Land Use Changes and Biofuel Feedstock Production in Brazil: The Role of Irrigation Water

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PAN-AMERICAN
BIOFUELS &
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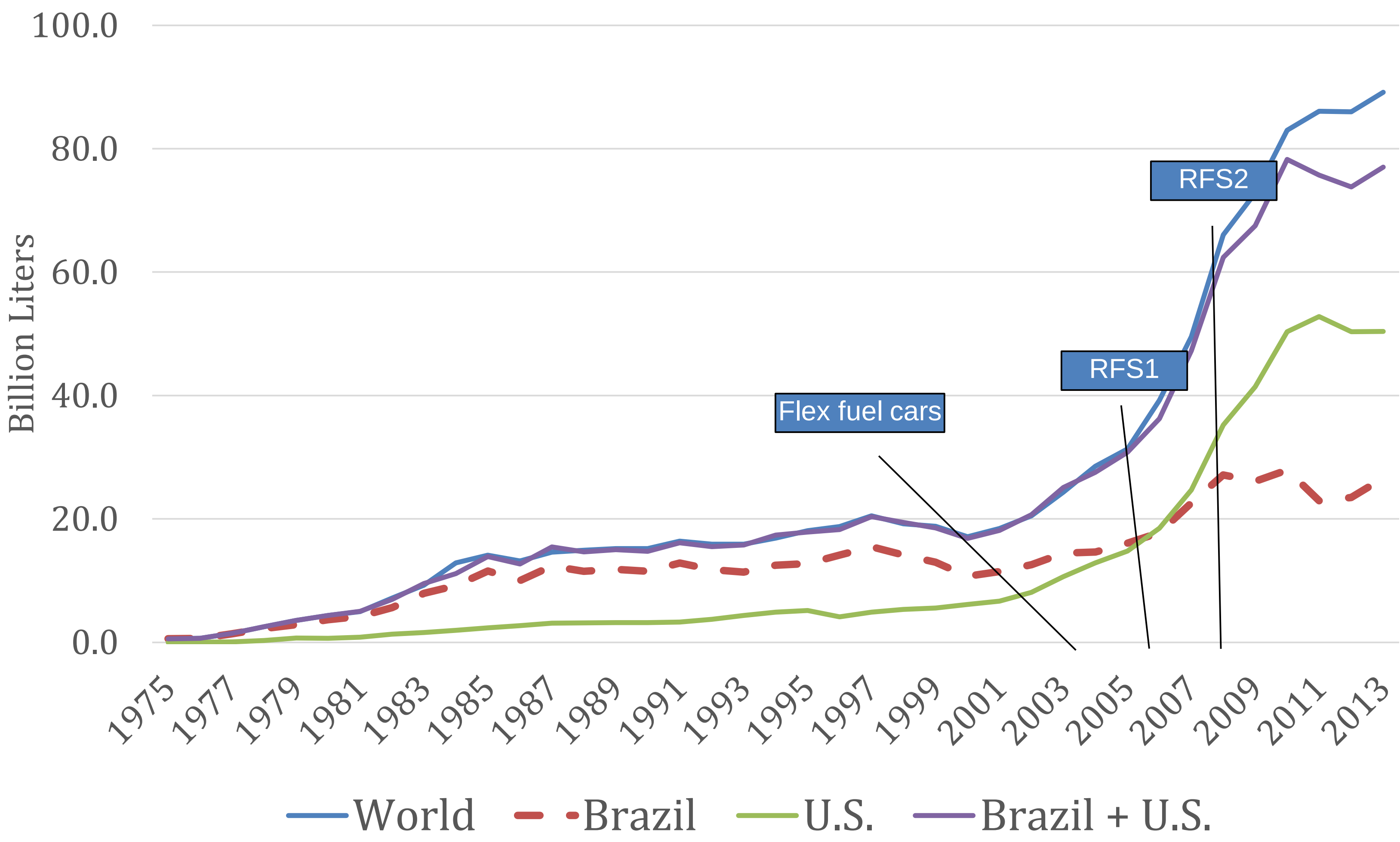
World Ethanol Production

