



**NEREUS**

Núcleo de Economia Regional e Urbana  
da Universidade de São Paulo

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# Integrating GIS and Input-Output systems for assessing the impacts of floods in São Paulo

*International Workshop on Urban Modeling  
São Paulo, Brazil, July 10, 2012*

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# Outline

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- ✓ The city of São Paulo

  - Data

  - Scenarios

  - Methodology

  - Some results

# The city of São Paulo

South America

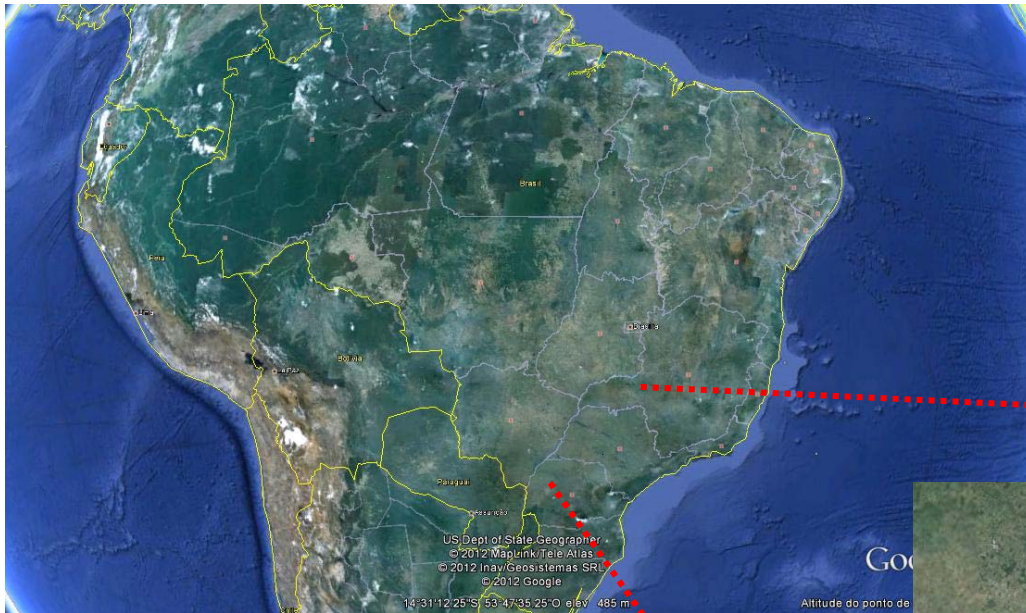


