



Projeto Educação - Extensão Educacional
um projeto de difusão do conhecimento científico

Curso de Extensão Educacional – Científica e Ambiental

Hidrologia e Mudanças do Uso e
Cobertura da Terra

Instituto Nacional de Pesquisas Espaciais - INPE
Cachoeira Paulista / SP, de 02/09 a 07/10/2017

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COPPE-UFRJ

Laboratório de Recursos Hídricos e Meio Ambiente (LABH2O)

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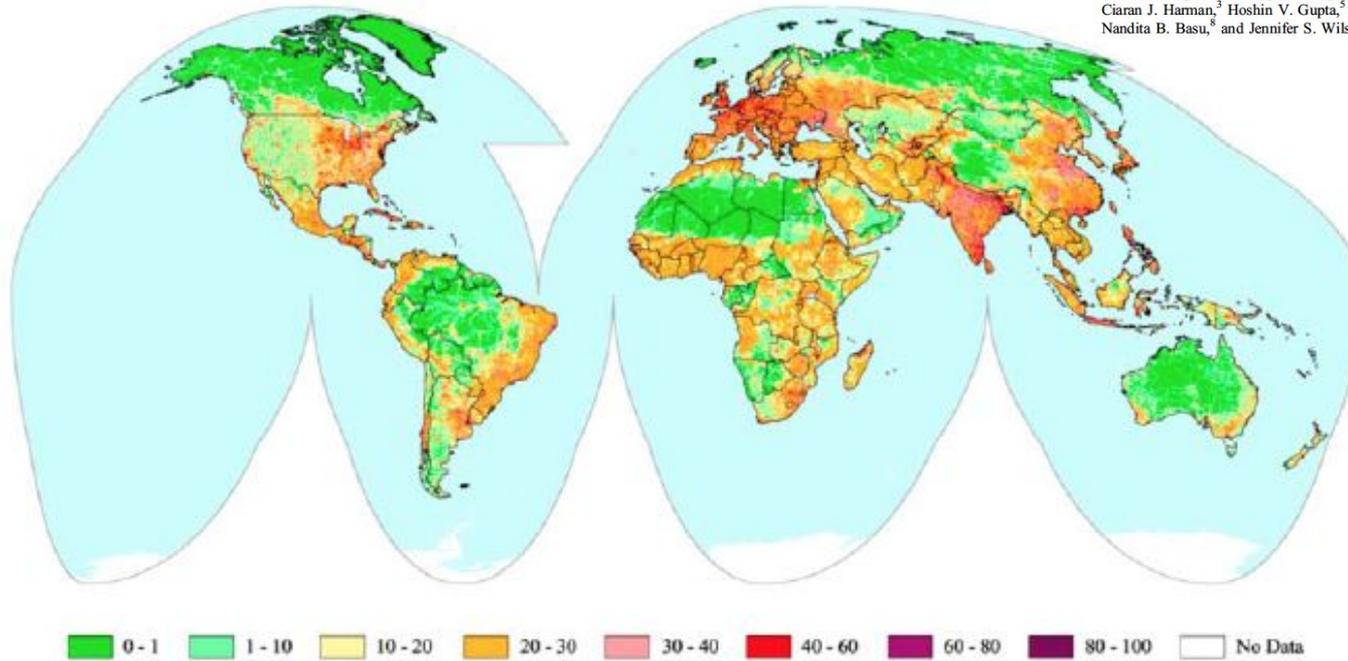


Figure 1. *Sanderson et al.* [2002] estimated the human footprint by quantifying how strongly humans impact the land surface, with a higher value of their human influence index indicating larger human impact (www.wcs.org/humanfootprint/). Their index integrates human population density, land transformation, human access, and electrical power infrastructure. Their study suggests that over 80% of the land surface is impacted by human activity [from *Sanderson et al.*, 2002].

- Crescimento da população tem aumentado as demandas por energia, água, alimentos e espaço, alterando nosso meio ambiente
- O impacto das atividades humanas se espalham e aprofundam através do planeta, competindo com forças de escala geológica

- A história humana tem evoluído em torno do acesso à água
- A localização de infraestrutura, modificações nos canais, captação de águas superficiais e subterrâneas, mudanças no uso e cobertura do solo, mudanças climáticas, entre outros, aumentam o risco de desastres como enchentes e secas, a qualidade das águas e o abastecimento de água.
- Importantes modificações na paisagem

Llanos de Moxos (Bolivia)



<http://cinabrio.over-blog.es/article-grandeza-y-misterio-arawak-en-los-llanos-de-moxos-119854593.html>

<http://www.sas.upenn.edu/~cerickso/applied3.html>

Peru



Terraços agrícolas Machu Pichu



Salinas de Maras

Vale Sagrado



Índia

Reservatórios para irrigação

Nepal

Campos de arroz



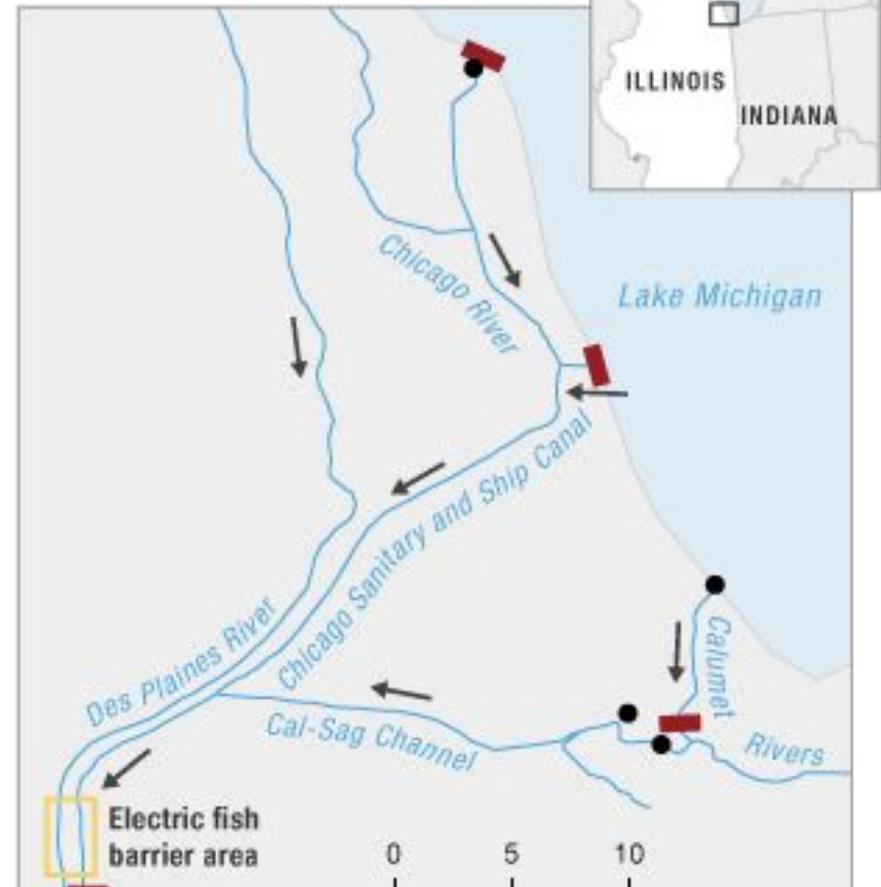
Chicago River (USA)

Mudança no curso do rio

Before Diversion



After Diversion



China

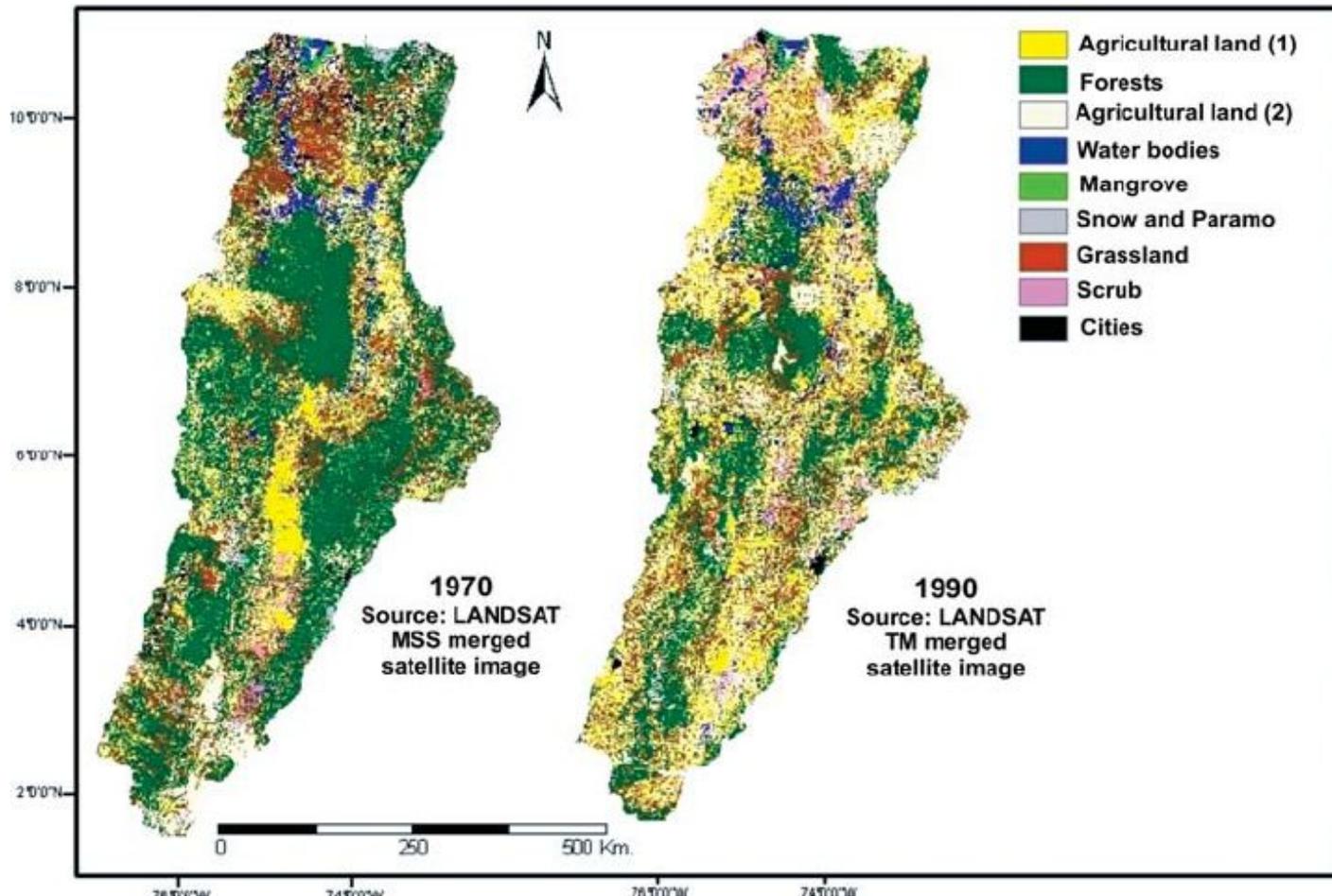
Hidrelétrica das Três Gargantas



<https://www.sciencedaily.com/releases/2007/06/070612134358.htm>

Colômbia- Rio Magdalena

Mudança no uso e cobertura do solo



Restrepo A., Juan D.. (2015). El impacto de la deforestación en la erosión de la cuenca del río Magdalena (1980-2010). *Revista de la Academia Colombiana de Ciencias Exactas, Físicas y Naturales*, 39(151), 250-267.

<https://dx.doi.org/10.18257/raccefyn.141>

São Paulo - Vale do Rio Verde

Urbanização

- Avenida Sumaré e a Paulo VI, Vale do Rio Verde, região de Pinheiros



Obras hidráulicas



Mudança na qualidade da água



Águas servidas e poluição

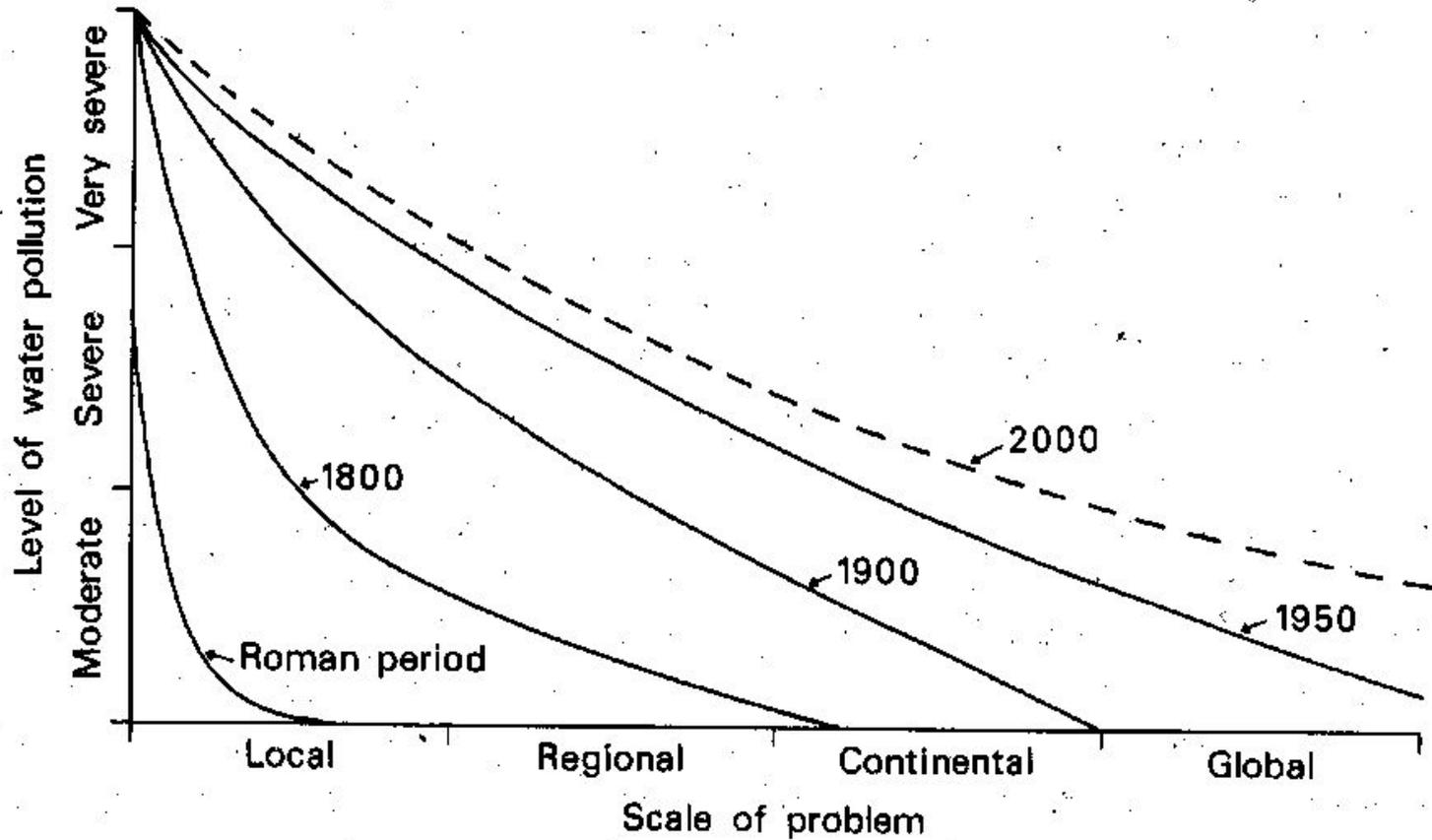


Figure 1.8 The global trend in water pollution. After Meybeck *et al.* (1990)

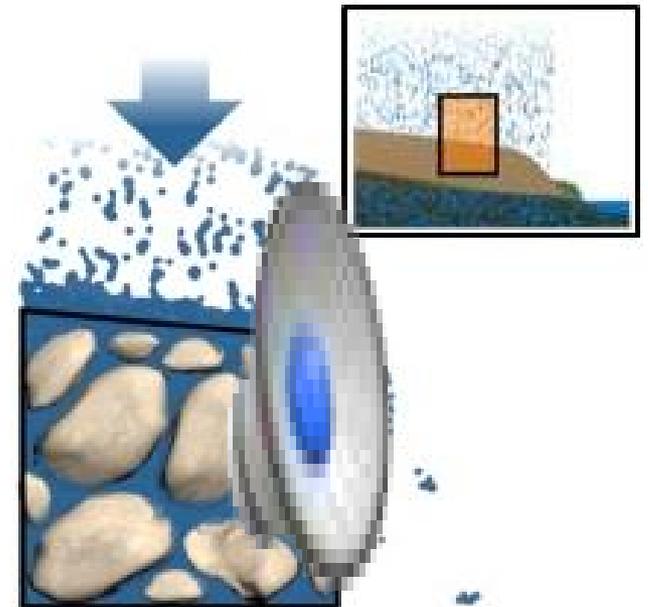
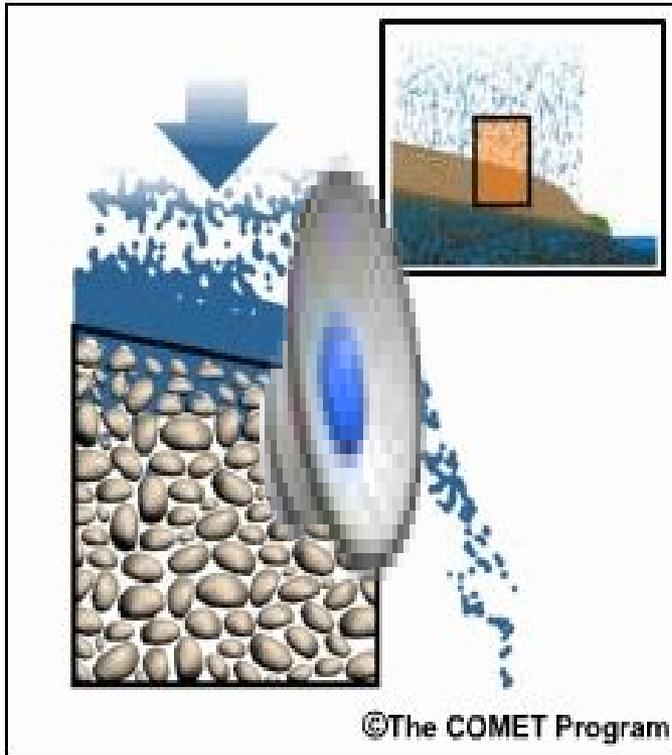
Mudança Hidrológica e a mudança no
uso e cobertura do solo:

Efeitos da urbanização

Propiedades da superfície

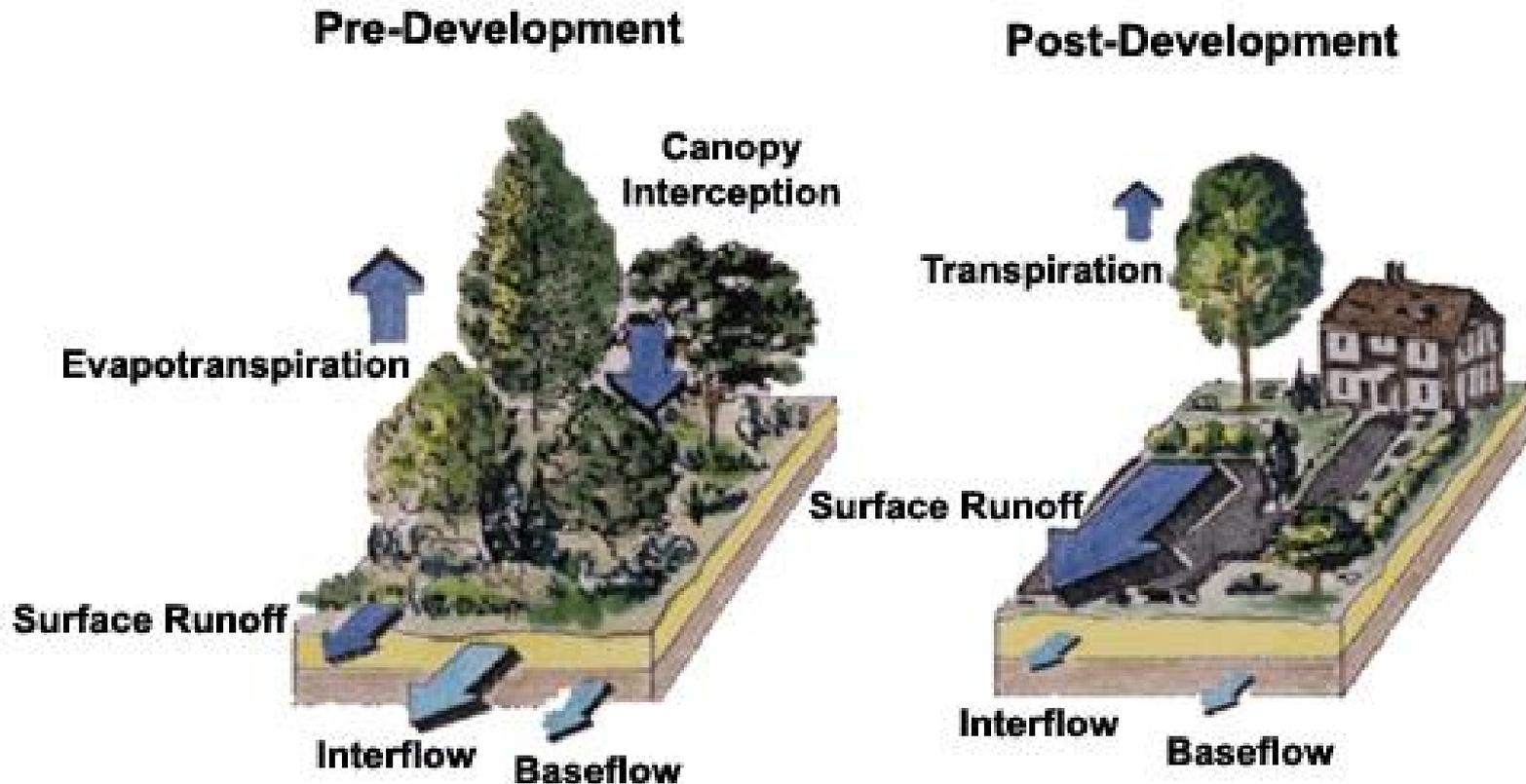


Processos de Geração de escoamento



Note: Enlarged soil particles are not drawn to scale. ©The COMET Program

Mudanças no uso da terra impactam a resposta hidrológica



Mudanças no ciclo hidrológico devido ao “desenvolvimento”

Efeitos da urbanização

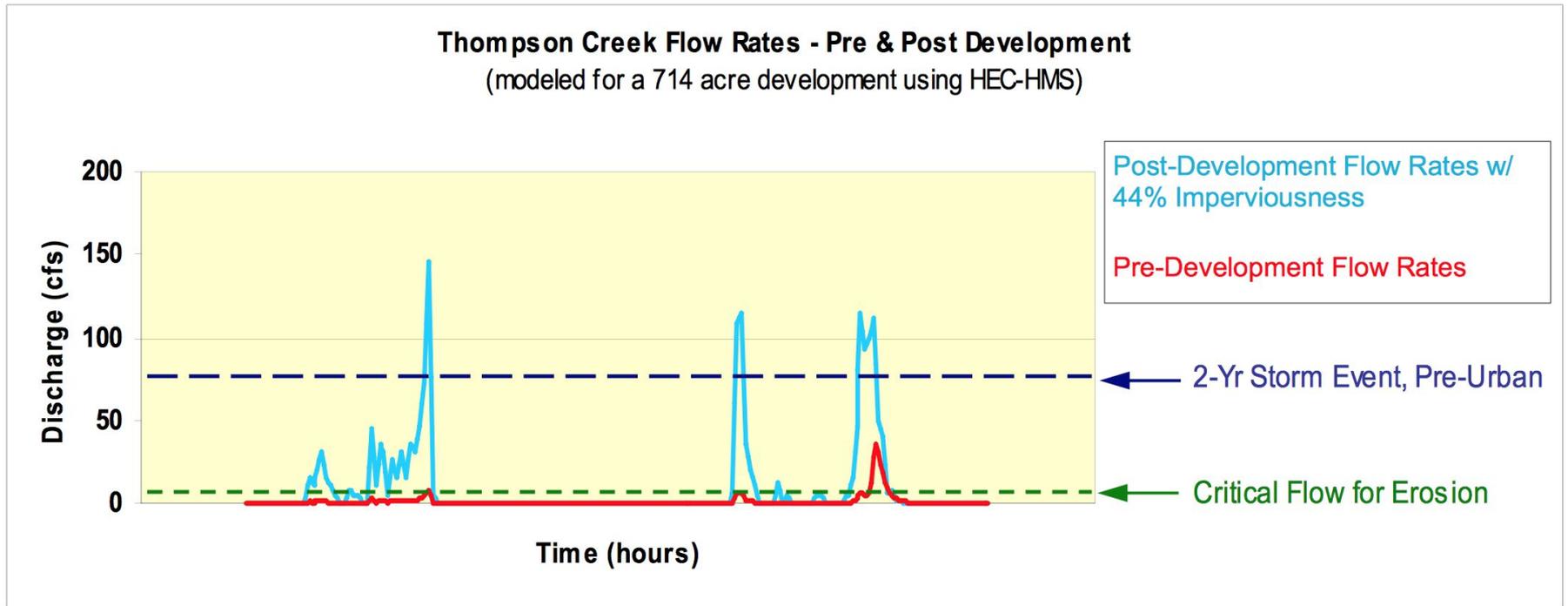


Figure 5. Comparison of Pre- and Post-Development Flow Conditions, Thompson Creek, Santa Clara Valley, CA.

How Urbanization Affects the Water Cycle

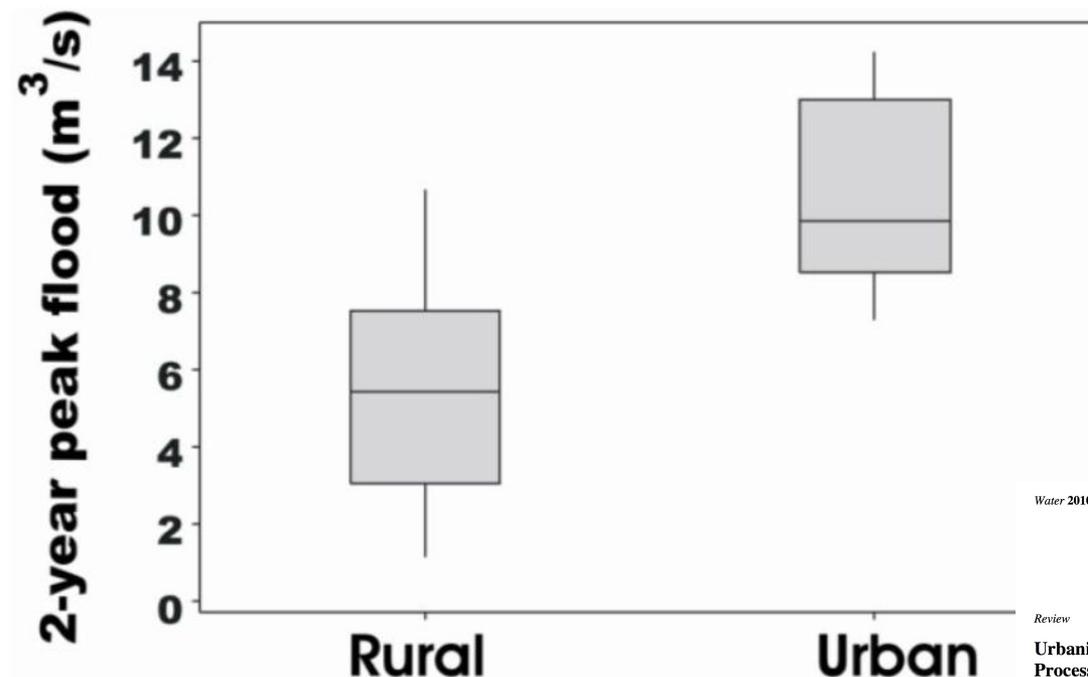
Why is the Water Cycle Important?

California Water & Land Use Partnership

An educational program for land use decision makers that addresses the relationship between land use and natural resource protection.

Bacias urbanizadas produzem picos de vazões muito superiores aos produzidos em bacias rurais

Figure 4. A boxplot (box represents, 25th, 50th, and 75th percentiles) comparison of urban and rural 2 year peak streamflows for 10 small watersheds (1 mi² or 2.6 km²) in 10 states (AL, DE, FL, GA, KY, LA, NC, SC, TN, TX) within the southern U.S. (using the National Streamflow Statistics Program (Turnipseed and Ries, 2007)). Simulated watershed impervious area was 25% TIA.



Water 2010, 2, 605-648; doi:10.3390/w2030605

OPEN ACCESS

water

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Review

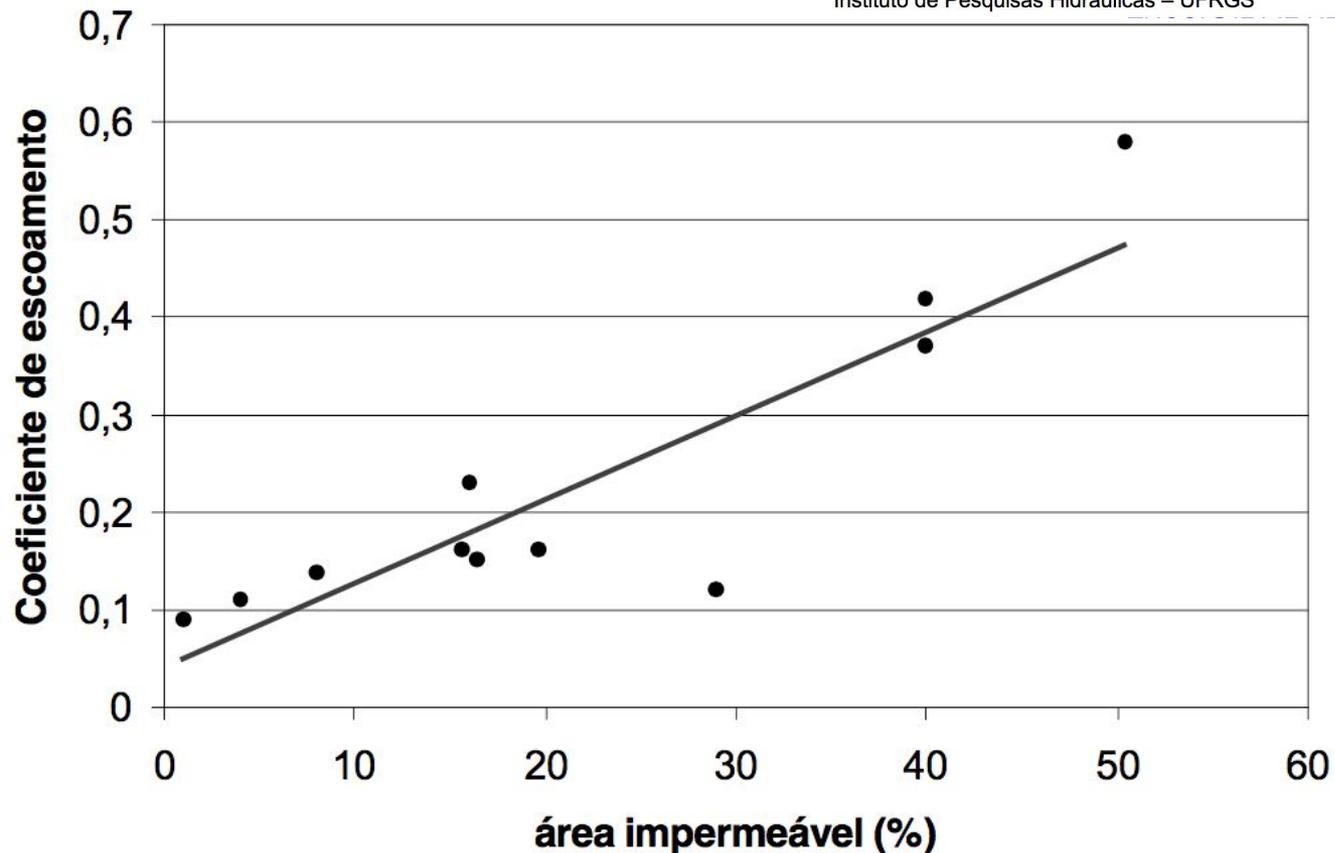
Urbanization Effects on Watershed Hydrology and In-Stream Processes in the Southern United States

Michael O'Driscoll ^{1*}, Sandra Clinton ², Anne Jefferson ³, Alex Manda ¹ and Sara McMillan ⁴

A quantidade de escoamento gerado em bacias urbanizadas é proporcional à extensão da área impermeabilizada

COEFICIENTE DE ESCOAMENTO E VAZÃO MÁXIMA DE BACIAS URBANAS

Carlos E. M. Tucci
Instituto de Pesquisas Hidráulicas – UFRGS



URBANAS

Figura 1 Coeficiente de escoamento em função da área impermeável

Efeitos da intervenção humana

Urbanização

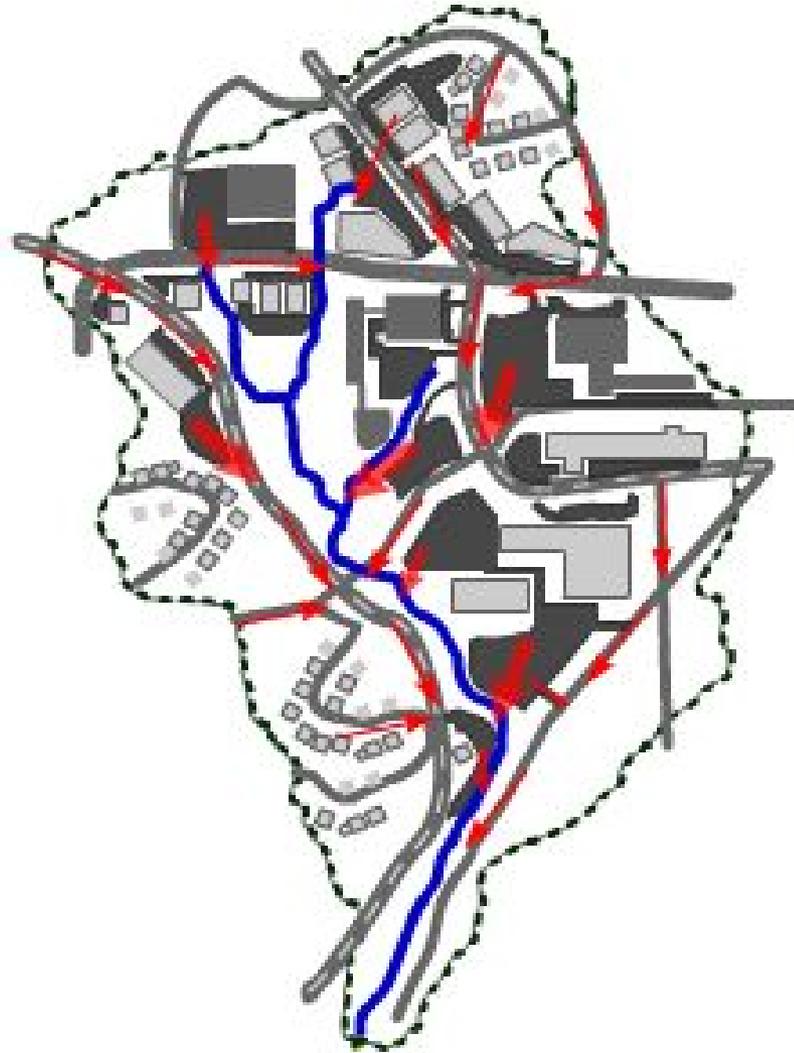


Impermeabilização da superfície

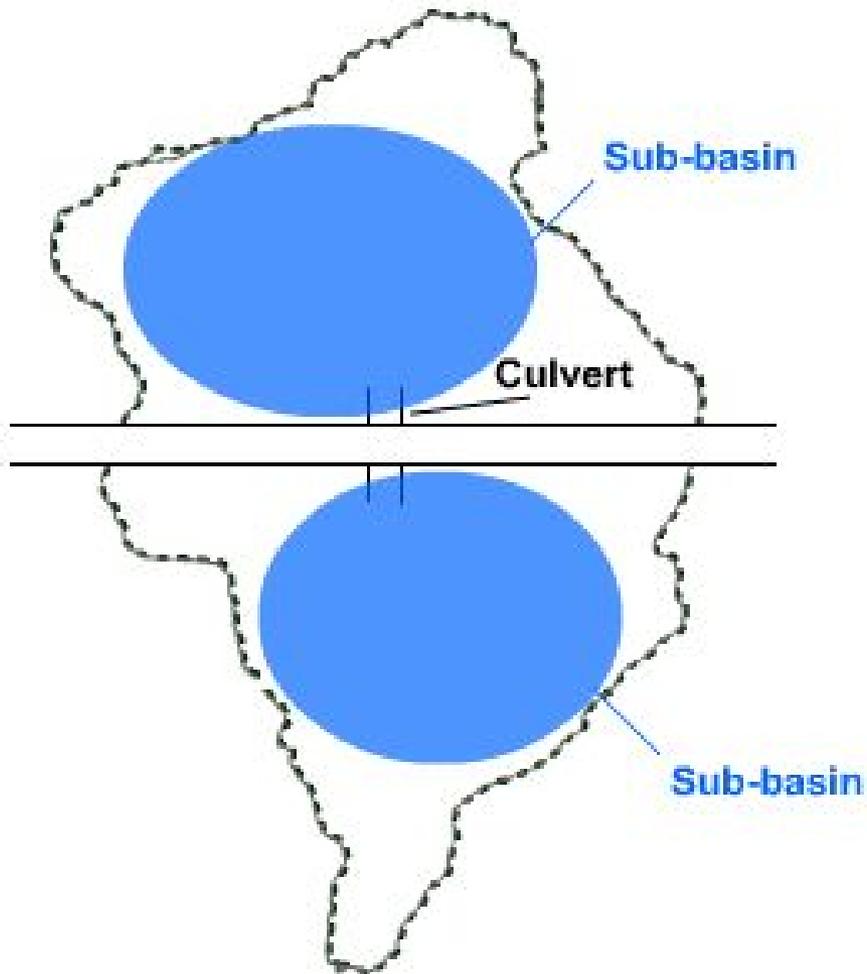
Urbanização

Bacias urbanas:
divisão em sub-bacias

Effect of Urban Grid on Runoff



Effects of Urban Grid on Runoff



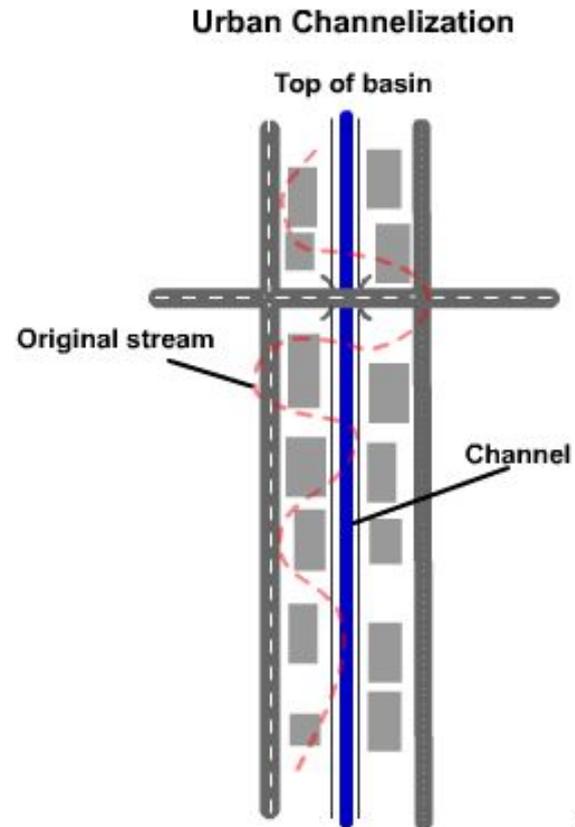
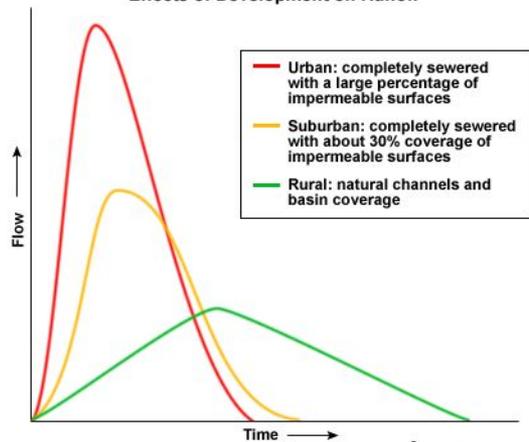
Efeito da presença de uma estrada

