Estimation of land cover and biomass change from remotely sensed data

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IGARSS TOPIC – C.11 LAND COVER CHANGE

Abstract - **This paper reports on progress in estimating land cover change, using aerial photography and satellite imagery and biomass change, based on field data, Lidar and satellite imagery, in the Fitzroy catchment, Australia.**

INTRODUCTION

Land clearing for agriculture contributes to carbon emissions through the burning of vegetation, decay of slash, soil disturbance during clearing and harvesting of timber. An estimated 10% of Australia's net greenhouse gas emissions were produced by land clearing activities in 1999 [1]. The quantification of emissions from this source has been largely uncertain until recently, due to a paucity of continental scale data.

Three recent analyses of land clearing by the, CSIRO Earth Observation Centre [2], Queensland Statewide Landcover and Tree Study (SLATS)[3, 4, 5] and the Australian Greenhouse Office [6] are being used to provide spatially explicit land cover change data to model greenhouse gas emissions from land clearing between 1970–2000.

The project is being undertaken in the Fitzroy catchment in Queensland (Fig. 1). The catchment covers 14 million hectares and has experienced a high rate of clearing since the 1960s. Clearing of the largely woodland vegetation has been carried out for grazing of beef cattle and cultivation of cereal crops (wheat and sorghum) and, more recently, cotton.

Land clearing practices and the occurrence and type of woody regrowth will be incorporated into a carbon model. Land clearing practices differ both spatially and temporally, and include mechanical clearing using chains and blade ploughs through to the use of herbicides by stem injection.

Land use, vegetation type and rainfall as well as clearing methods are expected to influence the occurrence and type of woody regrowth. Local knowledge suggests that regrowth is particularly common where clearing of Brigalow (*Acacia harpohylla*) has taken place and this will be validated through fieldwork.

A pilot study using the Landsat multispectral scanner (MSS) from 1980-1990 and Thematic Mapper (TM) from 1991-1999 as well as aerial photography interpretation for 1969-1981 and 1982-89, was carried out to establish techniques for compiling land cover history and estimating annual rates of change [7].

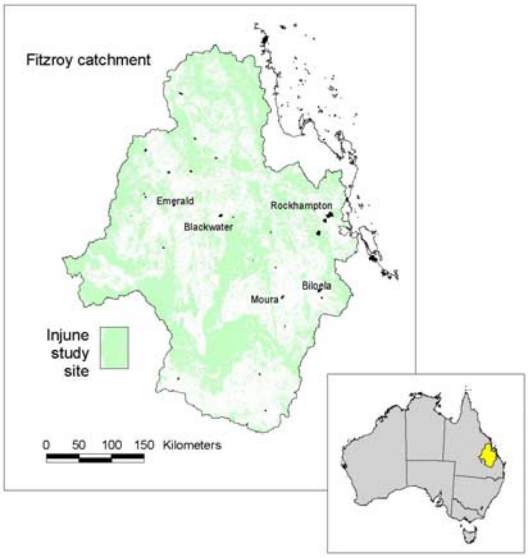

Fig. 1: Location and extent of woody vegetation in the Fitzroy catchment

Spatial and temporal gaps in the data were filled using a Markov probability function.

Woody biomass data are sparse in the catchment and limited to a few key species [8, 9], however, investigations into the use of multi-scale imagery (field, Lidar and Landsat Thematic Mapper) to estimate above-ground biomass and foliage cover are currently underway in the Injune study site [10] (Fig. 1). These will be used to estimate biomass based on broad vegetation type and cover in the Fitzroy catchment, and also the magnitude of biomass change from clearing and regrowth.

In this paper, we will report improvements to land cover history as well as investigation into the calculation of above-ground biomass.

METHODS AND MATERIALS

The land cover history has been compiled from two main sources:

- Landsat MSS 100m pixel size data from 1982-84 and 1990-91 [2]
- 1991 land cover, and land cover change data for 1991-95, 1995-97 and 1997-99 derived from Landsat TM imagery [3, 4, 5]

Land cover has been classified from the remote sensing data and compiled as a series of raster layers. These have been combined to create a string of cover codes and classified into change types:

- Unchanged woody or non-woody cover
- Cleared once, twice or more times
- Regrowth once, twice or more times.

Validation of the history will be carried out using aerial photography archives and fieldwork.