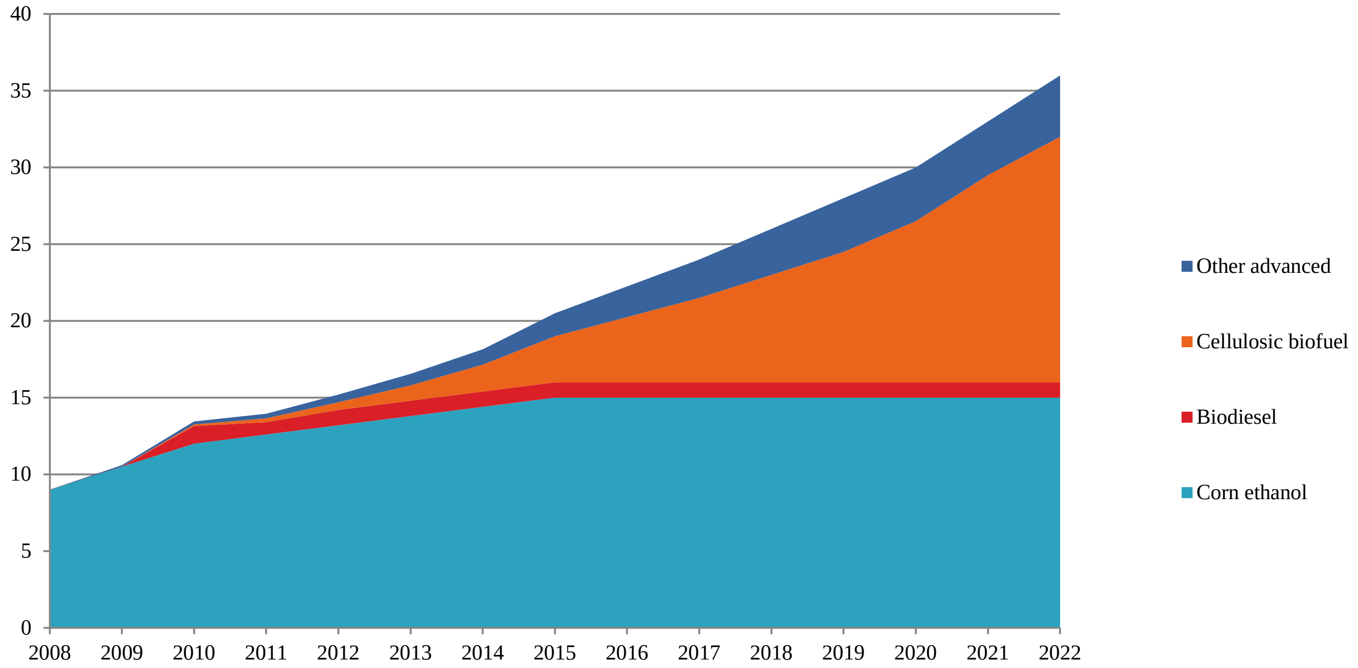


Flex fuel cars

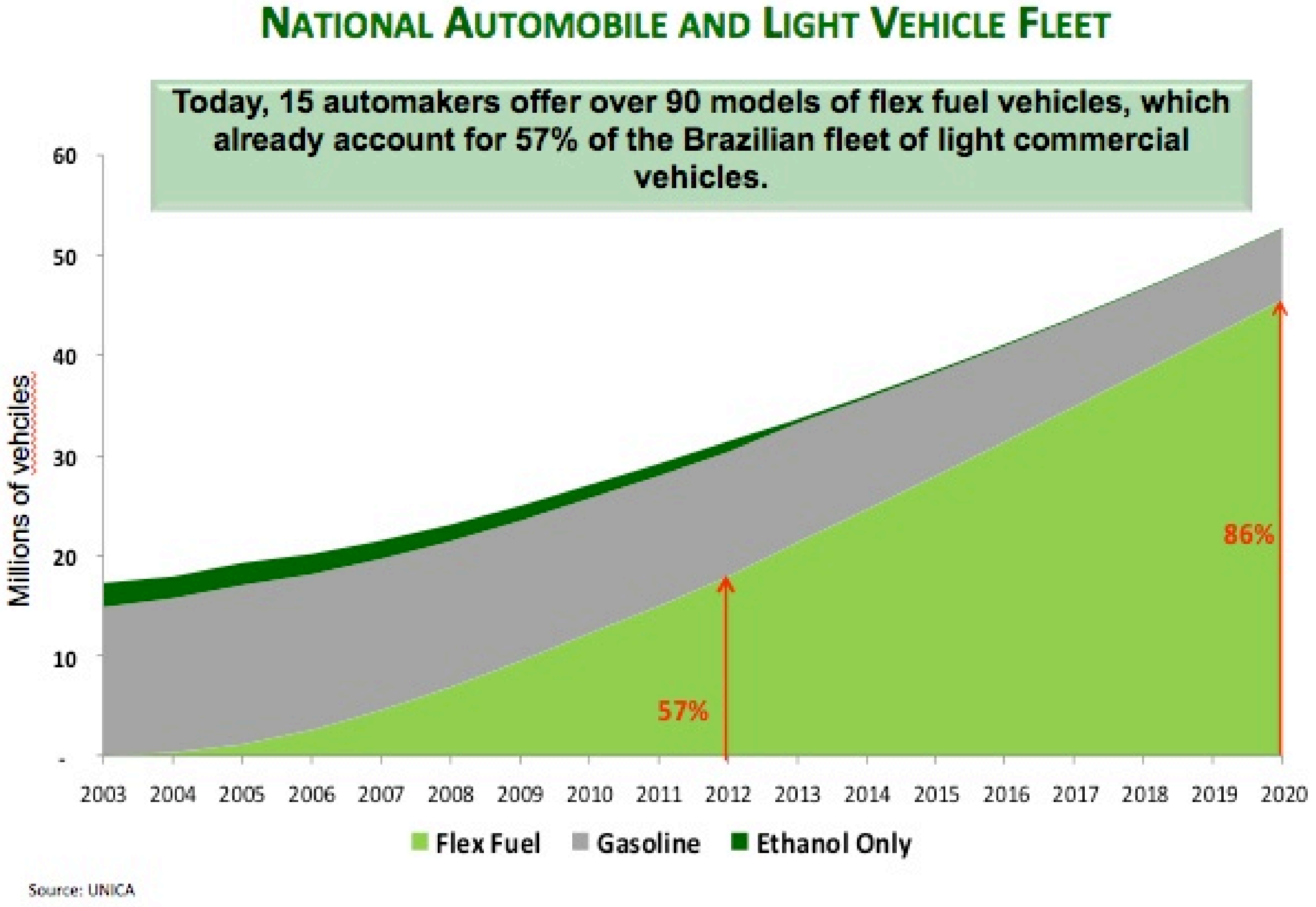
RFS1

RFS2

RFS Biofuel Blending Mandates
(Bil.Gallons/Yr)



Light Duty Vehicle Fleet Projections, Brazil



NATIONAL AUTOMOBILE AND LIGHT VEHICLE FLEET

Today, 15 automakers offer over 90 models of flex fuel vehicles, which already account for 57% of the Brazilian fleet of light commercial vehicles.

Source: UNICA

Research Issues

- Can Brazil ethanol industry respond to the growing demand for biofuels in the domestic and global markets?
- Investigate the potential for expansion in sugarcane and ethanol production, impacts on resource utilization in agriculture and food/feed commodity prices considering the competition between sugarcane and other crops.

Resource Availability

- Planted Area of Sugarcane in 2007= 7.1 million ha (Censo Agropecuário - IBGE), suitable area for expansion ZAE = 64.7 million ha (19 million ha with high potential)
- Expansion in biofuel production requires additional cropland for sugarcane production , can be within 1-5 million ha.
- Various modeling studies have looked at the expansion of sugarcane areas by intensification in the livestock sector and converting some of the pasturelands into crop production.
- **But, no comprehensive modeling study has looked at the other important resource: WATER**
- **Out of 24 billion m^3 of irrigation water use in 2007, 14.5 billion m^3 was used for sugarcane (60%) !**

Methodology

- We developed a multi-region, multi-market spatial equilibrium model including the agricultural and fuel sectors of Brazil and US to determine the production and consumption of food and fuel products in both countries and trade between them.
- The model maximizes producers' + consumers' surplus subject to resource constraints, technical constraints and policy constraints.
- Explicit demand functions are used for food commodities, km driven by light duty vehicles (conventional, flex-fuel, and ethanol-dedicated).

