Handling Raster Layers with QGIS

Import, modify, and analyze raster data layers

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Raster data represents powerful, information-rich spatial information that is increasingly essential in modern agricultural production systems. Common examples include satellite or drone imagery of crop field and digital elevation models (DEMs) used for irrigation planning.

Raster data consists of a grid of cells (also called pixels), each referenced by row and column positions or, in geographic terms, x and y coordinates (Bettinger et al., 2017). Within a single raster layer, cells are square and uniform in size, though cell size can differ across layers. This cell size, known as spatial resolution, determines the level of detail: smaller cells provide higher (finer) spatial resolution and greater detail for a given area, while larger cells result in lower (coarser) resolution. Each cell in a raster layer holds a single value (such as elevation, reflectance, or application rate), and multiple raster layers can be overlaid or combined to perform cell-by-cell calculations, enabling advanced analyses like change detection.

Working with raster data—viewing, editing, analyzing, and performing calculations— requires specialized software known as a geographic information system (GIS). Many proprietary GIS platforms are used in agriculture to manage drone imagery, equipment-generated maps, or weather data layers. While powerful, these tools are often highly specialized, industry-focused, and may involve licensing fees. A robust, widely adopted, and completely free open-source alternative is Quantum GIS (QGIS). QGIS is an official project of the Open-Source Geospatial Foundation (OSGeo) and is continuously updated and enhanced through global volunteer contributions (QGIS Development Team, 2025).

For a step-by-step guide to installing QGIS, understanding its interface, setting up a project, and a guide to QGIS menus and navigation buttons, refer to the University of Arkansas Division of Agriculture Factsheet FSA2230, Getting Started with Quantum Geographic Information System: An Introduction to Open-Source Spatial Data Handling (QGIS), available at https://www.uaex.uada.edu/publications/pdf/FSA2230.pdf.

QGIS offers extensive capabilities for working with raster data. This factsheet introduces key workflows for raster handling in agricultural contexts and walks through the following processes:

1. Importing raster layers into a QGIS project
2. Combining raster layers from raw bands (e.g., multispectral imagery)
3. Calculating vegetation indices
4. Extracting values from raster cells for further analysis or reporting

These steps provide a practical foundation for leveraging raster data to support precision agriculture decisions.

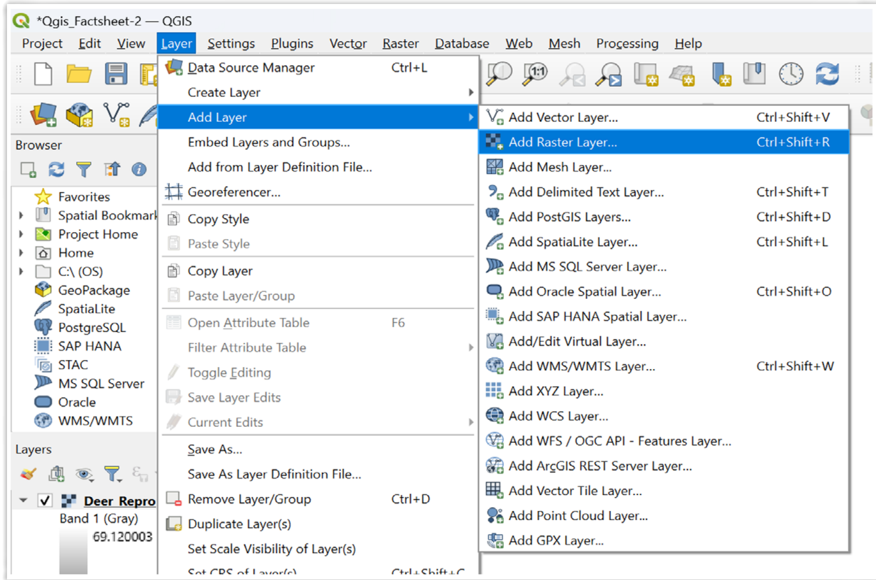

Figure 1.1

Adding raster layers to a project

Start by adding a raster layer (DEM in this example) to a project.