The following improvements to the land cover history were incorporated:

- Landsat MSS data was re-analysed using unsupervised classification. Each of the 100 classes was classified into change (clearing, regrowth or no change) and cover (woody or non-woody) and checked against the 1991 land cover data.
- All clearing and regrowth was referenced to 1991 land cover data, which was considered to be the most authoritative source.

Lidar (laser altimetry), Landsat TM and MSS and NOAA/ AVHRR data captured in 2000 are being used to calculate woody biomass and foliage cover in the Injune study site.

Foliage cover has been calculated at a range of scales. Transects were used in 29 field plots. Lidar returns above 2m in height were used in 150 7.5 hectare samples. Regression between the Lidar foliage cover and Landsat TM normalised difference vegetation index and Band 5 for the sample areas were then extrapolated to the rest of the study area.

The Injune site is similar to the Fitzroy catchment in both land use and vegetation types. The main land use is grazing of beef cattle with some cultivation in the south-west of the study area. Woody vegetation cover comprises 70% of the dominant species found in the Fitzroy catchment [11].

Land cover history and land use are also being compiled for Injune and will be validated in a field trip in April 2002. Land cover for 1977, 1982, 1988, 1990, 1991, 1995, 1997, 1999 and March and September 2000 have been compiled from aerial photography, Landsat MSS, TM and Enhanced TM. The land cover was compiled from the most recent imagery, using heads-up digitising. Each patch was then traced back using the earlier images. Patches of clearing will be investigated during the field trip to check when and how clearing was carried out and for the occurrence of regrowth, its structure and composition.

Results and Discussion

Land cover history has been compiled for the period 1970 to 2000 using 21 remotely sensed data sets for the Fitzroy catchment. Annual rates of clearing and regrowth have been calculated from the history and are presented in Fig. 2.

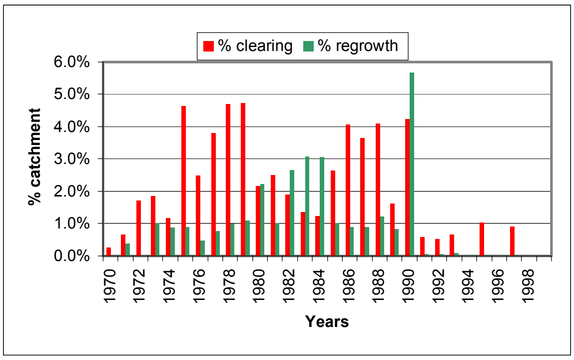

Fig. 2: Annual rates of clearing and regrowth for the Fitzroy catchment 1970-2000

Drivers for land clearing appear to mainly due to commodity prices and rainfall. Poor beef prices [12] in the 1970s with concomitant high wheat prices, coincided with a maximum clearing rate of nearly 5% in 1978. Summer rainfall for the years 1970-1978 was higher than normal [13]. Rates of regrowth are also high at about 1% per year.

Beef prices recovered in 1979 whilst wheat prices continued to climb during the 1980s and 90s reaching a peak in 1996 [12]. Rates of clearing decreased from the mid-80s through the 1990s to less than 1% per year and rates of regrowth to less than 0.1% year. This coincides with the use of blade ploughs, which turn over the soil to the depth of 30 cm and may sever roots of woody species preventing regrowth. Lower than normal summer rainfall was experienced in 1982, 1986, 1992 and 1994 [13].

The highest rates of clearing and regrowth occurred at the transition between different types of imagery as a result of differing classification methods and spatial resolution of the source data. In the temporal sequence of land cover there is less confidence in the data sets derived from historical aerial photography due to lack of knowledge on the interpretation methods. Conversely the interpretation of satellite imagery is well-documented and standardised. The incorporation of the AGO datasets as well as the 1988-91 SLATS data are expected to improve the temporal and spatial coverage of land cover data and overcome the some of these problems.

Land cover history has also been compiled for Injune. The methodology used delineates clearing from the most recent images and traces back the development of pastures and cropping through the data sets. Validation of this history will be carried out by field survey in April 2002. It is anticipated that the accurate history can be compared to the SLATS [3,4,5] and AGO data [6].

Woody biomass studies have been carried out in the Injune study site using satellite data, laser altimetry and field studies. Foliage cover and biomass shows a strong positive linear relationship between Lidar and field measurements ($r^2 = 0.89$) and initial results for Lidar and Landsat TM foliage cover data ($r^2 = 0.85$) [14].