Spatial Aspects

- The Brazil component includes 137 mesoregions producing eight annual crops and sugarcane, beef-cattle production under three different pastures types and production systems.
- Sugarcane expansion is limited to agro-ecological zones.
- Ethanol and livestock transportation costs between production and consumption regions are included.
- **Besides regional land constraints, the model also includes regional water use-supply constraints which incorporate irrigation water requirements and projected water supply for irrigated agriculture in 2030.**

Water Constraint

$$\sum_i w_{irt} \cdot \Delta_{ir} \boldsymbol{LAND_{ir}} \leq W_{rt}$$

w_{irt}= water consumption by crop *i* in region *r* in month *t* (m^3/ha/mo)
$\Delta_{\boldsymbol{ir}}$= irrigated/planted acreage of crop *i* in region *r*
W_{rt}= Total water supply in region *r* in month *t*
$\boldsymbol{LAND_{ir}}$=Land allocation for crop i in region r (endogenous)

$$\Delta_{i,r} = \frac{Area\ Ir_{i,r}}{Area\ Plant_{i,r}}$$

Water Data

- Data from irrigated and harvested areas in the states and municipalities provided by the IBGE Agricultural Census of 2006.
- The technical coefficients of water use published by Ministry of Environment in a partnership with Federal University of Viçosa (2011).
  - These were based on:
    - Evapotranspiration data from the database of ONS 2005 (1950-2000).
    - Precipitation data available from the National Water Agency - ANA by month for the period from 2000 to 2008.
    - Coefficients of crop moisture and irrigation efficiency application parameters from ANA / GEF / UNEP / OAS (2002).

Derivation of the Water Parameters

$$K_{it,m} = \left[\frac{\left(ETO_{t,m} \cdot Kc_{it,m} \cdot Ks_{i,m}\right) - pef_{it,m}}{Ea_{i,m}}\right] \cdot 10$$

$$w_{irt} = \sum_{m \in r} [AreaIr_{im} / AreaIr_{ir}].K_{itm}$$

$$W_{rt} = \sum_{i} w_{irt} \cdot AreaIr_{ir}$$

Projected Water Coefficients (2030)

For the 2030 projections, we update the irrigation water requirements based on the temperature and precipitation predictions of global climate scenarios **(IPCC, 2013)**.

$$K'_{it,m} = K_{it,m} + dK_{it,m}$$

$$dK_{it,m} = \frac{\partial K_{it,m}}{\partial ETO_{t,m}} \cdot \frac{\partial ETO_{t,m}}{\partial T} \cdot dT_{t,m} + \frac{\partial K_{it,m}}{\partial Pef_{t,m}} \cdot dPef_{it,m}$$

$$w'_{it,r} = w_{it,r} + dw_{it,r}$$

$$dw_{it,r} = \left[\frac{\left(Kc_i \cdot Ks_{i,r}\right)}{Ea_{i,r}}\right] \cdot 10 \cdot p_{t,r} \cdot 0{,}457 \cdot dT_{t,r} - \left[\frac{10}{Ea_{i,r}}\right] \cdot dPef_{it,r}$$

Projected Water Coefficients (continued)

$$\Delta'_{i,r} = \frac{Area\ Ir_{i,r} + \ Area\ Ir'_{i,r}}{Area\ Plant_{i,r} + \ Area\ Ir'_{i,r}}$$

$$Area\ Ir'_{i,r} = \ Area\ Ir_{i,r} + \left(Area\ Projeto_{r} * \frac{Area\ Ir_{i,r}}{area\ Ir_{r}}\right)$$

$$W'_{rt} = \sum_{i} w'_{irt} \cdot AreaIr'_{ir}$$

Estimated Data Variation of Precipitation and Temperature from IPCC for region 12 in the months of Dec -Feb

Dec-Feb	**Absolute Temperature**				**Percentage Change in Precipitation Media**			
IPCC Models\Families	A2	B2	A1FI	B1	A2	B2	A1FI	B1
CCSRNIES	0.9981	1.0123	1.1420	0.8406	-1.15	-2.28	-2.27	-0.45
CSIRO	0.9188	0.9804	0.9923	1.0422	-2.18	-1.4	-2.35	-1.45
ECHAM4	0.9568	0.9610	1.0525	0.8265	4.35	5.2	4.79	4.47
HADCM3	1.0022	0.8445	1.0924	0.7347	-0.57	3.57	-0.62	3.11
NCAR PCM	0.7206	0.7354	0.7927	0.6325	1.61	2.22	1.77	1.91
CGCM2	1.0471	1.1868			1.92	3.07		
GFDL-R30	0.8799	0.9197			2.87	0.84		

Source: IPCC, 2013.

