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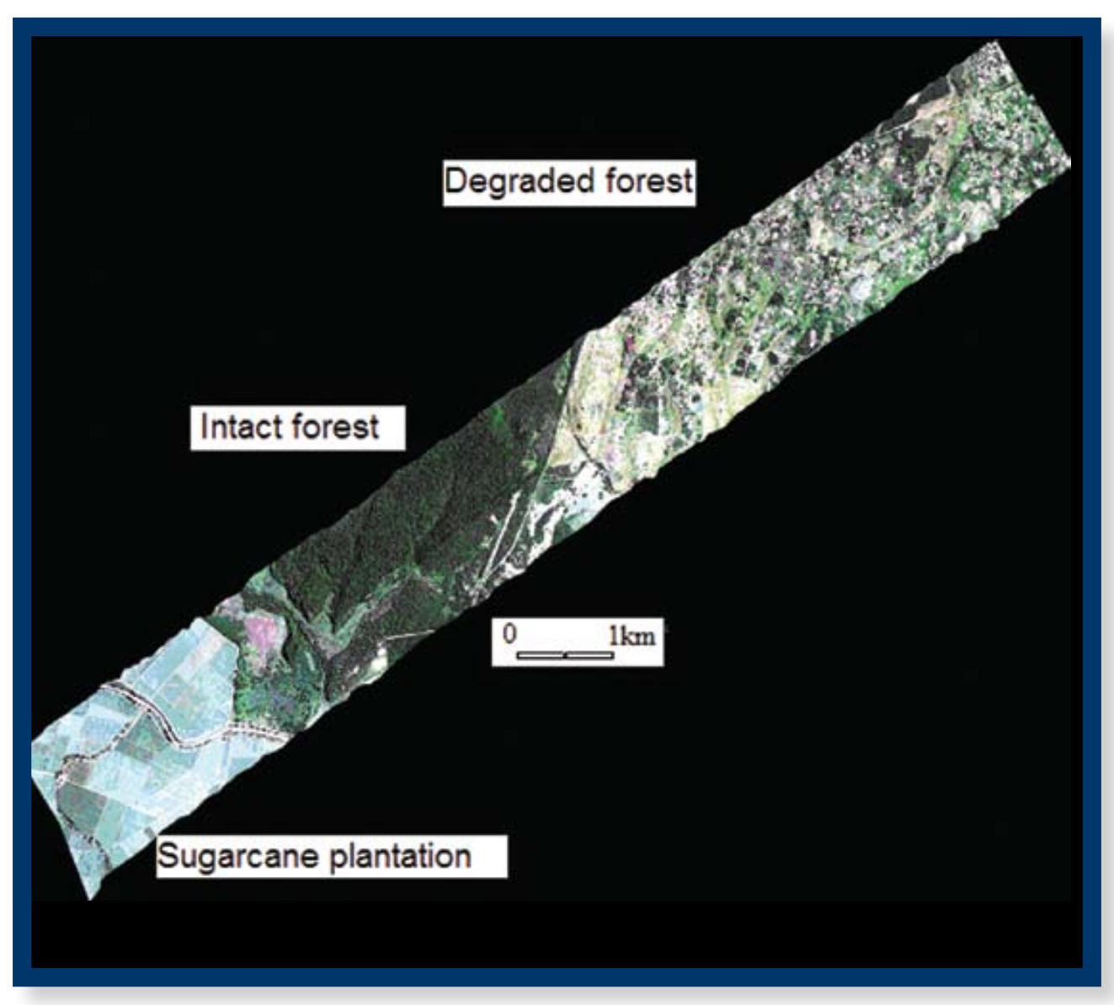
Potential utility of SumbandilaSat imagery for monitoring indigenous forest health

MA CHO[1] P DEBBA[2]
[1]CSIR NRE, Earth Observation Group P.O. BOX 395, Pretoria, 0001, South Africa
[2]CSIR BE, Logistics and Quantitative Methods (LQM) P.O. BOX 395, Pretoria, 0001, South Africa
Email: mcho@csir.co.za - www.csir.co.za

INTRODUCTION
Indigenous forest degradation in South Africa

Indigenous forest is the smallest biome in South Africa, covering an estimated area of 7000km^2, or 0.56% of the total land area of the country. Indigenous forest degradation is regarded as one of the most important environmental issues facing South Africa. Indigenous forest degradation is characterised by habitat fragmentation stemming from logging of large parcels of forest, forest clearance for agriculture and settlements as well as species loss as a result of selective logging or harvesting.



