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SIRKEL-N-LANDGOED: GESONDE MOERE VIR VOLHOUBARE AARTAPPELPRODUKSIE

SATELLITE-DERIVED CROP GROWTH INDICES FOR MANAGEMENT OF POTATO CROPS

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Satellite-derived crop growth indices for management of potato crops

By Prof Martin Steyn and Alex Mukiibi, University of Pretoria, and Fanie Ferreira, GeoTerraImage

The value of satellite images in precision farming applications is well-known. Satellite images can be used to identify problem areas in crop fields, such as stressed or diseased plants, as well as poor plant growth.

Images can also be overlaid with other GIS-linked maps, such as yield maps, or soil nutrient status grid-sample maps, in order to identify and address problem areas in crop fields. For example, areas with low yields may correlate with low soil pH, or deficiency of a specific nutrient in the soil. The value and uses of satellite imagery are therefore endless.

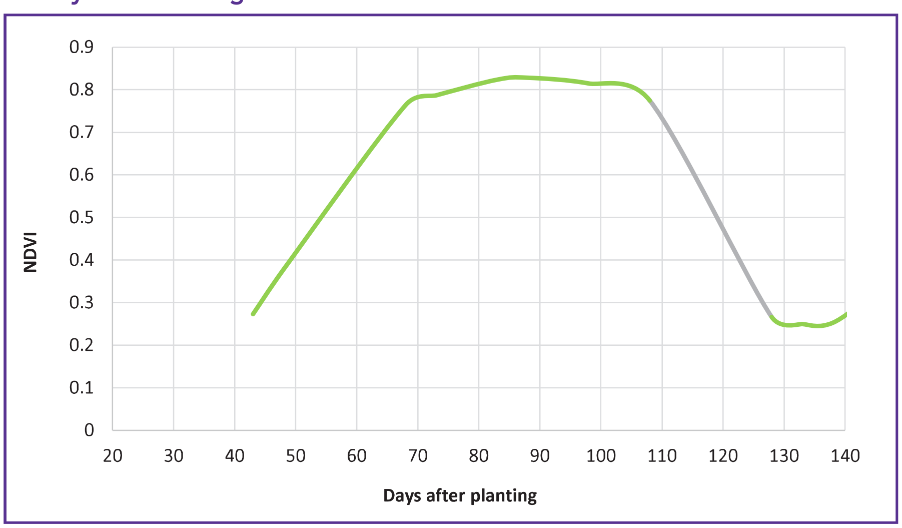
Uses of satellite image information

Potatoes SA has in recent years taken hands with GeoTerraImage, which created the GeoFarmer platform (*www.linkedin.com/showcase/geoterraimage-geofarmer*), to access satellite technology for the benefit of the potato industry. The initial focus was to use satellite technology on a macro scale to develop intelligence that can help with crop identification. This can for example be useful to estimate the areas planted to a specific crop, and the planting times in each production region.

Satellite image information can also be used to assess the extent and impact of severe climatic events (e.g. cold, frost, hail damage) on crops in a specific region. The primary aim is thus to develop management information that can benefit the industry as a whole. Ultimately, satellite image information in combination with other variables, such as weather data, may potentially be used to make early yield estimations for a region.

Nowadays, satellite images are more freely available and affordable to end users. For example, the revisit interval of the two Sentinel satellites used by GeoFarmer is once every five days, which means images are now more readily available and therefore could possibly be used for in-season potato management decisions.

Figure 1: NDVI values for potatoes should increase rapidly after emergence to reach maximum values of 0.75 or higher within about 25 to 30 days after emergence.



A further development in satellite imagery is the calculation of various crop growth index (indicator) values for each pixel of a field. The most commonly known crop indicator is the Normalised Difference Vegetation Index (NDVI). However, various other indicators can be derived from the acquired time-series Sentinel-2 spectral images. For example, apart from NDVI, four other crop growth indicators are calculated and available on the GeoFarmer platform, which could possibly provide useful in-season management information to growers on a micro scale.

The general trend of an indicator is important and relates to a crop's growth stage. The trend is an indication of whether crop growth during the season is progressing as expected and serves as an early warning if problems arise. The five GeoFarmer plant growth indicators are now briefly explained.

