# Remote sensing of land cover and land management practices affecting wind erosion risk in NW Victoria, Australia

Rob Clark [A], Richard MacEwan [B], Nathan Robinson[C] and Jonathon Hopley [D]

[A]Future Farming Systems Research, Department of Primary Industries, Epsom, VIC, Australia, Email Rob.Clark@dpi.vic.gov.au
[B]Future Farming Systems Research, Department of Primary Industries, Epsom, VIC, Australia, Email Richard.MacEwan@dpi.vic.gov.au
[C]Future Farming Systems Research, Department of Primary Industries, Epsom, VIC, Australia, Email Nathan.Robinson@dpi.vic.gov.au
[D]Future Farming Systems Research, Department of Primary Industries, Epsom, VIC, Australia, Email Jon.Hopley@dpi.vic.gov.au

**Abstract**
Wind erosion from farmed land in the Mallee region of NW Victoria occurs annually, varying in degree according to the season and the land management practices. Ground based surveys of erosion and land use practice have been carried out for more than twenty years in the Mallee but these surveys are limited to roadside transects across the region. We have interpreted satellite data (Landsat and MODIS) to provide coverage for the whole region and interpret land management factors that contribute to soil protection or to wind erosion susceptibility. The interpreted management factors have been combined with soil landform information to improve monitoring of wind erosion likelihood in the region.

**Key Words**
MODIS, Landsat, wind erosion, land management.

**Introduction**
North western Victoria is considered to be one of the areas at highest risk of wind erosion in Australia and the Mallee Catchment Management Authority requires a consistent and robust method to quantify wind erosion in the region in order to set and monitor targets. It is difficult to assess wind erosion directly from remotely sensed imagery. This is partly due to the unpredictability of wind erosion events and the often ephemeral nature of the aftermath. There is no steady build up of observable features preceding a dust storm and much of the physical evidence can disappear soon after the event if it is followed by rain that sets the tractors ploughing the paddocks. Given the likelihood that the observation period may be very short and the vagaries of cloud cover, it is often difficult to make direct measurements of wind erosion using airborne or satellite borne sensors. We have therefore used satellite imagery to map management factors that occur regularly through every season and contribute either to protection of the land from wind erosion or to increasing the likelihood of wind erosion. This management data was combined with estimates of land susceptibility based on expert knowledge in a risk assessment framework known as the Land Use Impact Model (LUIM) to generate regional maps of likely land degradation resulting from wind erosion for a given season. This paper describes the remote sensing component of the LUIM for wind erosion in the Mallee.

**Methods**
Rationale for the method is based on assumptions regarding the relationship between land management and soil protection. Key management factors are:

- crop type/ landcover,
- biomass in spring,
- the degree of ground cover,
- tillage practices,
- stubble management practices and
- stock management.

DPI agronomists have suggested that some land cover types present a greater risk of wind erosion than others. It is possible to directly assess this factor using remotely sensed data collected in spring.
Dry matter production (biomass) in the growing season is likely to have a significant influence on the vulnerability of soil to wind erosion, and low biomass production in a cropping season may increase the risk of wind erosion the following year. This land cover factor can be qualitatively assessed using remotely sensed time series data over the growing season.

Bare soil has a higher risk of soil erosion than soil with a good cover of well attached vegetation, either actively growing or as residual crop stubble. Soil cover post-harvest is a function of crop biomass produced in the growing season, farm management operations in preparation for sowing the next crop and stock management. It is not within the capability of remote sensing to discriminate between various tillage practices, stubble management practices and stock management that may increase the risk of soil erosion. However, remote sensing can directly assess the percentage of bare ground at a given time.
An on-ground survey and satellite imagery were used together to create reliable data layers for the region and provide information on summer and winter land management.

*Ground truth data collection*
Ground data was collected to calibrate the remote sensing analysis and to validate predictions.
Land cover type and management phase data was collected as part of the Mallee wind erosion survey (Wakefield, 2008) from 149 sites in spring. These sites were revisited in early autumn to record: management phase, estimated erosion severity, visual estimate of green and brown vegetation cover and a count of green and brown vegetation cover. Fixed attributes such as soil colour and texture were also recorded for each site.
In addition, land cover in spring, and 2007 crop yield and management data prior to the 2007 harvest, were collected from 348 paddocks on 17 farms across the Mallee via a postal survey. In late summer, counts of green and brown vegetation cover were made at nine 1 ha plots in paddocks at Speed and 12 plots at Swan Hill. DPI staff from Swan Hill made a visual estimate of erosion at the end of April 2008, soon after a major wind erosion event in the Mallee, collecting a photographic record and location of 49 paddocks significantly affected by that event.

