Chapter 1

Sustainable Feedstocks for Advanced Biofuels

Landscape Management and Sustainable Feedstock Production: Enhancing Net Regional Primary Production while Minimizing Externalities

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Introduction

The U.S. federal government and numerous states have adopted standards that require various levels of renewable energy supplies, generally within the next 10-20 years. The Federal Energy Independence and Security Act of 2007 (EISA) requires the production of 136 billion liters of liquid biofuels by 2022 with 79 billion liters from feedstock other than corn starch and at least 61 billion liters from lignocellulosic feedstocks (Sissine, 2007). Renewable Electricity Standards or Renewable Portfolio Standards have been adopted by up to 30 states and the District of Columbia although no federal standard currently exists for renewable electricity. National and state plans to meet these Renewable Portfolio Standards will depend heavily on bioenergy feedstocks, especially for the production of liquid transportation fuels. Although current liquid biofuels are almost exclusively corn starch based ethanol, future liquid biofuels will depend heavily on both sugar and lignocellulosic feedstocks in new conversion technologies that produce “drop-in” biofuels that directly replace gasoline, diesel, and jet fuel and thus can use the existing transportation fuel infrastructure. Conversion technologies such as Virent’s BioForming® Technology using aqueous phase reforming (Blommel et al. 2008) and multiple catalyzed reactors to produce non-oxygenated biofuels (Kunkes et al., 2008) will make use of both lignocellulose and simple sugars. Thus, feedstock production systems that produce feedstock materials ranging from sugar solutions to dried biomass will be useful in various types of “drop-in” biofuels production plants.

Reaching these national and state goals will require production of unprecedented amounts of biomass for energy. The “Billion Ton Feedstock Report” (USDA and USDOE, 2005) lays out a plan for this that includes using forestry waste, crop residues, grain crops, dedicated bioenergy feedstock crops, and animal waste to produce a billion or more tons of feedstock. Recent policy discussions have stressed the need to use feedstocks from numerous sources including perennial crops grown on marginal lands, crop residues, sustainably harvested wood and forest residues, double crops and mixed cropping systems, and municipal, industrial, and agricultural wastes (Tilman et al., 2009). From a purely agronomic perspective, dedicated bioenergy feedstocks can be grown on a wide variety of lands including land already in production for food and forest products and land that has been taken out of production for various reasons (Evans et al., 2010). However, it is increasingly recognized that careful research is needed to ensure the development and adoption of regional cropping systems that maximize feedstock productivity without posing unreasonable risks to the environment and human well-being.

Because of the relatively low energy content of biofuel feedstocks, they will necessarily be grown within a short distance of bioconversion plants. This means that the location of a biofuels conversion plant can have a large impact on the land use within a limited distance from the plant. In order to minimize the loss of existing agricultural production in these areas there is interest in growing feedstock on marginal, abandoned, and under-used cropland with minimal land use change in the existing cropland (Regalbuto, 2010, USDA and USDOE, 2005). The potential for feedstock production on marginal lands has been estimated globally based on the extent of abandoned agricultural land and could supply about 8% of current primary energy demand globally (Campbell et al., 2008). *"Raising bioenergy crops on agriculturally degraded and abandoned lands is emerging as a sustainable approach to bioenergy that provides environmental benefits and climate change mitigation without creating food-fuel competition or releasing the carbon stored in forests"* (Campbell et al., 2008).

In this paper, we will examine the change in land use for feedstock production from a landscape perspective. We will discuss attributes of agricultural landscapes and how knowledge of net primary productivity in natural and managed systems can guide the placement of feedstock production among different parts of the country and within a region, landscape, and watershed. Finally, we will discuss what is known about the potential effects of feedstock production choices on landscape and watershed scale processes and the need for conservation practices which enhance environmental sustainability at these larger scales.

Agricultural Ecosystems and Landscapes

An ecosystem is any area in nature where living organisms interact with the abiotic environment to produce an exchange of materials between the living and nonliving parts (Odum, 1953). At a different level of organization, "a landscape is a heterogeneous land area comprised of a cluster of interacting ecosystems that is repeated in similar form throughout" (Forman and Godron , 1986). The concept of landscape thus focuses on groups of ecosystems and the interactions among those ecosystems. A landscape is a non-random mosaic of interacting elements (and associated networks) over kilometer wide areas (Baudry, 1989). Networks are features such as streams, fence lines, hedgerows, and roads which can form either corridors or barriers for transfers among ecosystems. Both the elements and associated networks can be ecosystems or not, depending on the setting. In "natural" landscapes all elements and networks would be ecosystems or ecotones, the boundary between ecosystems. In human dominated landscapes, such as agricultural landscapes, the elements and networks may be ecosystems (forests, fields, streams) or not (fertilizer plants, feed mills, roads). According to Troll, 1968, (cited in Ryszkowski, 2002) the landscape can be studied in terms of its morphology, classification, and changes in time (history) as well as the functional relationships between its components which Troll (1968) called Landscape Ecology. In agricultural landscapes both the internal dynamics in ecosystems and the interactions of the ecosystems in the landscape are largely determined by technological factors (crops, domestic animals, fertilizer, tillage) interacting with weather, hydrology and edaphic conditions. Many internal attributes of ecosystems can be affected by the exchanges with other ecosystems and in the case of agricultural landscapes the rates and magnitudes of these exchanges are generally regulated by management practices. Interactions among individual fields within a farmstead have to be considered as interactions among landscape elements as do interactions between agroecosystems and non-agroecosystems that are part of the landscape. These interactions are exchanges of energy, matter, plant propagules, insects, vertebrates, etc. (Baudry, 1989). Perhaps the most overlooked attributes of agricultural landscapes are the human resources and the infrastructure support system for modern agriculture which are essential parts of agricultural landscapes.

Nationwide, there are over 373 M ha in farms (USDA, 2007). Of this total, 164 M ha (44%) are cropland (USDA, 2007). Harvested cropland is only 125.3 M ha. As of April 2010, 12.7 M ha of land remained in the USDA Conservation Reserve Program (CRP) after reaching a peak of 14.9 M ha in Fiscal Year 2007 (USDA-FSA, 2010). These figures indicate that in 2007 there was a total of at least 23.8 M ha of cropland that was not harvested and not in CRP. The totals are not known for 2010 but if the land that came out of CRP (2.2 M ha) is not back in row crop production then as much as 26 M ha of cropland will not be harvested in 2010, which includes CRP land and the rest of the marginal, abandoned, and under-used land that has not been put into perennial vegetation and is still included under the cropland base of a farm. This 24-26 M ha of land is critical in the effort to provide sustainable production of biofuels without undue impacts on the current crop production capability. If agriculture is going to meet the feedstock goals implicit in the EISA and meet the next round of bioenergy production goals, there will be large scale changes in farmland use in agricultural areas of the country. Just to provide some notion of the scope of these changes, it is likely that these changes in land use will be equal to or greater than the changes experienced in the past 25 years of the USDA Conservation Reserve Program, which at its peak had approximately 10% of the cropland in the country enrolled in the program (Figure 1).