1. With an open project, navigate to the Menu toolbar- click Layer > Add Layer > Add Raster Layer (Fig 1.1)
2. In the **Source** search bar click "..."
3. Navigate to the imagery layer, select **Open** and then **Add**.
4. The layer will load and display (Fig 1.2)

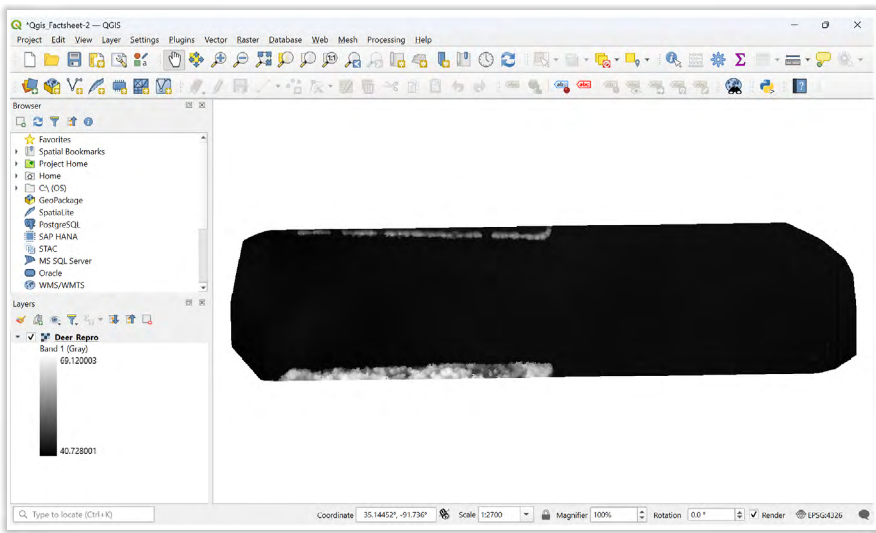

Figure 1.2

Shown in Figure 1.2 is a digital elevation model (DEM) where each pixel represents a height value above a specified model, such as above mean sea level (MSL) or above ground level (AGL). It is important to note that the source of elevation data determines the type of model used, which can significantly affect analyses such as slope calculations, water flow modeling, or irrigation planning in agricultural settings.

Common elevation models include Digital Surface Models (DSMs), which capture the top of features including vegetation, buildings, and other surface objects (often derived from drone or lidar data). Digital Terrain Models (DTMs) or Digital Elevation Models (DEMs) represent the bare-earth surface after removing above-ground features (Maune et al., 2017).

Additionally, elevations may be referenced to different vertical datums: many drone-derived or GNSS-based datasets provide ellipsoidal heights (measured relative to an ellipsoid approximating Earth's shape), while traditional topographic maps and hydrologic applications use orthometric heights (heights above mean sea level, approximated by the geoid—an irregular gravity-based surface). The difference between these reference layers can be tens of meters depending on location, so always check the datum and apply any necessary conversions in QGIS to ensure consistency and accuracy in your analyses when comparing different layers (Esri, 2025).

Importing raw bands as a single RGB image layer

Raster layers derived from satellite or drone imagery are typically provided as multiple **raw band layers** (e.g., separate files for red, green, blue, near-infrared, or other spectral bands). These individual bands must be combined (or "stacked") to form a single **multiband raster layer** for proper visualization and analysis, such as creating true-color RGB composites or calculating vegetation indices.

When imported separately into QGIS, each raw band appears as a grayscale (single-band) layer, which limits interpretation. A couple options are available to combine them into one multiband layer:

Option 1: Build Virtual Raster tool

1. Navigate to the menu tool bar and select *Raster > Miscellaneous > Build Virtual Raster*.
2. Add the individual band files as inputs.
3. Check the **Place each input file into a separate band** option.

Option 2: Merge tool

1. Similarly, navigate to *Raster > Miscellaneous > Merge (Figure 1.3).*
2. Select the input layers (already loaded in the project or browse to files).
3. Check **Place each input file into a separate band** and run the tool (Figure 1.4).

Both tools work whether the bands are already imported as layers or still on disk. After combining, adjust the layer's rendering properties (right-click layer > Properties > Symbology) to assign bands correctly (e.g., Band 1 = Red, Band 2 = Green, Band 3 = Blue for true color) and apply stretching for better visualization.

This step is a prerequisite for many subsequent processes in this factsheet, such as calculating vegetation indices from multispectral data.

It is worth noting that the output (combined raster) from both the Merge and Build Virtual Raster tools are temporary layers and will be deleted by QGIS upon closing the project. To make them permanent layers they must be saved as a permanent layer.

