

Precision Agriculture in Knock Farm

Knock Farm Cottages, Knock, Huntly, Scotland, UK

STUDY REPORT

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EXECUTIVE SUMMARY

Precision agriculture is a growing trend for its application in farming due to advancement of technology. It brings many benefits to a farm such as farm mapping, crop monitoring, spraying and crop estimation to name a few. It could be substantially advantageous for large farms such as Knock Farm as they require lot of resources and manpower to manage such farms. Specifically, use of precision agriculture and geospatial technologies could benefit the farm with land use classification, geospatial data management, remote sensing with UAVs, and web-based map visualisation using WebGIS tools.

This report discusses classification techniques such as simple classification, supervised classification, unsupervised classification and commonly used classification techniques such as NDVI in the context of Knock Farm. Amongst the classification techniques applied, supervised classification technique was found to be most suitable for Knock Farm. The report also details the use of geospatial databases such as SpatiaLite to store land parcel data, field cover details and soil analysis results in the form of feature classes and tables. The land parcel data is further joined with available water capacity data of Scotland to analyse the proportion of water being retained by each land parcel of Knock Farm.

Further, the report also highlights the uses of UAVs in the context of Knock Farm by using WebODM, a photogrammetry tool, to combine multiple UAV photographs to produce an orthophoto, a DSM and a 3D model. Using this, the farmer can not only effectively monitor crops but also improve production yields of the farm. The report also discusses the effective use of a WebGIS tool, ArcGIS Online, to create a web-based app showing available water capacity of knock farm for farmer to use.

INTRODUCTION

Knock Farm is a large organic farm spread across 450 hectares having 245 hectares of less favoured area and 79 hectares non-less favoured areas (better quality land). Farm mostly has rotational cropping between Spring Barley (SB) and combination of Arable Silage Undersown with Grass (ASUS) plus Grass (GRS) or Spring Barley Undersown with Grass (SBUS) plus Red Clover (RC). Overall, the farm has yield of approximately 18 t/ha. Being a large farm, several precision agriculture methods are well suitable for the farm.

This report aims to discuss several techniques of precision agriculture such as land use classification, geospatial database management and UAV applications along with building a WebGIS app for Knock Farm. The report objectively explores and compares various classification techniques such as simple classification, supervised classification, and unsupervised classification techniques using ERDAS Imagine software. In addition, the report also explores well known classification techniques such as standard NDVI and NDVI with Density Slicing in the context of Knock Farm.

Further, the report provides details for the use of geospatial databases with ArcGIS Pro with reference to Knock Farm. Specifically, the Spatialite database, an extension of SQLite database, was used to store feature classes and tables having land parcel, field cover details, field nutrition data for plantation field and available water capacity data for Knock Farm. Furthermore, this report also focusses on UAV applications, photogrammetry software tools, orthomosaic images, digital surface models, and 3D models produced using WebODM.

Additionally, this report also provides visualisation of maps useful to farmer in the form of WebGIS app created using ArcGIS Online. The visualisation provides farmer with details about available water capacity of all the Knock Farm's land parcels.

METHODOLOGY

Task I – Image Classification

There are numerous techniques of classifications such as simple classification with band combinations, several widely used classification techniques such as NDVI, unsupervised and supervised classification.

Examining existing classifications

Certain classification techniques are widely used like simple classification with band combinations and classification using NDVI index as detailed below.

Simple Classification with band combinations

Simple classification techniques require manual selection of three bands from the range of available bands in the image. The chosen bands are then assigned to red, green or blue colours for visual representation. With this technique, false colour image is then created which enables user to differentiate between features of the image which is otherwise not possible in visual spectrum. However, this technique requires prior knowledge of the area covered by the image.

ERDAS Imagine offers simple classification with 'Multispectral' tab where desired bands can be chosen. The bands available bands in the image (kfssubset.img) of Knock Farm from Sentinel-2 satellite are Blue, Green, Red and Near Infrared (NIR). Using any combination of available three bands, the image could be classified in multiple different ways for visual interpretation. Refer figure 7 showing false colour image of Knock Farm classified with Blue, Green and NIR band combinations.

In ERDAS Imagine, 'Multispectral' tab has band section where drop down menu allows assignment of one of the available bands to BGR colour guns. Subsequently, a map can be created from this image using 'Create New Map View' option from 'Add View' under 'Home' tab. Further, the map could be exported using 'Send to JPEG' option from 'Manage Data' tab.

Classification of a satellite image using NDVI image with and without Density Slicing

NDVI is an acronym for Normalised Difference Vegetation Index. It is computed as a difference between Near Infra-Red and Red bands and divided by their sum as shown in equation below (Gessesse, A.A. and Melesse, A.M., 2019). Lower value of NDVI suggests moisture-stressed vegetation whereas higher value shows high density of green vegetation (Gessesse, A.A. and Melesse, A.M., 2019).

$$NDVI = (NIR - RED) / (NIR + RED)$$

ERDAS Imagine offers visualisation and analysis of NDVI image using 'Raster' tab. Under 'Raster' tab, the classification section has 'Unsupervised' drop down which offers NDVI classification option. Choosing this option, a dialog box appears where input file and output file can be selected with other options kept default to produce standard NDVI without density

slicing image as shown in figure 8. The image shown in figure 8 is produced using 'Pseudocolour' tab with 'ETRF Colour Table' to enhance the image features as shown.

NDVI Image with density slicing can also be generated using ERDAS Imagine. For this, NDVI option under 'Unsupervised' classification is chosen with an output option as 'stretch to unsigned 8-bit' check marked. This causes output to be generated with 0-255 values instead of standard range between -1 to +1 (Gessesse, A.A. and Melesse, A.M., 2019). Further, figure 9 shows Unsigned 8-bit NDVI image with density slicing. The output image can be enhanced by applying different range of pseudo-colour to enhance the image even further. The range of colours applied in figure 9 are as per the Table 1 below.

NDVI range (0-255)	Pseudo-colour
0-100	Blue
100-125	Light Brown
126-150	Pale Yellow
151-175	Dark Green
176-200	Mid Green
201-255	Light Green

Table 1. Unsigned 8-bit NDVI range with assigned colours.

Unsupervised classification of a satellite Image

Unsupervised classification is a technique where system classifies the image based on the pixel values using an algorithm. Unsupervised classification does not have labels associated and algorithm simply depends on pixel data (Rivera, A.J. et al., 2022). Grouping of image pixels is performed in clustering algorithm based on their values and specific colour (Rivera, A.J. et al., 2022).

ERDAS Imagine supports many unsupervised classification algorithms including cluster-based classification. Cluster classification can be performed with multiple methods, but k-means method is a popular method of clustering which uses average values of all the pixels belonging to a specific cluster (Rivera, A.J. et al., 2022).

In ERDAS Imagine, unsupervised classification is available in 'Raster' tab. Choosing this opens a dialog box where input file, output file, method of clustering, number of classes, and colour scheme parameters are available, and they should be appropriately chosen. Once clustering is applied, output raster is created which can then be visualised to review if classification is correctly applied or not. If not, then further tuning to the previously mentioned parameters can be applied and output image is reviewed again. All the classified clusters in the output image further needs labelling which enables appropriate identification of the cluster. Figure 10 shows land classification of Knock Farm using unsupervised classification with k-means and 6 classes.

Supervised Classification

Supervised classification is a technique where classes are assigned to set of grid cells for raster being processed in GIS (Merry, K. et al., 2023). The process is known as supervised classification as it requires human to define classes for a training set based on prior knowledge of the satellite image being processed (Merry, K. et al., 2023). The training set is then referenced by the supervised classification algorithm to identify other similar areas within the image and categorise them in one of the predefined classes.

ERDAS Imagine offers supervised classification under classification section as part of 'Raster' tab. To perform supervised classification, there are many tools available for user in ERDAS Imagine. The user can first generate scatterplots for multiple combinations of available bands and link each scatterplot to the image to view how different features of the image are represented. Refer figure 11 which shows the scatterplot of Sentinel-2 image with different range of colours being represented for different features.

Once scatterplots are analysed, user can carefully identify different features of the image to be classified using 'Signature Editor' from 'Supervised Classification' section under 'Raster' tab. To appropriately use 'Signature Editor', user needs to define classes of features such as farm fields, soil, forest etc. as area of interest (AOI) on the image and add them in Signature Editor. Refer figure 12 showing the polygons drawn for each area of interest to be defined as classes. Once all the area of interests are added to Signature Editor, supervised classification can be triggered by opening 'Supervised Classification' dialog box from 'Raster' tab and supplying with input image file, signature file and classified output image filename. Figure 13 shows classified image produced by running supervised classification using a signature file having 12 different classes defined.

Task 2 – GIS Database & Mapping

Knock Farm Geospatial Database using available data.

Geospatial data for Knock Farm is available for many fields and their surrounding area. This data contains land parcel identification numbers and area in hectares for 111 land parcels. Additionally, field cover data for some of the fields is also available from the year 2017 to 2020. Further, the soil analysis data for few fields is also available in the form of report from SOYL, a precision crop production service provider. Even though several different types of data are available for Knock Farm, but datasets with geolocation from the available datasets were chosen for analysis.

