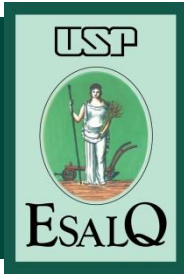


Modelos de Localização

Uma aplicação para o setor sucroenergético

Piracicaba
Outubro/2020

Expectativa de expansão do Setor Sucroenergético



Pretende levar a produção de etanol para 46 bilhões de litros até 2028.

Expectativa de expansão do Setor Sucroenergético



Qual a melhor distribuição espacial da produção futura para minimizar o custo do etanol entregue nas bases de distribuição?

Biomass and Bioenergy 127 (2019) 105249



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Biomass and Bioenergy

journal homepage: www.elsevier.com/locate/biombioe



Research paper

Study of optimal locations for new sugarcane mills in Brazil: Application of a MINLP network equilibrium model



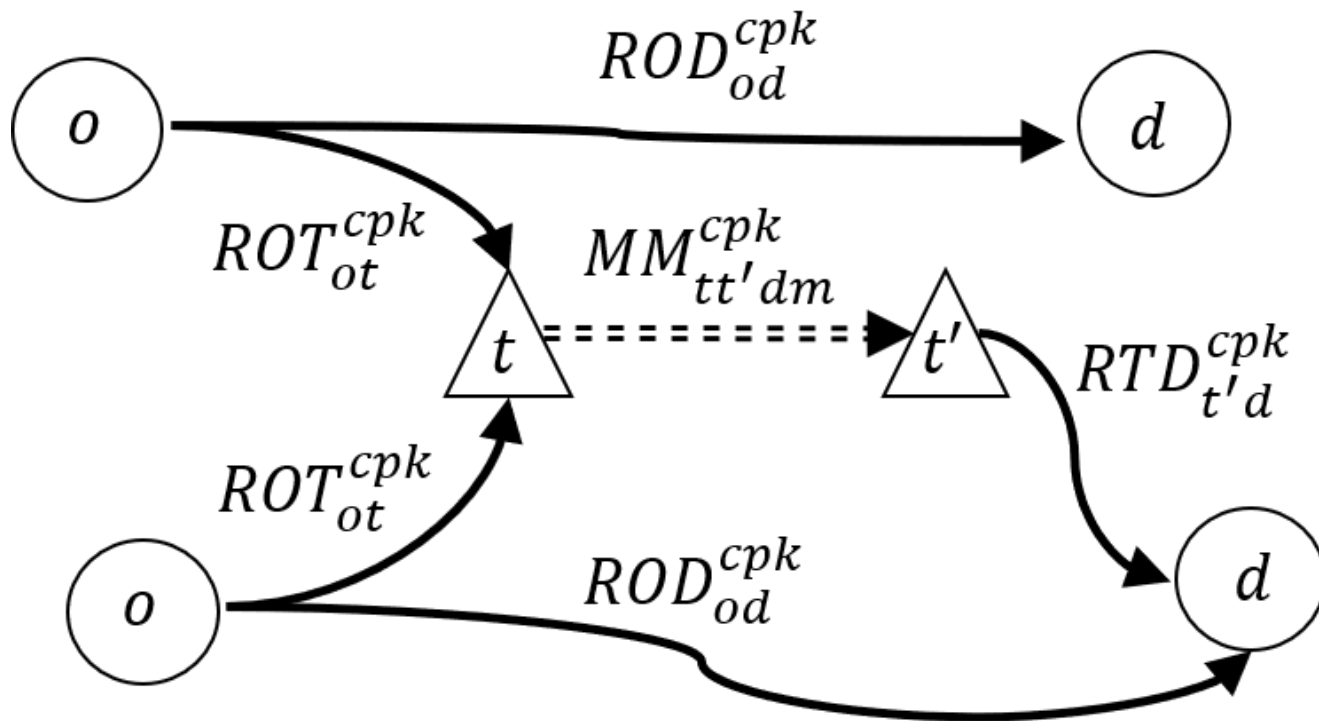
José Eduardo Holler Branco^{a,c,*}, Daniela Holler Branco^b, Edson Martins de Aguiar^c,
José Vicente Caixeta Filho^c, Luciano Rodrigues^c