1 Normalised difference vegetation index (NDVI)

This is an indicator of crop vigour and crop health, and is primarily defined in terms of the density of green vegetation (biomass) of a crop. This indicator is strongly influenced by the fraction of soil covered by vegetation and the chlorophyll content of leaves.

A high index value means healthy and actively growing vegetation. The index of a cropped field normally ranges between 0.20 and 0.85. Ideally, NDVI values for potatoes should increase rapidly after emergence to reach a maximum of 0.75 to 0.80 or higher within about 25 to 30 days after emergence. Maximum values should then remain at a plateau above 0.75 for as long as possible (≥40 days) before starting to drop at the onset of plant senescence (*Figure 1*).

The index is affected by all vegetation growing on a field, including weeds and potatoes. It is important to note that crop colour, and therefore also index values, can be influenced by weather conditions such as heat waves, cold spells and frost. NDVI values are also known to have a high correlation with crop yield, meaning that NDVI can potentially be used as a tool for estimating crop productivity and predicting final yields.

2 Leaf area indicator (LAInd)

This index gives an indication of the amount of green leaf coverage of the crop per unit area of the ground surface. It is therefore similar to the leaf area index (LAI) that can be determined through ground measurements. LAInd gives an indication of the total area of leaves per unit ground area and is directly related to the amount of light that can be intercepted by the leaves. The LAInd is thus a measure of the 'factory size' where assimilates are produced. The LAInd graph of a well-performing crop usually follows a smooth sigmoidal curve (*Figure 2*).

LAInd values are negatively influenced by adverse weather conditions such as heat waves, cold spells or frost. The index usually decreases when plants are stressed or if there is an early onset of senescence. Since healthy green leaves are essential for photosynthesis to produce assimilates and biomass, the LAInd of a crop will also influence the final yield.

For optimal production, LAInd values should increase rapidly after emergence to reach maximum values of at least 14 000 (up to >20 000) within 25 to 35 days after emergence and remain above 14 000 for as long as possible (≥35 days) before starting to decline at the onset of senescence.

Figure 2: The LAInd graph of a well-performing potato crop should follow a smooth sigmoidal curve and reach maximum values of at least 14 000 within 25 to 35 days after emergence.

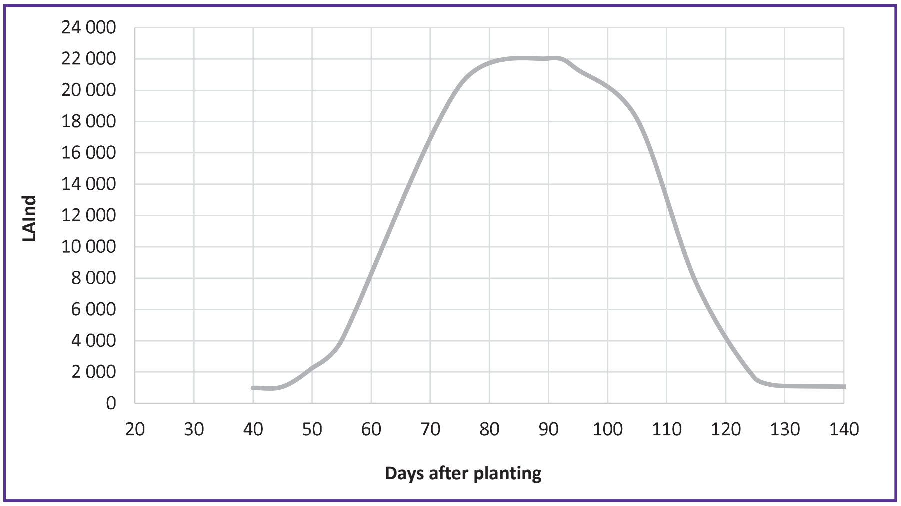
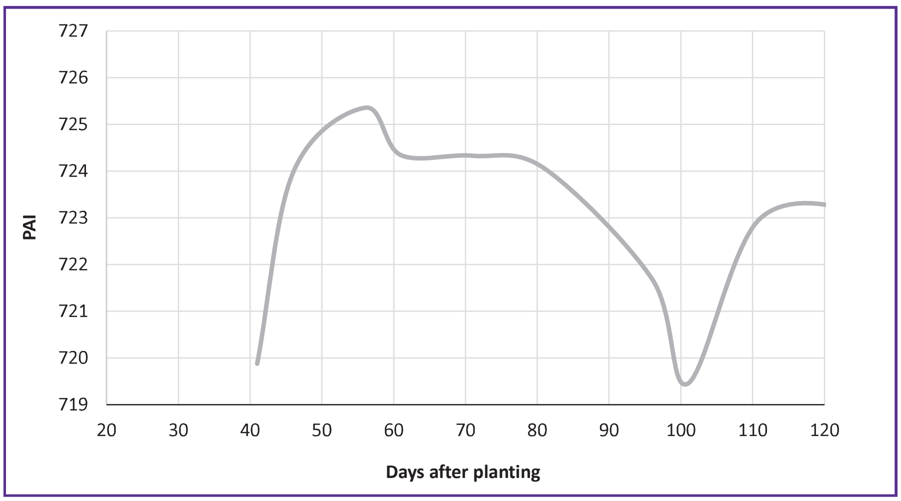