The environmental consequences of forest degradation include soil erosion, loss of biodiversity, diminished water production capacity of watersheds and loss of soil fertility, with dire consequences on rural economies

Figure 1: Airborne Imaging Spectroradiometer Imagery for a section of the Dukuduku forest. Image acquired in February 2009

MONITORING OF INDIGENOUS FOREST USING REMOTE SENSING TECHNOLOGY

Forest fragmentation can be conveniently monitored with broad-band remote sensing instruments such as Satellite Pour l'Observation de la Terre (SPOT) or Landsat Thematic Mapper (TM) imagery. However, a more challenging task is to monitor changes in forest condition resulting from selective logging or changes in species composition in general. The advent of high spectral resolution imagery has seen an improvement in the accurate detection and mapping of vegetation condition (Cho 2007; Mutanga & Skidmore, 2007). However, there is always a problem of waveband redundancy and cost for specific applications. It is for this reason that a medium resolution sensor was developed by the SunSpace, a South African company in collaboration with Stellenbosch University, called the SumbandilaSat. SumbandilaSat has six strategically located bands designed to satisfy various applications (**Table 1**).

Table 1: SumbandilaSat wavebands and associated potential applications (Mostert et al, 2008)

Wavelength range	Intended purpose
440-510 nm (blue)	Water bodies, soil/vegetation, deciduous/ coniferous
520-540 nm (xanthophyll)	Silt in water and deforest-land/urban areas
520-590 nm (green)	Green reflectance peak for plant vigour
620-680 nm (red)	Chlorophyll absorption, roads, bare soil
690-730 nm (red-edge)	Plant stress
840-890 nm (NIR)	Plant biomass estimates, water bodies, vegetation, water content

AIM OF STUDY

The aim of the study is to assess the potential utility of the band settings of SumbandilaSat for modelling forest condition (chlorophyll stress) in the Dukuduku remnant forest in northern KwaZulu-Natal. This study resampled hyperspectral data from the Airborne Imaging Spectroradiometer (AISA) Eagle image to the band configurations of SPOT 1 and SumbandilaSat.

METHODS
Canopy chlorophyll stress and effect on spectral reflectance

The leaf chlorophyll content generally decreases with insect infestation, drying or senescence. Changes in leaf chlorophyll content and leaf internal structure affect spectral reflectance in the region of the red-edge, from the red to the near-infrared (670-780 nm). Increases in the amount of chlorophyll cause a broadening of the major chlorophyll absorption feature centred on 680 nm (Dawson *et al*, 1998), causing a shift in the red edge slope towards longer wavelengths, particularly between 680 and 710 nm (**Figure 2**).