Urbanização

Diminuição da rugosidade e retificação dos canais



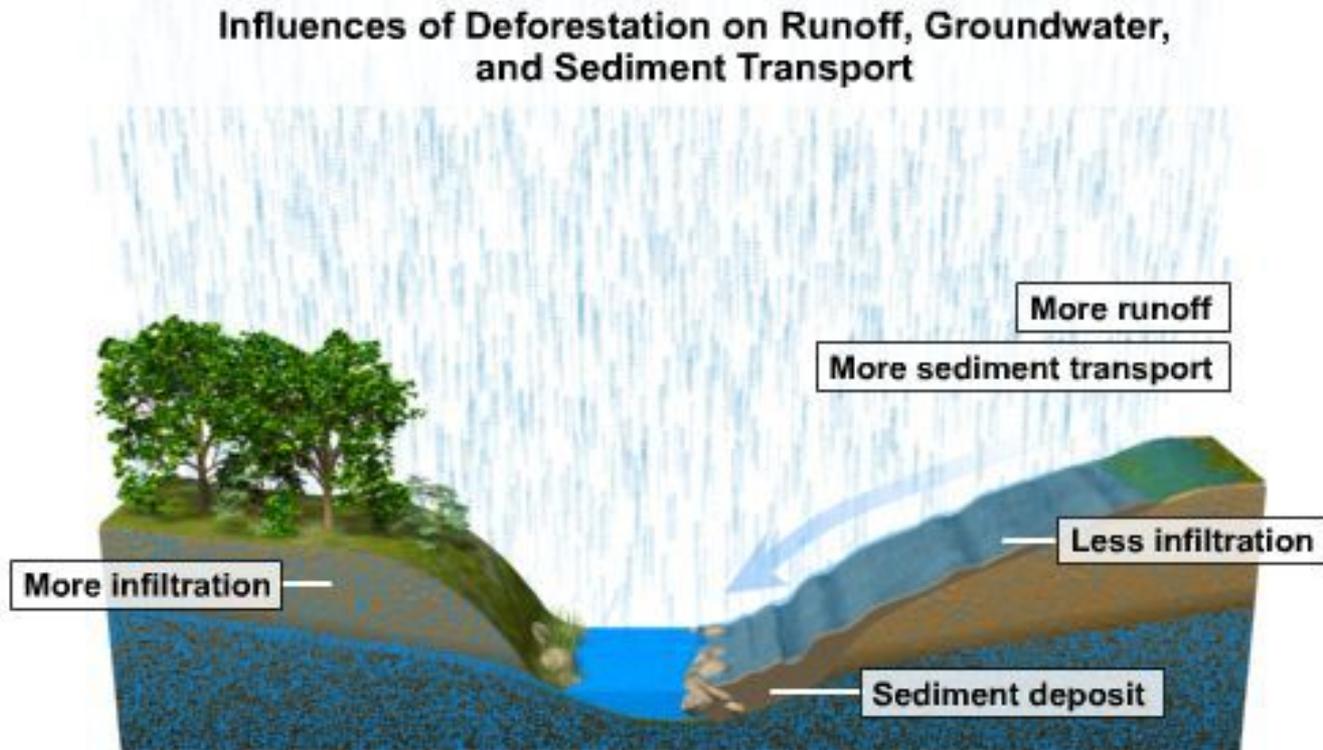
Effects of Development on Runoff



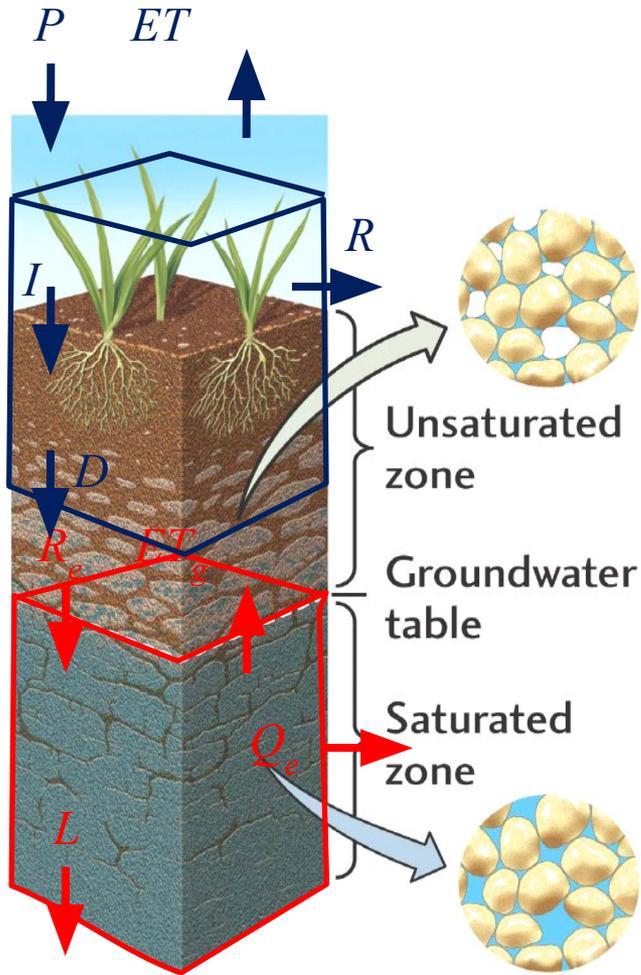
Mudança Hidrológica e a mudança no
uso e cobertura do solo:

Efeitos do desflorestamento

Propiedades da superfície



O Balanço Hídrico



$$R = P - ET$$

Rancho Grande (Rondônia)

Microbacias Preadas

Influence of land-use change on near-surface hydrological processes:
Undisturbed forest to pasture

Sonja Germer^{a*}, Christopher Neill^b, Alex V. Krusche^c, Helmut Elsenbeer^d

^a Berlin-Brandenburg Academy of Sciences and Humanities, Jägerstr. 22/23, 10117 Berlin, Germany

^b The Ecosystems Center, Marine Biological Laboratory, 7 MBL St., Woods Hole, MA 02543, USA

^c Centro de Energia Nuclear na Agricultura, University of São Paulo, PO Box 96, 13.400-970 Piracicaba, SP, Brazil

^d Institute of Geocology, University of Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Golm, Germany

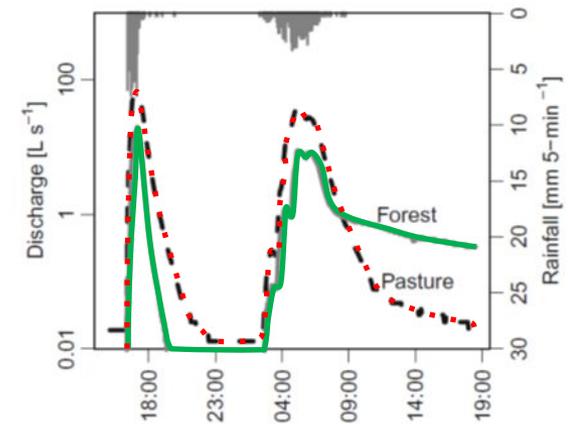
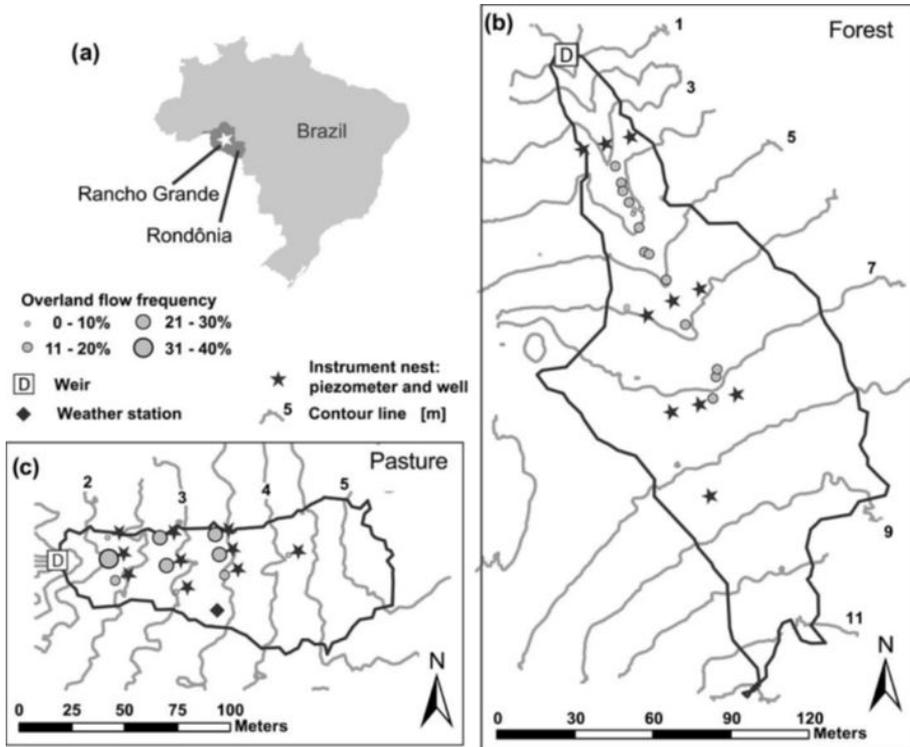


Fig. 7. Comparison of forest (grey solid line) and pasture (black dashed line) stormflow hydrographs for a rainfall event on March 5-6, 2005. Discharge is plotted on a logarithmic scale to show small flow differences more clearly. Bars in the top of the figure indicate 5-min rainfall sums.

Floresta (1.37 ha) e Pastagem (0.73 ha) Separadas 400 m aproximadamente.

Efeito da mudança no uso do solo nas características hidráulicas dos solos e na geração de fluxo

Infiltração

Movimento d'água dentro do solo

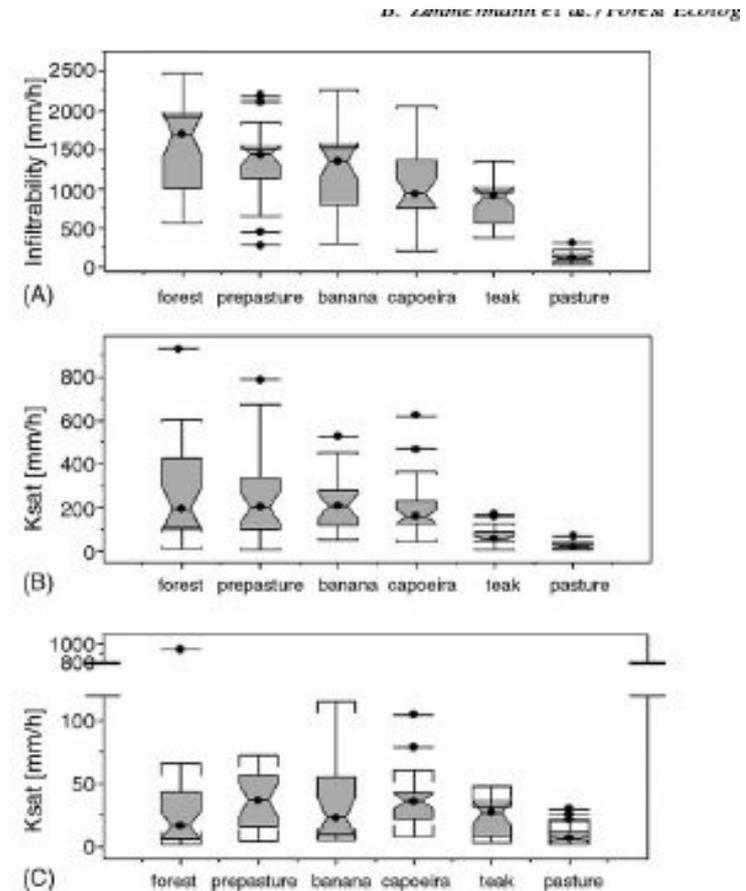


Fig. 3. Infiltrability and Ksat as a function of land use (at surface, at a depth of 12.5 and 20 cm: panels A–C, respectively). The crossbar within the box shows the median, the length of the box reflects the interquartile range, the fences are marked by the extremes if there are no outliers, or else by the largest and smallest observation that does not qualify for an outlier. Outliers are defined as data points more than 1.5 times the interquartile range away from the upper or lower quartile. The notches represent the 95% confidence interval for the median, and overlapping notches from two box plots indicate that there is no significant difference between the medians.

Mudança Hidrológica e a mudança no
uso e cobertura do solo:

Efeitos do desflorestamento

Grandes Bacias

Studies and methodologies implemented to investigate the effects of land use/land cover change (LUCC) on streamflow in large (>10,000 km²) tropical catchments. Methods refer to: TSA, time-series analysis; MOD, modelling.

Catchment (Country)	Area (km ²)	Forest cover change (%)	Period pre- and post-LUCC	Method(s)	Effects on streamflow (% change)	Reference
Pasak River (northern Thailand)	14,500	-50	1955–1980 ^a	TSA	No change	Dyhr-Nielsen (1986)
Citarum River (west Java, Indonesia)	4133	-50	1922–1929 1979–1986	TSA, MOD	Increase (11%)	Van der Weert (1994)
Tocantins River (central Brazil)	767,000	-19	1949–1968 1979–1998	TSA, MOD	Increase (24%)	Costa et al. (2003)
Nam Pong River (north-eastern Thailand)	12,100	-63	1957–1965 1969–1995	TSA, MOD	No change	Wilk et al. (2001)
Comet River (central Queensland, Australia)	16,440	-45	1920–1949 1970–2000	TSA, MOD	Increase (40%)	Siriwardena et al. (2006)
Ji-Paraná (southwestern Amazonia, Brazil)	33,012	-50	1978–2000 ^b	TSA	No change	Linhares (2005) and Rodriguez et al. (2010)
Pearl river and East, North and West Rivers (Guandong Province, China)	179,752	+37	1965–1986 1993–2006	TSA	No change	Zhou et al. (2010)

^a No distinctive pre- and post-LUCC periods.

^b No distinctive pre- and post-LUCC periods but transitory changes of LUCC and streamflow.

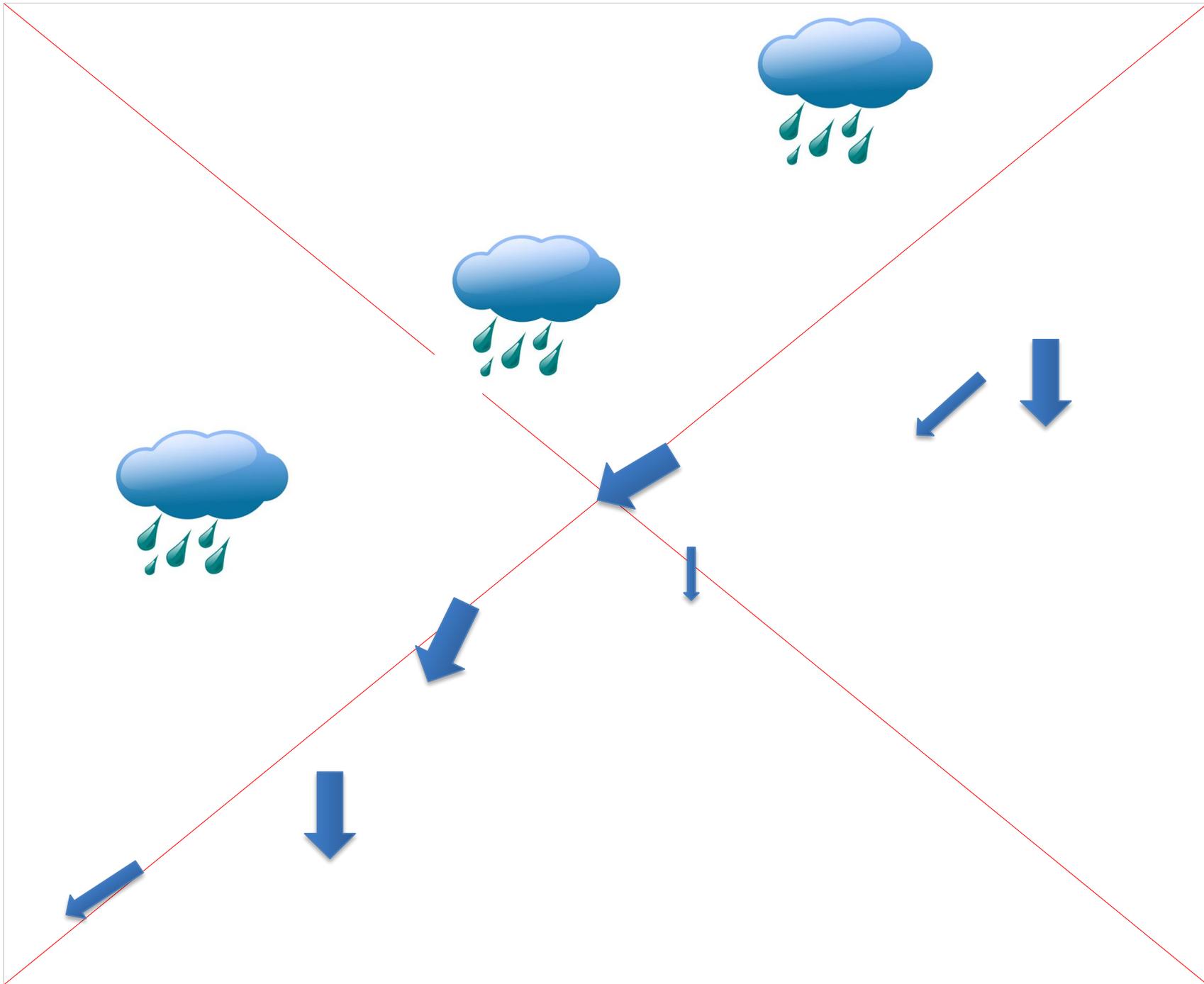
Heterogeneidade - Fragmentação da paisagem

- Paisagens incluem invariavelmente uma área contendo um mosaico de fragmentos ou elementos da paisagem
- A fragmentação afeta os processos ecológicos, hidrológicos e climáticos dos ecossistemas
 - Diferenças no balanço de energia
 - Geração de Gradientes de energia
 - Geração de Advecção
 - Influência no transporte de partículas e de gases
 - Influência no fluxo superficial da água



Efeitos da fragmentação no escoamento

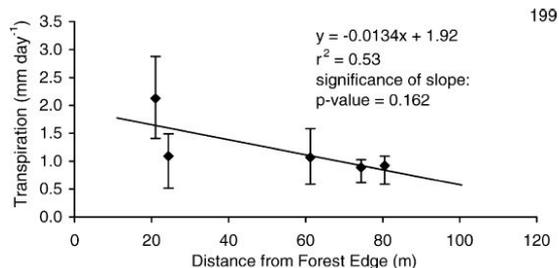




Efeito da fragmentação na evapotranspiração



- A magnitude e o padrão espacial da transpiração em fragmentos de floresta é influenciada pelas condições nas clareiras circundantes.
- A evapotranspiração regional pode ser influenciada pelo grau de fragmentação da paisagem.
- A fragmentação da paisagem pode contrabalancear a redução na evaporação devida ao desflorestamento



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Agricultural and Forest Meteorology 117 (2003) 1–22

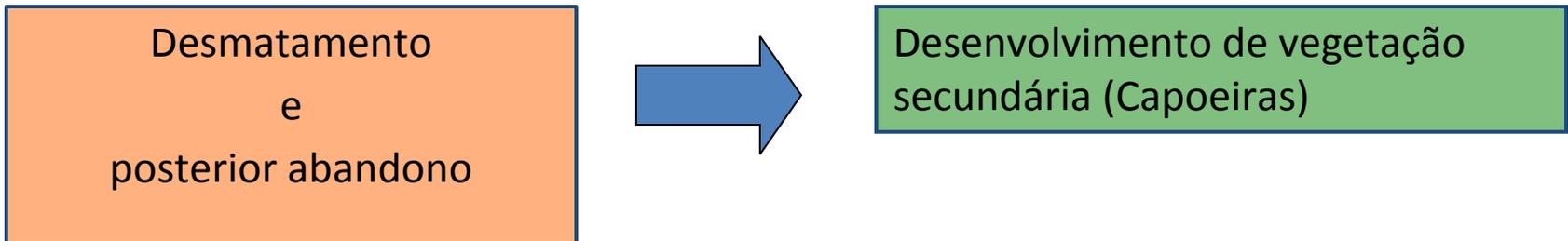
AGRICULTURAL
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FOREST
METEOROLOGY

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Transpiration in a small tropical forest patch

Thomas W. Giambelluca^{a,*}, Alan D. Ziegler^a, Michael A. Nullet^a,
Dao Minh Truong^b, Liem T. Tran^c

Vegetação secundária



- Tipo dominante de vegetação em áreas desflorestadas da Amazônia (Uhl et al., 1998; Moran et al., 1994)
- As características hidrológicas apresentam grande variabilidade temporal
- O albedo é inicialmente alto e decresce até valores similares aos da floresta depois de 30 anos (Giambelluca et al., 1997; 1999)
- A evapotranspiração pode exceder a da floresta (Shuttleworth, 1998; Giambelluca et al., 2003)

Vegetação secundária

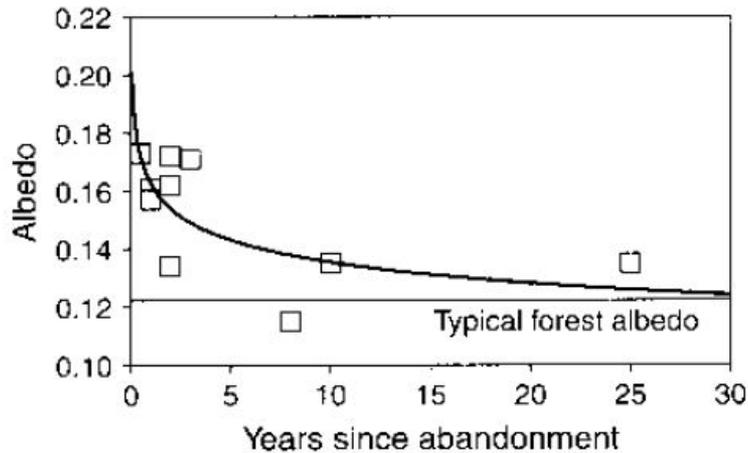


Figure 1. Albedo of secondary vegetation as a function of years since abandonment of clearing for sites in eastern Amazon Basin and northern Thailand; based on data from Giambelluca *et al.* (1997, 1999)

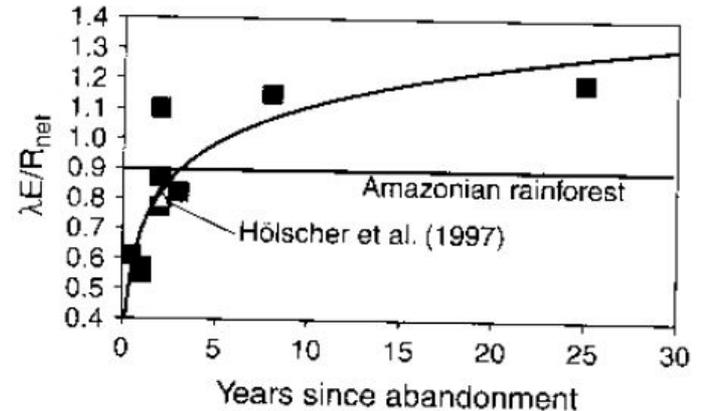


Figure 3. Evaporative fraction (ratio of energy used for evapotranspiration to net radiation) of secondary vegetation as a function of years since abandonment of clearing for sites in eastern Amazon Basin and northern Thailand; based on data from Hölscher *et al.* (1997) and Giambelluca *et al.* (2000)

EDITED COMMENTARY

HYDROLOGICAL PROCESSES

Hydrol. Process. **16**, 1665–1669 (2002)

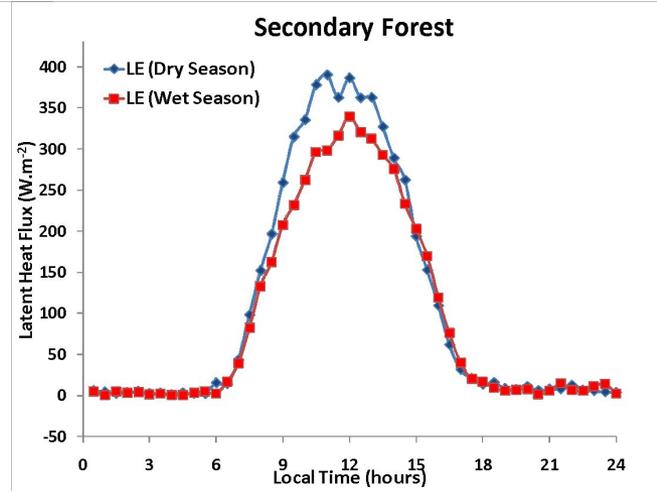
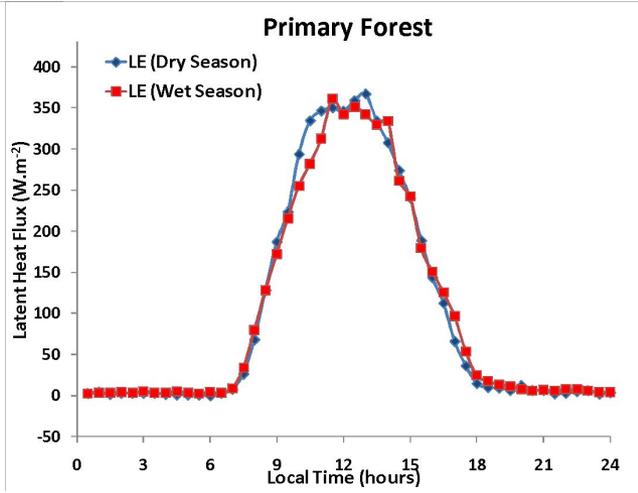
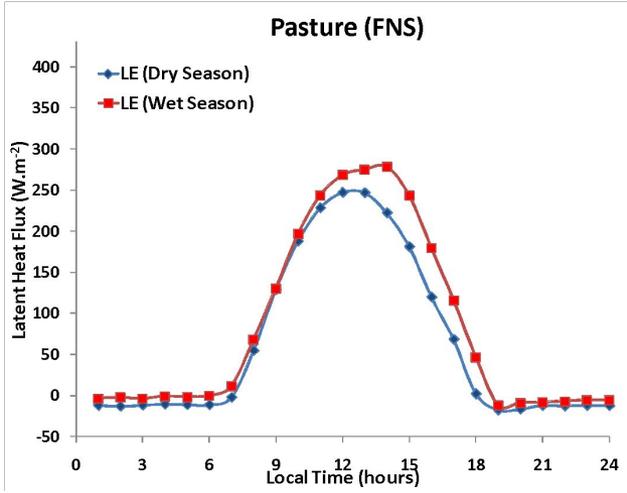
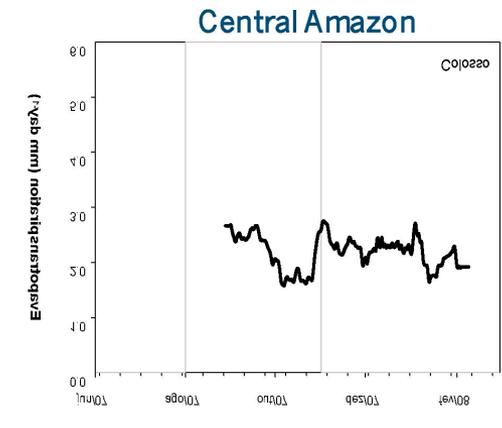
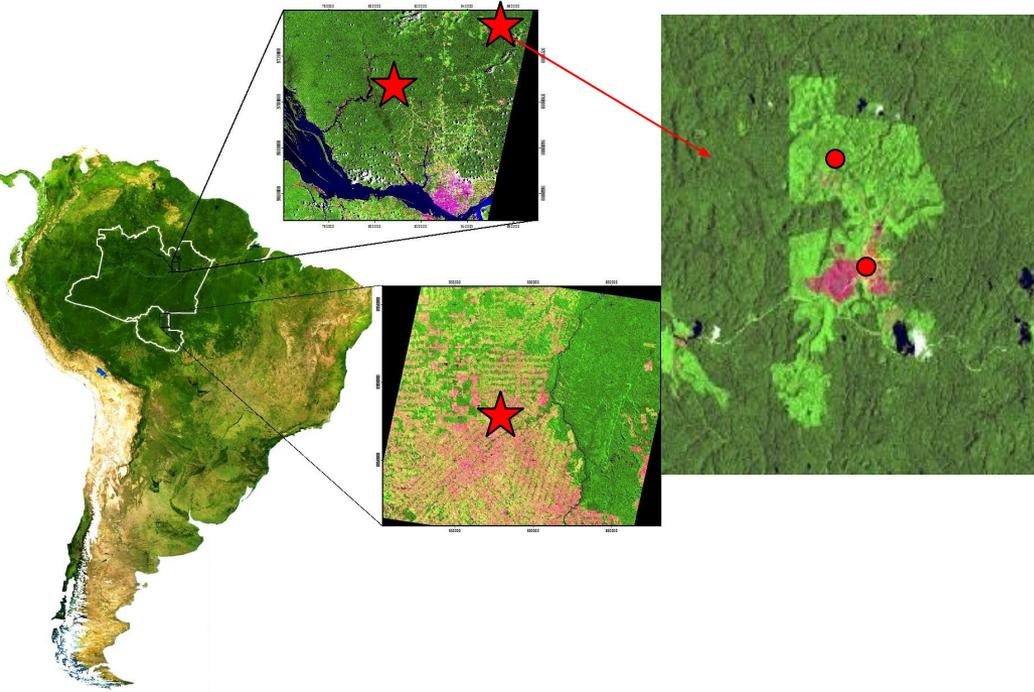
Published online in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hyp.5021

Hydrology of altered tropical forest

Thomas W. Giambelluca

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University of Hawai'i at Mānoa,
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HI 96822, USA*

Vegetação secundária (Von Randow, 2010)



Circulações de mesoescala resultantes da fragmentação da paisagem

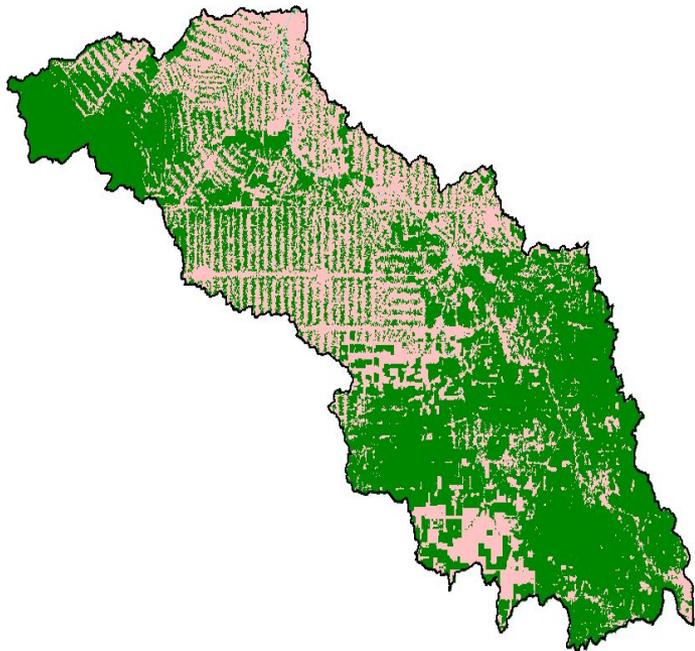
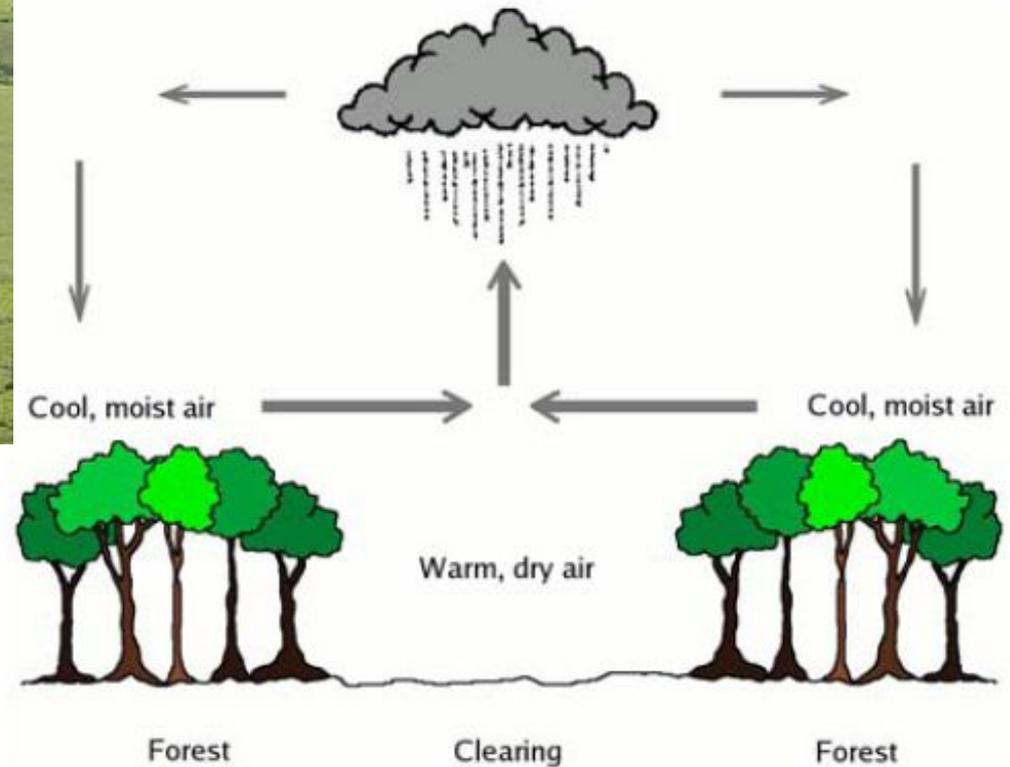


Figure 2. Schematic diagram of vegetation breeze. A horizontal temperature gradient forces cool, moist air from adjacent forests to converge over the clearings. Convergence generates strong updrafts, shallow cumulus clouds and precipitation, preferentially located over the bare patches.

