SPATIAL ANALYSIS OF DEFORESTATION FROM BIOFUELS: METHODOLOGICAL CHALLENGES

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ABSTRACT:

In this paper, we look for the spatial relations between deforestation and biofuel production at global level by analyzing available global deforestation and biofuels data, and find that, for a variety of reasons relating to data availability and its characteristics, and the way biofuels are produced, at the global level, this is extremely difficult if not virtually impossible. We argue that a multi-scale approach, based on systematic sampling at the case study level would help to better understand the relation between biofuels and deforestation. Given the fact the biofuels are a highly contested approach to reduction of global carbon emissions, clarity on the methodological difficulties of making statements of this kind, at least in a global spatial analysis, may help avoid false conclusions being promulgated in the future.

1. INTRODUCTION

1.1 Motivation

Plans to expand biofuel production have sparked debates concerning whether biofuel feedstock production threatens food security and reduces land-based income generation, and whether it is resulting, or will result, in a growth in deforestation rates (Ravindranath et al., 2009; Schubert et al., 2008). The latter concern is to a large extent related to the additional carbon emissions that result from forest clearing with impacts on climate change, and also has to do with broader concerns linked to sustainability in the sense of loss of natural heritage and biodiversity, and decrease in the environmental services and goods that forests provide to local populations. This article shares these latter concerns and seeks to explore the spatial interactions between biofuel feedstock production and deforestation.

1.2 Reference to related work

Within the biofuels debate there are two clearly contradicting perspectives: on the one side, environmental lobbies including the Global Forest Coalition, FERN, and Greenpeace as well as some conservation scientists, argue that biofuels will increase greenhouse gas emissions, destroy tropical forests, cause conflicts with local communities and undermine food security (Bringezu et al., 2009; Cotula et al., 2008; Dossche and Ozinga, 2008; Fearnside, 2001; Frondel and Peters, 2005; ICTSD, 2008;). On the other side, proponents of the biofuels industry argue that in addition to reducing the use of fossil fuels and related emissions and providing jobs and income opportunities, biofuels are grown almost entirely on agricultural or pastoral land, and thus do not involve deforestation (Goldemberg, 2008). Brazil, the largest producer of biofuels worldwide, has been at the centre of the biofuel-deforestation debate. In a simplified perspective, some argue that sugarcane expansion in the south of the country is pushing the expansion of soybean in the center west which in turn is displacing cattle further into the Amazon region, thus inducing increased deforestation (Nepstad et al., 2008). In contrast, others argue that there is lack of evidence supporting this argument and that bioethanol production does not lead to deforestation since more than 85% of the planted sugarcane in Brazil is located more than two thousand kilometers from the Amazon forest (Sawaya and Nappo, 2009). Contradictory arguments also prevail for soybean expansion in Mato Grosso, Brazil. Branford and Freis (2000) conclude that the expansion of soya plantations is a cause of deforestation resulting in various social problems. Others argue that (at least today) the Brazilian soya industry has little to do with the clearing of forests, and has an important role in promoting regional economic development (Brown et al., 2005; Goldemberg, 2007; Goldemberg and Guardabassi, 2009). On the other side of the world, palm oil is at the centre of the debate. World Growth, a circular published by the Malaysian palm oil industry, categorically denies that palm oil causes deforestation or emission of greenhouse gases (World Growth, 2009). However, it deals with each of the arguments with highly selective use of data

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and facts. Other reports argue that the expansion of palm oil plantations indeed caused deforestation in tropical countries, especially Malaysia and Indonesia (Butler, 2008). It is noted that more balanced views have also emerged regarding the relationships between biofuel development, deforestation and forest degradation. These nuanced views analyse both the pros and cons of biofuel development and suggest that within reasonable limits expansion of biofuel feedstocks might be possible while protecting forest resources (Demirbas, 2009; Gibbs, 2008;). In addition, the Roundtable on Sustainable Biofuels (RSB), the Roundtable on Sustainable Palm Oil (RSPO), and the Roundtable on Sustainable Soy (RSS) have emerged as formal initiatives involving producers, industry, government officials and experts, in order to actively seek ways in which responsible and sustainable production of biofuels can be promoted in accordance with strict standards.