To save the output as a permanent layer:

1. Right click the new temporary file in the **Layers** window and click Export > Save as…
2. Select the file path and name the new layer. Select **OK**. *(This may take a few seconds depending on how large the field is.)*
3. Once the layer has been displayed, close the **Save Raster** window.
4. Remove temporary layer by right clicking it in **Layers** window > Remove Layer > OK.

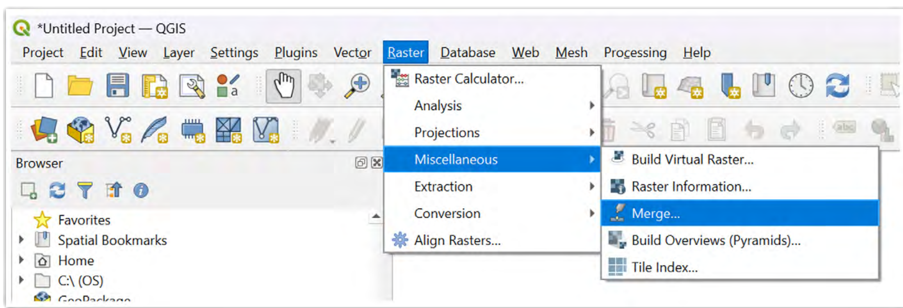

Figure 1.3

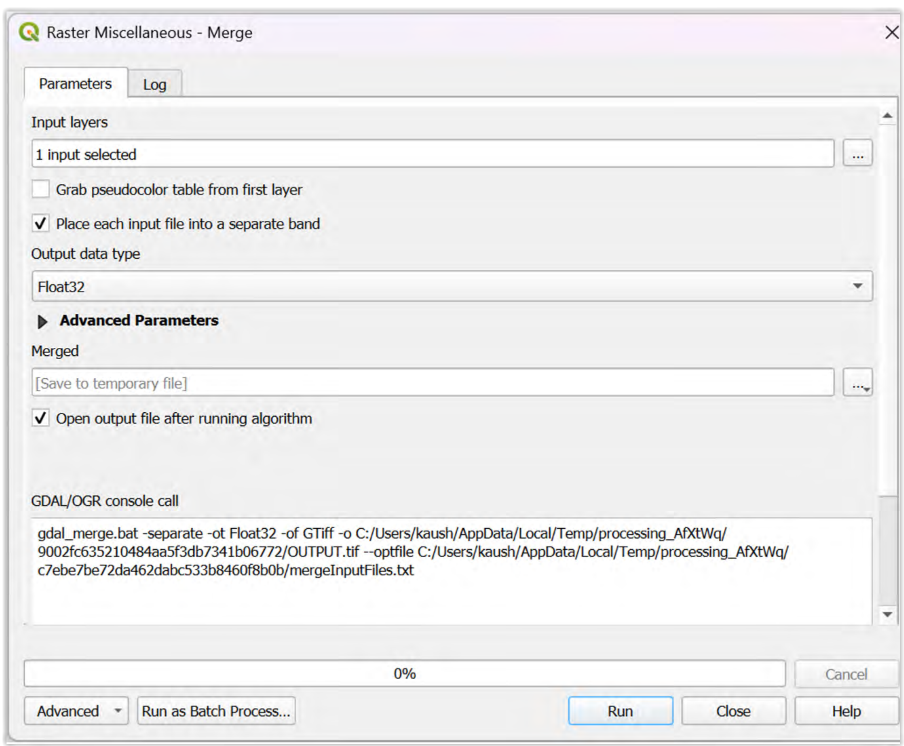

Figure 1.4

Calculating Vegetation Indices from Raw Bands in Raster Layers

Vegetation indices (VIs) are calculated from raster layers computed from combinations of spectral bands in multiband imagery. These mathematical representations of imagery highlight bands that correlate strongly with specific vegetation characteristics, such as health, density, chlorophyll content, or stress levels.

Some of the most used vegetation indices in agriculture include:

- **Normalized Difference Vegetation Index (NDVI)** - the most widely adopted for assessing overall plant vigor and biomass (Matsushita et al., 2007, Rouse et al., 1973).
- **Enhanced Vegetation Index (EVI)** - an improved version that corrects for atmospheric effects and soil background, performing better in dense canopies (Matsushita et al., 2007).
- **Green Normalized Difference Vegetation Index (GNDVI)** - sensitive to chlorophyll concentration and early stress detection, using the green band instead of red (Gitelson et al., 1996).
- **Soil-Adjusted Vegetation Index (SAVI)** - minimizes soil brightness influences in sparse vegetation areas (A.R. Huete, 1988).