New Water supply for Irrigated Agriculture in Brazil in 2030

24 billion m^3 in 2007

IPCC Model	**IPCC scenarios [using the] NEW PEF**			
	A2	B2	A1	B1
	Millions M^3			
CCSRNIES	27022	27428	26579	26122
CSIRO	26294	26103	26302	26278
ECHAM4	26212	25899	26219	25931
HADCM3	27540	27119	27655	26996
NCAR_PCM	25951	25802	25934	25854
CGCM2	26138	26246	26137	26137
GFDL-R30	25619	25548	26137	26137
Average	26397	26306	26423	26208

Data

- The model is calibrated using 2007 as the base year
- The data inputs include the base year domestic and global commodity prices and quantities demanded, price-demand elasticities, historical crop mixes (2003-2009), crop yields, costs of crop and livestock production, processing costs, and costs of fuel transportation.
- Data sources: USDA, Department of Agriculture of Argentina, EIA, IBGE , AgraFNP, CONAB , EMBRAPA , CEPEA , PECEGE, EPE, ANFAVEA, FAO , COMTRADE, FUNARBE, elasticities from the literature; Water coefficients are calculated using the MMA data and the data obtained from FUNARBE (2011).

Model Validation - Crop Acreages (2007)

(in million ha)	Observed	Original Model w/o water restriction	Extended model (w/water restriction)
Total cropland	47.98	42.65	41.83
Sugarcane	7.09	6.19	6.04
Corn	14.01	11.91	11.86
Soybeans	20.57	22.97	22.43
Wheat	1.86	2.78	2.78
Cotton	1.13	0.98	0.91
Rice	2.92	2.07	2.04
Sorghum	0.67	0.77	0.75
Pasture Land	127.00	124.40	124.95

Scenario Analysis (2030)

- *Scenario-1:* US, Brazil, EU and World ethanol mandates, disregarding the water constraints
- *Scenario-2:* Same as Scenario-1 except that the water constraints are included

