Modeling Recreational Demand for Land in a CGE Framework

Blandine Antoine*
Angelo Gurgel+
John M. Reilly‡

Abstract

We represent recreational demand for land in a CGE framework and apply it to investigate the potential of second generation biofuels production under possibilities of land use conversion from natural areas to agricultural land in the U.S, considering the recreational value of forests. We introduce recreational benefits of natural forests through "household" production sectors for hunting and fishing, for wildlife viewing in reserved areas, and wildlife viewing in other forest areas, based on extensive data available in the U.S. about those activities. We test the model assessing the land use changes and welfare impacts from a U.S. climate policy scenario. The new approach resulted in similar land use change as earlier work where land conversion was limited by an elasticity based on observed land supply response. The advantage of the new approach built here using recreation data is that it provides an obviously improved measure of welfare cost of policies that lead to land use change, because the preservation value of the land offsets the increased cost of the policy due to the restriction on use. The results are sensitive to the representation of people's willingness to substitute other inputs for natural land in their recreation experience, parameter not being well investigated empirically. The main contribution of the paper is not for its insights on biofuels potential but for the improved representation of welfare changes from models where the land supply response limits conversion.

Keywords: computable general equilibrium model, recreational services, land use change, biofuels

* Massachusetts Institute of Technology and Universit´e Paris-Est - CIRED, blandine@mit.edu
+ Massachusetts Institute of Technology and University of Sao Paulo, gurgel@mit.edu
‡ Massachusetts Institute of Technology, jreilly@mit.edu

1. Introduction

Competition for land will affect the potential for biofuels, food prices, and the provision of other "ecosystem services." There is much economic data and a strong tradition of economic modeling of the supply and demand for traditional market goods—food, fodder, and forest products—that might be counted as "ecosystem services." The potentially large role of biomass as a feedstock for low-carbon energy (electricity, transportation fuels and heat) has also received attention (IPCC, 2001, Reilly and Paltsev, 2007). Computable general equilibrium models have been widely used in climate change research for modeling mitigation costs (Whalley and Wiggle, 1990; Goulder, 1995; Paltsev, *et al.*, 2008) and more recently to investigate the impacts of environmental change (Matus *et al.*, 2008). A particular advantage of the CGE framework is that it allows a consistent estimate of welfare change and so provides a basis for cost-benefit analysis.

Gurgel *et al.* (2007) developed an approach to consistently represent land use in a CGE framework. A key issue that arose in that work is what to do with unmanaged land. Inputs and outputs in the CGE framework are measured in dollar terms—expenditures or rents paid—on a category of goods. As such, goods or inputs with different attributes are weighted by a price that, following neoclassical economic theory, reflects their marginal value. "Non-market" ecosystem values of land are not explicitly reflected in normal economic accounting. Gurgel *et al.* (2007) augmented standard economic data to assess the value of timber stocks and future timber harvests on unmanaged land. Here we augment that approach by creating a recreation service demand for land to more explicitly address the flow of welfare benefits from that land. We build on a standard partial equilibrium approach for valuing recreational land, which is generally referred to as the travel cost method. We then consider the implications of this formulation for competition for land, under conditions where biofuels strongly enter the market. In particular, we are interested in whether this formulation leads to less land available for other uses—biofuels, crops, forestry products, grazing—and whether it changes our estimate of costs of a greenhouse gas mitigation policy measured as welfare changes.[1]

The paper is organized as follows. In Section 2 we briefly describe the relationship of our approach to the existing literature. Section 3 describes the Emissions Prediction and Policy Analysis (EPPA) model and how we have augmented it to examine recreation demand. Section 4 provides results where we simulate the model under reference conditions and under a future greenhouse gas mitigation policy. Section 5 offers our conclusions

[1] As this special edition is devoted to the memory of Bruce Gardner we note that one of his consistent contributions to policy analysis over the years was an insistence on careful application of welfare analysis to policy issues. We hope this contribution to improving welfare analysis of an important policy issue is a fitting tribute to him.

2. Relationship to Existing Literature

This paper brings together two strands of literature. One strand is that of non-market valuation, based on partial equilibrium analysis. The goal of this work is simply to estimate a value for some public good—demands and all prices of market goods are taken as fixed and it is "simply" a matter of coming up with a number for the unobserved value of the ecosystem service. The question this work seeks to answer is whether it is worth it to protect an ecosystem asset, or if one is destroyed, what is the value of the associated damage. A second strand of the literature involves efforts to represent the "supply" of land. Often this is a partial equilibrium analysis as well: although these models find a market clearing price for the sectors of the economy they focus on—forestry or agriculture for example—they take other prices for labor, capital, and other inputs as fixed. Implicit in a land supply function is that there are other uses of land not included in the model. Welfare calculations are based on estimating consumer and producer surplus.

With regard to non-market valuation, there are a variety of non-market valuation techniques that deal with different classes of public goods (e.g. Smith, 1996) and there have been large and controversial efforts to associate values with all ecosystem services (see for e.g. Costanza *et al.*, 1997). Here we focus on outdoor recreation—hunting, fishing, and wildlife viewing. This does not address values for nutrient cycling, water management and storage related to land cover, or non-use values of land—the value of simply knowing pristine land exists somewhere or the option value of preserving it on the basis that one might use it (i.e. actual visit it) in the future. Given our limited focus, our valuation approach is closely related to the travel cost method for valuing recreational services of land. See, for example, a survey by Rosenberger and Loomis (2000). That is: we associate expenditures on market goods used in conjunction with the recreation experience to build up the value of outdoor recreation.

In terms of modeling land supply, an example is the intertemporal model of global forestry and land use of Sohngen and Mendelsohn (2007). They explicitly treat currently unmanaged land, and develop a representation of conditions under which it would be harvested. They also consider possible augmentation of forest land through a supply function, where, implicitly, the land would be reallocated from other uses. Computable general equilibrium models include the entire economy and so implicitly include land. However, unless land-using sectors are a particular focus of the model, land is often undifferentiated from the capital, and thus implicitly producible. What matters for economic models of this type is the economic value of land. Indeed, investment in it can improve land and thus increase its "quantity" in economic terms—i.e. in terms of how much can be produced from it. Thus, for shorter term analysis, explicit treatment of physical limits on land is likely not relevant.

Interest in agriculture and environmental issues where potentially new large demands for land may occur has led to more effort to bringing land explicitly into the CGE framework. An immediate advantage is that land must be explicitly allocated among uses since, by definition, the CGE framework covers the entire economy. Eickhout *et al.* (2008) assumes Constant Elasticity of Transformation (CET) functions among agricultural land types, and a land supply function that transforms non-agricultural land into agricultural land. The land supply is built assuming that land rents must vary in direct proportion to yields. Alternatively, Gouel and Hertel (2006) and Gollub *et al.* (2008) represent the possibility of conversion of unmanaged forest land to agricultural use assuming that new land is accessed only when present value of returns on land is high enough to cover costs of accessing new land. Access costs are modeled in order to capture explicit costs in accessing new areas, such as building roads and infrastructure, and short run adjustment costs that increase with higher conversion rates of natural areas.

The Gurgel *et al.* (2007) work on which we build produces higher productivity land from lower productivity land by adding inputs—essentially investing in land improvements. Two versions of the model were developed—one that limited conversion through an elasticity of substitution that was based on observed willingness to convert land and a second that simply allowed any conversion that was economic. The second version tended to lead to more conversion than we would expect based on historical evidence. A key element, especially in the second specification, is what value to place on currently "unused" land. If there are no restrictions on its use, then the implication is that it is of no current value; however, placing a zero value on it in the CGE framework means it simply does not exist. Gurgel *et al.* 2007 got around this by valuing the potential future harvest of the stock of standing timber and the residual value of land from future regrowth and harvest.

The modeling papers cited above are only interested in unmanaged land to the extent that it is a source of land supply for traditional market goods. An early attempt to address ecosystem impacts was that of Lewandrowski *et al.* (1999) who used a CGE framework to estimate the costs of protecting global ecosystem diversity, but such an approach does not get at the value of the protected land. In a more explicit set up, Cretegny (2001) included environmental services from agriculture in a CGE model. He assumed that protection of natural resources and maintenance of landscape are produced as public goods from a joint production of public and private agricultural goods. Use of environmentally friendly techniques, meeting specific government criteria and standards, generate a public good which is remunerated by the government to the farmers. Another way to capture ecosystem services was used by Pattanayak *et al.* (2007), who assumed that changes in labor endowments are due to disease vectors associated with changes in biodiversity under adverse climate change. They also considered, as had Lewandrowski *et al.*, the cost of protecting ecosystems by constraining the model to prevent land conversion.

