EVALUATION OF A WEED DETECTOR

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Summary. Experiments were done to determine the system characteristics of a prototype weed detector. The instrument uses red and infra-red reflectance to discriminate green vegetation from soil or litter. The width of the detector field of view is to be matched to that of each herbicide spray nozzle on a spray boom so as to apply herbicide only where green vegetation is present. Early results suggest that green vegetation with an area greater than 15% of the field of view can be detected.

INTRODUCTION

A method to selectively spray scattered weed populations is being developed. For operational purposes a weed detector will need to be able to sense a field of view for each herbicide nozzle, and operate under a wide range of environmental conditions. It will need to sense surfaces that can be extremely variable in terms of soil types and conditions, and discriminate green vegetation from other covers in an automatic and consistently accurate way.

The programme is examining a prototype instrument to;

1. analyse the system characteristics,
2. determine response characteristics of single surface types,
3. determine accuracy of the instrument in deciding on green weed or not,
4. conduct semi-operational evaluation to link detectors to herbicide nozzles.

EVALUATION

The evaluation of the system characteristics was conducted as a series of seven experiments.

1. <u>Determination of the field of field of view of the detector</u>. The purpose of this experiment was to plot signal attenuation as a function of angular distance from the normal to the field of view of the fibre-optic sensing head and to locate the centre of the field of view.

The field of view of the fibre-optic was determined by moving a point light source (100 Watt DC globe) about the fibre-optic sensing head through an arc of 60° either side of the axis to the objective. The distance between the light source and the sensing head was kept constant so that detector response was a function of angular displacement from the axis. At 5° increments, sets of 30 readings were taken and averaged. This procedure was repeated after the sensing head had been rotated through 90° about its axis of symmetry to establish the field of view in 2 orthogonal planes.

The field of view of the target sensors was found to be concentric with the fibre-optic axis of symmetry. An angle of 30° (from the vertical) was chosen to define the conical field of view.

2. <u>Analysis of the cosine response of the incident objectives</u>. The signal attenuation as a function of angular distance from the normal to the surface

of the diffuse plates of the incident objectives was determined. A similar method to that used for the fibre-optic was employed, through an angle of 85° relative to the normal to the objective. The readings were divided by the cosine of the angle from the normal for each observation.

Initial observations showed a marked loss of irradiance above 60° either side of the normal. In consequence the metal housing for the plates was removed and the plates bedded into the blackened housing of the detector so that they were within 1 cm of the filters.

The diffuse plates appear to closely obey the cosine law, and are providing a reliable estimate of incident radiation.

3. Calibration of the detector. The purpose of this experiment was to determine the red and infra-red reflectance values of a barium sulphate coated reference surface using a Collins spectroradiometer to allow calibration of the weed detector to true spectroradiometer reflectances. A control panel of aluminium plate and sandwiched chipboard sheet was constructed. The aluminium plate on one side was then acid etched and spray painted with four coats of matt white paint containing barium sulphate as a base, to provide a Lambertian surface. A spectral curve was generated and the reflectance determined at the 650 and 850 nm wavelengths. The panel was observed with the weed detector, for known gain settings, to compute an estimate of reflectance. The calibration constant, for those gain settings and detector status at that date, is determined as the ratio of the two sets of observations.

It was found that the reflectance values for the barium sulphate standard were: red reflectance = 88%; and near infra-red reflectance = 85%.

4. Determination of the relationship between gain settings. The linearity of the second stage amplifier gain settings of the detector was examined. Readings were taken under full sunlight conditions using the barium sulphate reference as a target. Whilst keeping the target gain control constant, the incident gain was increased from its lowest to highest setting. This was repeated for the next target gain control setting. However, only the two lowest gain settings of the target sensors can be used without saturation (ie. reaching maximum value).

The changes in gain settings gave a linear change in the readings from the incident detectors. Dividing the readings by the gain value brought the derived reflectances to very similar values at all gain settings.

