The Effect of Future Diet on Bioenergy Availability. Extended abstract

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The Effect of Future Diet on Bioenergy Availability

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Introduction

Many countries look to bioenergy to improve energy security, boost rural economies, and to reduce the amount of carbon intensive fuels in their energy portfolios. These motivations, coupled with improvements in bioenergy technology, have led to a dramatic increase in the production of bioenergy in the last decade: in 2010, global biofuel production surpassed 100 Gl yr^{-1}; up from only 18 Gl yr^{-1} in 2000 (REN21 2011). Future potential for bioenergy production is based on land availability and future crop yields, as well as technological advancements and economic competition among other energy alternatives. Several studies suggest that the future potential for bioenergy could be much higher, as much as 400 EJ yr^{-1} by the end of the century (Berndes, Hoogwijk et al. 2003). Using cropland for the production of biomass feedstocks has led to concern that this will lead to increasing food prices and shortages (Ranses, Hanson et al. 1998; Johansson and Azar 2007) and conversion of natural areas to agricultural use (Righelato and Spracklen 2007; Wise, Calvin et al. 2009).

Historically, agriculture has been one of the most substantial ways in which humans have changed the surface of the Earth (Houghton 1994). Already, the intensification and expansion of agriculture, particularly in the last century, has allowed human population to increase substantially (Matson, Parton et al. 1997), and it is furthermore projected that further intensification and expansion of agriculture will be necessary to meet a growing population in the 21st century (Tilman, Fargione et al. 2001). Moreover, as economies develop, there is expected to be an increased demand for calories from animal products (Rae 1998; Wang, Fuller et al. 1998; Delgado 2003), which may requires more land and resources than vegetal calories (Pimentel and Pimentel 2003).

Globally, however, the proportion of per capita caloric intake from animal to total caloric intake has remained relatively constant for the last 50 years at slightly above 15% (FAO Statistics Division 2012). Nevertheless, there are large discrepancies across regions and through time. For example, northern European countries derive over 30% of calories from animal products, while India is under 10%; between 1961 and 2007, China's per capita consumption of animal calories has increased by over a factor of ten, while in the US, animal calorie consumption has remained constant (FAO Statistics Division 2012). In general, per capita consumption of animal products is lower in developing countries than in developed countries, and it is commonly assumed that future animal product consumption will increase as developing countries become wealthier. On the other hand, wealthier countries are remaining constant or even decreasing their proportional consumption of animal calories, and this could be a different way that future diets may evolve. Thus, much of the question about future potential of bioenergy depends on how future diets develop, since the amount of food consumed and the type of food consumed has different demands on the available cropland of the planet.

Methodology

First, historical (1961-2007) diet data (FAO Statistics Division 2012) are aggregated into 14 aggregate categories (rice, maize, wheat, other grains, tubers, oil crops, sugar crops, miscellaneous crops, beef, sheep and goat, pork, poultry, dairy, and other) and 14 world regions. The historic trends are analyzed for each region, noting relationships between per capita income (Purchasing Power Parity) (Heston, Summers et al. 2011) and total caloric intake, percentage of animal products in the diet, fat demand, and protein demand (FAO Statistics Division 2012). From here, scenarios are created to give different possible pathways for how future diets could develop; adjusting the future per capita annual calorie demand for vegetal products and animal products based on historical national trends

and estimated income elasticities for these various food products. Five scenarios are created and are summarized in Table 1 below.

Table 1. Scenario Descriptions

Global Diet Scenario	Description
Low Animal Product	Regional diets with approximately 2500 kcal cap^{-1} day^{-1}, with 10% of calories coming from animal products, similar to the diet currently in India.
High Animal Product	Regional diets with approximately 3750 kcal cap^{-1} day^{-1}, with 40% of calories coming from animal products, similar to the diet of the US, Western Europe, and Australia
Healthy Diet	Regional diets with 2800 kcal cap^{-1} day^{-1} with specific dietary consumptions targets in terms of fat, protein, and distribution of meats, grains, dairy, vegetables and fruit; based on World Health Organization (2003).
Current Diet	Regional diets of 2005 are held constant through time (price and income elasticity are set to 0) and population change is the only driver.
Projected Trend	Using regression relationships from 1961-2007 between diet variables and per capita GDP (purchasing power parity), trends are projected into a future storyline of how future diets may develop.

GCAM-DTU (Global Change Assessment Model- Denmark Technical University) (Clarke, Lurz et al. 2007) is used to explore the effect of these different global and regional diet scenarios on land use and thus economic bioenergy potential up to the year 2095. GCAM-DTU is a global integrated assessment model with an included land use module. GCAM-DTU is a partial equilibrium model that contains aggregated historical data on the transportation, buildings, industry, and agricultural sectors. It runs in 5-year time steps to the year 2095. Land use is allocated to meet regional and global food and bioenergy demand, using a nested hierarchy of land classes (Figure 1), including both managed and unmanaged land. The model allocates land across a number of categories, assuming that farmers maximize profit. These decisions reflect current and historical preferences for land use and land cover, and use free market and free trade assumptions. Bioenergy demand is a function of cost competitiveness within both the energy sector and agriculture sector. Two types of biomass are considered: bioenergy crops, and residue biomass (which includes crop residue, forestry residue, and mill residue). More information about the GCAM model can be found at (http://wiki.umd.edu/gcam/).

Scenarios are created by changing income elasticities for each GCAM-DTU food category in each region to achieve desired scenario by 2095 in a linear approach. The GDP and population are exogenously assumed: global population increases to 9 billion by 2065 (UN median estimate) and the global economy expands by a factor of approximately 4 in the 21st century. For all scenarios, it is assumed there is no climate policy or global price on greenhouse gases, thus there is no economic penalty for land use change emissions.