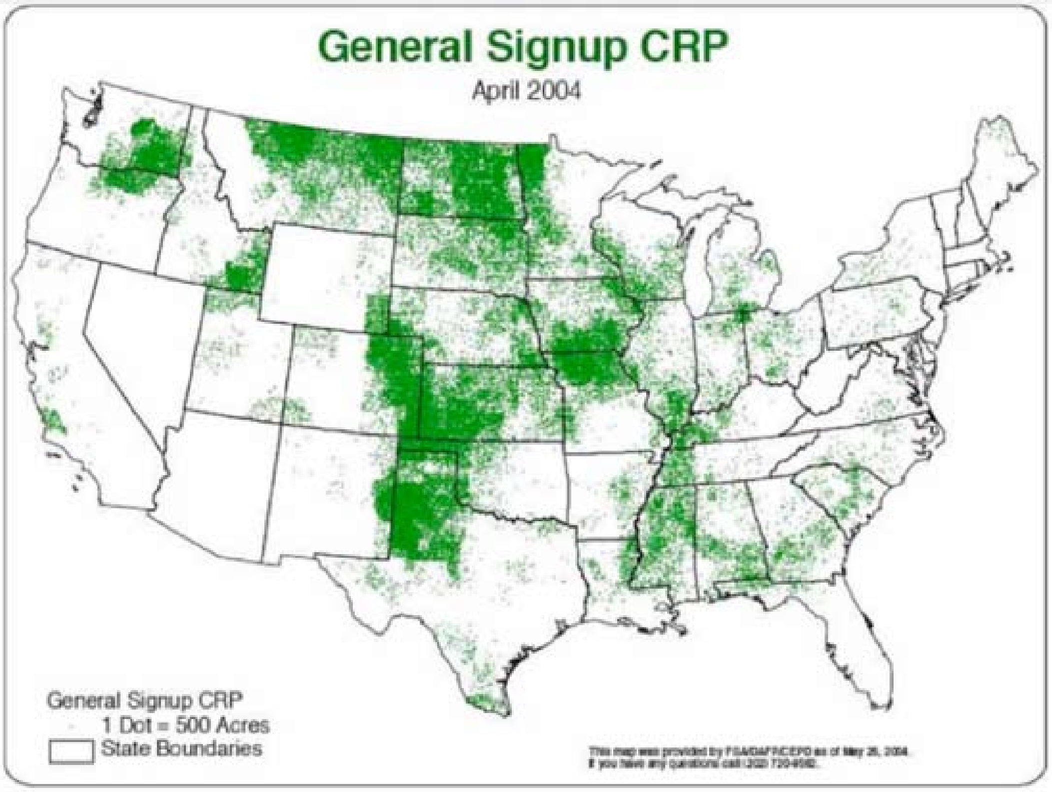


Figure 1. Distribution of Conservation Reserve Lands.

The key difference is that during the 10-15 year period that the CRP land was put in place, land was coming out of production based on USDA incentives, while current government incentives provide the opposite pressure, i.e. to bring marginal land back into production. Intensifying land use on this scale may require the development and implementation of conservation practices targeted to bioenergy crops to avoid losing the improvements in soil and water quality which have resulted from the past 70 plus years of natural resources conservation.

Relationship of NPP to Feedstock Production

The net primary productivity (growth) for a plant community is simply:

NPP (Growth) = Assimilation – Respiration

NPP is almost always an extrapolation from Aboveground Net Production (ANP) based on relationships between above and belowground production (Mitchell, 1984). ANP is the most widely measured and modeled attribute of community production. The natural time unit for the gross production of a plant community is either the natural growth cycle (breaking dormancy to senescence) for perennials or the life cycle of the plants (germination to death) for annuals. Patterns of natural NPP are controlled by five major factors: climate, nutrients, year to year variation in production, community structure, and time scale (Mitchell, 1984). Agronomic plant production is controlled both by these factors and the genetic traits of plants. Management of these factors is central to modern agronomy.

ANP is relatively easy to measure and a large database of NPP measurements exist (e.g. Oak Ridge National Laboratories Distributive Active Archives Center, http://daac.ornl.gov/NPP/npp_home.shtml). Models allow the prediction of NPP based on fundamental controlling factors on plant growth and models can predict changes in NPP based on changing factors such as rainfall, CO2 concentration, etc. One such model Biome 3 (Haxeltine and Prentice, 1996) has been used to predict the effects of changing climate on NPP. Output from this model in association with measured NPPs is shown in Figure 2 from Izaurralde et al., 2005. These patterns of NPP show clearly that natural NPP is greater in some parts of the country than others. The greatest natural NPP is generally in the humid southeast, consistently 1000-1200 g C m^{-2} yr^{-1} or approximately 20-24 Mg green biomass ha^{-1} yr^{-1} (based on a carbon mass to green biomass conversion of 2).

NPP of currently produced agricultural crops show very different patterns (Hicke et al., 2004; Figure 3). In general, crops grown in the southeast have lower NPP per unit area and coupled with lower proportion of land in crops, the current crop NPP of the southeast is much lower than for the corn belt and other areas of the country with lower natural NPP. Given the current plan to produce nearly 50% of the feedstock in the southeast from dedicated bioenergy crops (USDA, 2010); achieving NPP more consistent with natural NPP is essential to current national goals.

For at least the past 75 years, crop production has been driven by the concept of yield goals, with inputs provided (within the constraints of soil and water availability) to produce maximum yield. It has only been in the past 25 years, generally, that crop production has focused at all on input management, largely because of the dual concerns of maximizing net economic return and reducing the external effects of agriculture (water and air pollution). Thus as non-renewable resources shrink, become more expensive, or become subject to more competition, the focus on input management increases. With biofuels, a new dimension is added because of the need to grow biofuel feedstocks that are carbon negative (releases fewer greenhouse gases in the life cycle from seed to combustion than fossil fuel alternatives). Therefore input management is of utmost importance. Bioenergy feedstock production is also constrained in a way not typical of conventional crop production. Notably, attention must be paid to three issues that have been a source of significant controversy in scientific and policy literature about biofuels: 1) achievement of greater net energy benefits than current biofuel processes, particularly corn ethanol, that show relatively low net energy yields (Hill et al., 2006; Evans and Cohen 2009) or potentially even net energy losses (Giampetro and Ulgiati 2005; Pimentel and Patzek, 2005, 2007); 2) avoidance of land use changes that could increase soil erosion, forest losses, and greenhouse gas fluxes due to loss of soil and biomass carbon stores (Fargione et al., 2008; Searchinger et al., 2008); and 3) use of lands and crop types that minimize morally problematic "food vs. fuel" conflicts (Naylor et al., 2007; Runge and Senauer, 2007). Studies are now being conducted on how feedstocks can be produced without reducing crop acreages and without creating large carbon debts associated with land clearing and land use change. "USDA assumes that biomass may be grown on defined agriculture cropland (agriculture cropland where crops are produced and agriculture cropland in pasture). … Importantly, USDA will assess the acreage of fallow and underutilized lands that can be sustainably converted into dedicated energy crops" (USDA, 2010).

