DETECTING OIL PALM TREE GROWTH VARIABILITY USING A FIELD SPECTRORADIOMETER

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ABSTRACT

An analysis of average annual yield of fresh bunches of oil palm fruit in Malaysia showed clearly that there is spatial and temporal variability in yield. Various factors – such as environment, genetics, management, and biotic stress – that occur across oil palm growing areas are known to be the main factors that cause yield variation. These variability factors are normally determined through an analysis of in situ *measurement of related parameters, including corresponding environmental information. Systematic and accurate information regarding factors affecting oil palm tree growth and yield variability, such as water stress and the nutrition status of oil palm trees, is required. However, such an analysis technique is very costly, timely and laborious in nature. Remote sensing techniques offer the most cost-effective method in obtaining such information. Crop growth performance can be identified and mapped using information obtained from remote sensing on the basis of spectral characteristics that have been widely accepted. This study demonstrates the potential of using remote sensing technique for detecting oil palm tree growth variability. Results of the study indicate that oil palm crop performance can be explained by analysing the shape of spectral reflectance.*

1. Introduction

The growth rate for oil palm in Malaysia varies with location and season. These differences in growth rate and, consequently, yield appear to be due to differences in water stress and soil nutritional status across the oil palm plantation. Monthly and annual yield variations of oil palm also result from a combination of various climatic elements such as rainfall, temperature and sunshine (Hartley 1967). Of all these climatic elements, the annual dry season has been considered as the primary factor. Accurate and timely information regarding spatial variability of oil palm tree growth and yield are required to assist oil palm managers in identifying strategies for proper and effective management strategies to overcome these problems. Presently, sampling for water stress and foliar analysis is carried out using conventional methods, where only representative candidates are chosen and measured. These samples are then chemically analysed in the laboratory (Ochs and Olivin 1976). However, this technique of data collection has been found to be laborious and time-consuming. It is also very costly for large areas, so spatial variability analysis of plantation area for selective agronomic measures cannot be implemented. Remote sensing techniques, however, may be used as an effective alternative for analysing spatial variability in oil palm tree growth. A major advantage of this approach is that it can provide an up-to-date assessment of the overall crop health and tree growth performance.

The main objective of this study is to determine the potential of using remote sensing techniques to detect oil palm tree growth variability, which is considered to be the main contributing

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factor in yield variation. Information obtained from this analysis will be the main input for the development of an on-site prototype electromagnetic radiation (EMR) sensing system for capturing variations in oil palm trees as they are growing, variations that may be due to differences in soil nutrient content. The EMR responses from oil palm under different biomass treatments were analysed, and an attempt to find a correlation with the level of nutrients in the soil was made. Regression analysis between reflectance and the nutrient content in the leaves, obtained from foliar analysis, was also carried out to describe the relationship between the spectral pattern and its nutrient content. The establishment of these relationships is very useful as a basic principle in determining the best wavelength that can be used to explain tree growth variability, the prime parameter needed in designing a dedicated sensor system for oil palm.

2. EMR characteristics and tree-growth variability

The relative variations in EMR can be utilized to identify landscape characteristic and conditions. The visible portion of EMR from sunlight starts off with fairly equal parts of blue, green and red light, and when it interacts with an object, the object's composition causes it to absorb varying amounts of different wavelengths of EMR light. The light that is not absorbed is reflected back into space. In the case of vegetation, the physiology of a leaf determines the relative absorption and reflection of light. The equal portions of blue, green and red light from the sun are basically unaffected by the surface of the leaf, but when it encounters the chloroplasts containing chlorophyll-a and chlorophyll-b it is radically altered. These pigments absorb most of the blue (400-500 nm) and red (600-700 nm) portion of the visible spectrum, with relatively less absorption in the green (500-600 nm) portion.