First, to create a geospatial database, ArcGIS Pro is used in conjunction with Spatialite database. The Spatialite database is an extension of SQLite database that has an ability to store geospatial data in the form of feature classes and tables. This database is fully compatible with ArcGIS Pro for processing and storage of geospatial data. Features such as points, line and polygons can be easily accessed and stored in Spatialite database from ArcGIS Pro.

Next, to store the available geospatial data, following geopackage feature classes and tables were created in Spatialite database.

- Land Parcel
- Field Details for the year 2017, 2018, 2019 and 2020.
- Soil Nutrition for Plantation field.

Subsequently, Available Water Capacity dataset from SpatialData.gov.scot was accessed and combined with land parcel mentioned datasets for relevant geospatial analysis and visualisation. Projected coordinate system for the maps was set to default WGS 1984 in ArcGIS Pro.

Land Parcel Data defined as Polygons in Feature Class.

Land Parcel geopackage feature class was created to define polygons for Knock Farm's land parcels. All the land parcels were available in the form of photographs within a PDF document that could not be directly processed in ArcGIS Pro as the photograph does not have geographic coordinates associated with each land parcels. Thus, the photograph was first loaded into ArcGIS Pro for georectification to match with the base map. After georectification process, the polygons were created using 'Create Feature' function under 'Edit' tab of ArcGIS Pro. This function allows polygons to be drawn for the feature class with reference to a map. The polygons are also associated with data such as Counter, Land Parcel ID, and Area (in hectares). Refer figure 1 for sample data from the table associated with the feature class.

	OBJECTID *	Shape *	COUNTER	LAND_PARCE_ID	AREA_HA
1	2	Polygon Z	1	NJ/53421/53613	5.86
2	3	Polygon Z	2	NJ/53626/52638	32.09
3	5	Polygon Z	3	NJ/53705/53209	1.21
4	11	Polygon Z	4	NJ/53734/53393	4.8
5	13	Polygon Z	5	NJ/53740/53611	10.77

Figure 1. Land Parcel Feature Class Table.

Field Cover Details data as Feature Class

Field Cover Details for six identifiable land parcels were captured from XLSX file available for Knock Farm. The data was then associated with respective polygons representing the land parcels and subsequently they were stored in the database as a geopackage feature class also. The data included field name referenced by the farmer, field number, field cover and the year of the field cover. The field cover data was available from the year 2017 to 2020. Refer figure 2 for sample data associated with Field Cover Details feature class.

	OBJECTID *	Shape *	COUNTER	LAND_PARCE_ID	AREA_HA	FIELD_NAME	FIELD_NUM	FIELD_COVER	YEAR
1	86	Polygon Z	12	NJ/53909/53501	0.89	Pond	13	Rough Grazing	2020
2	42	Polygon Z	17	NJ/54038/53553	5.97	Plantation	19	3rd Year Grass	2020
3	11	Polygon Z	25	NJ/54242/53792	4.06	Behind Cottages	33	5 Year Grass	2020
4	71	Polygon Z	34	NJ/54357/53253	1.69	Tinks Rd Rough Grou...	42	Rough Grazing	2020
5	73	Polygon Z	38	NJ/54417/53562	0.39	House Paddock	45	Permanent Grass	2020
6	48	Polygon Z	48	NJ/54510/53374	5.05	Dipper	58	Spring Barley	2020

Figure 2. Field Cover Details for six land parcels.

Soil Nutrients for Plantation Field

The knock farm data has soil analysis report which includes nutrient study for few of the Knock Farm fields. Primarily the nutrient levels studied from the fields were Potassium, Phosphorus, Magnesium, and pH. For each nutrient study, seven different samples from the fields were collected. Further, trace elements such as Available Copper, Available Zinc, Hot Water-Soluble Boron, Available Iron, Organic Matter, Available Molybdenum, Available Calcium, Exchangeable Manganese, and Available Sulphate were analysed from the collected samples by SOYL. Data for the nutrients and trace elements were captured from the report for identifiable fields such as Plantation and stored in the database as shown in figure 3 and figure 4. Additionally, figure 15 shows soil samples collected from the Plantation field.

	OBJECTID *	Shape *	COUNTER	LAND_PARCE_ID	FIELD_NAME	NUTRIENT	MEASUREMENT	UNIT	NUTRIENT2	MEASUREMENT2	UNIT2
1	1	Point Z	17	NJ/54038/53553	Plantation	Potassium	65.7	PPM	Phosphorus	4.7	PPM
2	3	Point Z	17	NJ/54038/53553	Plantation	Potassium	224.4	PPM	Phosphorus	7.4	PPM
3	4	Point Z	17	NJ/54038/53553	Plantation	Potassium	99.5	PPM	Phosphorus	5.1	PPM
4	5	Point Z	17	NJ/54038/53553	Plantation	Potassium	213.5	PPM	Phosphorus	7.9	PPM
5	6	Point Z	17	NJ/54038/53553	Plantation	Potassium	143	PPM	Phosphorus	5.8	PPM
6	7	Point Z	17	NJ/54038/53553	Plantation	Potassium	249.4	PPM	Phosphorus	7.9	PPM
7	8	Point Z	17	NJ/54038/53553	Plantation	Potassium	110.4	PPM	Phosphorus	5.3	PPM

Figure 3. Soil Nutrients for Plantation Field.

	OBJECTID *	COUNTER	LAND_PARCE_ID	FIELD_NAME	ELLEMENT	RESULT	UNIT	INTERPRETATION
1	1	17	NJ/54038/53553	Plantation	Available Copper	4.3	mg/l	HIGH
2	26	17	NJ/54038/53553	Plantation	Available Zinc	0.6	mg/l	LOW
3	27	17	NJ/54038/53553	Plantation	Hot Water Soluble Boron	0.5	mg/l	LOW
4	28	17	NJ/54038/53553	Plantation	Available Iron	80.8	mg/l	HIGH
5	29	17	NJ/54038/53553	Plantation	Organic Matter	8.9	%w/w	VERY HIGH
6	30	17	NJ/54038/53553	Plantation	Available Molybdenum	0.5	mg/l	VERY HIGH
7	31	17	NJ/54038/53553	Plantation	Available Calcium	1405	mg/l	NORMAL
8	32	17	NJ/54038/53553	Plantation	Exchangeable Manganese	1.1	mg/l	NORMAL
9	33	17	NJ/54038/53553	Plantation	Available Sulphate	31.1	mg/l	NORMAL

Figure 4. Trace Elements identified from the Plantation field soil samples.

Available Water Capacity analysis for Knock Farm (Geo-visualisation)

Available Water Capacity data is available for entire Scotland from (spatialdata.gov.scot, 2019). This data was calculated for the proportion of water (mm) held in the soil (spatialdata.gov.scot, 2019). This data is available in shape file format with British National Grid as coordinate reference system which was then projected to WGS 1984 coordinate system in ArcGIS Pro for analysis.

To analyse the available water capacity data in the context of knock farm, the shape file was first converted to raster using 'Feature To Raster' conversion tool from Geoprocessing toolset of ArcGIS Pro. Subsequently, the converted raster was clipped to the area specific to knock farm using 'Clip Raster' tool (Data Management Tools) from the Geoprocessing toolset. The output raster with range of different available water capacity is shown in fig. 16 below.

Task 3 – UAV Data & Image Processing

UAVs have several useful applications in Precision Agriculture primarily for crop monitoring and spraying process (Radoglou-Grammatikis, P. et al., 2020). Precision Agriculture offers many benefits to the farmer such as increased crop yields, improved crop quality, save energy, and protect environment (Radoglou-Grammatikis, P. et al., 2020). These benefits are highly achievable with the use of UAVs as they can not only be efficient in applying agricultural products such as fertilisers and pesticides in the farm, but also provide high resolution imaging using multispectral and hyperspectral instruments mounted on them. These images are more capable to provide useful insights in comparison to aerial photography. For instance, the images produced using UAVs can be further filtered thru one or more indices such as NDVI, GNDVI, SAVI etc. to enable the farmer with useful information about amount of moisture present in the soil and health of vegetation as well.

Aerial photography captured using UAVs are useful for creating ortho-mosaic image which can also be beneficial to manage large farms such as Knock Farm. Ortho-mosaic photo is one large image stitched together from multiple photos captured using drones. Once individual photographs are captured, they can be processed through specialised photogrammetry software tools such as WebODM, Pix4D, Global Mapper, PhotoModeler etc. to produce ortho-mosaic photo of the farm.

Most of the mentioned software tools are downloadable and require installation on computers, however WebODM does offer a cloud version of its software known as WebODM Lightning which can be accessed online too.

Ortho-mosaic, DSM, 3D Model using WebODM for Knock Farm

The available aerial photographs are 183 JPEG format photographs captured using DJI drones of Knock Farms. These files are then uploaded to WebODM for creating assets such as orthophoto, digital surface model, textured model, point cloud, 3D models and reports. Once all the individual photographs are uploaded to WebODM, processing can be submitted. Figure 5 below shows the image upload process in WebODM.