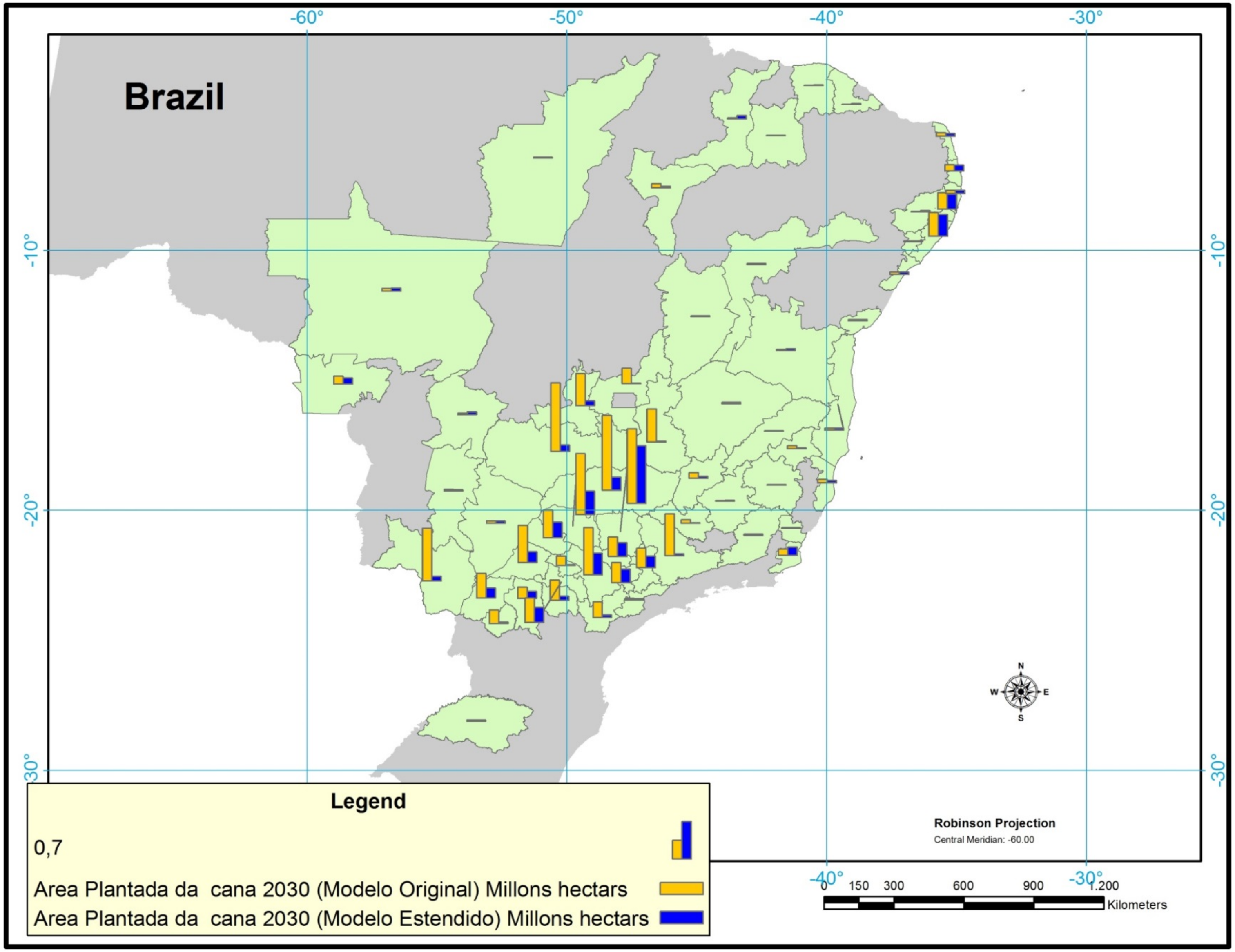
Simulated Land Use (2030)

	Base Run	Scenario-1 w/o water	Scenario-2 w/water
Sugarcane	6.04	15.90	6.34
Corn	11.86	15.13	16.49
Soybeans	22.43	30.06	30.97
Wheat	2.78	2.73	2.65
Cotton	0.91	1.44	1.54
Rice	2.04	2.46	2.45
Sorghum	0.75	0.61	0.54
Total Cropland	**41.83**	**63.52**	**56.29**
Pasture Land	**124.95**	**108.79**	**116.02**
Total Agr. Land	166.78	172.31	172.31

Simulated Performance of the Sugarcane Industry in 2030

	Scenario-1 w/o water	Scenario-2 w/water	Percent Change
SCane Acreage (Mil. Ha)	15.90	6.35	-60
SCane Production (Mil. MT)	1,870.44	702.99	-62
for sugar (Mil. MT)	459.84	440.54	-4
for ethanol (Mil. MT)	1,410.60	262.45	-81
Ethanol production (Bil. lt)	115.93	21.56	-81
Hydrous ethanol price ($/lt)	0.41	0.71	73