Figure 3: PAI values usually reach maximum values just after full canopy cover and decline as plants get older. PAI values are only reliable from the period of full canopy cover until the onset of plant senescence.



3 Photosynthetic activity index (PAI)

This index is an indicator of chlorophyll content (greenness) of the crop, which may be seen as an indirect measure of leaf nutrition status, especially nitrogen. PAI is also very sensitive to stress conditions (other than nutrition) that may affect the colour of vegetation, like environmental changes (hot and cold cycles, frost and drought conditions), or crop yellowing due to e.g. herbicide damage. It is important to note that PAI values are only reliable from the period of full canopy cover (NDVI > 0.7) until the onset of senescence.

PAI values usually reach maximum values just after full canopy cover and decline as plants get older (*Figure 3*). During this period, maximum PAI values of around 722 to 726 seem to be desirable for potatoes and indicate healthy green plants. Decline in the PAI graph over time should preferably be gradual and only drop below 720 after about 100 days after planting (DAP) for short- to medium-growing season length cultivars.

It is suggested that PAI values may relate to SPAD colour meter readings, which is an instrument that measures leaf chlorophyll content in situ, and therefore holds potential as a tool to manage nitrogen during the growing season.

4 Moisture stress indicator (MSI)

The MSI is an indicator of crop stress due to a lack of soil moisture required for normal crop functioning. The indicator is sensitive to plant water content, which is usually also related to soil water content, although other factors that affect plant water status (e.g. diseases) may also affect the MSI.

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Similar to PAI, MSI values are only reliable from the period of full canopy cover (NDVI > 0.7) until the onset of plant senescence.

When irrigation is managed well, the graph starts high after planting (usually >1.0) and shows a declining trend until full canopy cover is reached, whereafter it stabilises at a low value (*Figure 4*). Low MSI values in the range 0.3 to 0.4 (but not higher than 0.5) for at least 30 to 35 days during the period of full canopy cover are desirable and indicate healthy growing plants.

If there is an upward trend during the mid-season full canopy cover period, it is a warning sign that the soil may be drying out and the crop is suffering from water stress. When senescence sets in, it is normal for the MSI curve to start increasing (>0.5) and thereafter the index is no longer a reliable moisture stress indicator.

5 Senescence onset indicator (SOI)

Senescence onset is related to the timing of the crop starting to 'die off' as a result of natural ageing and ripening at the end of the growing season, or due to external stress-induced factors. One of the first tissues in plant leaves to degrade during senescence is the energy-converting green pigment, chlorophyll. SOI is based on the ratio between the chlorophyll and carotene (orange-yellow) pigment contents in leaves.

The senescence onset growth curve starts at a high value (usually >0.3) and then decreases as leaf area increases until full canopy cover is reached (*Figure 5*). SOI values are therefore also only useful during the period of full canopy cover. During full canopy cover (NDVI > 0.7), low SOI values of about -0.15 to -0.3 for at least 25 to 30 days are desirable and indicate healthy green plants. If the senescence onset curve starts increasing or shows an upward trend during the middle of the growing season, it is an indication of crop stress and early induced senescence.