Knock Farm

Select Images and GCP Import

2 Tasks View Map Edit Filter Sort

183 files selected. Please check these additional options:

Name A95 - 18/09/2017

Processing Node spark1.webodm.net:443 (queue: 0)

Options Default Edit

Resize Images Yes 2048 px

Cancel Review

Figure 5. Image upload process in WebODM



Figure 6. Image processing in WebODM.

Once processing is completed, the processed assets can be downloaded or visualised online. Online access is available for Orthophotos, Plant Health Monitoring and Digital Surface Model (DSM) in 2D and 3D model viewing. Additionally, WebODM also offers many WebGIS tools for zoom in, zoom out, measurements, identifying contours using DSM and sharing functionality. Refer figure 17, figure 18 and figure 19 for the orthophoto, DSM, and 3D Model created using WebODM.

Remote Sensing in Agriculture

Many remote sensing technologies are useful in agriculture such as multispectral, hyperspectral, thermal, and LIDAR sensors. Multispectral sensors have fewer bands compared to hyperspectral sensors (Radoglou-Grammatikis, P. et al., 2020). Multispectral sensors primarily use visible bands, red-edge and near-infrared (NIR) band, while hyperspectral sensors offer much higher number of bands in comparison (Radoglou-Grammatikis, P. et al., 2020). On the other hand, thermal sensors are useful for identifying water status in farms; and LIDAR sensors provide estimation of plantation volume for specific soil parcels (Radoglou-Grammatikis, P. et al., 2020).

Use of vegetation Indices in Agriculture

Visible and near-infrared bands from multispectral sensors are well suitable for vegetation analysis using one of several well-known indices such as NDVI, GNDVI, CWSI, and SAVI to name a few. Normalised Differential Vegetation Index (NDVI) uses NIR and Red band to differentiate between healthy and unhealthy vegetation which highlights healthy vegetation reflecting more infrared light as compared to unhealthy vegetation (GISGeography, 2023). On the other hand, Green Vegetation Differential Vegetation Index (GNDVI) uses NIR and Green band to detect chlorophyll variation in the crop. GNDVI is more sensitive to the variation as compared to NDVI (Auravant, 2022). While Crop Water Stress Index (CWSI) is primarily used to detect water stress level in crops and planning the irrigation schedule accordingly (Gu, S. et al., 2021), whereas Soil Adjusted Vegetation Index (SAVI) can provide information about soil reflectance for necessary corrections for improving vegetation productivity and growth (ClimateEngine.org, 2023).

Task 4 - WebGIS

GIS capabilities made available on web benefits the farmers. WebGIS interfaces such as ArcGIS online are capable of presenting maps with useful feature such as zoom in, zoom out, pan, measure, legend, adding map layers and additional information from the attribute table with a click on the displayed layer.

ArcGIS Online itself has several powerful features for advanced GIS users that are traditionally available in desktop GIS software tools. It offers access to 2D maps, 3D scenes, layers (shape, KML, geopackage etc.), tables, range of basemaps, charts, export, sharing and print features. Further, it also allows to add symbology, change transparency, filters, effects, customise attributes for on click popups, advanced analysis tools and raster functions.

Preprocessing of Knock Farm datasets

To create WebGIS interface for Knock Farm that could be usable for the farmer, a shape file format data is needed for interactive visualisation with ArcGIS Online. For that matter, the land parcel data created in geodatabase (SpatialLite) and Available Water Capacity data for Scotland from spatialdata.gov.scot (spatialdata.gov.scot, 2019) were chosen for preprocessing in ArcGIS Pro. First, both the datasets were joined using 'Spatial Join' geoprocessing tool available in Analysis Tools from ArcGIS Pro. This process was required to connect available water capacity data with Knock Farm's land parcel ids. As a result, an output shape file was created which is usable on ArcGIS Online platform.

Knock Farm WebGIS Interface using ArcGIS Online

The shape file created during preprocessing was then uploaded to ArcGIS Online using 'Add layer from file' option under 'Layers' section of newly created project. Refer figure 20 showing the shape file named 'Available Water Capacity by Land Parcel ID' in ArcGIS Online platform. After uploading the shape file, symbology was applied from 'Properties' panel which in turn enables appropriate legend on the online web interface for reference. Additionally, required set of columns from the associated attribute table were chosen and named accordingly using 'Popup' panel. Finally, an instant app was created using 'Create App' panel in ArcGIS Online. Refer figure 21 for the app created for farmer's use having legends, measuring tool, zoom, pan, sketch and save features.

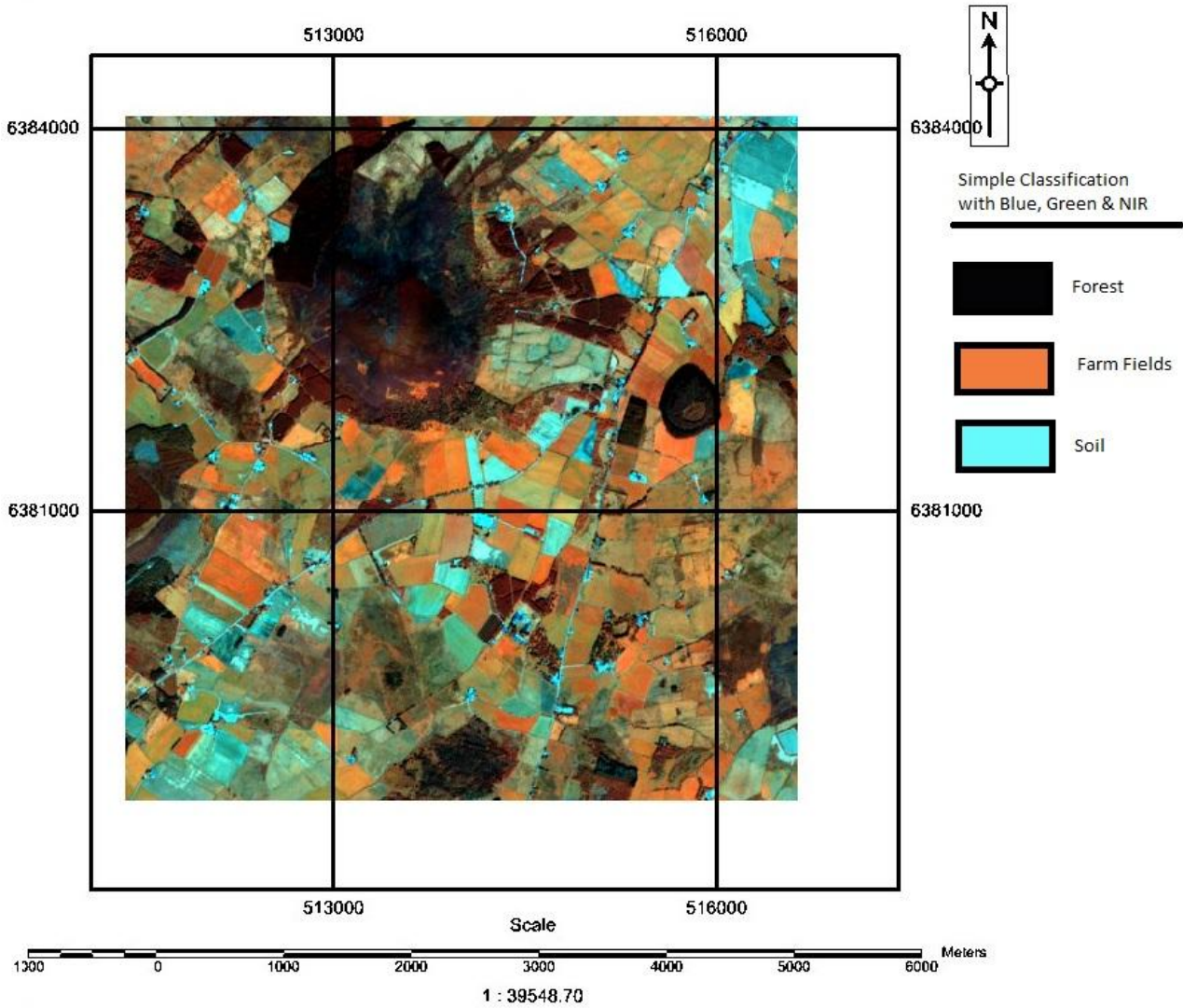


Figure 7. Simple Classification with Blue, Green, and NIR Bands.