While many VIs focus on vegetation, others target different phenomena, such as water content or soil moisture. Examples include the **Normalized Difference Water Index (NDWI)** for monitoring crop water status and vegetation moisture (McFeeters et al., 1996), or the **Moisture Stress Index (MSI)** for detecting moisture deficits in plants or soils (Ceccato at el., 2001).

In agricultural applications, whether monitoring crop fields, forages, pastures, or timber stands, **NDVI** remains one of the most prevalent indices for modeling plant health due to its simplicity, reliability, and strong correlation with photosynthetic activity and biomass.

To create an NDVI layer in QGIS from a multiband raster:

1. First, ensure that the input raster is multiband.
2. On the Menu toolbar select Raster > Raster Calculator (Figure 1.5).
3. In the Raster Calculator window, click "…" next to **Output Layers**.
4. Designate a file path and new file name.
5. Write the NDVI formula in the **Expression** box by double-clicking on each layer and connecting with the proper symbols. (NIR-R)/(NIR+R)

These indices typically combine raw bands such as red, near-infrared (NIR), green, or red-edge to produce a single value per cell. The resulting raster allows for intuitive symbology (e.g., a color ramp from red/low values for stressed or sparse vegetation to green/high values for healthy, vigorous plants), enabling quick visual interpretation of field variability.

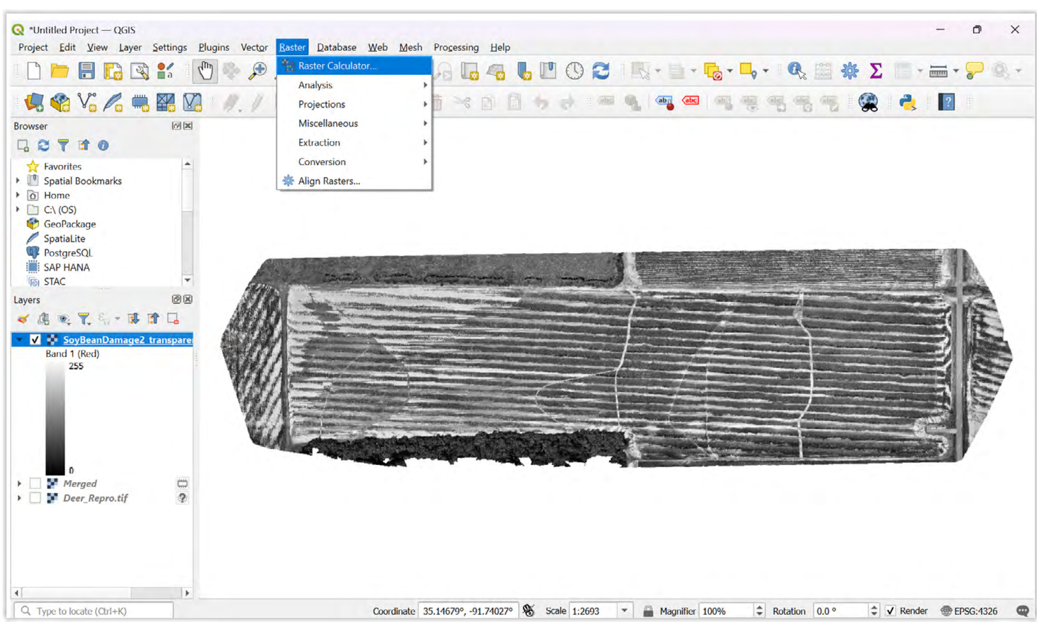

Figure 1.5

6. Press **OK**. *(This may take a few seconds depending on the size of the field.)*
7. A new raster will be added to the layers window, and an NDVI Layer should be displayed. (Fig 1.6)
8. Adjusting NDVI symbology (greyscale by default)
   - Double-click NDVI layer in the **Layers** window. **Symbology** should be selected on the left.
   - Click **Render type** and select **Singleband Pseudo-color**.
   - Verify that **interpolation** is linear.
   - Select Color ramp > All Color ramps > RdYlGn.
   - Select **OK**. (Fig. 1.7)
   - IF colors are inverted, Select **Color ramp** again and **Invert Color Ramp**.
   - Select **OK**.