When the light penetrates deeper into the leaf, it interacts with the spongy mesophyll, the bubble-like structures, which can act like a mirror and reflect the light back toward the sky. Since the plant has already used most of the red and blue wavelengths, we see a predominance of green in the light. This is particularly the case for a healthy green plant, and a great deal of difference can be observed in remote sensing images for an unhealthy plant. Typical spectral characteristics for healthy green vegetation and unhealthy vegetation are shown in figure 1 (Jensen 1996). Generally, healthy green vegetation reflects about 40-50 per cent of energy in the near-infra-red region (700-1,100 nm), with the chlorophyll in plants absorbing approximately 80-90 per çent of energy in the visible (400-700 nm) part of the spectrum (Jensen 1983). Because dead or unhealthy vegetation reflects a greater amount of energy than healthy vegetation in the visible spectrum and reflects less energy in the near-infra-red region, this characteristic can be utilized as a measure of crop performance.

3. Study area

This study has been conducted to determine the relationship between EMR and oil palm tree growth variability due to differences in the soil nutrient content in four different types of biomass treatment. The Malaysian Palm Oil Board research station in Kluang, Johor, has been chosen for this purpose (figure 2). These experimental plots were established in June 1994 and set up after the felling of a 23-year-old oil palm plantation of first rotation with the palm planted at a density of 136 ha^{-1} (Khalid and Anderson 2000). The soil in the study area consists of a reddish-yellow sandy clay developed from granite and is classified as the Rengam series (Typic Paleudults). A total of 16 plots were laid out in a randomized complete block design with four replicates. Each plot consisted of 20 palms planted in an area of 0.15 ha, numbered as plant 1 to 20 in each plot. Four types of biomass treatments were "chipped and shredded" (C/S), "complete removal" (C/R), "chipped and pulverized" (C/P) and "partial burning" (P/B). In the C/S treatment, the palm trunks and fronds were chipped and shredded into pieces of about 10 cm thick across at 45-60° angle.

Before chipping and shredding treatment was done, the operator needed to clear or vacate an area of about 1.5 m^2 between old stands for new planting points. The chipped and shredded materials were then spread evenly about 3-4 m wide to avoid thick pile formation. For complete removal (C/R) treatment, the old oil palm trees were cut down and the felled trunks were then cut into several pieces with about 2-3 m in length without chipping. These trunks fronds and other palm components were loaded onto a lorry and removed from the plantation. In the chipped and pulverized (C/P) treatment, the palm trunks and fronds were chipped, shredded and spread out as in the C/S treatment; after one week, these residues were pulverized into small pieces using a pulverizing machine mounted on a 120-hp tractor. In the case of partial burning (P/B) treatment, partial burning of chipped and shredded materials was conducted one month after felling. The unburnt materials, which mainly consisted of about 50 per cent chipped trunks, were left to decompose in the field.

Legume plants appeared after all the treatments had been completed, that is, one week after partial burning. New planting points were marked in old planting rows between old stands. Dura Cross Pisefera, also known as DXP, 12-month palm seedlings were field planted in late August 1994 at 8.8 x 8.8 x 8.8 m triangular spacing. No fertilizers were applied during the experimental period except for an initial treatment of 250 g of phosphate rock in each planting hole at the time of field planting. In normal estate practice, inorganic fertilizers are applied six months and 12 months after field planting, but this practice was omitted in this experiment.

4. Methodology

Spectral measurements over oil palm canopy were taken using field radiometer over 400-1100 nm range in November 2000. The instrument used was a field portable spectral radiometer manufactured by Analytical Spectral Devices, Model A 103000, in Boulder, Colorado, United States. The specifications for the field radiometer are given in table 1.

Table 1. Specifications for field radiometer used

Spectral range	325-1,075 nm
Spectral resolution	3.5 nm
Sampling interval	1.6 nm
Scan speed	100 milliseconds
Detectors	512-element silicon photodiode
Stray light	0.02%
Wavelength accuracy	± 0.8 nm
Wavelength repeatability	± 0.02 nm
Measurement modes	Reflectance

Source: Analytical Spectral Devices, 1998. Manual for field portable spectral radiometer, Model A 103000 (Boulder, Colorado, United States, Analytical Spectral Devices).