Brazil

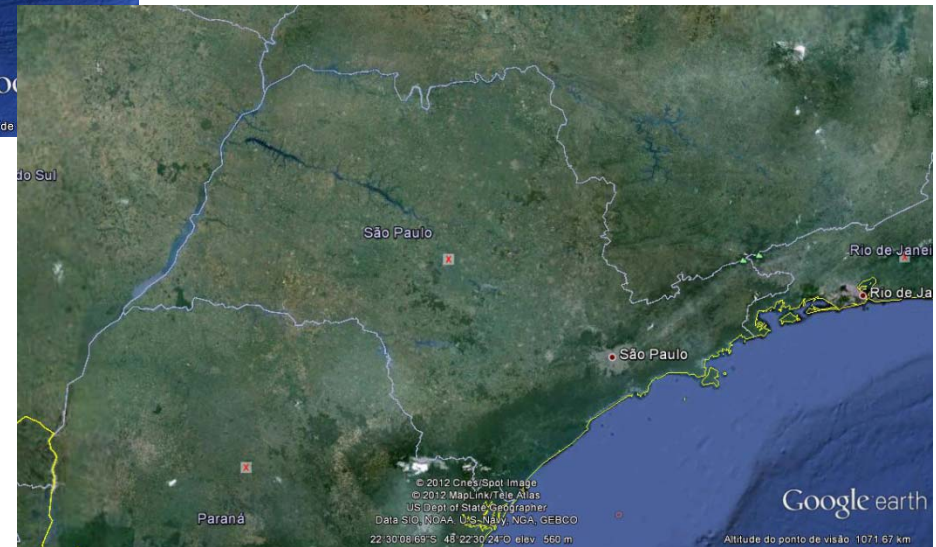


# The city of São Paulo

**Brazil**

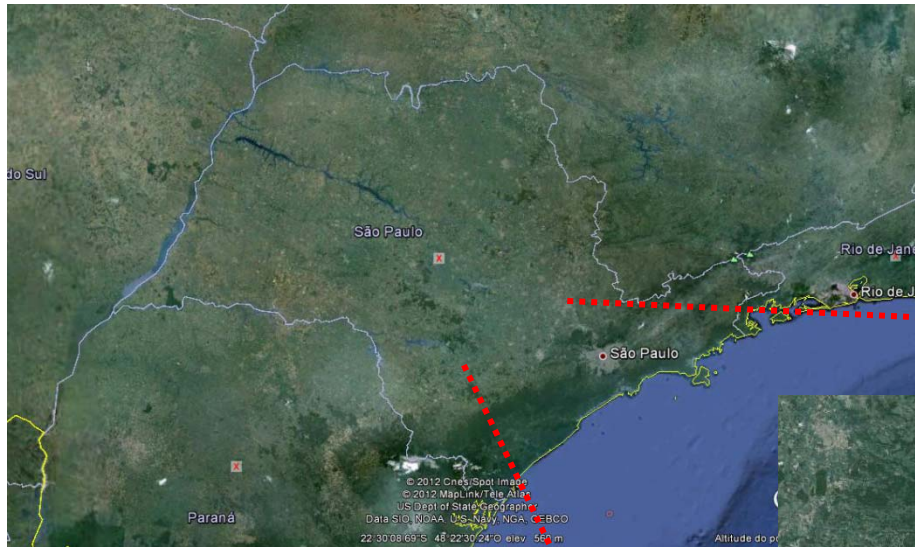


**The state of São Paulo**

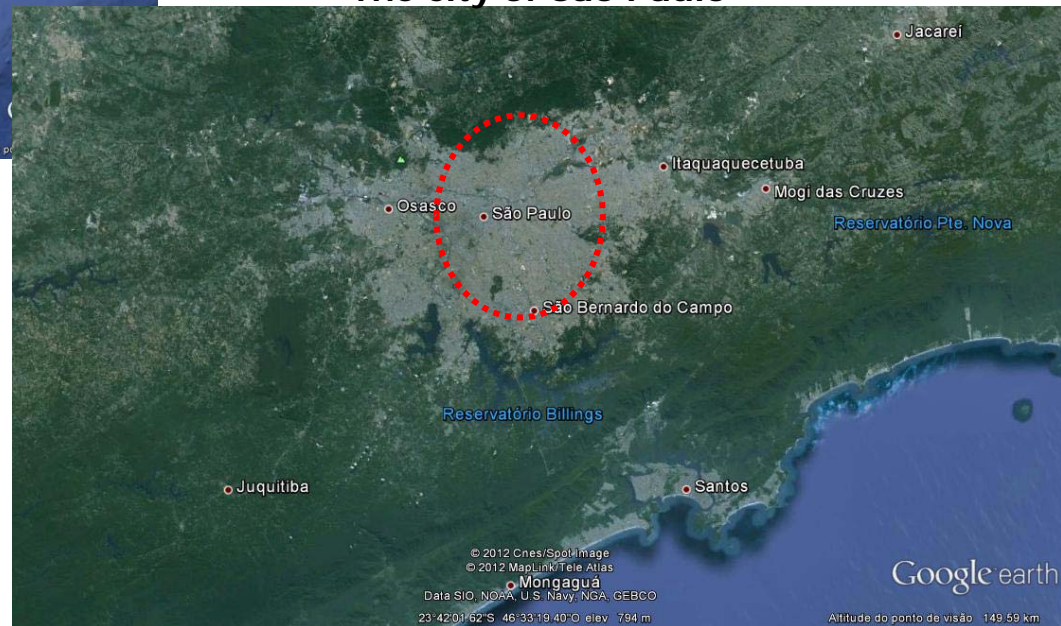


# The city of São Paulo

The state of São Paulo

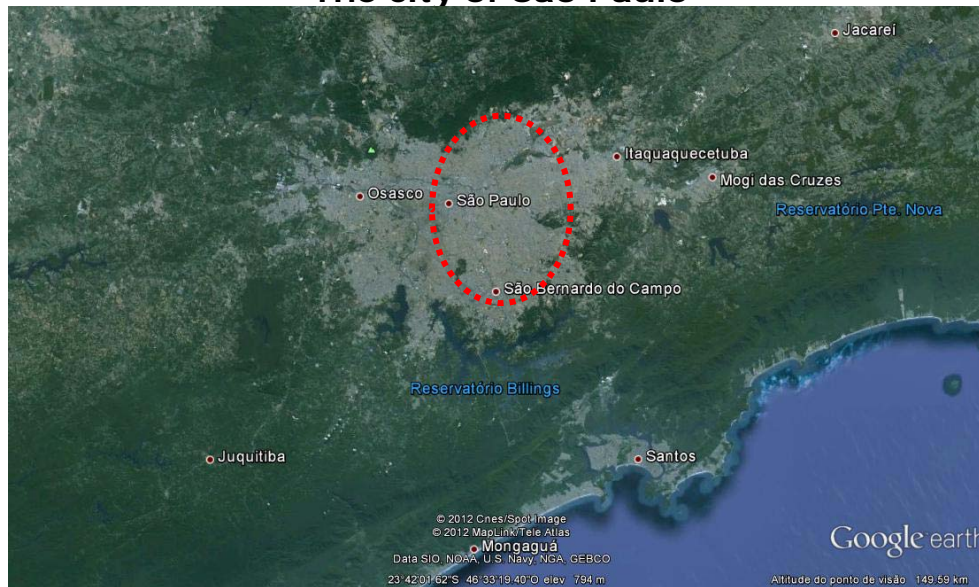


The city of São Paulo



# The city of São Paulo

## The city of São Paulo



# Impact assessment of floods in São Paulo

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Climate forecasts present changes in frequency and intensity of short-lasting extreme events \*