5. Evaluation of response with changes in light intensity. An experiment was conducted to check that the barium sulphate target and incident radiance values respond proportionately to changes in light intensity. If this occurs then variations in illumination conditions should not alter the target reflectance values.

The incident and target sensors were set up facing a point light source. A number of readings were taken and then, by removing a resistor from the lamp circuit, illumination was increased for a second series of readings. The radiance values changed as expected. The reflectances also changed, but by a much smaller factor than radiances, the change being greater in the red than the near-IR band. The reflectances should not change in this test. It will be necessary to evaluate the instrument much more exhaustively to identify the nature of the changes, and the reasons for those changes.

6. Analysis of reflectance stability with changes in radiance. The effect of

cloud cover on reflectance was investigated. The detector was set up over the control panel and observations taken under both sunny and cloudy conditions. Ideally the detector should provide a continuous reflectance value in both wavebands under all light conditions.

A plot of the detector responses against time is shown in Fig 1. The event of passing cloud is labelled. As expected the sensor responses drop quite dramatically under the effect of cloud shadow. It is also apparent that the reflectance values dropped during this time. By comparing incident and reflected light responses in a given band before and after the event it can be seen that these two factors suffered disproportionate changes thus causing the drop in reflectance, and that this effect was reduced in the near-IR band. Further experiments are being carried out to monitor the performance of the detector under varying light conditions.

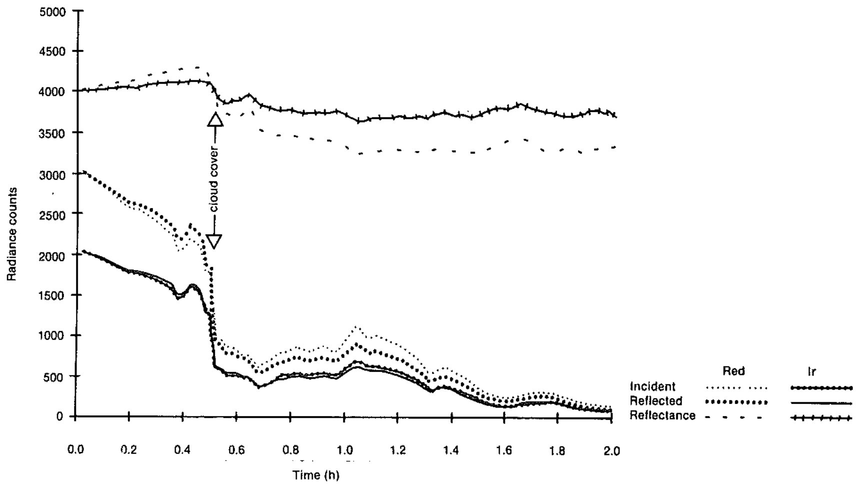

Figure 1. Plot of radiance counts and reflectance versus time.

7. Examination of the effect of dust on the objectives. The effect of dust occurring on the objective surfaces of the detector on the detector response is important for commercial application of the device. Dust was sprinkled onto the sensor objectives and readings taken under artificial light conditions using the barium sulphate reference surface as a target. Eight different dust types were used: dusts from five soils (ranging from black to white beach sand) and three types of vegetation (green, brown, and yellow). The vegetation dusts were prepared by grinding soybean plants to a coarse powder. For each treatment 30 readings were taken, and then averaged to give reflectance values in the red and IR bands. These values were plotted on a bispectral plot to determine the effect each dust type had with respect to the two frequencies.

The results suggest that dry dust on the fibre optic surfaces does not have a significant effect on the accuracy of the detector. The effect of dust is approximately linear in both wavebands, causing a maximum signal attenuation of approximately 15%. The slope of the line through the origin of the bispectral plot varies from 1.02 to 1.11.