Impacto do desflorestamento na nebulosidade



Available online at www.sciencedirect.com
 ScienceDirect
 Remote Sensing of Environment 96 (2003) 132–140

Remote Sensing of Environment
 www.elsevier.com/locate/rse

The impact of deforestation on cloud cover over the Amazon arc of deforestation

Laurent Durieux^{a,b}, Luiz Augusto Toledo Machado^b, Henri Laurent^{a,b,*}

^aIRD, Institut de Recherche pour le Développement, France
^bCentro Técnico Aeroespacial, Instituto de Aeronáutica e Espaço, Divisão de Ciências Atmosféricas, Brazil

- Durante a estação seca se desenvolve um maior número de nuvens baixas durante a tarde e menor convecção durante a noite.
- Na estação úmida a convecção é maior nas áreas desflorestadas
- Os processos são controlados por umbral na percentagem de desflorestamento

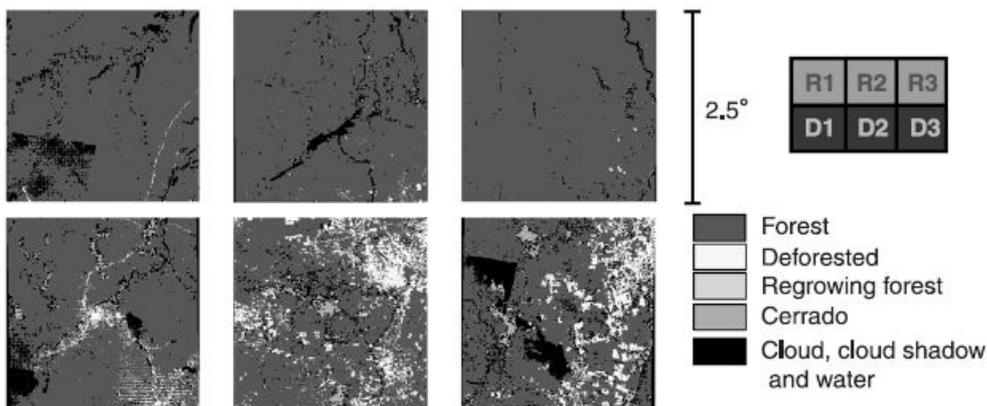


Fig. 3. Vegetation of Reference and Deforested GCs in 1992 using full-resolution TRFIC data.

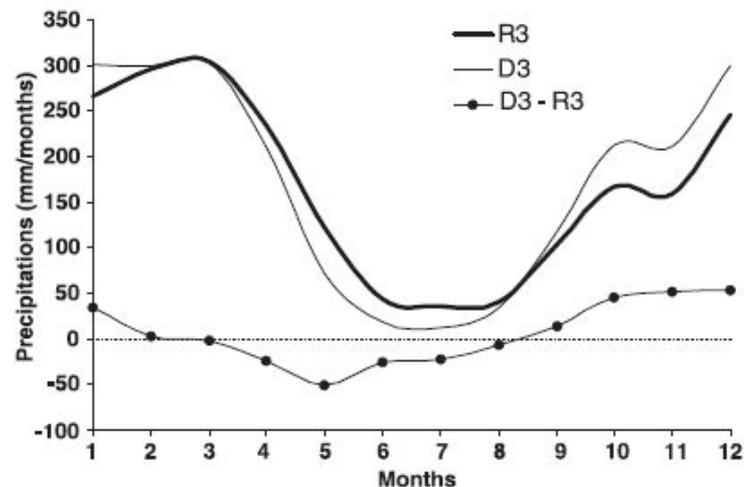


Fig. 6. Mean monthly precipitation for R_3 and D_3 and difference $D_3 - R_3$.

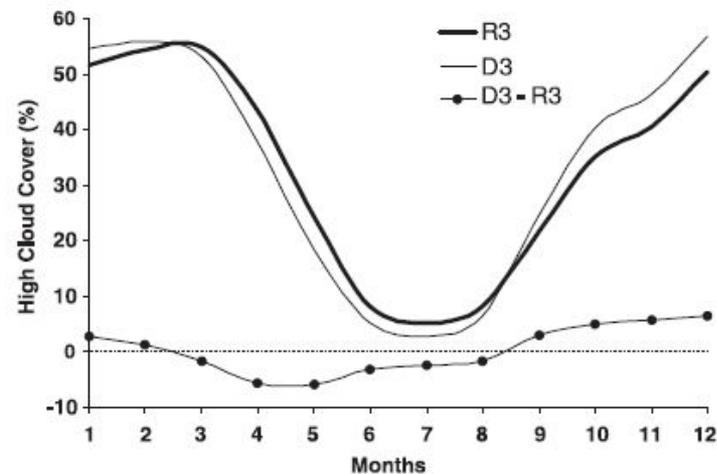
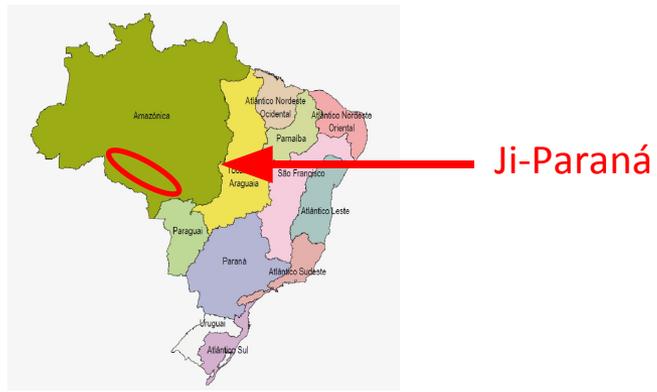
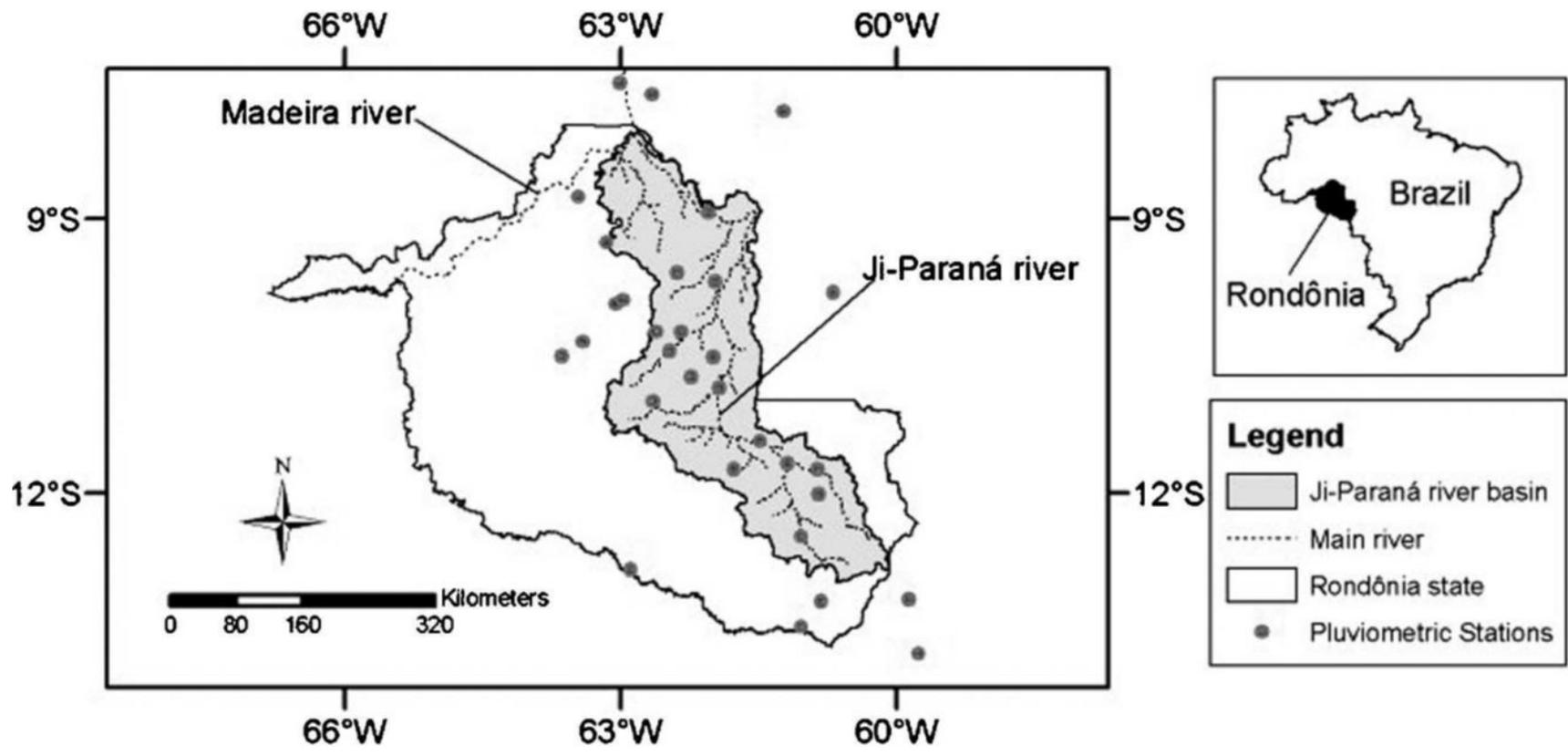
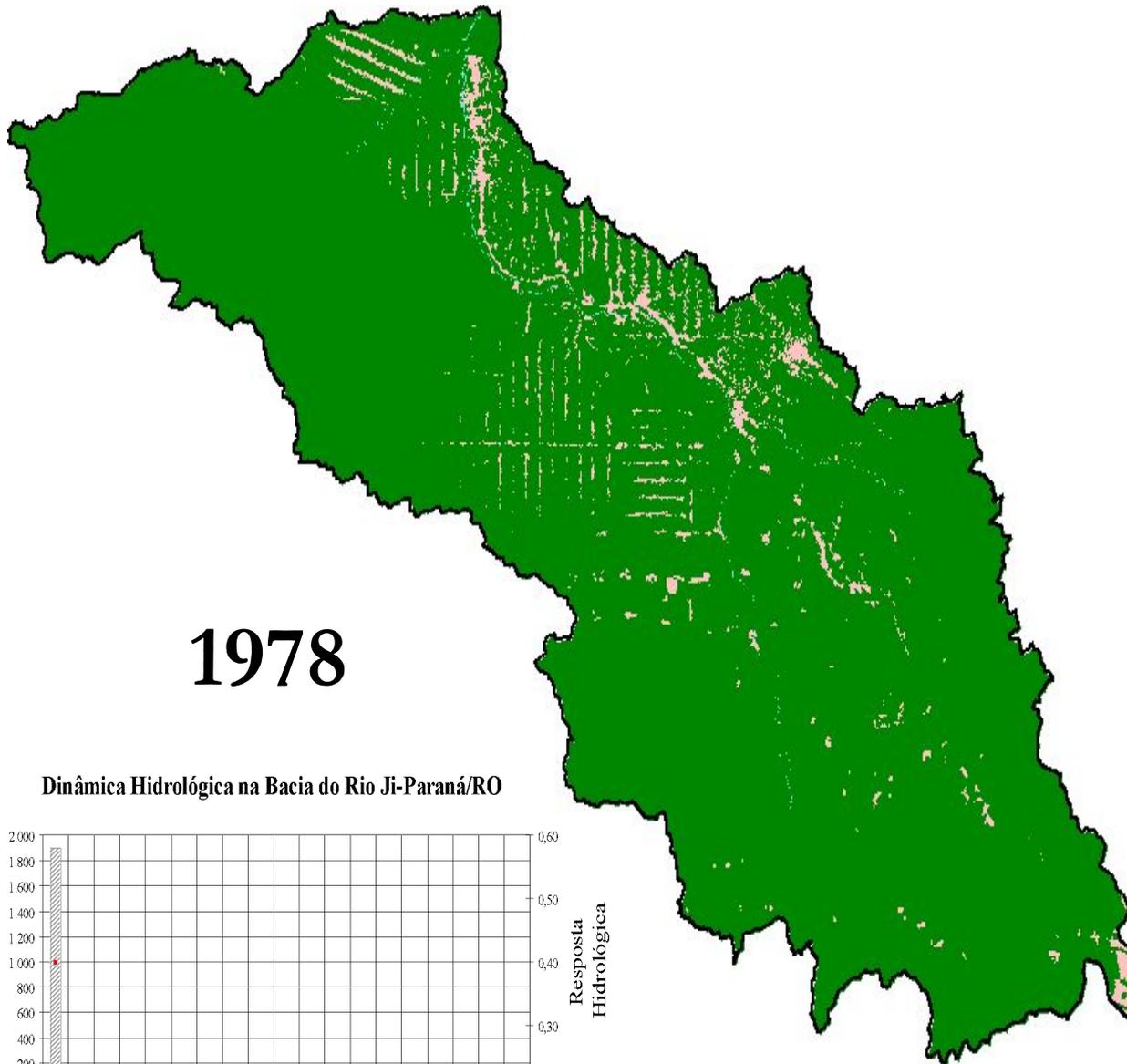


Fig. 5. High cloud cover monthly mean for R_3 and D_3 and difference $D_3 - R_3$.

