A new tool for calculating the carbon footprint of WA farms

Deborah Engelbrecht, Wahidul Biswas, Deborah Pritchard (Curtin University) Waqar Ahmad (CSIRO)

Key messages

A new tool for calculating carbon emissions from WA cropping enterprises has been developed to allow the user to identify areas where mitigation measures may be applied to achieve cleaner production.

Carbon credit trading is a feature of the Carbon Farming Initiative (CFI) and for trading to occur accurate estimates of emissions are required.

Australia is responsible for the accounting and control of carbon emissions under the Kyoto Protocol.

Aim

To develop a method of calculating the carbon footprint from various WA farming systems, at a paddock level.

Background

This study considers the carbon footprint of crop production in the context of Australia's commitment to its international Greenhouse Gas (GHG) reporting requirements within the United Nation Framework Convention on Climate Change (UNFCCC) and Australia's targets under the Kyoto Protocol. Whilst the current government in Australia has disposed of carbon tax (Clean Energy Act 2011), it is likely that the National Greenhouse and Energy Reporting (NGER) Act (1) will continue as a national framework for corporations to report on GHG emissions, energy use and energy production.

As a part of the redundant Clean Energy Act 2011, the Carbon Farming Initiative (CFI) was devised and introduced to enable landowners to quantify and control the emission of GHGs during farming (2, 3, 4). The CFI aims to provide a mechanism wherein farmers are able to generate and sell carbon credits using approved methodologies. Although limited methodologies exist within the CFI it is still active whilst other carbon taxation methods for Australia are being investigated. The integration of life cycle assessment (LCA), remote sensing (RS) and geographical information systems (GIS), as the integrated spatial technology (IST) was developed. The IST is a comprehensive tool for the quantification and evaluation of carbon pollution from crop growing (3). Additionally it could be used by farmers to identify and evaluate appropriate mitigation measures. This paper presents the methodology used in an Integrated Spatial Technology (IST) that aims to reduce GHG pollution in Western Australian agriculture by integrating Life Cycle Assessment (LCA), Geographical Information Systems (GIS) and Remote Sensing (RS).

Method

The integrated spatial technology (IST) methodology involves two key stages i.e. a) the use of remotely sensed data from satellite images and aerial photographs of the selected paddocks as an input to GIS and; b) the use of a streamlined Life Cycle Analysis (LCA)-based approach for calculating the carbon footprint of grains grown on those paddocks for incorporation into GIS images (Figure 1).

