Observations on agricultural expansion in the Sinop area of Mato Grosso state, Brazil

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Background

The development of commercial agriculture is pushing further north into the Brazilian Amazon and increasing in importance as a driver of deforestation (D'Avila 2003; Sato 2003). This particularly affects the states of Rondonia and Mato Grosso, which together make up the world's largest agricultural frontier. Between 2001 and 2004, deforestation, to provide land for highly mechanized agriculture in this area, reached unprecedented rates (Morton *et al*., 2006). In the next decade, crop production in this frontier is set to expand massively, with an estimated 70% of future deforestation predicted to be carried out to provide land directly for crops by 2020 (Cerri *et al*., 2007).

As mechanised agriculture is a relatively new activity in this part of Brazil, land management practices change rapidly as farmers use trial and error to increase productivity/reduce losses and react to market pressures. Detail of practices such as clearing methods, crops grown, crop rotations, tillage operations, inputs and off-takes are lacking. Such details are needed to enable scientists to predict the future impacts of agricultural expansion on carbon (C) dynamics and greenhouse gas (GHG) emissions and to estimate the sustainability of the land management systems being introduced. Without this information, the Brazilian government may be underestimating the environmental impacts of forest cleared to provide land for croplands, especially in terms of national reports of GHG emissions resulting from land use change.

Over the past 6 years a group of scientist from The University of São Paulo, Brazil and Colorado State University, USA, have been using the Century Model (Figure 1), (Parton *et al.*, 1988) and the GEFSOC modelling system, which includes Century, (Milne *et al*., 2007; Easter *et al*., 2007) to estimate changes in C stocks and GHG emissions resulting from land use change in the Brazilian Amazon (Cerri *et al*. 2004; Cerri *et al.* 2007). Century is a general ecosystem model which models the turnover of C, nitrogen (N) and phosphorus (P) in above and below ground pools of an ecosystem, but with emphasis on below ground dynamics (Figure 1). To date, efforts for the Brazilian Amazon have concentrated on modeling forest-to-pasture changes as this has been the dominant form of land use change. However there is now a need to parameterize Century for the forest to cropland changes for which (as stated above) little information is available.

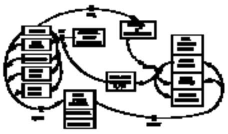

Figure 1. Overview diagram of the Century Ecosystem Model (Parton *et al.*, 1987)

This poster therefore covers the findings of a preliminary planning visit, funded by the United States National Science Foundation, to Sinop, Mato Grosso, Brazil. The purpose of the trip was to develop a collaborative research program around parameterization of the Century General Ecosystem Model for cropping systems on newly cleared land in the Brazilian Amazon. We report on preliminary findings of the cropping systems being used following deforestation, how this varies with farm size and the implications this has for a future research program to fully parameterize the Century model so it can be used to estimate C stock changes and GHG emissions in the Brazilian Amazon in the future.

Study area

The study considered the area surrounding Sinop (11.85° S 55.46° W), a frontier city ~ 400 miles north of Cuiabá, the capital of the state of Mato Grosso, the largest soybean producing state in Brazil. Sinop lies on the edge of the agricultural expansion zone in the Southwest Amazon and has one of the highest grain productivity rates in the world. The city was established in 1974 during the time when soybean varieties were adapted for tropical conditions leading to agricultural expansion. However, the greatest growth in the city and clearance of the surrounding vegetation have occurred in the past 20 years, coinciding with a move to larger scale mechanised agriculture (primarily soybean) for the export market. Native vegetation in the area is Cerrdão meaning 'big Cerrado or savanah'. It comprises of dense tree cover but lacks some of the key hardwood species that would formally classify it as tropical forest.