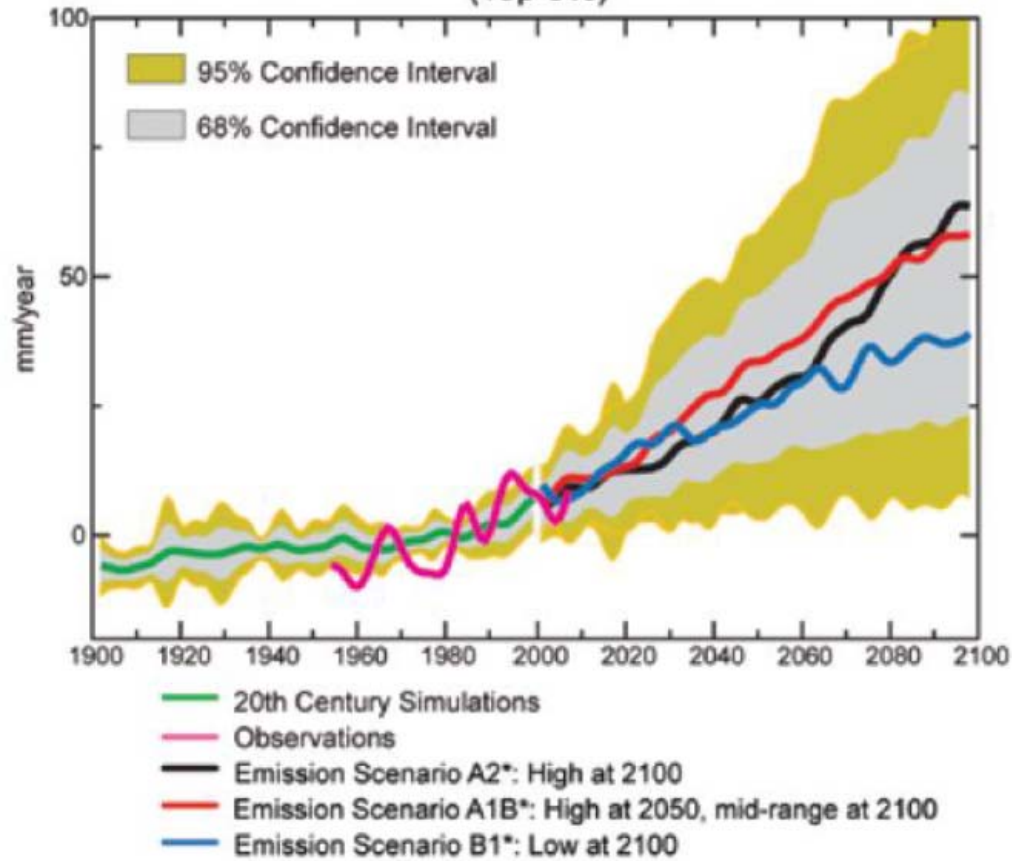
Preliminary climate change studies suggests that between 2070 and 2100 a rise between 2°C to 3°C in São Paulo can double the number of days with intense rain (above 10 mm).

\* Vulnerability of Brazilian megacities to climate changes: São Paulo Metropolitan Region (2010) - INPE, UNICAMP, USP, IPT, UNESP

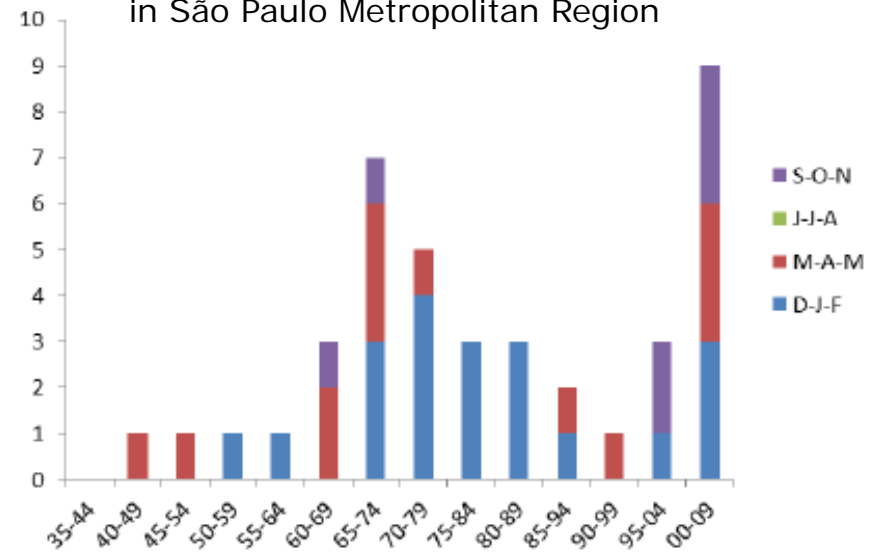
# Impact assessment of floods in São Paulo

IPCC 2007

Increase in Heavy Daily Precipitation  
(Top 5%)