The radiometer is mounted on telescopic poles to allow measurements to be made above the plant canopy. In this study, the average palm is about 2.5 m tall and the radiometer is placed 2 m above the canopy, set to observe spectral responses in a 125° field of view. The configuration of the radiometer during the observation is illustrated in figure 3. A total of 30 observations were taken from frond 17 of plant number 8 from all the 16 plots in the study area. Each palm has about 39-40 fronds, and frond number 17 is in the middle of the "leaf" structures, so it is representative of the plant sample. Observations were made from 8:30 to 11:30 a.m. local standard time (8 hours ahead of GMT) on days of clear sky (no visible cloud cover). Radiometer calibration on the prefix reference was carried out before and after each tree spectral measurement. Readings were carried out at one-minute time intervals. All spectral readings were recorded in a notebook attached to the radiometer.

5. Results and discussion

5.1 EMR characteristic and biomass treatment

Data for all 30 observations taken from palm number 8 from all the 16 plots were pre-analysed. All the spectral responses from 400-930 nm were plotted, and it was noted that all the spectral response were within the vegetation trend, that is, low in both the blue and red regions of the spectrum, and the reflectance is much higher in the near-infra-red (NIR) region (figure 4). The increase in reflectance from near 700 nm to 1,000 nm is a normal indication for mature and healthy green leaves (Goillot 1980).

Theoretically, observation of one tree (same target) would give one unique signature, that is, one graph. However, due to errors in observation, there are differences in the reflectance curve for the 30 observations. It is also observed that there are "biases" within responses, so that reflectance in some cases exceeds the reflection limit, especially in the NIR region (figure 5). Many factors may contribute to this, and one possible reason may be and error in the pointing of the radiometer. During observation, the tree's frond may have been moved by the wind. Because of the shape of the frond, which is a blade-like leaf with petiole, the observation might record the background soil instead.

Two techniques have been applied to correct errors caused by this problem: (a) calculate the mean value for all observations to produce a more presentable graph for each biomass treatments, and (b) omit all those spectral responses that exhibit bias, leaving only the good spectra that can be used for producing a graph of treatment response. Figure 6 shows all graphs that have been corrected.

It is very clear that the crop performance under different types of biomass treatment can be explained by analysing the shape of spectral reflectance. In the visible band, the differences between the biomass cannot be distinguished, but in the infra-red region, the type of data treatment and the biomass can be easily recognized (figure 6). Therefore, the spectral pattern in the near-infrared range can be considered as the band that can best explain the differences in crop performance. Lillesand and Kiefer (1987) also proved that the differences in crop health could be determined using the spectral pattern in the infra-red region of the electromagnetic spectrum, where healthy green vegetation is characterized by very high reflectance and very low absorption in the infra-red region. The high reflectance for oil palms in C/S treatment, followed by the reflectance of palms under C/P, is an indication of better performance of palm growth under those two treatments. The ability of EMR to differentiate growth under different types of biomass treatment can be used to detect oil palm crop performance in oil palm plantations. Further analysis was carried out to correlate EMR from leaves with soil nutrients. However, results indicate that direct correlation of soil nutrient with EMR from leaves cannot be extracted using simple linear regression.

5.2 EMR responses and foliar analysis

Nutrient levels in the foliage of the oil palm reflect general deficiencies and sufficiency for growth. The nutrient content of the foliage (N, P, K, Ca and Mg) can be obtained through foliar analysis of oil palm leaf from frond number 17. Before foliar analysis is carried out in the laboratory, spectral reading from that particular leaf is measured. Regression analysis between reflectance and the nutrient content in the leaf is carried out to describe the relationship between the spectral pattern and its nutrient content. However, results showed no significant correlation.

5.3 Prototype sensor for variability

The EMR responses due to the oil palm variability parameter clearly indicate that only a certain wavelength within NIR is relevant for determining the performance of oil palm tree growth. Therefore, this information is the main input in designing the oil palm sensor. The prototype sensor in this study is design to view oil palm crop from a terrestrial mobile platform (which is meant to be attached as a tow unit behind harvesting machinery) (see figure 7). The image capturing at every "instantaneous field of view" is carried out at stop-points at predetermined intervals in order to "scan" the entire platform.