*Image data*
Image analysis was based on single date Landsat 5 images in mid-spring, mid-summer and a time series for all 2007 constructed of images captured by the Moderate Resolution Imaging Spectrometer (MODIS) sensor. The MODIS time series was based on the MOD13Q1 v5 product produced by the National Aeronautics and Space Administration (LPDAAC, 2008).

*Image pre-processing*
All Landsat 5 images were rectified to a map grid using GDA94 as Datum and a Universal Transverse Mercator (UTM) projection for zone 54 (MGA54) and calibrated to a base image, using a national image mosaic developed for the Australian Greenhouse Office (AGO) carbon accounting procedure in 2000 (Furby, 2002). The MOD13 EVI product is produced from atmospherically corrected bi-directional surface reflectance that has been masked for water, clouds, heavy aerosols, and cloud shadows. Atmospheric correction has been applied to remove residual atmosphere contamination caused by smoke and sub-pixel thin cloud clouds (LPDAAC, 2008). Little pre-processing was required except to re-project the EVI layer to MGA54. A time series was then created by stacking 24 images for all of 2007 and clipping them to the Mallee catchment management region.

*Identifying land cover type in spring*
DPI agronomists suggested that it would be easiest to discriminate between different land cover types when crops had achieved full leaf cover and commenced to flower. This usually occurs between mid August and late September. Analysis to identify land cover type was based on the pre-processed Landsat 5 images from this period and the MODIS time series data for all of 2007. Varying environmental conditions between regions may require development of different indices and/or thresholds to discriminate land cover types for each region (Furby and Clark 2004). Prior to analysis the Landsat 5 images were stratified so that particular vegetation and landuse features produced a similar spectral response within each zone. Within each stratified region, a maximum likelihood classification was run on the single date Landsat 5 images based on training data selected from the ground data. The training data generally comprised no more than 20% of the ground data with the remainder used for validation. At this point, the classifications were tested against the remainder of ground data (the validation data) to determine if confusion existed between any of the cover classes. The MODIS time series was examined in conjunction with the training data to identify temporal patterns of vegetation growth that may correct any classification errors. To produce the final classification for land cover type, the MODIS data were incorporated into the classification using a decision tree based on the maximum likelihood classification of the single date Landsat 5 image. For an accuracy assessment, the final classification was tested against the validation data.

*Estimating biomass in the growing season.*
To limit the analysis to agricultural paddocks over the growing season, the MODIS EVI time series data was restricted temporally to the growing season, i.e. the period from 30/4/2007 till 7/10/2007, and spatially to exclude forested areas and water bodies. The EVI values for each pixel were summed and their minimum, maximum, mean and standard deviation calculated. The data were divided into groups with equal numbers of members, i.e. one third of the population in each group, representing low, medium and high biomass over the growing season.

*Estimating ground cover post harvest*
The method used to estimate vegetation cover post harvest was developed by Roberts *et al.* (2007) and employed a suite of tools designed to select the optimal end-members or reference spectra for Spectral Mixture Analysis (SMA) and then calculate and interpret SMA and Multiple End-member Spectral Mixture Analysis (MESMA). The method is described in detail by Roberts *et al.* (2007). The MESMA estimates were compared to the ground measurements of ground cover and a linear regression was fitted to the data. The regression equation was used to rescale the MESMA estimates to the ground measurements and the ground data and the mean MESMA estimates of averaged wind erosion risk for each plot were each assigned to their wind erosion risk class.

## Results

*Image analysis to identify landcover type in spring*
The final classification for land cover in spring was assessed against validation data in each stratification zone and the results are shown in
**Table 5**.