Number of days with **rain above 80mm**  
in São Paulo Metropolitan Region



Source: Maria Assunção Faus da Silva, IAG/USP



# Impact assessment of floods in São Paulo



# Outline

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The city of São Paulo

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# Data: floods

## EMC – Emergency Management Center

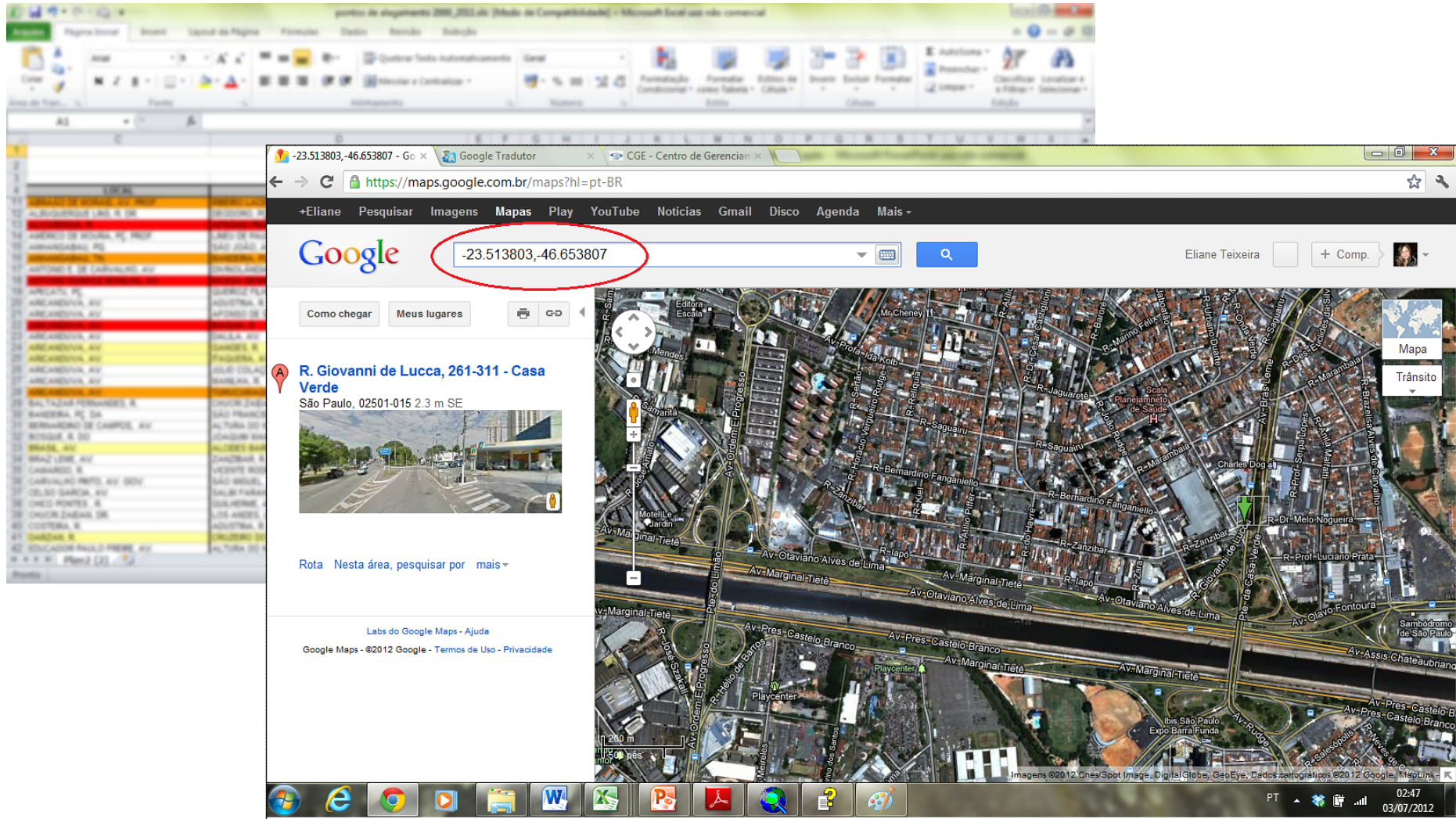
Microsoft Excel screenshot showing a spreadsheet titled "pontos de alagamento 2000\_2011.xls". The spreadsheet lists flooded streets and their frequency of floods across various periods.

LOCAL	REFERENCIA	SUB	PERÍODO DE CHUVAS INTENSAS																			
			00_01	01_02	02_03	03_04	freq04	04_05	freq05	05_06	freq06	06_07	freq07	07_08	freq08	08_09	freq09	09_10	freq10	10_11	freq11	
ABRAÃO DE MORAIS, AV. PROF.	RIBEIRO LACERDA, R.	IP			X											X	3	X	3	X	3	
ALBUQUERQUE LINS, R. DR.	DEODORO, PC. MAL.	SE																				
ALVAREZ, R.	APARECIDO, AV.	BT			X										X	4			X	4	X	4
AMÉRICO DE MOURA, PC. PROF.	LINEU DE PAULA MACHADO, AV.	BT																				
ANHANDABAU, PQ.	SÃO JOÃO, AV.	SE																				
ANHANDABAU, TN.	BANDEIRA, PC. DA	SE			X	X			X	3					X	3			X	3	X	3
ANTONIO E. DE CARVALHO, AV.	DIVINOLÂNDIA, PC.	PE																				
ANTONIO MUNHOZ BONILHA, AV.	NOSSA SENHORA DO O. AV.	FQ													X	4	X	4	X	4	X	4
APECATU, PC.	QUEIROZ FILHO, AV.	LA																				
ARICANDUVA, AV.	ADUSTINA, R.	IQ													X	1						
ARICANDUVA, AV.	AFONSO DE SAMPAIO E SOUZA, AV.	IQ							X	1					X	1						
ARICANDUVA, AV.	BAQUIA, R.	AF	X	X	X				X	4	X	4			X	4	X	4	X	4	X	4
ARICANDUVA, AV.	DALILA, AV.	AF																			X	1
ARICANDUVA, AV.	GANGES, R.	AF																			X	2
ARICANDUVA, AV.	ITAQUERA, AV.	AF		X					X	2						X	2	X	2			
ARICANDUVA, AV.	JULIO COLAÇO, R.	AF				X	2								X	2		X	2			
ARICANDUVA, AV.	MANILHA, R.	AF																			X	1
ARICANDUVA, AV.	TUMUCUMAQUE, R.	AF	X	X	X	X			X	3	X	3				X	3	X	3		X	3
BALTAR, R. FERNANDES, R.	CHUCRI ZAIDAN, AV. DR.	PI																			X	1
BANDERA, PC. DA	SÃO FRANCISCO, R.	SE																			X	1
BERNARDINO DE CAMPOS, AV.	ALTURA DO N. 144/170	SE													X	1						
BOSQUE, R. DO	JOAQUIM MANUEL DE MACEDO, R.	LA																			X	1
BRASIL, AV.	ALCIDES BARBOSA, R. ENG.	PI																			X	2
BRAZ LEME, AV.	ZANZIBAR, R.	CV																			X	2
CAMARGO, R.	VICENTE RODRIGUES, PC.	BT			X										X	1						
CARVALHO PINTO, AV. GOV.	SÃO MIGUEL, AV.	PE																			X	1
CELSO GARCIA, AV.	SALIM FARAH MALUF, AV.	MO																				X
CHICO POMTES, R.	GUILHERME, AV.	MG																				X
CHUCRI ZAIDAN, DR.	LOS ANDES, LG.	PI													X	1						
COSTEIRA, R.	ADUSTINA, R.	IQ													X	1						
PARZAN, R.	CRUZEIRO DO SUL, AV.	ST		X					X	2	X	2				X	2					X
EDUCADOR PAULO FREIRE, AV.	ALTURA DO N. 950	MG																			X	1