Figure 8 is a block diagram of the prototype sensor. Visible sunlight in the range of 0.4-0.7 µm is the source of energy for this equipment. The photodiode is positioned facing the target of interest. The op-amp amplifies the input current from the photodiode and sends the output as voltage to the voltmeter. An experiment was carried out to show the reflectance responses from different surfaces. For this purpose, reflecting surfaces with different colours – blue, yellow, white, black, orange, green and red – were used. The voltage readings from the voltmeter are shown in table 2 below. Further testing will be carried out to see the characteristics of reflectance from various types of leaves.

Table 2. Voltmeter readings from various surfaces

Surface colour	Responses in NIR (volts)
White	11.31
Yellow	9.25
Green	7.31
Orange	7.11
Red	6.00
Blue	5.40
Brown	4.65

6. Conclusion

This study has demonstrated the potential of using remote sensing for detecting spatial variability due to crop vigour, attributed to soil nutrients. Specific wavelengths identified to produce optimum responses of EMR have led to the development of a dedicated sensor for capturing variability of oil palm tree growth. This provides a new dimension in the oil palm industry and will be a very useful tool in planning better strategies for proper and efficient management systems in all major oil palm growing areas to ensure stability in production and yield, and thus have good economic returns.

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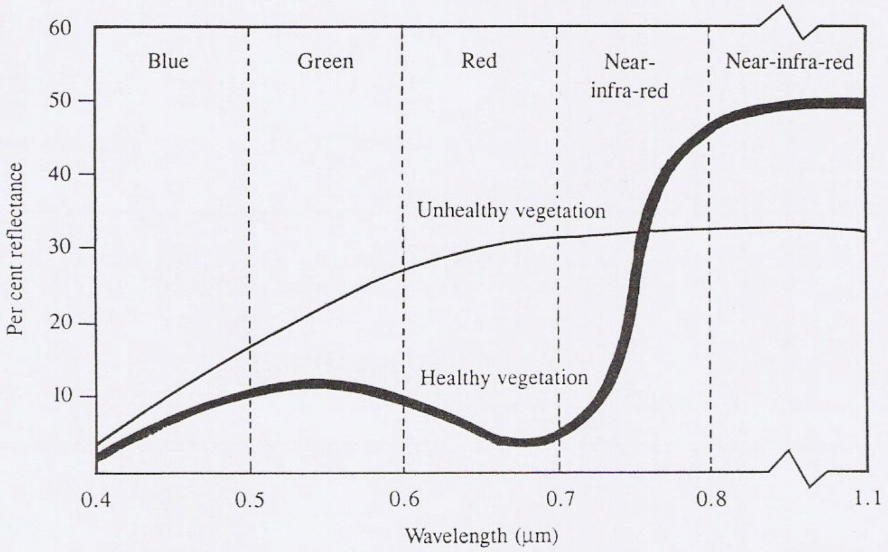

Source: Jensen, J.R., 1996. *Introductory Digital Image Processing: A Remote Sensing Perspective*, 2nd edition (Englewood Cliffs, New Jersey, Prentice Hall).