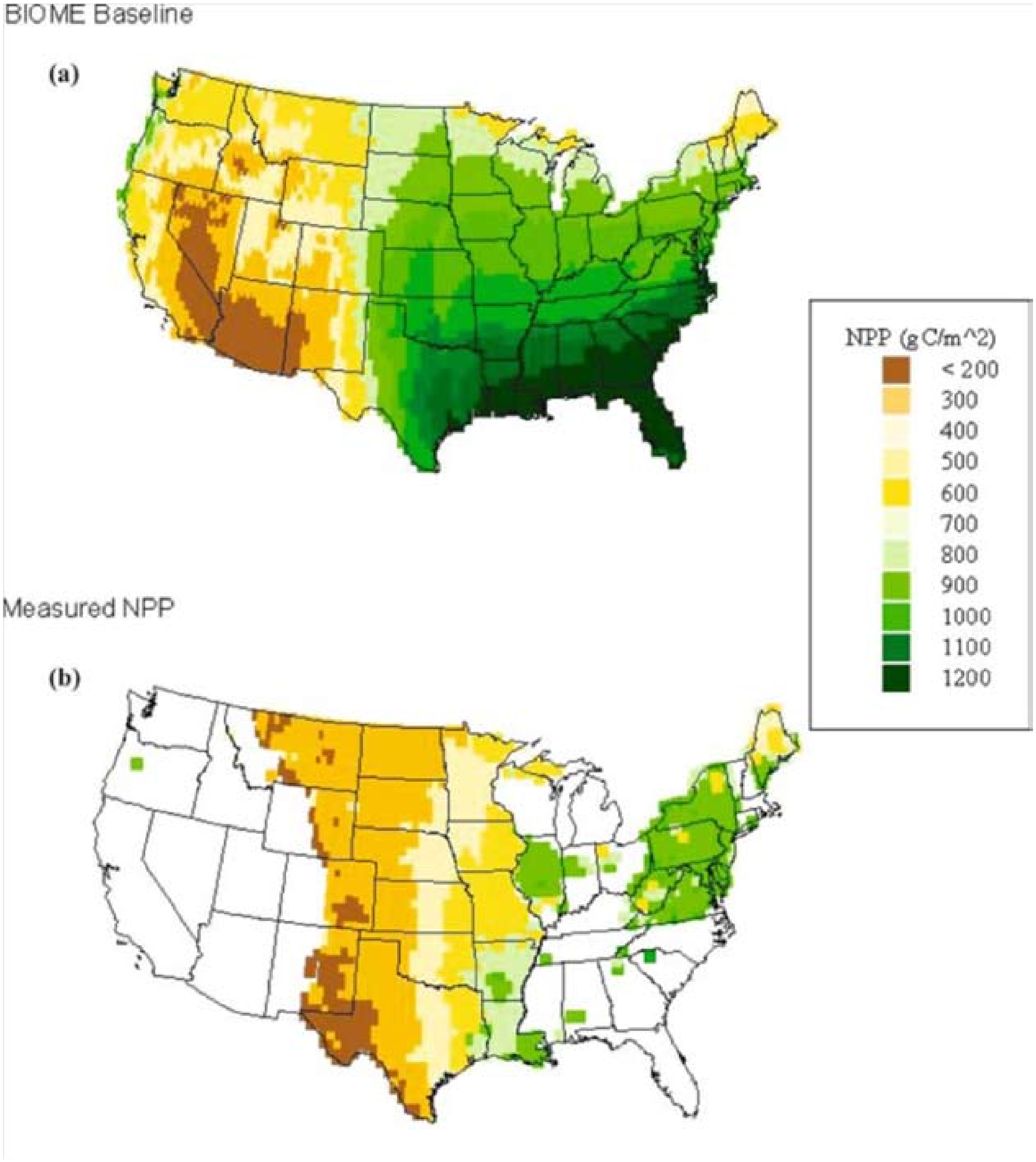
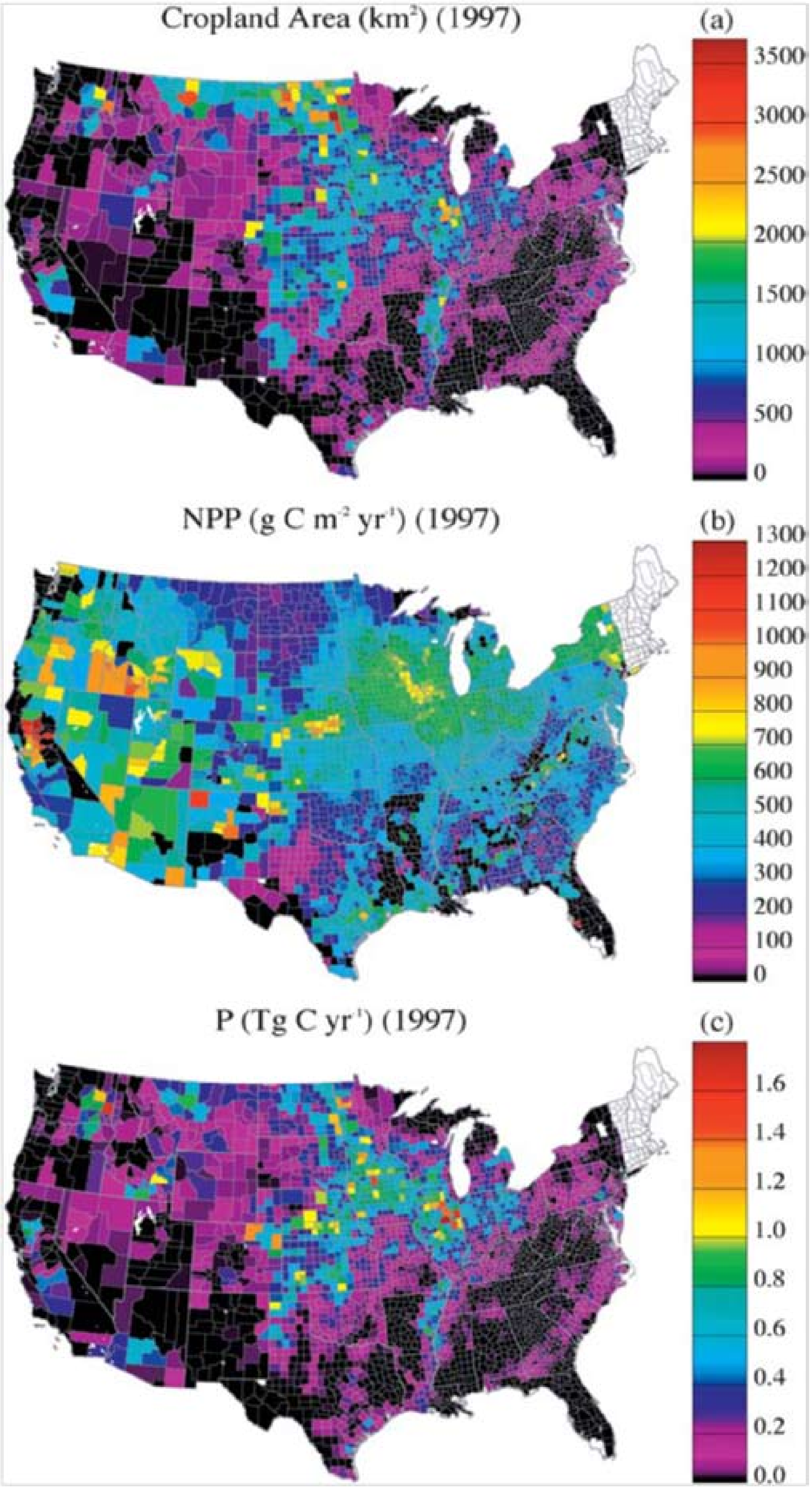


Figure 2. Annual net primary productivity (NPP, gCm−2) of unmanaged ecosystems under (a) current (baseline) climate as predicted by BIOME 3 and (b) as reported by Zheng et al. (2001). From Izaurralde et al., 2005.



Cropland Area (km^2) (1997)

NPP (g C m^{-2} yr^{-1}) (1997)

P (Tg C yr^{-1}) (1997)

Figure 3. Cropland Area, NPP from cropland, and total production by county. From Hicke et al., 2004.

Because of the factors discussed above that are critical to the sustainability and acceptability of bioenergy, it is anticipated that much of the dedicated crop feedstock production will be accomplished with lower external inputs from areas that are not currently in crop production or which are underused land. Thus regional comparisons of natural NPPs are expected to be a better guide to production of feedstocks such as perennial grasses and short rotation woody crops than current crop NPP. Modeling of miscanthus (Miscanthus x giganteus) and switchgrass (*Panicum virgatum L.*) show just this pattern with the high yields predicted for parts of the Southeast and South Central regions and the biggest difference between corn biomass yields and miscanthus biomass yields predicted for the Southeast and South Central areas. (Figures 4, 5, and 6, F. Miguez et al., unpublished).