Biomass surfaces have been prepared based on foliage cover classes and intersected with land cover history data. Preliminary results suggest that 23,240 hectares has been cleared since 1977, which equates to 840,000 – 850,000 tonnes of carbon based on Lidar and Landsat TM biomass estimates respectively.

CONCLUSIONS

A history of land cover change is being constructed for the Fitzroy catchment in Queensland in order to investigate the impacts of clearing and regrowth on greenhouse gas trajectories.

Problems encountered with compiling a land cover history include classification methods and sensors leading to over-estimates of clearing and regrowth at transition zones between different data sources. In order to gain an insight into what the over-estimates are, an intensive study is being conducted at the nearby Injune site. These data will be validated in the field and compared with the data sets from the Statewide Landcover and Tree Study and Australian Greenhouse Office.

Compilation of other data required for the estimation of impacts of carbon emissions is currently underway; these include soil carbon, climate, and land management practices. Land clearing practices, for example, will be captured temporally and spatially using local knowledge.

These data will provide input to carbon models including the Rothamsted soil carbon model and a dynamic landscape model under development at the Cooperative Research Centre for Greenhouse Accounting.

Further improvements are expected through incorporation of the Australian Greenhouse Office's land clearing data for 1972–2000, which is developed from eleven satellite images and Queensland Department of Natural Resources and Mining 1988-91 data when these become available later this year.

ACKNOWLEDGMENTS

This project is jointly funded by the Cooperative Research Centre for Greenhouse Accounting and the Bureau of Rural Sciences. We gratefully acknowledge the provision of data from the Queensland Department of Natural Resources and Mining, the Queensland Herbarium, and CSIRO Earth Observation Centre.

REFERENCES

[1] Australian Greenhouse Office, *National Greenhouse Inventory: Land Use Change and Forestry 1990-1999*, Canberra, Australia 2000.

[2] R.D. Graetz. The Terrestrial Carbon Pools of the Australian Continent: an assessment of their size, dynamics and tractability. Report for the National Greenhouse Gas Inventory, Environment Australia. CSIRO Earth Observation Centre: Canberra, 1998.

[3] Queensland Department of Natural Resources. Land Cover Change in Queensland 1991-1995. *Statewide Landcover And Trees Study (SLATS) reports*, July 1999.

[4] Queensland Department of Natural Resources. Land Cover Change in Queensland 1995-1997. *Statewide Landcover And Trees Study (SLATS) reports,* August 1999.

[5] Queensland Department of Natural Resources. Land Cover Change in Queensland 1997-1999. *Statewide Landcover And Trees Study (SLATS) reports,* September 2000.

[6] Australian Greenhouse Office. Specification for remote sensing analysis of land cover change 1970-1990 Phase 1 and 2 *National Carbon Accounting System, Technical report 9,* Canberra, Australia 2000.

[7] M.M. Barson, Randall, L.A. and Barry, S. C. Modelling Greenhouse Gas Emissions from Land Cover Change: Linking Continental Data with Point/Patch Models. MODSIM 2001, Canberra, Australia.

[8] W. H. Burrows, B. K. Henry, P.V. Back, M. B. Hoffmann, L.J. Tait, E. R. Anderson, et al. "Growth and carbon stock change in eucalypt woodlands in north-east Australia: ecological and greenhouse sink implications," *Global Change Biology,* vol 8, pp1-16, 2002

[9] D. J. Barrett, I. E. Galbally, and R.D. Graetz. "Quantifying uncertainty in estimates of C-emissions from above-ground biomass due to historic land-use change to cropping in Australia," Global Change Biology, vol 7, pp883-902, 2001

[10] P. K. Tickle, C. Witte, A. Lee, R.M. Lucas, K. Jones, J. Austin. Use of airborne scanning lidar and large-scale photography within a strategic forest inventory and monitoring framework. 2001 *Proceedings IGARSS Conference, Sydney, Australia*, 2001

[11] Queensland Herbarium. Pre-clearing and extant vegetation data, Queensland Environmental Protection Agency, 2000.

[12] Australian Bureau of Agricultural and Resource Economics. Australian Commodity Statistics 2000, Canberra.

[13] Bureau of Rural Sciences. Rainfall Reliability Wizard. (http://www.brs.gov.au/rainfall). Canberra 2001

[14] P.K. Tickle, A. Lee, C. Witte, R.M. Lucas, K. Jones, J. Austin, et al. The operational use of airborne scanning lidar and large-scale photography within a strategic forest inventory and monitoring framework. Unpublished.