Our approach is in the vein of this latter group of studies, especially those that attempt to explicitly value non-market ecosystem services. We develop an approach to add a recreational demand for land that we hope can better explain why forest conversion is not as rapid as we otherwise might expect. That was achieved with the elasticity formulation of Gurgel *et al.* 2007, although a peculiar aspect of that approach was that it slowed conversion while the value of the unmanaged land remained low. If people indeed resist converting land, then that should be expressed as value in welfare terms. The main contribution from this work is thus to propose an improved estimate of welfare cost. In particular, *ad hoc* supply curves restrict land use and raise the cost of policies that would lead to greater land use, but do not explicitly value the land conserved by the restriction.

3. The Model

3.1. The MIT Emissions Prediction and Policy Analysis model

The MIT Emissions Prediction and Policy Analysis (EPPA) model is a recursive dynamic multi-regional computable general equilibrium (CGE) model of the world economy (Paltsev *et al.*, 2005). Built on the GTAP data set, which accommodates a consistent representation of energy markets in physical units as well as detailed accounts of regional production and bilateral trade flows (Hertel, 1997; Dimaranan and McDougall, 2002), it uses additional data for greenhouse gas and urban gas emissions.

The EPPA model used here augments that developed in Gurgel *et al.* (2007) and includes 16 regions, 24 sectors, and 15 primary factors as shown in **Table 1**. The additional recreation sectors and forest types added for this paper are shown in non-italicized bold and are described more fully in Sections 3.2 to 3.6. The base year for the EPPA model is 1997. From 2000 onward, it is solved recursively at 5-years intervals. The EPPA model production and consumption sectors are represented by nested Constant Elasticity of Substitution (CES) production functions (including the Cobb-Douglas and Leontief special cases of the CES). The model is written in GAMS-MPSGE (Rutherford, 1995) and has been used in a wide variety of policy applications (e.g. Jacoby *et al.*, 1997; Reilly *et al.*, 1999; Babiker *et al.*, 2003; Reilly and Paltsev, 2007; Gurgel *et al.*, 2007).

Because of its focus on climate policy, the EPPA model further disaggregates the GTAP data for energy supply technologies. It includes a number of energy supply technologies that were not in widespread use in 1997 but could take market share in the future under changed energy price or climate policy conditions. Bottom-up engineering details are incorporated in EPPA in the representation of these alternative energy supply technologies.

Competition for labor, capital, land and other resources in the economy is represented in the model. Backstop energy technologies (including electricity and liquid fuels from biomass) endogenously enter if and when they become economically competitive with existing technologies. Competitiveness of different technologies depends on the endogenously determined prices for all inputs, as those prices depend on depletion of resources, climate policy, and other forces driving economic growth such as the savings, investment, energy-efficiency improvements, and the productivity of labor.

Two main changes are made to this core model in order to proceed with our endeavor: further disaggregate the land categories used in EPPA on one hand, build the recreational services functions on the other.

Table 1. Regions, Sectors, and Primary Factors in the EPPA Model

Country or Region	Sectors	Factors
Developed	***Non-Energy***	Capital
United States (USA)	Services (SERV)	Labor
Canada (CAN)	Energy-Intensive (EINT)	***Energy Resources***
Japan (JPN)	Other Industries (OTHR)	Crude Oil
European Union+ (EUR)	Commercial Transp. (TRAN)	Natural Gas
Australia/N.Zealand (ANZ)	Household Transp. (HTRN)	Coal
Former Soviet Union (FSU)	***Other HH Consumption - Recreation***	Oil Shale
Eastern Europe (EET)	**Hunting and Fishing (REHF)**	Nuclear
Developing	**Wildlife Viewing in Reserves (REWV_R)**	Hydro
India (IND)	**Other Wildlife Viewing (REWV_N)**	Wind/Solar
China (CHN)	***Fuels***	***Land***
Indonesia (IDZ)	Coal (COAL)	Cropland
Higher Inc. East Asia (ASI)	Crude Oil (OIL)	Pastureland
Mexico (MEX)	Refined Oil (ROIL)	Managed Forest
Centr. & S. America (LAM)	Natural Gas (GAS)	**Non-Reserved**
Middle East (MES)	Oil from Shale (SYNO)	**Natural Forest**
Africa (AFR)	Synthetic Gas (SYNG)	**Reserved Natural**
Rest of World (ROW)	Liquids from Biomass (B-OIL)	**Forest**
	Electricity Generation	Natural Grassland
	Fossil (ELEC)	Other
	Hydro (HYDR)	
	Nuclear (NUCL)	
	Solar and Wind (SOLW)	
	Biomass (BIOM)	
	Coal with CCS (IGCAP)	
	Adv. gas without CCS (NGCC)	
	Gas with CCS (NGCAP)	
	Agriculture	
	Crops (CROP)	
	Livestock (LIVE)	
	Forest products (FORS)	
	Food Processing (FOOD)	

Note: Additions for this work are shown in non-italicized bold. Detail on the regional composition is provided in Paltsev *et al.* (2005). CROP, LIVE, FORS, FOOD, SERV, EINT, OTHR, COAL, OIL, ROIL, GAS sectors are aggregated from the GTAP data (Dimaranan and McDougall, 2002), TRAN and HTRN sectors are disaggregated as documented in Paltsev *et al.* (2004), HYDR and NUCL are disaggregated from electricity sector (ELY) of the GTAP dataset based on EIA data (2006), BIOM, NGCC, NGCAP, IGCAP, SOLW, B-OIL, SYNO, SYNG sectors are advanced technology sectors that do not exist explicitly in the GTAP dataset.

3.2. Initial Land Endowments

Whereas the land categories resulting from the aggregation of GTAP data were previously limited to cropland, pasture, managed forests, unmanaged forests, natural grassland and other (**Table 2**), two new categories of unmanaged forests are created. Non reserved forests (NNFORS) are natural forests that are not institutionally protected and can be converted to managed forests. Reserved forests (RNFORS) are natural forests that are institutionally protected and cannot be converted to managed land types. They include natural parks, biodiversity forest reserves and other types of protected forests.

Table 2. Land use allocation in EPPA's base year (Mha)

	Pasture	Cropland	Managed Forest	Natural Grass	Natural Forest	Other Land	TOTAL
USA	119.2	186.6	119.4	98.4	263.8	174.3	962
CAN	12.1	52.8	34.6	11.1	333.3	574.9	1019
MEX	59.6	21.9	45.6	15.8	52.2	8.6	204
JPN	0.6	4.6	10.3	0.0	25.7	0.5	42
ANZ	301.2	22.5	38.6	52.3	190.8	22.1	628
EUR	43.2	87.5	67.7	21.8	96.1	88.9	405
EET	10.9	49.5	20.0	2.4	4.5	3.6	91
FSU	294.4	272.9	90.8	68.0	756.0	536.2	2018
ASI	0.1	46.5	6.1	6.6	74.4	4.2	138
CHN	184.8	199.5	53.3	60.3	185.3	256.3	939
IND	6.2	177.0	31.1	12.7	77.0	17.4	321
IDZ	4.9	25.6	7.3	0.4	142.8	26.5	208
AFR	744.4	160.8	290.2	296.7	497.4	1031.4	3021
MES	183.2	13.7	14.5	96.1	68.0	147.9	523
LAM	377.9	158.3	202.9	149.9	749.0	236.0	1874
ROW	149.7	119.3	31.3	99.6	191.9	272.5	864
TOTAL	2493	1599	1064	992	3708	3401	13257

Source: Underlying data based on Hurtt *et al.* (2006), here summarized by EPPA region

We use data from the World Resource Institute's (WRI) EarthTrends database (WRI, 2000). In the category "Forests, Grasslands and Drylands", we sum the areas of "protected non-tropical forest", "protected tropical forest" and "protected disturbed natural forest and plantation" to obtain the area of protected natural forest as of 2000. The data from the 159 countries is then aggregated to indicate how much protected forest there is in each of the EPPA regions. The EarthTrends database also provides data on total forest area in 168 countries (including plantations). Because the forest data differs somewhat from the data in EPPA we apply the fraction of protected forest from the WRI data to the EPPA total forested area (**Table 3**).