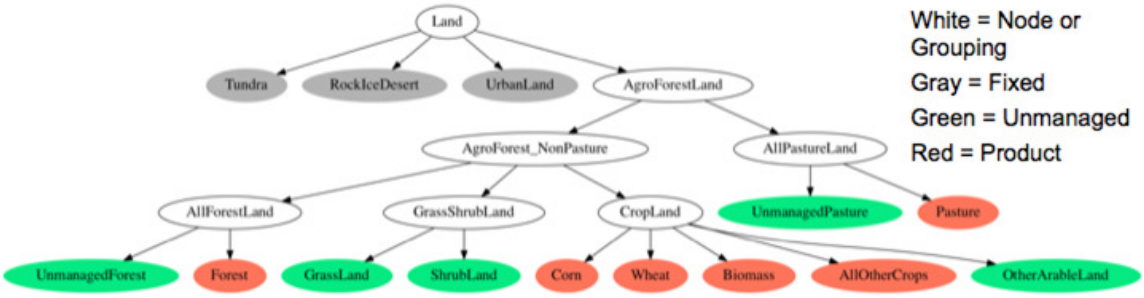

Figure 1. GCAM-DTU Land Hierarchy Structure

Results and Discussion

Across the scenarios, there are large differences in the global and regional land use, and therefore bioenergy production. These results suggest that the way in which the future global diet develops will have a profound impact on the amount of economically competitive bioenergy that can be produced. In particular, the proportion of animal products demanded is a major driver of not only demand for pasture, but for crops devoted to animal feed.

Figure 2 summarizes the economic bioenergy potential for the next century. In the Low Animal Products Diet Scenario, much of the Earth's agro-forestry land becomes remains unmanaged, leaving natural forests, shrub land, and grassland. Moreover, there is 1.4 Gha devoted to bioenergy crops, creating nearly 80 EJ yr^{-1} by the end of the century. In contrast, the High Animal Products Diet and Healthy Diet Scenario, nearly all agro-forestry land becomes managed for food production, and there is little land left for natural forests of bioenergy crops. In this scenario, the only biomass available is from crop, forestry, and mill residue. Land use is not affected greatly in the Current Diet Scenario, with the exception of a gradual increase in managed pasture and the decrease in forest with the increase of bioenergy crops. Bioenergy production in the Projected Trend Diet Scenario is similar to that of the Low Animal Product scenario by 2050, and little lower by 2100.

While there is a historical relationship between diet and per capita wealth, diet is also highly cultural, and there are substantial differences across regions concerning this relationship. Land pressure from bioenergy may have an effect on food prices, thus altering dietary preferences. This is likely to be more the case in developing countries where food represents a larger share of personal budgets and demands will there for have a higher degree of price elasticity. These relationships have a large effect on bioenergy potential, further demonstrating the link between food and energy demand.

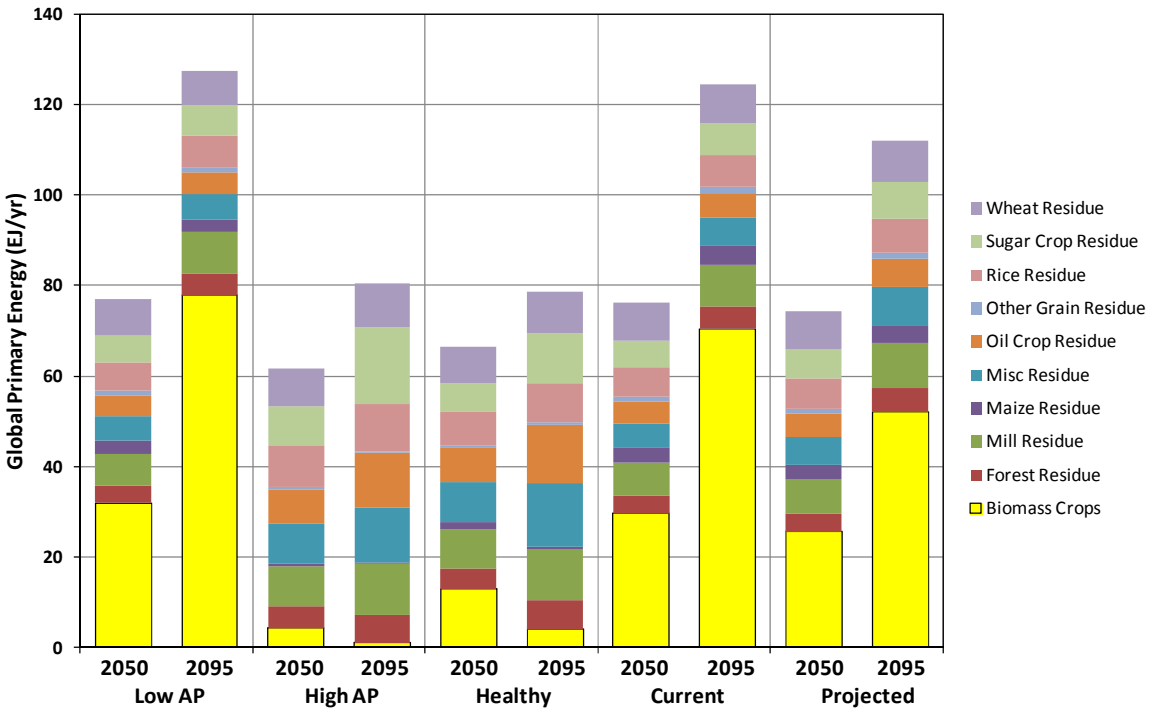

Figure 2. Future economic potential of bioenergy from various sources, given differing scenarios for diet.

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