Figure 4: The MSI graph starts high after planting (usually >1.0) and shows a declining trend to full canopy cover, whereafter it stabilises at a low value.

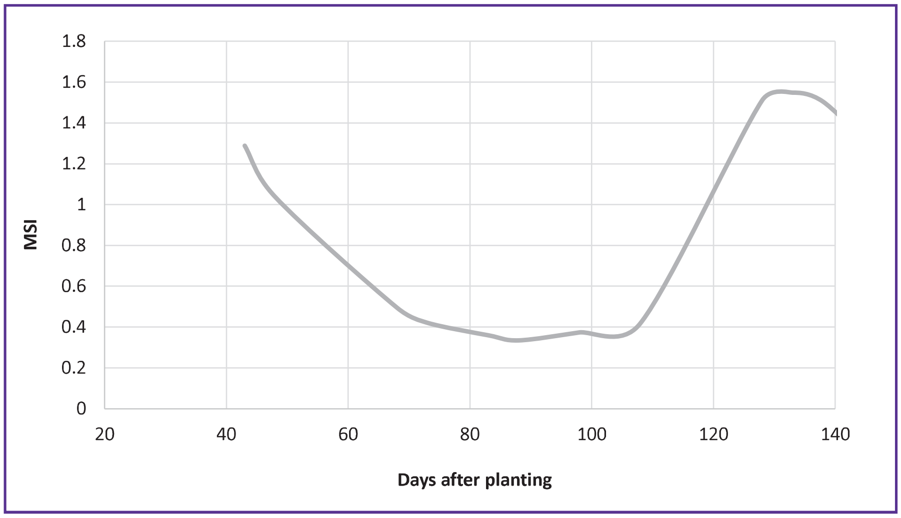
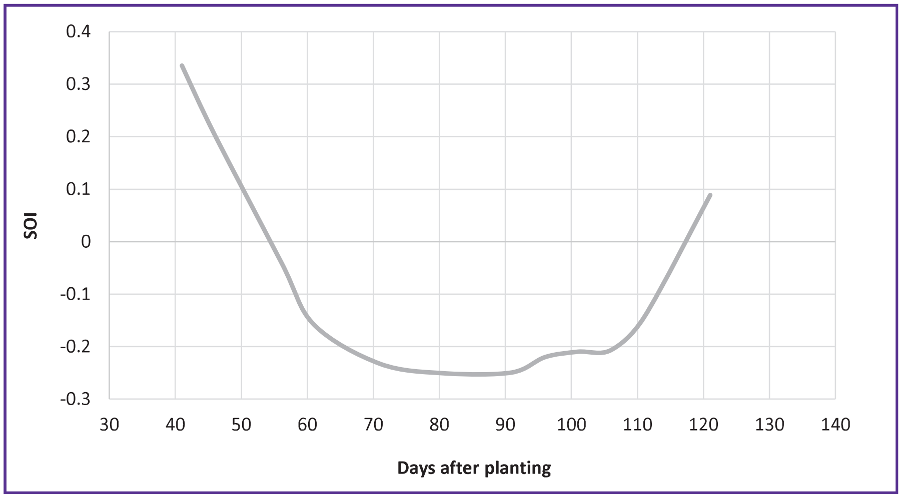


Figure 5: The SOI growth curve starts at a high value (usually >0.3) and then decreases as leaf area increases to reach a minimum when full canopy cover is reached.



Field evaluation of indicator values

For the application of satellite indicators at farm level, reliable norms for the acceptable ranges of the different indicators should be known. The preliminary norms given are based on early grower feedback and experience to date. These broad norms at this stage mostly apply to the cultivars Sifra and Mondial, for which most experience was gained. Threshold values must thus also be updated for other important cultivars as we gain more experience.

One of the challenges with this technology is that very little information is currently available and intelligence (norms, limits) for each index should be developed over time. Research work was therefore initiated to conduct ground truthing by comparing satellite indicator values with in-field measurements on grower fields. We also started case studies in the southwestern Free State, western Free State, Limpopo and the Sandveld regions to analyse the indicator graphs for specific fields in an effort to better understand changes in indicator values over time in response to plant growth, management practices and environmental variables. Progress on these findings will be reported in a follow-up article in *CHIPS*.

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