Table 3. Protected and non protected forest areas per EPPA region (km^2)

	WRI total forest (km²) in 2000	WRI protected forest (km²) in 2000	% of protected forest in total forest	Total EPPA forest = FORS + NFORS	Protected forest RNFORS	Non-protected natural forest NNFORS
USA	3,022,940	296,582	9.8%	3,832,291	375,988	2,261,902
CAN	3,101,340	400,054	12.9%	3,679,810	474,673	2,858,806
MEX	655,400	26,163	4.0%	977,620	39,026	482,874
JPN	248,760	8,266	3.3%	359,424	11,943	244,714
ANZ	1,728,710	122,900	7.1%	2,294,542	163,127	1,745,184
EUR	1,369,730	98,676	7.2%	1,637,657	117,978	842,691
EET	265,040	32,133	12.1%	244,413	29,632	15,179
FSU	8,500,730	163,061	1.9%	8,467,855	162,430	7,397,418
ASI	506,560	70,561	13.9%	804,811	112,106	632,092
CHN	1,770,010	44,638	2.5%	2,385,547	60,161	1,792,885
IND	675,540	47,927	7.1%	1,080,812	76,680	693,551
IDZ	978,520	185,342	18.9%	1,501,024	284,310	1,144,016
AFR	6,553,480	496,389	7.6%	7,876,014	596,563	4,377,526
MES	162,970	2,818	1.7%	824,211	14,252	665,258
LAM	8,734,850	936,019	10.7%	9,519,270	1,020,077	6,470,354
ROW	1,583,470	154,761	9.8%	2,232,855	218,229	1,701,269
TOTAL	39,858,050	3,086,290	7.74%	47,718,156	3,757,175	33,325,719

3.3. Government Expenditures to Maintain Protected Forests

The protected areas need government expenditure to be maintained. As described further below, we used data on expenditures for protection and maintenance of these areas together with the land itself in a production structure that "produces" improved protected forest area. James *et al.* (1999) compiled data on these protection expenditures for 108 countries. We used the average expenditure per km² from these data for each EPPA region (**Table 4**).

Table 4. Government expenditure per km^2 of protected forests, in 1996 US$ (extrapolated from James *et al.*, 1999)

	USA	CAN	MEX	JPN[1]	ANZ	EUR	EET	FSU
Protected area reported in James *et al.* (1999) in km^2	693,765	295,345	107,061		111,177	222,597	45,941	5,762
Reported budget / km^2	2,560	1,104	52		1,032	2,227	778	575
PPP	1.00			0.69				
Calculated budget / km^2	2,560	1,104	52	3,873	1,032	2,227	778	575

	ASI	CHN[1]	IND	IDZ[1]	AFR	MES	LAM	ROW[1]
Protected area reported in James *et al.* (1999) in km^2	81,504	417	1,011		939,535	338,489	633,819	117,828
Reported budget / km^2	1,988	69,036	277		127	42	153	1,619
PPP		4.46		3.99				
Calculated budget / km^2	1,988	574	277	642	127	42	153	567

[1]Data were absent or adjusted for these regions. We used US data per km^2 adjusted for purchase power parity (PPP) for JPN, CHN, and IDZ. For ROW we excluded the Pacific Islands expenditure data because it was not representative of the rest of this large region.

3.4. Land-use Change Mechanisms

As in the version of EPPA described by Gurgel *et al.* (2007), land use can change over time, in response to changes in land relative values. We extend the same approach to include new forest types. We allow non reserved natural forests (NNFORS) to be converted to managed forests (FORS) or protected natural forest (RNFORS). We assume that existing and future additions to protected natural forests (RNFORS) are protected indefinitely. We use a Leontief production structure to combine land of type RNFORS with government expenditures on protection to produce Improved Reserved Natural Forest (INFORS; see **Figure 1**).

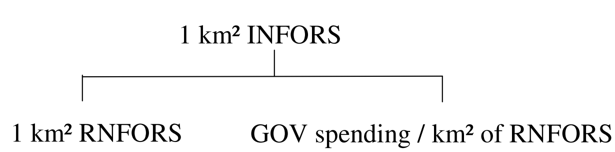


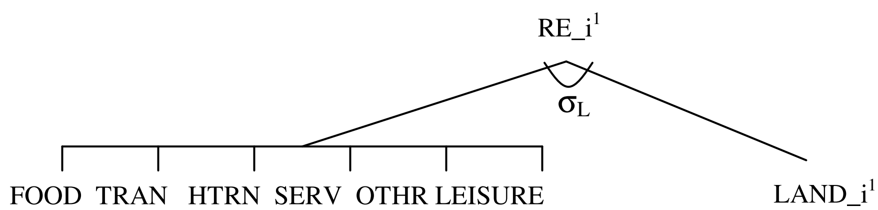
Figure 1. Production of improved protected natural forest.

3.5. The Outdoor Recreation Sector

We introduce an outdoor recreation sector in the household sector. The basic approach is consistent with the familiar travel cost method (TCM) for valuing natural systems as discussed earlier. The TCM approach adds up the households costs of reaching a site and other related expenditures including the value of people's time. The data to support this development exists for the US, and we describe the US data and the structure of the sector in this section. In Section 3.6 we describe how we extend these data to other regions.

For time spent, we use US census data on the number of days that American hunters, anglers and wildlife watchers spent in wildlife related recreation activities in 1996, and assume this applies to our base year of 1997.[2] Multiplied by the net average daily wage paid to American workers in 1997,[3] this time expense is the Leisure input in the outdoor recreation services (see **Figure 2**).

The 2000 US census also includes data on sportsmen's expenditures on food (FOOD), lodging (SERV), public transportation (TRAN), private transportation (HTRN), other trip related costs and diverse expenditures (OTHR), as well as sport specific, auxiliary and special equipment (OTHR). The partition of expenses among these different goods is very similar for fishing and hunting activities; we thus aggregated them into a single sector (REHF). Wildlife watching is represented as two activities, one that takes place in parks and nature reserves (REWV_R) and one that takes place in non-reserved forested areas (REWV_N). These data allow us to fully parameterize the recreation services sectors for the US as shown in **Figure 2**.



[1]Land_i = NNFORS for RE_i = REHF or REWV_N ; Land_i = RNFORS for RE_i = REWN_R

Figure 2. Structure of the outdoor recreational services functions.

[2] The US Census (US Census Bureau, 2000) data includes days spent wildlife viewing only for those activities that occur more than one mile from home, called "non-residential" viewing. The data provide the number of people who participate in wildlife viewing from their residence but there is no count of the number days they spend. To associate some time with the "residential" viewing activity we assumed that it was the same per viewer per year as for nonresidential viewing.

[3] http://www.ssa.gov/OACT/COLA/awidevelop.html (accessed on August 11th 2008)

The REHF and REWV_N use non reserved natural forests, leisure, public and private transportation, food, services, and intermediate inputs from other industries. Wildlife viewing in parks and reserves is identical except that it uses improved reserved forests, rather than non reserved natural land. This structure allows us to protect this land indefinitely. The productivity of land of all types is augmented exogenously and is modeled as a non-depletable resource. Forested area has public good attributes. The implication of our models structure—more demand for recreation creates more demand for forest land—means forest area is represented as a "congestible" public good.

This approach is an initial attempt to bring the recreation services of land into the CGE framework as a test of whether including such a demand for land changes our estimates of the amount potentially available for biofuels and our estimates of welfare costs of climate policy. There are many further refinements that are possible.

One issue that arises is the association of expenditures on these outdoor activities with natural forest areas. Doing so means that these activities occur on, and are only possible because of the presence of, natural forests. Clearly these activities also occur on grasslands, grazing, and cropland. Extensive fishing on the Great Lakes is not directly related to forest cover. An improved representation would try to create different activities related to these specific resource types; however, in many cases these resources are inter-related (a hunting or wildlife viewing activity on cropland area may benefit from a woodland that provides shelter and habitat; water quality and the quality of the fishing experience may be enhanced by forest cover). Thus, one can, at some level, question the separability of these different resource inputs.

A second issue arises in representing recreation services in a market framework. This means that increased demand for improved natural forestland is met as if it was supplied by a competitive producer. In fact, these lands may be in public hands; these agencies (or the private owners) do not directly recover full costs of maintenance or lack the ability to enforce pricing for use of these services. For our approach to represent reality, we must imagine a process where public agencies that manage this land respond to public pressure and a willingness of taxpayers to support the purchase of more area and maintenance of it.

Finally, the critical parameters are substitution elasticities between land and other inputs in the recreation structure (σ_L in Figure 2), and between recreation and other consumption in the consumption structure (σ_{rec}) in **Figure 3**. The parameter σ_L represents the ability to create a valuable recreation experience with less land—perhaps creating stocked hunting and fishing areas, hiring guides, augmenting the experience with more equipment and lodging, or traveling further to avoid congested areas. The parameter σ_{rec} represents the ability to substitute completely different activities for outdoor recreation such as going to the movies, playing a baseball game, etc.