streets flooded

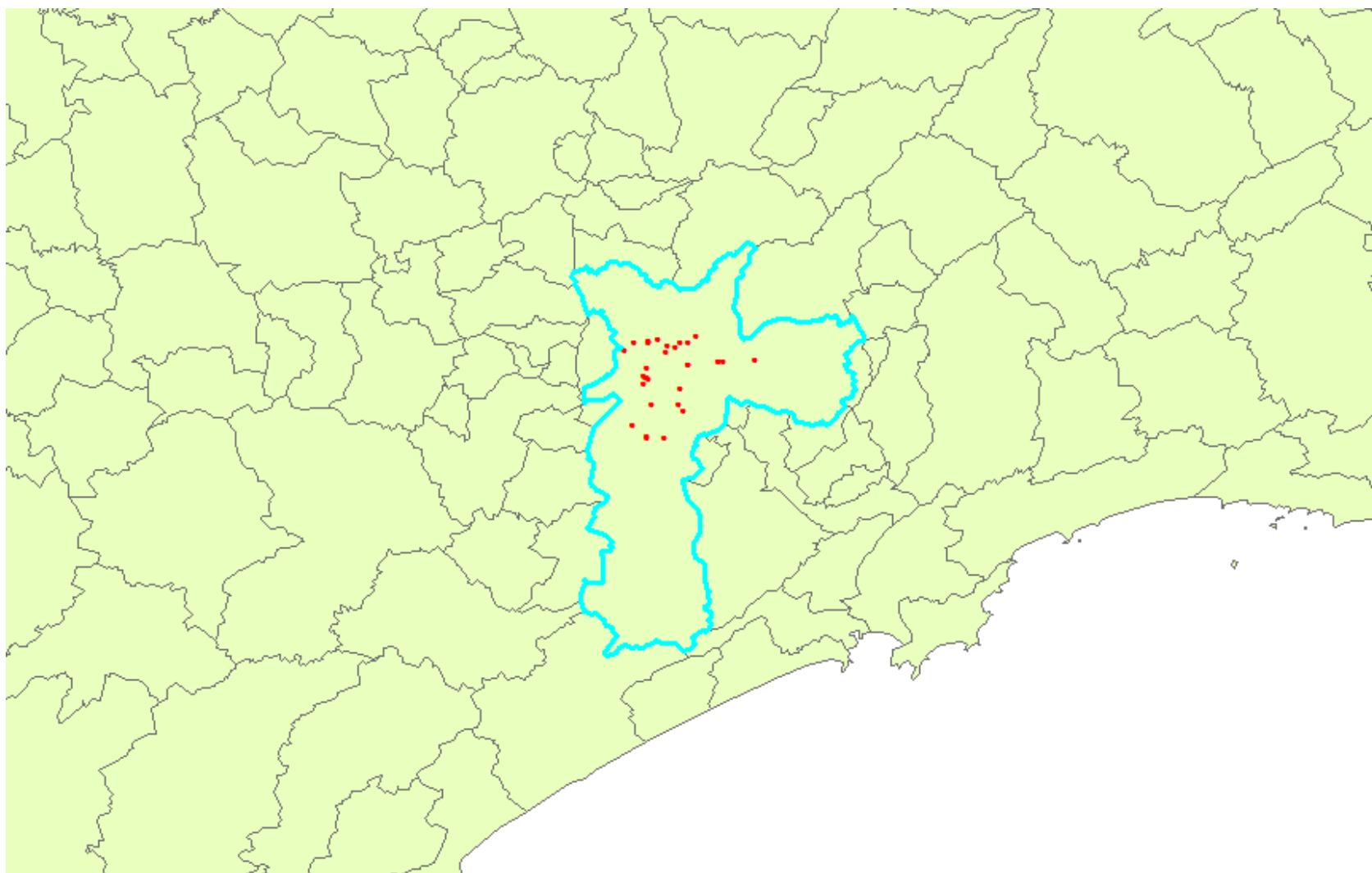
frequency of floods

# Data: georeferencing floods



## Data: georeferenced floods

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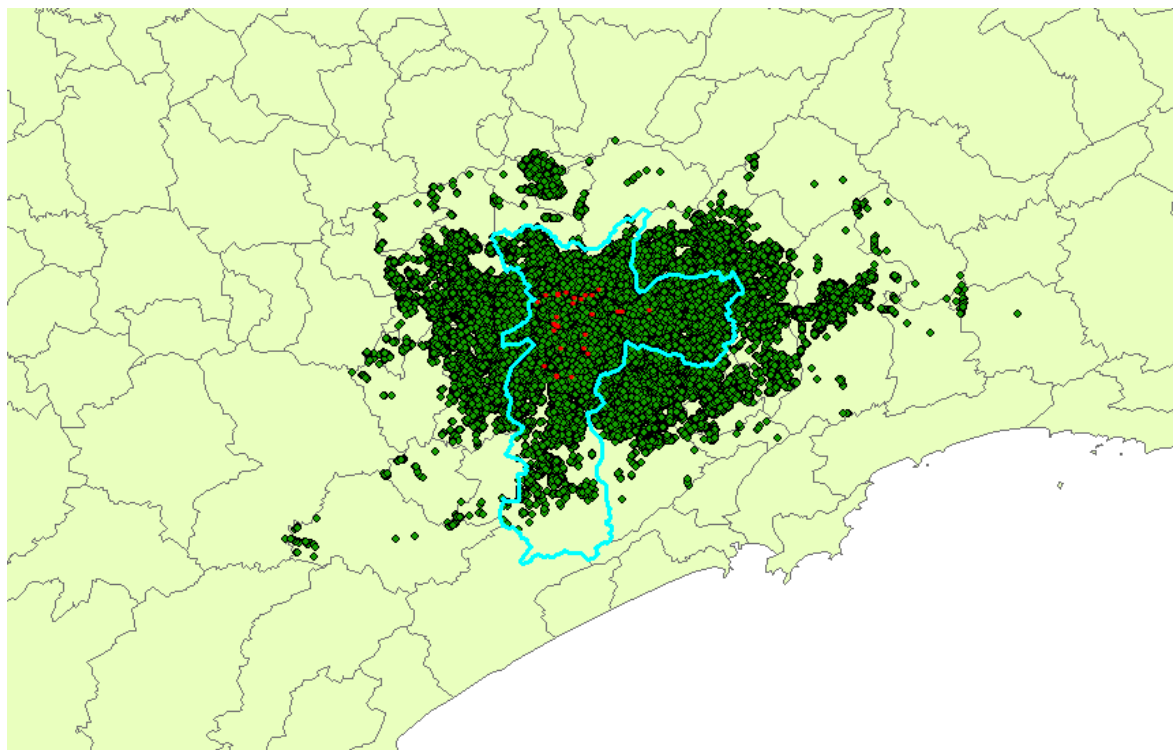
## Data: ARSI (RAIS)

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ARSI - Annual Relation of Social Information