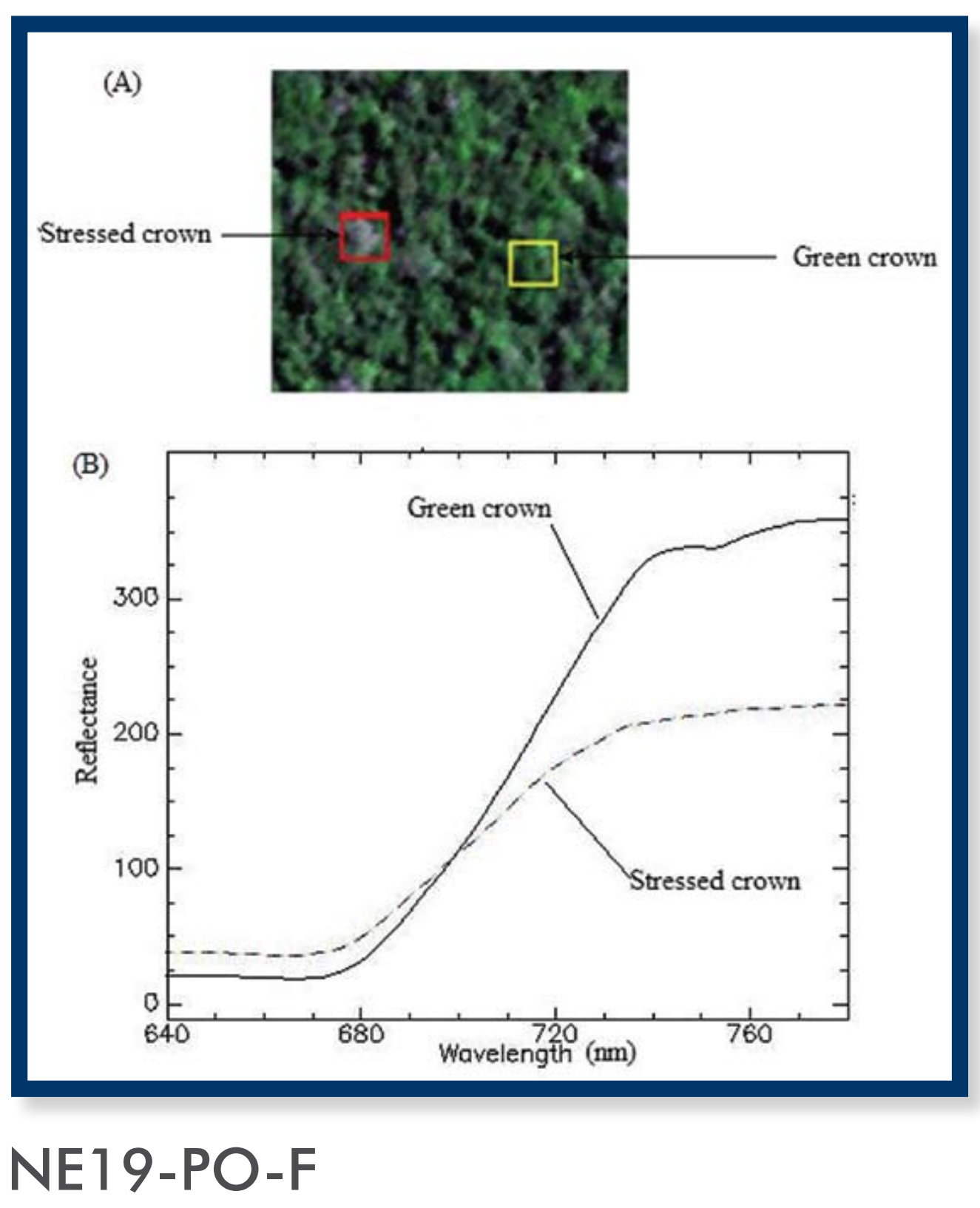


Figure 2: Image spectra illustrating shifts in the red-edge slope with varying canopy chlorophyll stress – (A) is a true colour composite of a closed canopy section of the AISA image

Simulating canopy chlorophyll stress

Miller et al (1990) suggested that the spectral shape of the red-edge reflectance can be approximated by one half of an inverted1Gaussian (IG) function (Eq. 1),

$$R(\lambda) = R_s - (R_s - R_o)\exp\left(-\frac{(\lambda_o - \lambda)^2}{2\sigma^2}\right) \qquad (1)$$

where Rs = maximum spectral reflectance, Ro = minimum spectral reflectance, λo = wavelength at minimum reflectance and σ = Gaussian function variance. Thus, shift in the red-edge is determined by Rs, Ro and σ. Chlorophyll stress was simulated for three subset areas in a closed canopy forest as illustrated in **Figure 3**. We fitted a Gaussian function (Eq. 1) in the 660-760 nm range for every pixel in the original AISA image. Low, medium and high chlorophyll stress levels were simulated by simultaneously increasing Ro and decreasing σ. The original AISA and chlorophyll stressed images were then spectrally resampled to SPOT 1 and SumbandilaSat using their respective spectral response functions.