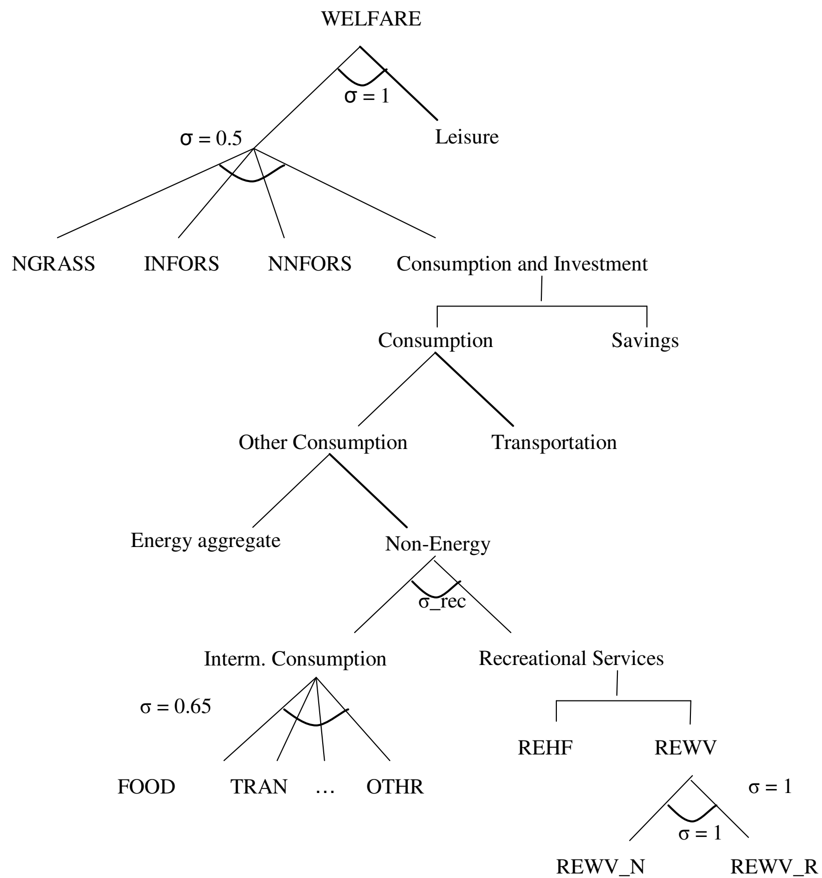


Figure 3. Production function for each of the outdoor recreational services.

Unfortunately, the non-market valuation literature tends to provide a one-shot valuation of these activities but insufficient evidence to evaluate people's willingness to substitute away from the activity as prices change, and that substitution elasticity becomes a fairly critical value for welfare analysis. The general presumption is that recreational activities are generally more elastically demanded than essentials like food, shelter, clothing, transportation, or medical care. One might also believe that just as demand elasticities for a single food item can be quite high because one can substitute other food items, the demand for one leisure activity—outdoor recreations—might be fairly high because one can substitute other leisure activities. On the other hand, while all consumers may not enjoy these activities, those consumers who actively participate and show up in the data we base this model on may be quite avid and unwilling to easily substitute something else. We choose a value of 1.0 for σ_{rec}, and a value of 0.3 for $\sigma_{L.}$ We conducted sensitivity analysis on these values; the results were particularly sensitive to the value of σ_L, as will be shown below.

3.6. Building Recreational Services Production Functions in Other Regions

Our focus in the scenarios sections is on the US. However, and following the results of initial simulation, we were concerned that introducing recreation services only in the US would lead to greater flexibility in preserving land for recreation than was warranted. In particular, greater demand for recreation in the US could be met by importing food and forest products from abroad, without any consideration of the implications for recreation services abroad. We thus used the US data in conjunction with data in GTAP to develop estimates of outdoor recreation demand for the rest of the EPPA regions.

In particular we used the GTAP 5 data for "Recreation and other services" (ROS), assuming the share of this consumption good in the 2001 Total Private Demand (TPD) was the same for 1997, the base year of the version of EPPA with which we are working. With this we can calculate an estimate for the value of this sector in the 1997 economy of each of the EPPA regions. We calculate the ratio of our outdoor recreation activities in the US to our 1997 estimated value of US ROS based on GTAP. For REHF, REWV_N and REWV_R these shares are respectively equal to 27.3%, 24.7% and 2%. We then assume the same shares of ROS for all other regions. We expect demand for recreational activities to be highly income elastic and so that demand would differ for richer and poorer countries. By using ROS from GTAP we hope to capture differences in incomes across regions. Implicitly, whatever effect varying income levels across regions had on the entire ROS sector is the same for our outdoor recreation sectors. These estimates are shown in **Table 5**. While a somewhat crude attempt to approximate outdoor recreation demands for other regions of the world, "benefits transfer"—using non-market benefits data from one site and applying it elsewhere—is often used in non-market studies to avoid the high cost of new estimates at each site. Our approach is similar; it has the advantage of actually adjusting the benefits for income levels given our method for benchmarking them to the ROS data.

Finally, we assume that the shares of the different inputs to the outdoor recreational functions are identical, whatever the region of interest, to those of the USA for which we have data.

Table 5. 1997 Recreation services to be used in EPPA regions (US$ millions)

	USA	CAN	MEX	JPN	ANZ	EUR	EET	FSU
Data GTAP 5 2001 ROS	502,159	29,581	35,313	167,846	11,191	367,839	8,077	14,664
Share of ROS in TPD	7.3%	8.0%	8.6%	7.5%	4.9%	8.2%	3.6%	6.2%
Data GTAP 4 1997 TPD	5,650,504	372,371	263,015	2,551,666	283,273	5,135,240	203,147	368,729
calc. 1997 ROS	409,685	29,873	22,621	191,454	13,938	422,396	7,220	23,009
calc. 1997 REHF values	111,905	8,160	6,179	52,295	3,807	115,377	1,972	6,285
calc. 1997 REVW_N values	101,255	7,383	5,591	47,318	3,445	104,396	1,785	5,687
calc. 1997 REVW_R values	8,081	589	446	3,777	275	8,332	142	454
	ASI	**CHN**	**IND**	**IDZ**	**AFR**	**MES**	**LAM**	**ROW**
Data GTAP 5 2001 ROS	41,341	5,162	9,185	7,369	5,115	15,176	42,067	13,796
Share of ROS in TPD	5.9%	1.0%	3.0%	8.4%	1.5%	4.4%	5.0%	4.0%
Data GTAP 4 1997 TPD	637,757	522,280	262,611	132,232	377,188	276,214	1,104,873	456,963
calc. 1997 ROS	37,826	5,441	7,946	11,052	5,483	12,270	54,944	18,140
calc. 1997 REHF values	10,332	1,486	2,170	3,019	1,498	3,352	15,008	4,955
calc. 1997 REVW_N values	9,349	1,345	1,964	2,732	1,355	3,033	13,580	4,483
calc. 1997 REVW_R values	746	107	157	218	108	242	1,084	358

3.7. Scenarios

To test the implications of this structure, two scenarios are implemented. One is a business as usual (BAU) scenario, also referred to as "no policy case", where there is no attempt to control greenhouse gases emissions. The second is a climate policy scenario in the USA following Paltsev *et al.* (2007) that reflects pending bills before the U.S. Congress. The policy linearly reduce greenhouse gas (GHG) emissions to 50% of today's level by 2050 starting in 2012, and achieves similar reduction in emissions as those obtained by Paltsev *et al.* between 2050 and 2100. The cumulative level of emissions in USA under this policy case is approximately 60% of the BAU emissions from 2012 to 2050 and 40% of the emissions from 2012 to 2100.

In both cases, we run the model with and without the inclusion of the recreation services. Our objective is to assess the implications for welfare measurement of inclusion of recreational services. The GHG policy case creates a large and relatively early demand for biofuels putting pressure on all land use types. Previous work (Paltev *et al.*, 2007) illustrates the confounding effects terms of trade changes can have when policies are implemented in the entire world. Wanting here to focus clearly on the inclusion of outdoor recreation services, we impose the GHG policy only on the USA, and we enforce the requirement that biofuels demanded in the USA (and other countries) must be produced domestically.