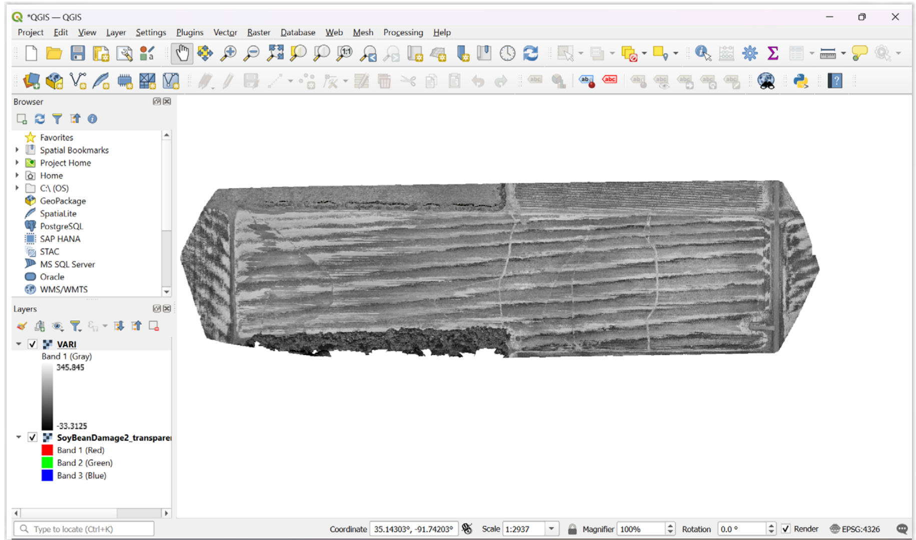

Figure 1.6

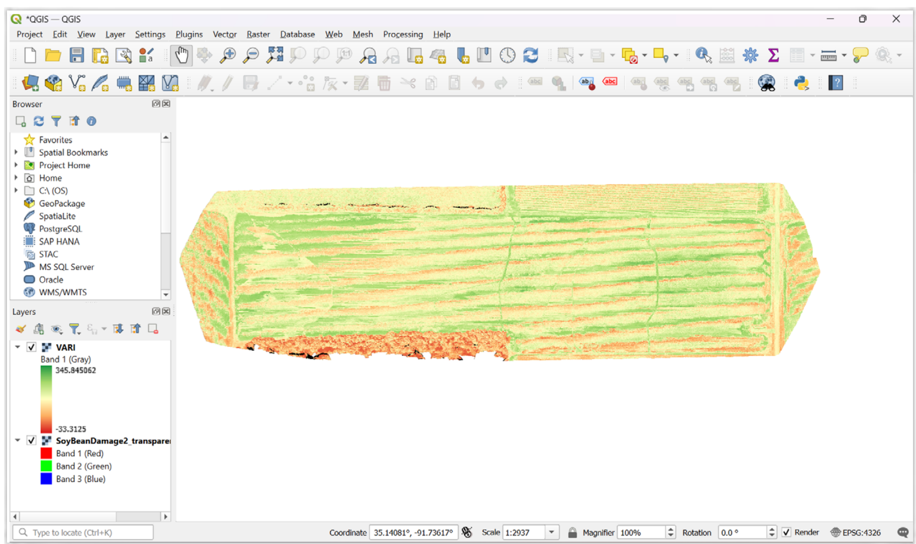

Figure 1.7

This process can be adapted for other indices by substituting the appropriate band math (e.g., for EVI or GNDVI). Always verify band assignments — such as, checking that the red band is listed as band number 1 — against your sensor specifications to avoid errors.

Clipping Raster Layers to a Field Boundary (Clip by Mask)

Often, raster datasets like satellite or drone imagery cover large areas beyond a specific field, farm, or county of interest. Extracting (or "clipping") only the pixels within a defined polygon boundary creates a smaller, more manageable layer. This reduces file size, speeds up rendering and processing in QGIS, keeps your project organized, and focuses analyses on the relevant area.