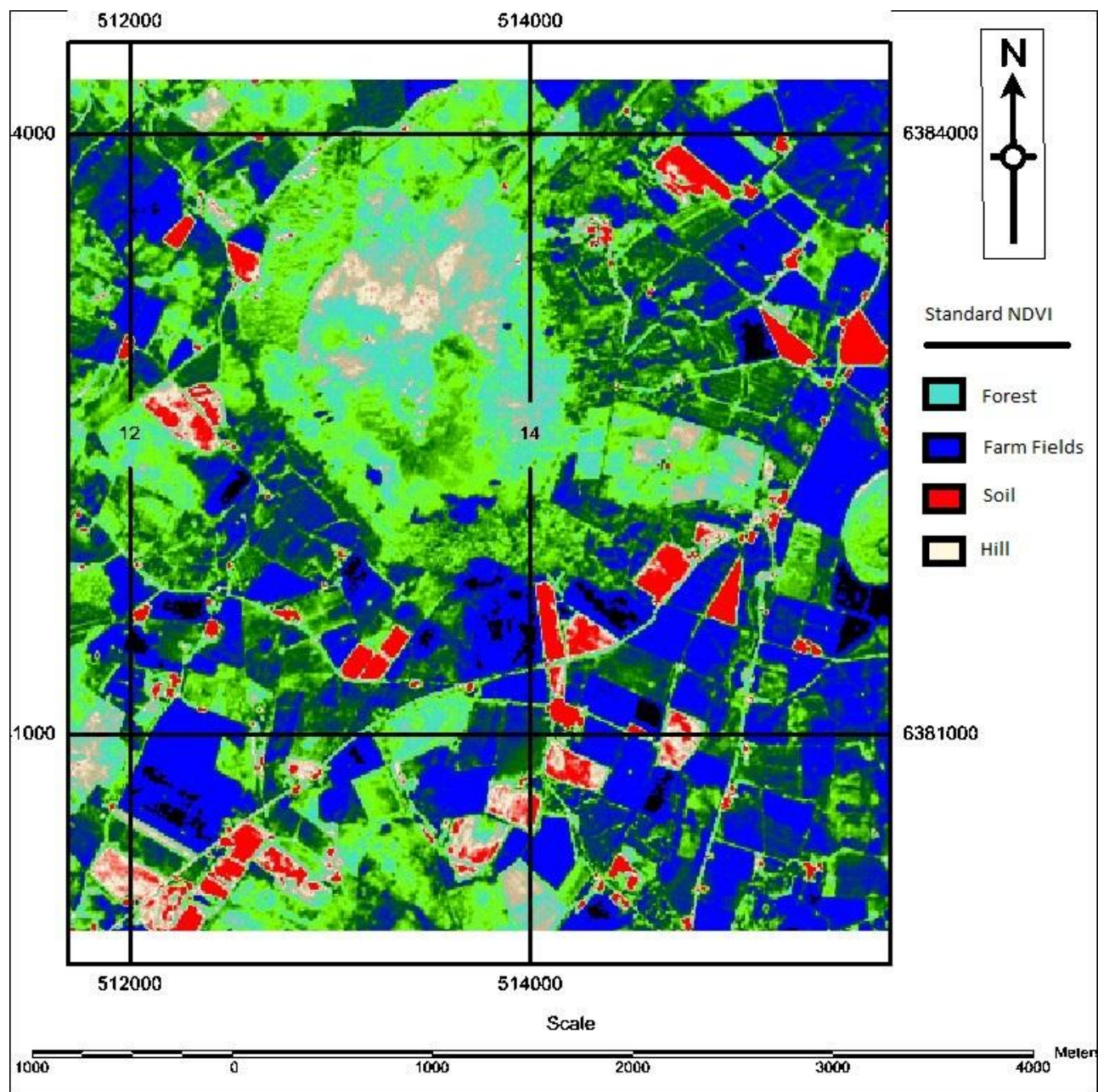


Figure 8. Standard NDVI Classification.

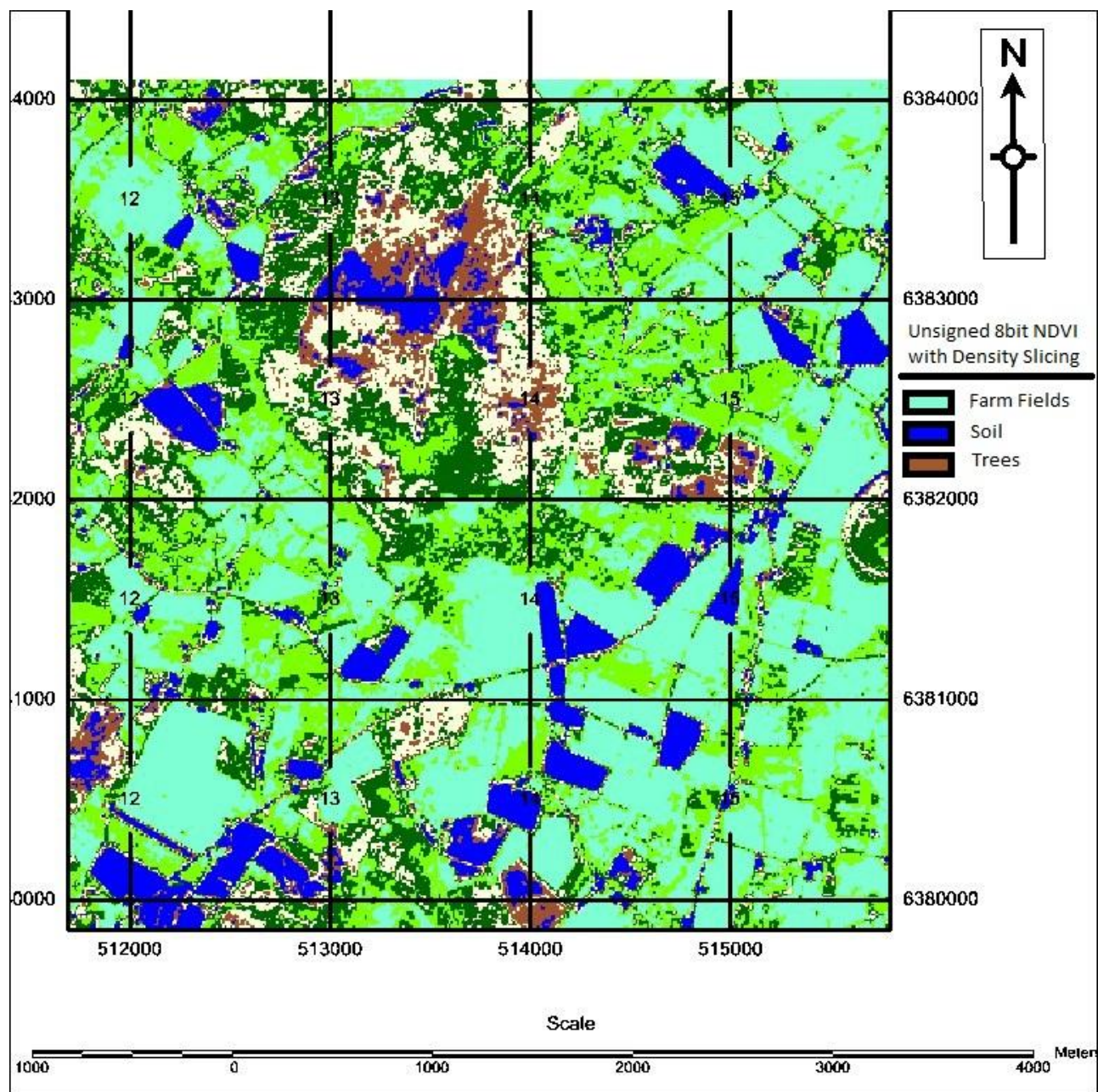


Figure 9. Unsigned 8-bit NDVI image with Density Slicing.