4. Results

4.1. Land-use Changes in the USA

4.1.1 Inclusion of recreational services in the business as usual scenario.

In the reference case (no policy) without recreation services included in the model, the demand for reserved natural forests (RNFORS) slowly increases through time and the amount of land they occupy peaks in 2075 before stabilizing (**Figure 4a**). Here natural lands are simply entering the utility function of the representative consumer directly; that preserves some demand for them. This was the approach of Gurgel *et al.* (2007) although with just one type of natural forest. The model brings in some biomass for electricity generation in the near term (in 2010) which is quickly phased out as other technologies for electricity generation are deployed. Demand for biomass for electricity is thus responsible for the changes in land use in 2010. The later use of land for biomass is for liquid fuels and is brought on by rising crude oil prices as higher grade (lower cost) resources are depleted and production moves to backstops such as shale oil.

The inclusion of outdoor recreation services preserves more land in natural forests and adds more land to reserved forests (**Figure 4b**). This is at the expense of all other land uses but it appears to squeeze the area for biofuels significantly. Thus, the land use changes we see are as we expected. Adding the explicit valuation and demand for recreation services tends to reduce conversion. As noted earlier, Gurgel *et al.* (2007) used an elasticity of supply to limit conversion to rates like we have seen in the past but that led to a somewhat artificial constraint on conversion, and therefore to a widening gap in the price of land used in market activities and unmanaged lands. By introducing a recreation service we do not need that artificial elasticity and instead explicitly represent the value of retaining natural lands for recreation.

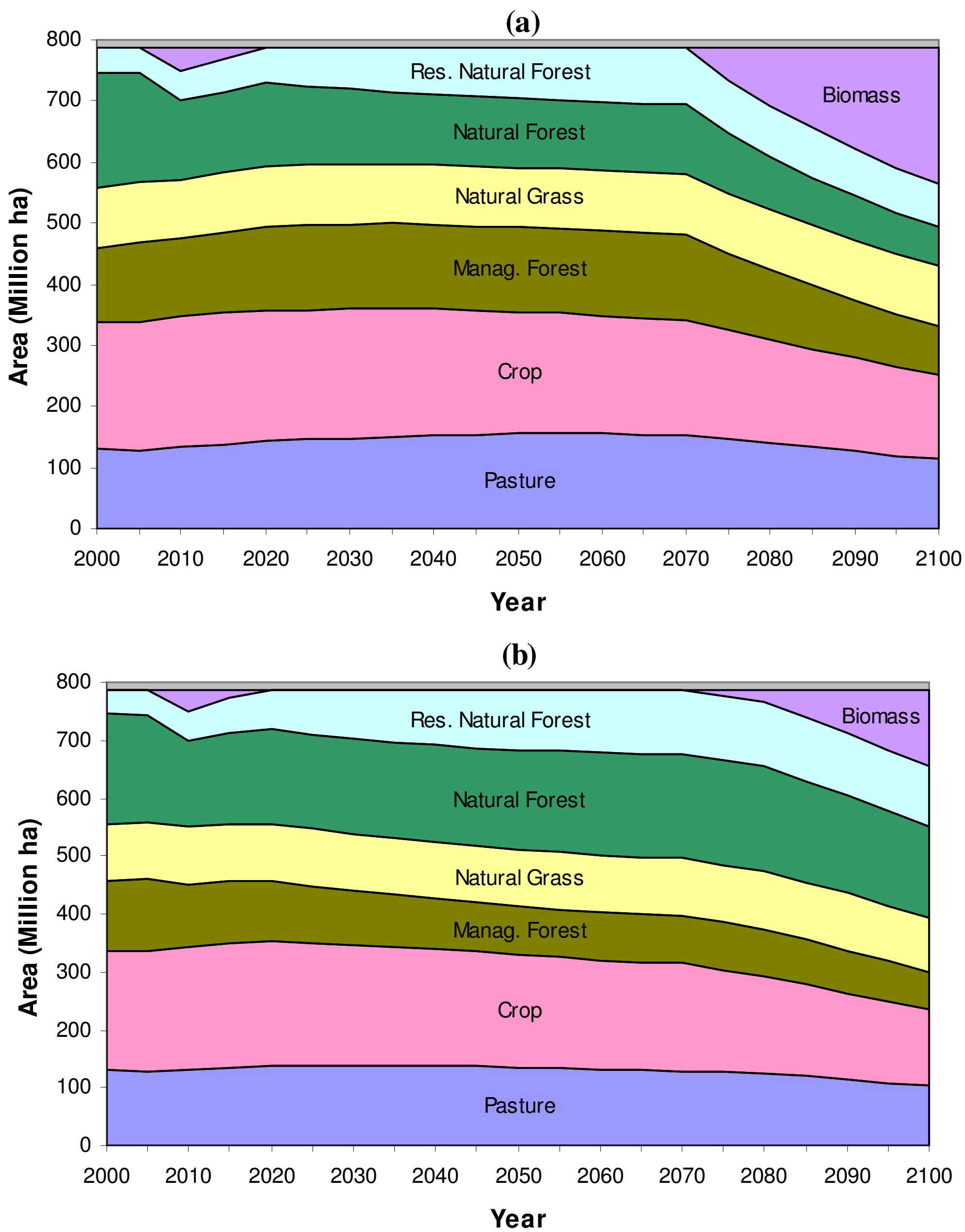


Figure 4. Land-use allocation in the USA: (a) BAU, no recreation services; (b) BAU, recreation services.

4.1.2 Inclusion of recreational services in the policy scenario

With the climate policy and no recreation service demand (**Figure 5a**), biofuels are strongly demanded to satisfy transportation needs. Given that we have restricted biofuel use to that produced domestically, and given the large demand for transport fuels in the US, the biofuels industry requires a large amount of USA land, and this comes at the expense of all land uses. The policy tightens gradually over time. In the early phase of the policy (up to about 2040) most of reductions in GHG emissions occur in sectors other than transportation (e.g. reduction in the electricity sector through use of carbon capture and storage technologies) or through efficiency improvements in transport and elsewhere. By 2040, reductions in other sectors become insufficient to achieve the policy goals. With recreation services represented (**Figure 5b**), reserved forest area does not grow much but other forest areas are reduced much less than without recreation services. Thus, total forested area is not reduced nearly as much as in the case without recreation services. The (relative to Figure 5.a) preservation of natural forest area occurs at the expense of all other land types but there remains substantial biofuels production.

How are food and forestry products being produced on so little land? As in previous work by Reilly and Paltsev (2007), restricting biofuels in the USA to domestically produced fuel results in large imports of the products from abroad and a reduction of exports, turning the USA–who use land resources to produce biofuels instead of conventional agricultural products–into a substantial net importer of these products. This is shown in **Figure 6**. Net imports are slightly larger in the case with recreation services because the preservation of forest land further reduces the amount of land available for all other uses.

While beyond the scope of this paper, previous work shows that relaxing the restriction on biofuel trade leads to the US importing biofuels and continuing to produce conventional agricultural products. Also, while not shown here, we find that more of the conversion of land occurs in the tropical and lower income countries whereas preservation of natural forest areas is stronger in higher income regions like that shown for the USA. That further enhances imports, especially from the poorer countries. We noted in the methods section of the paper, how we used the ROS data in the GTAP data to calibrate our recreation benefits transfer from the USA. This approach apparently captures the stylized fact that such recreation demand is not as strong in poorer regions, which can explain the differential rates of deforestation. Put another away, even though owners of forest resources may not fully recover the value of recreations services from users of them, other institutional processes may work to insure that these demands are somehow reflected in conversion decisions. While there are other mechanisms that may work to reduce conversion rates or lead to expansion, our representation of recreation demand can at least provide a scenario that is casually consistent with trends in land conversion and differences among regions.