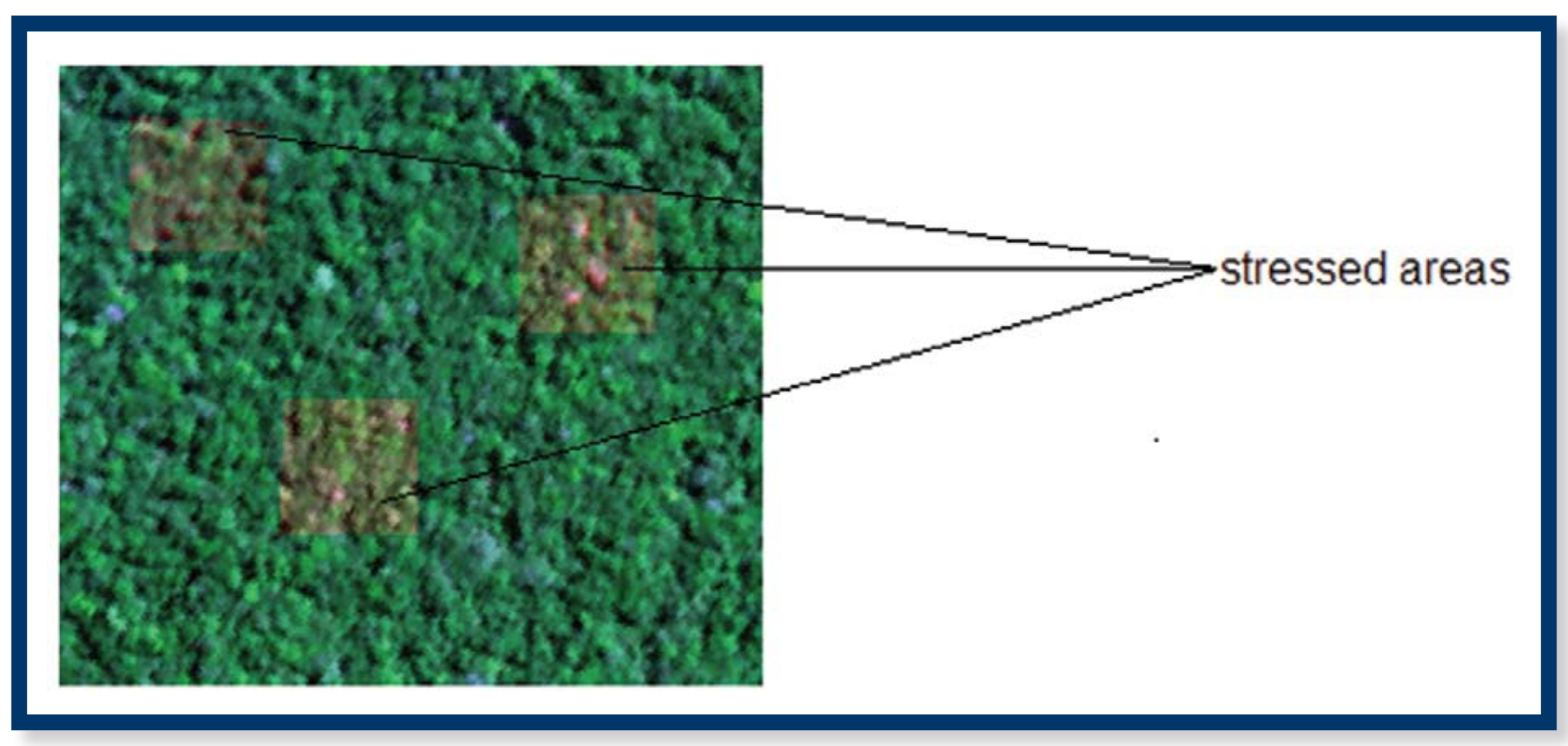


Figure 3: Simulated canopy chlorophyll stress areas

RESULTS
Assessing potential of SumbandilaSat for detecting forest canopy chlorophyll stress

Three band coloured image composites and shift in the red-edge slope were used to assess the potential of the various sensors to detect stress. Image composites were produced using bands at 800 nm, 710 nm and 545 nm for AISA, bands located at 816 nm, 636 nm, and 541 nm for SPOT 1 and bands located at 865 nm, 710 nm and band 530 nm for SumbandilaSat. Only a slight shift was observed for the SPOT 1 data. The AISA and SumbandilaSat images clearly showed the chlorophyll stressed areas. The differences between the various stress levels are not visible with the simulated SPOT 1 images (**Figure 4**). The results for AISA and SumbandilaSat showed shifts in the red-edge slope towards shorter wavelengths with increasing chlorophyll stress (**Figure 5**).

