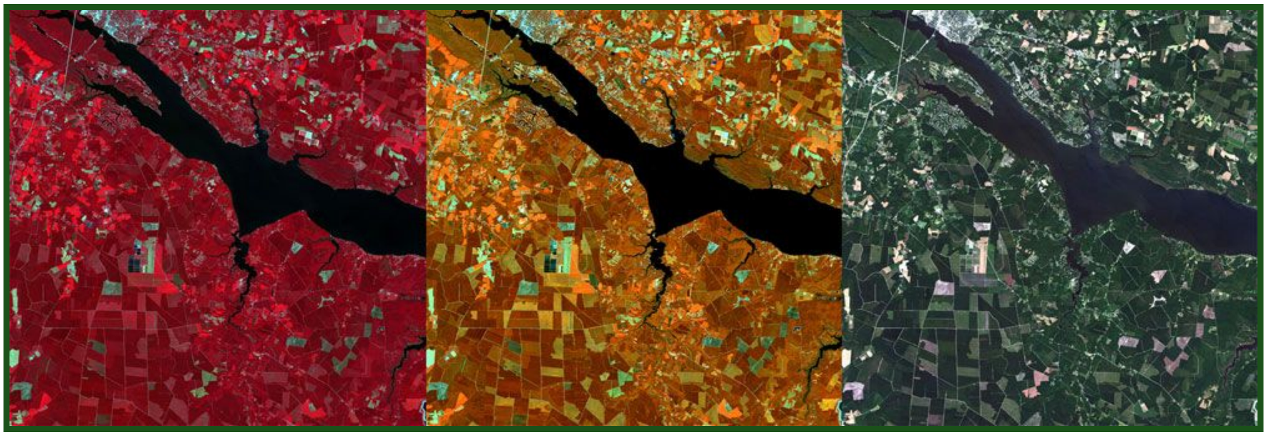

**Figure 3.** Full-spectrum(Red-Edge, NIR, RGB) image from RapidEye.

## CVI design, production and performance

The purpose of the CVIs and subsequent patterns map is to identify within land parcel anomalies due to seasonal drivers, such as nutrient deficiency, weed infestation and other trends using multispectral satellite imagery acquired throughout the cultivation cycle.

Arupa AG has hypothesized a novel Crop Vigor Index called A-CVI using a ratio of bands that best captures changes in crop health that are linked to crop phenology and end of season outcomes. The index describes each parcel's variability with respect to its average state. It is based on the Modified Soil-Adjusted Vegetation Index (MSAVI), which was found to have a good correlation with vegetation. However, our focus was specifically on monitoring agriculture, as opposed to more generalized vegetation indices, which allowed us to tailor the way spectral information was combined in the index. An example of Arupa-Crop Vigor Index is shown in figure 4.

A broader index is being explored by classifying all pixels of the spectral band into three broader categories: average state and less or more than average. An example of a patterns map is depicted in figure 5. Arupa Crop Vigor Index exhibits a much less saturated response to the mid to end of season yield relative to many mainstream vegetation indices, in particular versus the most popular VI today, NDVI. With A-CVI, we are able to detect varying index signal even at the top of the yield range; whereas, NDVI, for example, reaches its maximum well before peak yield.

 


**Figure 4.** Arupa-Crop Vigor Index map obtained using RapidEye.


**Figure 5.** A broader Arupa-Crop Vigor Index map obtained using RapidEye.

## Crop masking

A crucial aspect of developing crop indices is knowing where the crops are, which changes seasonally in many places, and focusing only on those pixels for crop health monitoring.

 

The following crop mask (Figure 5) was done using multitemporal Sentinel 1-A radar and RapidEye images. The analysis of the “temporal signature” of crop fields allows realizing very accurate maps, highlighting the distribution of crops.