Scope: national territory  
municipal level  
97% of formal labor market

Firms: localization  
total wages

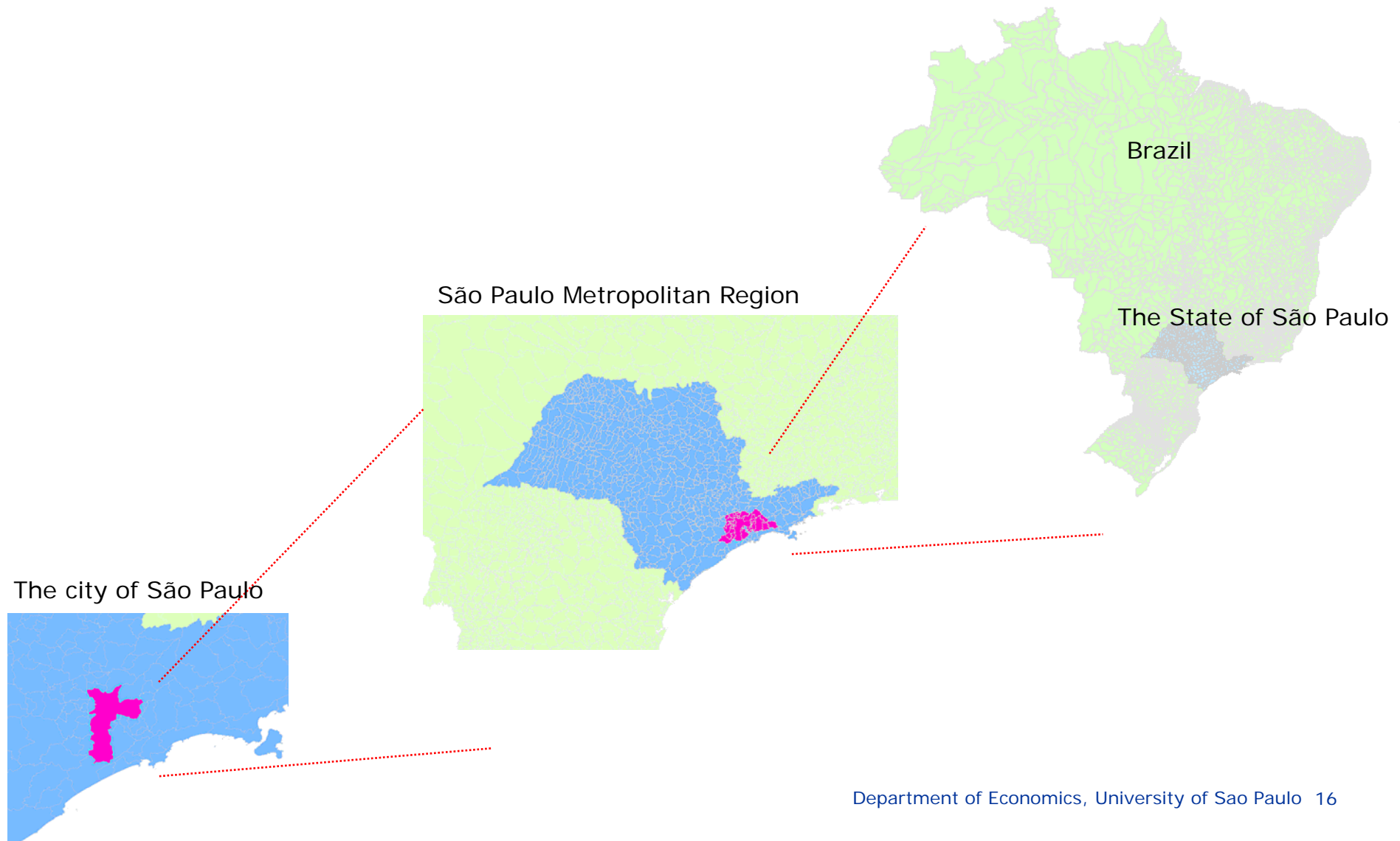


# Data: Extended Input-Output Model [2008]

		SP				SPMR				SPS				BR				Households				
		1	2	3	...	56	1	2	3	...	56	1	2	3	...	56	1	2	3	...	56	
São Paulo	1	$Z^{SP,SP}$				$Z^{SP,SPMR}$				$Z^{SP,SPS}$				$Z^{SP,BR}$				$C^{SP}$				
	2																					
	3																					
	:																					
	56																					
Rest of São Paulo Metropolitan Region	1	$Z^{SPMR,SP}$				$Z^{SPMR,SPMR}$				$Z^{SPMR,SPS}$				$Z^{SPMR,BR}$				$C^{SPMR}$				
	2																					
	3																					
	:																					
	56																					
Rest of São Paulo state	1	$Z^{SPS,SP}$				$Z^{SPS,SPMR}$				$Z^{SPS,SPS}$				$Z^{SPS,BR}$				$C^{SPS}$				
	2																					
	3																					
	:																					
	56																					