The range of conditions, and targets, that will be met by the detector make it very difficult to develop criteria that can be used to indicate to the user that dust is affecting instrumental observations and hence accuracies. The only obvious criteria is to cease operations once response values are too low. It is therefore necessary to determine precisely the effect of dust on both objectives in both wavebands so as to either take this source of error into account, or correct for it, in the operational use of the instrument. The evaluation so far has concentrated on dry dust on the fibre optic objectives. Of equal importance is the effect of dry dust accumulating on the diffuse plates, and moist dust, due to herbicide spray, accumulating on the fibre-optic objectives.

The instrument is being modified to include two sensing heads. Dust from dirt and vegetation, will be applied to each objective in turn for one of the sensing heads. Both heads will then be tested on the standard. Different densities of dust will be applied and observations taken at each density to evaluate the impact of dust on both objectives for the one sensing head.

8. Response characteristics of single surface types. Reliable decisions by the weed detector on whether to activate a herbicide spray nozzle depend on the location of a decision line in the two dimensional reflectance domain of the two bands. If this line is too close to the reflectance of soil and litter, then the detector will sometimes be activated when the field of view contains negligible green material. If it is too far away then the detector will not be sensitive enough for operational use. Establishing the location of this decision line requires data on the reflectance of all surface conditions likely to be met by the instrument including soils (wet, dry, rough and smooth) of different colours, dead vegetation of different types and in different conditions, and green vegetation for different species. These data will be collected under various lighting conditions, as some of these surfaces may not approximate a Lambertian surface.

The distribution of these reflectance values in the two dimensional response domain will suggest one or more decision surfaces for evaluation. These alternatives will then be programmed into the instrument's central processing unit for evaluation and comparison, so as to select one as the best algorithm to use under the majority of conditions.

Observations were made of mixtures of three soil types, vegetation litter and green vegetation. The soil types were red, fawn and black. The litter was a mix of standing straw and lying decomposing material. The green vegetation was a small plant of lamb's tongue, *Plantago lanceolata* in a pot buried in the soil. The litter and green vegetation covered about 15% of the instrument's field of view.

The results in Fig 2 suggest that the instrument records soil and litter

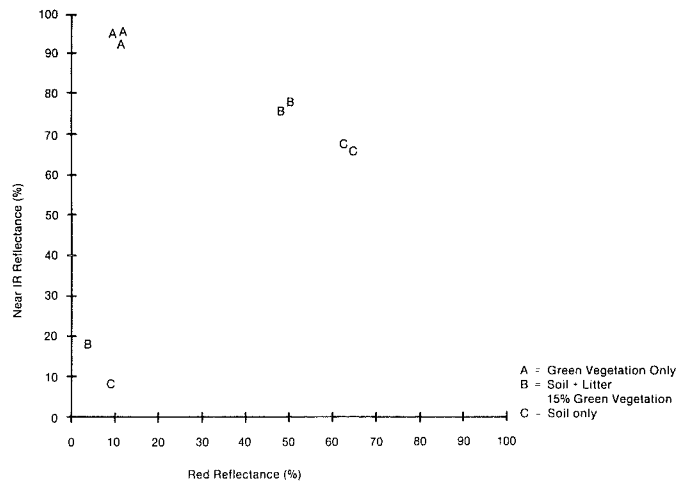

Figure 2. Bispectral plot of observations of (A) green vegetation only, (B) soil, litter and 15% green vegetation and (C) soil only.

reflectance in close vicinity to a line in the two dimensional space. This suggests that green vegetation can be discriminated from other covers with about 15% or more of green cover. Further evaluation may show that it is possible to reliably detect smaller percentages of green cover than this.

The experiments designed to evaluate the detector's system characteristics have generally been successful in verifying anticipated characteristics or suggesting improvements in the design. The only outstanding issue not resolved in this work is the apparent change in reflectance with change in intensity. Whilst the instrument could work as currently configured, elimination of this problem will improve its accuracy level in estimating percentage green in the field of view.

Experiments on the accuracy of the instrument in discriminating green vegetation have been initiated but are incomplete.

ACKNOWLEDGMENTS

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