NPP on Marginal and Underused Lands

Clearly there are challenges to growing a substantial amount of the nation's biofuels feedstocks on marginal, abandoned, and underused lands. In many cases these lands include soils that are not in use because they are less productive either due to inherent characteristics or due to earlier resource degradation. Additionally, these lands may be comparatively less productive and require higher levels of input to bring into production because they have not received soil amendments such as lime and fertilizer. Marginal cropland in uplands may be more prone to soil erosion or nutrient and pesticide leaching and require more careful management and more extensive buffer systems to produce feedstocks sustainably. Finally, although previously cultivated, the re-conversion of marginal lands to annual crops for feedstock production could lead to decreases in SOC pools (Davidson and Ackerman, 1993).

In some cases ecosystem services from marginal lands may be enhanced through production of perennial feedstock crops. Perennial crops generally have advantages over annuals in maintaining important ecosystem functions, particularly on marginal landscapes or where resources are limited (Tilman, 2009). In addition to marginal lands as defined above, other land at the margins of fields can be used as buffers to provide water quality and wildlife habitat benefits as well as providing long term feedstock production. Riparian and edge of field buffers as well as grass waterways are of great importance to water quality in many agricultural landscapes and these benefits have been documented in both empirical field studies and modeling studies (for reviews, see Mayer et al., 2007 and Vidon et al., 2010). If these buffers can be used to produce feedstocks without additional inputs, multiple benefits can be achieved in intensively managed agricultural watersheds.

Although a review of all studies of potential bioenergy crop production will not be attempted in this chapter, we will discuss a number of studies that focus specifically on marginal lands or low inputs. More complete reviews are available (e.g. Sanderson and Adler, 2008).

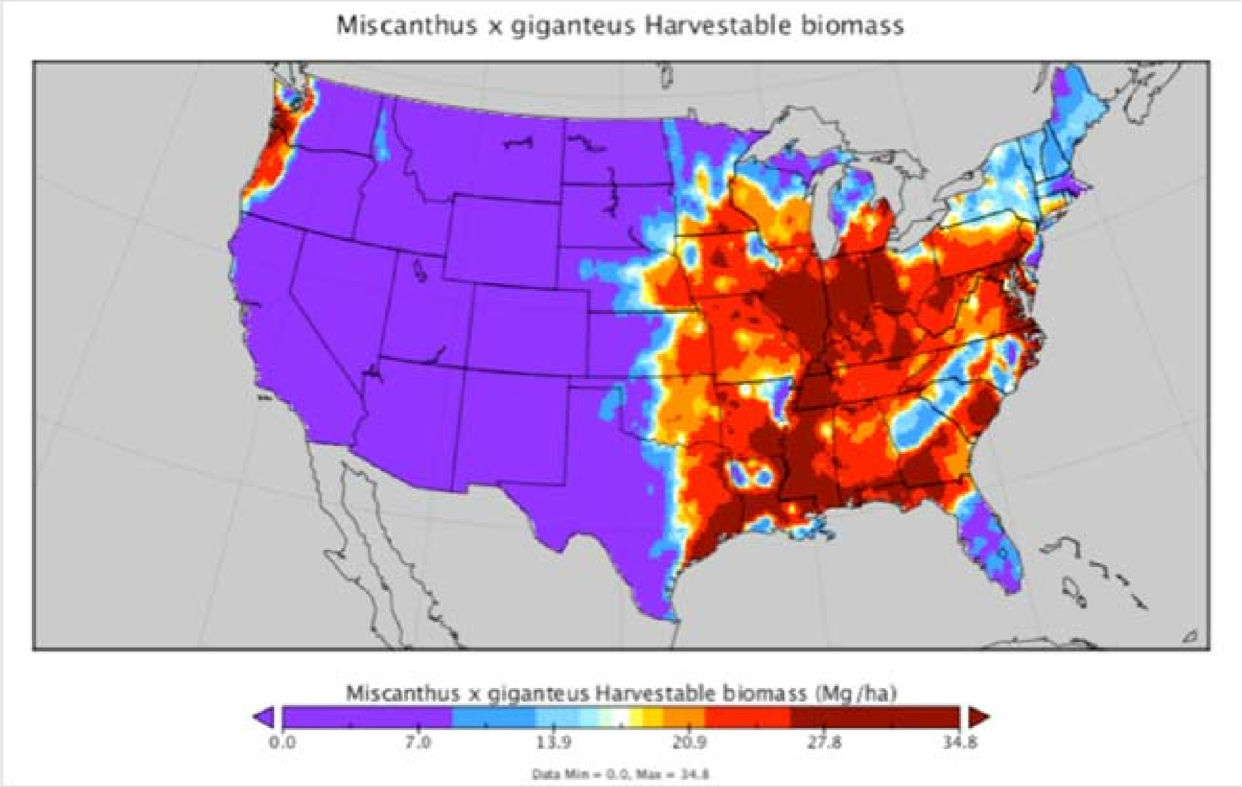


Figure 4. Predicted Miscanthus X giganteus production, harvestable biomass (F. Miguez, unpublished).

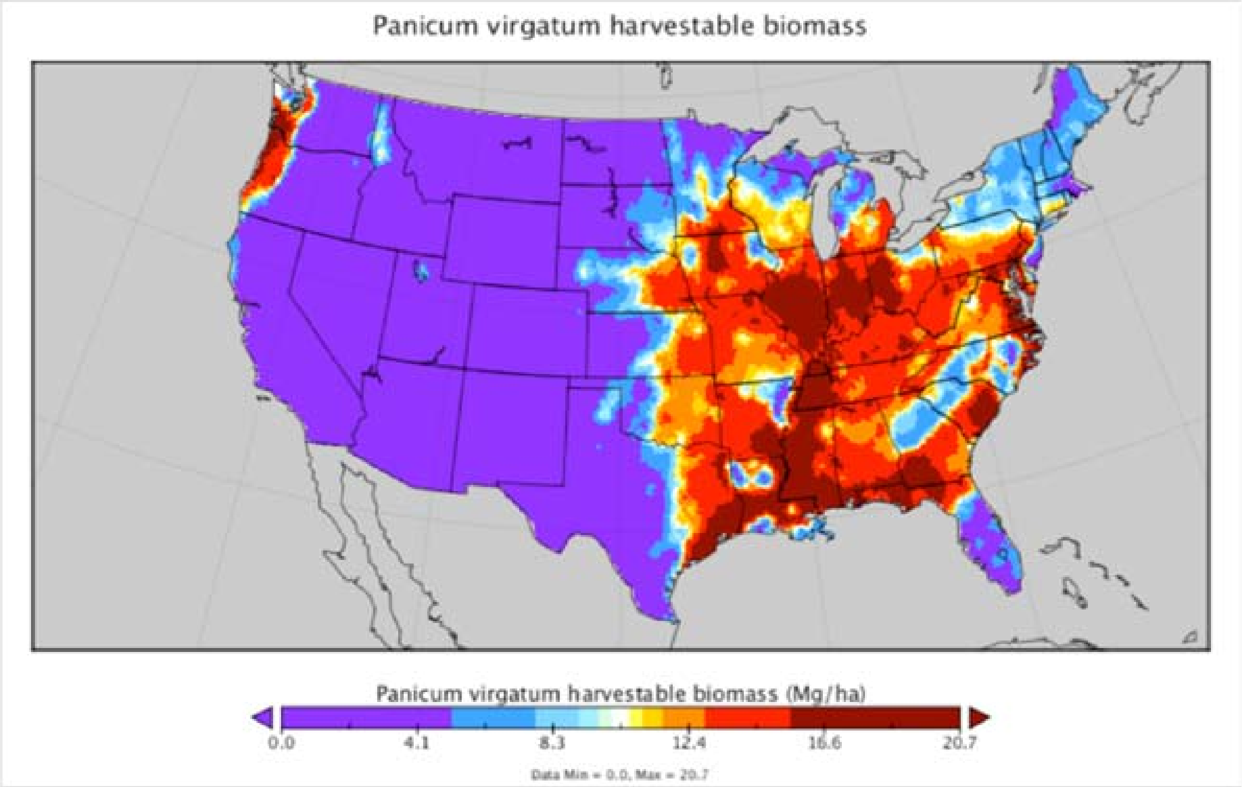


Figure 5. Predicted switchgrass production, harvestable biomass. (F. Miguez, unpublished.)