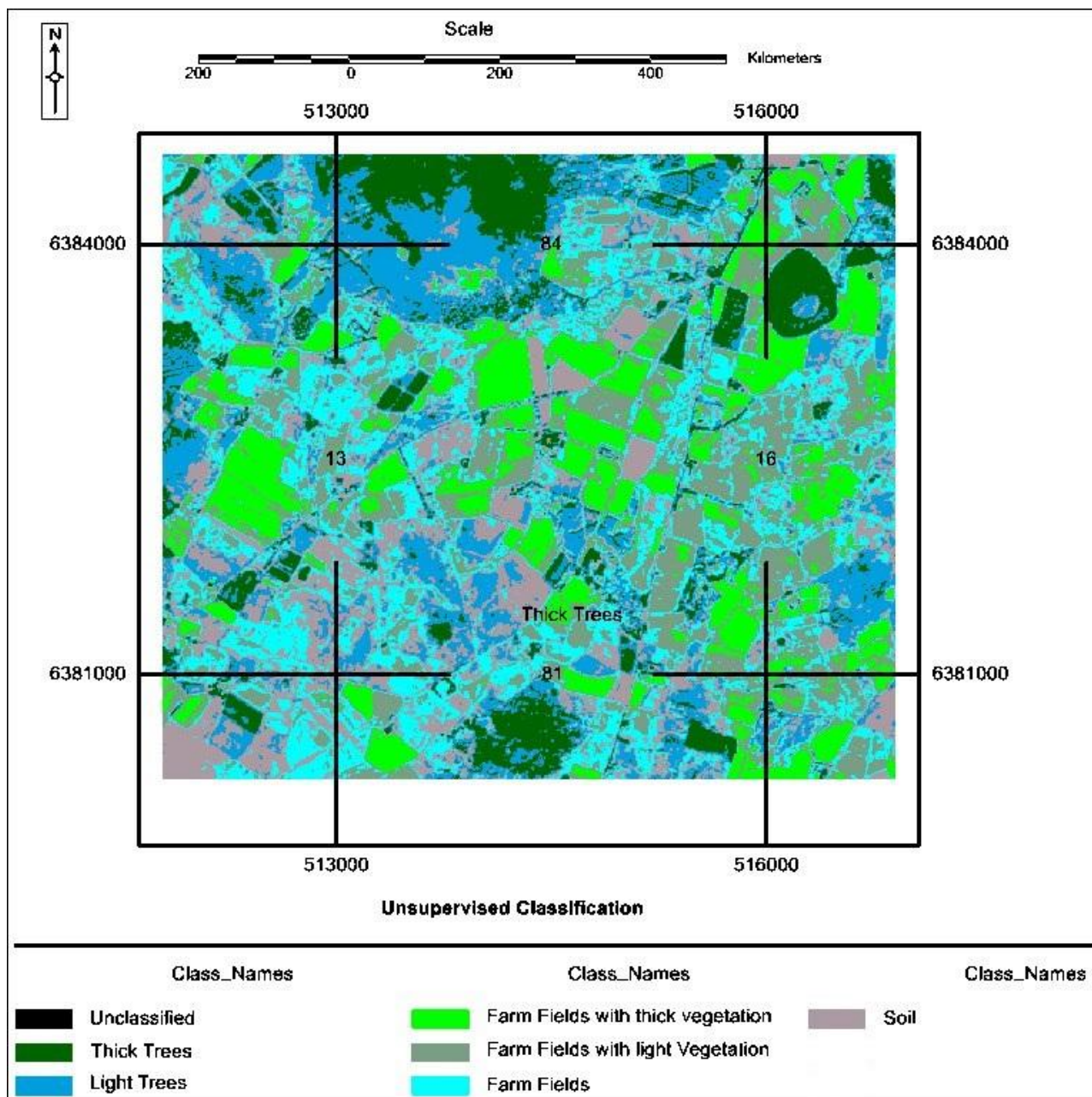


Figure 10. Land cover map with unsupervised classification using clustering technique with k-means and 6 classes.

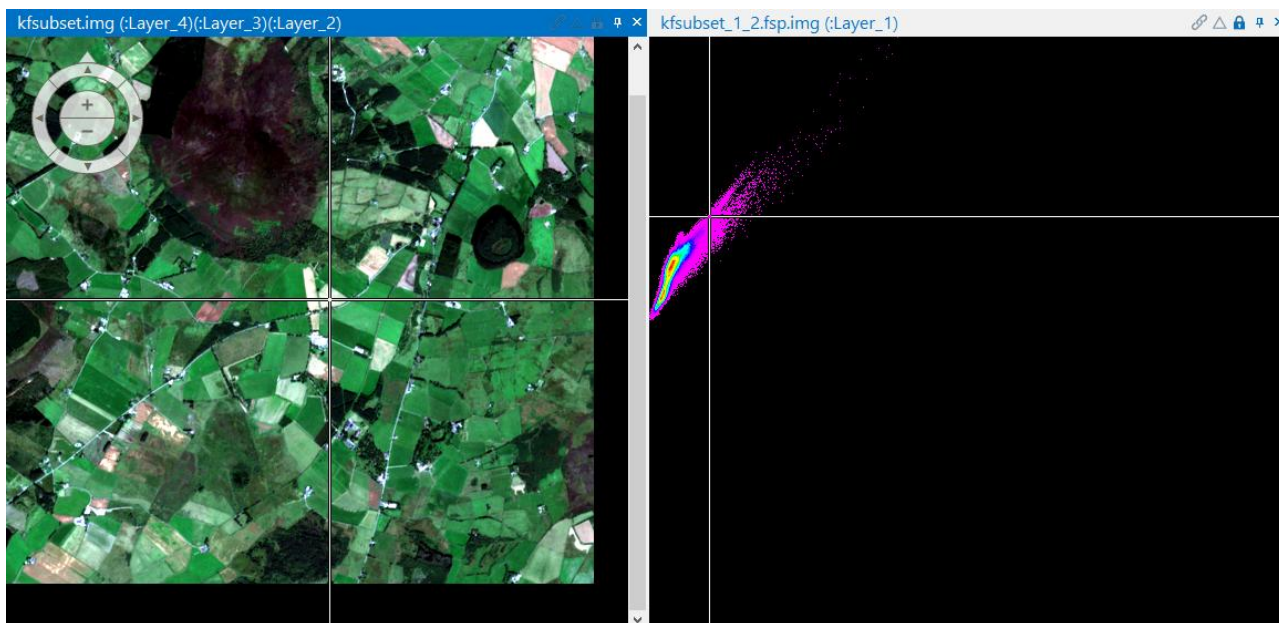


Figure 11. Scatterplot showing range of values for different features on the Sentinel image.



Figure 12. Polygons are drawn on satellite image for classification.

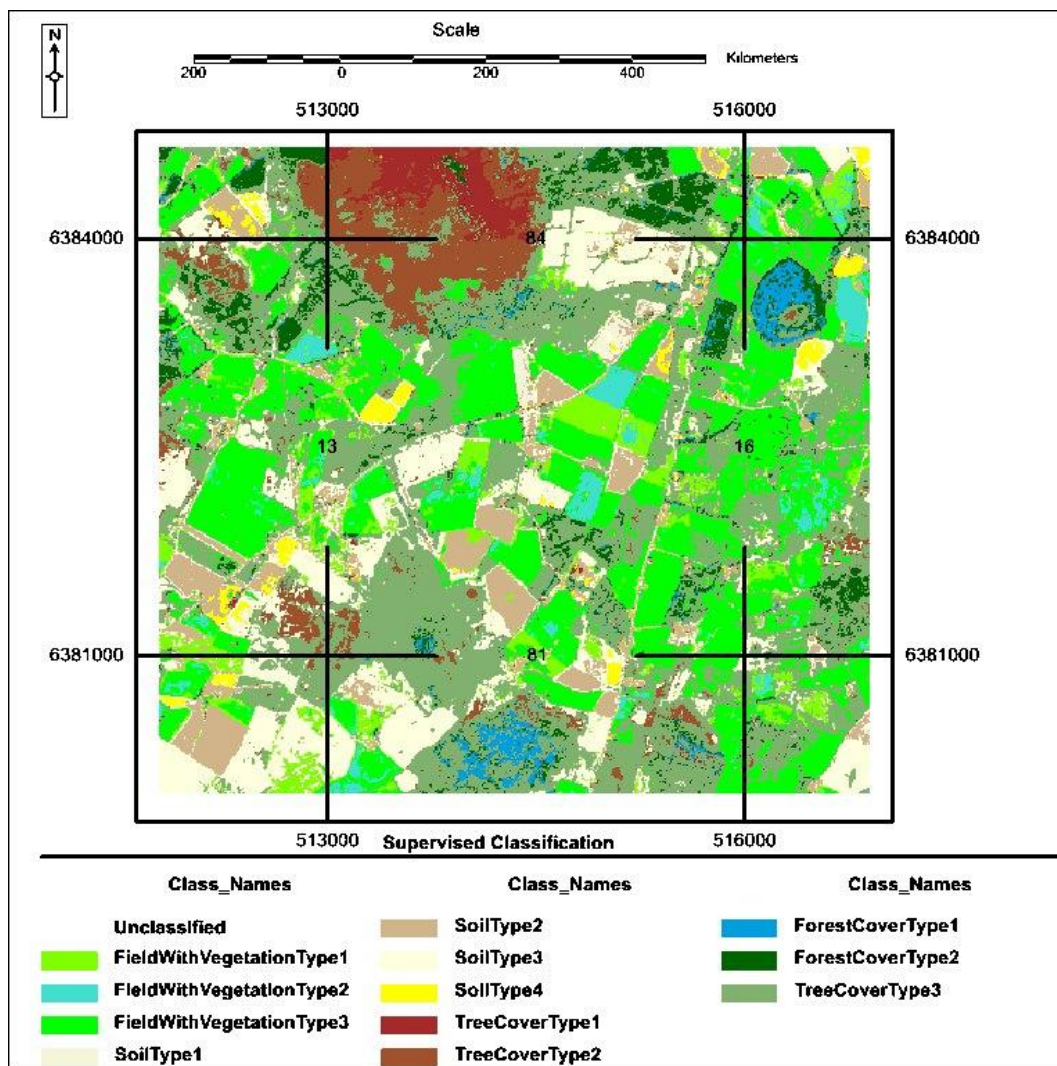


Figure 13. Land cover map classified with 12 classes produced using Supervised Classification and signature file.