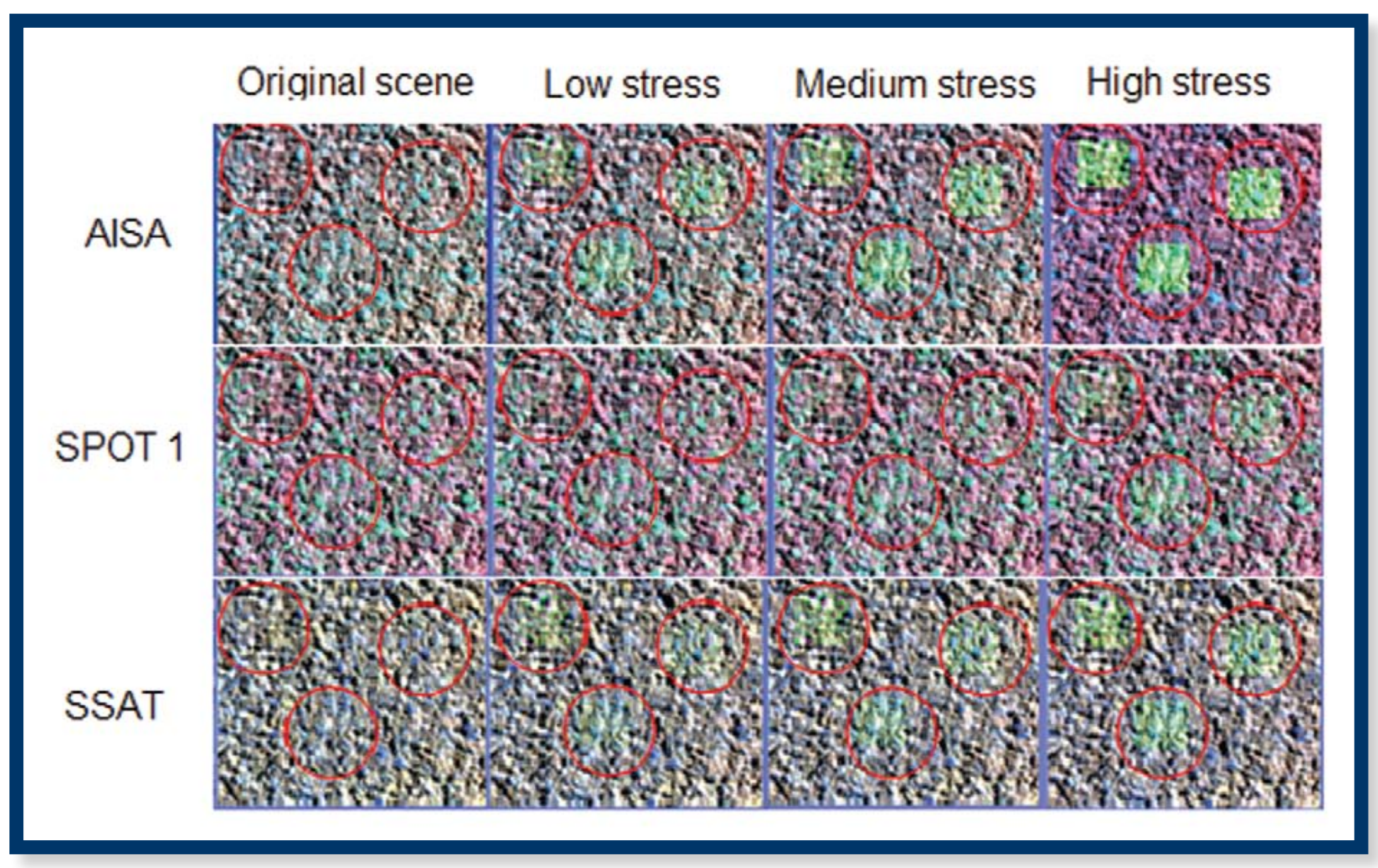


Figure 4: Simulated stress levels for the three different sensors: AISA, SPOT 1 and SumbandilaSat (SSAT)