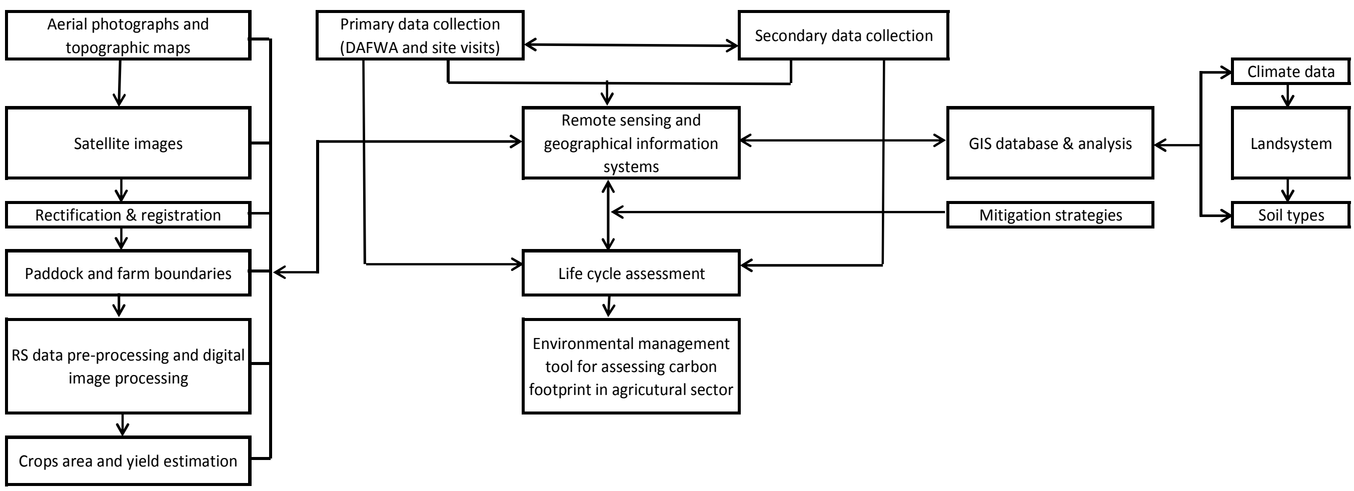


Figure 1. IST model

The data were provided by the Department of Agriculture and Food Western Australia (DAFWA) from a crop sequencing project initiated in 2010. DAFWA allocated 44 paddocks to this project on the basis of differences in climate, farm management practices and distances from input suppliers. The sample was further refined by superimposing the geographical co-ordinates of each paddock on the available remote sensing images thereby identifying the paddocks for inclusion. The final sample included 24 paddocks from eight farmers in two regions (WANTFA and Liebe). Additional primary and secondary data were obtained through interviews with the selected farmers, suppliers, manufacturers, literature and academic professionals.

The LCA methodology, proposed by ISO 14040-14044 (4, 5), was used for calculating the carbon footprint of grain production for a variety of soil types and agro-ecological zones. At the outset the functional unit selected was the GHG emissions generated from the production of one tonne of a crop from the paddock for 2010 and 2011. For the development of the inventory, the data obtained from DAFWA were separated into pre-farm[1] and on-farm[2] stages for each paddock. The inventory lists quantified all the inputs and outputs in terms of one tonne of crop production by calculating the GHG emissions along the supply chain in terms of kg GHG emitted per tonne of crop produced. It included all emissions generated in the pre-farm and on-farm processes (for example the GHGs emitted when transporting a chemical from Asia to delivery at the paddock). Thereafter the inputs and outputs were converted to carbon footprint by multiplying with the corresponding emission factors. Finally the calculated total carbon footprint values were incorporated into a GIS image to provide the user with a visual representation of the areas of concern (hotspots) during the annual farming cycle for the selected years. Additionally the IST aided with the identification of the maximum and minimum levels of GHG emissions across all pre-farm and on-farm classifications.

Application of IST framework

For demonstration purposes the results obtained from three of the paddocks are included in Table 1. The IST uses the data available from both years for testing the framework and also for use in exploring further mitigation strategies. These mitigation measures focus on farm management practices in this project and may include crop rotations, adjustment or alteration of chemical dosage, burning practices and grazing amongst others. In this scenario the three paddocks fall within the same rainfall (300-400 mm per annum) and temperature (18-21 °C) zones, and grew the same crop (Table 1).

Table 1. Agro-ecological characteristics of three paddocks (7)

Paddock	GPS co-ordinates	Soil common name	Soil scientific name	Rainfall (mm)	Average temperature (°C)	Crop 2010	Crop 2011
1	30.38421 S, 116.75146 E	red sandy earth	red kandosol	300-400	18-21	Wheat	Wheat
2	30.35706 S, 116.72453 E	calcareous loamy earth	calcic calcarosol	300-400	18-21	Wheat	Wheat
3	30.35196 S, 116.71128 E	calcareous loamy earth	ironstone gravelly soils supergroup	300-400	18-21	Wheat	Wheat

Using a GIS application (ArcMap) and the GPS co-ordinates (Table 1) the paddock locations were identified which subsequently assisted with the demarcation of each paddock (Figure 2). Figure 2 shows, from left to right, the total study area in Australia covered by the satellite images, the three adjacent paddocks owned by a farmer, and a more magnified image of these maps.

Results

The first step was to identify the stage producing the most GHG emissions. Accordingly, the IST framework was able to generate multiple images of the pre-farm, on-farm and total GHG emissions for the three aforementioned paddocks, for years 2010 and 2011 (Figure 3a-c).

For each paddock, (Figure 3 a-c) an output map, a graph and a table showing carbon footprint for pre- and on–farm stages have been produced. The graph illustrates the totals for each stage and the table a sum of the emissions for each year and paddock. Using the images and carbon footprint information of the three paddocks the farmer would be able to identify the paddock with the lowest and highest GHG emissions. The IST can potentially be used as a

[1] Pre-farm processes: agro-chemical production, chemical transportation, farm machinery production
[2] On-farm processes: farm machinery operation, direct soil emissions, indirect soil emissions, emissions from stubble burning and emissions from grazing

decision making tool as these outputs mentioned above will confirm that the pre-farm stage of Paddock 1 in 2010 (Figure 3a), had the highest GHG emissions. Figure 3b shows the highest GHG emissions for 2011 in the on-farm stage for Paddock 3. However, using the image (Figure 3c) illustrating the total GHG emissions (total GHG emissions are the sum of the pre-farm and on-farm emissions) it may be concluded that the emissions in the pre-farm stage for Paddock 1, in 2010, were the most concerning.