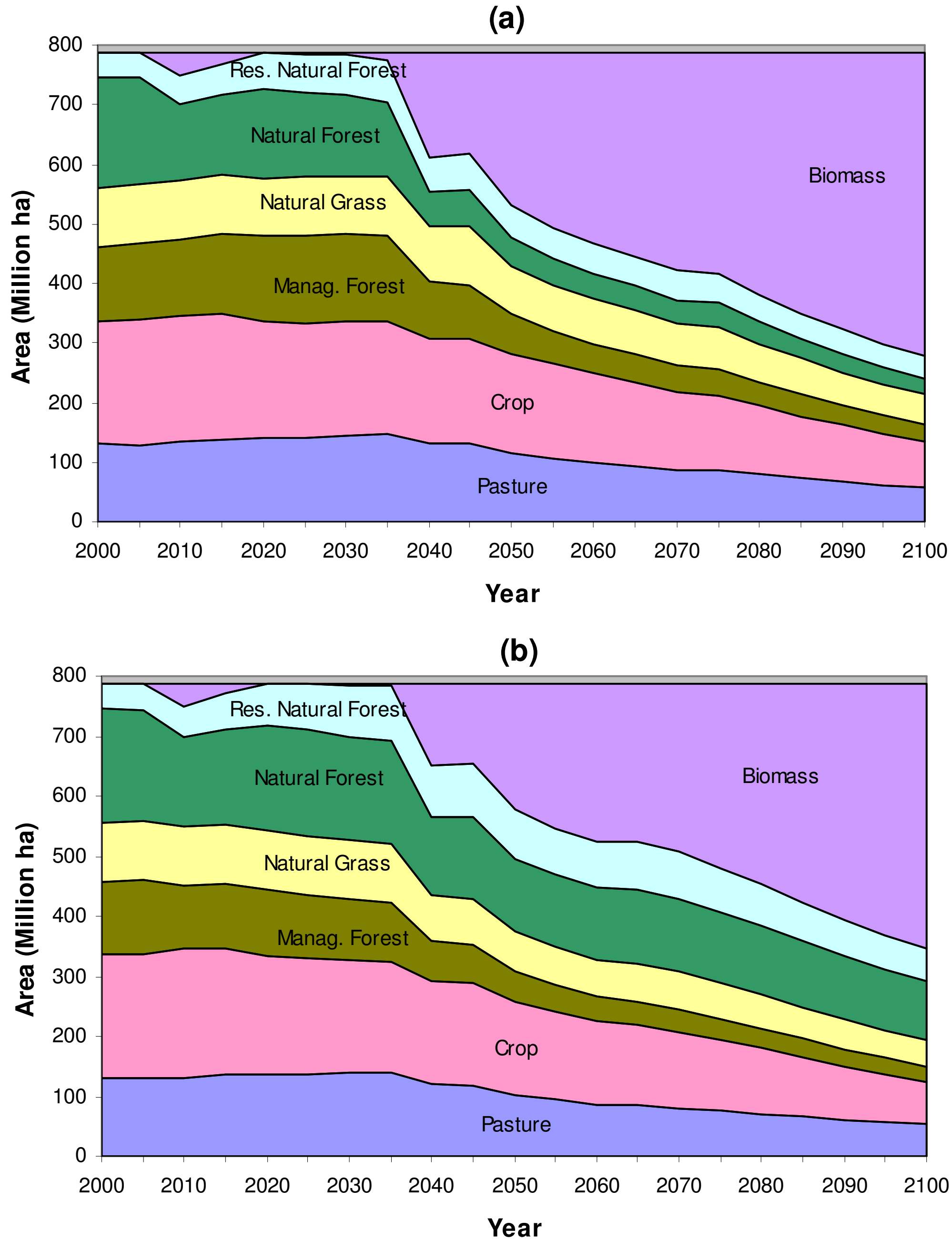


Figure 5. Land-use allocation in the USA: (a) Policy, no recreation services; (b) Policy, recreation services.

Gurgel *et al.* (2007) found relatively small increases in food prices from a large biofuels program and we find the same. **Figure 7** show agriculture and food price indices for the policy cases relative to the no climate policy case (i.e. the index in the policy case divided by the index in the BAU case). The main difference between these cases is the larger biofuels industry in the policy case : the constructed index therefore shows the impact of the much larger biofuels industry. Here the impacts are reduced further from Gurgel *et al.* (2007) because there is no climate policy abroad and thus no pressure from biofuels expansion abroad, allowing the USA to meet food demands through imports (and reduced exports). By 2100 the livestock price increase is about 20% and the crop price increase is about 15% in the policy case relative to the no policy reference. The price index

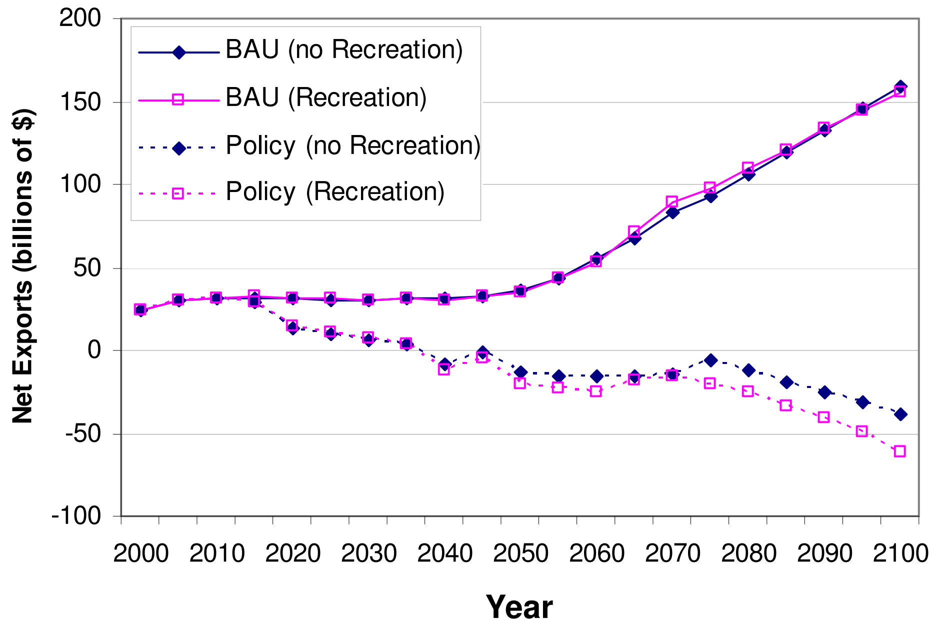


Figure 6. Net agricultural exports by the USA.

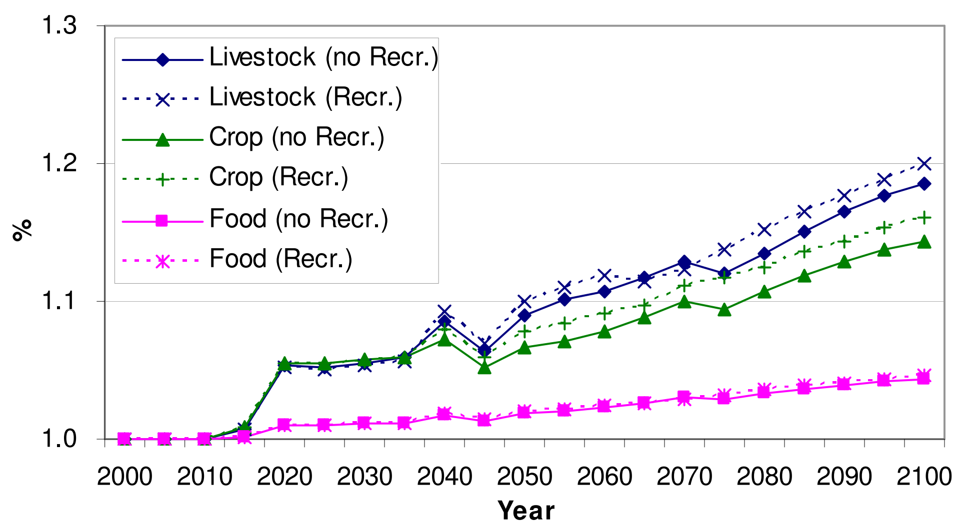


Figure 7. Agricultural and food price indexes in the USA in the policy case relative to the no policy case.

for food increases only about 5%. This ordering reflects the fact that livestock is affected by land prices directly (grazing land) and indirectly through higher feedgrain prices. The smaller food price increase reflects the fact that commodity prices are a smaller share of final food prices—other costs of processing food are not rising as much. As expected, the agricultural price impacts in the recreation services case are somewhat greater, although the difference is relatively small. The result is that there is almost no difference in the food price index between the recreation and no recreation services case. We plot them both but one lies almost on top of the other.

