Mapping land cover in cotton growing regions using multi-temporal Landsat TM satellite data.

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Introduction

This paper describes the results of a two season pilot study assessing the utility of Landsat TM satellite data for identifying and mapping land cover in mixed agricultural regions. In order to effectively understand, model and forecast *Helicoverpa* population dynamics within a mixed agricultural region it is essential to have information on the spatial and temporal distribution of the various crops and weeds on which the pests develop. Host plants are an essential resource for *Helicoverpa* moths and their developing eggs, larvae and pupae. The distribution, type and growth stage of cultivated and wild host plants affect the regional population dynamics of *Helicoverpa* in three major ways:

- by influencing where adult moths choose to lay their eggs within a region.
- by determining the relative proportions of larvae that will survive to adulthood.
- by providing refuges that allow *Helicoverpa* populations to continually re-infest areas within the region from which they may have been temporarily eliminated.

The HEAPS simulation model of *Helicoverpa* dynamics (Dillon and Fitt 1997) requires information on the spatial distribution of host crops. Current methods of collecting this data include ground and aerial surveys, and collating information from farmers, consultants, researchers and aerial spray companies. Obtaining this information for a given region and season has proven to be time consuming, and often relatively qualitative rather than quantitative. In an effort to devise a more timely, accurate and cost effective method of mapping regional land cover, we undertook this pilot study to assess the utility of Landsat TM satellite data for identifying crops. Satellite data also provides the potential for retrospectively retrieving historical data for a given region.

The US Landsat 5 satellite has been continually recording 7 spectral bands of Thematic Mapper data over the entire Australian continent since September 1987. The satellite passes over Australia between 9.25am and 9.35am each day, recording a swath of data

185 km wide. Repeat coverage of each swath occurs every 16 days. Each data pixel represents a 30 x 30 metre patch on the ground. This equates to approximately 11 pixels per Hectare. The Australian Centre for Remote Sensing (ACRES) retrieves, archives and sells all of this data (Ralph and Tupper 1992).

Methods

Our study area is a 25 x 25 km (625km2) portion of the Namoi Valley between Narrabri and Wee Waa in NSW. The centre of the study area is located 5km North-East of the Australian Cotton Research Institute. The site was selected because of the relatively broad range of crop types present. However dry seasonal conditions in 93/94 and 94/95 resulted in significantly less area sown to non-irrigated summer crops than normal. (Brandsema *et al.* 1996).

Farm maps and land use data were collected for 49 properties within the study area, containing a total of 435 fields. This represented 75% of the cultivated land within the study area. Crop ground truth data for each field was catalogued for the 93/94, 94/95 and 95/96 spring and summer cropping seasons, and previous historical data were also collected where available. Natural vegetation such as forest, woodlands and riverside habitats were excluded from the study. The land cover types recorded within the study area were: cotton, wheat, barley, faba bean, chickpea, soybean, sorghum, maize, sunflower, safflower, mungbean, cowpea, potatoes, canola, lucerne, pasture, fallowed fields, water storages, and roadside weeds including wild turnip and Pattersons curse.

Four sets of digital Landsat image data covering the study area were purchased during the 1993/94 cropping season (23 July 93, 11 October 93, 30 December 93 and 30 March 94), and four sets of image data were purchased during the 1995/96 cropping season (14 August 95, 17 October 95, 20 December 95 and 9 March 96). The July 1993 satellite image was rectified to the Australian Map grid using 1:50,000 topographic map sheets. All other images were then registered to this image, and the area common to all images was extracted. For each season, the four images were stacked together to form a 28-band Thematic Mapper image. The ground truth data set was linked to this coverage. Cloud and cloud shadows on each of the images were identified and combined to create a cloud mask, so that cloud/shadow areas in any one image were removed from all four images in a season. For the 95/96 images, the field boundary coverage was buffered by 100 metres (50 m on either side of the boundary) and a paddock boundary mask created. This mask was then applied to the combined 28-band image, so that mixed pixels in the field boundaries were removed, thus providing purer signatures.