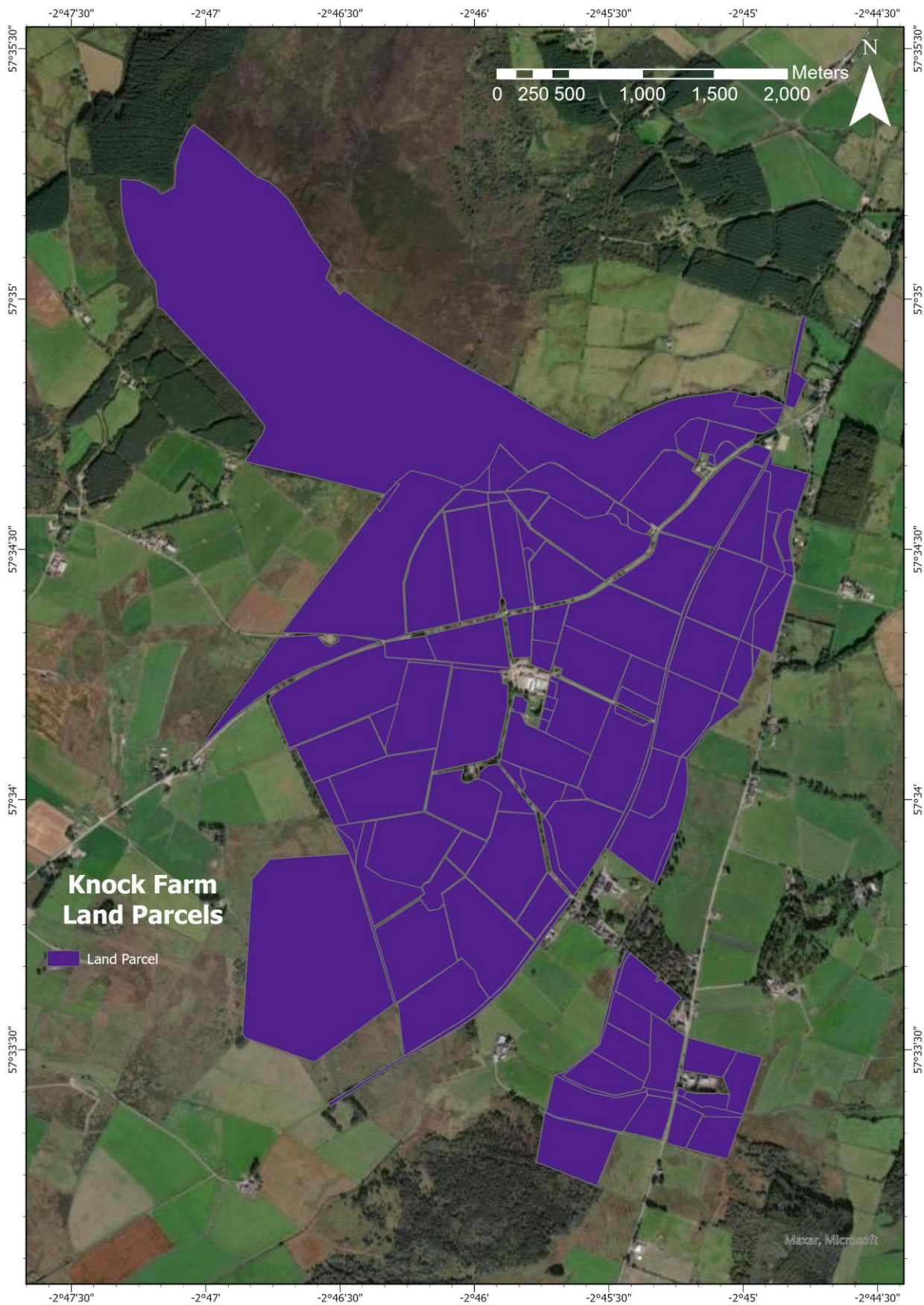


Figure 14. Land Parcels for Knock Farm

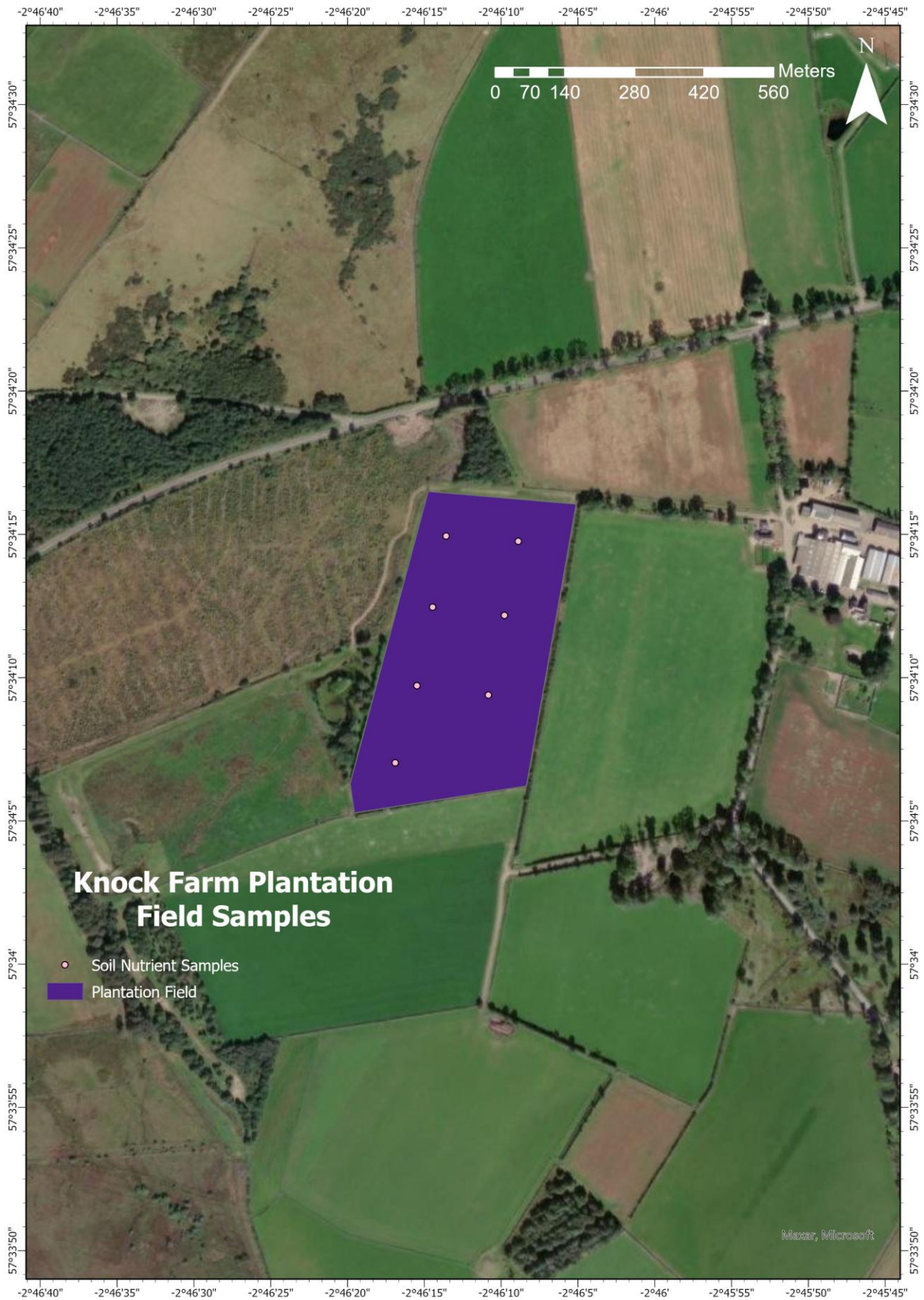


Figure 15. Soil samples from Plantation Field.