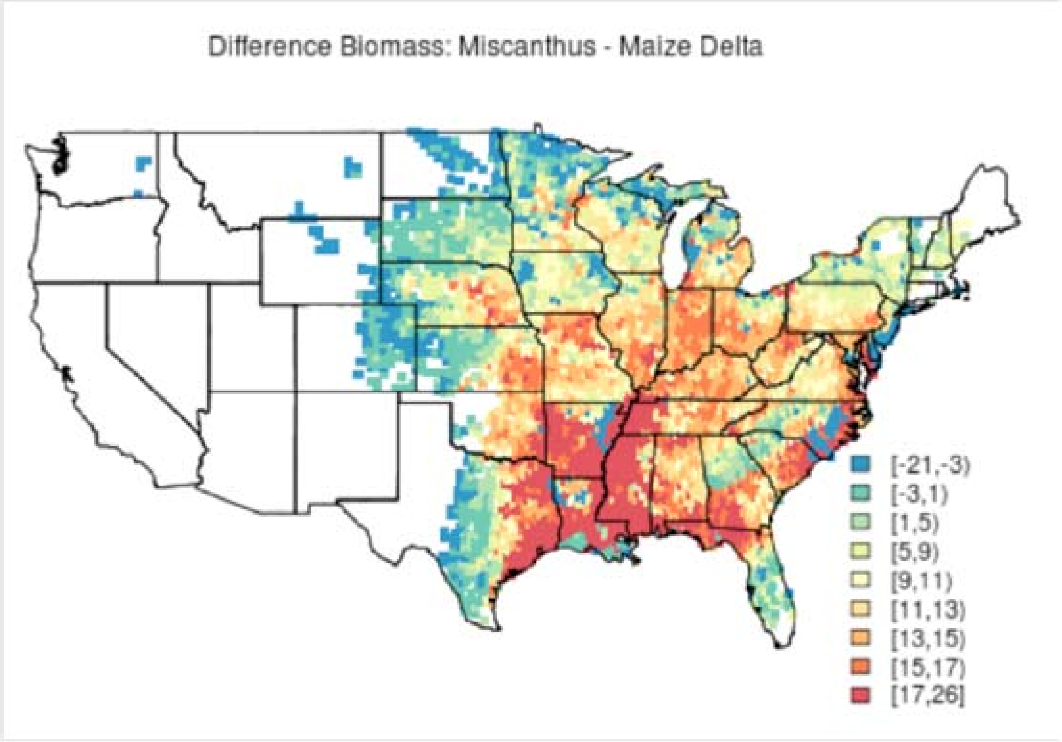


Figure 6. Difference in Maize and Miscanthus production (F. Miguez, unpublished).

Estimates of natural NPP on marginal lands are important because with minimal inputs, the amount of feedstock produced on marginal lands may be similar to that amount of ANP achieved in natural ecosystems. Campbell et al. (2008) used the natural production (ANP) as an upper limit on the production of biomass from marginal lands because on a global scale, agricultural harvest is about 65% of natural ANP. Estimates ranged from negligible to 23 Mg ha^{-1} yr^{-1} with a global average of 4.3 Mg ha^{-1} yr-^{1}. Their estimates did not account for irrigation or high fertilizer application which could increase yields. DeBolt et al (2009), in a similar study for the state of Kentucky used estimates of biomass production by three native warm season grasses; switchgrass, eastern gamagrass (*Tripsicum dactyloides* L.), and big bluestem (*Andropogon gerardii* Vitman) that ranged from 10.2 to 14.5 Mg ha^{-1} yr-1dry matter. These yield estimates were based on fertilized plots (N- 67 kg ha^{-1} yr^{-1}, P and K to soil test recommendation) of the grasses grown as monocultures (Stork et al., 2009). DeBolt et al. (2009) estimated that the abandoned land would yield 65% of the field trial yields (8.0 to 9.4 Mg ha^{-1} yr^{-1}). Gopalakrishnan (2009) estimated yields of biomass crops in Nebraska on marginal land resources as 4 Mg ha^{-1} yr^{-1} with rain fed systems and 8 Mg ha^{-1} yr^{-1} where degraded water resources (nitrate contaminated groundwater and livestock/municipal wastewater) were used for irrigation. Schmer et al. (2008) grew switchgrass on field scale plots on marginal lands with fertilizer rates up to 212 kg N ha^{-1} yr^{-1} in the Great Plains and found yields of 5.2 to 11.1 Mg ha^{-1} yr^{-1}. Ongoing research on biofuels crops in the Southeastern Coastal Plain has shown the potential for production of warm season grasses such as elephant grass (*Pennisetum purpureum* Schum.) in buffer areas on marginal or non-prime land. Preliminary data show that yields of elephant grass in buffer areas are similar to yields in upland row-crop fields receiving N fertilizer and greater than yield of the grass in upland area receiving no fertilizer (Anderson et al., unpublished). In the second year of production, elephant grass in unfertilized fields averaged about 22 Mg ha^{-1} yr^{-1} dry matter while elephant grass in buffers below a fertilized field averaged about 33 Mg ha^{-1} yr^{-1} dry matter. Five potential feedstock grasses were grown with no fertilizer applications or irrigation on a well drained agricultural soil near Tifton, GA and all showed yield declines by the 4th year of no-fertilizer application (Figure 7; Knoll et al., 2010). Yield maxima ranged from 40 Mg ha^{-1} yr^{-1} dry matter for erianthus (*Erianthus arundinaceum* Retz. Jesw.) to less than 10 Mg ha^{-1} yr^{-1} dry matter for one of the giant reed (*Arundo donax* L.) entries. By the fourth year of no fertilizer application (2009) all plots had yields less than 10 Mg ha^{-1} yr^{-1} dry matter.