Uso do solo na bacia de Ji-Paraná

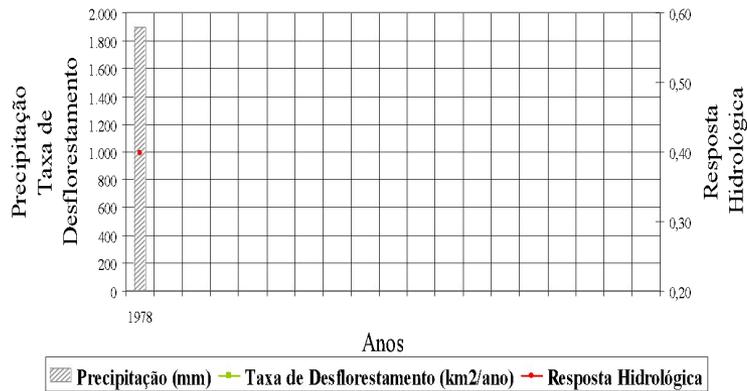
The Ji-Paraná River Basin



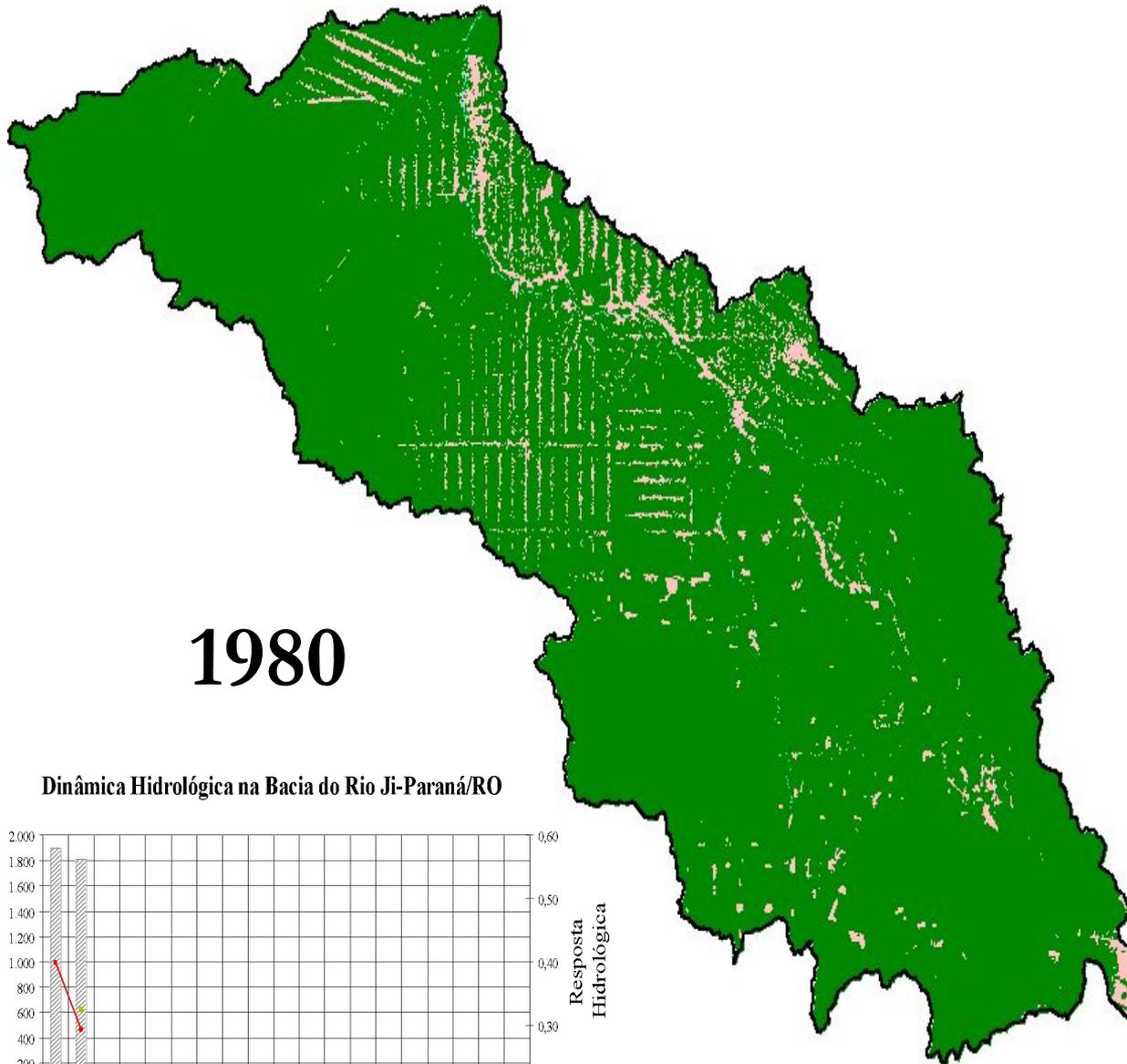


1978

Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

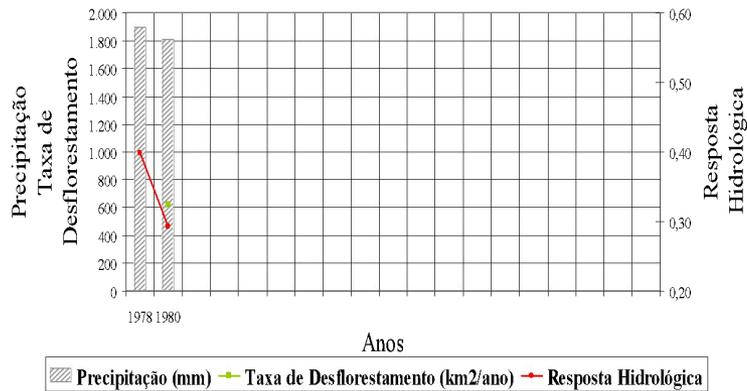


Fonte: Linhares, 2005

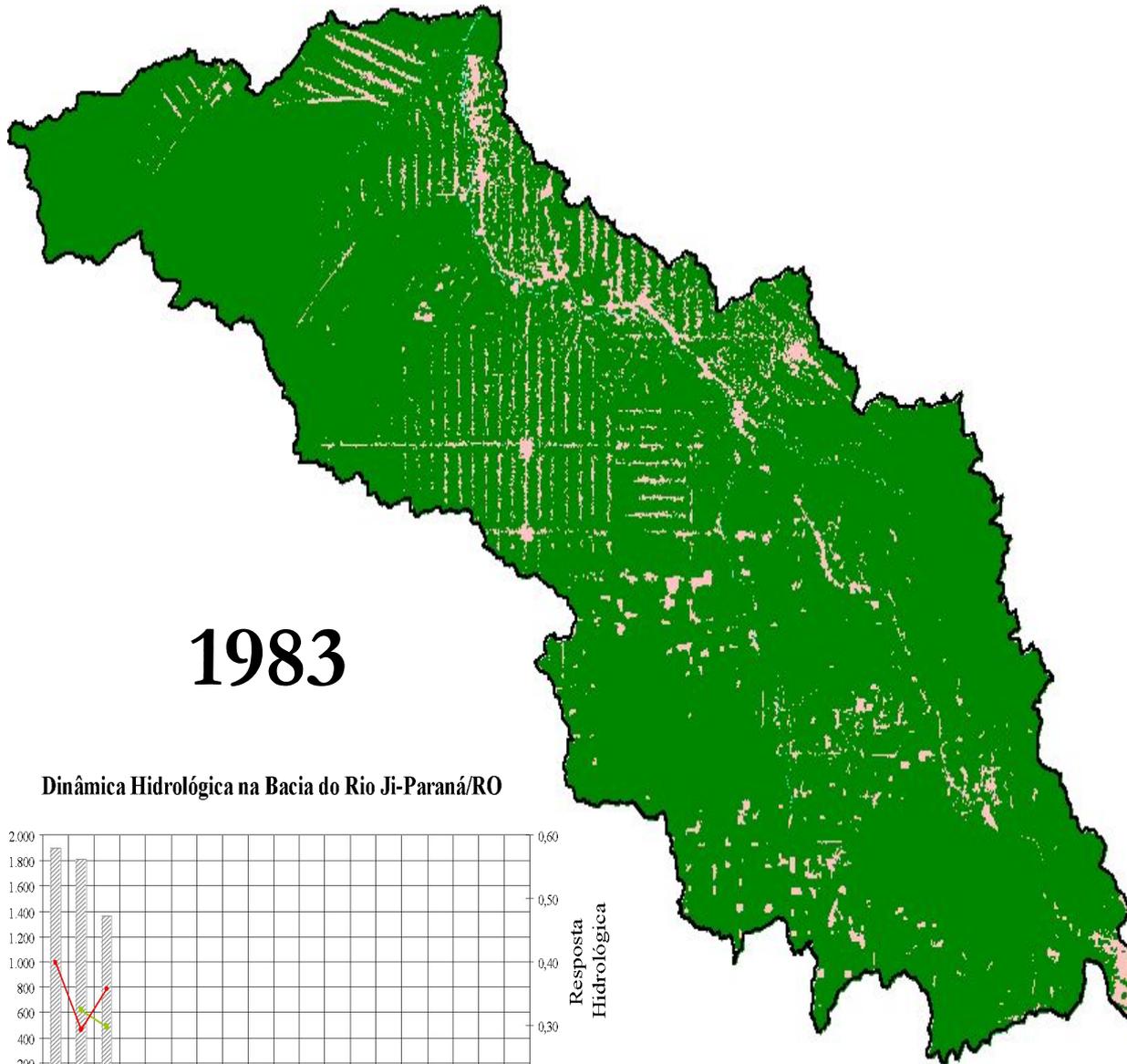


1980

Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

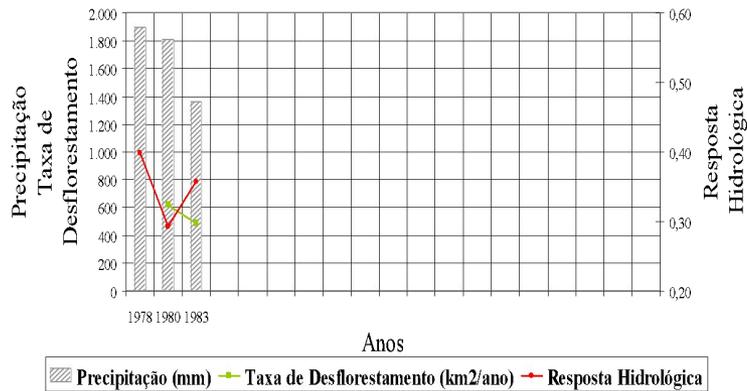


Fonte: Linhares, 2005

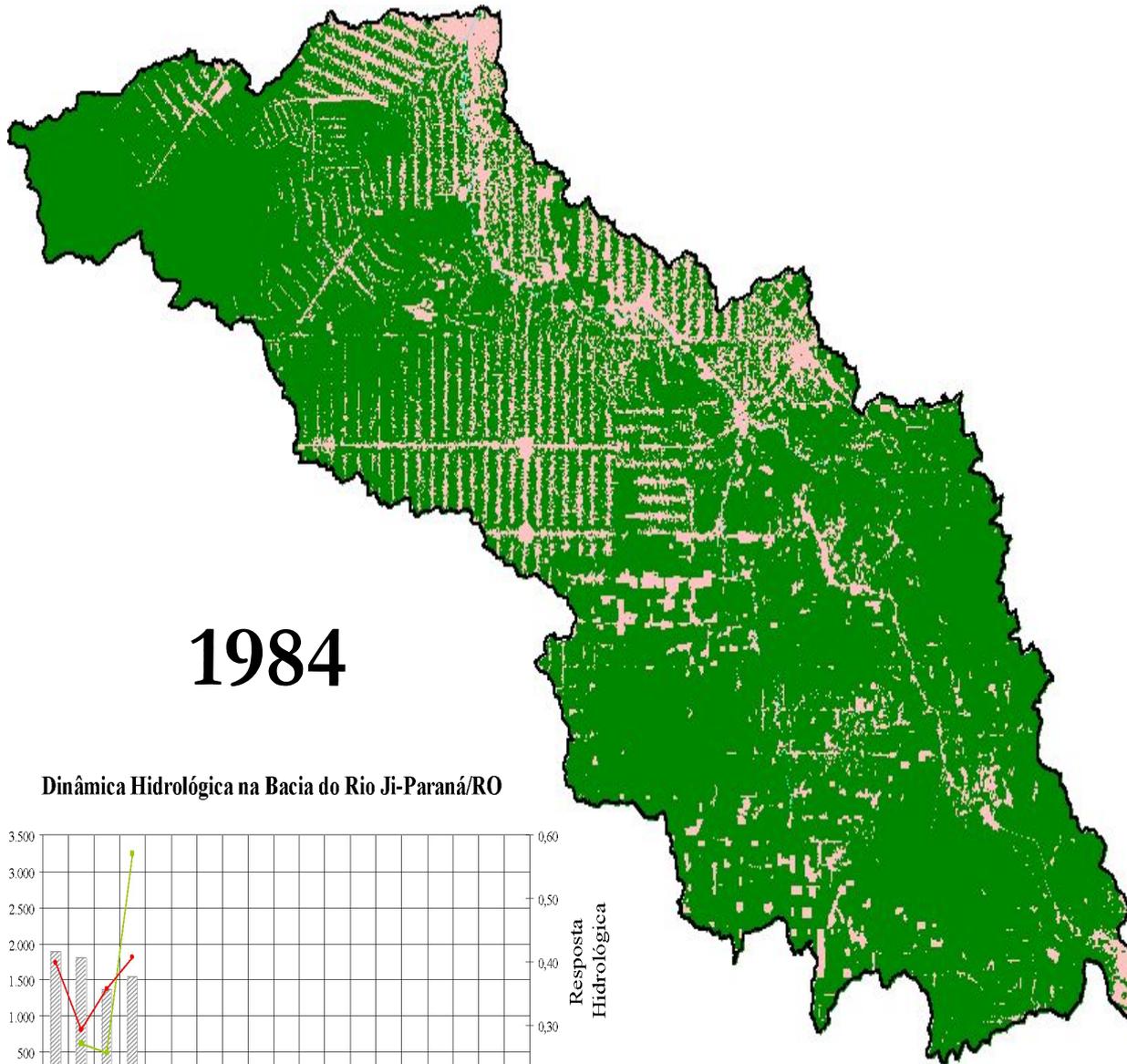


1983

Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

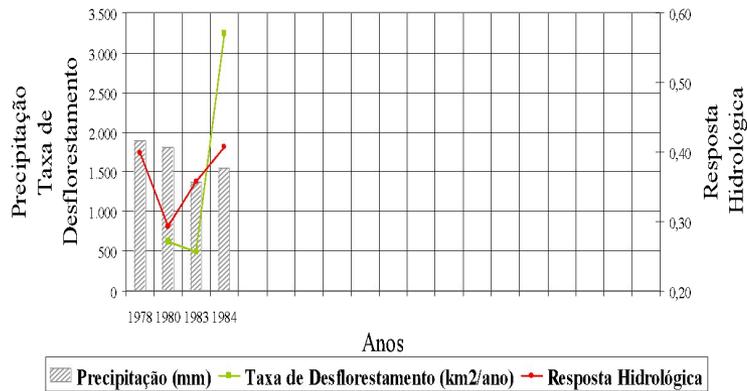


Fonte: Linhares, 2005

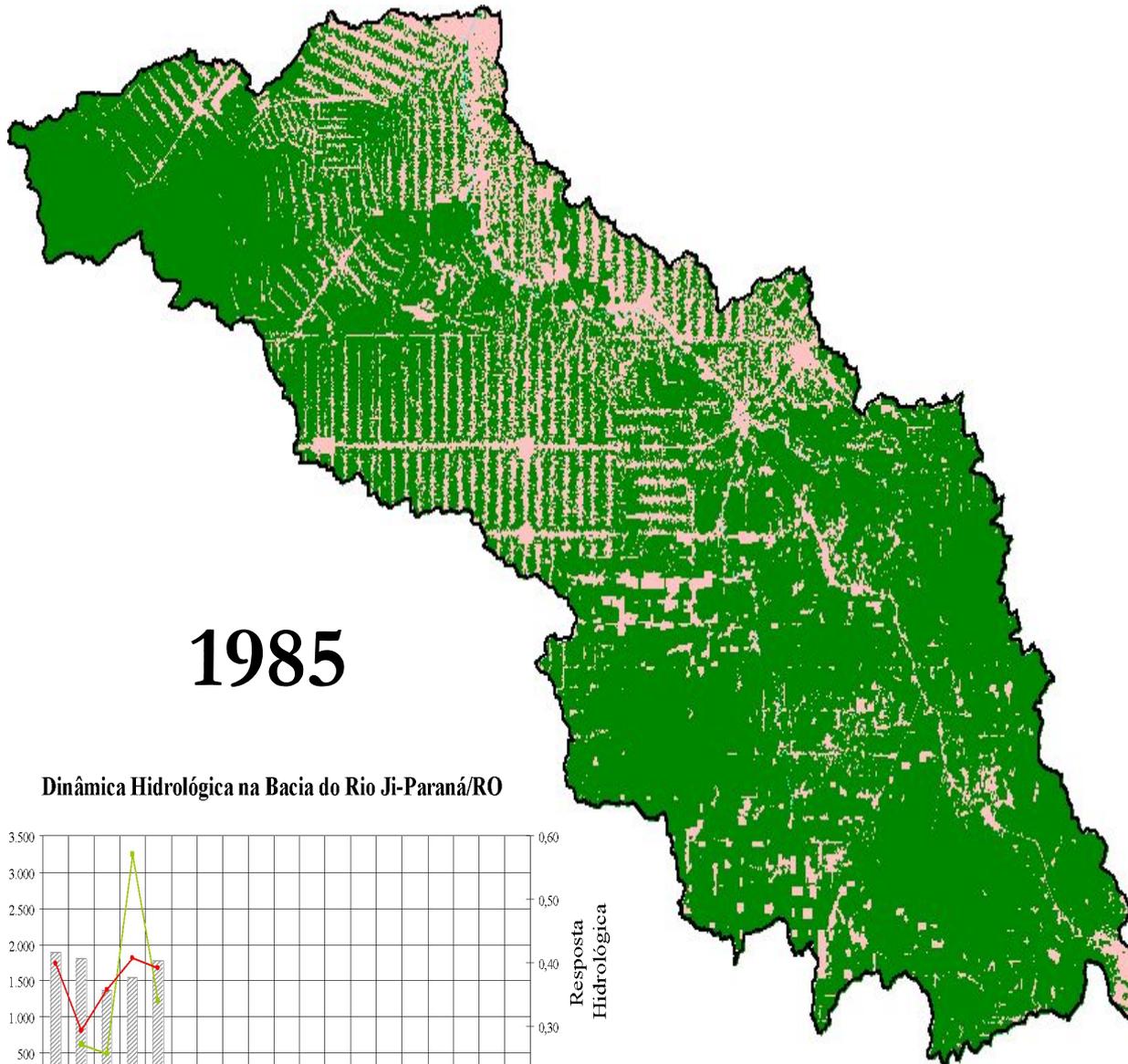


1984

Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

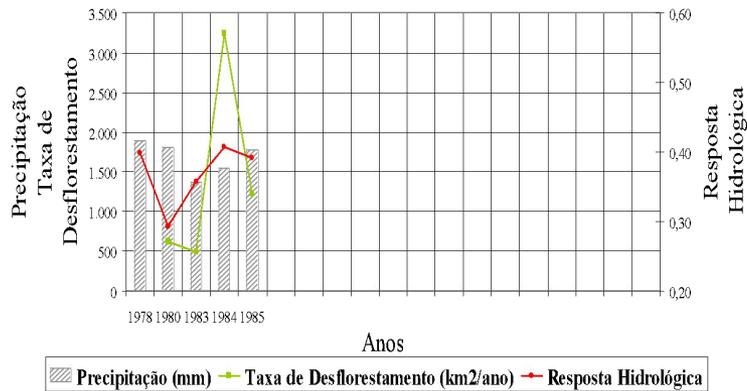


Fonte: Linhares, 2005



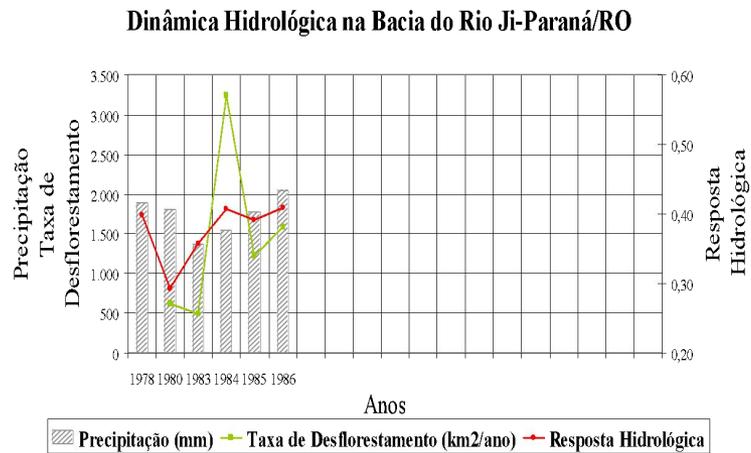
1985

Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

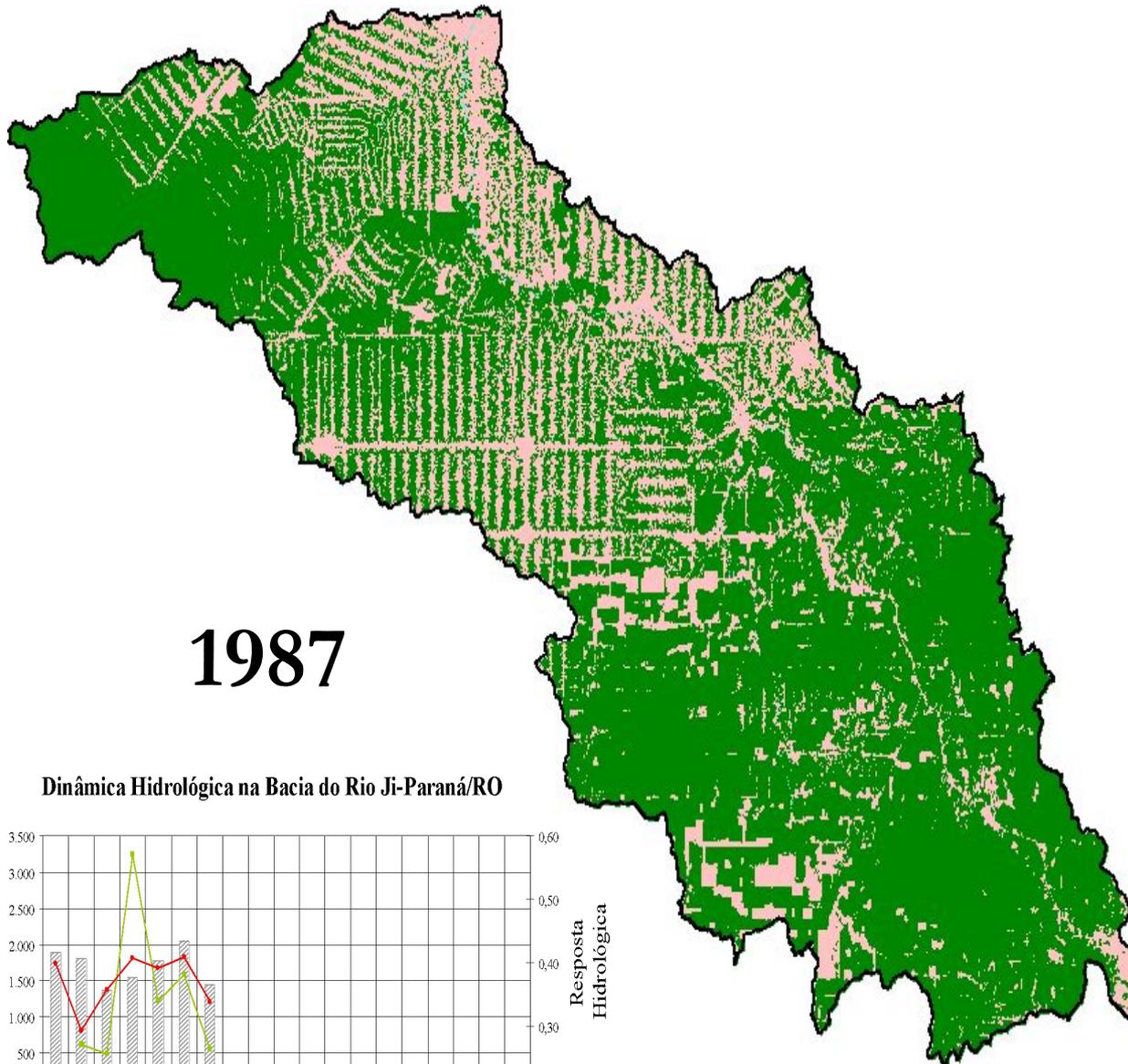


Fonte: Linhares, 2005

1986

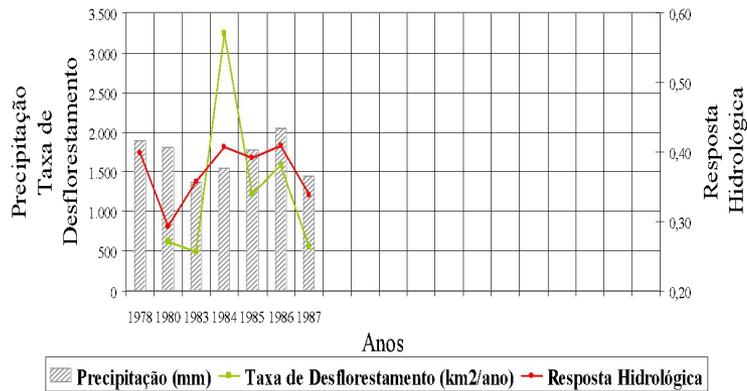


Fonte: Linhares, 2005

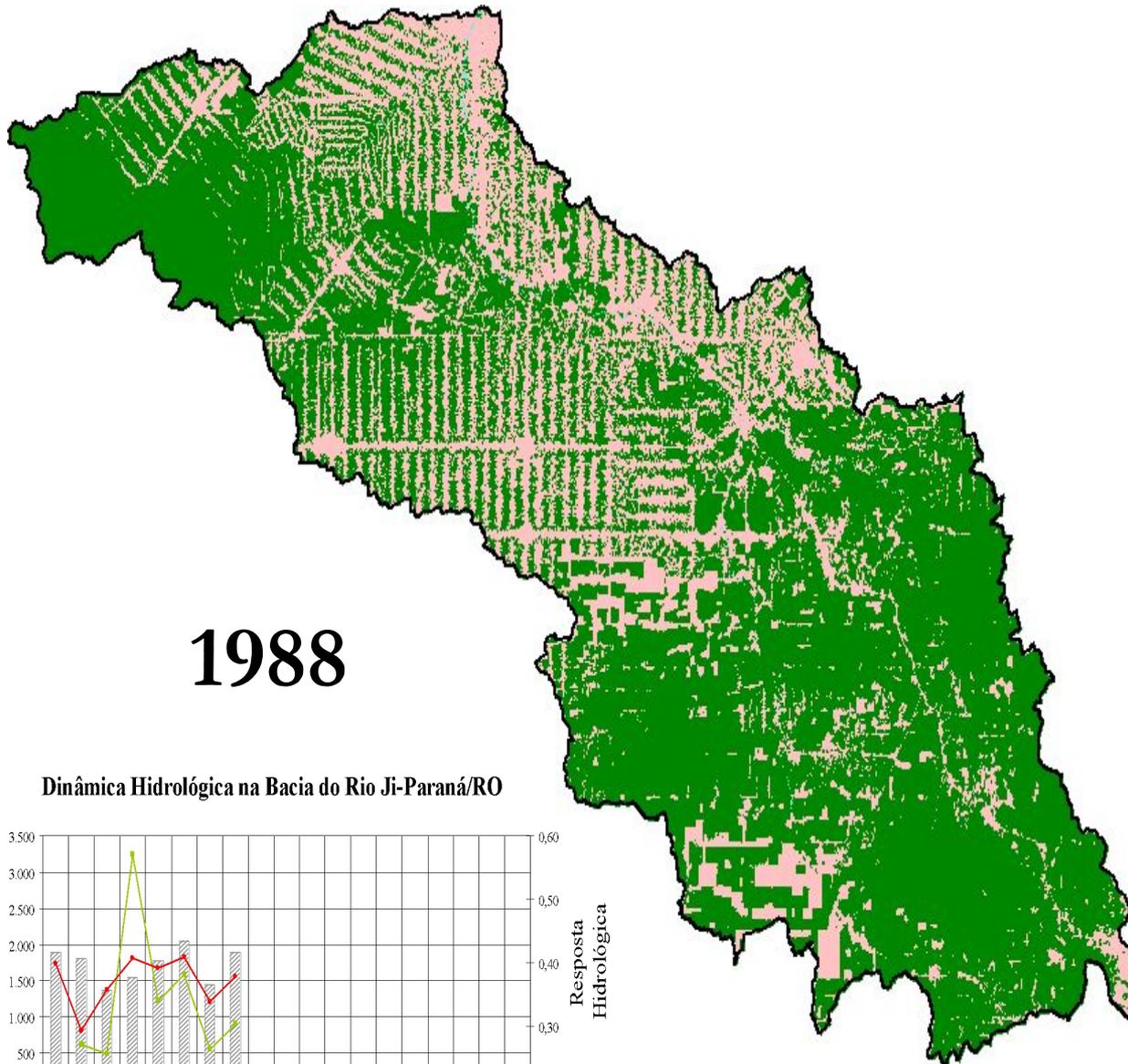


1987

Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

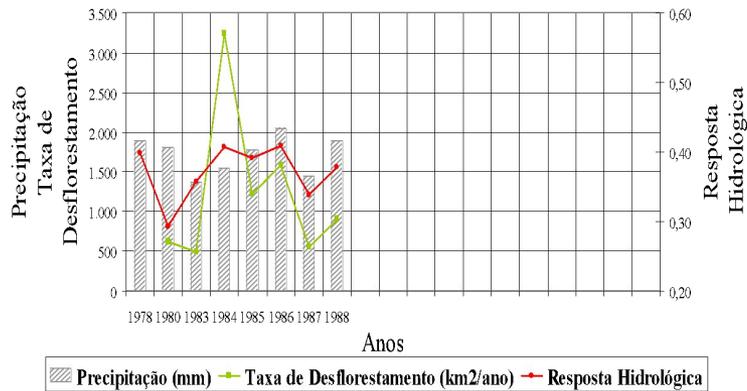


Fonte: Linhares, 2005

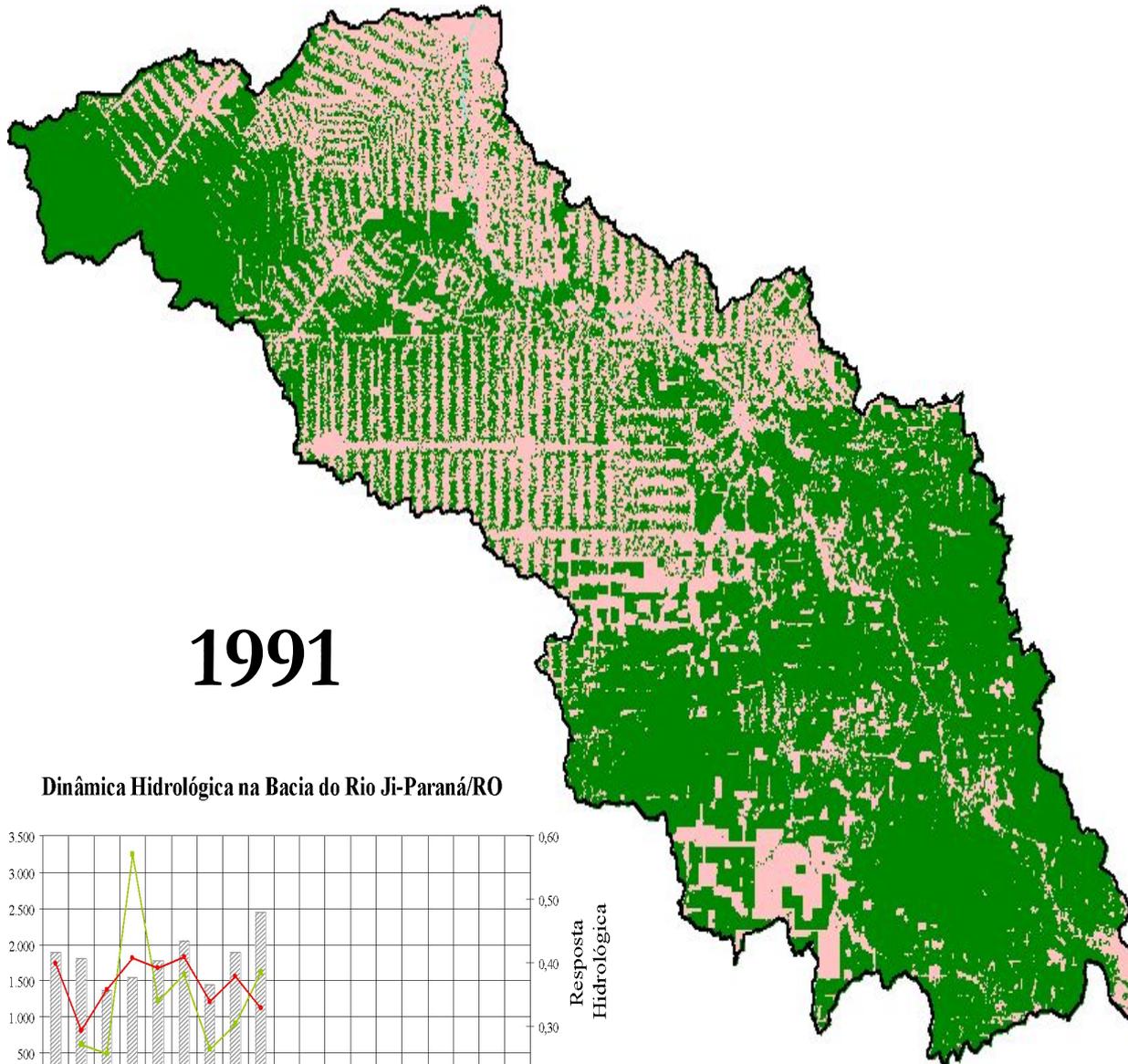


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Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

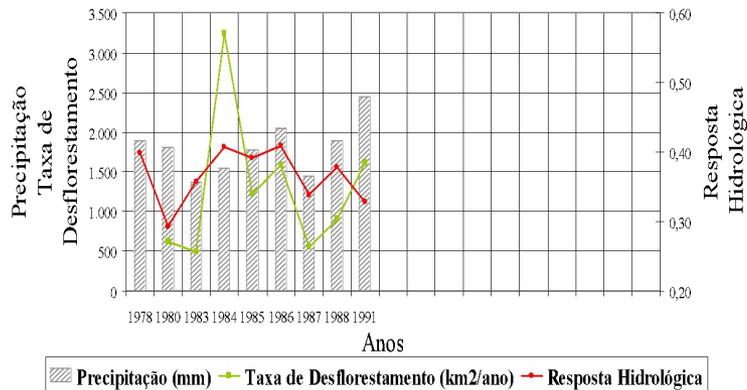


Fonte: Linhares, 2005

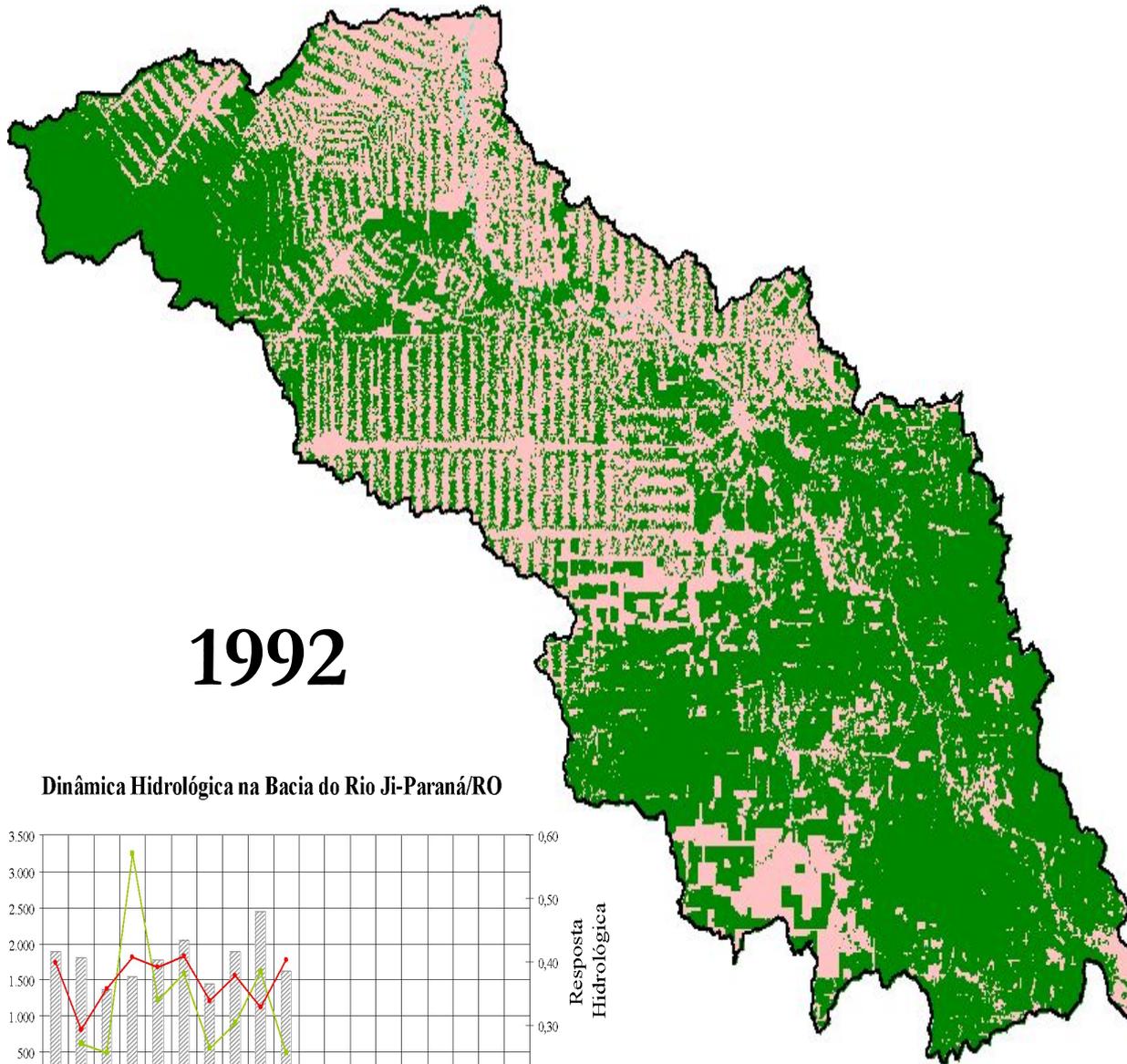


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Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

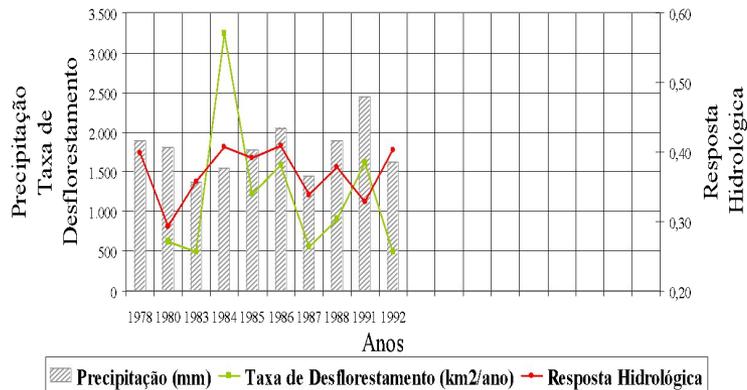


Fonte: Linhares, 2005

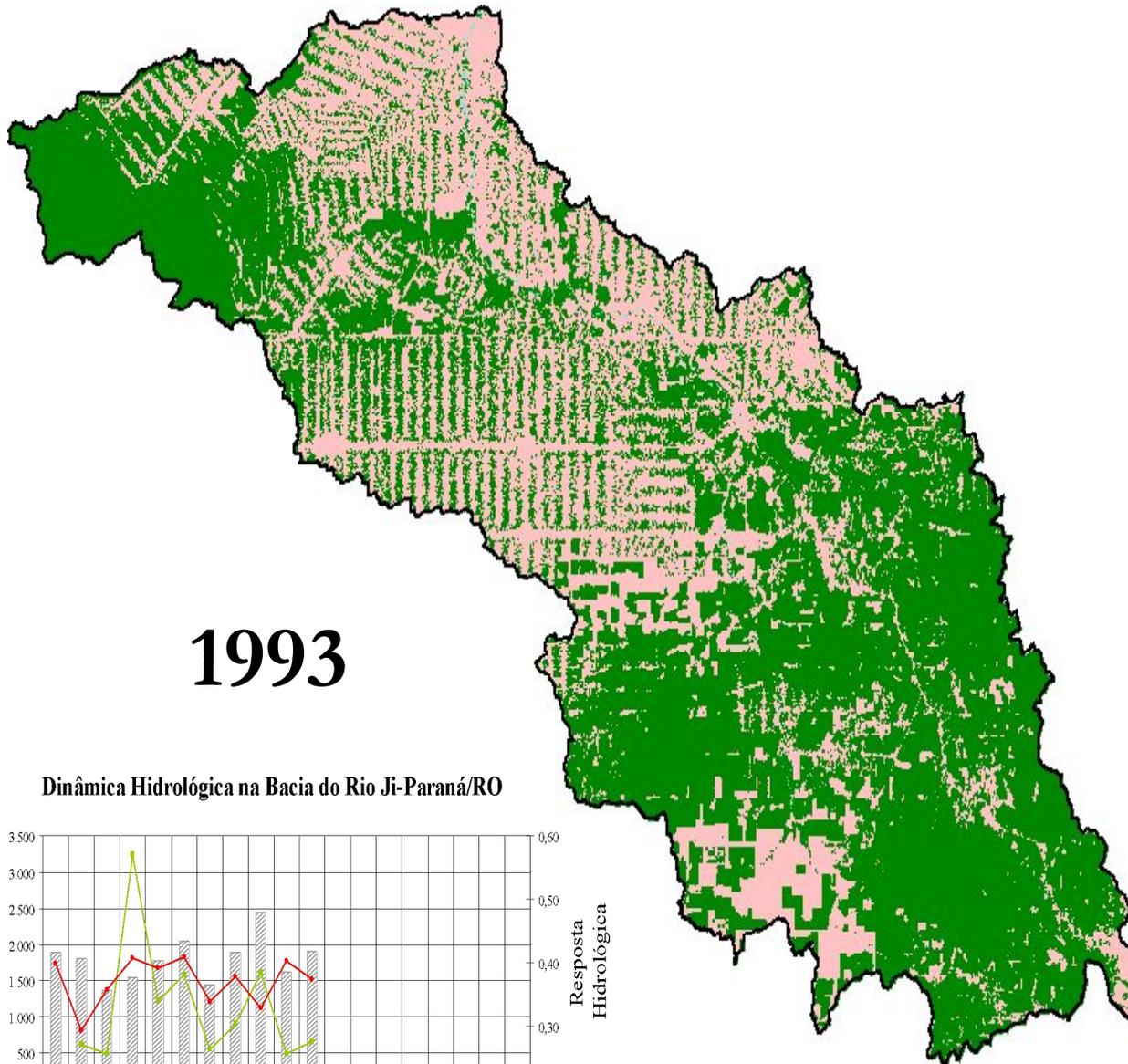


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Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

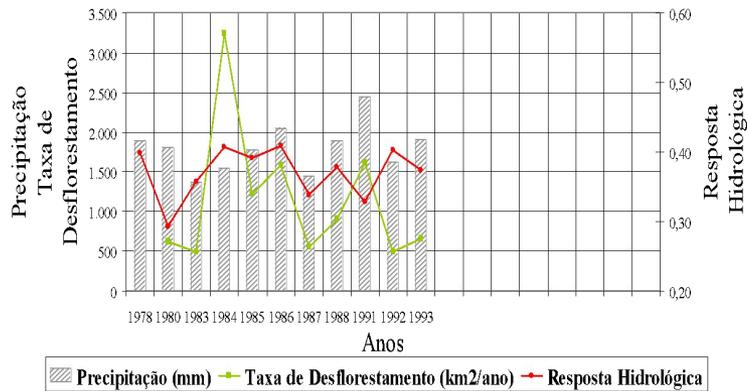


Fonte: Linhares, 2005

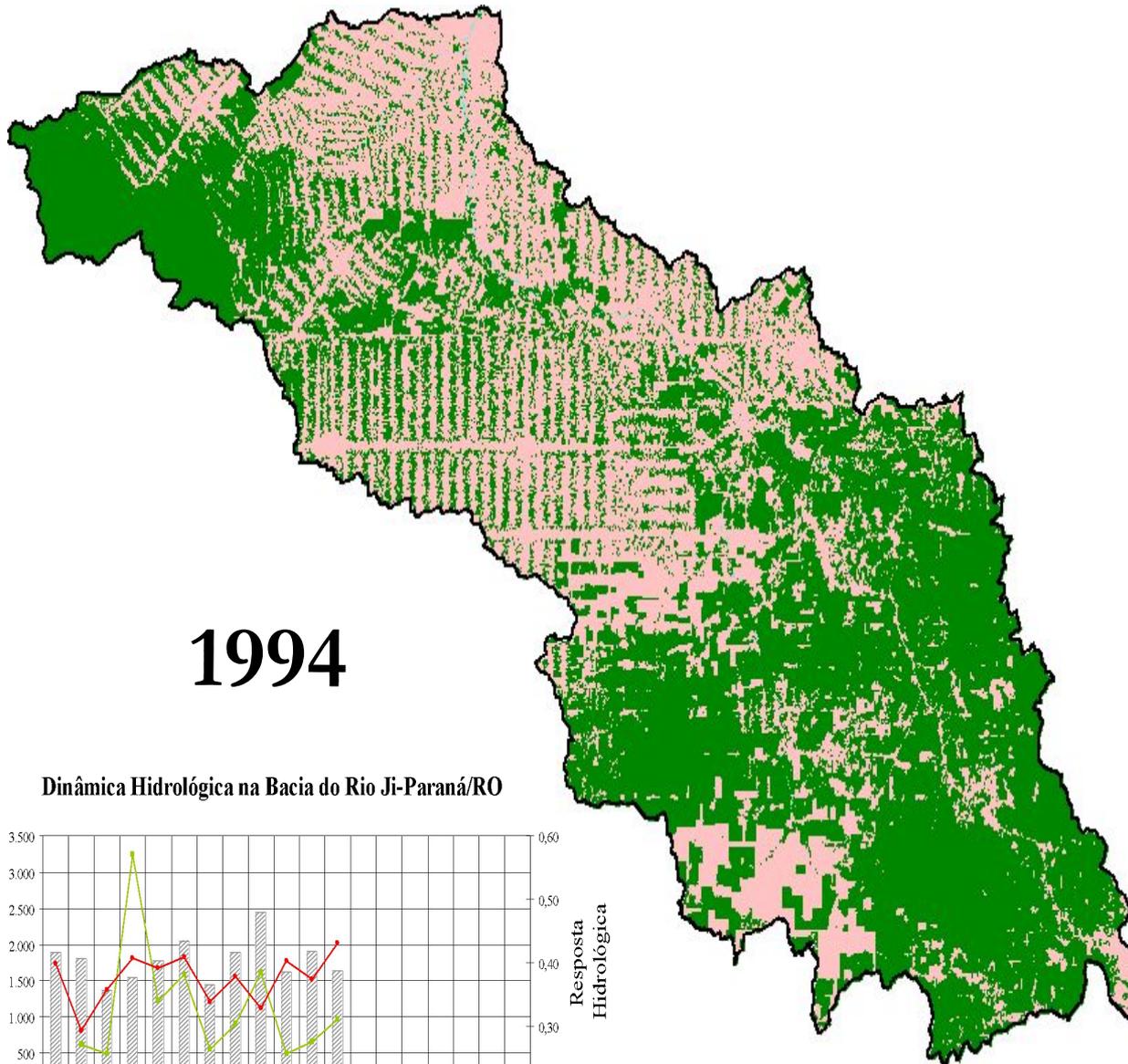


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Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

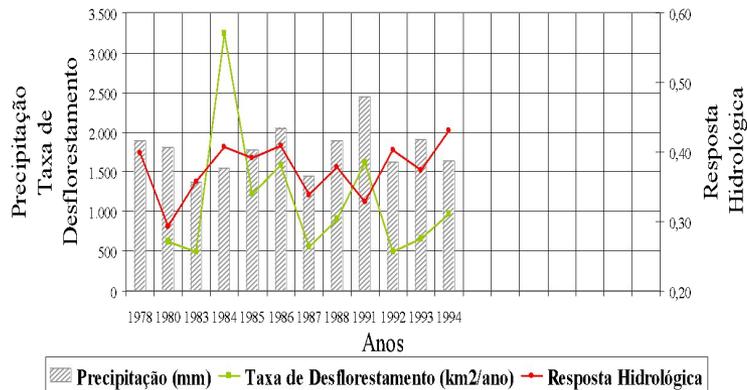


Fonte: Linhares, 2005

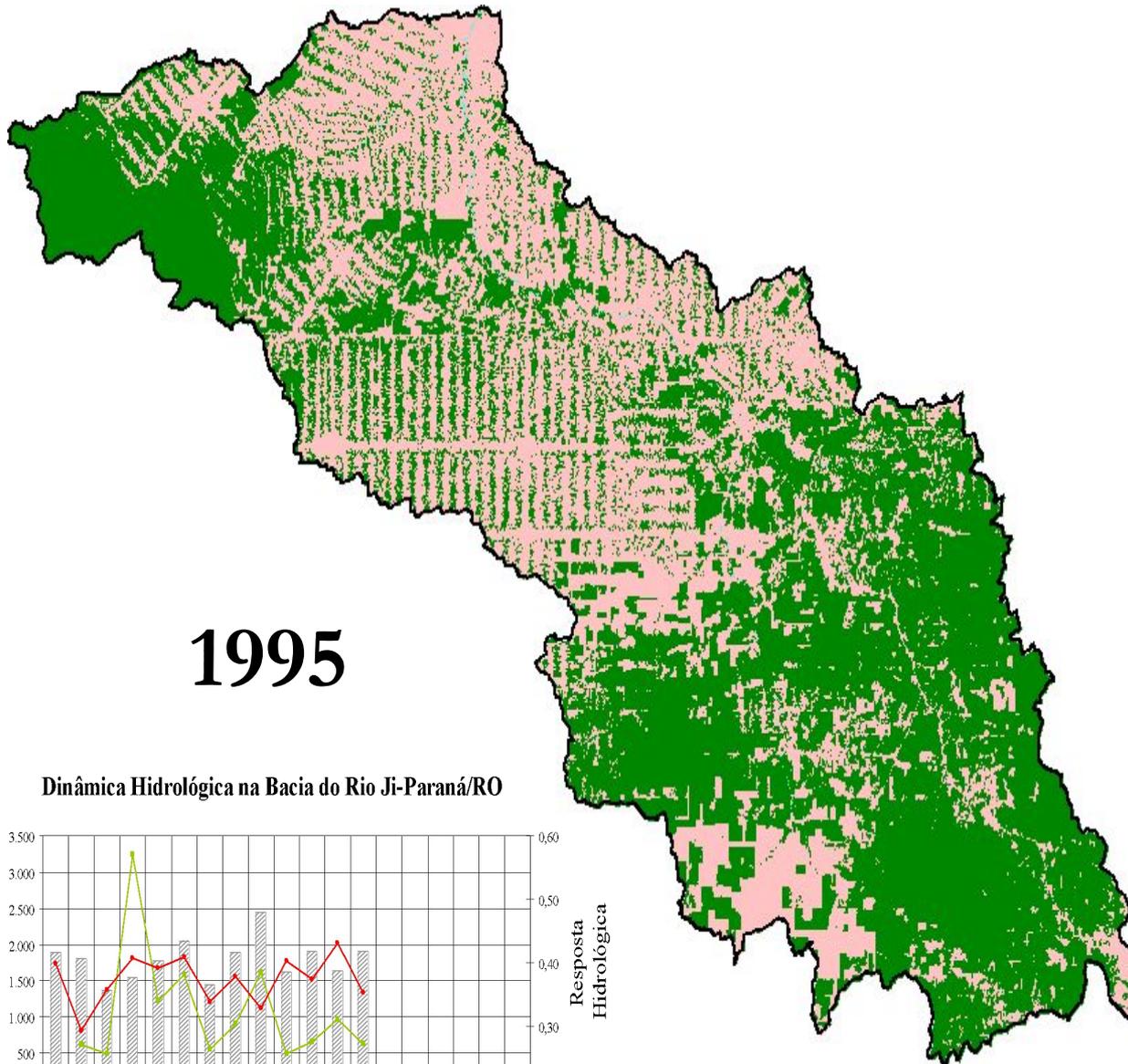


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Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

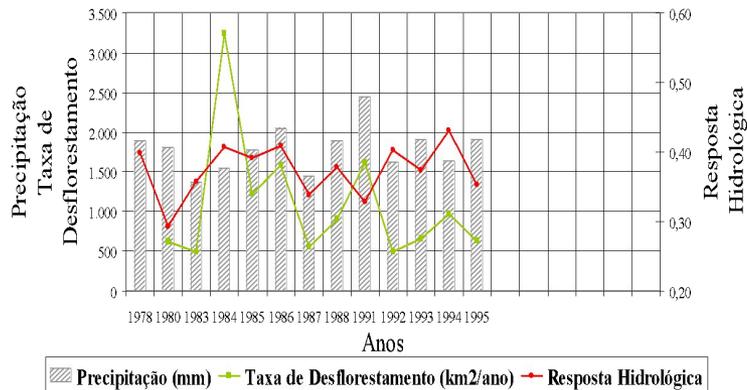


Fonte: Linhares, 2005

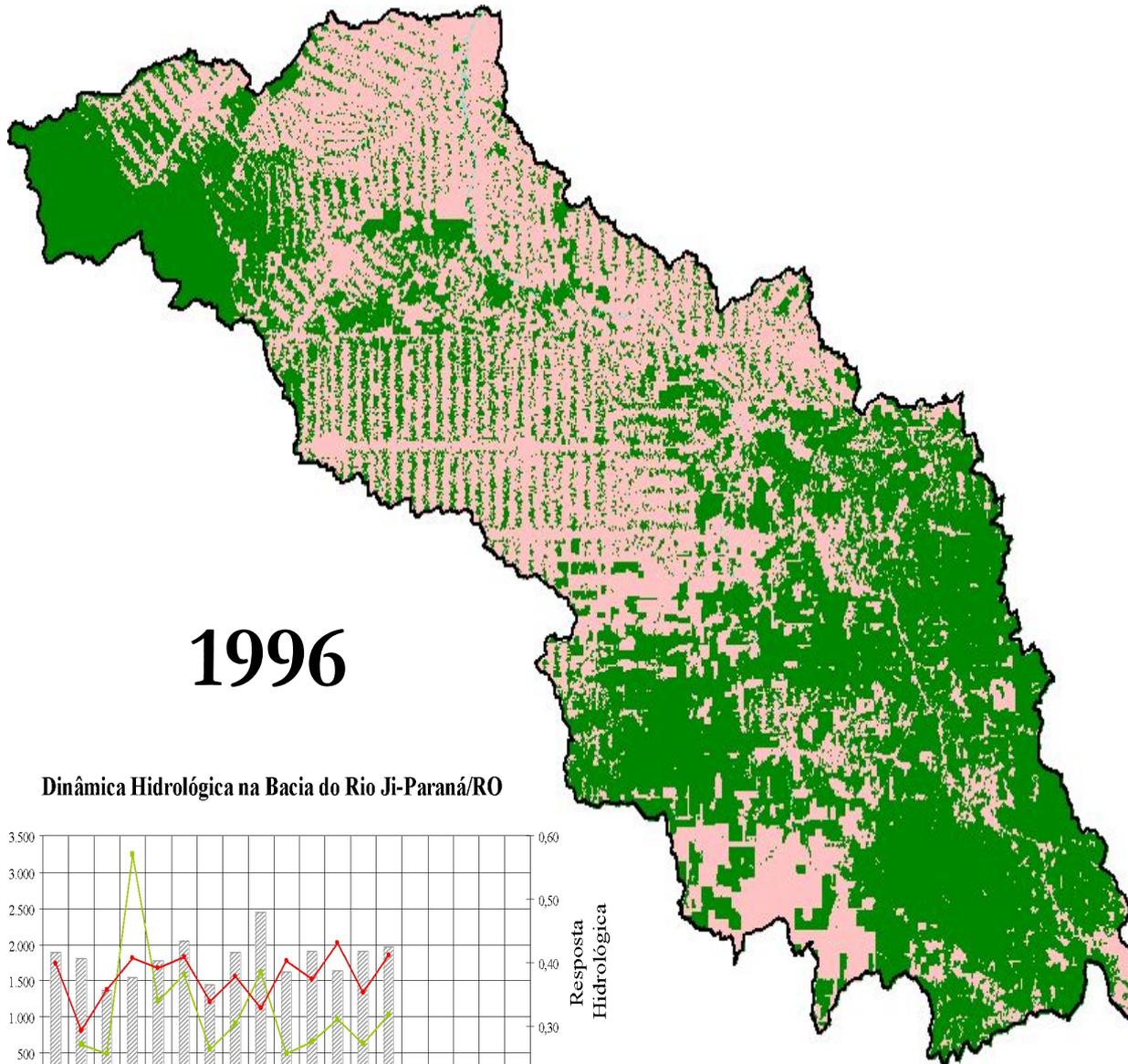


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Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