Figure 1. Typical spectral reflectance characteristics of vegetation

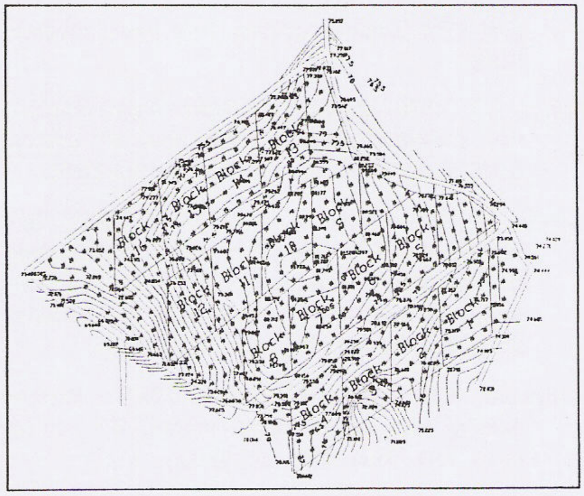

Figure 2. Study area

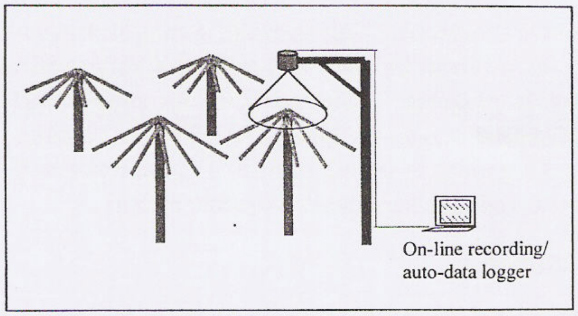