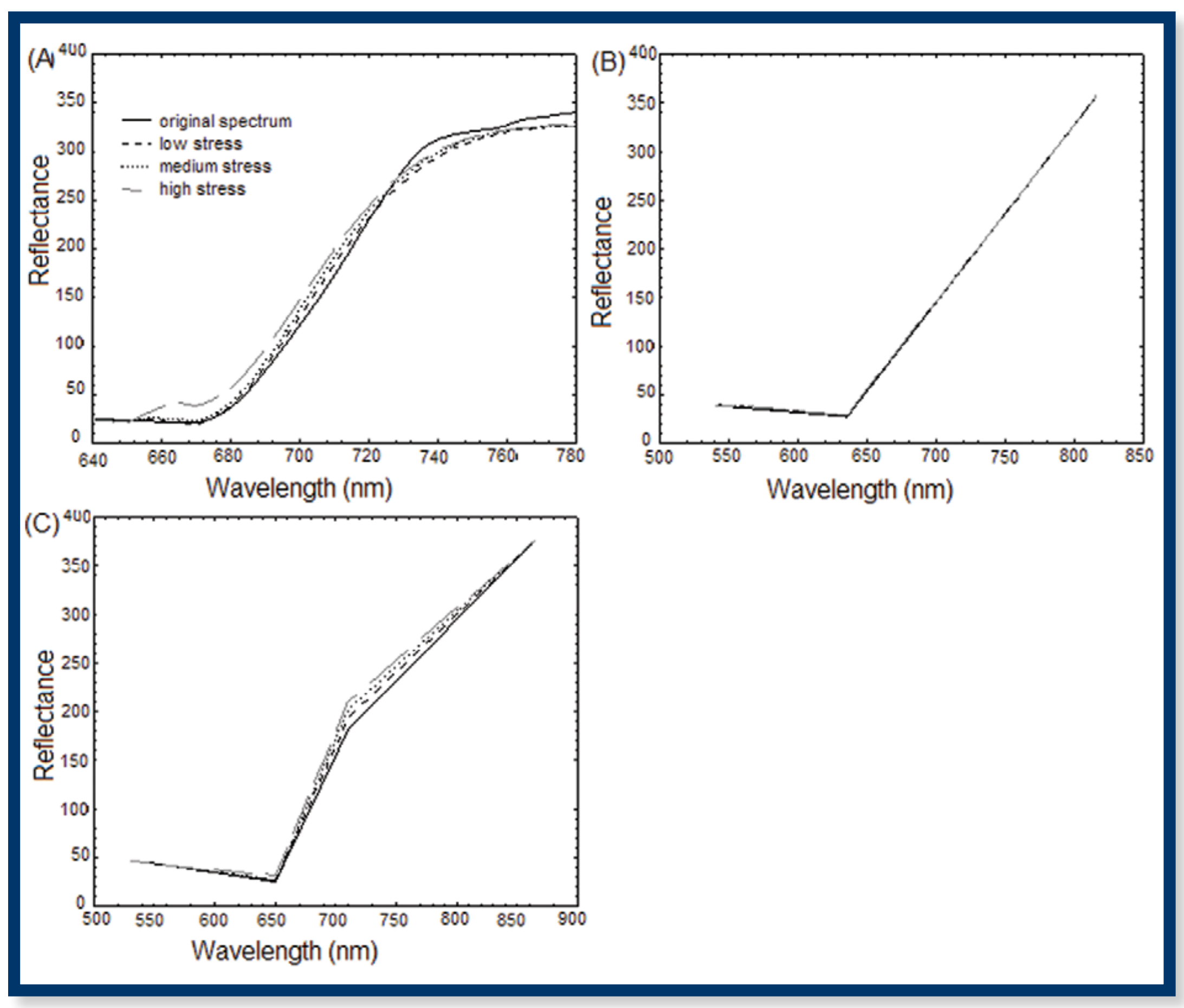


Figure 5: Shifts in the red-edge slope with increasing leaf chlorophyll stress for AISA (A), SPOT 1 (B) and SumbandilaSat (C)

The red edge bands contained in SumbandilaSat images are important for detecting vegetation stress. The development of low-cost SumbandilaSat type sensors could be crucial in assessing vegetation response to climate change or land use change at the regional to global scale.

CONCLUSION

The results show the importance of the red edge bands contained in the SumbandilaSat image for detecting vegetation stress. The development of low-cost SumbandilaSat type sensors could be crucial in assessing vegetation response to climate change or land use change at the regional to global scale.

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