Farmer Interviews

The Embrapa representative in Sinop linked us to local farmers in the area and arranged visits to five farms. Farms varied in size, from large (20 thousand ha) to relatively small (200 ha). Farms were considered in terms of crop choice, crop rotations and cropping practices from the time of farm establishment (the mid 1980's onwards) through to anticipated activities for the future. At each farm we interviewed farmers to determine:

- Location
- Farm size
- The time the farm was established
- Current and past crops grown
- Past Rotations (since farm establishment)
- Current Rotations
- Tillage operations
- Inputs and timings of inputs (fertiliser, organic manure, herbicide)
- Crop residue returns
- Future intentions for crops/management practices
- Farmers opinion on areas in Mato Grosso most likely to change in the future

Case Study Findings

We found that all five farms were initially set up to repeatedly grow a monoculture, generally soybean, with corn or millet as a second crop. Immediately following deforestation (the first 2-3 years) farmers grew rice as this is a robust crop that grows well in the acid soil in the area. This practice prepares the soil for the subsequent more valuable crops. Management practices employed by the small (> 500 ha) farms differed markedly from those employed by medium (> 500 ha) and large (> 10,000 ha) farms. This was an interesting finding as these differences are likely to have consequences for soil organic carbon (SOC) turnover, nitrogen cycling and GHG emissions from soils.

Fertiliser

Fertiliser inputs appear to have varied over the years as farmers have tried different systems and market prices of both fertiliser and crops have changed. Inputs were not necessarily associated with farm size. Only one farm (a small one) added nitrogen (N) fertiliser to soybean. All farmers added N to rice at rates ranging from 34 – 70 kg ha^{-1}. Whether or not N was added to corn depended on the farmer, the amount of rain and the value of corn on the market. None of the farmers added manure to any of the crops. Where the larger farms operated rotations involving livestock manure was added by default, but in this provisional study farmers were unable to quantify how much. The variation in fertiliser application and the way this continues to fluctuate emphasizes the need for a larger study, as fertiliser use affects GHG emissions, SOC turnover and the sustainability of the soil.

Farm Machinery

All of the farms were heavily mechanised, in contrast to the small scale slash and burn agriculture used 30 years ago. Large farms typically had a set of machines for every 700 ha, many of which used the latest technologies such as the application of Geographical Information Systems (GIS), remote sensing and tools associated with precision agriculture. Even the smaller farms had their own harvesting machines and tractors.

Tillage

All of the farms we visited of all sizes practiced no-tillage for soybean, with a mixture of conventional till and no-till for other crops. The use of no-till is motivated primarily by cost, although all farmers were aware of the benefits of no-tillage to soil fertility and structure. Tillage increases decomposition rates, leading to a loss of soil organic matter (SOM) and therefore soil fertility and structural stability (Rowell, D.L. 1996). The breaking up of soil aggregates can lead to problems of soil compaction and root penetration having detrimental effects on crop productivity. The Century model allows the user to simulate tillage events on a monthly basis and slows or speeds up decomposition based on tillage related disturbance.

Crop rotations and integrated crop/livestock systems

It appeared that the smaller the farm the more simplistic the rotation used. Small and medium farms grew rice or soybean with a second crop (either corn or millet) and occasionally swapped the rice and soybean growing areas to avoid the build up of pests.

The larger farms appeared to have moved away (in the last 5 years) or be moving away from monoculture towards crop-livestock integration systems involving different crops and rotations. The owners of the larger farms that we interviewed informed us that almost all large farms in the area employed a similar rotation (Box 1) where the land was split into four areas, with three areas (comprising 60% of the total) rotated between constant corn, soybean-corn and rice-millet or soybean-millet and the remaining area (40% of the total) being an integrated livestock/cropping system where livestock grazed on crop residue or the whole crop (in the case of millet) and pasture planted with Brachiaria (a fast growing tropical grass species).

Box 1. Rotation becoming popular among large farms around Sinop, Mato Grosso

- 20% of the area is kept under corn (for cattle feed). This may vary from year to year depending on the price of corn.
- 20% of the area is soybean with corn as a second crop.
- 20% of the area soybean/millet or rice/millet on alternate years. Farmers may do more than one year of rice or soybean depending on the price.
- 40% of the area integrated livestock and agriculture (soybean) system. They sometimes grow soybean/sorghum and allow the cows to go onto the field and eat the sorghum (the whole crop).
- Every 2 years the farmer will rotate options 2,3 and 4.