Rest of Brazil	1	$Z^{BR,SP}$				$Z^{BR,SPMR}$				$Z^{BR,SPS}$				$Z^{BR,BR}$				$C^{BR}$				
	2																					
	3																					
	:																					
	56																					
Wages																						

# Data: Interregional Input-Output Model

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# Outline

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The city of São Paulo

Data

✓ Scenarios

Methodology

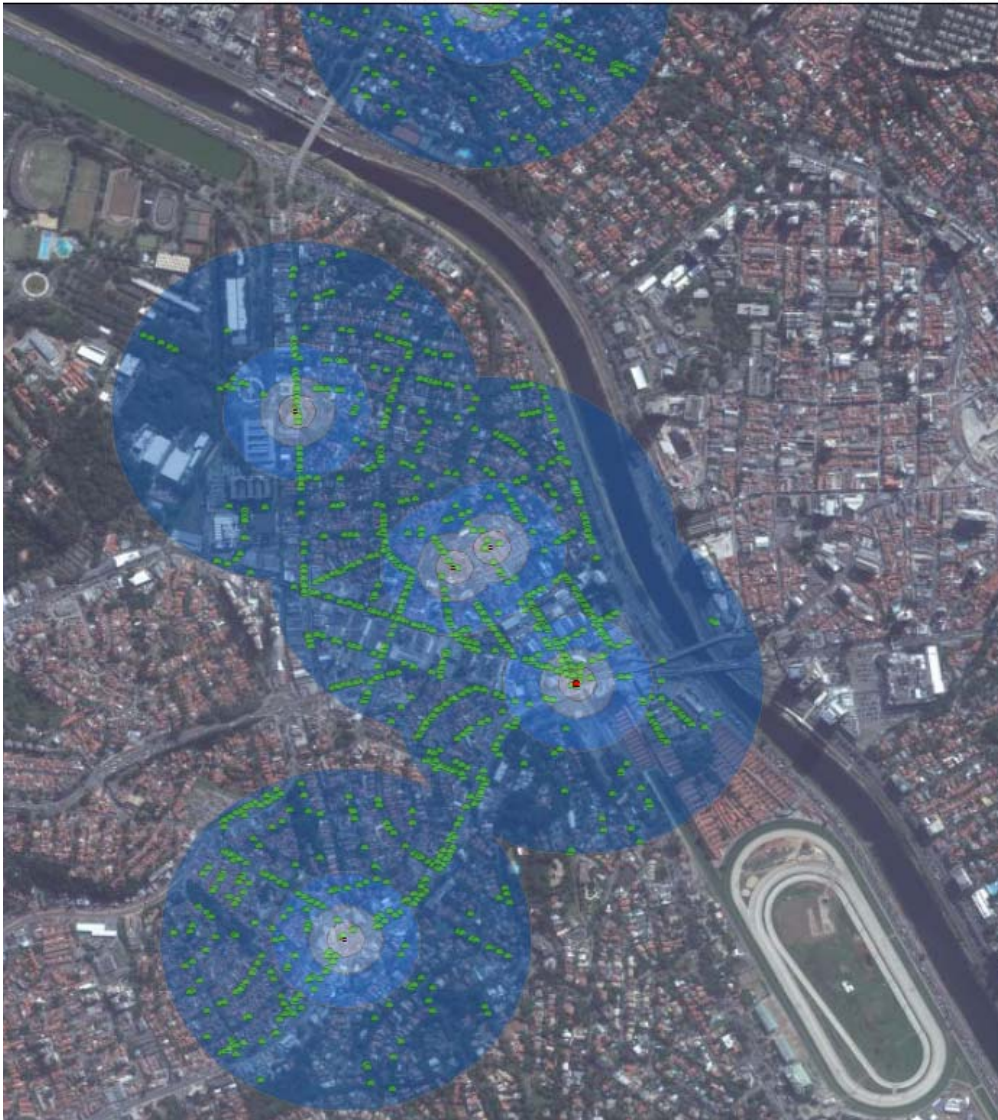
Some results

# Scenarios

Scenario 1		Scenario 2		Scenario 3		Scenario 4	
Influence Zone	Affected Firms	Influence Zone	Affected Firms	Influence Zone	Affected Firms	Influence Zone	Affected Firms
50 m	352	100 m	1.004	200 m	3.905	500 m	21.395



## Scenarios: an example



### The most problematic flood point in 2008

Latitude -23.57267	
Longitude -46.70449	
Influence Zone	Affected Firms
<b>100 m</b>	<b>137</b>