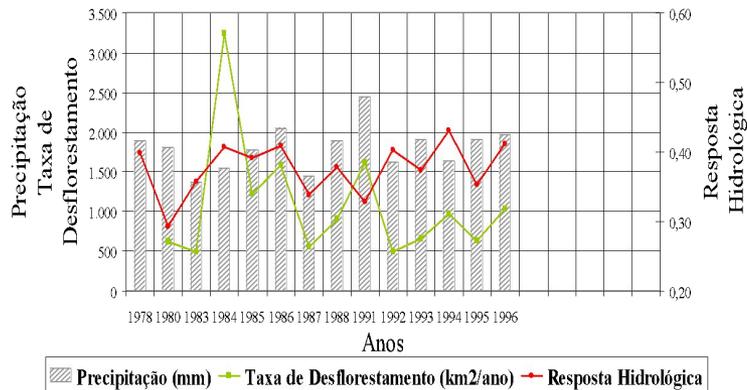


Fonte: Linhares, 2005

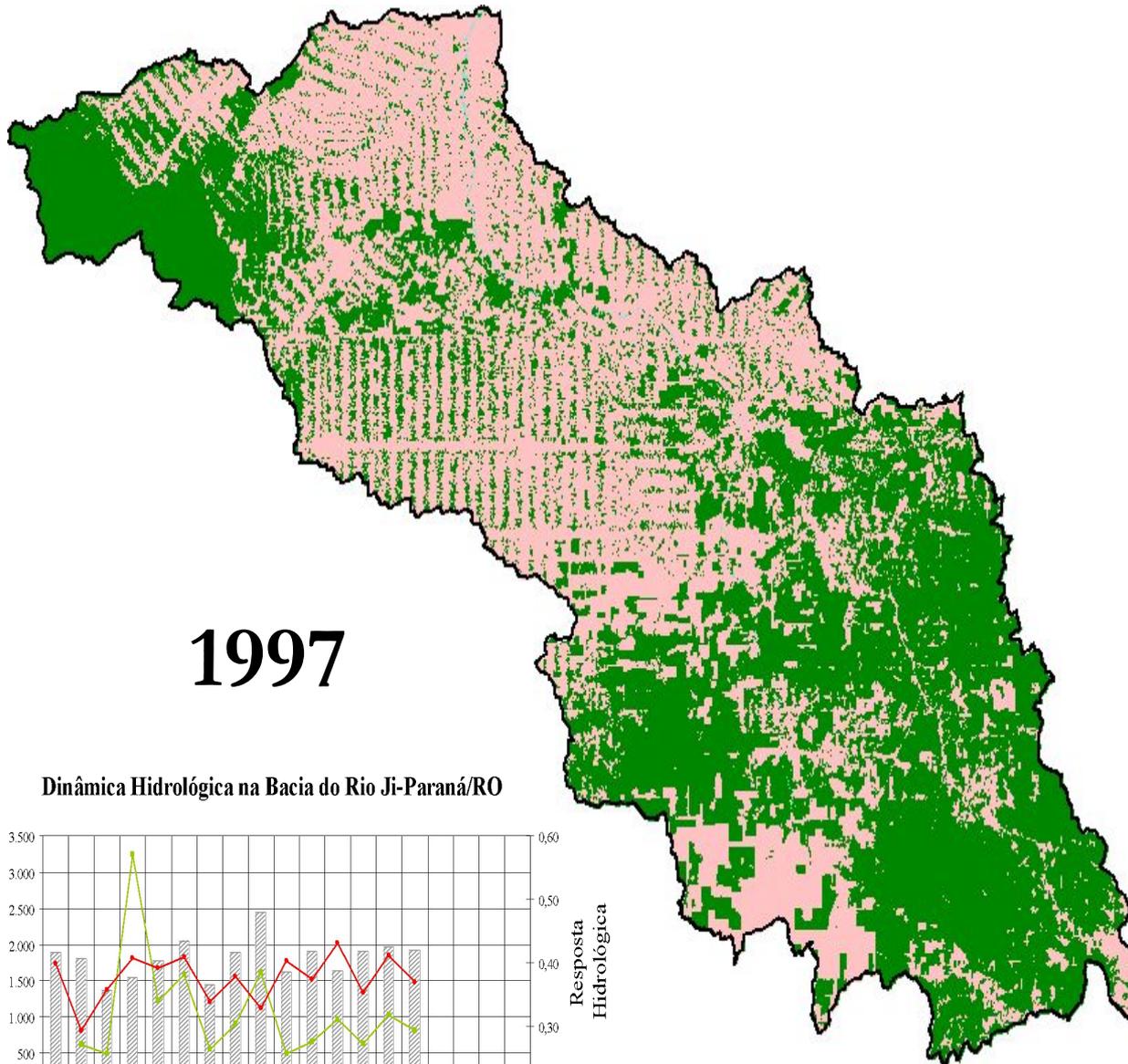


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Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

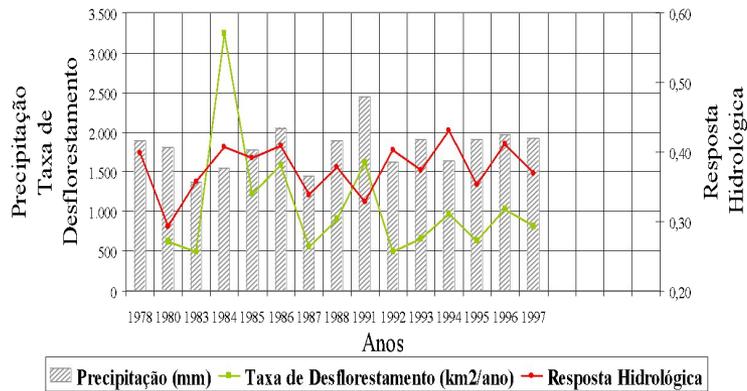


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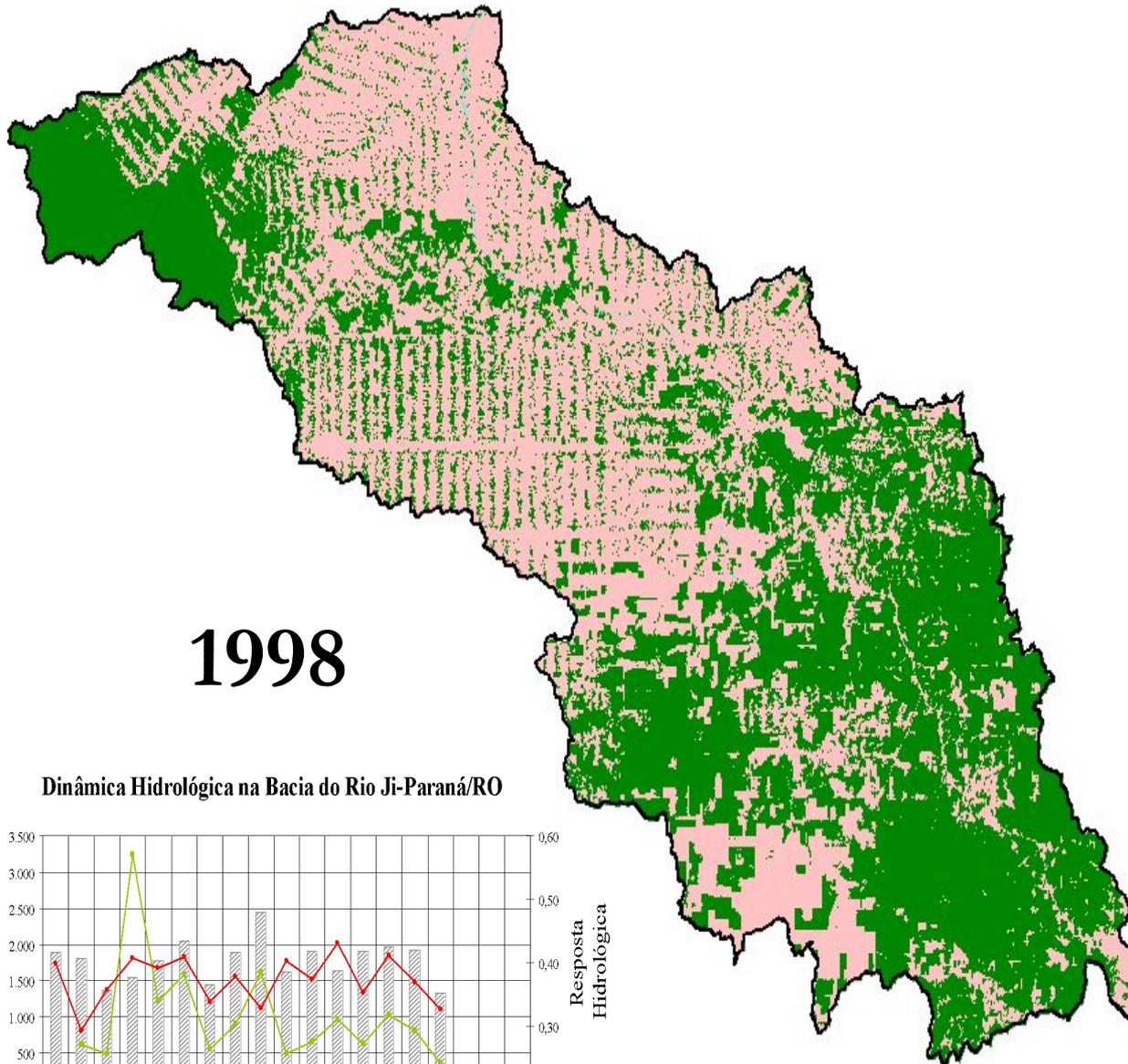


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Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

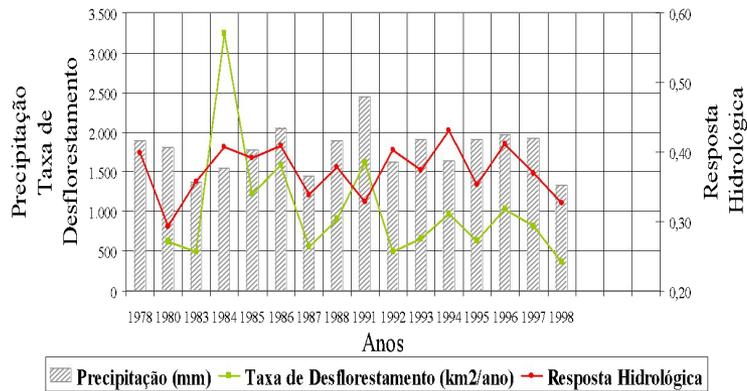


Fonte: Linhares, 2005

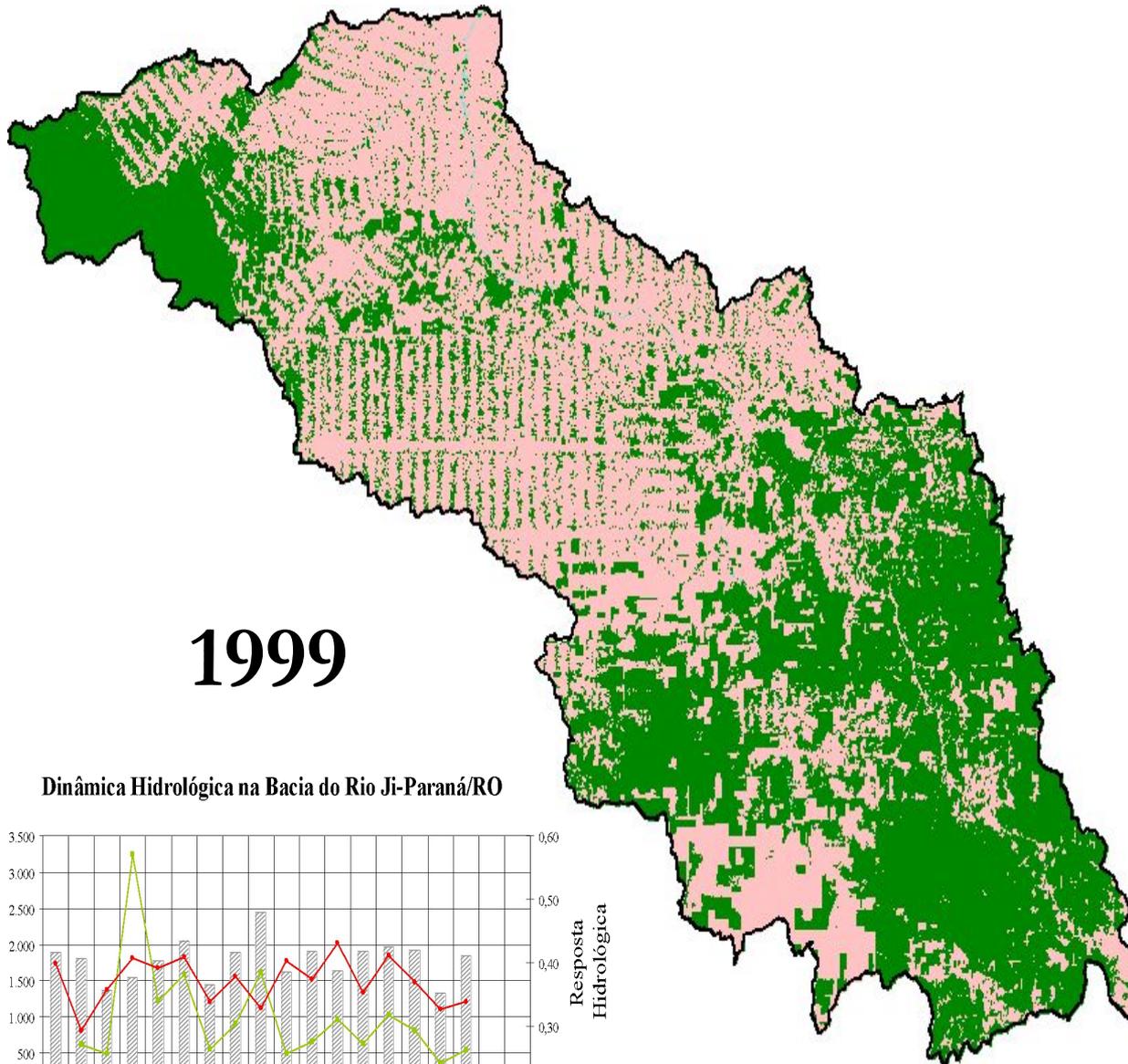


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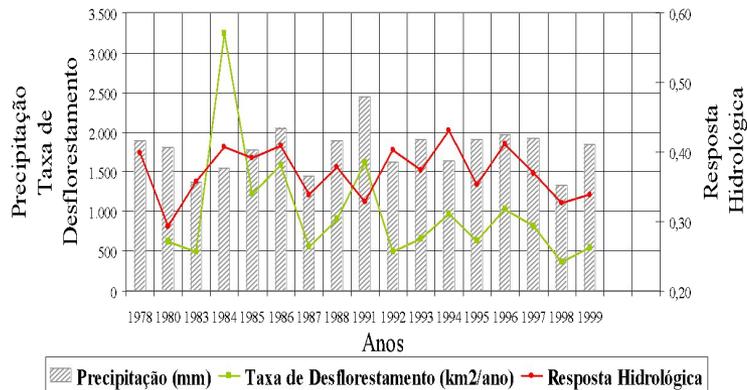


Fonte: Linhares, 2005

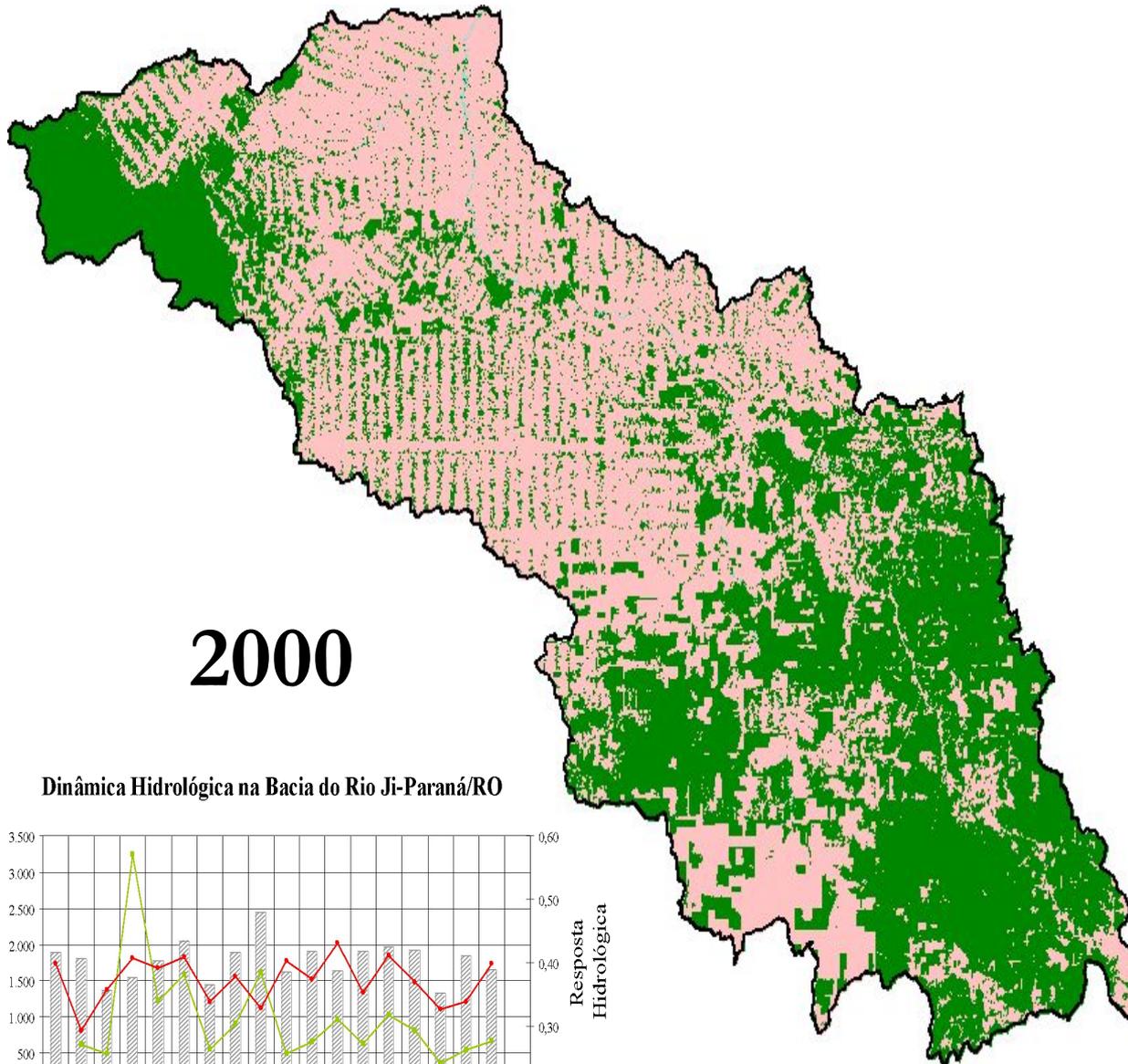


1999

Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

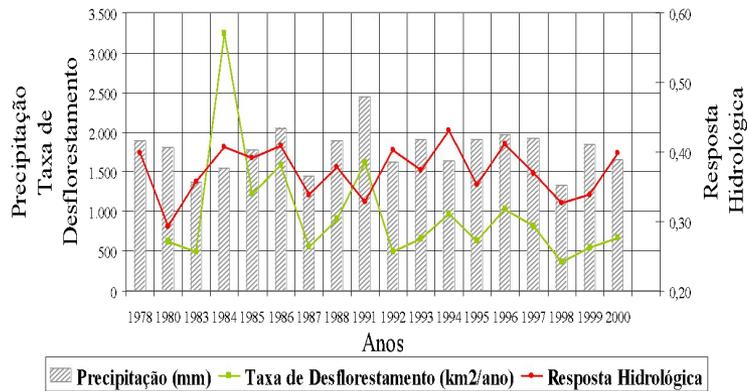


Fonte: Linhares, 2005

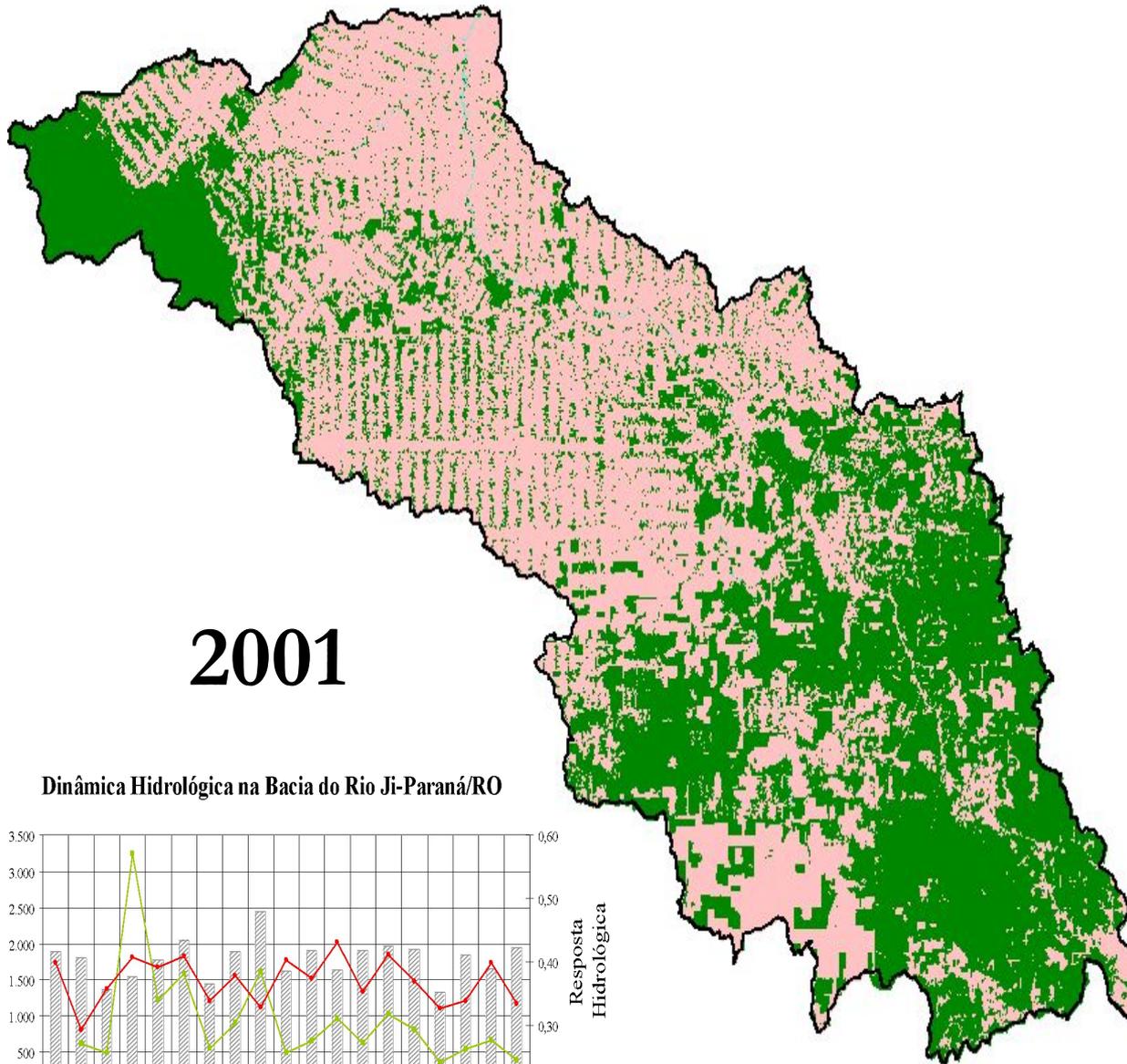


2000

Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO

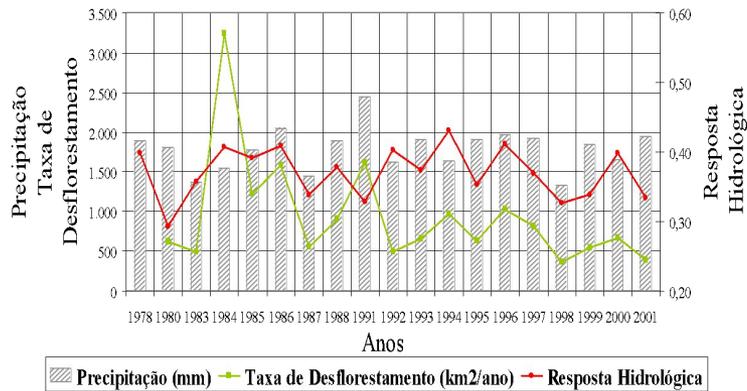


Fonte: Linhares, 2005



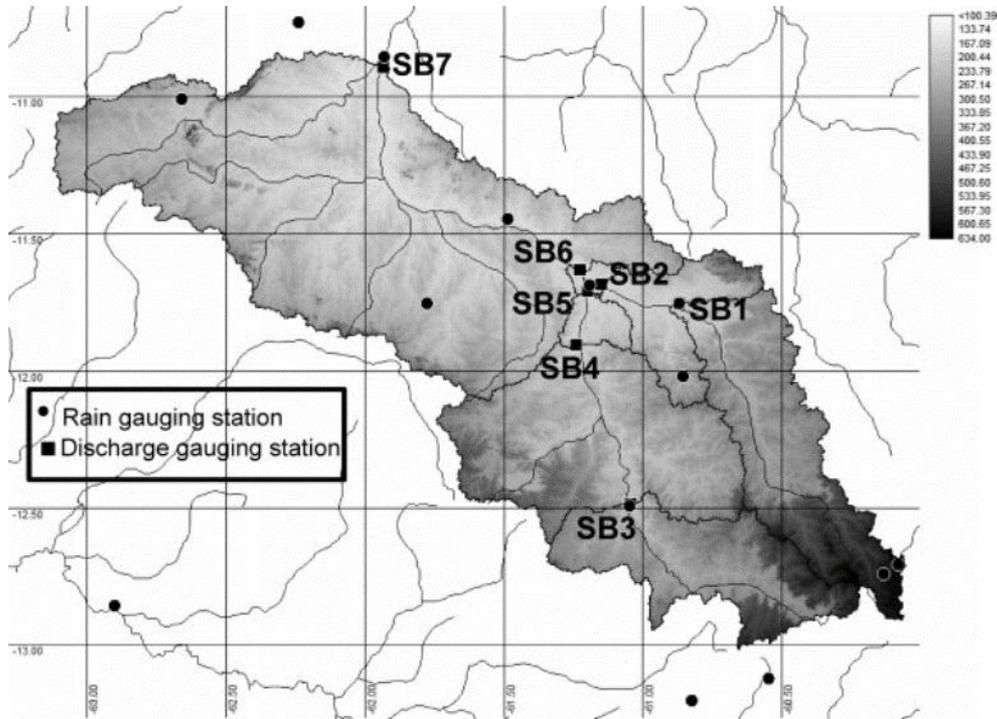
2001

Dinâmica Hidrológica na Bacia do Rio Ji-Paraná/RO



Fonte: Linhares, 2005

Bacia de Ji-Paraná



Incremento da área desflorestada

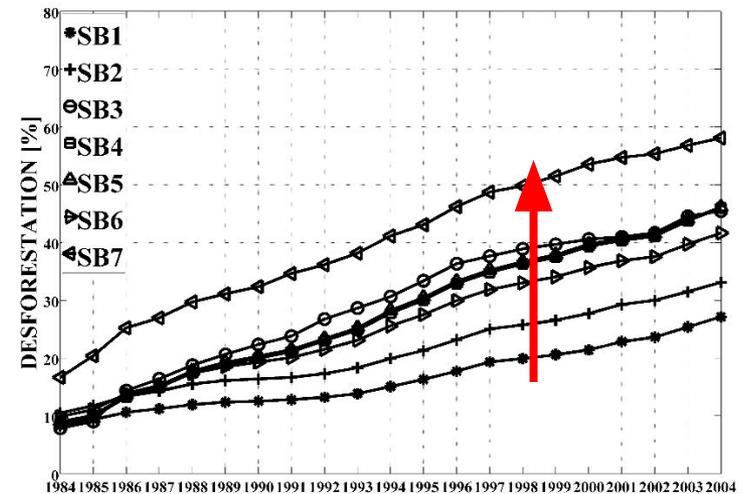
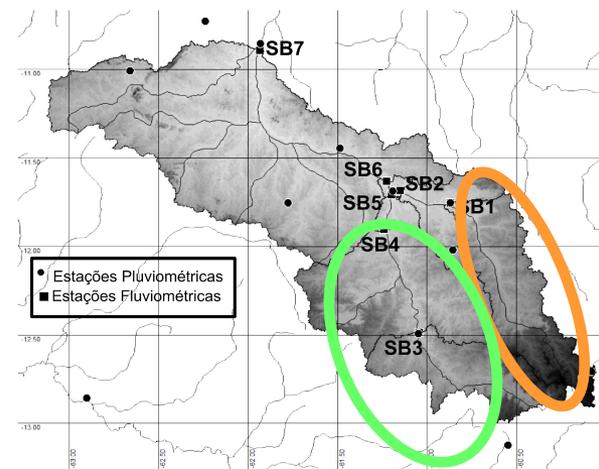


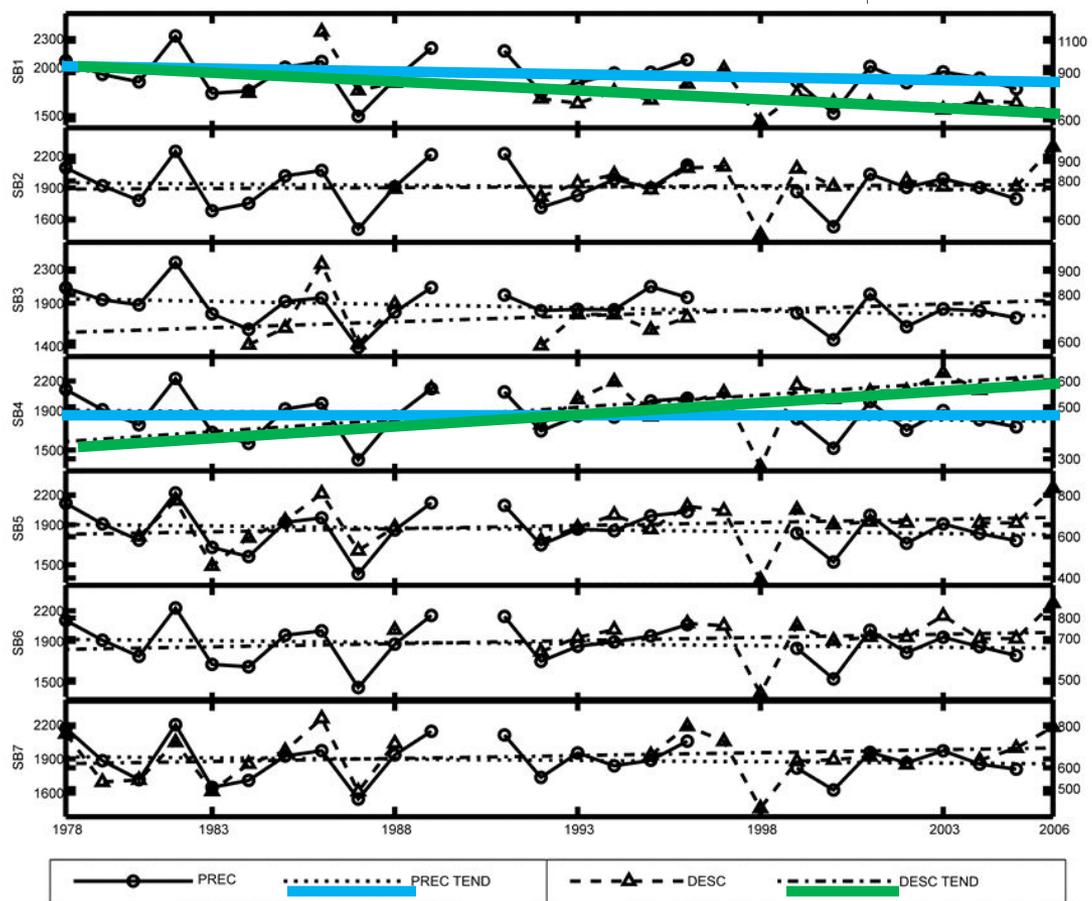
Table I. Streamflow gauge series: temporal coverage

BASIN	SB1	SB 2	SB 3	SB 4	SB 5	SB 6	SB 7
ST	Flor do Campo	Comemoração	Fazenda Expansão	PCH Primavera	Pimenta Bueno	Bela Vista	Ji-Paraná
LAT	-11-74	-11-67	-12-48	-11-9	-11-68	-11-62	-10-87
LON	-60-86	-61-18	-61-05	-61-24	-61-19	-61-22	-61-94
AREA [km ²]	4230	5940	3686	9705	10114	16092	33012

Sem tendências na Precipitação



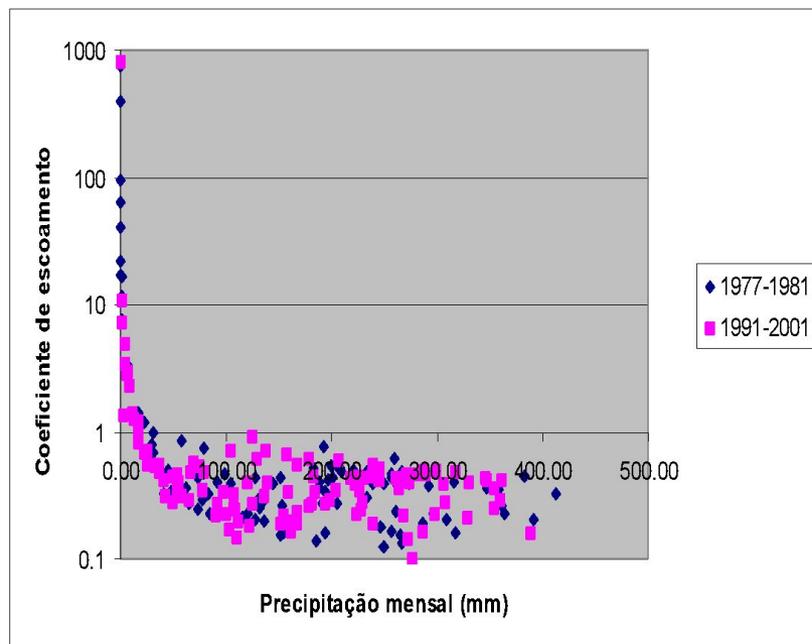
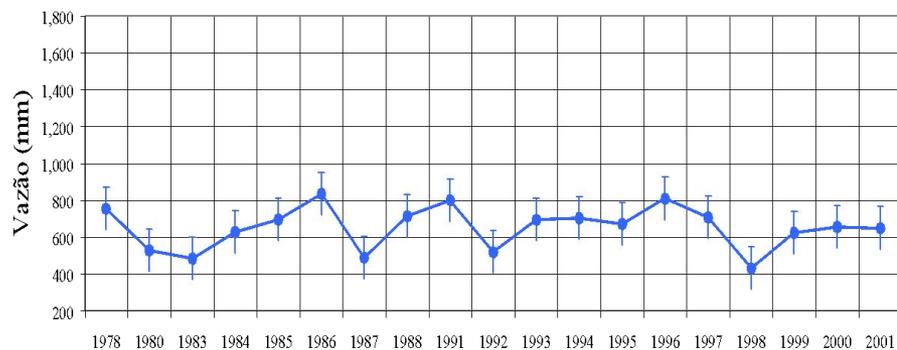
PRECIPITAÇÃO [mm]



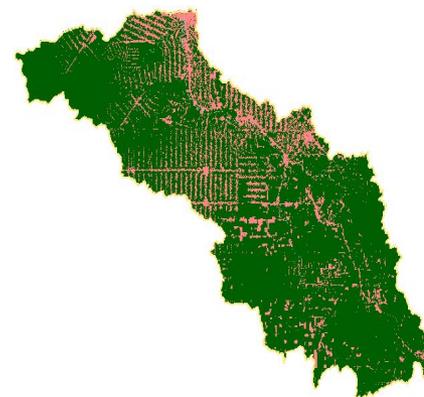
DESCARGA [mm]

Claudia Linhares (2005)

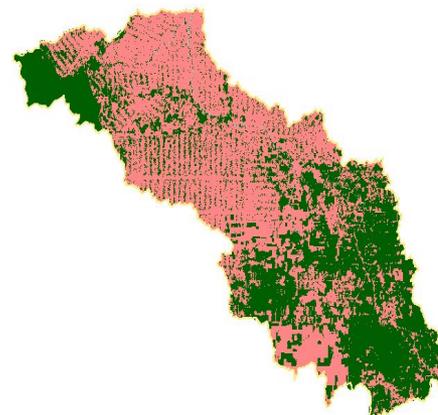
VAZÃO ANUAL Ji-Paraná



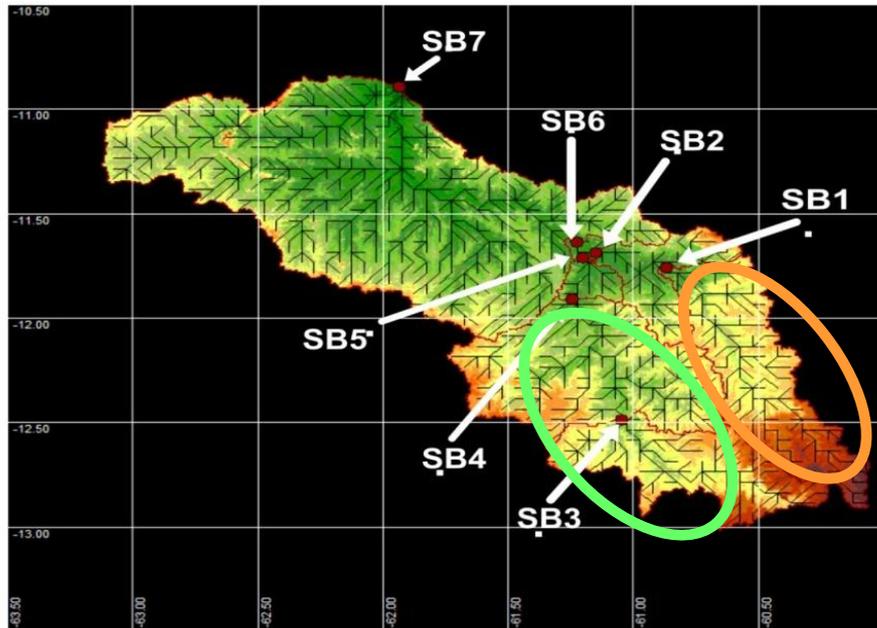
1984



2001



Analysis of the trends in discharges



Basin	SB 1	SB 2	SB 3	SB 4	SB 5	SB 6	SB 7
Period	1991-2004	1990-1999	1991-1995	1991-2004	1990-2005	1995-2005	1993-2001
P02							
VMX	+						
P10				+			
UPQ							
AVG				+			
SLP							
MDN	-						
VAR				+			
SKW	+						
KUR	+						
LWQ	-	-			-		
VMN	-						
P90	-	-					
T07				-	-	-	
T15	-				-		
DEF	+	+	+	+	+	+	+
PD	+	+		+	+	+	+
ED	+	+		+	+	+	-

Bacia do Rio Tocantins

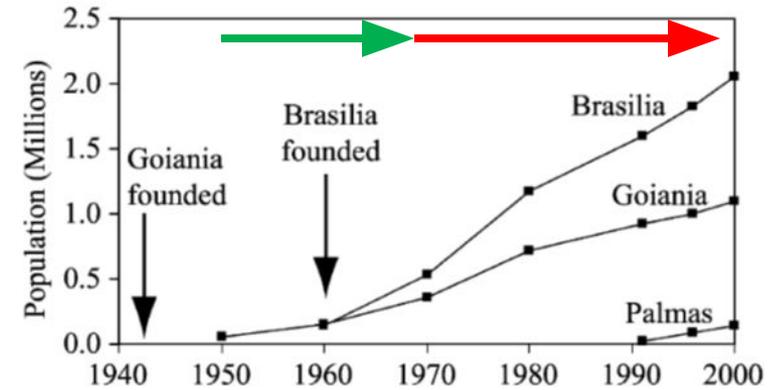
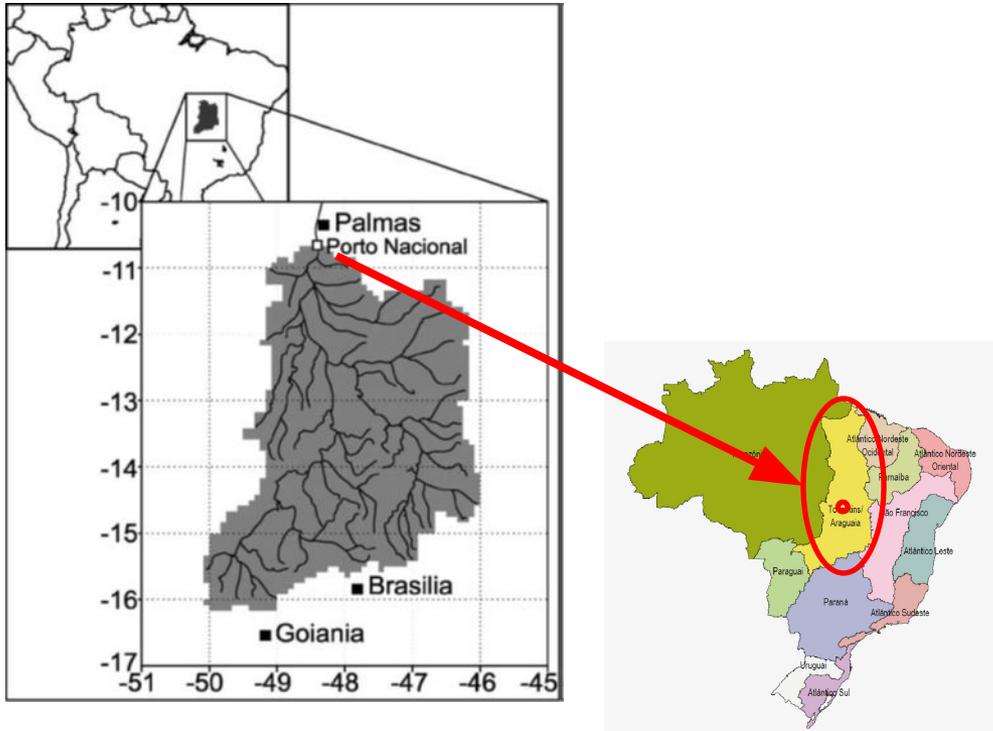


Fig. 2. Population trends in the main cities near the area of study. Goiânia was founded in 1942 to be the new capital of the state of Goiás. Brasília was founded in 1960 to be the new capital of Brazil. Palmas was founded in 1989, to be the capital of the new state of Tocantins. Data are from IBGE (1950, 1960a, 1970, 1980, 1991 and 2000) demographic censuses and one IBGE population count (1996). Data for 1991, 1996 and 2000 were downloaded from <http://www.ibge.gov.br>.