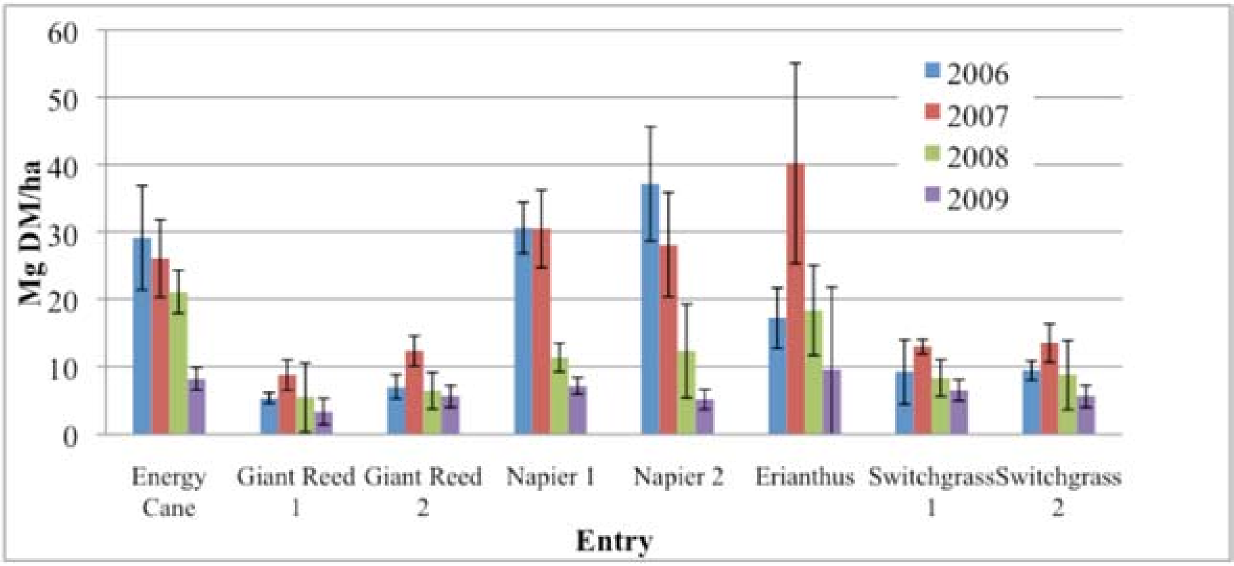


Figure 7. Annual production of perennial grasses under no-fertilizer and no-irrigation (Knoll et al., 2010).

Regional Examples

Regional examples can help illustrate both the potential and challenges for producing bioenergy feedstocks without major changes in land cover and without impacting the production of food, fiber, etc from agricultural lands and the production of wood and paper products from forest lands. At this point, few studies have been done to address whether feedstock production on marginal or underused land would be adequate to meet supply needs and what would be the sustainability challenges for this type of production. In a study of global potential of bioenergy on abandoned agricultural lands, Campbell (2008) estimated that the energy content of biomass grown on 100% of the abandoned agricultural land generally accounted for less than 10% of the primary energy demand for most developed countries. Although the biofuels produced on marginal lands could provide a larger proportion of energy demand in less developed countries, challenges exist to increase per ha production on marginal land and to determine how to bring other lands such as marginal forests into production.

Studies of how marginal lands could contribute to biofuels production in at least two U.S. states are available. Debolt et al. (2009) estimated that abandoned agricultural and mine land in Kentucky comprised over 2.2 M ha, or 21% of the total area of the state. They estimated that the biomass produced from those lands could account for 13 to 17% of the state's aggregate energy demand depending on whether the biomass was converted to cellulosic ethanol or burned to generate electricity. In a study of marginal lands in Nebraska, up to 22% of the total energy demand and the majority of feedstock for biorefineries could be produced on marginal and degraded lands, road rights of way and buffers (Gopalakrishnan, 2009).

Identification of marginal lands will vary from region to region. In portions of the country such as the Upper Midwest where the best agricultural soils are prairie soils, marginal soils may be those developed under original forest cover. Sauer et al., (2008) used the Iowa Soil Properties and Interpretations Database to identify soils that were a) formed under forest cover, b) have a corn suitability rating (CSR) less than the county average and c) which were highly erodible. Of the 14.5 million ha of land in Iowa, 1.05 million ha or 7.2% of the state land area was identified as marginal using these criteria. Using 2004 National Agricultural Statistics Service (NASS) data, 64% of this marginal land was still under agricultural land use (row crops, small grains, and pasture). Study of four representative soils of these marginal lands indicated that most of these soils were highly eroded but that soil organic carbon had increased on soils which have had reestablished forest compared to soils which have stayed in agriculture. This study points out the potential to derive multiple ecosystem services from these marginal lands if forests are re-established for bioenergy crops (Sauer et al, 2008).

The use of current agricultural landscapes for production of dedicated bioenergy feedstocks is expected at least in part because of the existing infrastructure and equipment available on the farms and in the communities of existing agricultural regions. The more agricultural parts of the Southeastern U.S. are areas where both the infrastructure and the farmers exist to produce bioenergy feedstocks in a part of the country that has some of the highest natural NPPs. To illustrate the potential in this region, we have used data on land cover and soils for the Little River Experimental Watershed (LREW, near Tifton, GA) to estimate the availability of land for feedstocks. The soils of the watershed have been grouped into prime farmland soils, non-prime farmland soils, and other soils based on county soil survey data (Calhoun, 1981, 1983; Stoner, 1990). The prime soils are listed in the Soil Survey as "prime farmland"; the non–prime soils are listed in the soil surveys as "other important agricultural soils." The other soils are generally wetland and riparian soils or soils associated with the wetland and riparian soils. Land use land cover is based on the year 2005 land cover from the Georgia Land Use Trends Project (http://narsal.uga.edu/glut.html).

Soils of the watershed are shown in Figure 8. Exactly half of the watershed is classified as prime soils and 76% of the prime soils and 54% of the non-prime soils are already in row crops/pastures (Table 1). The non-prime soil already cleared (in row crop/pasture) would be the most likely areas for producing bioenergy feedstocks while minimizing the impact on either conventional crop production or changing land cover from forest. The challenges of using these non-prime soils are illustrated by more detailed examination of the Coastal Plain Landscape (Figures 9 and 10). In the northern part of the watershed most of the non-prime and substantial portions of the prime soils are in forest cover. In the southern part of the watershed most of the non-prime soils are in crop/pasture. Producing feedstocks on non-prime land in the southern part would mainly impact existing crops while in the northern part would mainly impact forest land.

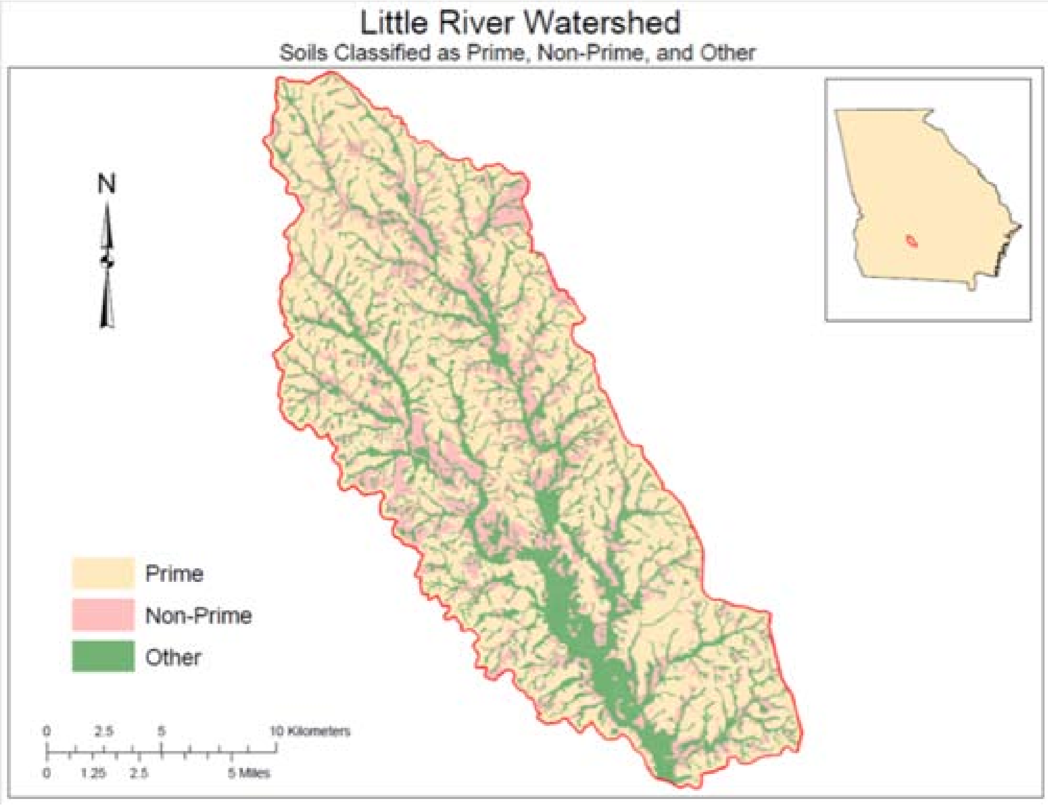


Figure 8. Soils of the Little River Watershed grouped as prime, non-prime, and other.