The truth, however, is that to date, little in-depth research has been carried out on the spatial links between biofuel development and deforestation at a global scale. There are several underlying problems when it comes to assessing the implications of biofuel development on land use change, and specifically on deforestation. The first relates to the availability and quality of recent data on deforestation at global level, and on biofuel production. Biofuel data is problematic both as regards geographical location of feedstock plantations and the level of production. The second has to do with the multipurpose nature of feedstocks since most of them are used for both food and fuel consumption (for example, soya, which is used for food and cattle feed as well as for biodiesel production). The third challenge is that deforestation is often caused by multiple drivers, of which in any given area biofuel may be just one. These challenges suggest that making simple spatial correlations between biofuel production and deforestation is likely to be a difficult task.

1.3 Objective

In order to assess the extent to which it is possible, we conducted a comprehensive review of both global deforestation data and biofuel production areas in Latin America, Asia, and Africa. To help understand the relation between deforestation and biofuel development, a detailed methodology for the analysis at the case study level was presented. The study focuses on developing countries, and does not analyse or include data from North America and Europe.

2. METHODOLOGICAL CHALLENGES

2.1 Challenges related to deforestation

Deforestation is a complex process and getting reliable estimates at the global level remains a challenge. The main issues to deal with are related to the differences in definitions, poor reliability of the available global deforestation data, limited time-series data for recent years, and restrictions in the spatial resolution of the satellite images for mapping deforestation at the global level. Finally, there is difficulty involved in attributing deforestation dynamics to particular drivers.

There is as yet no universally accepted definition of deforestation, which makes it difficult to make comparative analyses across countries. The United National Framework Convention on Climate Change (UNFCCC) defines deforestation as occurring when the canopy cover of a forested area falls below a minimum threshold already selected by each country, in the range between 10 – 30%, with some attendant height and area thresholds (Achard et al., 2007). The USDA Forest Service considers deforestation a non-temporary change of land use from forest to other land use or depletion of forest crown cover to less than 10%. Clear cuts (even with stump removal) if shortly followed by reforestation for forestry purposes are not considered deforestation. The difficulty is therefore to distinguish those losses that are temporary and part of a sustainable cycle from those that are permanent and contributing to long-run increased atmospheric carbon dioxide.

During the last 50 years, the United Nations Food and Agriculture Organisation (FAO) reports have been the main, and often the only, reference for discussion and analysis of forest and deforestation data at regional and global level. However, the FAO data has uneven quality and inconsistent definitions across nations, which makes it difficult to compare and verify (Drigo et al., 2009; Jepma 1995; Rudel et al., 2005; Stokstad, 2001; Zahabu, 2008). Moreover, FAO's data on forest cover and deforestation is reported as aggregate figures at the national level. Based on FAO (2006),it is estimated that about 11.8 million ha per year were lost worldwide during 2000 – 05; 80% of total deforestation took place in Tropical Africa and Tropical America, and the global deforestation figures have remained almost constant between 1990 – 2000 and the period 2000 – 05 (Drigo et al., 2009). In fact, deforestation rates have increased within Tropical Asia and Latin America while decreasing for Africa. However, the estimation of deforestation rates at country level offers little insight into the causes and mechanisms behind this phenomenon. In particular, it is not possible from the FAO database to ascertain where in the country deforestation is occurring, which is critical in relating deforestation to biofuel production.