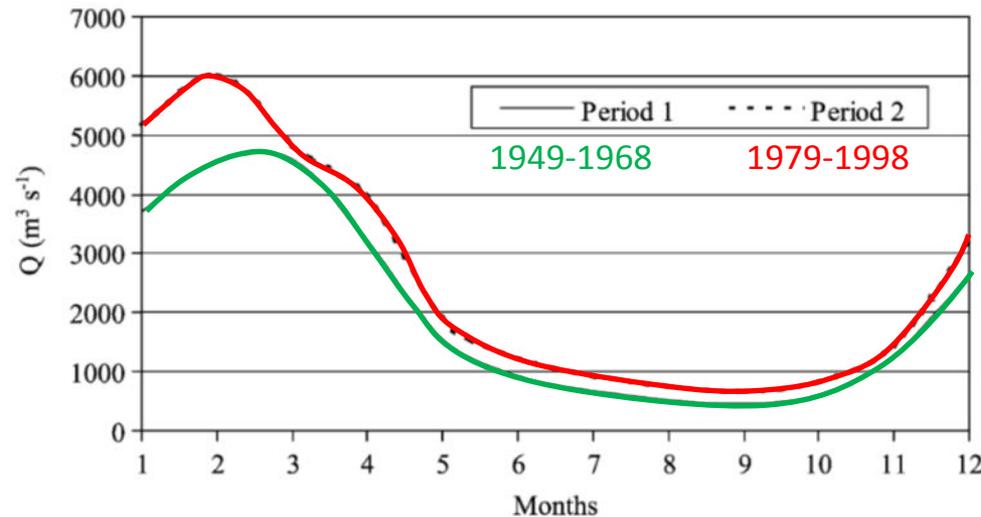


Table 2

Long term mean of hydrological variables in the Tocantins River basin upstream of Porto Nacional

Period	P (mm/day)	Q (m^3/s)	Q (mm/day)	ET (mm/day)	C
1949–1968	4.22	2055.6	1.00	3.22	0.237
1979–1998	4.35	2532.3	1.24	3.11	0.285

P is precipitation (calculated from the CRU dataset), Q is discharge (from the ANEEL records), ET is evapotranspiration ($P - Q$), and C is the runoff coefficient (Q/P).

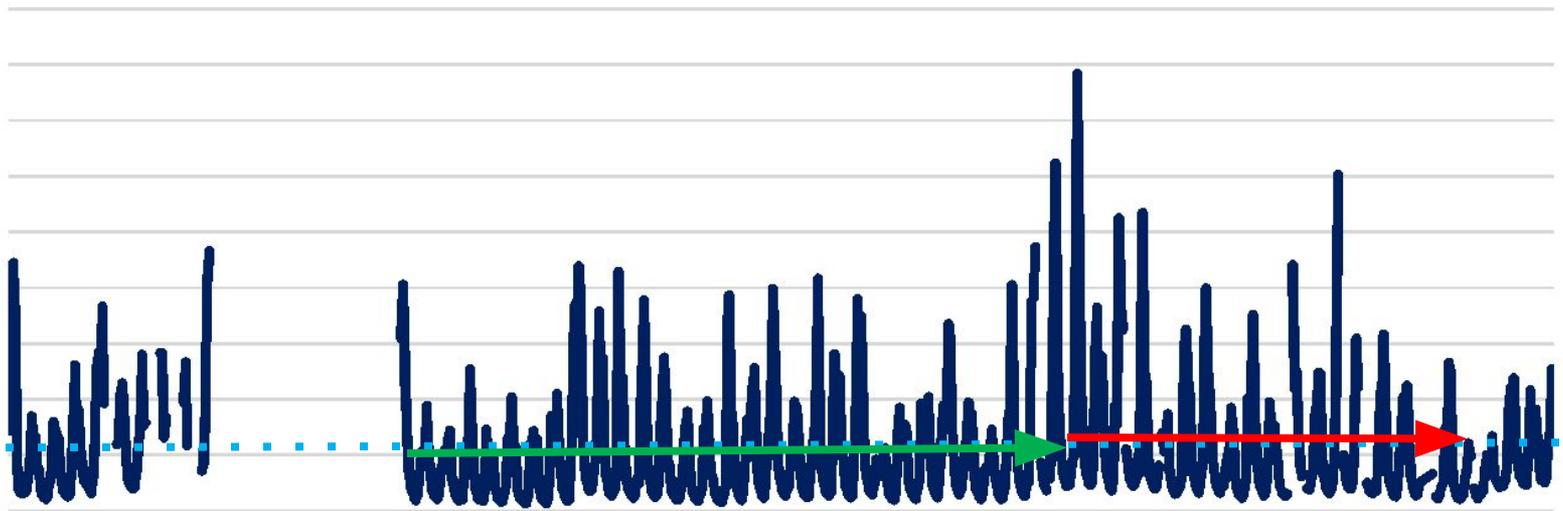
Não obstante se consideramos uma serie temporal de maior extensão

$Q(1949-1968) = 2055 \text{ m}^3 \text{ seg}^{-1}$

$Q(1979-1998) = 2532 \text{ m}^3 \text{ seg}^{-1}$

$y = -0.005x + 2367.9$

$R^2 = 0.0003$



Impacto da mudança do uso do solo e da variabilidade climática em função da escala

HYDROLOGICAL PROCESSES
Hydrol. Process. 21, 1241–1247 (2007)
Published online 14 March 2007 in Wiley InterScience (www.interscience.wiley.com). DOI: 10.1002/hyp.6669

INVITED COMMENTARY

HP
TODAY

At what scales do climate variability and land cover change impact on flooding and low flows?

Günter Blöschl,^{1*}
Sandra Ardoin-Bardin,²
Mike Bonell,³
Manfred Dörninger,⁴
David Goodrich,⁵
Dieter Gutknecht,¹
David Matamoros,⁶
Bruno Merz,⁷ Paul Shand⁸
and Jan Szolgay⁹

¹ Institute of Hydraulic and Water Resources Engineering, Vienna University of Technology, Karlsplatz, 10, A-1040 Vienna, Austria

² UMR HydroSciences Montpellier, France

³ UNESCO Division of Water Sciences, Paris, France

⁴ University of Vienna, Austria

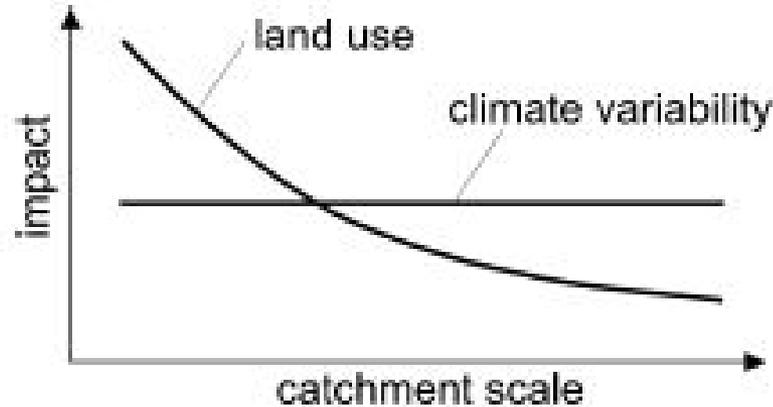
⁵ USDA-ARS-SWRC, Tucson, AZ, USA

⁶ FIMCH-ESPOL, Campus Guano, Galindo, Guayaquil, Ecuador

⁷ GeoForschungsZentrum Potsdam, Germany

⁸ CSIRO Land and Water, Glen Osmond, Australia

⁹ Slovak University of Technology, Bratislava, Slovakia



Mudança no uso do solo

- Fenômeno Local
- O impacto diminui com o tamanho da bacia
- A forma e posição da forçante dentro da bacia pode modular o efeito na escala

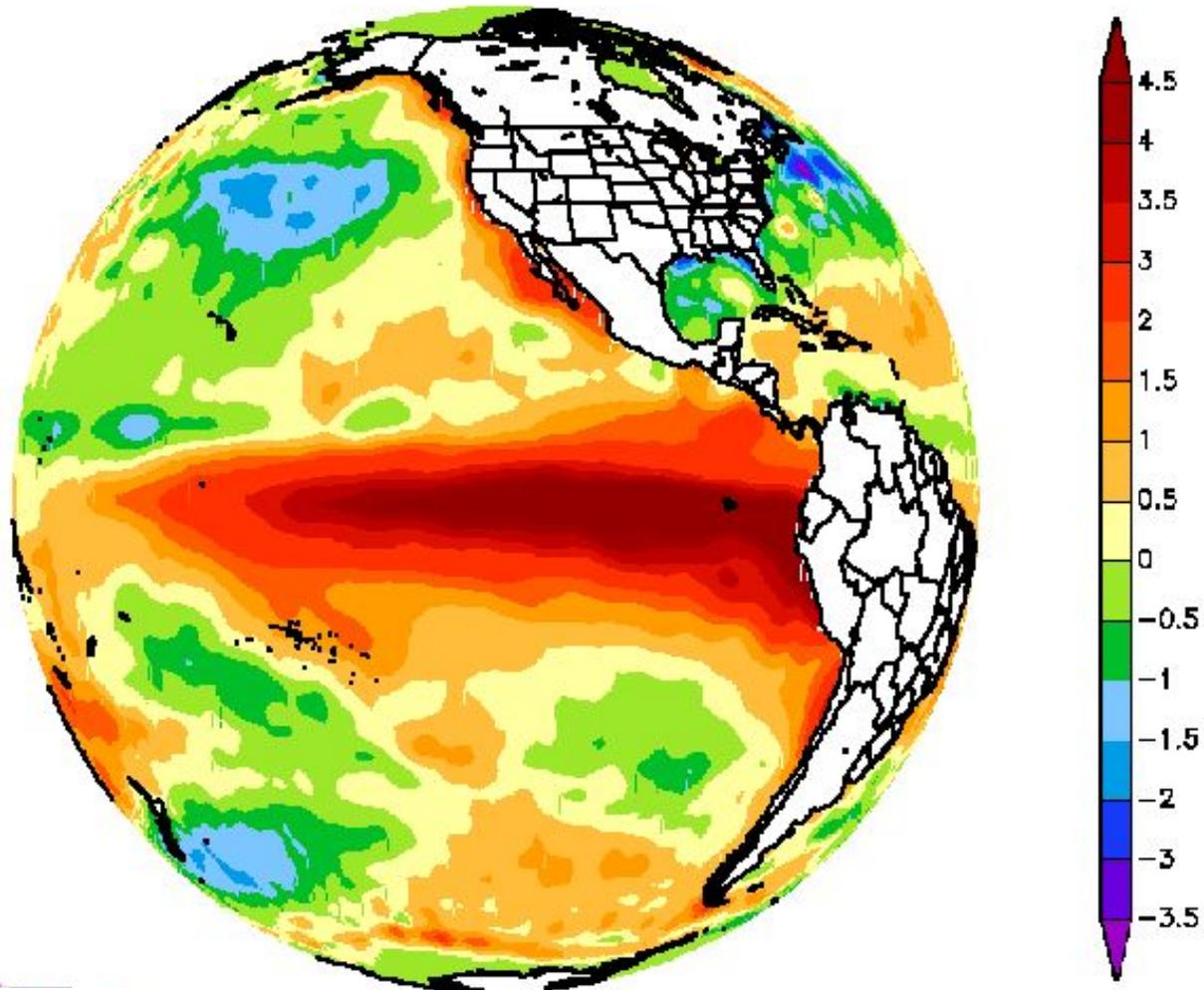
Variabilidade climática

- Impactos podem ocorrer em grande escala
- O impacto pode ser encontrado tanto em pequenas como em grandes bacias
- São regionalmente consistentes

Mudança Hidrológica e a variabilidade climática de longo prazo

EL NIÑO

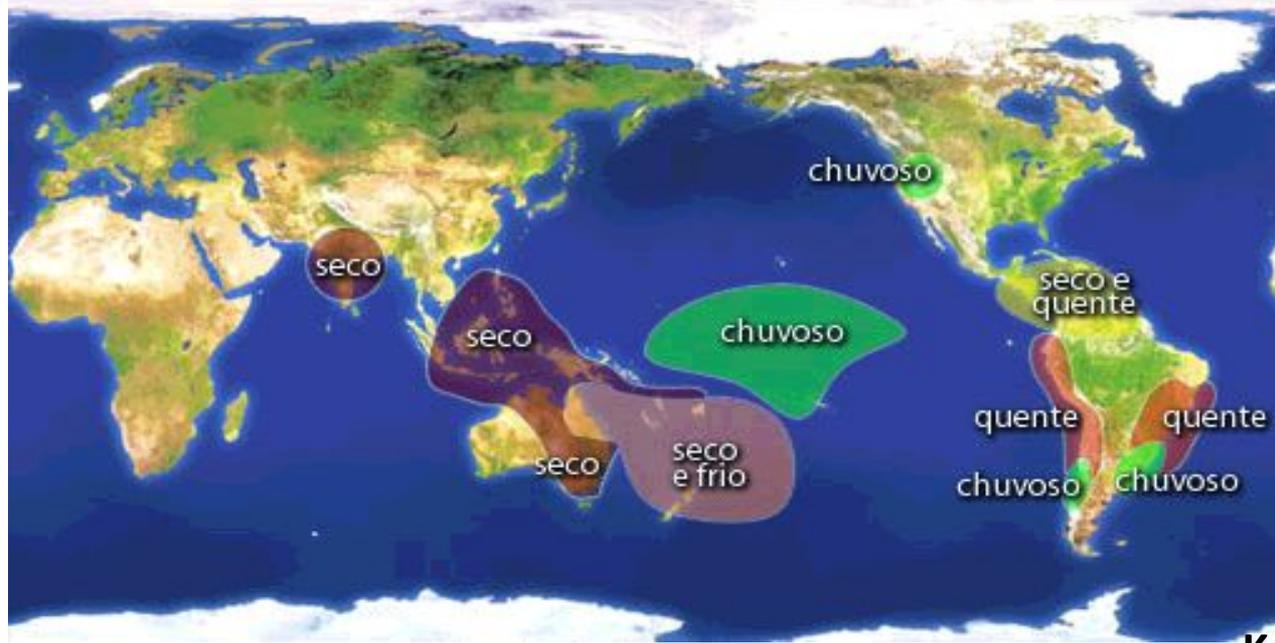
Anomalia de Temperatura da Superfície do Mar (Celsius)



Kevin E. Trenberth

EL NIÑO

DJF



JJA

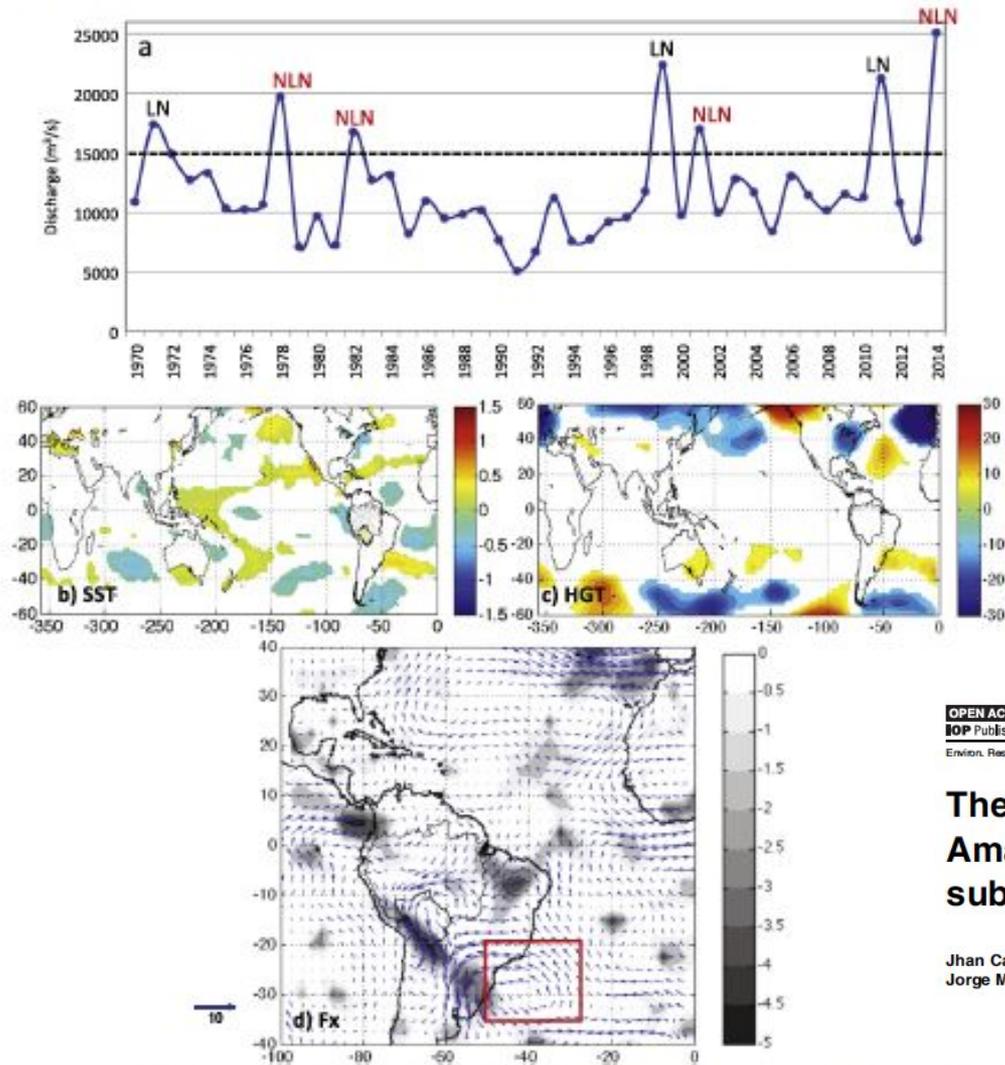


Figure 5. (a) Annual maximum discharge in Rurrenabaque station (upper Madeira). Composite analysis of (b) SST, (c) 850 hPa Geopotential height and (d) vertically integrated humidity transport flux (vectors, in $\text{kg m}^{-1} \text{day}^{-1}$) and standardized negative divergence values (grey shaded, without unit), during no La Niña extreme floods (1978, 1982, 2001, and 2014) (December (n-1)–February (n) average). A black line represents the boundaries of the Amazon and of the upper Madeira basins. Only values higher than $1 \times \text{std}$ are plotted in panels (b) and (c).

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Environ. Res. Lett. 9 (2014) 124007 (9pp)

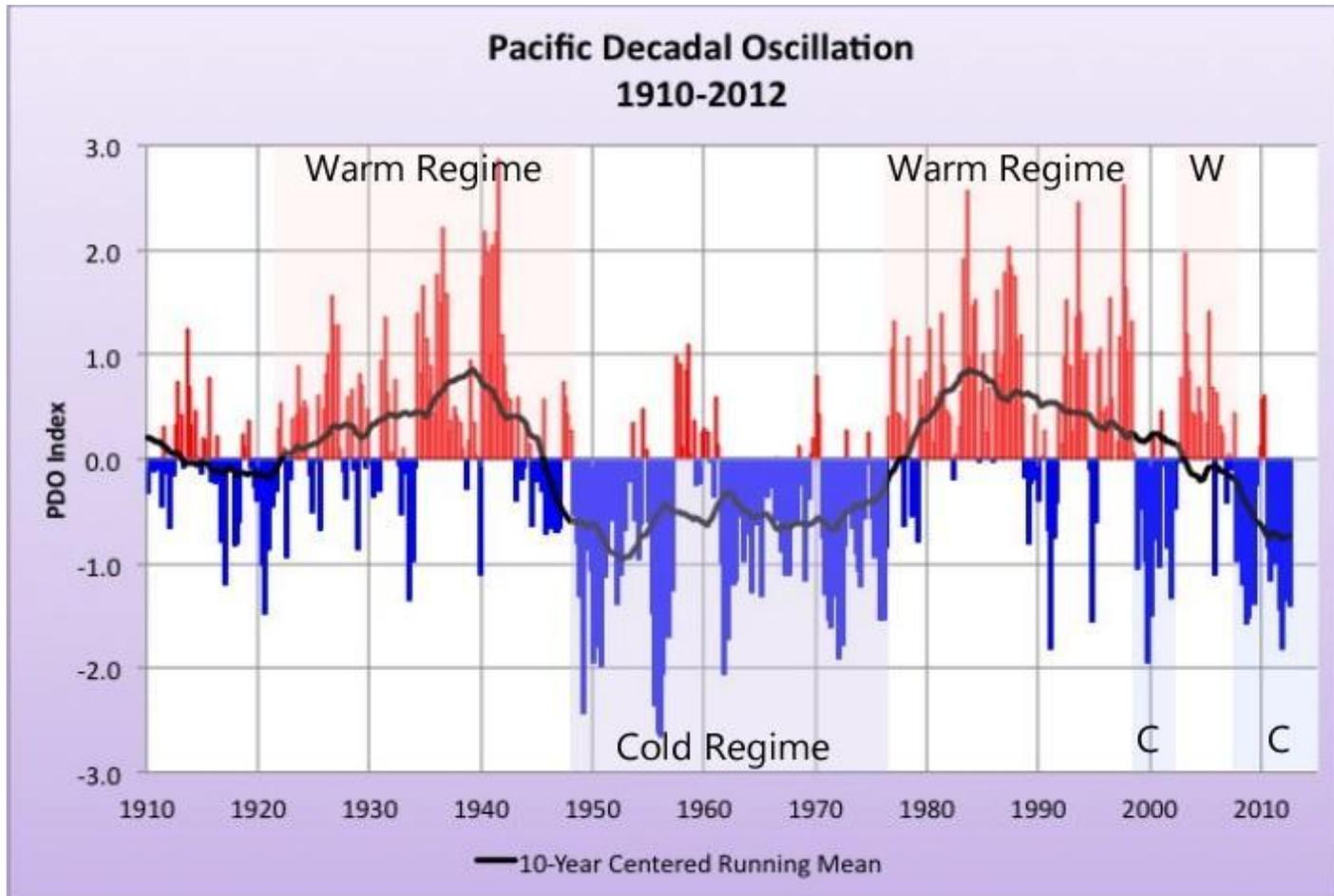
Environmental Research Letters

doi:10.1088/1748-9326/9/12/124007

The extreme 2014 flood in south-western Amazon basin: the role of tropical-subtropical South Atlantic SST gradient

Jhan Carlo Espinoza¹, José Antonio Marengo², Josyane Ronchail³, Jorge Molina Carpio⁴, Luis Noriega Flores⁵ and Jean Loup Guyot⁶

Variabilidade climática de longo prazo



Variabilidade climática de longo prazo

Mudanças dos modos de variabilidade do Atlântico Tropical no
Século XX

Dalton Kei Sasaki

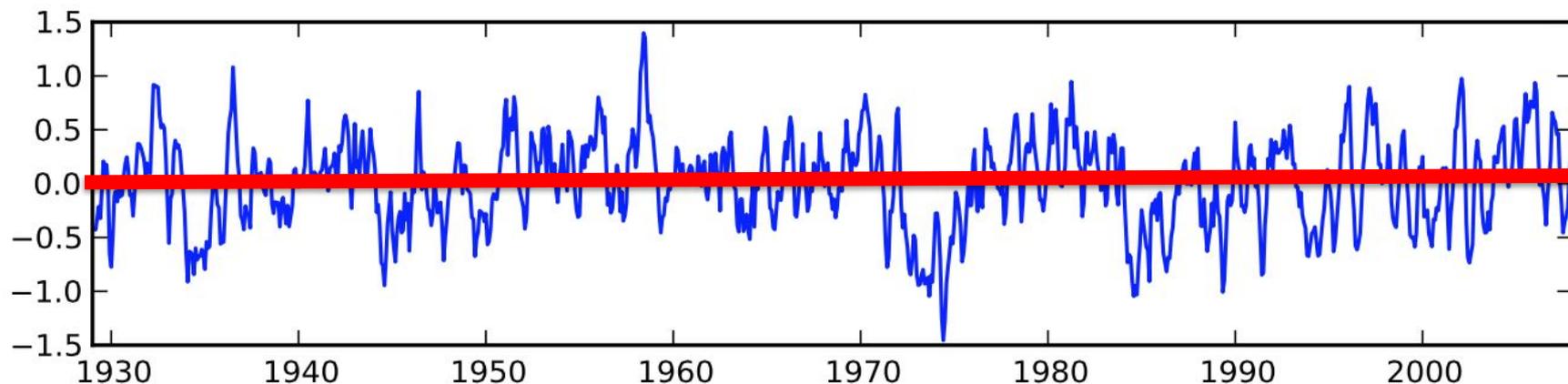


Figura 12: Série temporal do índice do GMT (anomalia de temperatura) para o período de 1929 a 2008.

Variabilidade Interdecadal na Amazonia (Marengo 2004,IJC)

1975

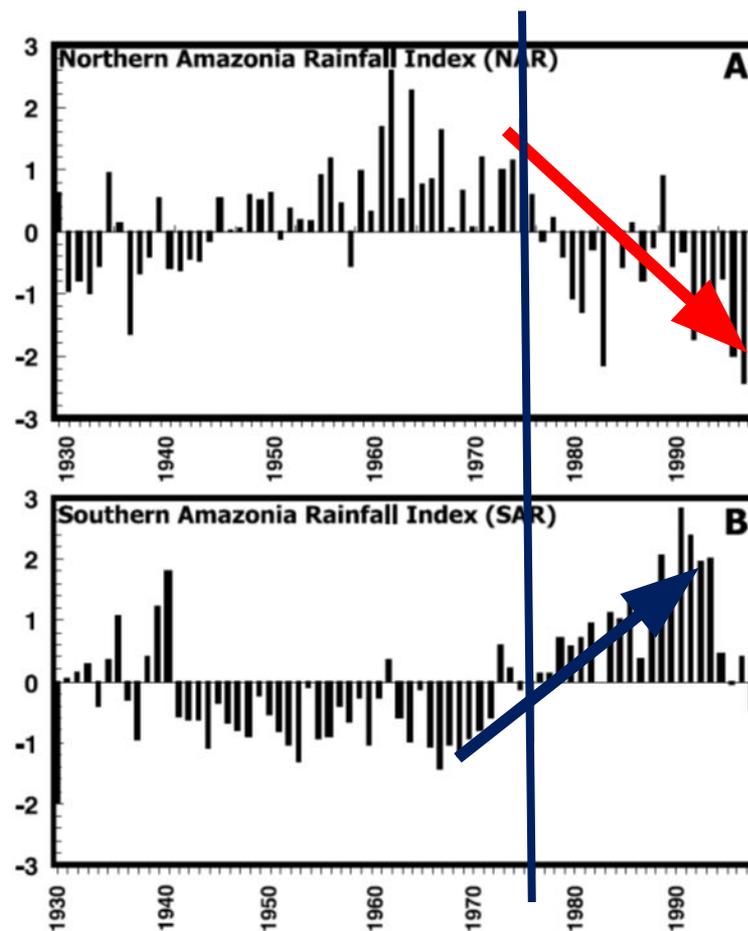
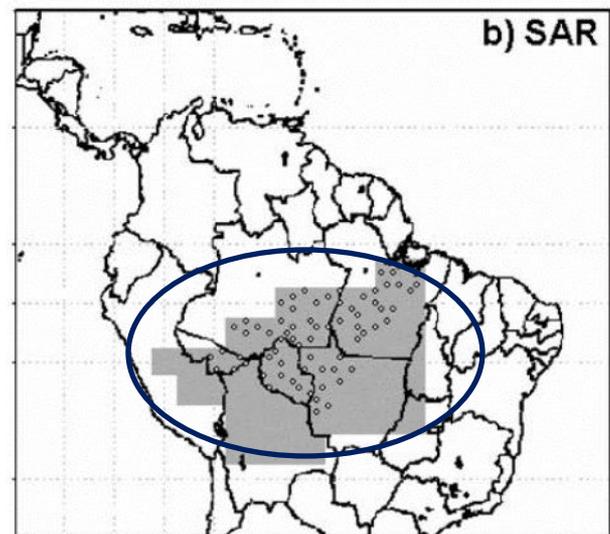
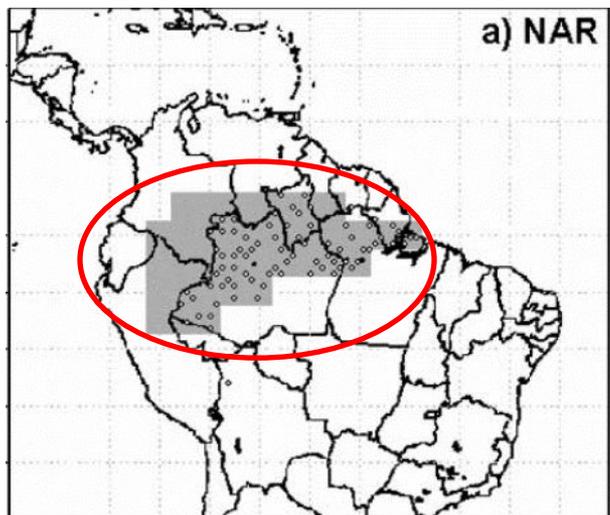


Fig. 3. Rainfall indices in northern (NAR) and southern Amazonia (SAR) from 1929/30 to 1998/99. Indices are expressed as departures normalized by the standard deviation, from the reference period 1949–1998

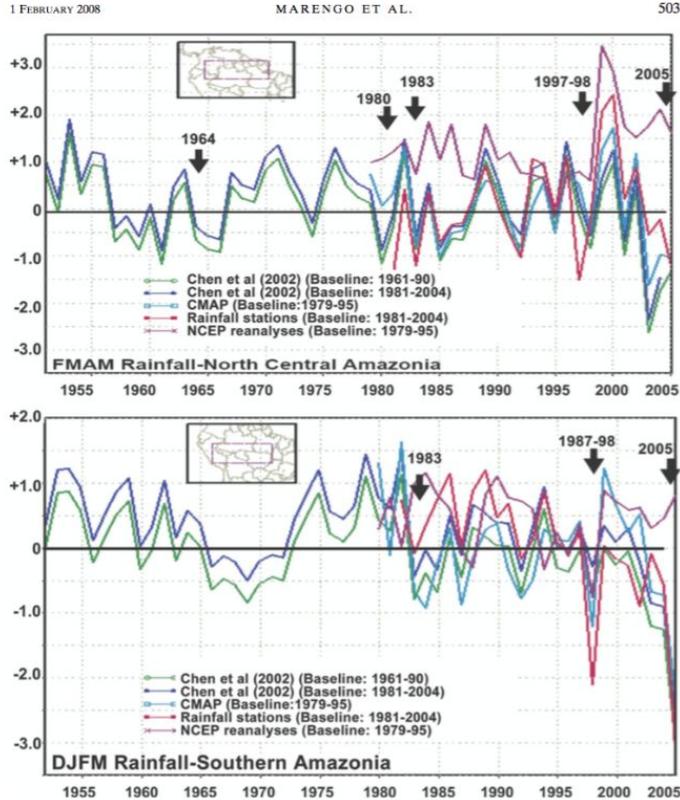


FIG. 4. Time series of rainfall indices for (a) northern Amazonia (FMAM) and (b) southern Amazonia (DJFM) from 1950 to 2005. These seasons correspond to the peak of the rainy season in those sections of the Amazon basin. Rainfall datasets are from Chen et al. (2002), CMAP (Xie and Arkin 1997), and an index derived from rainfall stations. Anomalies (mm day⁻¹) are derived using different baseline periods. Arrows indicate major drought events for this period.