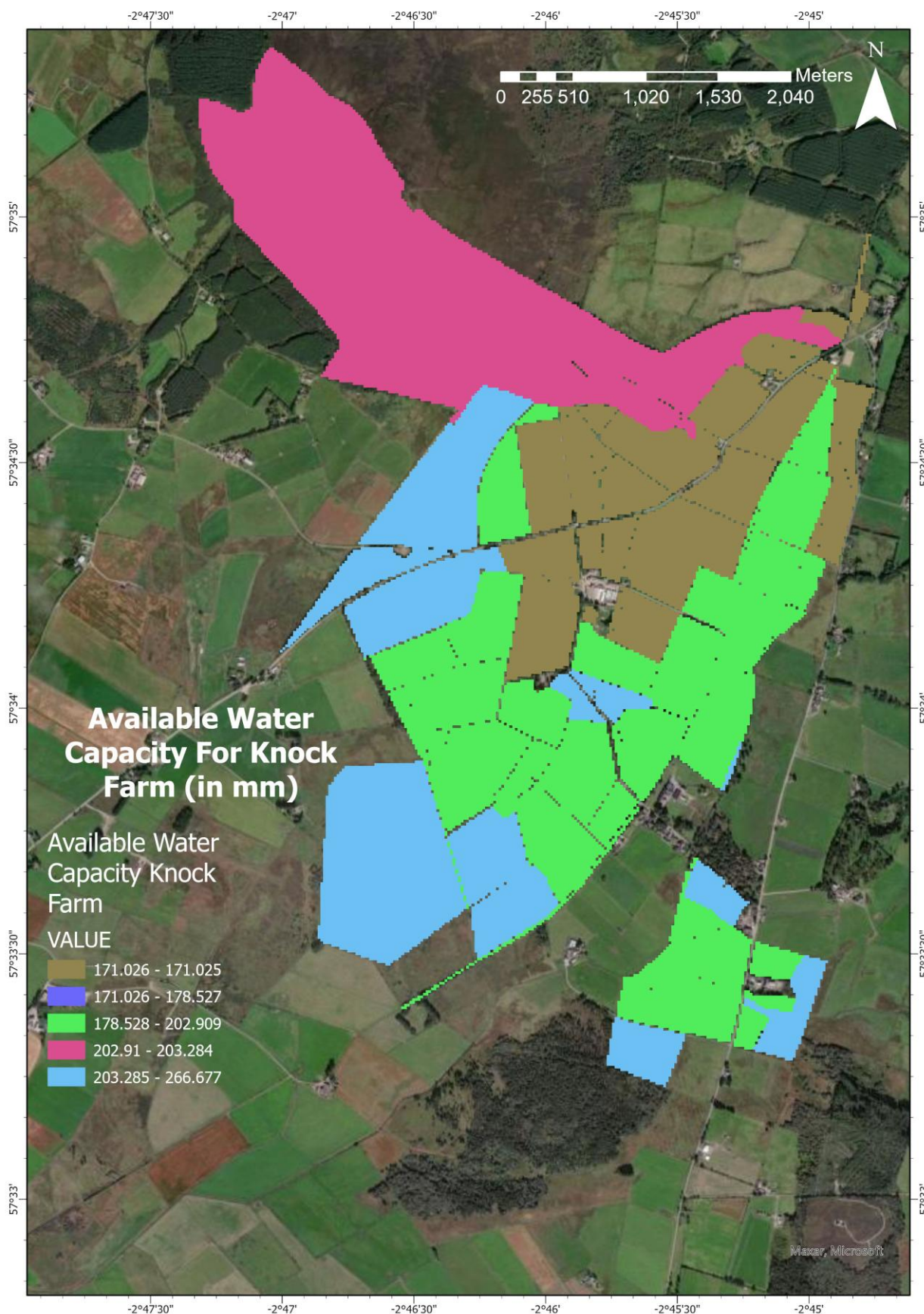


Figure 16. Available Water Capacity for Knock Farm (Geo-visualisation).



Figure 17. Orthomosaic photo created with WebODM using 183 Knock Farm drone images.

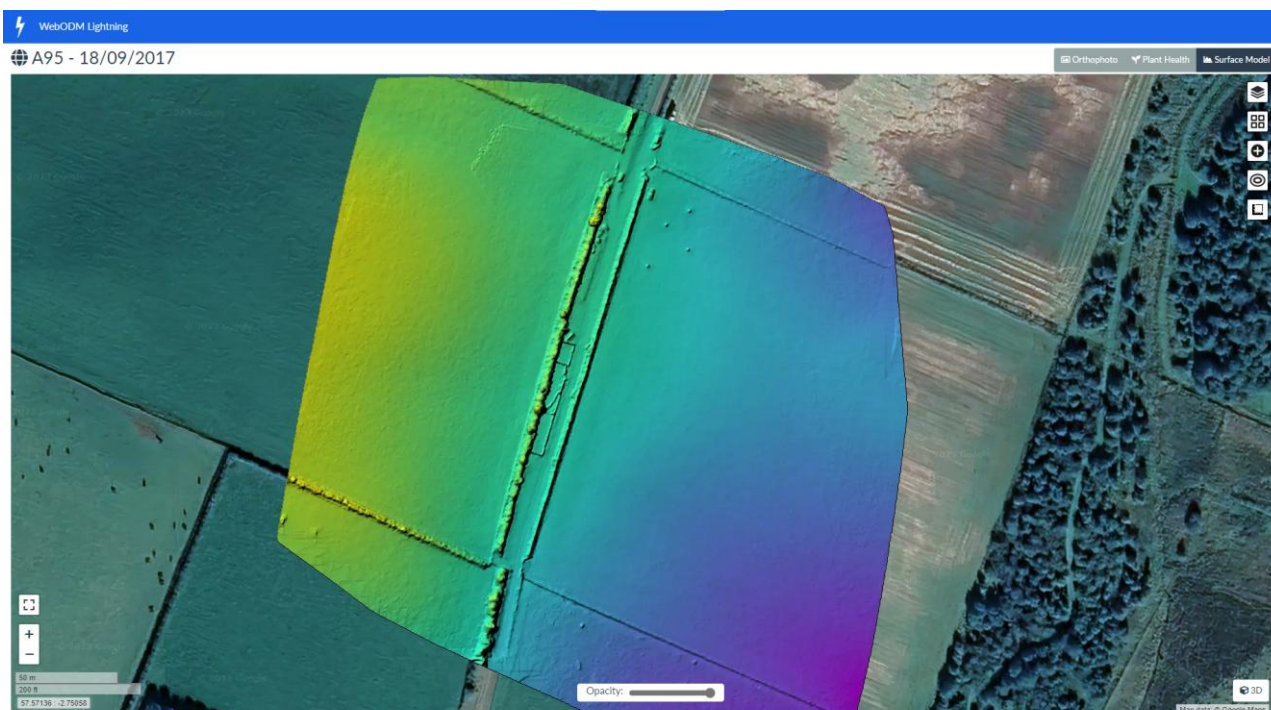


Figure 18. Digital Surface Model created with WebODM.

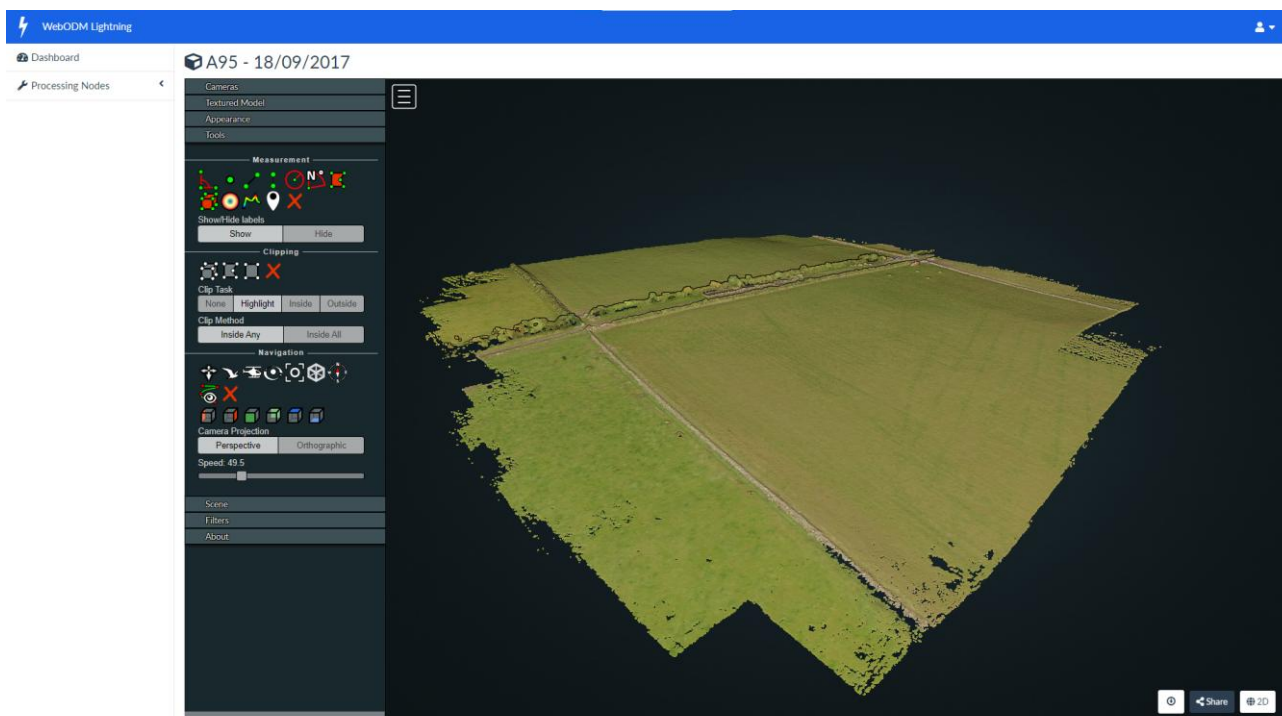


Figure 19. 3D Model created with WebODM.



Figure 20. Available Water Capacity data for Knock Farm in ArcGIS Online platform.