Cattle grazing on *Brachiaria brizantha* as part of an integrated livestock system at an Embrapa test site, Sinop, Mato Grosso, Brazil. This field is in a rotation with soybean and rice and will change use every 2 years. The native Cerrdão vegetation can be seen in the background.

The integrated crop/livestock rotation system is advocated by Embrapa (the Brazilian Agricultural Research Corporation) who have some preliminary trials in the area showing marked increases in productivity (Trecenti et al., 2008). However, farmers themselves also stated that they saw integrated systems as a means of increasing productivity, protecting themselves from changes in the market, reducing soil degradation, increasing C stocks and decreasing pest infestation. It appeared that the owners of the smaller farms that we interviewed lacked the capital needed to change to an integrated production system such as this. They were unable to afford the initial outlay needed to purchase the livestock and additional machinery and they did not have land to spare to put into permanent corn to use as livestock feed. These findings have very interesting implications for the future trajectory of land management systems in the Southwest Amazon and therefore our ability to model the impacts of these systems on GHG emissions, SOC turnover and land degradation.

These preliminary finding suggests that farm size will have to be considered when parameterising Century. Even if the same crops are being grown in the same locations, with different schedule files (Century files that describe management practices) being written for small, large and potentially medium farms separately.

Farmers perception of the future

Interviews with the farmers, the Embrapa representative and members of staff at EMPAER-MT (who house Emrapba in Mato Grosso) revealed a view that the areas of Mato Grosso most likely to change in the future are the central and northern areas. Most farmers said that they thought farm sizes would grow in the next 5-10 years, with small farmers either being bought out or out competed by the large agribusiness companies. The large farms we visited were already owned by large agribusiness companies. Farmers from the medium and large farms anticipated diversification of crops in the future with a move to integrated crop/livestock systems. The farmer from the largest farm also anticipated that there may be a need for 'green certification' of his farm products in the future and was therefore investing in riparian buffer zones and leaving buffer strips of native vegetation between his fields to act as wildlife corridors. At the moment less than 1% of farms in the area leave buffer strips. None of the farms we visited were growing biodiesel crops, however two farmers informed us that their neighbours were beginning to switch to sunflower production as an agribusiness in the area was providing free seed and fertiliser and a guaranteed price for sunflower seeds produced.

Grain storage buildings at a large (> 40,000 ha) farm, Sinop, Brail

Need for a wider study

Livestock production is still the main activity following land clearance in the Brazilian Amazon. However, in the past 10 years, mechanised agriculture has grown in importance as a driver of deforestation (Morton *et al.* 2006) and is it likely to become even more important in the next decade. This has implications for regional GHG emissions, SOC stock changes and therefore the future sustainability of the area. Tools such as the Century Ecosystem Model, when part of a spatially explicit system such as GEFSOC, can be used to estimate the future impacts of forest to agriculture changes on C stocks and GHG emissions. However, details are needed to create relevant crop, tree, forest and land management files within such models if reliable estimates are to be made. In addition information on past land management practices is needed to account for the long-term trajectory of changes in below ground C.

Cerri *et al.* (2007) made substantial progress in the parameterisation of Century for various soil climate combinations for pasture land throughout the Brazilian Amazon. It appears that an even more comprehensive study needs to be carried out for cropland given the wide variation of practices (both over time and with farm size) we found in this study in a small area surrounding one city in Mato Grosso. We have no reason to believe these practices are representative of those across the whole agricultural frontier in the states of Mato Grosso and Rondonia. We do not currently have information on crop rotations, inputs, off-takes, the use of buffer strips, double cropping or integrated systems, how practices have changed since agriculture came to this frontier area or how they are likely to change in the future. A comprehensive study across the whole of the agricultural expansion zone is therefore planned to parameterize Century for the specific crops grown and the management practices involved.

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