The drivers of deforestation are very diverse and vary by countries and states. A number of important studies have attempted to generalise and pull together large numbers of local studies (Angelsen and Kaimowitz, 1999; Geist and Lambin, 2002). This work is hampered, however, by the fact that most of the information on drivers is not quantitative, so that few direct quantitative correlations can be made linking certain quantities of deforestation to particular activities. Angelsen and Kaimowitz (1999) showed that, when looking at proximate causes, deforestation is often associated with presence of more roads, higher agricultural prices, lower wages, and a shortage of off-farm employment. Also, they considered it likely that policy reforms included in the current economic liberalisation and adjustment efforts increase the pressure on forests. They pointed out, however, that many research studies have adopted poor methodology and low quality data, which makes the drawing of clear conclusions about the role of macroeconomic factors, and that of other underlying factors inducing deforestation, difficult. Geist and Lambin (2002) identified four broad clusters of direct causes: agricultural expansion, wood extraction, infrastructure extension and other factors. Besides the direct causes, they found that underlying economic factors are prominent driving forces for tropical deforestation (81%); institutional factors are involved in 78% of the cases of deforestation and technological factors in 70%. In addition, cultural, socio-political and demographic factors are relatively less important drivers of deforestation, and have different effects in different regions. They concluded that there is no universal link between cause and effect in analysing the drivers of deforestation. The causes and driving forces are often region specific which means that deforestation dynamics are shaped by geographical and historical contexts, which coincides with the findings of Drigo et al., (2009). These reviews however do not examine the role of biofuels in deforestation. The principal reason for this is that biofuel development only started in most places in the last five years, while the studies are based on data from the 1990s.

2.2 Challenges related to biofuel development

On the side of biofuel production, two issues that present serious challenges in estimating their role in deforestation are: 1) The lack of information about the location of biofuel production, and 2) many feedstocks used for biofuels have other uses as food or fodder, and in most cases, these other uses tend to dominate.

At present no good universal and easily accessible global databases exist, either on production of feedstocks or on production of ethanol or biodiesel at a sub-national level. Biofuel is a relatively new topic and what data are available are often not in the public domain, because of the commercial interests involved. To correlate biofuel production with deforestation, it would be necessary to work at the subnational level and in spatial terms, and ideally data would be needed on: (a) different types of feedstock production at a relatively detailed level of disaggregation (e.g., at municipal level) both in terms of area and crop yield and (b) clear indications of how much of each feedstock in each location is processed into biofuel and how much is used for other purposes (food, fodder, soap, cosmetics, etc.), with data of both types in time series which could be compared to time series data on deforestation. Unfortunately this data is simply not available. Databases which provide information on the volumes of biofuels processed only have data at a high level of aggregation (usually national totals per year). For example, F.O. Licht (http://www.agra-net.com/portal2/), which is probably the most comprehensive source, provides information on national production of the major biofuels, and in a few countries (e.g. Brazil) this is broken down by state, but data at lower levels (district, municipal levels) are simply not available.

Many biofuel feedstocks are multipurpose. For example, palm oil is used to produce both biodiesel and food or cosmetic products; sugar cane is used for both bioethanol and food. Data on feedstock plantation area and the yield do not provide an indication of the biofuel output of this production. The fuel and non-fuel distinction is crucial, but there are hardly any data available which would enable the spatial identification of the 'dedicated' plantations for the most prominent feedstocks (sugar, soya, palm oil, maize, even castor). Crops that are usually intended only for biofuel production, such as jatropha, are an exception. In addition, data relating to individual biofuel processing plants tend to be limited because of commercial secrecy. It is possible to get data on plant capacity, usually in broad ranges i.e., large, medium and small (www.worldbiofuelplants.com), but data on actual production levels is not available, although a simple count of the number of processing plants listed by country gives some notion of the level of biofuel activity. The location of the biofuel plants is only a proxy indicator of biofuel production and thus it is difficult to relate to deforestation. For example, in Brazil, there is a concentration of biofuel production plants near the coastal cities. This has probably more to do with the centres of demand for biofuels and opportunities for their export, as feedstock can be transported by road or rail to the processing centres from various parts of the country. The location of biofuel processing plants is in no way a reliable indicator of the location of feedstock production. Moreover, as the quantity of biofuel produced at individual plants is rarely available so it is not possible to calculate backward the quantity of the feedstock in the supply area. The uncertain link between locations of feedstock cultivation and locations of processing plants is also affected by the different nature of biofuel processing from different feedstocks. Biofuel feedstocks such as sugarcane, soya, and palm oil follow different paths in their processing. Sugarcane, if used to produce fuel, is directly pressed to produce a solution of sugar which is then converted to ethanol, usually at a single plant. Because of the weight of the cane, it is usual that sugar ethanol is processed close to the feedstock production areas. Soya, on the other hand, first needs to be pressed, and separated into soy meal and soy oil (roughly 80 to 20%). The oil is then processed to produce biodiesel. Since soy oil is relatively compact in terms of commercial value per ton, and can be transported relatively easily, this means that the processing plants for biodiesel may not be in the same locations as the crushing plants.