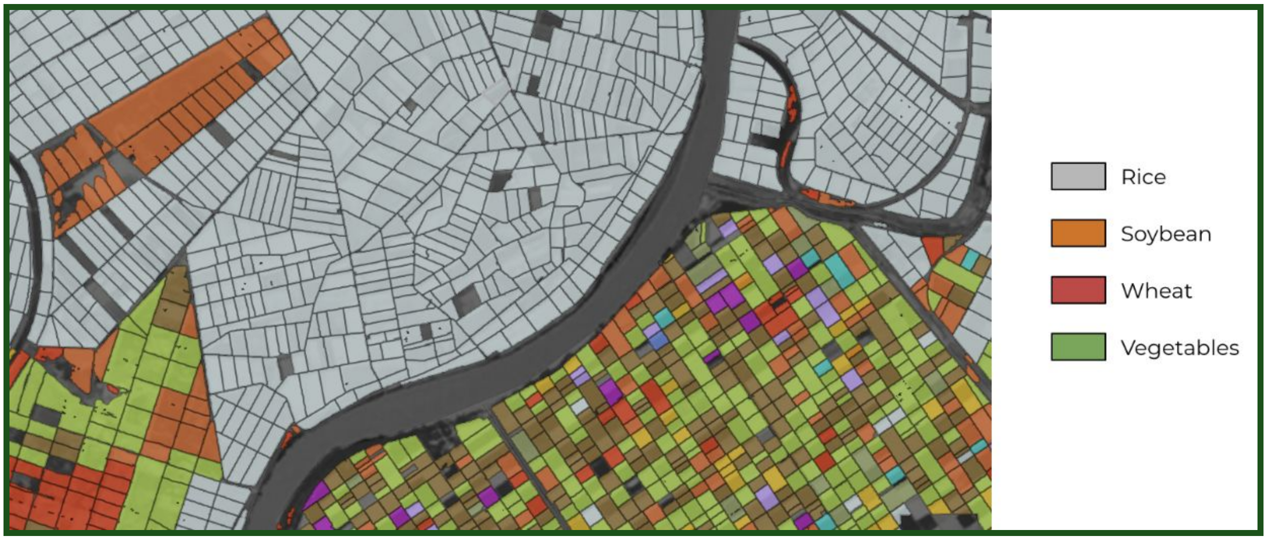


**Figure 5.** Crop mask using Sentinel 1-A radar & RapidEye images.

## Prescription masking

Exploiting the information provided by the Arupa Crop Vigor Indices, the prescription mask analyses the images in order to identify within-field anomalies. The A-CVI was used for identifying within-field anomalies specific to crop type, relatively to each crops average state. This anomalies map (Figure 6) guides on field agronomist to where he should collect soil and crop intake data – using specific coordinates identified by the accurate mapping process. Combining the map with on field data helps design a variable fertilization map (Figure 6), where areas with no anomalies received normal fertiliser dose whereas areas with anomalies receive specific dose.

In a limited test it was seen that treated parcels respond to the variable rate fertilization as desired, that is, areas with initially poor growth increase their biomass with a high rate, whereas the development rate is controlled for areas that already exhibited relatively higher biomass before fertilization. As a consequence, the parcels appear more homogeneous which leads to a higher yield rate for the whole parcel, reducing inputs and the risk for lodging due toto overgrowth.

 

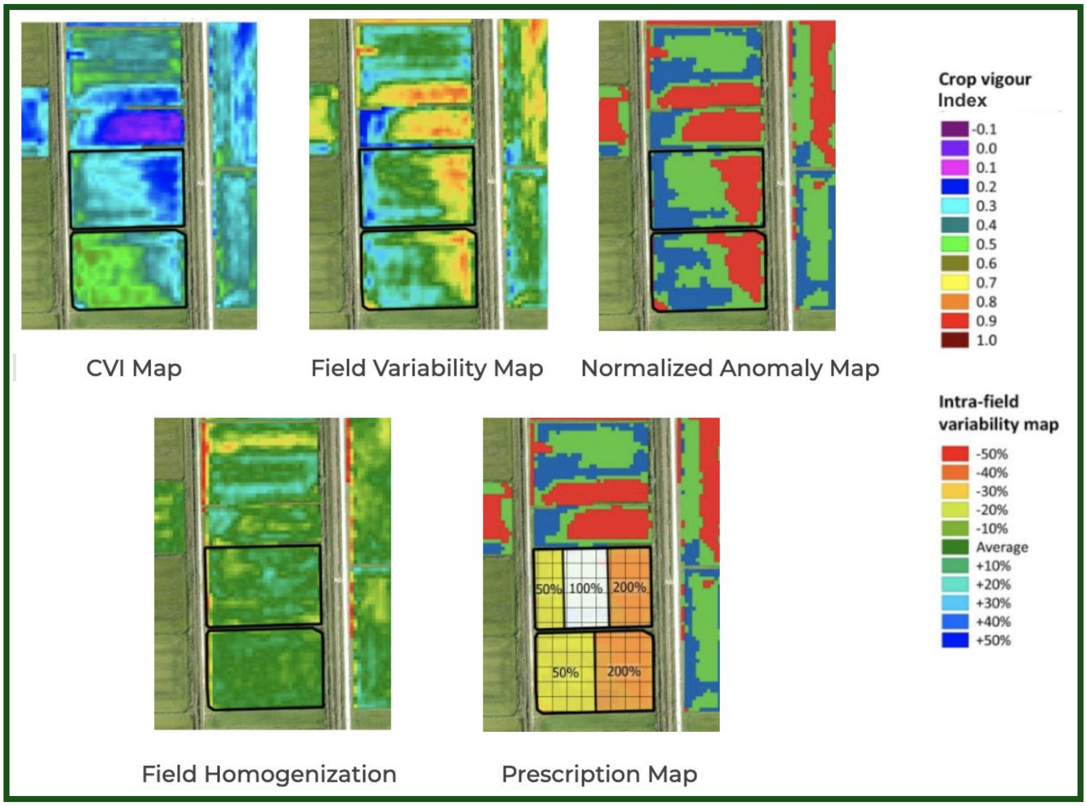


**Figure 6.** Precision Prescription mask using A-CVI.

## Conclusion

With this publication, we are presenting very early possibilities of the Arupa AG Agronomy Platform. However, we see this line of research as an ongoing opportunity for improvement. Future roadmap includes field scale validation, new satellite and ground data streams, as well as more explicitly integrating phenology and fine tuning algorithms. Future offerings would incorporate data from multiple optical sensors, including the addition of Planet Explorer operated PlanetScope constellation, NASA operated Landsat & Sentinel and ISRO operated Resourcesat & Cartosat.

We will also experiment with incorporating high throughput radar signals to better capture the structure and moisture profiles of the vegetation. We recognize that every instrument is a compromise. Challenges ahead include cross-calibration of multiple instruments and ensuring similar levels of processing/quality (e.g., atmospheric correction, radiometric calibration, etc.) between sensors.

Select references

Further reading