# Outline

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# Methodology: Interregional I-O System, closed in households

$$\Delta X = \overbrace{(I - A)^{-1}}^{\text{Leontief Inverse}} \underbrace{f}_{\text{shock vector}}$$

	SP					SPMR					SPS					BR					Households																																			
	1	2	3	...	56	1	2	3	...	56	1	2	3	...	56	1	2	3	...	56																																				
São Paulo	$Z^{SP,SP}$					$Z^{SP,SPMR}$					$Z^{SP,SPS}$					$Z^{SP,BR}$					$C^{SP}$																																			
Rest of São Paulo Metropolitan Region	$Z^{SPMR,SP}$					$Z^{SPMR,SPMR}$					$Z^{SPMR,SPS}$					$Z^{SPMR,BR}$					$C^{SPMR}$																																			
Rest of São Paulo state	$Z^{SPS,SP}$					$Z^{SPS,SPMR}$					$Z^{SPS,SPS}$					$Z^{SPS,BR}$					$C^{SPS}$																																			
Rest of Brazil	$Z^{BR,SP}$					$Z^{BR,SPMR}$					$Z^{BR,SPS}$					$Z^{BR,BR}$					$C^{BR}$																																			
Wages																																																								

$$a_{ij}^{rs} = \frac{Z_{ij}^{rs}}{X_j^s}$$

# Methodology

$$\text{Shock Vector} = \underbrace{\text{Productivity Coefficient}}_{\text{average sectoral productivity}} * \text{Total wages in Flood Days}$$

$$\text{Productivity Coefficient} = \frac{\text{Gross Output}}{\text{Cost of Labor}}$$

## Underlying Assumptions:

- Continuous production in business days
- 1 day of flood impacts 1 day of production

Sectors	90	100	200	300
1	0	0	1,022	128,563
2	700	700	700	17,810
3	0	0	0	0
4	0	0	0	0
5	2,525,716	2,525,575	1,897,861	21,469,628
6	0	0	0	181,767
7	0	0	171,408	1,080,267
8	0	0	95,217	1,362,129
9	0	0	9,212	162,919
10	0	2,672	1,672	29,289
11	0	0	225,814	1,394,843
12	0	6,212	1,118,276	5,227,663
13	0	0	0	0
14	0	0	0	0
15	0	0	0	1,539,190
16	0	0	0	237,463
17	0	0	17,242	6,125,227
18	0	0	0	0
19	0	5,438,294	5,477,289	5,511,342
20	0	0	0	89,827
21	0	0	11,738	262,105
22	105,486	105,252	110,964	1,206,303
23	0	0	0	16,039
24	0	0	1,936	202,664
25	0	0	211,904	1,147,301
26	0	77,116	77,116	583,995
27	0	2,140	117,536	1,766,752
28	11,615	68,617	94,617	1,381,038
29	0	0	0	227,534
30	0	0	0	1,139,768
31	2,508,775	2,509,451	2,509,451	1,623,619
32	348	348	282,617	1,676,683
33	0	0	0	647,686
34	0	0	0	0
35	0	0	0	0
36	0	7,695	18,746	4,647,044
37	0	0	0	291,768
38	25,171	90,900	190,665	1,539,617
39	0	0	0	2,488,241
40	399,634	547,619	1,469,199	11,463,207
41	284,983	1,679,458	5,083,405	27,131,752
42	5,534	10,846	649,963	21,462,950
43	22,234	474,364	5,017,974	16,293,467

# Outline

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## Some results: Potential Product Losses

	Direct Damage (in R\$)			
	<b>Scenario 1 50 m</b>	<b>Scenario 2 100 m</b>	<b>Scenario 3 200 m</b>	<b>Scenario 4 500 m</b>
São Paulo	6.296.382	16.888.093	47.584.343	565.876.814
Rest of São Paulo Metropolitan Region	0	0	0	0
Rest of São Paulo (state)	0	0	0	0
Rest of Brazil	0	0	0	0
	<b>6.296.382</b>	<b>16.888.093</b>	<b>47.584.343</b>	<b>565.876.814</b>

	Total Damage (in R\$)			
	<b>Scenario 1 50 m</b>	<b>Scenario 2 100 m</b>	<b>Scenario 3 200 m</b>	<b>Scenario 4 500 m</b>
São Paulo	8.971.487	24.679.478	72.637.226	938.946.439
Rest of São Paulo Metropolitan Region	1.225.752	3.177.525	8.667.814	113.064.773
Rest of São Paulo (state)	2.187.005	5.083.498	11.898.803	143.264.062
Rest of Brazil	3.715.509	7.480.972	16.074.355	185.498.488
	<b>16.099.752</b>	<b>40.421.473</b>	<b>109.278.198</b>	<b>1.380.773.763</b>



## Some results: Potential Product Losses

	Total Damage (in %)			
	<b>Scenario 1</b> <b>50 m</b>	<b>Scenario 2</b> <b>100 m</b>	<b>Scenario 3</b> <b>200 m</b>	<b>Scenario 4</b> <b>500 m</b>
São Paulo	56	61	66	68
Rest of São Paulo Metropolitan Region	8	8	8	8
Rest of São Paulo (state)	14	13	11	10
Rest of Brazil	23	19	15	13
	<b>100</b>	<b>100</b>	<b>100</b>	<b>100</b>

	Damage ratio = Total Damage / Direct Damage			
	<b>Scenario 1</b> <b>50 m</b>	<b>Scenario 2</b> <b>100 m</b>	<b>Scenario 3</b> <b>200 m</b>	<b>Scenario 4</b> <b>500 m</b>
Damage Ratio	3,0	2,8	2,8	3,1

Thank you!

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