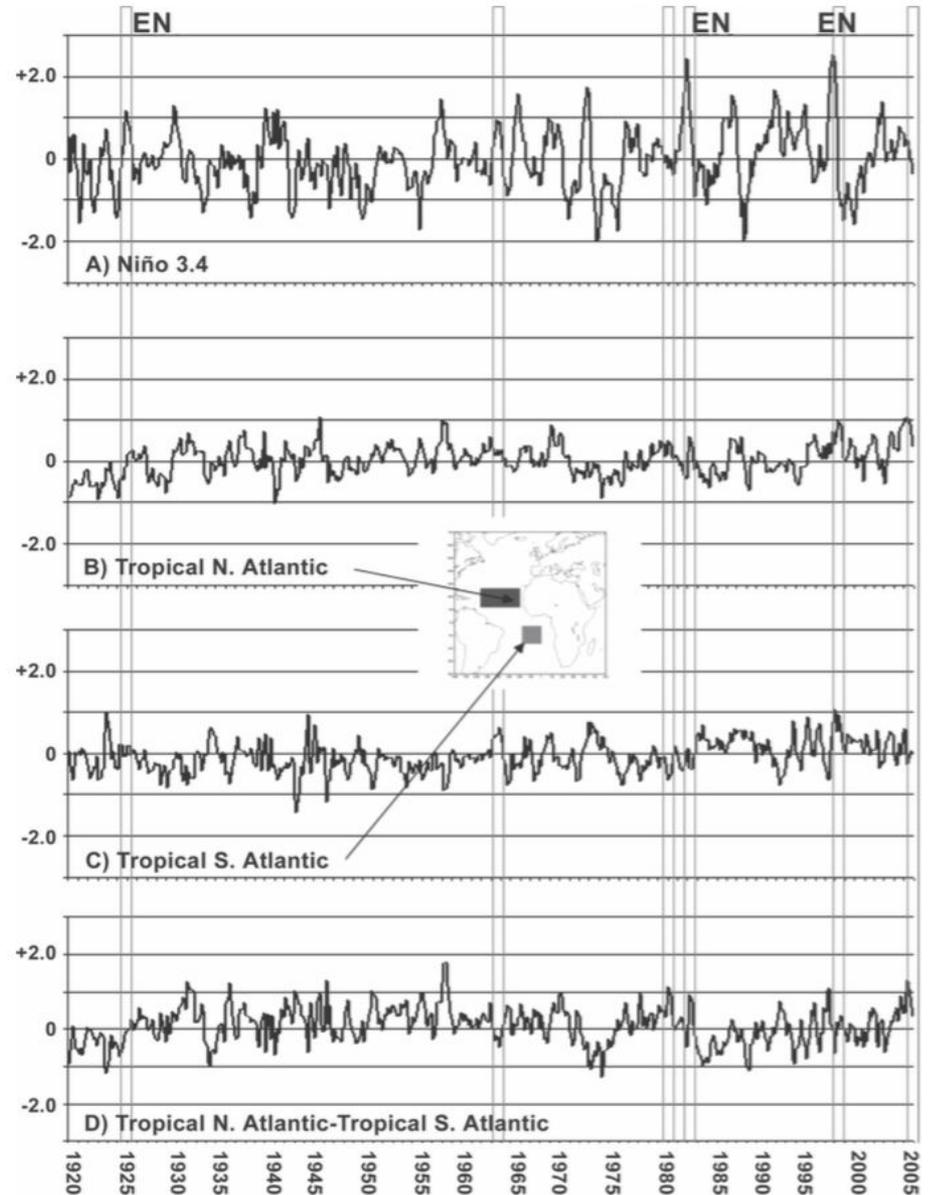


FIG. 11. (a)–(c) Time series of bimonthly SST anomalies since 1920. Series are for the Niño-3.4 region, the tropical North and South Atlantic, as well as the gradient between tropical North and South Atlantic SSTs. Anomalies are with relation to the 1961–90 period. Boxes indicate years with drought in Amazonia.

The Drought of Amazonia in 2005
 JOSÉ A. MARENGO, CARLOS A. NOBRE, AND JAVIER TOMASELLA
 CPTEC/INPE, Cachoeira Paulista, São Paulo, Brazil

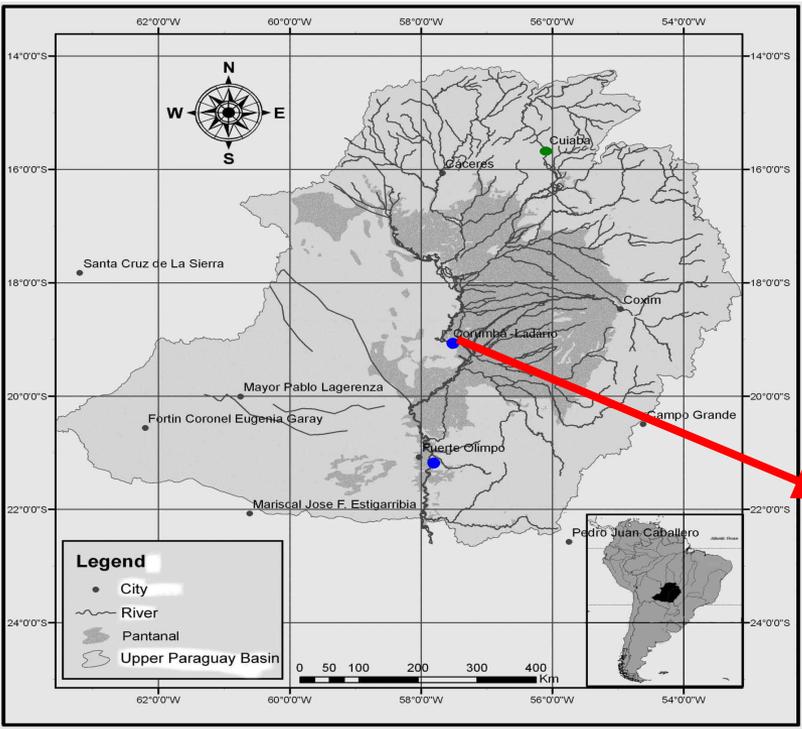
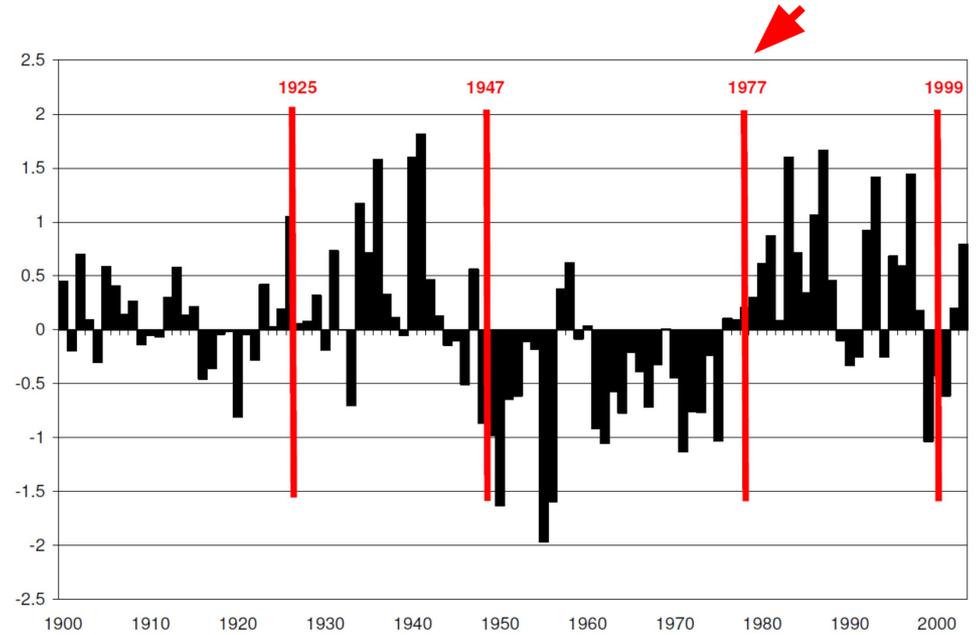
MARCOS D. OYAMA
 Divisão de Ciências Atmosféricas Centro Técnico Aeroespacial, Instituto de Aeronautica e Espaço, São José dos Campos, São Paulo, Brazil

GILVAN SAMPAIO DE OLIVEIRA, RAFAEL DE OLIVEIRA, HELIO CAMARGO, AND LINCOLN M. ALVES
 CPTEC/INPE, Cachoeira Paulista, São Paulo, Brazil

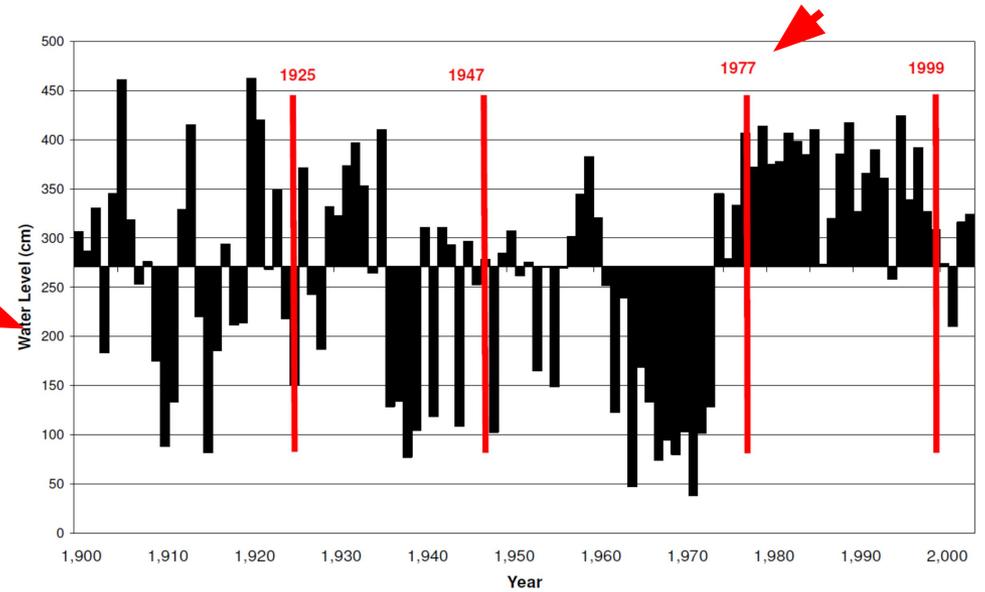
I. FOSTER BROWN
 Woods Hole Oceanographic Institution, Woods Hole, Massachusetts, and Zoobotanical Park, Federal University of Acre, Acre, Rio Branco, Brazil

Variabilidade Interdecadal na Bacia do Paraná (Allasia, 2008)

Pacific Decadal Oscillation (Mantua et al. 1997)



Alturas do rio em Ladário



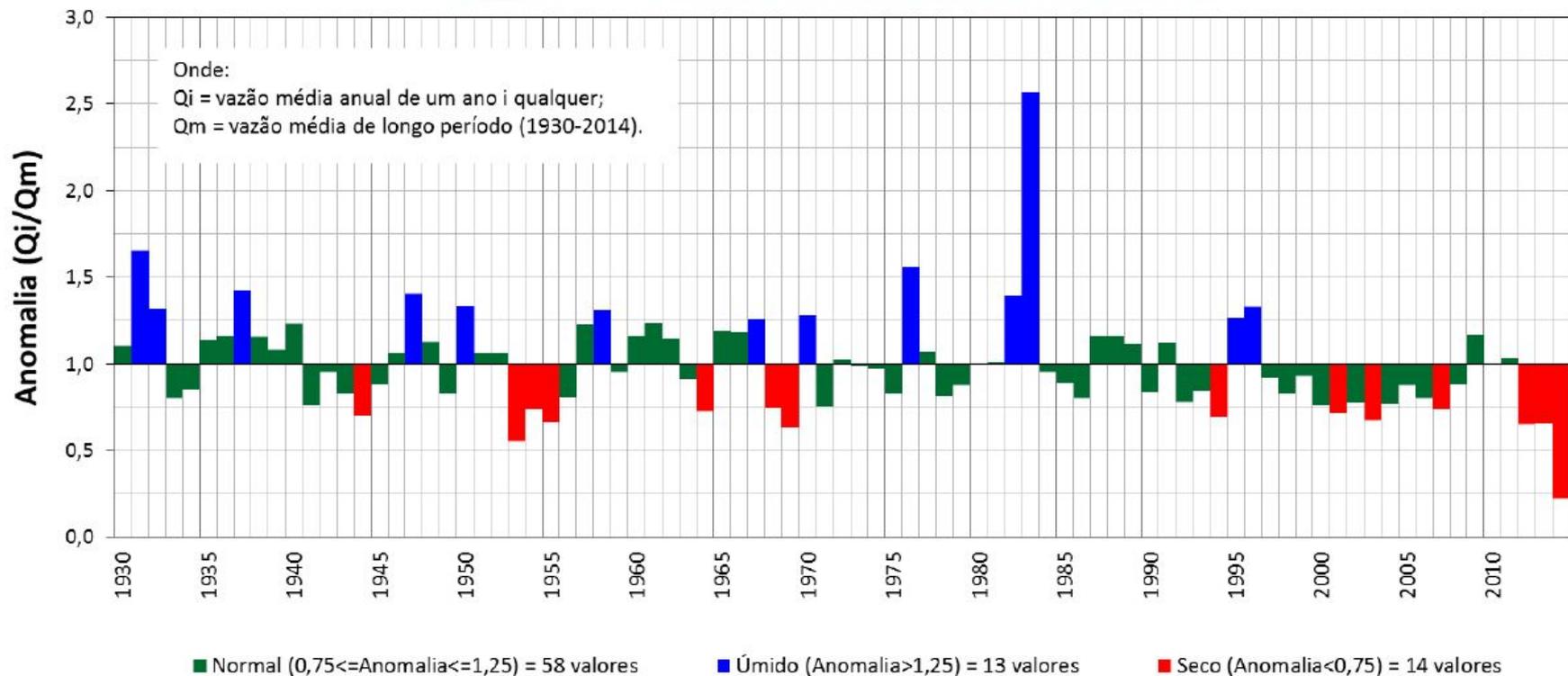
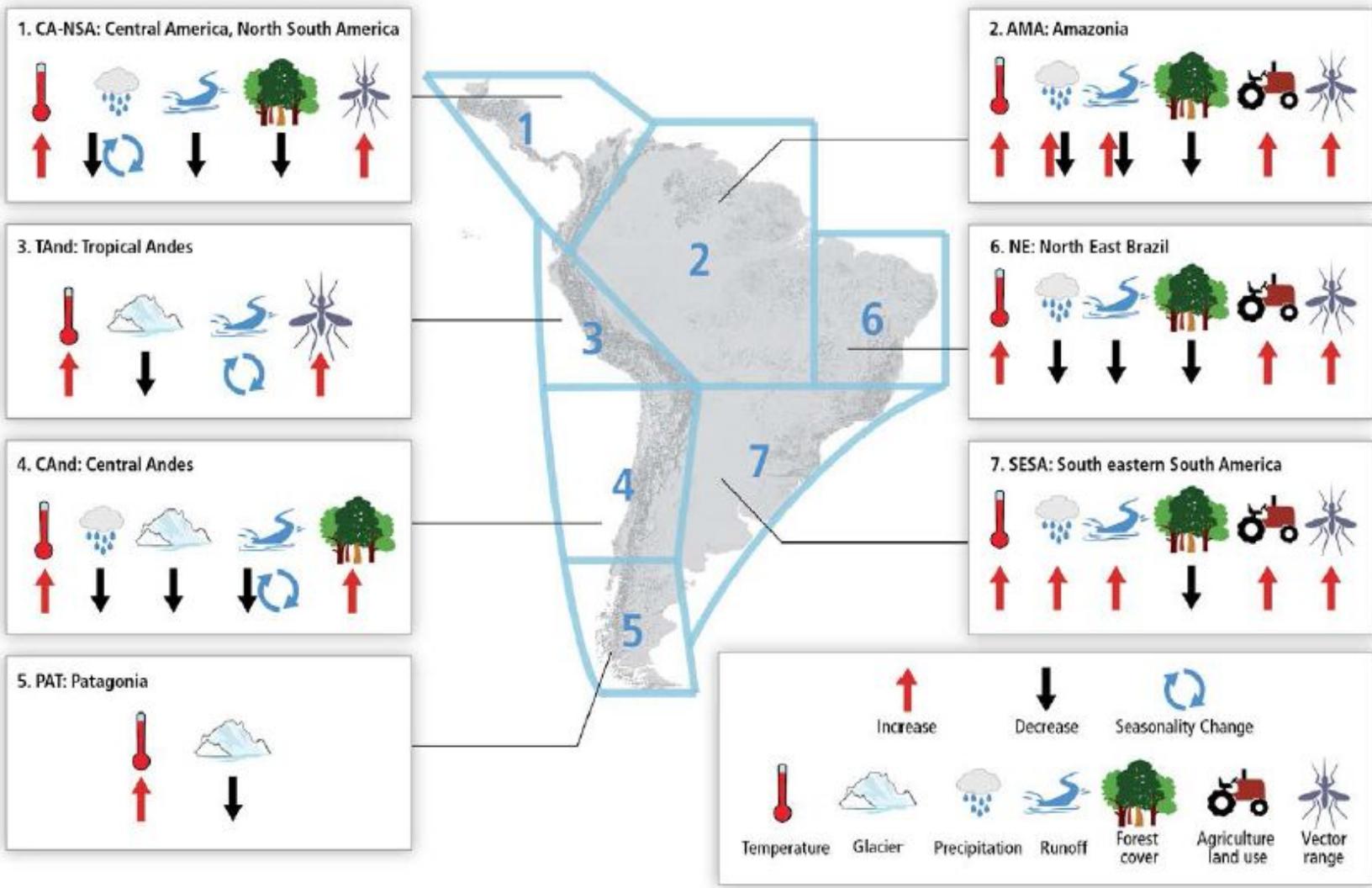


Figura 3 - Anomalia das vazões médias mensais para o Sistema Equivalente.

Mudança Hidrológica e as Mudanças Climáticas

Impactos Observados das Mudanças Climáticas nos Recursos Hídricos



Impactos Observados: Eventos Extremos



e: Magrin, 2007)

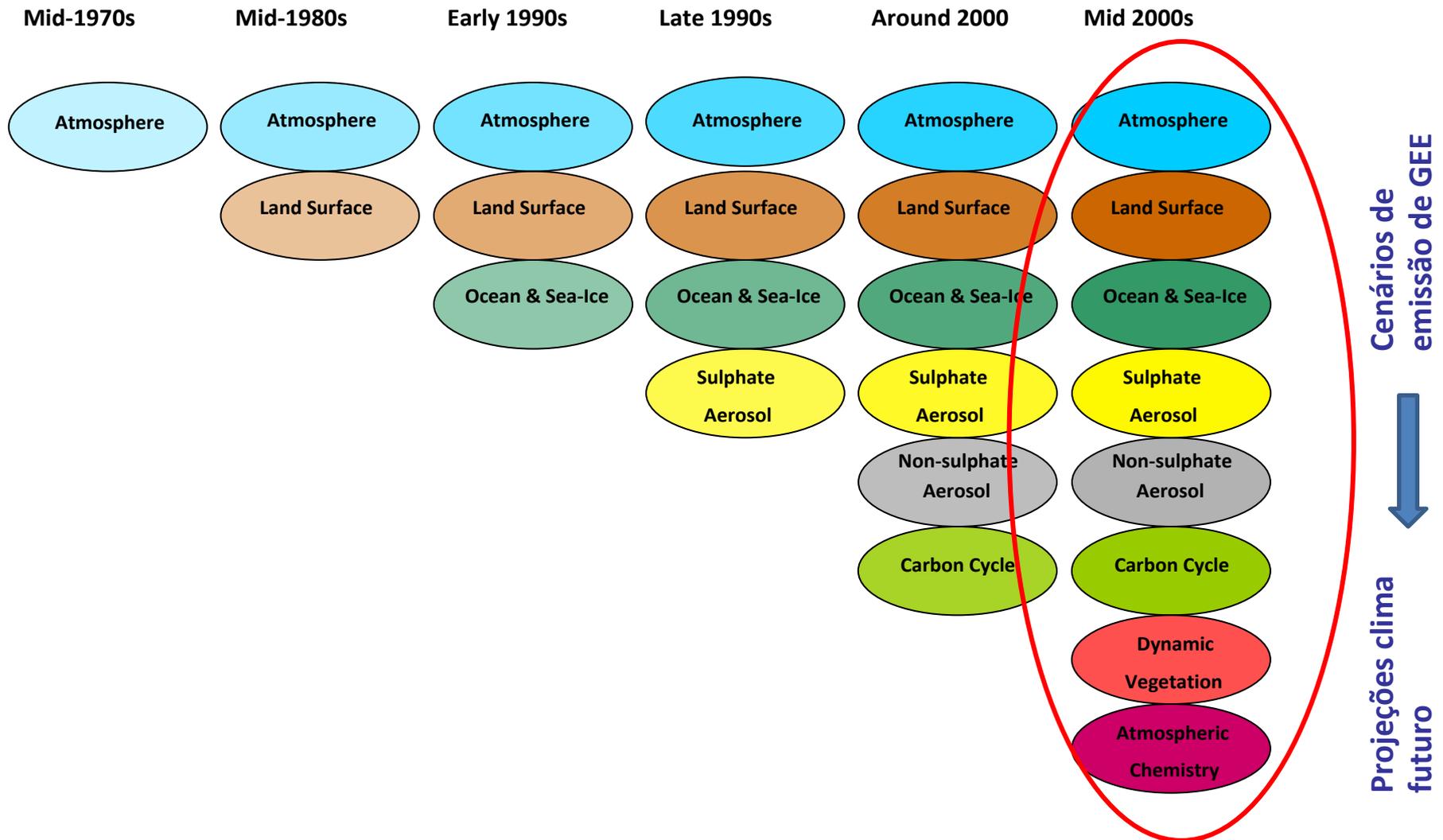
Esquema de Modelo Atmosférico Global

Grade Horizontal (Latitude-Longitude)

Grade Vertical (Altitude e Pressão)



EVOLUÇÃO DA MODELAGEM CLIMÁTICA GLOBAL → PROJEÇÕES DE MUDANÇAS DE CLIMA



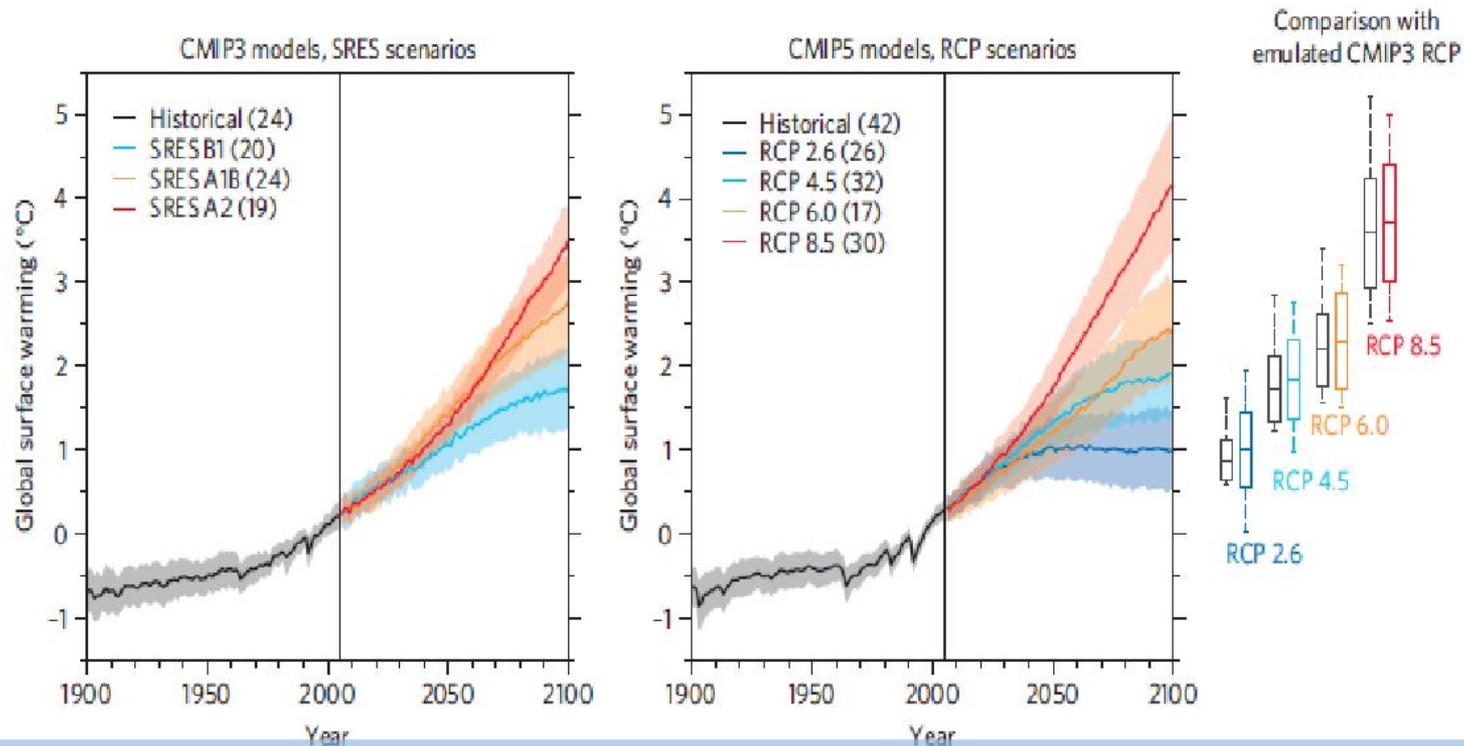
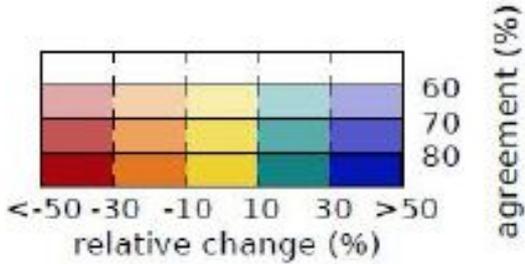
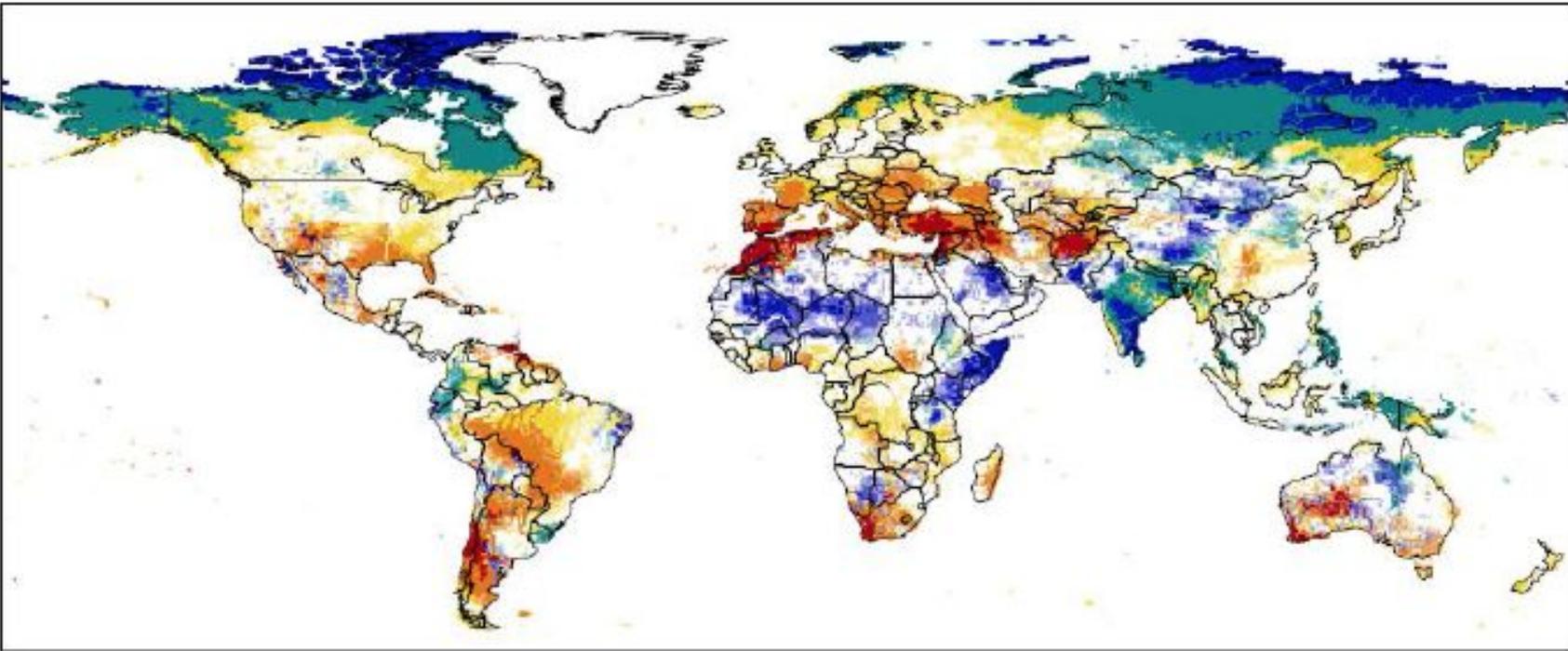


Figura 5. Mudanças na temperatura média global (linhas em cores) e incertezas (áreas sombreadas em cores), relativas a 1986–2005, para os cenários SRES do IPCC AR4 e RCPs do IPCC AR5. O número de modelos é indicado entre parênteses. As caixas no lado direito mostram a média e o desvio padrão das projeções de aumento da temperatura até 100 (Knutti et al 2012)

Mudanças Hidrológicas Projetadas - Globais

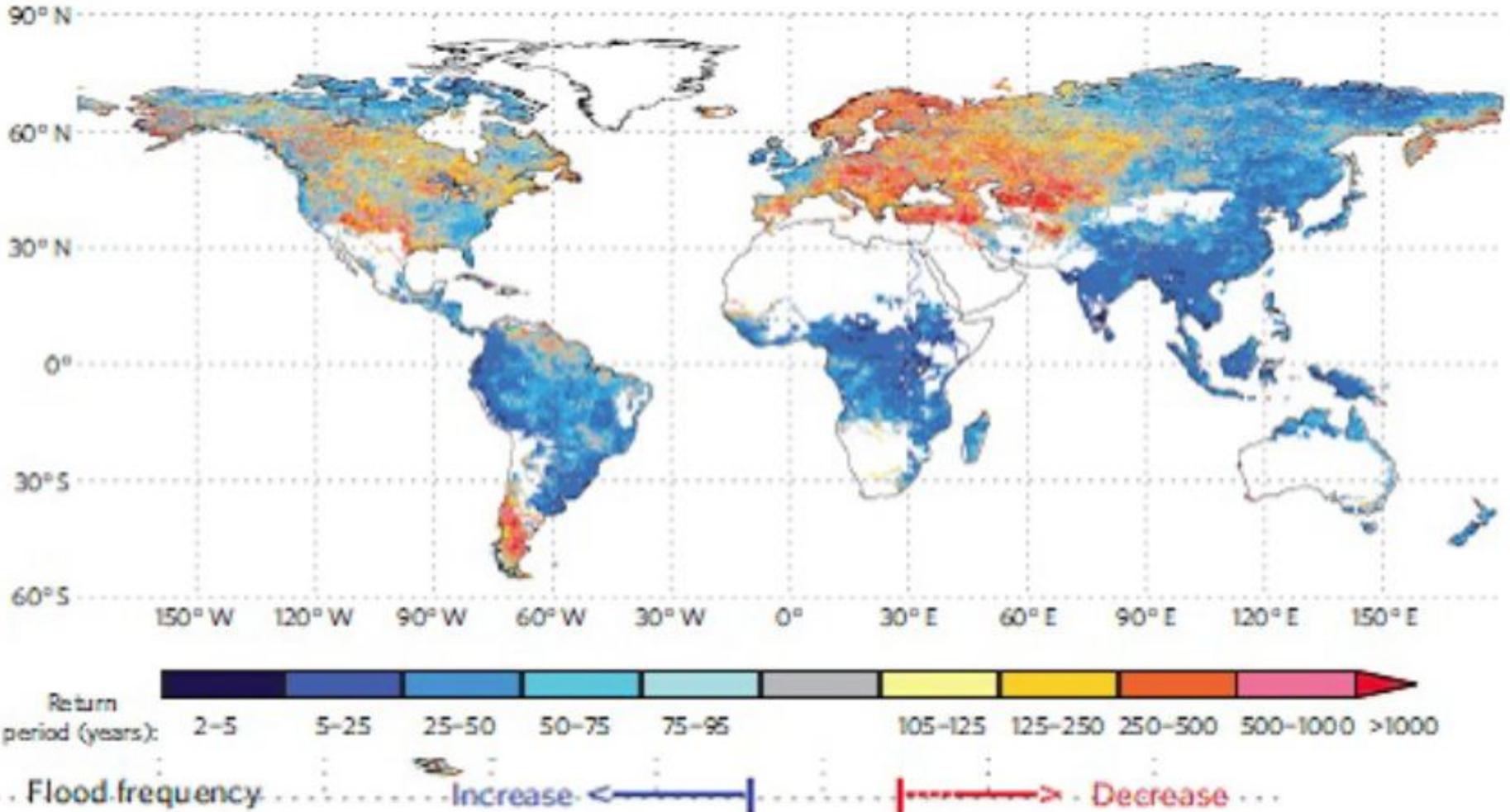
Percentagem de mudança nas descargas líquidas, considerando um incremento de temperatura de 2 C sobre a media de 1980-2010



11 Modelos Hidrológicos Globales
4 Modelos Atmosféricos Globales

Mudanças Hidrológicas Projetadas - Globais

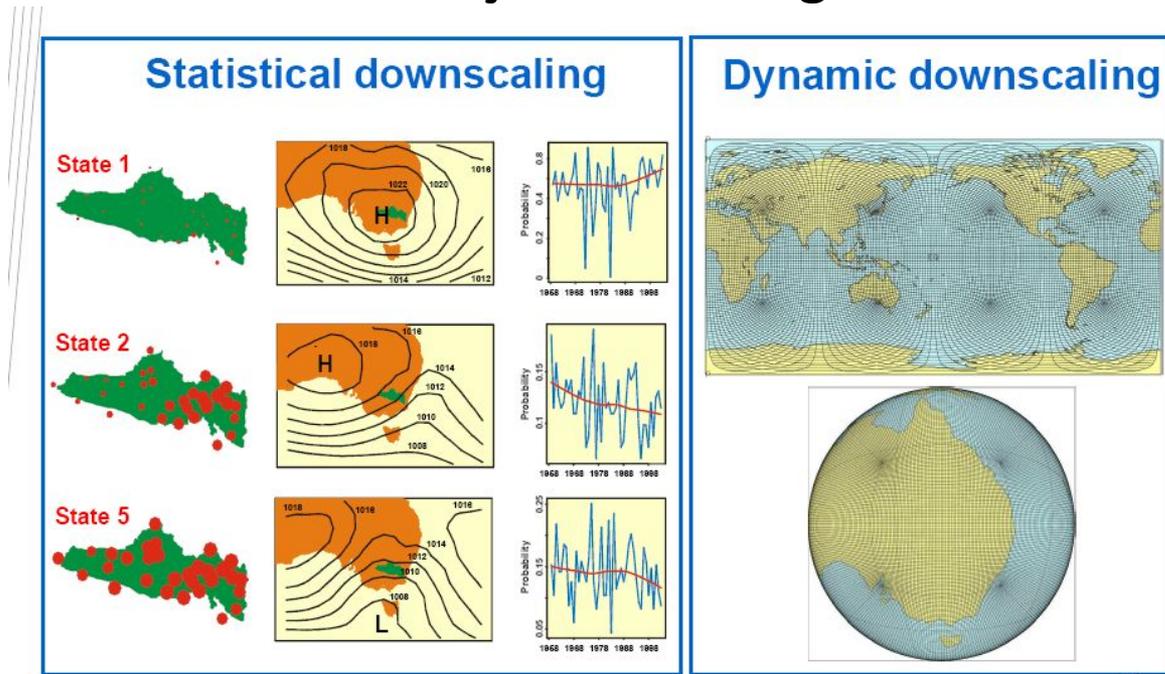
Media multi-modelos do Tempo de Retorno em 2080 da cheia de 100 anos do século 20



1 Modelo Hidrológico

11 Modelos climáticos Globales CMIP5

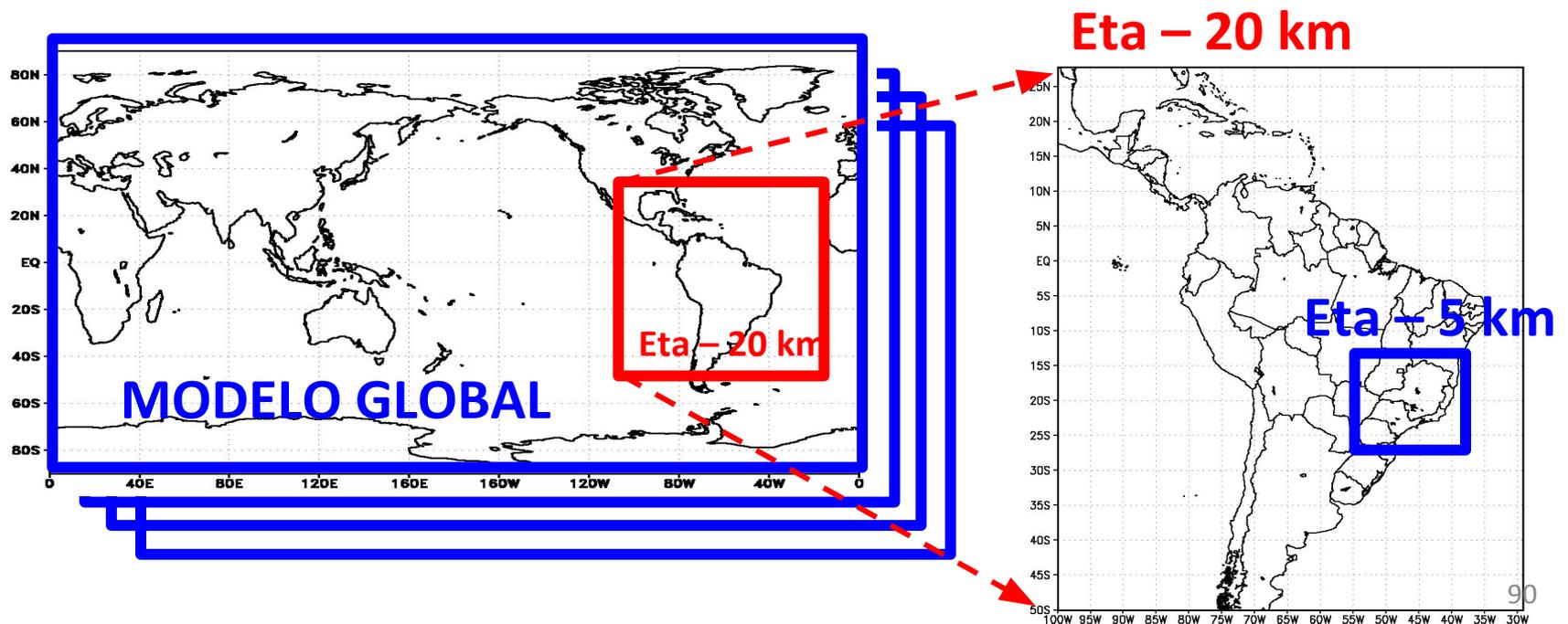
Geração de cenários da resposta hidrológica de bacias com simulações hidrológicas