4.2. Sensitivity Analysis of Land Use Projections

As noted earlier, the elasticity of substitution between land and other inputs in the recreation sectors turns out to be a critical parameter. As shown in **Figure 8** panels **a-d**, the value of this elasticity is an important determinant of whether land is preserved for recreation or not. Shown in this figure are the results when we vary σ_L to be 0.0 or 0.6 from the 0.3 value used in the previous simulations. The choice of 0.0, a fairly extreme choice, leads to very large expansion of natural areas, as early as the first simulation year of 2000. It greatly limits biofuels, even in the climate policy case, and eliminates them in the case without climate policy. On the other hand, the 0.6 elasticity allows substantial conversion of land. There is some expansion of preserved natural forest in this case, especially with no climate policy, but the unpreserved areas are severely diminished, especially in the climate policy case. Gurgel *et al.* (2007) developed two version of the model, one with an elasticity that prevented land use conversion, and one where conversion was land was unhindered. That led to less or more conversion of land. The σ_L parameter plays a similar role in this analysis but the results differ even more than between the two cases in Gurgel *et al.* The earlier work led to less deforestation with the inclusion of a land-supply elasticity. Here we find that we actually expand forested area with an elasticity of 0.0. In that case, the increase in recreation demand outcompetes other uses of land. This seems, however, to be a relatively extreme assumption, and the large expansion of forest land almost immediately is inconsistent with trends in land use in the USA. The 0.0 value for σ_L seems inconsistent with that observation. Similarly, the 0.6 value allows more land conversion than seems consistent with recent trends. Unfortunately, the non-market valuation literature focuses mostly on getting a value for non-market resources but not on how users would respond to changing (implicit) prices. Would users easily substitute more inputs—traveling further distances or changing the way they use land resources—as they become more heavily used? Or, would the greater use lead them to, in one way or another, preserve or increase areas devoted to forests—through pressure on public agencies or, possibly, through private purchases of land that are held out of conventional use? Developing empirical methods to get at this willingness to substitute would seem to be an important research objective.

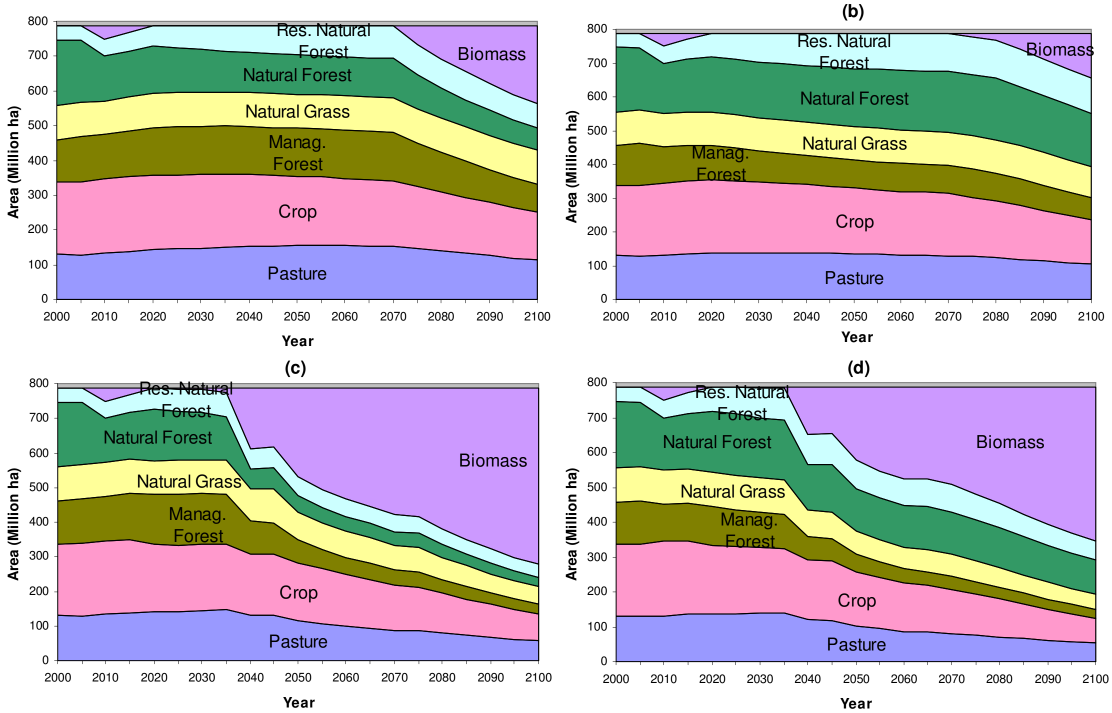


Figure 8. Land-use allocation in the USA (billions of hectares) under different elasticity assumptions in the recreation services: (a) BAU, $\sigma = 0.6$; (b) BAU, $\sigma = 0$; (c) $\sigma = 0.6$; (d) $\sigma = 0$.

4.3. Welfare Changes

An important motivation for including recreation services in the model was to improve our representation of welfare cost. **Figure 9** shows the climate policy cost of including recreation demand in the model, compared with the case without recreation demand. We see little difference through 2040, which is not surprising given that there are only little impacts of the climate policy on biofuel production until then. The impact of including recreation demand would seem to have opposing effects: on the one hand, by limiting land use, it would increase the mitigation policy costs because biofuels would be more expensive to produce while, on the other hand, preserving that land has greater value because it supports recreation services. The results show that, for most of the period, including recreation demand results in a somewhat lower estimate of the welfare cost of the policy.

It is difficult to compare this result with the earlier Gurgel *et al.* (2007) work. There, with the artificial land supply elasticity, land supply was restricted to the biofuels industry without the model measuring the full benefit of preserving that land. Thus, compared to that approach, the explicit inclusion of recreation services should reduce welfare costs and provide a more accurate estimate. We simulated the Gurgel *et al.* (2007) model under the same policy assumptions we have used here, and show that result in Figure 9. It confirms our hypothesis for most of the period of the analysis (2025 to 2065). Note, however, that the comparison depends in part on how much land is converted.[4] Because this is controlled by elasticities in very different production structures in the two model versions, it is not possible to get the exact same land supply responses.

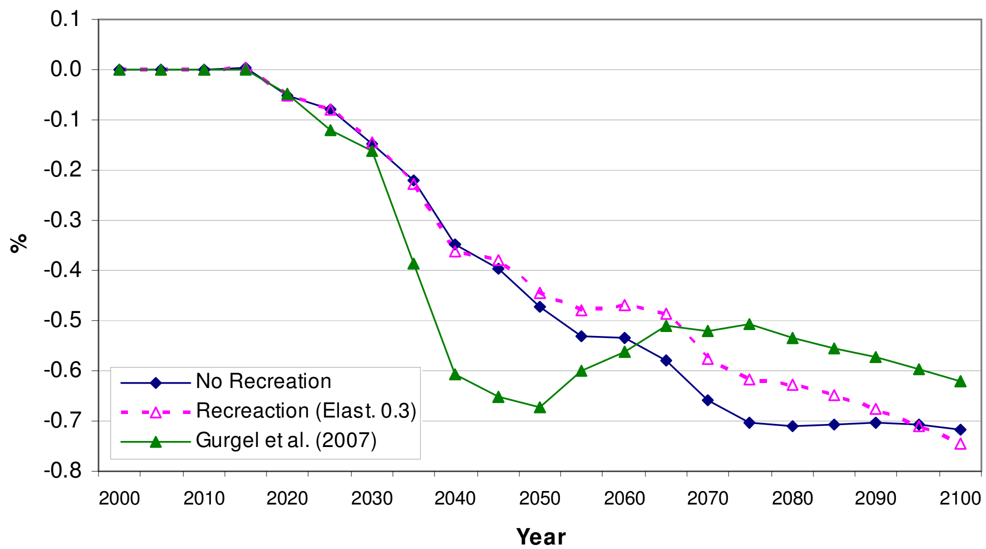


Figure 9. Changes in Welfare (%) from the Policy.

5. Conclusions

Previous work has examined the potential for biofuels and found a large potential but with possible implications for loss of natural forest areas. That work attempted to represent resistance to land conversion by introducing an elasticity based on observed land supply response. That approach limited land conversion but a result was that a large wedge in the price of managed and unmanaged land developed that lacked an explicit explanation. The approach restricted use of the land beyond the cost of converting it but there was no measured economic benefit of the restriction. The restriction increased the cost of climate policy by restricting biofuels production but with no offsetting benefit of keeping the land in its natural state. While there are other possible explanations for limited conversion of land, one is that this land has recreational benefits that are preserved either through public management of the land or through private ownership, land trusts, conservancies, and the like.

[4] The welfare changes in the OLSR model are larger in the middle of the century compared to the end of the horizon due to some peculiarities, as higher prices of agricultural products in the periods of strong expansion of biofuels but lower prices later as other regions increase agricultural production and exports to US since they are not constrained by a climate policy and don't need to produce much biofuels. Also, higher electricity prices are observed during the initial years of development of carbon capture and sequestration technologies in this model.