Figure 3. Configuration of radiometer during observation

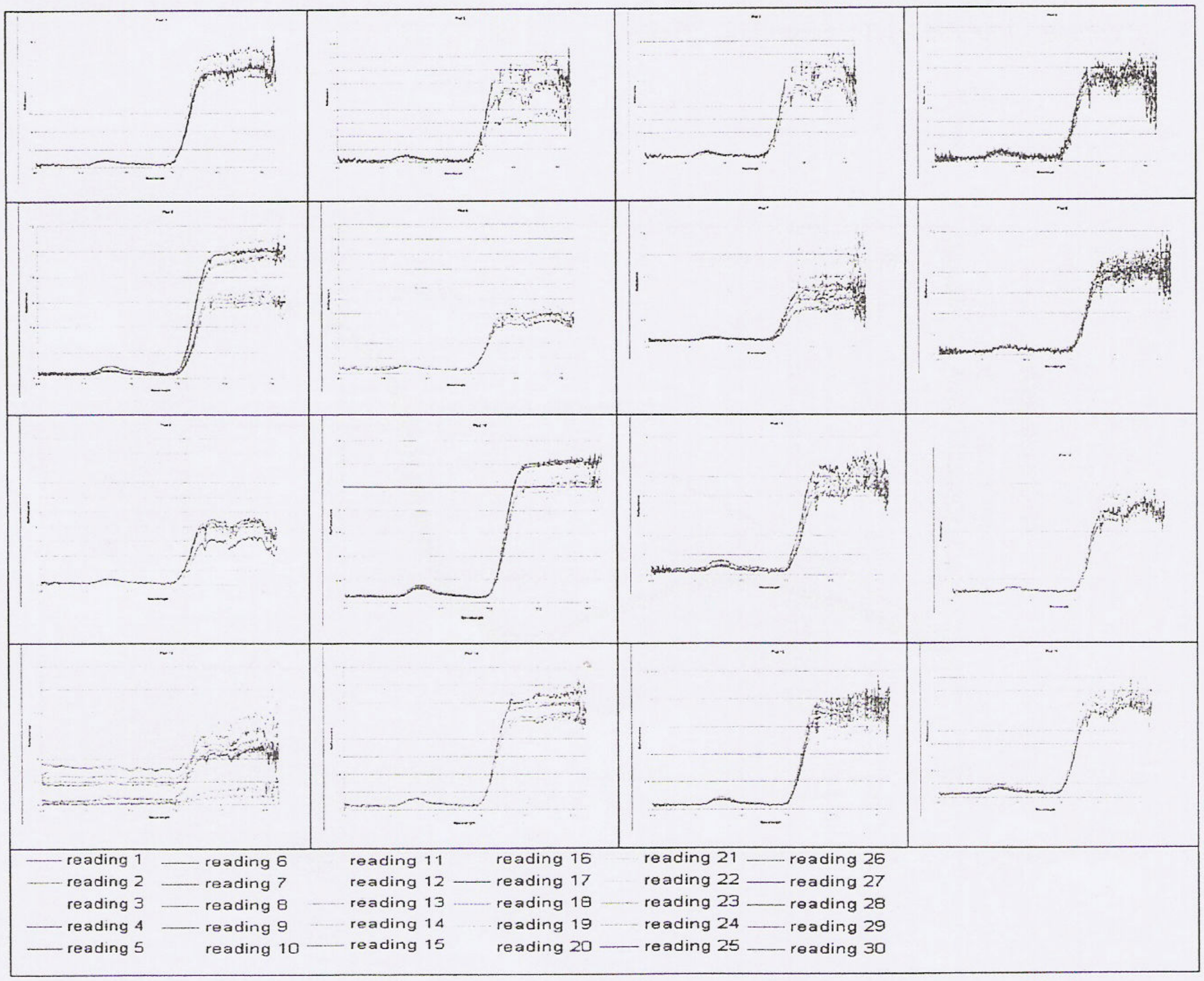

Figure 4. EMR readings for all 16 plots

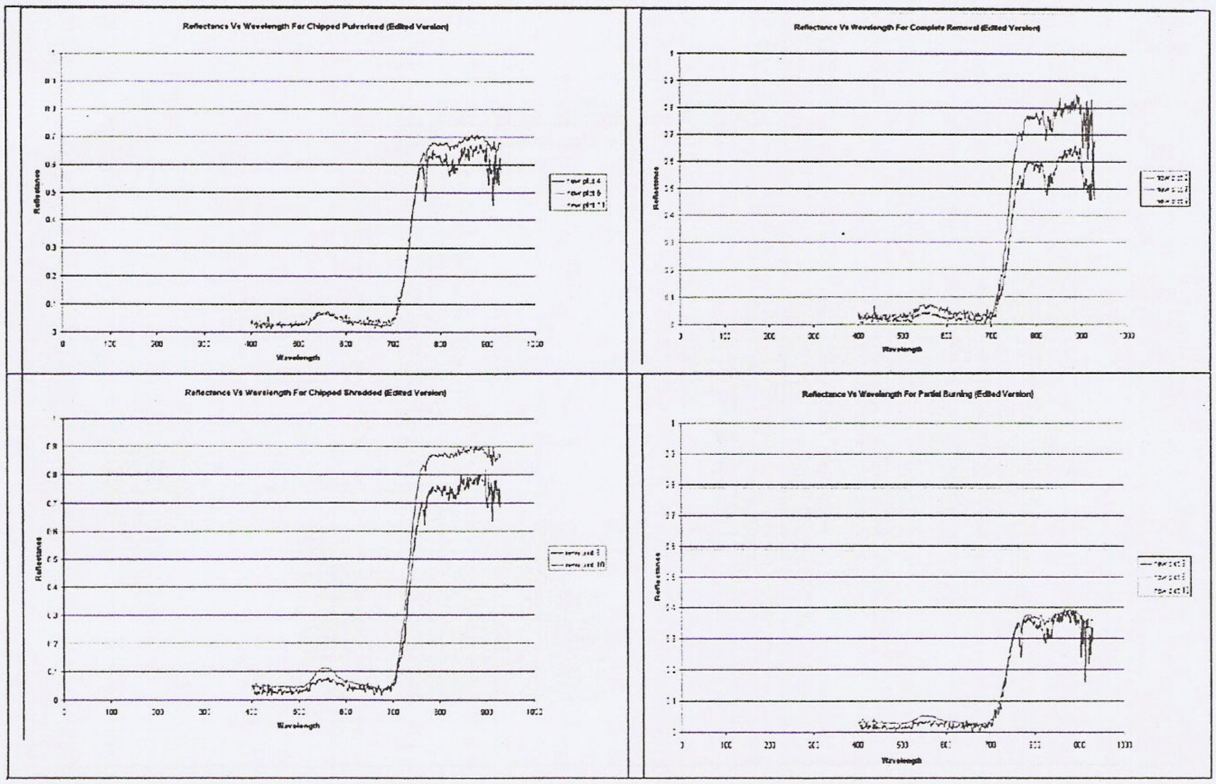

