The Land and Water Implications of Biomass Co-Firing in the MISO region

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Most states in the MISO region have created State Renewable Portfolio Standards that require electric utilities to generate a certain portion of their power from renewable and clean energy sources. Accordingly, power plants need to modify their practices to meet requirement. For coal-fired power plants, biomass co-firing is considered to be a promising and efficient way to enhance the renewable portfolio, but at a lower cost and higher efficiency compared to power plants fully dedicated to biomass (IRENA 2012). Due to the high transportation cost associated with biomass feedstock, the potential for co-firing at a given coal-fired power plant depends on the local availability of biomass. In the MISO region, there are many coal power plants which are candidates for co-firing with biomass. For most of these plants, corn residue is the most available and cost-effective biomass resource. However, if there is a significant shift to co-firing with corn residue, this could have important implications for agriculture in the region, as it will increase the returns to corn production relative to other crops. This, in turn is expected to have important implications for land and water quality, as corn is relative intensive in nitrogen fertilizer use – and in some locations it is an important user of irrigation. Nitrate leaching is, in turn, a significant source of water quality degradation in the region, as well as downstream – as far away as the Gulf of Mexico (Goolsby et al. 1999). The main objective of this study is to explore the potential for biomass co-firing and the associated impacts on land and water resources in the MISO region.

Biomass available for co-firing in the United States mainly includes forestry residue, agricultural residue, and dedicated energy crops. In this study, we only consider residue biomass because residues do not require additional cultivation and land and are considered as near-term cost-effective feedstocks (DOE 2016). Forestry residue is the preferred option because it is less expensive and does not cause changes in land use. However, the availability of forestry residue in the MISO region is very limited and is not sufficient to provide a regular supply of low cost biomass for co-firing. Corn residue, as the main agricultural residue suitable for co-firing in the MISO region, is available in a large quantity throughout the MISO region and provides a reliable feedstock supply. In the MISO region, corn and soybeans are two dominant crops produced, but only corn residue is suitable for co-firing, which increases the payoff of corn production relative to soybeans production, as well as other crops, for the areas where farmers can sell corn residue to nearby power plants. In those areas, biomass co-firing motivates farmers to switch production from soybeans to corn and leads to land use changes between corn and soybeans. Corn and soybeans have very different requirements on nitrogen fertilizer during the growing process; corn requires much heavier use of nitrogen and causes more nitrogen leaching to water system (Kanwar et al., 1997; Andraski et al., 2000). It is important to measure the land use changes from soybeans to corn induced by biomass co-firing and investigate if the environmental benefit of biomass co-firing – reduction of GHG emission, is offset by the environmental cost – the increase of nitrogen leaching to water.

Methods and key findings

Feedstocks represent the most important cost of biomass co-firing, and transportation costs comprise about half of the total feedstock cost because of the low density of biomass. Therefore, the co-firing potential of a certain power plant largely depends on the local availability of biomass, which is heterogeneous across different areas. To estimate the heterogeneous potential of co-firing and the induced land use changes, we conduct this study in five steps. (1) We first *estimate supply* *functions of forestry residue and corn residue* which report the local supply quantity of biomass at different price levels for each power plant, and we find that these functions display high heterogeneity (Fig. 1). Forest Inventory and Analysis (FIA) dataset from U.S. Forest Service is used in the estimation of forestry residue supply, and USDA Cropland Data Layer (CDL) data is used to estimate corn residue supply. Other data (e.g., data used to calculate harvest cost and transportation cost of forestry residue and corn residue) are from previous literature. (2) We then use the Power Planning and Operations Model, a well-established power generation decision model (Morales-España et al., 2013), to simulate the equilibrium pattern of power generation and biomass demand for a given level of co-firing mandated by the state and local biomass availability. (Some plants are not competitive and therefore do not generate under these conditions.) (3) Based on the equilibrium biomass demand and the spatial distribution of biomass around each power plant, we plot a supply circle of biomass around each power plant. Not surprisingly, even higher heterogeneity is observed from the sizes of supply circles due to the additional heterogeneity of co-firing capacity in different power plants. (4) The model is complicated by the fact that some supply circles overlap with each other, which means that multiple power plants compete for the same biomass supply. To address this issue, we combine power plants involved in the spatial competition for the same biomass into one group. Treating the group of power plants as one decision unit, we re-estimate biomass supply, re-simulate the equilibrium demand of biomass, and re-plot the supply circle for the group (Fig. 2). (5) In order to draw out the implications for land use and water quality, we use the gridded version (5 arc minute within the US) of SIMPLE (a Simplified International Model of Prices Land-use and the Environment), which has been extensively validated against historical data and highly recognized in literature (Baldos and Hertel 2013; Hertel et al. 2014; Hertel and Baldos 2016), to simulate the impact of this additional revenue source within the supply circles on land use, nitrogen fertilizer applications and nitrate leaching.

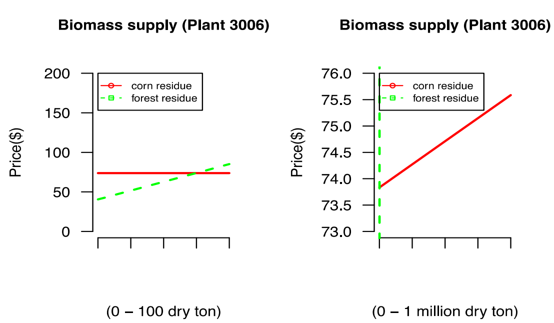

Fig. 1 Supply functions of biomass

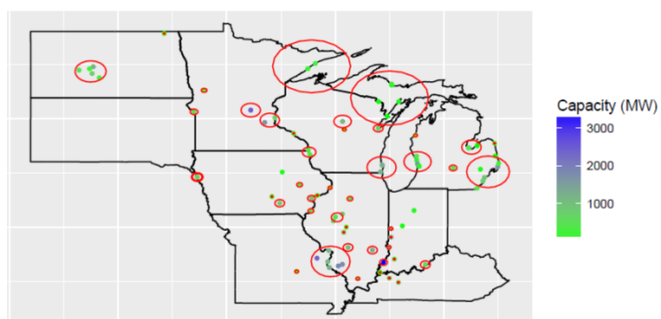

Fig. 2 Supply circles of biomass

Co-firing means replacing coal with biomass for a certain proportion in electricity generation. IEA (IEA-ETSAP and IRENA, 2013) estimates that the proportion of biomass in current co-firing coal-fired power plants is below 5% in most cases, but current co-firing technology is mature enough to support co-firing with 20% of biomass, and 50% is technically achievable (IEA-ETSAP and IRENA, 2013). Based on the current situation and the feasibility of co-firing, we conduct our analysis with four scenarios: (1) no co-firing; (2) 5% co-firing rate; (3) 10% co-firing rate; and (4) 20% co-firing rate.

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