**Table 5. Error matrix for the combined land cover classification for the whole Mallee in pixel numbers**

| | Ground truth (Pixels) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Image Class | cereals | canola | legume | pasture | fallow | scrub | bright soil | irrigated | hay cut | stubble | Total |
| cereals | 129539 | 1298 | 3627 | 3282 | 3383 | 4 | 13 | 160 | 6 | 11 | 141323 |
| canola | 3678 | 4379 | 408 | 820 | 79 | 0 | 0 | 2 | 0 | 0 | 9366 |
| legume | 7183 | 1185 | 4571 | 1215 | 462 | 0 | 0 | 44 | 3 | 0 | 14663 |
| pasture | 3137 | 7 | 678 | 8561 | 2107 | 21 | 5 | 0 | 367 | 100 | 14983 |
| fallow | 5334 | 224 | 8 | 3682 | 16707 | 829 | 0 | 86 | 0 | 0 | 26870 |
| scrub | 79 | 0 | 23 | 47 | 18 | 19196 | 0 | 357 | 0 | 0 | 19720 |
| bright soil | 207 | 3 | 615 | 200 | 47 | 52 | 4974 | 0 | 0 | 2 | 6100 |
| irrigated | 0 | 0 | 0 | 53 | 0 | 7 | 0 | 3547 | 0 | 0 | 3607 |
| hay cut | 337 | 20 | 9 | 1128 | 0 | 0 | 1 | 0 | 2628 | 21 | 4144 |
| stubble | 0 | 0 | 31 | 195 | 0 | 0 | 0 | 0 | 0 | 542 | 768 |
| Total | 149494 | 7116 | 9970 | 19183 | 22803 | 20109 | 4993 | 4196 | 3004 | 676 | 241544 |

*Image analysis to estimate biomass in the growing season*
**Figure 8** shows typical examples of the temporal signature for pixels in the low, medium and high biomass classes.

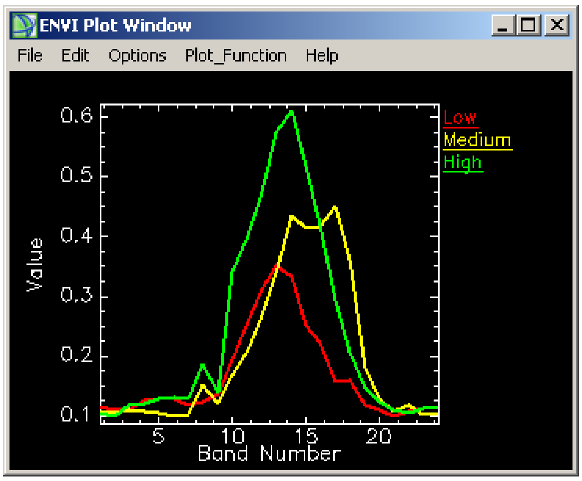


**Figure 8. Plot of MODIS EVI time series data over the 2007 growing season for typical examples of pixels**

**demonstrating low, medium and high biomass production**

*Image analysis to estimate ground cover post harvest*

The calculated $R^2$ value of 0.4513 indicates that only a moderate relationship exists between the MESMA estimates and ground measurements of ground cover. A comparison of the ground wind erosion risk to the mean MESMA estimates produced an overall accuracy of 51/70 or 73% correctly classified.

## Conclusion

We have used remote sensing to interpret wind erosion risk factors in the Mallee for the 2007-2008 season. The principal findings and issues with regard to the methods are:

1. A single Landsat image in Spring and another in mid to late Summer combined with the MODIS time series is sufficient to estimate the major factors that contribute to the likelihood of wind erosion.
2. For spring cover type, cereal crops were discriminated accurately and reliably, but canola and legumes tended to be confused with each other and with cereals and, to a lesser extent, with pasture. If we combined all crop types plus the 'haycut' class into a single 'crop' group it was discriminated from all other groups very accurately and reliably. 'Fallow' and 'pasture' classes, tended to be confused with each other and with the cereal class. This is partly due to the inconsistent use of terminology by agronomists and farmers for 'pasture' and 'fallow' types that occur in the Mallee and needs to be resolved. Highly reflective patches of bare soil (usually dune crests likely to be susceptible to wind erosion) were discriminated from all other classes very accurately and reliably. Combining the MODIS time series data with the Landsat single date image improved the classification accuracy.
3. Although there was no validation data available, the estimates of biomass production levels seemed to make sense. However, future estimates should be based on class thresholds developed using long term data to cope with climatic variation between seasons.
4. The MESMA estimates of ground cover only had a moderate relationship with the ground measurements ($R^2$ value of 0.4513), although when converted to wind erosion risk classes the overall accuracy was 73%. However, not all classes were adequately represented in the ground data and this needs to be addressed in the future.
5. To produce the best quality ground data for calibration and validation of the image analysis, ground data should be collected as close as possible to the date of Landsat image acquisition.
6. Cloud cover may significantly limit the usefulness of remote sensing analysis in some seasons.

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