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^c São Carlos School of Engineering, University of São Paulo, Brazil

Modelo Matemático



Teoria Clássica da Localização

Von Thunen (1826)
O Estado Isolado



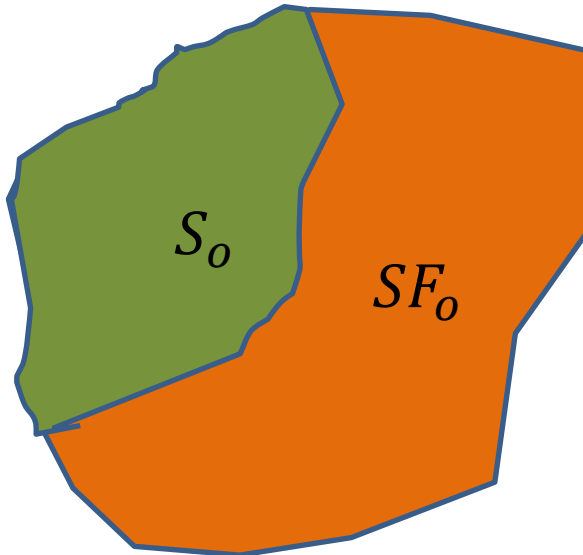
Fonte: www.cadernizando.com.br

Alfred Weber (1826)
Teoria da Localização das Indústrias



Uso de variáveis binárias para escolha de localização

Microrregiões com viabilidade edafoclimática para produção de cana-de-açúcar



S_0 : Produção atual de cana-de-açúcar

SF_0 : Produção futura de cana-de-açúcar

$$TS_0 = S_0 + SF_0$$

$$\frac{SF_0}{YLD_0} \leq LND_0 \cdot B_0, \forall o$$

$$SF_0 \geq MSF \cdot B_0, \forall o$$

B_0 : Binária de escolha das áreas para produção adicional futura

MSF : Módulo mínimo de produção futura

Modelo Matemático

Função Objetivo

$$\text{MIN } C = PC + TC \quad (1)$$

$$PC = \sum_o \sum_d \sum_t \sum_c \sum_p \sum_k (ROD_{od}^{cpk} + ROT_{ot}^{cpk}) \cdot PC_o^p \quad (2)$$

$$\begin{aligned} TC = & \sum_o \sum_t \sum_c \sum_p \sum_k ROT_{ot}^{cpk} \cdot TC_{ot}^p + \\ & \sum_o \sum_t \sum_c \sum_p \sum_k ROT_{ot}^{cpk} \cdot TC_{ot}^p + \\ & \sum_t \sum_{t'} \sum_m \sum_c \sum_p \sum_k MM_{tt'm}^{cpk} \cdot TC_{tt'}^p + \end{aligned} \quad (3)$$

Modelo Matemático

Restrições de Oferta

$$\sum_d \sum_c \sum_p \sum_k \frac{ROD_{od}^{cpk}}{TEC_o^p} + \quad (4)$$

$$\sum \sum \sum \sum ROT_{ot}^{cpk} / TEC_o^p = S_o + SF_o, \forall o$$

$$\frac{SF_o}{YLD_o} \leq LND_o \cdot B_o, \forall o \quad (5)$$

$$SF_o \geq MSF \cdot B_o, \forall o \quad (6)$$

$$\sum_d \sum_c \sum_k ROD_{od}^{cpk} / TEC_o^p + \quad (7)$$

$$\sum_t \sum_c \sum_k ROT_{ot}^{cpk} / TEC_o^p \leq (S_o + SF_o) \cdot 70\%, \forall o \text{ and } p = s$$