Land Use	Soil Classification			
	Prime (50%)	Non-Prime (19%)	Other (31%)	All Soils (100%)
Upland Forest	15%	29%	28%	22%
Row Crop/Pasture	76%	54%	26%	56%
Wetland Forest/Wetland/Open Water	2%	6%	39%	14%
Clear Cut/Sparse	1%	4%	4%	3%
Urban	6%	8%	3%	6%

Table 1 – Percentages of land cover classes in the three groups of soils in Little River Watershed in the Georgia Coastal Plain.

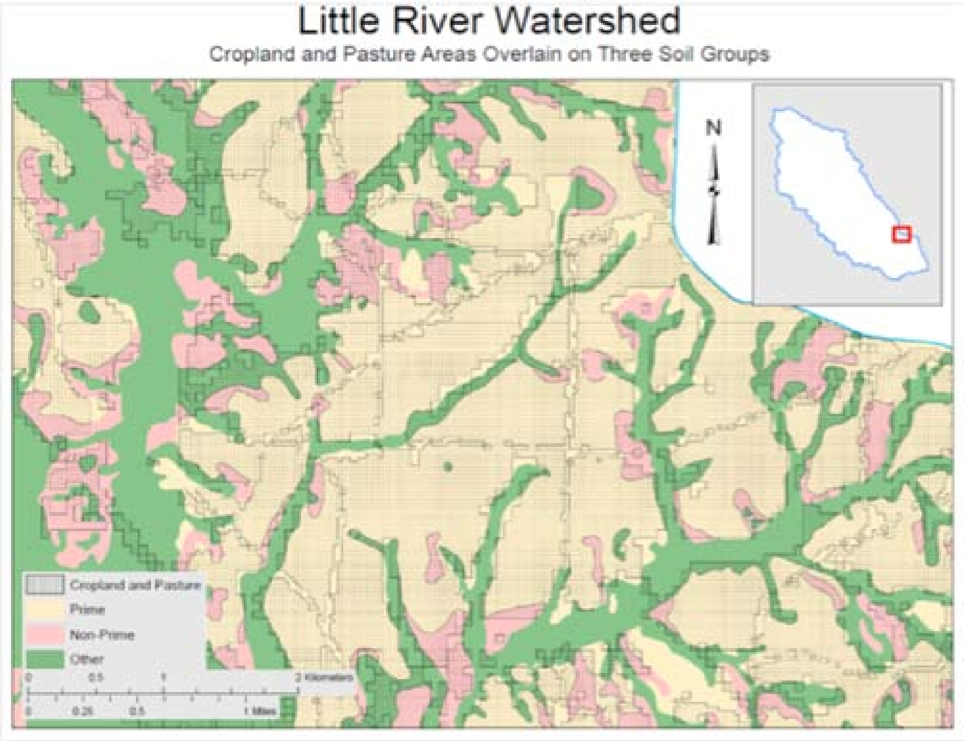


Figure 9. Land used for crops and pasture overlaid on soil groupings in southern part of LRW.

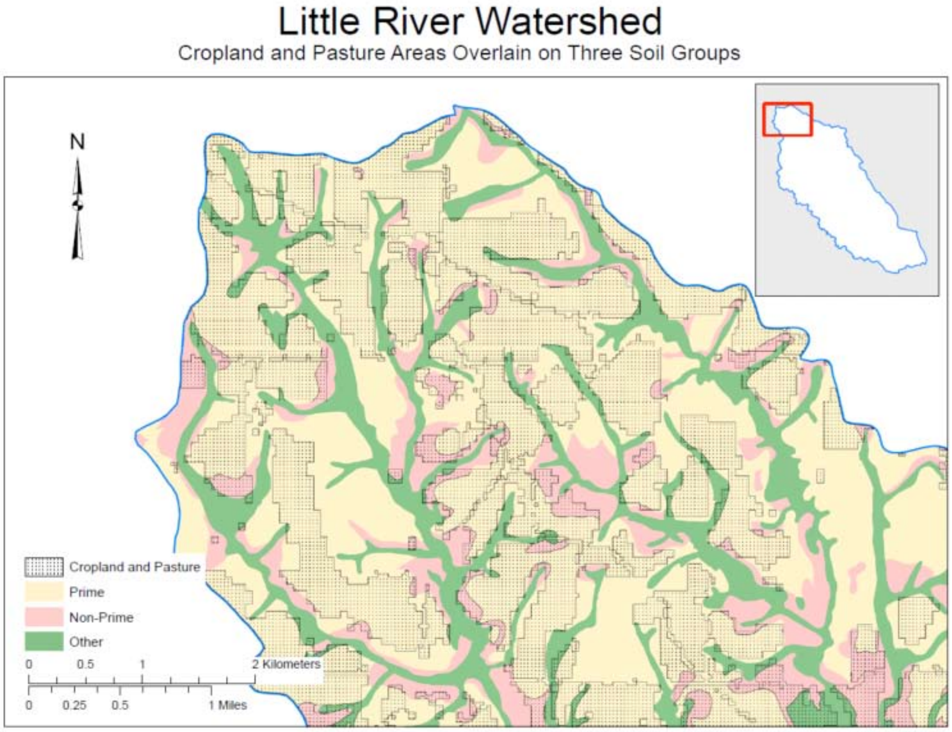


Figure 10. Land used for crops and pasture overlaid on soil groupings in northern part of LRW

Further analysis for the entire Georgia Coastal Plain region has focused on the use of non-forested riparian zones and grass waterways as feedstock production areas. Assuming that feedstock production on 14,160 ha would be necessary within 40 km of a 136 million liter per year biofuel conversion facility (criteria based on projections by Vercipia Biofuels, Tampa, FL; http://www.vercipia.com/pdfs/Highlands_FactSheet_080410_Final.pdf), we determined how much of the feedstock could be produced by re-vegetating riparian zones in 10 m buffers and grassed water ways (Figure 11). Based on land cover and hydrography, anywhere from 6% to 38% of the 14,160 ha could be gained from buffers and waterways (Table 2). The remaining acreage, if taken from agricultural land in the 40 km radius would be from 3% to 18% of the agricultural land. More heavily agricultural areas would need to devote a much smaller percentage of the total agricultural land to feedstocks under these scenarios. Based on the analysis of soil groupings in the LREW discussed above, there would be an estimated 51,750 ha of crop/pasture on non-prime land within a 40 km radius of Tifton. If the additional feedstocks (8,779 ha) were grown on these marginal lands, it would represent conversion of at least 17% of the non-prime soils to feedstocks. It should be noted that some of the area counted in buffers and waterways is on non-prime land so the total conversion of non-prime acres from current crop/pasture to feedstocks would be greater than 17%. This analysis suggests a potential for producing about 215 million liters of ethanol per year (at 270 liters per Mg dry matter and 33 Mg ha^{-1} yr^{-1} dry matter; see Strickland et al., 2010) from 10 m riparian buffer strips below fields in the Coastal Plain of Georgia.