Simulated Sugarcane Areas- Scenarios 1&2



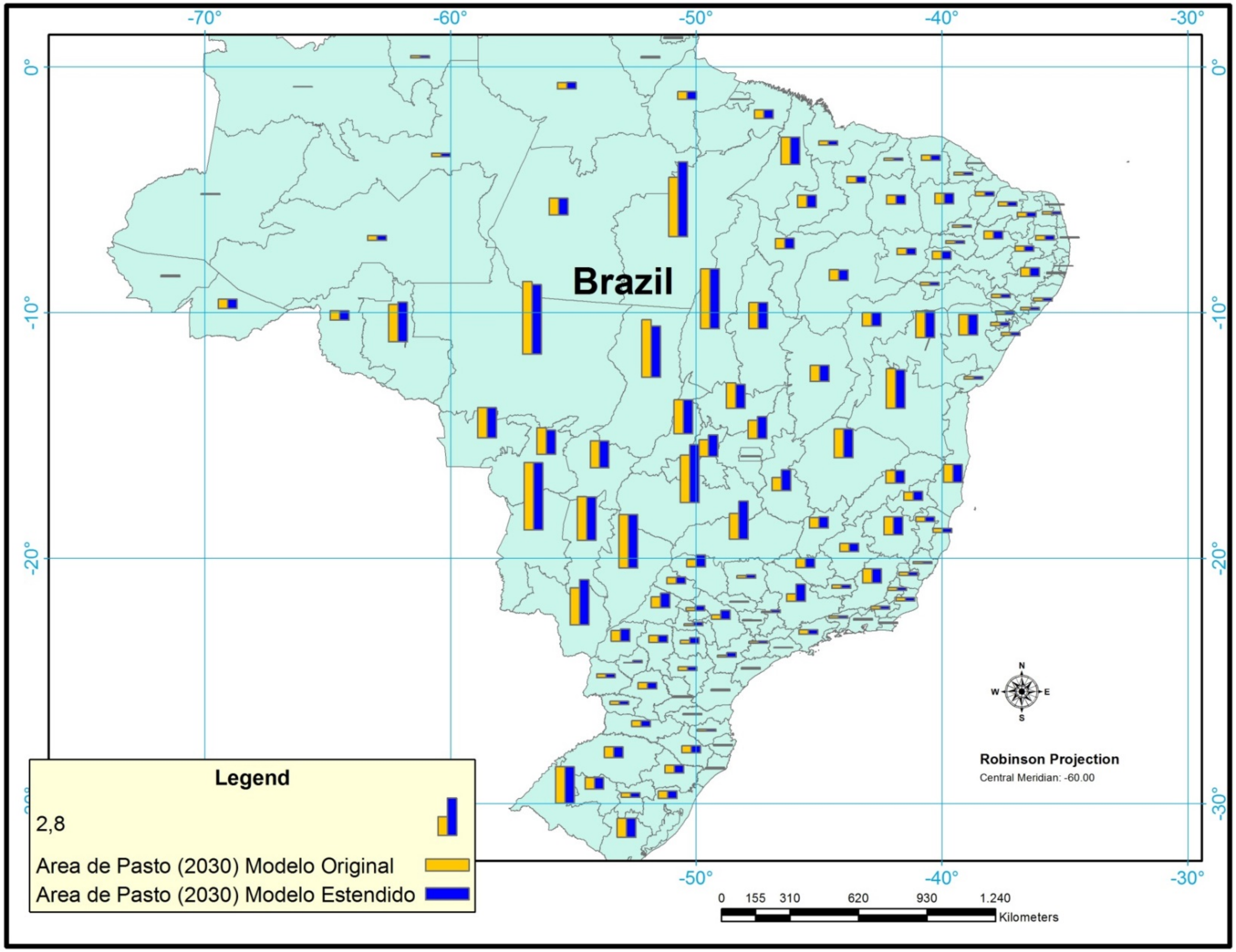
Legend

0,7

Area Plantada da cana 2030 (Modelo Original) Millons hectars 🟧

Area Plantada da cana 2030 (Modelo Estendido) Millons hectars 🟦

Simulated Pasture Areas- Scenarios 1&2



Concluding Remarks

- The simulation results indicate that consideration of regional irrigation water constraints would have substantial impacts on land use, livestock intensification, and expansion of sugarcane production potential.
- Without infrastructure investments and improvement in efficiency, irrigation water requirements due to climate change may put significant pressure on other uses of water.
- Water scarcity may intensify conflicts in regions such as Northeastern Brazil where water availability is limited and irrigation water has important role for socioeconomic development.
- The results under various water availability scenarios may provide useful insight to agricultural producers and public policy makers.

Concluding Remarks

- Investment in irrigation technologies, which can lead to an increase in use efficiency, should enhance the expansion of crops, even without an increase in the availability of water for the irrigated agriculture sector.
- To this end, public water allocation policies need to encourage the rational and efficient use of water through an effective management of demand.
- The possible impacts of the likely expansion of biofuel production in developing countries requires more attention internationally in approaches to public policies that help to secure property rights to land and water for the poorest.
- Results of economic- integrated models are able to support the decision in the design of management tools for effective demand, such as water pricing, and others that induce an economically optimal allocation

Thank You!