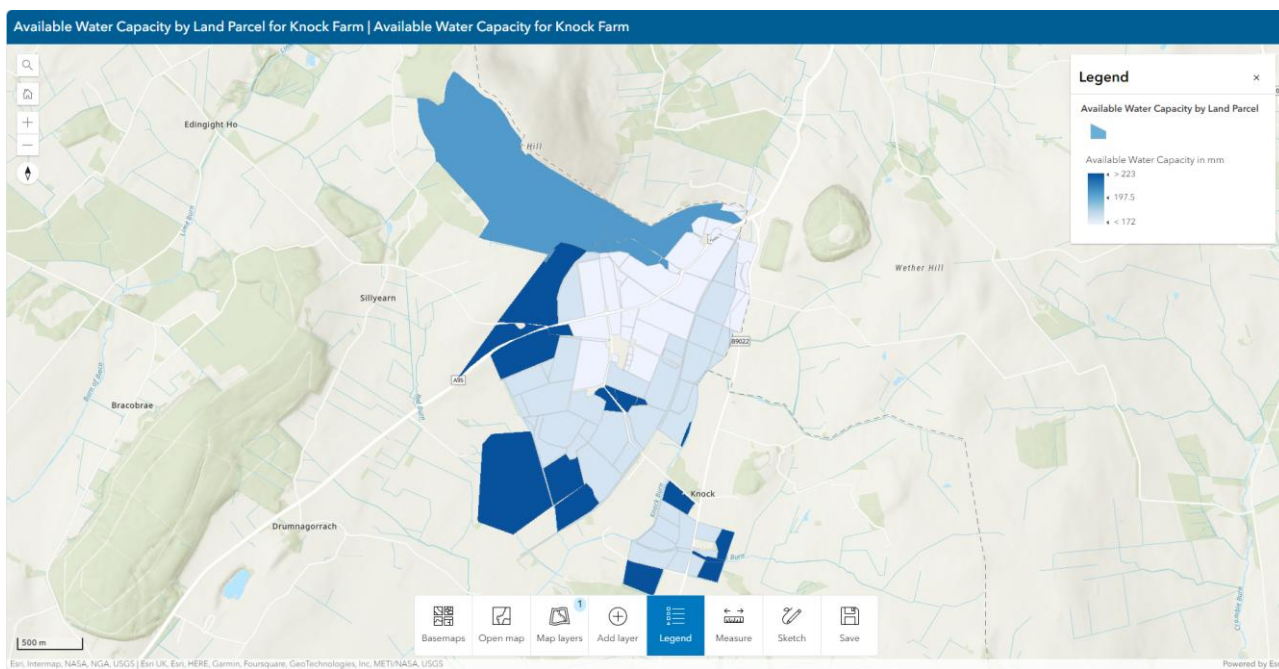


Figure 21. An app for farmer showing available water capacity data for Knock Farm.

DISCUSSION

Preferred classification technique for land cover map

As detailed earlier, there are several methods of classification applicable to Sentinel-2 image available, but all the methods may not be best suitable for Knock Farm analysis. On one hand, there is a simple classification created for Knock Farm using Blue, Green and NIR bands which can only provide some insight to differentiate between soil, farm fields, and forest as shown in figure 7, while on the other hand, well known methods such as NDVI (with or without application of density slicing) can comparatively differentiate the land better. It was identified that supervised classification technique can significantly differentiate between different types of soil, vegetation, tree and forest cover as shown in figure 13, whereas unsupervised classification can adequately perform clustering of different landforms as shown in figure 10. Even though, supervised classification technique requires scatterplot analysis and definition of area of interests (AOI) for appropriate identification of classes, but still the supervised classification is a recommended technique for land cover map for Knock Farm.

Advantages and Disadvantages of Satellite Images

There are several advantages of using satellite images for farm management.

1. They are readily available for analysis.
2. They provide data in visible, near infrared, and infrared bands.
3. They can be used for land use land cover classification.

However, there are few disadvantages of using the satellite images in farm management.

1. The resolution of image cannot be as good as the images captured from ground-based stations or UAVs.
2. Satellite images cannot be used for analysing frequent changes occurring in the farm on daily basis.
3. Accuracy of measurement from satellite-based sensors cannot be as good as ground-based sensors.

Application of Geospatial Database for Knock Farm

Integration of external geospatial databases such as SpatialLite which is an extension of SQLite are useful addition to GIS capabilities of software tools such as ArcGIS Pro. This allows several types of feature classes and tables to be stored together in one database file. For Knock Farm, land parcel data, field cover data, and soil nutrients data collected from the farmer were stored as feature classes in the database. These feature classes are polygons and points created using ArcGIS Pro are further visualised using maps as shown in figure 14 and figure 15. Further, land parcel data was joined with available water capacity data to highlight the amount of water is held in the soil for each land parcel as shown in figure 16. This data is beneficial for farmer to know what level of irrigation may be necessary

for healthy crops. As shown in the figure 16, most of the fields in the north are having lower water capacity as compared to the fields in south and west of the map.

UAV, Photogrammetry and Remote Sensing for Knock Farm

The use of UAVs is well suited for large farms such as the Knock Farm as they can help with spraying as well as monitoring applications and assist farmer with improved crop productivity as well. Further, UAVs can not only capture several still photographs but also remotely sensed multi and hyperspectral images which can be combined in orthomosaic for holistic view and analysis to identify health of the crops and soil using vegetation indices. Photogrammetry tools such as WebODM can create orthomosaic photos and also use calculate heights of the objects using parallax method which it can use construct digital surface models as well. Subsequently, the tool can create 3D model of the farm using digital surface model which could be useful in estimating crop and silage volume as well.

WebGIS App for the farmer

The WebGIS app created for Knock Farm shows available water capacity data for each land parcel as polygons on topographic map by default. Polygons are coloured with different shade of blue based on available water capacity for that land parcel and additional details about a polygon can be viewed by clicking the polygon. The details about the shades are provided in the legend which can be viewed by clicking the legend button from the strip of buttons available for farmer. The bottom strip offers range of buttons such as Basemaps, Open map, Map layers, Add layer, Legend, Measure, Sketch and Save. Additionally, zoom, pan, home and search buttons are also available for the farmer to move around the map. Figure 21 shows the app with range of additional features discussed above.

CONCLUSION

As discussed in this report, precision agriculture has multiple applications for Knock Farm such as land use classification, use of geospatial databases, UAV applications, UAV imaging software tools, and usable map visualisation on WebGIS app.

Being a large farm, satellite images were useful for classification of land cover for Knock Farm. Out of several classification techniques discussed earlier, it was found that supervised classification technique is best suitable for land cover analysis of Knock Farm in comparison to other classification techniques.

It was also observed that Knock Farm has many useful data reports which were converted into feature classes and tables for storing them into geospatial database such as SpatiaLite and subsequent visualisation in ArcGIS Pro. Further, a particularly useful available water capacity data was processed for Knock Farm to highlight the amount of water is held for each land parcel of the farm.

Also, the applications of UAVs can benefit Knock Farm by producing orthophotos, DSM and 3D models using photogrammetry and geospatial software tools as they can be used for farm mapping, crop mapping, crop monitoring, spraying and yield estimation.

Finally, a usable map on a web-based app was also produced using ArcGIS Online for the farmer to show the available water capacity for all the land parcels of his farm.

REFERENCES

- Auravant (2022) Vegetation indices and their interpretation: NDVI, GNDVI, MSAVI2, NDRE, and NDWI. <https://www.auravant.com/en/articles/precision-agriculture/vegetation-indices-and-their-interpretation-ndvi-gndvi-msavi2-ndre-and-ndwi/>.
- ClimateEngine.org (2023) Soil Adjusted Vegetation Index (SAVI). <https://support.climateengine.org/article/118-soil-adjusted-vegetation-index-savi>.
- Gessesse, A.A. and Melesse, A.M. (2019) 'Temporal relationships between time series CHIRPS-rainfall estimation and eMODIS-NDVI satellite images in Amhara Region, Ethiopia,' in Elsevier eBooks, pp. 81–92. <https://doi.org/10.1016/b978-0-12-815998-9.00008-7>.
- GISGeography (2023) What is NDVI (Normalized Difference Vegetation Index)? <https://gisgeography.com/ndvi-normalized-difference-vegetation-index/>.
- Gu, S. et al. (2021) 'Crop Water Stress Index as a Proxy of Phenotyping Maize Performance under Combined Water and Salt Stress,' Remote Sensing, 13(22), p. 4710. <https://doi.org/10.3390/rs13224710>.
- Merry, K. et al. (2023) 'Geographic data processing—raster data,' in Elsevier eBooks, pp. 231–267. <https://doi.org/10.1016/b978-0-323-90519-0.00009-1>.
- Rivera, A.J. et al. (2022) 'Analysis of clustering methods for crop type mapping using satellite imagery,' Neurocomputing, 492, pp. 91–106. <https://doi.org/10.1016/j.neucom.2022.04.002>.
- Radoglou-Grammatikis, P. et al. (2020) 'A compilation of UAV applications for precision agriculture,' Computer Networks, 172, p. 107148. <https://doi.org/10.1016/j.comnet.2020.107148>.
- SpatialData.gov.scot (2019) Available Water Capacity, Scotland WMS. <https://www.spatialdata.gov.scot/geonetwork/srv/eng/catalog.search#/metadata/71e38c05-cf6c-4732-b966-7c202e146cc4>.

APPENDICES