To extract a portion of a raster using a polygon mask layer in QGIS:

1. Ensure that both your raster layer (e.g., multiband imagery, DSM, or NDVI) and polygon mask layer (e.g., a shapefile outlining the field boundary) are loaded in the project. The polygon should overlap the raster appropriately.
2. Navigate to the Menu toolbar- Raster > Extraction > **Clip Raster by Mask Layer.**
3. In the tool dialog:
   - **Base raster layer** (or Input layer): Select your raster to clip.
   - **Mask layer:** Choose your polygon vector layer from the dropdown.
   - (Optional but recommended) Check **Keep resolution of input raster** to preserve the original raster's spatial resolution.

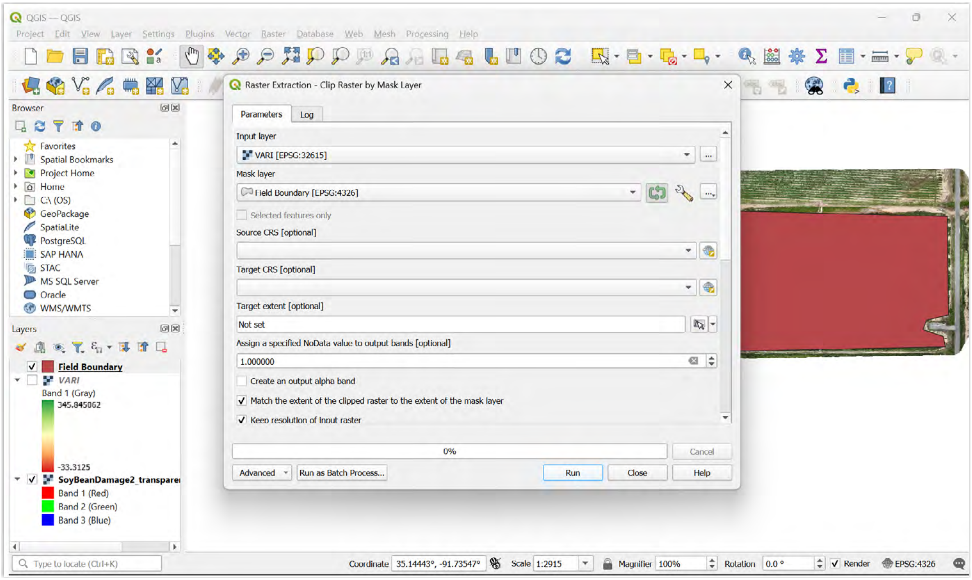

Figure 1.8

4. Click **Run**. The tool processes quickly for small areas but may take longer for large rasters. (Fig 1.8)
5. A new clipped layer appears in the Layers panel.
6. **Important: Save the temporary output.** Right-click the new layer > **Export > Save As…** (or click the temporary scratch icon if present). Choose GeoTIFF (or preferred format), set file path/name, and run. This creates a permanent file.
7. Remove the temporary layer: Right-click it > **Remove Layer** > confirm.
8. Style the new clipped layer as needed (right-click > **Properties > Symbology**)—e.g., apply singleband pseudocolor for NDVI (commonly red-low to green-high) or singleband pseudocolor with a desired color ramp for elevation/DSM data.

This clipped raster retains the original data values and resolution (when options are set appropriately), making it ideal for further steps like index calculations or value extraction. Always verify the output aligns correctly with your polygon by zooming in and toggling layers.

Conclusion

Raster data layers are information-rich and increasingly valuable in modern agricultural production systems. With drone and satellite imagery becoming more accessible and affordable, combined with the fact that nearly every piece of equipment in production fields now generates precise as-applied maps for pesticides, nutrients, and other inputs—alongside soil texture, nutrient, and water management maps—these datasets provide critical insights that directly influence yield optimization, resource efficiency, and sustainability decisions. These benefits are fully realized only when the data is handled properly in a geographic information system (GIS) like the free, open-source QGIS. Mastering foundational skills—such as importing raster layers, visualizing them effectively, computing new derived layers from raw spectral bands (e.g., vegetation indices like NDVI), and extracting (clipping) the most relevant areas of interest using polygon boundaries—forms the essential toolkit for proper raster data management.

By applying these techniques, producers, consultants, and researchers can transform raw spatial information into actionable intelligence, supporting precision agriculture practices that enhance crop health monitoring, variable-rate applications, irrigation planning, and overall farm profitability. QGIS empowers users to unlock the full utility of these maps, paving the way for data-driven decisions that promote more efficient, resilient, and sustainable agricultural systems.

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