Biomass and Bioenergy 81 (2015) 452–461

Contents lists available at ScienceDirect

Biomass and Bioenergy

journal homepage: http://www.elsevier.com/locate/biombioe

Research paper

Brazil's current and future land balances: Is there residual land for bioenergy production?

Selma Lossau [a,*], Günther Fischer [b], Sylvia Tramberend [b], Harrij van Velthuizen [b], Birgit Kleinschmit [a], Reinhard Schomäcker [a]

[a] Technical University Berlin, D-10632 Berlin, Germany
[b] International Institute for Applied System Analysis (IIASA), A-2361 Laxenburg, Austria

ARTICLE INFO

Article history:
Received 30 October 2014
Received in revised form
17 April 2015
Accepted 17 July 2015
Available online 11 August 2015

Keywords:
Brazilian land balance
Residual land
Sequential downscaling
Sustainability criteria

ABSTRACT

This study presents a new database of land use categories in Brazil at a spatial resolution of 30 arc-second (about 1 km^2). The spatial representation of current major land uses formally combines agricultural statistics from Brazil's latest census of the year 2006 at micro-region level and the Food and Agriculture Organization 2010 forest statistics with spatial land cover data sets. Spatial allocation ("downscaling") algorithms were applied to obtain a spatial distribution of seven major land use categories. Remaining shares in each grid-cell were termed residual land, and were categorized according to legal protection status, biodiversity value, and whether they belong to the territory of the Amazon biome. We found a total of 84 Mha residual land of which 37 Mha occurred outside the territory of the Amazon biome and was neither legally protected nor categorized as highly biodiverse land. The 37 Mha "available residual land" equates to 4.4% of Brazil's geographical area and to 50% of its current cultivated land area. We assessed land quality using the Agro-ecological Zones modelling framework provides land suitability and productivity estimates of the available residual land. Nearly one-third of land emerged of prime quality and is therefore promising for biofuel feedstock production. Analysis of potential food-fuel competition suggests that until 2030 productivity improvements on current pastures could accommodate land demand for Brazil's increasing cattle herd and expanding croplands. If these productivity increases could be achieved on current agricultural land, residual land could provide areas for the sustainable expansion of biofuel feedstock production.

1. Introduction

Demographic changes and economic growth will cause a more than a doubling of world transport capacity over the next half-century and substantially increase demand for fuel, particularly in the developing countries [1]. The combustion engine will continue to be a dominant engine system for many years to come, especially for freight transport. The automotive industry is therefore interested in finding alternative fuels — especially biofuels — for combustion engines.

With demand for liquid biofuel on the world market increasing, Brazil, today's largest producer and consumer of sugarcane ethanol, is considered a major potential supplier of biofuels to the world market. Brazil has large land endowments and technologically advanced sugarcane agro-industries that have been developed since the 1970s. These place Brazil in a leading position to produce biofuels economically, and this implies a substantial potential for mitigating anthropogenic greenhouse gas (GHG) emissions. Food security and promotion of renewable energy, including modern uses of biomass as a source of energy, are key global goals. This raises the important question as to whether it is possible to integrate these goals into strategies for sustainable land use.

The amount of land resources that can be dedicated to agricultural land expansion for biofuel feedstock production may be limited and needs to be assessed in depth [2]. Doubts have been raised regarding as to whether direct and indirect land use changes can help mitigate GHG emissions [3]. There are also questions about the potential environmental, social and economic impacts of growing biofuels; for example, the competition they pose to the food supply, the risks of reducing biodiversity, the impacts on water availability and quality, and the lack of benefits to those directly

* Corresponding author. Eyachstr.37, D-70165 Sindelfingen, Germany.
E-mail address: selma.lossau@gmail.com (S. Lossau).

http://dx.doi.org/10.1016/j.biombioe.2015.07.024
0961-9534/

affected by large-scale introduction of biofuel production [4].

Brazil is endowed with significant land resources and is a land use change hot spot; these challenges for Brazil thus have both local and global dimensions [5]. Brazilian agriculture covers about one-fourth of the country's territory; it has expanded substantially during recent decades and is expected to expand further in response to the growing demand for food, livestock feed, and liquid biofuel feedstocks [6]. At the same time, safeguarding biodiversity-rich ecosystems and the avoidance of GHG emissions from deforestation and land use change are essential for achieving sustainable land use.

Securing food production involves both meeting the increasing demand locally for a rapidly growing middle class and serving the growing markets for export of agricultural commodities. Brazil is spearheading the development of sugarcane-derived ethanol for the country's growing fleet of flex-fuel vehicles and increasing world market demands. Today the vast majority of liquid biofuel feedstocks, primarily sugarcane for ethanol production, are benefiting from the favorable climatic conditions of Brazil's southeast and central-east regions. Brazilian sugarcane based bioethanol production in 2013 was 28 billion litres [7]. In view of the envisaged expansion of sugarcane, the Brazilian government conducted a study to identify new areas suitable for sugarcane production [8].