There is extensive data for the USA that allows the construction of recreational uses of forest land. We introduced into a CGE model "household" production sectors for hunting and fishing, for wildlife viewing in reserved areas, and wildlife viewing in other forest areas. These services are used by the household and thus create an explicit recreation value for this land. We found that suitable parameters for these recreation sectors led to sensible patterns of land use change—consistent with recent trends. The approach resulted in similar land use change as the earlier work that was based on the *ad hoc* elasticity. The advantage of the revised approach is that it provides an obviously improved measure of welfare cost of policies that lead to land use change, because the preservation value of the land offsets the increased cost of the policy due to the restriction on use.

We find that the results are sensitive to the elasticity of substitution between land and other inputs in the recreation sectors. This elasticity represents people's willingness to substitute other inputs for natural land in their recreation experience. This might involve traveling further to find less congested areas, stocking hunting or fishing areas, or altering the experience by using more equipment, lodging, or other inputs. Unfortunately, there is not much empirical evidence on people's willingness to make such tradeoffs. Most non-market valuation work simply values a recreation site, but does not investigate how users would change their behavior if the site was more congested.

In terms of the potential for biofuels production, this formulation of the model does not radically change our earlier results. However, that conclusion mainly results from the fact that both our new method and the older work was parameterized to be generally consistent with observed rates of land conversion, as that is the main evidence we have for what is a sensible calibration of the model. The main contribution of our new approach is not for its insights on biofuels potential but for the improved representation of welfare changes from models where the land supply response limits conversion.

References

Babiker, M.H., G.E. Metcalf and J. Reilly, 2003: "Tax distortions and global climate policy." *Journal of Environmental Economics and Management*, **46**: 269-287.

Costanza, R., R. d'Arge, R. de Groot, S. Farber, M. Grasso, B. Hannon, K. Limburg, S. Naeem, R. O'Neill, J. Paruelo, R. Raskin, P. Sutton, M. van den Belt, 1997: "The values of the world's ecosystem services and natural capital." *Nature*, **387**: 253-260.

Cretegny, L., 2001: "The Reform of the Swiss Agricultural Policy : An Approach Through the Multifunctionality of Agriculture in a CGE Framework." Ph.D. Thesis, Department of Economics, University of Lausanne.

Dimaranan, B., and R. McDougall, 2002: *Global Trade, Assistance, and Production: The GTAP 5 Data Base*. Center for Global Trade Analysis, Purdue University, West Lafayette, Indiana.

Eickhout, B., H. van Meijl, A. Tabeau and E. Stehfest, 2008: "The impact of environmental and climate constraints on global food supply." GTAP working paper 47, Global Trade Analysis Project, West Lafayette. Available at: https://www.gtap.agecon.purdue.edu/resources/download/3678.pdf

Energy Information Administration (EIA). Emissions of Greenhouse Gases in the United States 2005. Energy Information Administration, U.S. Department of Energy, Washington DC, November, 2006.

Gollub, A., T. W. Hertel and B. Sohngen, 2008: "Land use modeling in recursively-dynamic GTAP framework." GTAP working paper 48, Global Trade Analysis Project, West Lafayette. Available at: https://www.gtap.agecon.purdue.edu/resources/download/3679.pdf

Gouel, C. and T. W. Hertel, 2006: "Introducing forest access cost fuctions into a general equilibrium model." GTAP Research Memorandum 8, Global Trade Analysis Project, West Lafayette. Available at: https://www.gtap.agecon.purdue.edu/resources/res_display.asp?RecordID=2215

Goulder, L. H., 1995: "Environmental Taxation and the 'Double Dividend': A Reader's Guide." *International Tax and Public Finance*, **2**:157-183.

Gurgel A., J. Reilly, S. Paltsev, 2007: "Potential Land Use Implications of a Global Biofuels Industry." *Journal of Agricultural & Food Industrial Organization*, **5**: Article 9.

Hertel, T., 1997: *Global Trade Analysis: Modeling and Applications.* Cambridge University Press, Cambridge, UK.

Hurtt, G. C., S. Frolking, M. G. Fearon, B. Moore, E. Shevliakovas, S. Malyshev, S. W. Pacala and R. A. Houghton, 2006: "The underpinnings of land-use history: three centuries of global gridded land-use transitions, wood-harvest activity, and resulting secondary lands." *Global Change Biology* **12**: 1208-1229.

IPCC, 2001: *Climate Change 2001: Mitigation*. Contribution of Working Group III to the Third Assessment Report of the Intergovernmental Panel on Climate Change, B. Metz *et al.* (eds.), Cambridge University Press, UK.

Jacoby, H.D., R.S. Eckhaus, A.D. Ellerman, R.G. Prinn, D.M. Reiner and Z. Yang, 1997: "CO2 emissions limits: economic adjustments and the distribution of burdens." *The Energy Journal,* **18**: 31-58.

James, A.N., M.J.B. Green, and J.R. Paine, 1999: "A Global Review of Protected Area Budgets and Staffing." WCMC – World Conservation Press, Cambridge, UK.

Lewandrowski, J. , R. F. Darwin, M. Tsigas and A. Raneses, 1999. "Estimating costs of protecting global ecosystem diversity." *Ecological Economics*, **29**: 111-125.

Matus, K., T. Yang, S. Paltsev, J. Reilly and K-M. Nam, 2008: "Toward Integrated Assessment of Environmental Change: Air Pollution Health Effects in the USA." *Climatic Change*, **88**: 59-92.

Paltsev, S., H. Jacoby, J. Reilly, L. Viguier and M. Babiker. "Modeling the Transport Sector: The Role of Existing Fuel Taxes in Climate Policy." MIT Joint Program on the

Science and Policy of Global Change Report 117, Cambridge, MA, 2004. Available at: http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt117.pdf

Paltsev, S., J. Reilly, H. Jacoby, R. Eckaus, J. McFarland, M. Sarofim, M. Asadoorian and M. Babiker, 2005: "The MIT Emissions Prediction and Policy Analysis (EPPA) Model: Version 4." MIT Joint Program on the Science and Policy of Global Change Report 125, Cambridge, MA. Available at: http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt125.pdf

Paltsev, S., J. Reilly, H. Jacoby, A. Gurgel, G. Metcalf, J. Holak, A. Sokolov, 2008: "Assessment of U.S. Cap-and-Trade Proposals." *Climate Policy*, **8**: 395-420.

Pattanayak, S. K., M. T. Ross, M. D. Brooks, S. C. Bauch, C. Timmins, K. J. Wendland and K. Alger, 2007: "Climate Change, Contagion and Conservation: Valuing Services and Evaluating Policies in Brazil via Applied CGE." Presented at the Association of Encironmental and Resource Economics Annual Workshop, Mystic, Connecticut, June 2007.

Reilly, J., R. Prinn, J. Harnisch, J. Fitzmaurice, H. Jacoby, D. Kicklighter, J. Melillo, P. Stone, A. Sokolov and C. Wang, 1999: "Multi-gas assessment of the Kyoto Protocol." *Nature,* **401**: 549-555.

Reilly, J. and S. Paltsev, 2007: "Biomass energy and competition for land." MIT Joint Program on the Science and Policy of Global Change, Report 145, Cambridge, MA. Available at: http://web.mit.edu/globalchange/www/MITJPSPGC_Rpt145.pdf

Rosenberger, R. and J. Loomis, 2000: "Benefit transfer of outdoor recreation usevalues: a technical document supporting the Forest Service strategic plan(2000 Revision)", Gen. Tech. Rep. RMRS-GTR-72. Fort Collins, CO: US Department of Agriculture, Forest Service, Rocky Mountain Research Station.

Rutherford, T., 1995: "Demand Theory and General Equilibrium: An Intermediate Level Introduction to MPSGE." GAMS Development Corporation, Washington, DC. Available at: http://www.gams.com/solvers/mpsge/gentle.htm

Smith, V.K., 1996: *Estimating Values for Nature: Methods for Non-Market Valuation*. Edward Elgar, Northhampton.

Sohngen, B. and R. Mendelsohn, 2007: "A sensitivity analysis of carbon sequestration." In: Schlesinger, M. (Editor): *Human-Induced Climate Change: An Interdisciplinary Assessment*. Cambridge University Press.

US Census Bureau, 2000: Statistical Abstract of the United States: 2000, Section 7 – Parks, Recreation and Travel.

Whalley, J. and Wiggle, R., 1990: "Cutting CO_2 emissions: the effect of alternative policy approaches." *The Energy Journal*, **14**, 109-124.

World Resource Institute, 2000: EarthTrends online database, 2000 data on protected forests areas, http://earthtrends.wri.org/miscell/sitemap.php?theme=0 , accessed online July 31, 2008.