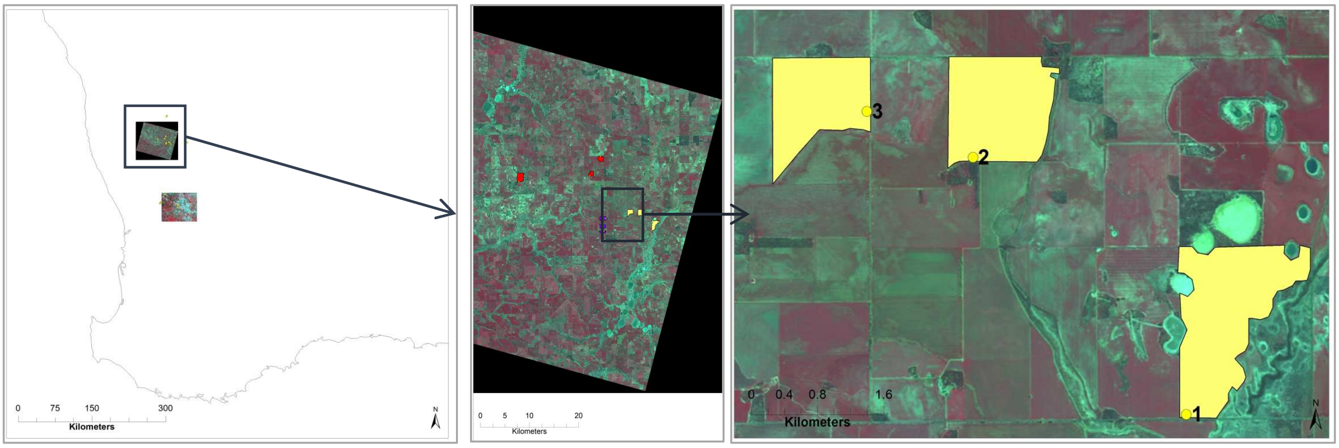
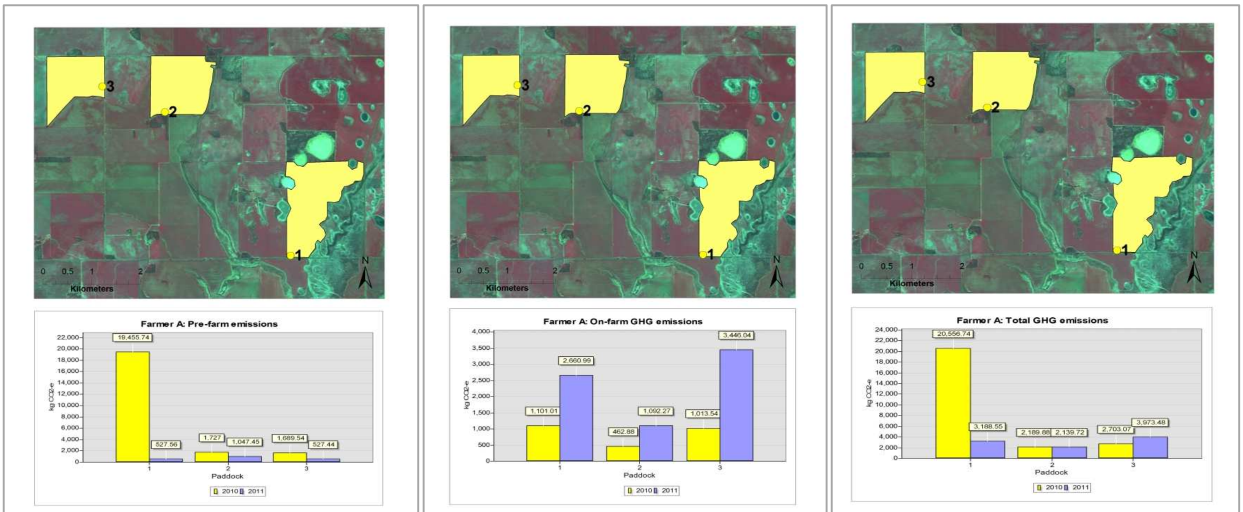


Figure 2. Imagery showing the position and shapes of the paddocks (7)



Pre-farm emissions		
	2010	2011
Paddock	kg CO_2-e	kg CO_2-e
1	19455.7	527.6
2	1727.0	1047.5
3	1689.5	527.4