Modelo Matemático

Restrições de Demanda



$$\sum_o \sum_u \sum_k ROD_{od}^{cpk} + \sum_{t'} \sum_k RTD_{t'd}^{cpk} = DEM_d^p, \quad \forall d, p \text{ and } c = dm \quad (8)$$

$$\sum_o \sum_{d \in \{st\}} \sum_k ROD_{oud}^{cpk} + \sum_{t'} \sum_{d \in \{st\}} \sum_k RTD_{t'd}^{cpk} = EXP^p, \forall p \text{ and } c = im \quad (9)$$

$$\sum_o \sum_k ROD_{od}^{cpk} + \sum_{t'} \sum_k RTD_{t'd}^{cpk} \geq EXPD_d^p, \forall p, d \in \{st\} \text{ and } c = im \quad (10)$$

Modelo Matemático

Capacidade da malha de transporte

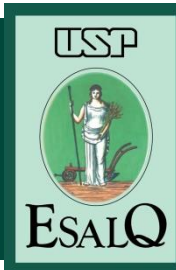


$$\sum_o \sum_c \sum_k ROT_{ot}^{cpk} \leq TCAP_t^p, \forall t \quad (11)$$

$$\sum_o ROT_{ot}^{cpk} = \sum_{t'} MM_{tt'm}^{cpk}, \forall t, m, c, p \text{ and } k \quad (12)$$

$$\sum_t MM_{tt'm}^{cpk} = \sum_d RTD_{t'd}^{cpk}, \forall t', m, c, p \text{ and } k \quad (13)$$

Dados



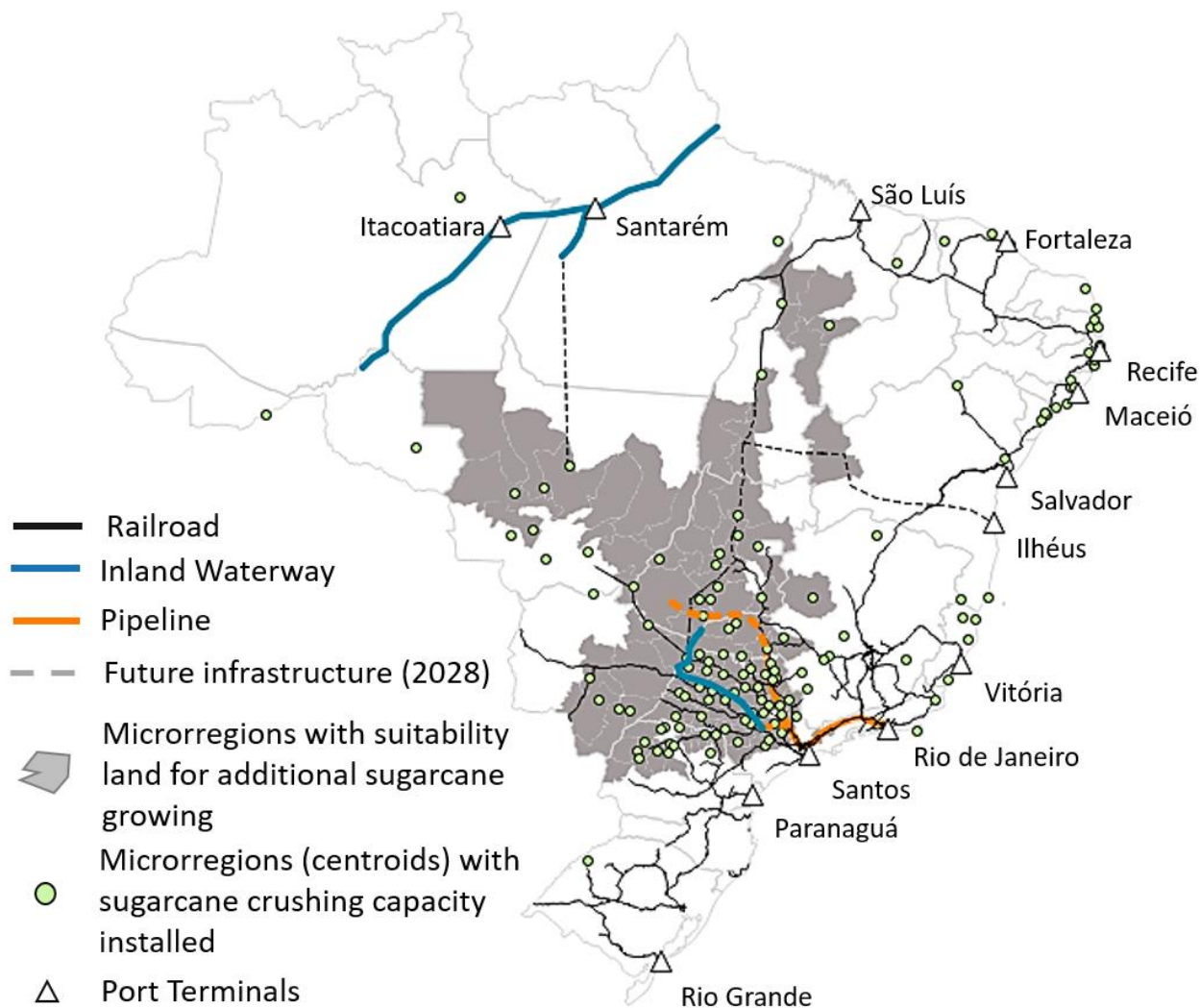
Freight equations and statistical significance tests of the log-linear regression.

