



Remote imaging in sugar beet harvest and storage research

A review

William English, Nordic Beet Research, Sweden

1

Overview

- Background to review
- Technologies
 - Sensors
 - Mounts
 - Processing and analysis
- Metrics the technologies can capture



2

Background

- Interest within the organisation
- Preliminary testing in 2018



3

Background



4

Background

- Interest within the organisation
- Preliminary testing in 2018
- Internal review
- Systematic testing in 2019



5

Remote imaging

Remote sensing

- No physical contact
- Non-destructive

Imaging

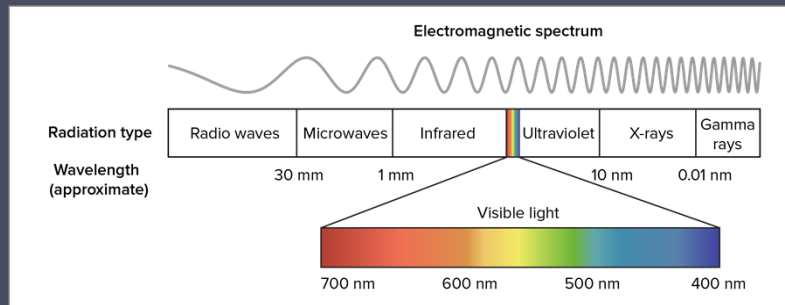
- Yes: photometric;
 - visible and non-visible light reflected or emitted.
 - Active v passive
- No: radar, laser, acoustic, geodetic, etc



6

Sensors

- Defined by which part of the light spectrum they capture light from




7

Sensor type	Description	Example wavelengths (nanometers, nm)
Red-Green-Blue (RGB)	Visible light, at three bands. Omni present in society...	475nm, 560nm, 668nm
Red Edge (RE)	Single band in range 680nm to 750nm	717nm
Near Infra Red (NIR)	Single band in range 750nm to 1000nm	840nm
Normalised Difference Red Edge (NDRE)	RE + NIR	720nm + 840nm
Normalised Difference Vegetative Index (NDVI)	Red + NIR	625nm + 850 nm
Thermal	Relatively long waves, measuring emittance instead of reflectance	8000nm - 14000nm
Multispectral	Measures at specific bands. Typically 3 to 15.	RGB + RE + NIR
Hyper-spectral	Measures continuous bands (or, at least, at many different (eg more than 100) specific wavelengths)	



8

Sensor type	Description	Example wavelengths (nanometers, nm)
Red-Green-Blue (RGB)	Visible light, at three bands. Omni present in society...	475nm, 560nm, 668nm
Red Edge (RE)	Single band in range 680nm to 750nm	717nm
Near Infra Red (NIR)	Single band in range 750nm to 1000nm	840nm
Normalised Difference Red Edge (NDRE)	RE + NIR	720nm + 840nm
Normalised Difference Vegetative Index (NDVI)	Red + NIR	625nm + 850 nm
Thermal	Relatively long waves, measuring emittance instead of reflectance	8000nm - 14000nm
Multispectral	Measures at specific bands. Typically 3 to 15.	RGB + RE + NIR
Hyper-spectral	Measures continuous bands (or, at least, at many different (eg more than 100) specific wavelengths)	



9


Sensors - resolution

Spatial

- **function of number of pixels and capture area**
 - eg drone at 30m with 10MP camera = 0.8cm resolution
 - same camera at 30cm = 0.1mm resolution

Temporal

- **technical limitations**
 - 1/1 000 000 sec to ca. 2 sec
- **practical/ economic limitations**
 - data storage/ analysis capacity



10

Mounting of sensors

Mobile

- drone
- on machinery
- handheld

Fixed

- over a particular place
 - a field
 - a moving belt



11

Mobile sensors - drones



12

Mobile sensors - drones

DJI model	Sensor	Euro
Mavic 2 Pro	RGB	900
Mavic 2 Enterprise Dual	RGB + thermal	3 500
Phantom 4 Pro	RGB	1 400
RTK Phantom 4	RGB	6 000
Inspire 2	RGB	6 000
Matrice 200/ 600 series	Extra	10 000
Agras	None	15 000

Fixed-wing?



13

Processing

- Often none or automatic
- Drone
 - stitching together: 'orthomosaic'
 - online or desktop?