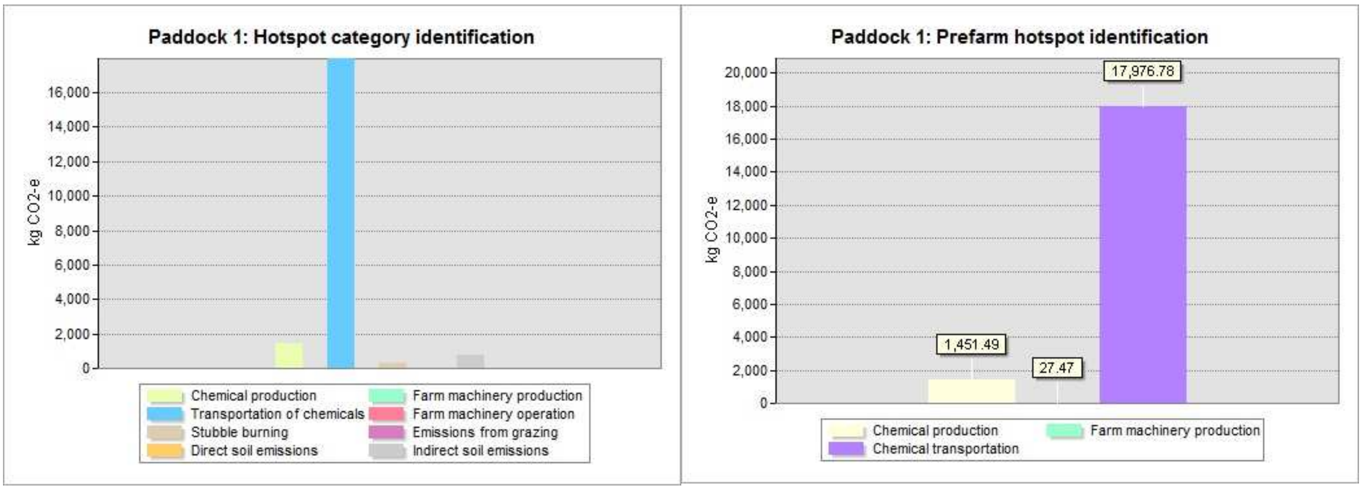
On-farm emissions		
	2010	2011
Paddock	kg CO_2-e	kg CO_2-e
1	1101.0	2661.0
2	462.9	1092.3
3	1013.5	3446.0

Total emissions		
	2010	2011
Paddock	kg CO_2-e	kg CO_2-e
1	20556.7	3188.5
2	2189.9	2139.7
3	2703.1	3973.5

a) Pre-farm GHG emissions **b) On-farm GHG emissions** **c) Total GHG emissions**

Figure 3. Imagery generated by the IST

The next step of the framework was to assist in the cause and diagnosis for developing mitigation strategies. After identifying the hotspot the user is then able to produce further images to determine the exact category in which the highest GHG emissions were generated. Figure 4a showing the breakdown of GHG emissions in terms of inputs and outputs was generated after Paddock 1 was identified as the paddock with the highest emissions in 2010 (using only Figure 3c). The graph clearly shows that the transportation of chemicals was the area of concern. Figure 4b further consolidates this fact. Figure 4b was generated on the basis that the pre-farm stage (using both Figures 3a and 3b) for Paddock 1 in 2010 had the highest emissions. Hereafter, the user is able to investigate as to why the emissions from chemical transportation were the highest by generating further images or by research into their own personal records of on-farm management practices.



a) Overall hotspot identification per category **b) Pre-farm stage hotspot identification per category**

Figure 4. Hotspot identification per category

Conclusion

The example given illustrates the use of the IST, which is an integration of GIS, RS and LCA. It demonstrates that by integrating these three tools a new tool has been developed which will show the user, potential land users and policy makers, “at a glance” the impact of land use changes and the farm management systems used. This IST framework will enable the user to generate other GHG mitigation options depending on their personal preferences. Maps, graphs and tables can be included or excluded subject to the envisaged use of the image. Furthermore the user will be able to visually interpret hotspots from an overall (total GHGs) perspective to a more defined and accurate assessment, for example, identifying which chemical generated the most GHGs when transported. Finally it could aid with the identification of mitigation methods by allowing the user to input variables, generate images, allow for analyses of these images and thereafter aid with decision making.

Key words

Integrated spatial technology, life cycle assessment, remote sensing, geographical information systems

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