Each seasons 28 band image was run through an ISOCLASS unsupervised classification using "ERDAS Imagine". Groups of pixels with similar spectral characteristics were grouped into discrete categories without reference to field data. Only TM bands 2,3,4 and 5 were utilized in the classification. A total of 100 classes and 4 iterations were allowed. Half of the paddocks polygons were selected at random for use as training data, and the other half were reserved for data verification. A matrix coincidence of the 100 clusters was done with the paddock training data using the ARC/INFO GRID extension, and the resulting clusters were assigned to 14 land cover classes.

Results

The result of the classification is given in Table 1. Of the total 123,582 pixels tested in 1995/96, 80,575 pixels were classified correctly, giving a total image accuracy of 65%. In 1993/94 142,042 pixels were classified correctly from 208,886 pixels tested for accuracy assessment, giving a total image accuracy of 68.2%.

About 78% of cotton was classified correctly, as was 79.5% of water. Classification of the individual crops was relatively poor, the best being cotton and water storages. Two minor crops, potato and mungbean, showed very high classification accuracies. However, it may be that these results are due to the small sample size of these crops.

Wheat classification was very poor, with only about 23% of wheat being classified correctly. Much of the wheat was being confused with safflower and potato winter crops. A significant percentage of wheat was being confused with pasture and fallow, which is surprising. A possible explanation is that the acquisition of the first image of the series (14 August 95) is too late to distinguish between a winter crop and pasture/fallow. In order for the distinction to be apparent, the cultivated ground for crop should be visible.

Amalgamation of the crops by season (winter and summer) and amalgamation of pasture and fallow into one class increased the overall image accuracy substantially, to 82.7%. Winter crops were classified with 86% accuracy and summer crops with almost 94% accuracy. Tables 2 and 3 present the classification accuracies for the amalgamated data.

Table 1: Confusion Matrix of individual crop classification for the 1995-96 season.

The numbers in each cell represent the number of pixels classified into that cells category. The diagonal set of shaded cells represent correctly classified pixels. Of the total 123,582 pixels tested, 80,575 were classified correctly, giving a total image accuracy of 65.2%. 77.76% of cotton pixels were correctly identified, but most other crops were less accurate.

Ground truth data

		Barley	Chickpea	Cotton	Fallow	Lucerne	Maize	Mungbean	Pasture	Pea	Potatoe	Safflower	Sorghum	Water	Wheat	TOTAL	Correct	Commission
Crop	Barley	6911	0	187	4032	1	0	0	1	0	0	0	0	2	214	11348	60.90%	39.10%
as	Chickpea	1403	0	922	1901	1	0	0	742	0	0	2078	0	85	65	7197	0.00%	100.00%
class-	Cotton	0	0	48642	854	1	0	0	0	22	0	0	0	65	0	49584	98.10%	1.90%
-ified	Fallow	82	0	191	15571	8	0	0	47	10	0	0	0	10	785	16704	93.22%	6.78%
	Lucerne	0	0	70	323	468	18	0	226	21	0	0	0	27	56	1209	38.71%	61.29%
	Maize	0	0	141	546	0	141	0	6	49	0	0	20	0	6	909	15.51%	84.49%
	Mungbean	47	0	1116	1010	0	0	238	241	2	0	51	26	55	16	2802	8.49%	91.51%
	Pasture	0	0	128	601	339	57	0	2619	149	0	7	34	5	461	4400	59.52%	40.48%
	Pea	0	0	9343	251	2	1	0	385	565	0	0	0	0	1	10548	5.36%	94.64%
	Potatoe	0	0	811	25	3	61	0	11	169	222	0	0	3	1580	2885	7.69%	92.31%
	Safflower	4058	0	43	370	1	0	0	61	0	0	1140	0	2	2081	7756	14.70%	85.30%
	Sorghum	0	0	132	184	20	36	0	44	55	1	0	0	381	56	909	0.00%	100.00%
	Water	0	0	591	207	0	0	0	0	0	0	0	0	2492	0	3290	75.74%	24.26%
	Wheat	10	0	233	2129	3	0	0	94	0	0	0	0	6	1566	4041	38.75%	61.25%
	TOTAL	12511	0	62550	28004	847	314	238	4477	1042	223	3276	80	3133	6887	123,582		
	% Correct	55.24%	NA	77.76%	55.60%	55.25%	44.90%	100%	58.50%	54.22%	99.55%	34.80%	0.00%	79.54%	22.74%		80,575	
	Omission	44.76%	NA	22.24%	44.40%	44.75%	55.10%	0.00%	41.50%	45.78%	0.45%	65.20%	100%	20.46%	77.26%		65.2%	