	Area of 10 m Buffer & Grass Waterways	Total Cropland & Pasture Area	Area of Non-Buffer Cropland & Pasture Remaining	Area of Cropland & Pasture Needed	Remaining Cropland & Pasture needed for feedstock crops
Location of Biorefinery	---------------------------hectares----------------------------------				%
Tifton	5,385	269,170	263,784	8,779	3
Albany	2,669	250,740	248,071	11,496	5
Waycross	994	72,640	71,646	13,171	18
Americus	1,459	198,927	197,468	12,706	6
Camilla	1,649	224,573	222,924	12,516	6
Eastman	1,440	150,176	148,736	12,725	9
Douglas	1,705	132,542	130,837	12,459	10
Vidalia	1,162	119,702	118,539	13,002	11
Ashburn	2,740	231,226	228,485	11,424	5
Fitzgerald	2,172	189,663	187,491	11,993	6
Soperton	843	107,580	106,737	13,322	12

Table 2 – Potential changes in land use for 14,165 ha of feedstock production within 40 km of eleven cities in the Georgia Coastal Plain.

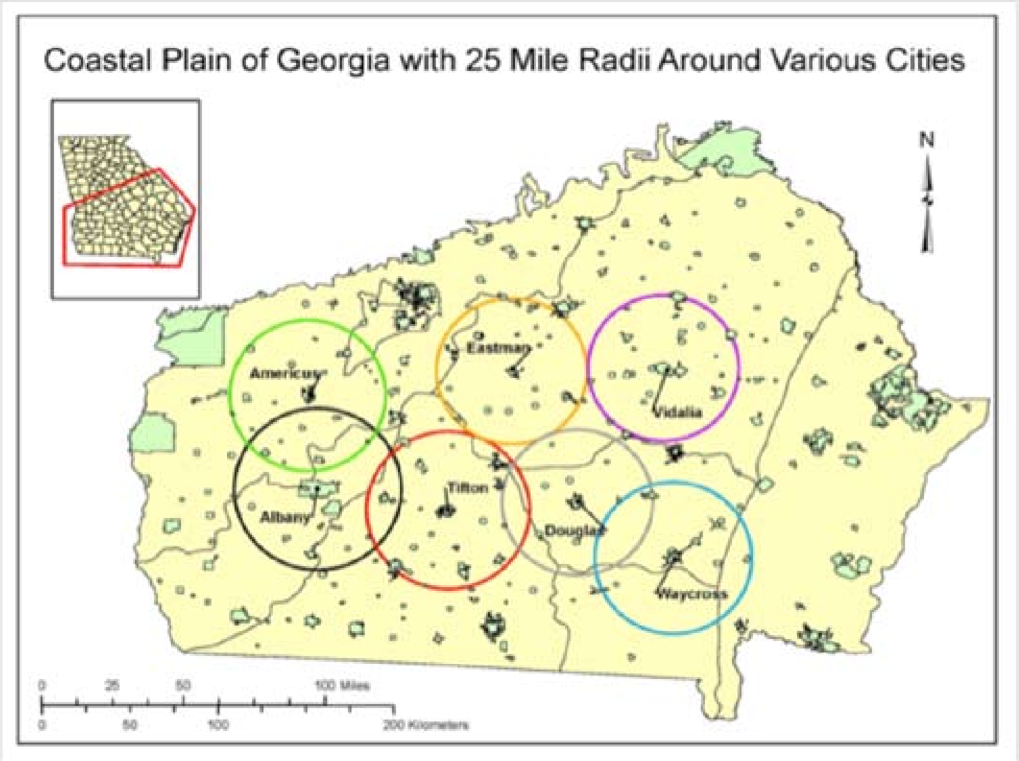


Figure 11. Coastal Plain of Georgia with 25 mile (40 km) radii around 7 of the 11 small cities.

Landscape Management and Conservation

Conservation practices are applied both at the agroecosystem level and at the agricultural landscape level. In general, for a given field, increasing the proportion of the year when vegetation is actively growing or has a living root system in place will generally lead to gains in natural resource conservation. For a landscape increasing the proportion of the landscape where vegetation is actively growing or has a living root system for most of the year will also lead to gains.

Examples of conservation practices at the agroecosystem level are numerous-nutrient management, pesticide management, residue management; contour plowing, terracing, etc. At the landscape level, conservation practices include those aimed at restoration/management of the non-agroecosystems (e.g. riparian forest buffer, wetland restoration, tree planting) as well as those practices that are designed to affect the network connecting landscape elements (e.g. grass waterways, field borders, stream bank restoration). In many cases, such as wetland restoration or enhancement, the non-agriculture portions of the landscape are needed to compensate for functions and values lost from the larger agricultural landscape.

The use of marginal, abandoned, and underused land for bioenergy feedstock production is likely to lead to the need for more conservation practices applied on both existing cropland (e.g. prime farmland) and in the bioenergy production on marginal lands. The need for conservation practices on marginal lands will be mitigated by the use of perennial crops, especially perennial native species. To the extent that sequestering of nutrients is enhanced by removal of biomass, there may be improvements in chemical water quality in areas where bioenergy crops can be grown as buffers and nutrients are harvested with biomass. In contrast, where early native successional ecosystems such as old-fields are replaced with bioenergy crops, one would expect a loss of ecosystem services. Where buffer services are lost from marginal lands, they may need to be replaced with enhanced conservation practices on existing cropland.

Landscape management conservation practices (Lowrance et al., 2006) are generally compatible with increased bioenergy feedstock production on marginal lands or on prime land. Landscape management seeks to direct the interactions among ecosystems to achieve societal objectives. Landscape management conservation practices differ in two key ways from conservation practices applied at the field-scale: (1) landscape management typically involves practices outside the main production units of a farm and (2) landscape management often requires long-term (or permanent) commitment of land to ecosystems other than those that might provide the highest short-term economic return (Lowrance et al., 2006). For this reason, landscape management generally is implemented through a series of transfer payments from society to farmers. If it is possible to produce feedstocks and achieve other landscape management goals centered on increasing the perennial coverage of the landscape, society will derive a double benefit.

Summary and Conclusions

Potentially productive lands are available for bioenergy feedstock production in many agricultural and other rural landscapes. The special sustainability constraints placed on the emerging bioenergy industry make it more likely that sustainability problems will be recognized and solved as the industry moves forward. In response to one of the first sustainability problems, the effects of feedstock production on food, feed, and fiber supplies, there is considerable interest in how bioenergy feedstocks can be produced on marginal and underused land. The advantages of using marginal lands in agricultural landscapes are numerous. First and foremost, it will provide a means of producing feedstocks without substantially reducing agricultural outputs to other sectors. This should provide both enhanced income for farmers and farm communities while also maintaining food, feed and fiber production. Second, marginal lands and buffers are embedded in an agricultural landscape where infrastructure exists for ongoing agricultural production. Thus fertilizer and chemical dealers, transportation and processing infrastructure and water supply infrastructure will generally be available. Thirdly, when marginal lands and buffers are brought into production in areas of existing agricultural production, the feedstocks grown on the expanded land base can be integrated with feedstocks produced on existing agricultural lands, especially feedstock crops that are grown in rotation with existing non-feedstock crops. Finally, establishment of perennial feedstock crops such as native warm season grasses and short rotation woody crops on marginal lands and buffers may provide environmental benefits such as increased soil organic carbon sequestration and improvements in wildlife habitat on those lands (Blanco-Canqui, 2010).

Substantial challenges exist for use of abandoned, marginal, or underused land for feedstock production. In the U.S. these marginal lands or non-prime farmlands defy easy definition. In many landscapes the marginal lands are either eroded, have leaching problems, or have wetness constraints. In some landscapes they are scattered at the margins of prime farmland or may be linear corridors such as utility rights of way and roads. To the extent that perennial vegetation can be grown and achieve simultaneous conservation benefits associated with perennial growth habits, feedstock production may provide multiple societal benefits of replacing fossil fuels, holding soil in place, and building soil organic carbon.

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