Statistical tests	Sugar	Ethanol
Equations	$\ln F_{ij} = 0.31 + 0.18 \ln x_{ij}$	$\ln F_{ij} = 0.32 + 0.17 \ln x_{ij}$
R squared (R^2)	0.88	0.84
F test	57.64	36.95
F critical	11.25	11.25
P Value	0.00006	0.00050

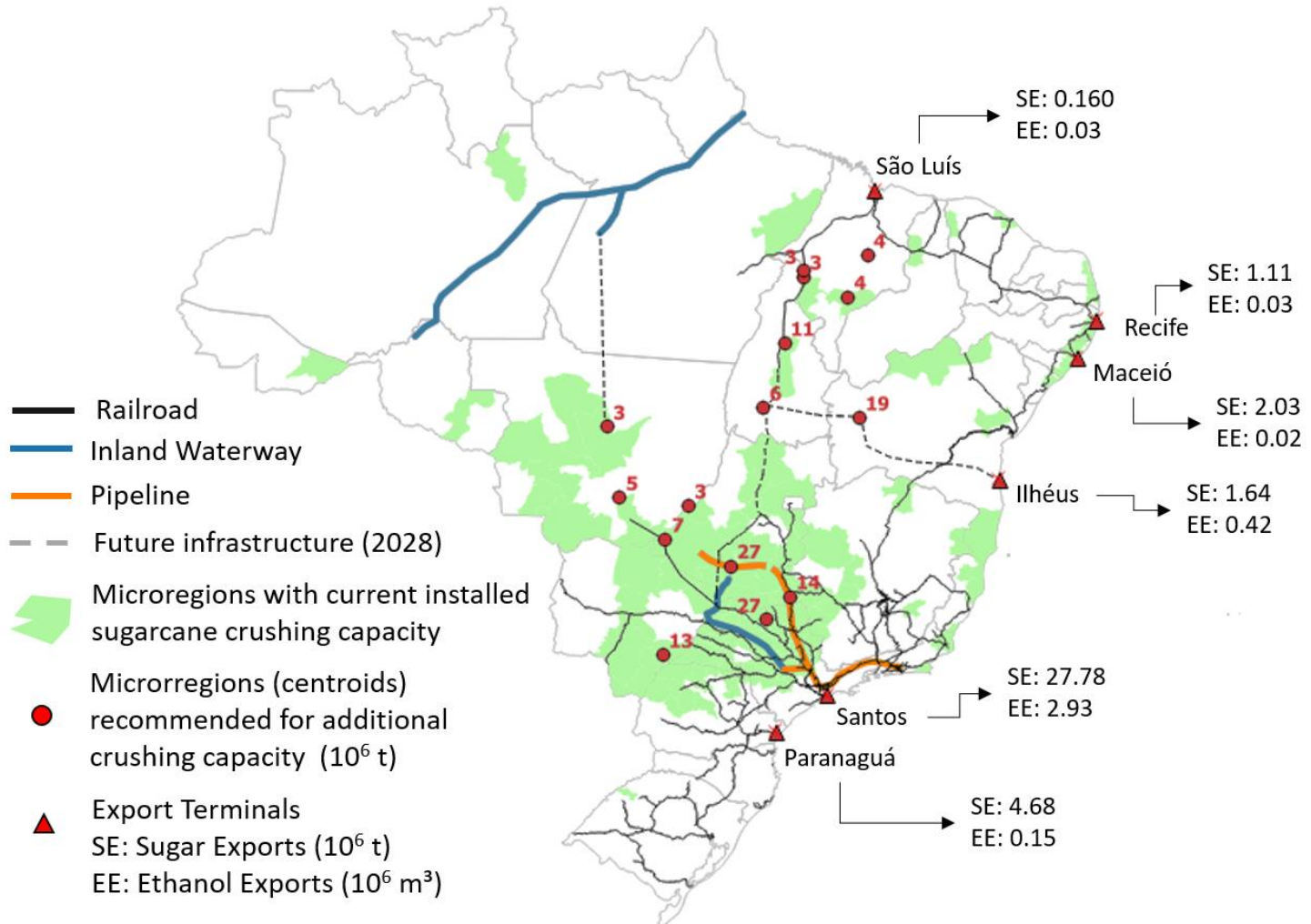
Sugarcane mill sugar and ethanol supply (2016 and 2028).