Figure 5. Mean spectral reflectance for 30 observations

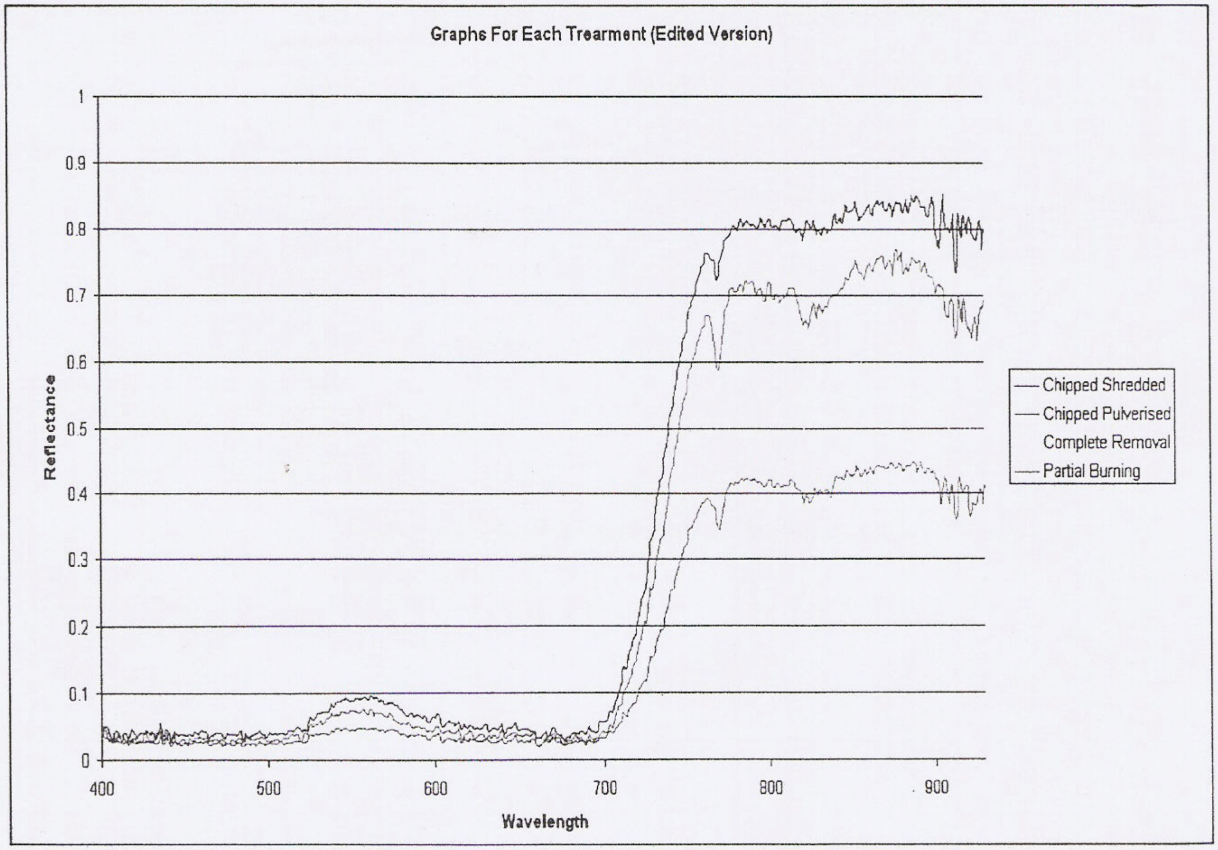

Figure 6. Mean spectral reflectance for biomass treatment

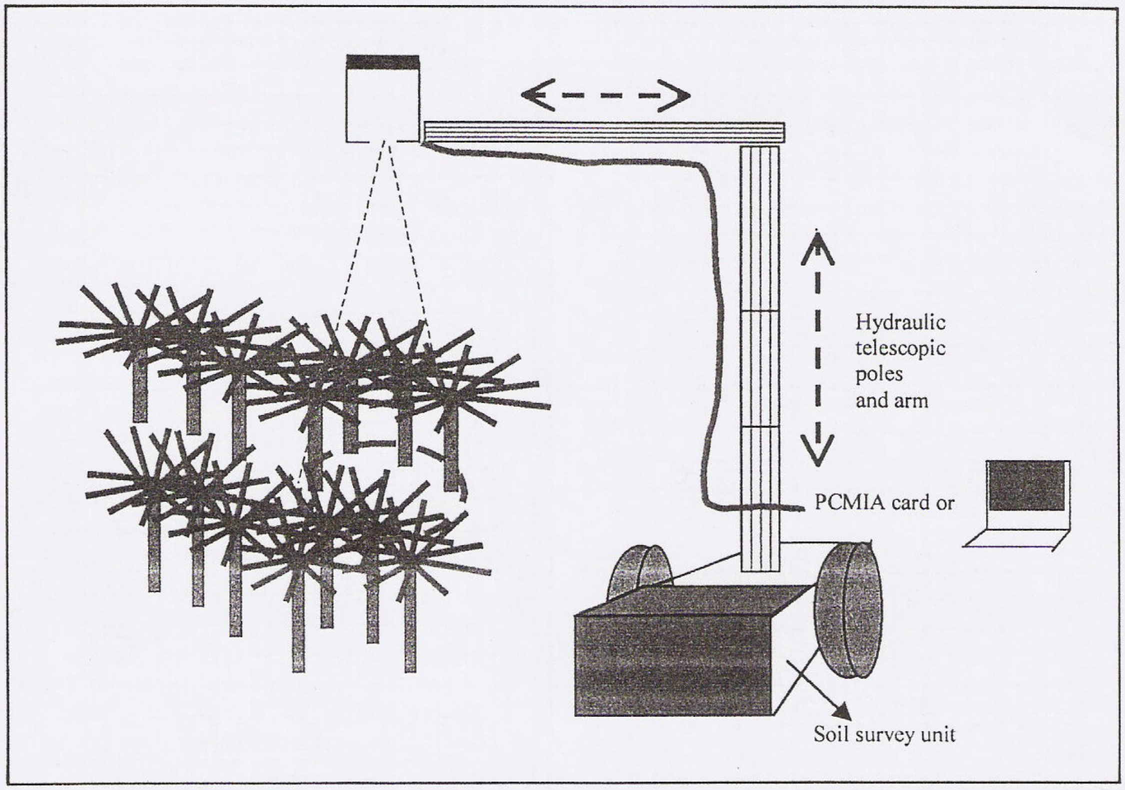