3. PRELIMINARY DATA ANALYSIS

3.1 Global deforestation hotspots

The analysis draws on MODIS Vegetation Cover Conversion (VCC) deforestation data produced using MOD44A data, designed and generated at the University of Maryland, Department of Geography (Carroll et al., 2006), which is the best available global map of deforestation. The VCC deforestation product is distributed by GLCF in GeoTIFF format. It is a "alarm" product, to be used as an indicator of changes and not as a means to measure change. We built a mosaic based on 68 MODIS images in GeoTIFF format from which a global tropical deforestation map was derived as shown in figure 1. A red area indicates that deforestation has been identified at this location, but does not represent the size of the area deforested. To facilitate the display, the deforested areas are actually exaggerated, though the true information can be accessed and managed in any GIS software.

Fig 1. Global deforestation map (2001 – 05).

3.2 Global Biofuel hotspots

The identified global biofuel hotspots including both established and emerging ones were also presented in a global map in figure 2. Since there is no information available that indicates the exact geographic locations of the hotspots, they are represented by the states where they are located. The biofuel hotspots data are very preliminary. For the cases that use multipurpose feedstocks, the plantation area data do not represent the feedstock used for biofuel, but the total plantation area of the feedstock.

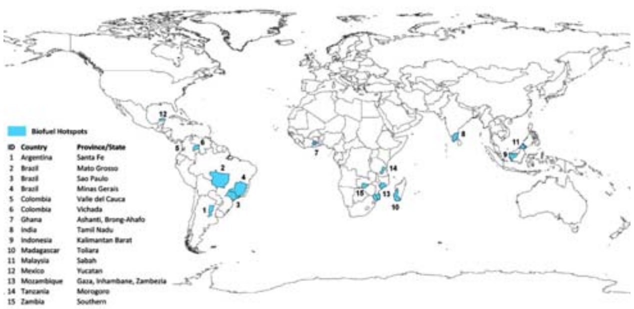

Fig 2**.** Global biofuel hotspots; only the main state or region is shown per hotspot for illustration purposes. We only analyzed data for Latin America, Asia, and Africa.

3.3 The spatial relation analysis

To assess the effects of biofuel development on deforestation, we would need to compare the loss of the forests with the increase in feedstock area devoted to biofuels within the same period. While global deforestation data is available for the period 2001 – 05, data on global biofuel hotspots are comparatively much poorer. First, the data on the hotspots are from different dates. Second, the data represent a single point in time, not the change from two different time periods. Third, the location of the biofuel feedstock plantations in those hotspots is unknown. In fact, the jatropha based biofuel hotspots such as those detected in Africa, and the cases of Mexico and Brazil, the plantation establishment is more recent than the deforestation map. Thus, an analysis of spatial coincidence at the global level cannot be conducted, though it brings out the possible study areas to focus on for the analysis at the finer scales, such as the case study level.