Table 2: Confusion matrix of the combined classes for the 1995-96 season.

		Ground Truth							
		WINTER	SUMMER	WATER	POTATO	Pasture/Fallow	TOTAL	Correct	Commission
Crop as classified	WINTER	19526	1391	95	0	9330	**30,342**	64.35%	35.65%
	SUMMER	233	61129	528	1	4070	**65,961**	92.67%	7.33%
	WATER	0	591	2492	0	207	**3,290**	75.74%	24.26%
	POTATO	1580	1044	3	222	36	**2,885**	7.69%	92.31%
	Pasture/Fallow	1335	916	15	0	18838	**21,104**	89.26%	10.74%
TOTAL		22674	65071	3133	223	32481	**123,582**		
% Correct		86.12%	93.94%	79.54%	99.55%	58.00%		102,207	
Omission		13.88%	6.06%	20.46%	0.45%	42.00%		82.7%	

Table 3: Confusion matrix of the combined classes for the 1993-94 season.

	Ground Truth							
	Summer	Winter	Pasture/Fallow	Trees	Water	Total	Correct	Comm error
Summer	125404	4090	12908	237	505	**143,144**	87.61%	12.39%
Winter	3363	24484	16323	45	370	**44,585**	54.92%	45.08%
Pas & Fall	5512	4719	20682	276	177	**31,366**	65.94%	34.06%
Trees	481	104	818	12376	5	**13,784**	89.79%	10.21%
Water	3625	936	1102	25	3629	**9,317**	38.95%	61.05%
TOTAL	138385	34333	51833	12959	4686	**242,196**		
% Correct	90.62%	71.31%	39.90%	95.50%	77.44%		186,575	
Omission	9.38%	28.69%	60.10%	4.50%	22.56%			**77.03%**

The removal of paddock boundary pixels probably contributed to the slightly better results obtained in the study for the 1995-96 season.

Discussion

The choice of image dates is vital when adopting this classification approach. The structure of the crop canopy and the proportion of soil visible to the satellite have a major influence on the reflectance recorded for each of the 7 spectral bands. This can be used advantageosly to distinguish between alternative crops, because differences in sowing dates and crop phenology are 'captured' by the composite 28 band image created by merging satellite data from multiple dates over a cropping season. It is likely that the accuracy of this approach could be further improved by (i) careful timing of imagery, (ii) utilizing more imagery for each season, (iii) utilizing all 7 TM spectral bands in the unsupervised classification and (iv) accurately recording the timeing of agricultural practices such as cultivations, sowing and harvesting for each crop type within a region being investigated.

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References

Brandsema FA, Dillon ML and Dudgeon GS. 1996. Mapping agricultural land cover in cotton growing districts using Landsat satellite technology. Proceedings of the *8th Australasian Remote Sensing Conference*, Canberra.

Dillon ML and Fitt GP. 1997. A spatial simulation model of the regional population dynamics of *Helicoverpa* moths. Agricultural Systems and Information Technology. 7:32-34.

Ralph I and Tupper G. 1992. Understanding remote sensing. Agfact P2.1.11 NSW Agriculture.