Figure 7. Illustration of the prototype sensor to be developed

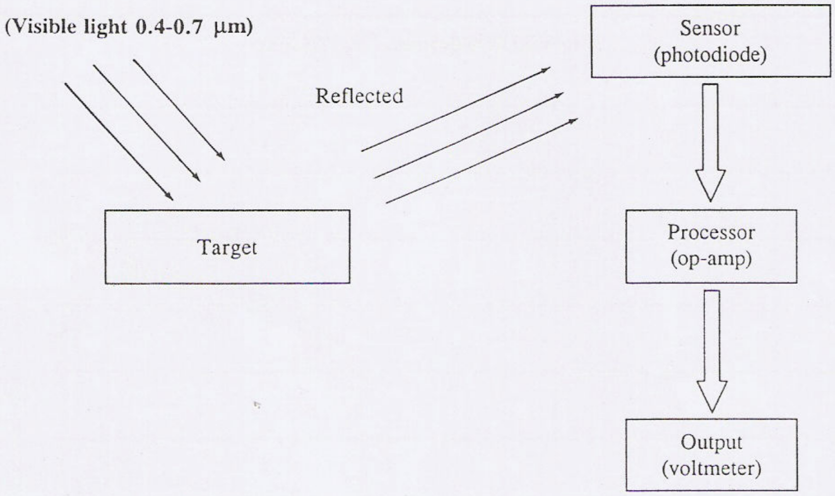

Figure 8. Illustration of components of prototype sensor