Description	2016	2028
Total Sugar Supply—Demand (10^6 t)	33.8	49.3
+ Domestic consumption	10.3	11.9
+ Exports	23.5	37.4
Total Ethanol Supply—Demand (10^6 m ³) ¹	30.2	41.2
+ Exports	1.9	3.5
+ Domestic market – fuel	27.5	37.7
Hydrous	17.5	25.8
Anhydrous	10.0	11.9
+ Domestic market - industrial uses	0.8	1.7

Regionalização e Malha Logística



Resultados



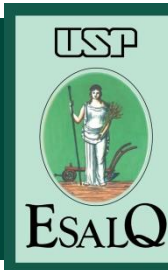
Resultados



Recommended micro-regional additional sugarcane mill crushing capacity.

Micro-region	State	Additional Mill Crushing Capacity (10 ³ t)	%
Quirinópolis	GO	27,459	18%
São José do Rio Preto	SP	26,797	18%
Barreiras	BA	19,464	13%
Uberaba	MG	13,720	9%
Nova Andradina	MS	12,707	8%
Porto Nacional	TO	11,307	8%
Alto Araguaia	MT	6,950	5%
Gurupi	TO	5,782	4%
Primavera do Leste	MT	4,920	3%
Alto Mearim e Grajaú	MA	4,481	3%
Chapadas das Mangabeiras	MA	4,325	3%
Alto Teles Pires	MT	3,483	2%
Médio Araguaia	MT	3,117	2%
Porto Franco	MA	3,000	2%
Imperatriz	MA	3,000	2%
Total		150,512	100%

Resultados



Share of each transportation mode in the total transportation of production.

Mode	Current Scenario (2016)		Future Scenario (2028)	
	Sugar	Ethanol	Sugar	Ethanol
Truck (%)	61%	86%	52%	79%
Rail (%)	39%	6%	48%	5%
Pipeline (%)	0%	8%	0%	15%
Average Distance (km)	515	512	509	527

Production and freight costs.

Total Cost ¹	Current Scenario (2016)		Future Scenario (2028)	
	S (US\$/t)	E (US\$/m ³)	S (US\$/t)	E (US\$/m ³)
Production cost	\$276.75	\$441.48	\$274.83	\$434.17
Transportation cost	\$30.71	\$24.51	\$29.44	\$24.48
Total	\$307.46	\$466.00	\$304.27	\$458.65