Brazil began biodiesel production in 2006 and has since increased its installed production capacity rapidly in response to envisioned mandates. Soybean is by far the most important source for biodiesel production (72%) followed by animal fats (24%) and cotton seeds (2%) [7].

In 2010 the biodiesel use mandate was set at 5%; since November 2014 a 7% mandate has been set. Industry has long requested an increase in the biodiesel blend, as capacity is more than twice the actual production goals. In 2013, 2.9 billion litres of biodiesel transport fuel were sold, supplying 5% of the diesel market in Brazil.

In addition to increased blending mandates, new guidelines have been proposed that favors the production of biofuel feedstock in underutilized or degraded pasture land and rain-fed cropland [2]. Suitability of land for biofuel production strongly depends on local biophysical conditions (climate, soil, terrain) and management regimes (input level, pesticide and weed control, machinery). Regional planning for biofuel feedstock expansion or intensification must account for the spatial (and temporal) variations of biofuel feedstock suitability and productivity in order to maximize energy return effectiveness per land area while minimizing GHG emissions [9].

For these reasons, the large automobile company Daimler AG launched a project in cooperation with the International Institute for Applied System Analysis (IIASA) and the Technical University of Berlin to assess biofuel feedstock production potentials, while taking into account the following sustainability criteria:

The production of biofuels (i) excludes competition with food, livestock feed and fiber supply; (ii) neither directly nor indirectly results in deforestation; (iii) does not encroach in legally protected areas; (iv) does not cause biodiversity loss; (v) does not compete for scarce fresh water resources: (vi) will not cause land degradation and reduces GHG emissions, in spite of increased fertilizer use and/or land use conversion to biofuel feedstocks.

To comply with the first four of these sustainability criteria an important first step is to assess the availability and quality of available land resources in Brazil. Research presented in this paper provides: (i) spatially detailed land balances to identify residual land; (ii) assessments of quality of residual land for agricultural purposes, and (iii) analysis of potential food-fuel competitions in residual land resources.

2. Methodology and data

2.1. Overview and approach

To estimate Brazil's residual land areas as accurately as possible we allocate statistically recorded extents of agricultural and forest land to a spatial grid of 30 arc-second (about 1 km^2) in accordance with remotely sensed land cover information. The allocation also accounts for built-up land, water bodies, and sparsely vegetated and barren areas. The remainder of the estimated land balance, at the grid-cell level, is designated as residual land. The spatial inventory of residual land was further categorized according to its legal protection status, biodiversity value, and whether it belongs to the territory of the Amazon biome. Applying these criteria led to three increasingly restrictive definitions of residual land, which we termed respectively residual-I, -II and -III land. The latter is located outside the Amazon biome and classified as not protected or of high value for biodiversity. We earmark residual-III land as Brazil's potential land reserves for sustainable expansion of biofuel feedstock production. Further, we assess the agronomic land quality of Brazil's residual lands in terms of the suitability and production potentials of Brazil's major commercial food and livestock feed crops using the IIASA/FAO Agro-ecological Zones (AEZ) modelling framework [10].

2.2. Assessment of land balances and residual land

For an accurate estimation of Brazil's residual land areas, current land-use data is of critical importance. This study combines geographic land-use data derived from remote sensing analysis with statistical information from Brazil's latest agricultural census of the year 2006 [11] and with forest data from FAO's Forest Resource Assessment (FRA) 2010 [12]. Supplementary Information (Table SI-1) summarizes the geographic and statistical data sources used.

An iterative sequential downscaling procedure [13] was implemented to estimate land cover shares for major land use categories in individual 30 arc-second longitude/latitude grid-cells (about 1 km^2). The resulting land balance comprises of seven major land use categories (i) cropland, (ii) pasture, (iii) forest, (iv) built-up land required for urban, industrial and infrastructure and rural settlements, (v) sparsely vegetated and barren land, and (vi) inland water. Remaining shares in each grid-cell were termed (vii) residual land.

Table 1 summarizes sequence and data sources applied in the sequential downscaling procedure.

Built-up land intensities were calculated from estimated relationships of per capita land requirements and applied to a year 2000 spatially detailed population data from Landscan global population distribution data [14].

Land cover data and the Harmonized World Soil Database (HWSD) [15] were used to delineate inland water bodies.

Built-up land, inland water, agricultural land and forest[1] area were allocated in accordance with statistical data and geographic land cover distributions. Brazil's 559 micro-regions reported in the 2006 agricultural census [11], include extents of total farmland, and the sub-categories, cropland and different pasture land types. Forest area statistics reported in FRA 2010 [12] for Brazil's six biomes

[1] As we downscale FRA2010 forest statistics our forest definition follows the FRA2010 definition: “Land spanning more than 0.5 ha with trees higher than 5 m and a canopy cover of more than10% (land cover criteria), or trees able to reach these thresholds in situ. It does not include land that is predominantly under agricultural or urban land use (land-use criteria).”