3.4 The case study analysis

Looking at the scope of this study from a methodological perspective and considering the difficulties regarding to the data, cause-effect mechanisms, products end-use, etc., it appears that the most suitable approach would be to observe land use changes at the required spatial and thematic resolution over a representative statistical sample, rather than attempting wall-to-wall global map coverage. This way, the land use changes at different scales can be captured and if crop type and product destiny (i.e.,energy or food) are also observed in these sample areas, the direct relation between deforestation and feedstock production could be objectively determined.

We suggest here a methodology to study the relationship between deforestation and biofuel development using a representative statistical sample. Figure 3 explains the process of spatial analysis of deforestation due to biofuel development at the case study level. The demonstrated satellite images are located in Mato Grosso, Brazil with the approximate center coordinates (x: 778319, y: 8676483), covering 224 km^2. Purposive sampling would be used to focus on areas where it is known that feedstocks are sourced for biofuel processing, and the necessary sample size would first be estimated with a view to obtaining a pre-determined level of statistical probability of the results.

Through GIS processing, the direct feedstock induced deforestation can be calculated. With local information on the proportion of the feedstock that is used for biofuels, an estimate of the biofuel induced deforestation in the sample area can be obtained.

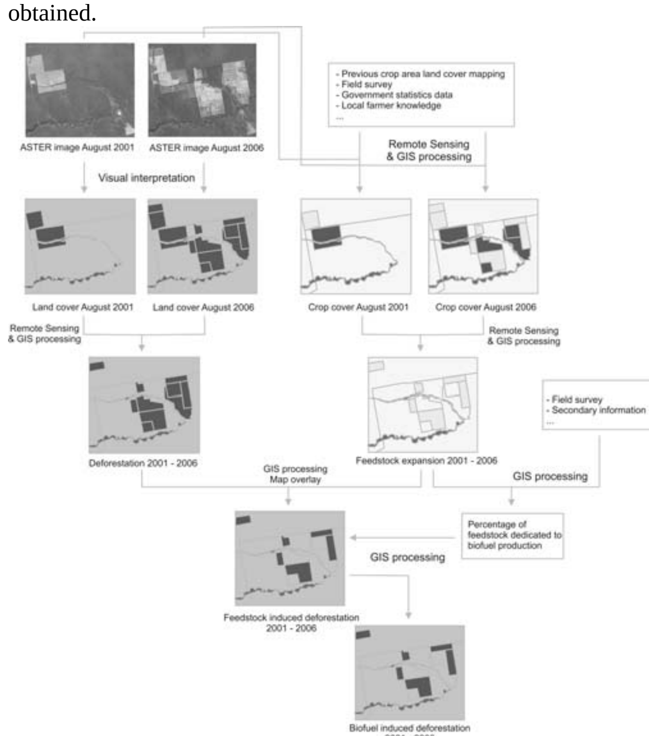

Fig 3. Flowchart of the analysis of the spatial relation between deforestation and biofuels development at the case study level.

4. CONCLUSION

Insecurity of fuel supplies for transportation and global warming are driving a move towards the use of the alternative fuels. Biofuels are being produced on a large scale in only a limited number of locations at the moment, but if production were to increase, the impact on deforestation would have to be seriously taken into consideration. The global analysis indicates that the relationship between biofuel development and tropical deforestation is complex and difficult to pin down in spatial terms. Limited data availability, lack of time series with sufficient resolution at global scale, the multipurpose nature of many feedstocks and the very recent boost in biofuel production in most countries and regions preclude a quantification of the problem.

Looking at the scope of this study from a methodological perspective and considering the difficulties as regards data, cause-effect mechanisms, products end-use, etc., it appears that the most suitable approach would be to observe land use changes at the required spatial and thematic resolutions using a representative statistical sample. We have shown that wall-to-wall global map coverage is virtually impossible. However using samples, land use changes at different scales can be captured. If crop type and product density are also observed in these sample areas, the direct relation between deforestation and feedstock production could be objectively determined. A detailed methodology was proposed for the analysis at the case study level.

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