14

Processing

Name	Desktop/ Online	Price	Services
SOLVI	Online	€159/ month	Processing, storage, agri-centric analysis. Plot statistics
Pix4D	Both	€159/ month	Processing, storage, agriculture package, construction package.
DroneDeploy	Online	\$250/ month	Processing, storage, agriculture package, construction package.
PrecisionHawk	Online	Unknown	Processing, storage, agricultural package, construction package. Plot statistics.
Agisoft	Desktop	\$3500	Processing (inc. 3D), editions, bespoke analysis.
QGIS	Desktop	Free	Bespoke analysis


Prices are for the base agricultural package



15

Analysis

- Metric dependent
- Desktop and on-line versions available
 - drone images process and analysed in the same software
- Real-time?
 - yes (Yara N-sensor)
 - and no (Full RGB)



16

Metrics

- **Storage**
 - Temperature
 - Size
 - Disease prevalence


- **Beet**
 - Dimensions
 - Damage



17

Thermal drone and storage temperature

Sensor	Mount	Processing	Analysis
Thermal	Drone (Mavic or Matrice)	Agisoft	Agisoft




Source: Sugarpub.com, Nov/Dec 2018. Used with permission


An infrared image of two Minn-Dak sugarbeet piles. Two interesting points: the hot spot in the bottom left of the image is a payload. The hot spot on the right side is a train locomotive. Photo



18

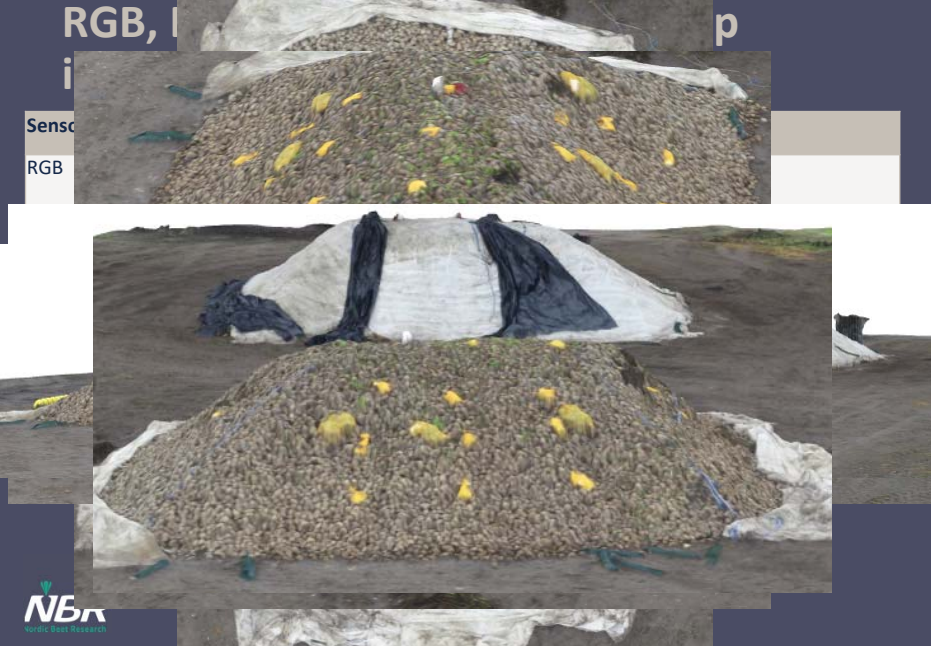

RGB, Drone, Agisoft and 3D clamp image

Sensor	Mount	Processing	Analysis
RGB	Drone	Agisoft/ Online	Agisoft/ Online



19

RGB, Drone, Agisoft and 3D clamp image

20

Multispectral and fungal coverage

Sensor	Mount	Processing	Analysis
Multispectral	Drone/ Hand-held	Zone identification/ In heldheld unit	Desktop/ handheld unit

21

Smart phone + FruitSize = beet size

Sensor	Mount	Processing	Analysis
RGB on Smartphone & backing panel	Handheld	Smartphone	Excel?

22

Fixed camera over belt and damage

Sensor	Mount	Processing	Analysis
RGB	Fixed on harvester	Real-time	Real-time: colour differentiation and AI?



23

Legal and data issues

- **Legal**
 - 'Aviation' laws
 - Size
 - Location
 - 'Monitoring' laws
- **Data**
 - Lots of it
 - Privacy



24

Further information

- we@nbrf.nu
- meran.se



25



26