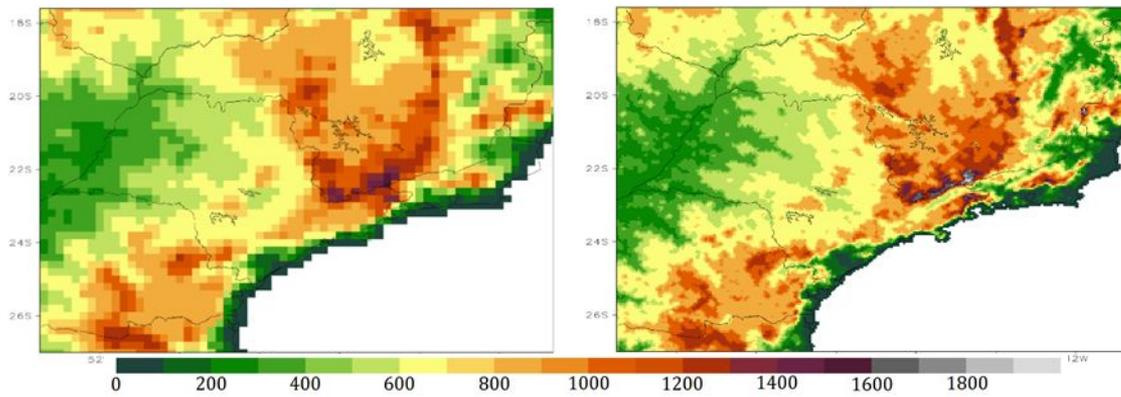


- A diferença de escalas entre a informação resultante dos modelos climáticos e a resolução dos modelos hidrológicos tem sido um fator limitante
- Os métodos mais utilizados para resolver este problema são o downscaling dinâmico e o downscaling estatístico
- Downscaling dinâmico: utiliza modelos atmosféricos regionais alimentados com as informações dos modelos globais
- Downscaling estatístico: utiliza funções de transferência estatísticas ou empíricas que relacionam o clima local com as saídas do modelo global

REGIONALIZAÇÃO (‘*DOWNSCALING*’)

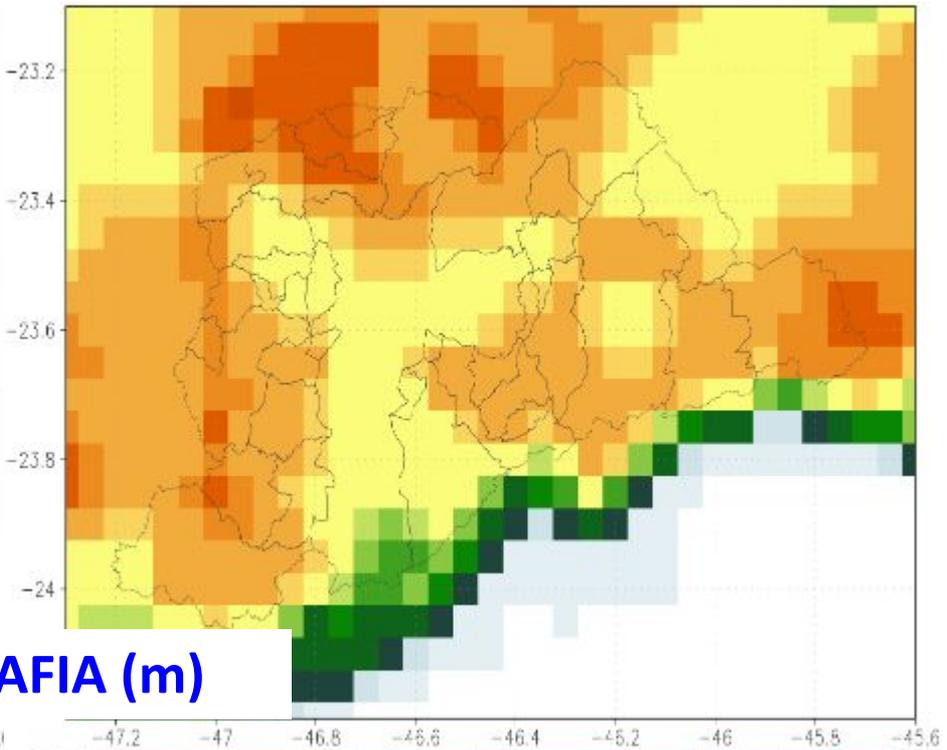
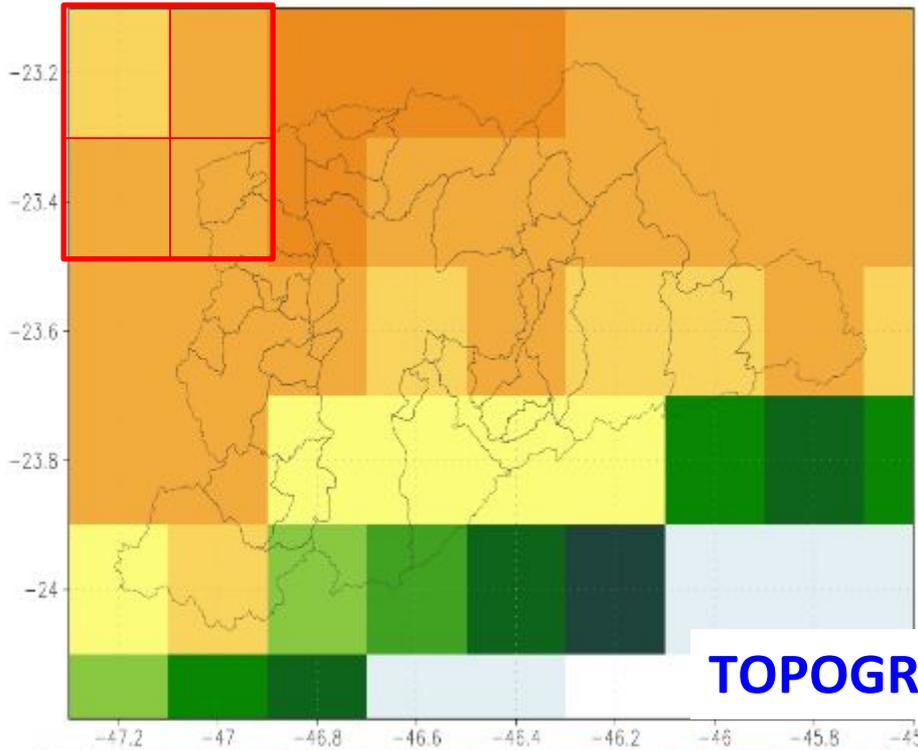
- Para os modelos globais simularem vários séculos e reproduzirem as mudanças climáticas globais, necessitam utilizar grades de tamanhos grandes (baixa resolução espacial).
- Entretanto, para estudos de impactos, vulnerabilidade, adaptação e resiliência, é necessário maior detalhe pois estes estudos geralmente têm caráter local.
- Os modelos atmosféricos regionais provem o detalhamento do modelo global (regionalização) para um determinado período de tempo e para uma determinada região.





20km

5km



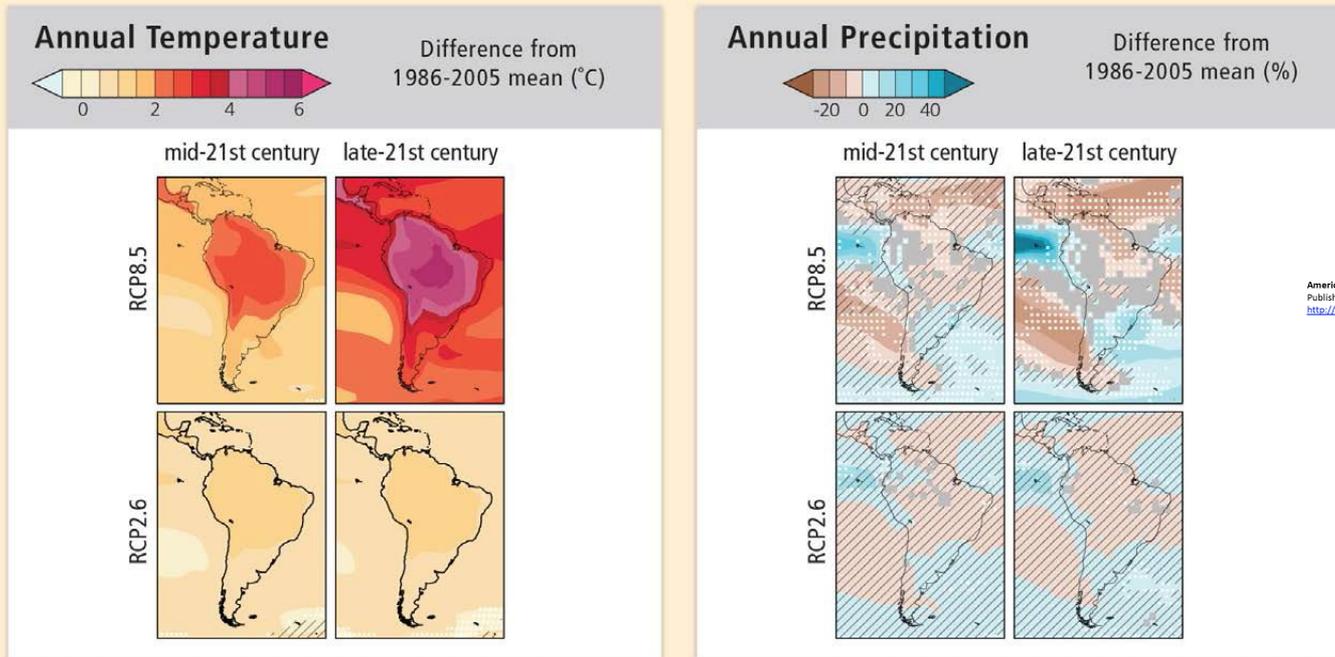
TOPOGRAFIA (m)

Região Metropolitana de São Paulo



Mudanças Hidrológicas Projetadas - Regionais

- RCP 8.5:
 - América Central: aquecimento médio anual de 2,5 ° C e 10% de diminuição da precipitação durante o verão
 - América do Sul: 4 ° C aquecimento médio, diminuição da precipitação de até 15% da região leste tropical dos Andes, e aumento de 15-20% no Sudeste da América do Sul.



American Journal of Climate Change, 2014, 3, 438-454
Published Online December 2014 in SciRes. <http://www.scirp.org/journal/ajcc>
<http://dx.doi.org/10.4236/ajcc.2014.35039>



Evaluation of the Eta Simulations Nested in Three Global Climate Models

Sin Chan Chou¹, André Lyra¹, Caroline Mourão¹, Claudine Dereczynski², Isabel Pilotto¹, Jorge Gomes¹, Josiane Bustamante¹, Priscila Tavares¹, Adan Silva¹, Daniela Rodrigues¹, Diego Campos¹, Diego Chagas¹, Gustavo Sueiro¹, Gracielle Siqueira¹, Paulo Nobre¹, José Marengo³

¹National Institute for Space Research, Cachoeira Paulista, Brazil

²Department of Meteorology, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil

³Centre for Monitoring and Warning of Natural Disasters, Cachoeira Paulista, Brazil

Email: chou.sinchan@cpqec.inpe.br

Solid Color Very strong agreement

White Dots Strong agreement

Gray Divergent changes

Diagonal Lines Little or no change

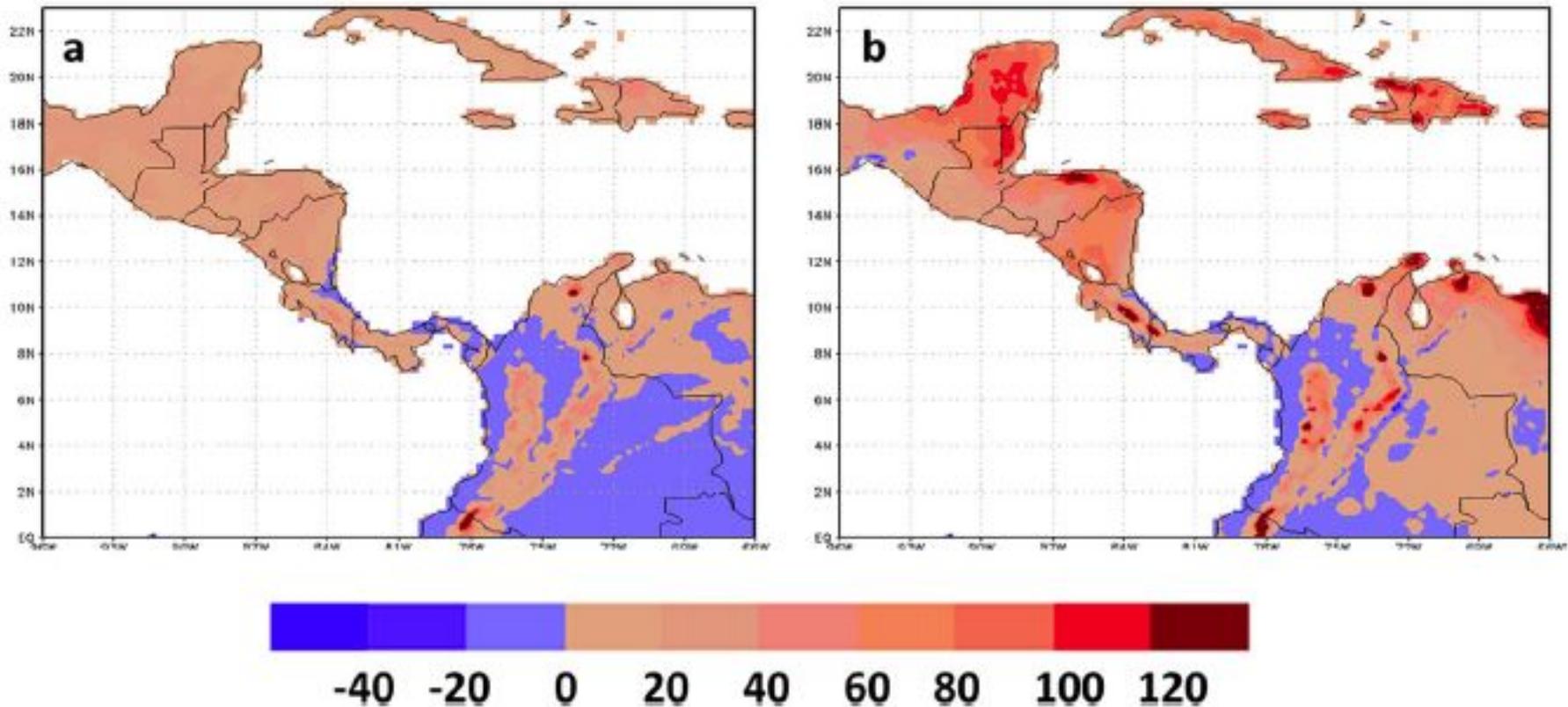
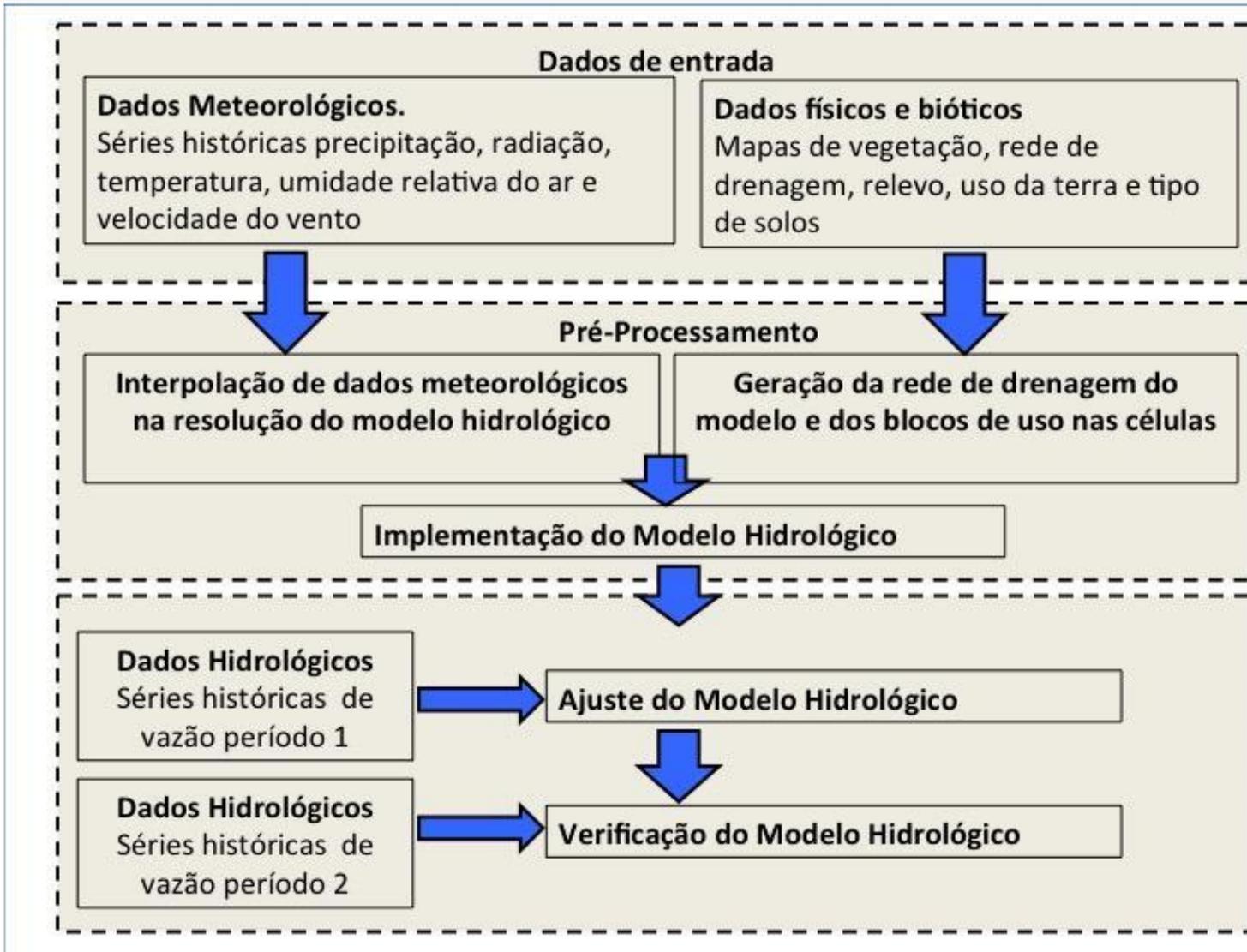


Fig. 4 Difference between the baseline (1961–1990) and the future (2070–2100) dry spells (days) projected by the Eta-HadGEM2 simulations for the **a** RCP4.5 and **b** RCP8.5 scenarios

PROJEÇÕES HIDROLÓGICAS DOS EFEITOS DAS MUDANÇAS CLIMÁTICAS EM ESCALA DE BACIAS

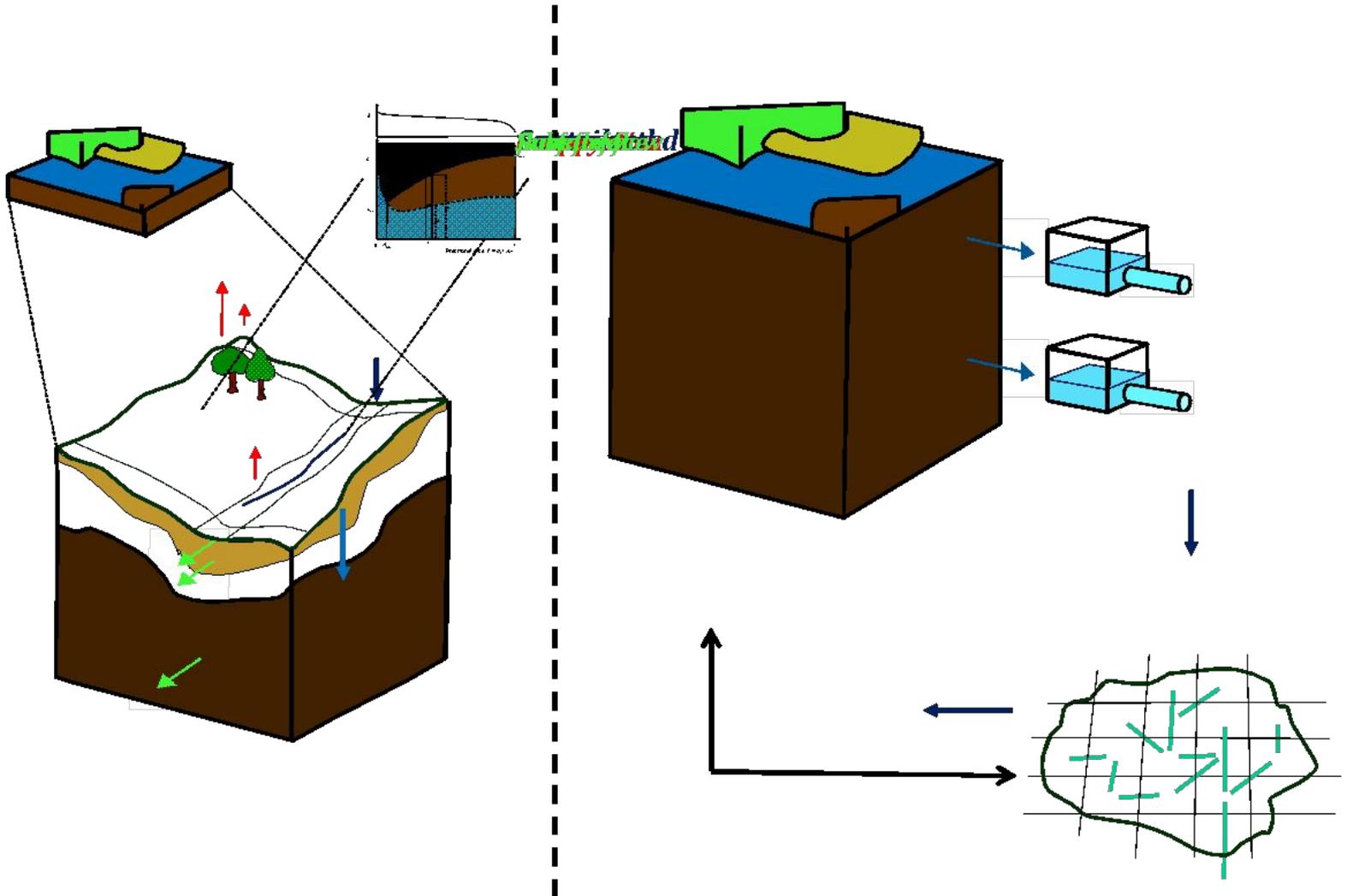
METODOLOGIA

IMPLEMENTAÇÃO E CALIBRAÇÃO DO MODELO HIDROLÓGICO

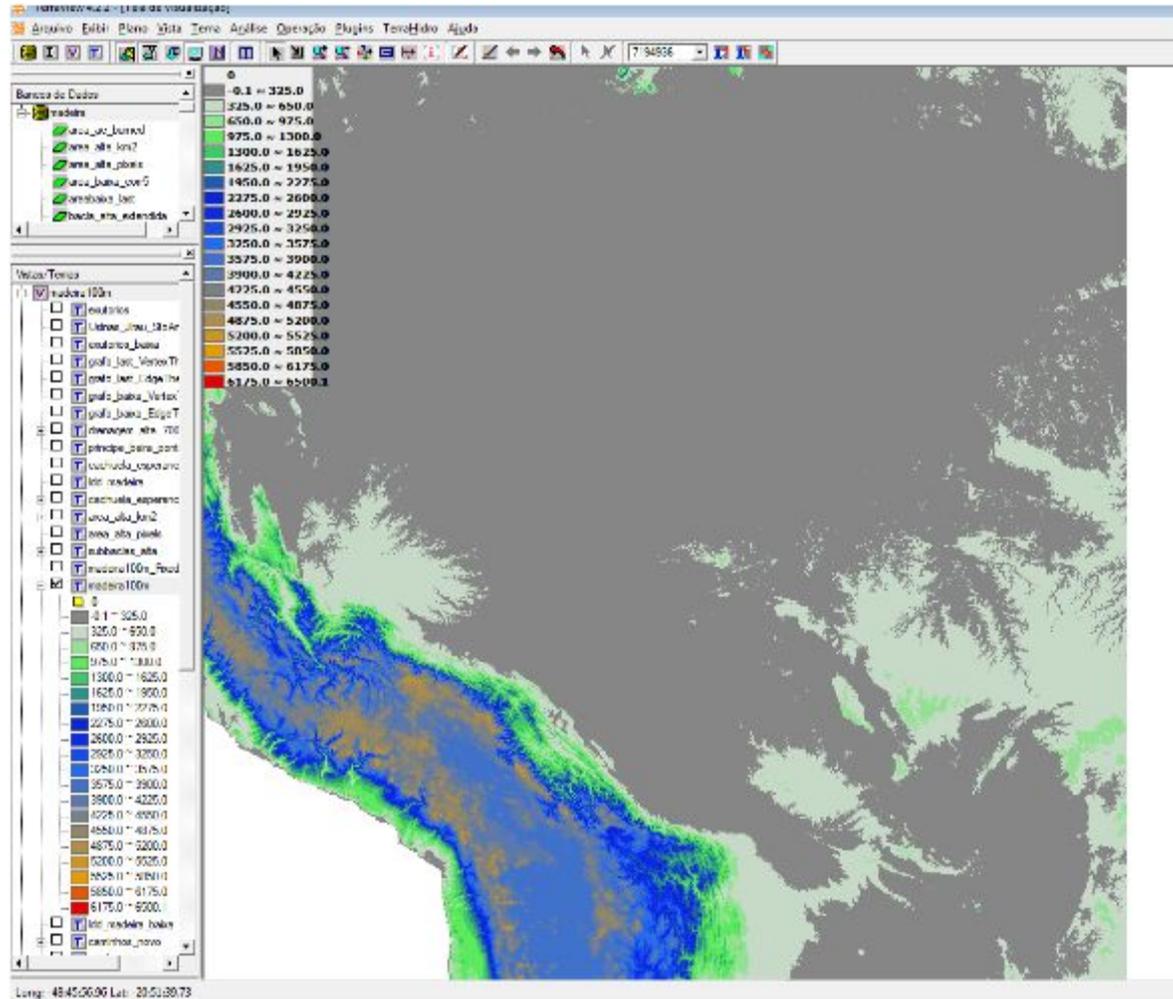
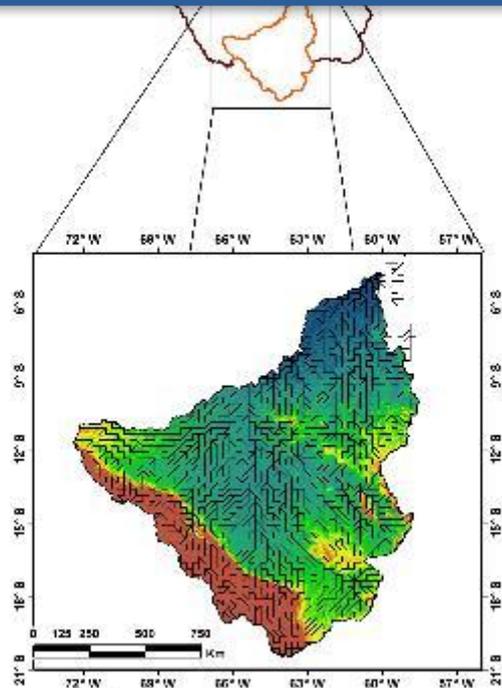


MHD-INPE

UNIVERSIDADE FEDERAL DO RIO DE JANEIRO



REDE DE DRENAGEM E GEOMORFOLOGIA



DPI

TerraHidro

TerraHidro: A Distributed Hydrology Modelling System With High Quality Drainage Extraction

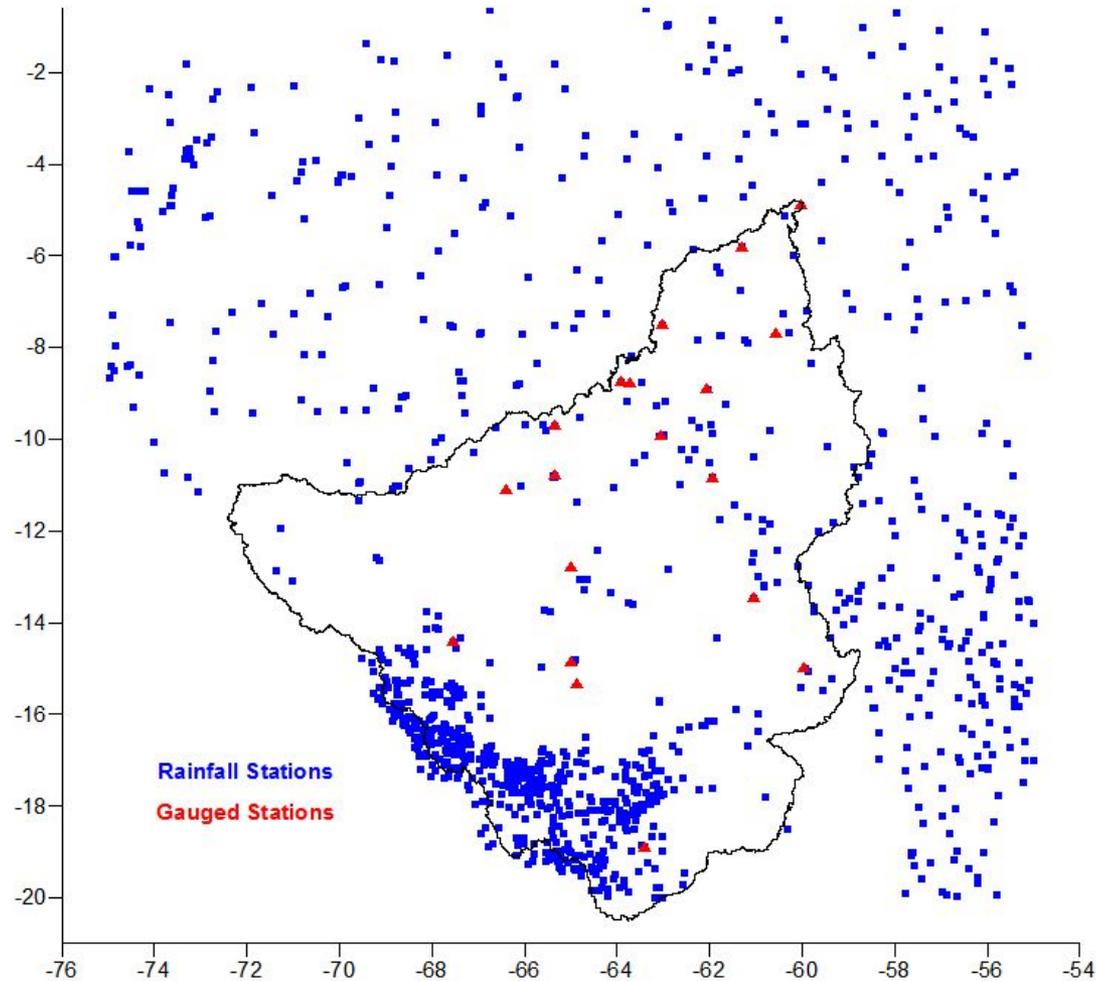
Copyright © 2010. The fifth International Conference on Advanced Geographic Information Systems, Applications, and Services.

Sergio Nash, João Ricardo de Freitas Oliveira, Alexandre Caporozo Jordão, Leandro Niziane Jordanián,
 Cássio Dutra Rinaldi,
 Ingrid Domingos Duarte,
 National Institute for Space Research,
 São José dos Campos, Brazil
 (sergio.nash, joaofo, leandro, alexandre)@cpqde.inpe.br

MHD-INPE: Rede de Drenagem

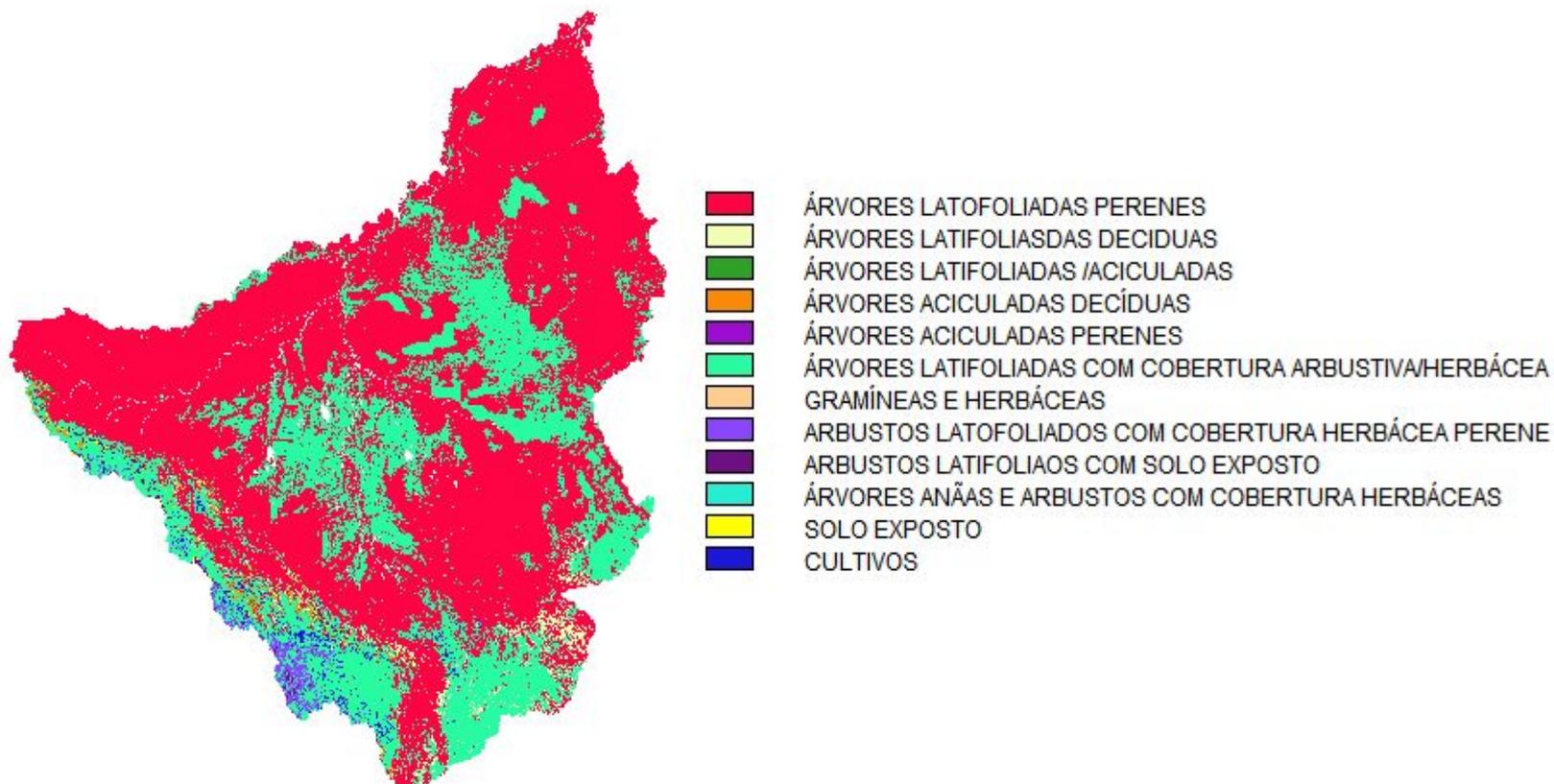
A rede de drenagem foi obtida a partir do modelo digital de elevação SRTM 4 na resolução 0.00833°(~90 metros), disponibilizado pelo CGIAR-CSI (<<http://srtm.csi.cgiar.org/>>).

Estações Pluviométricas e Fluviométricas



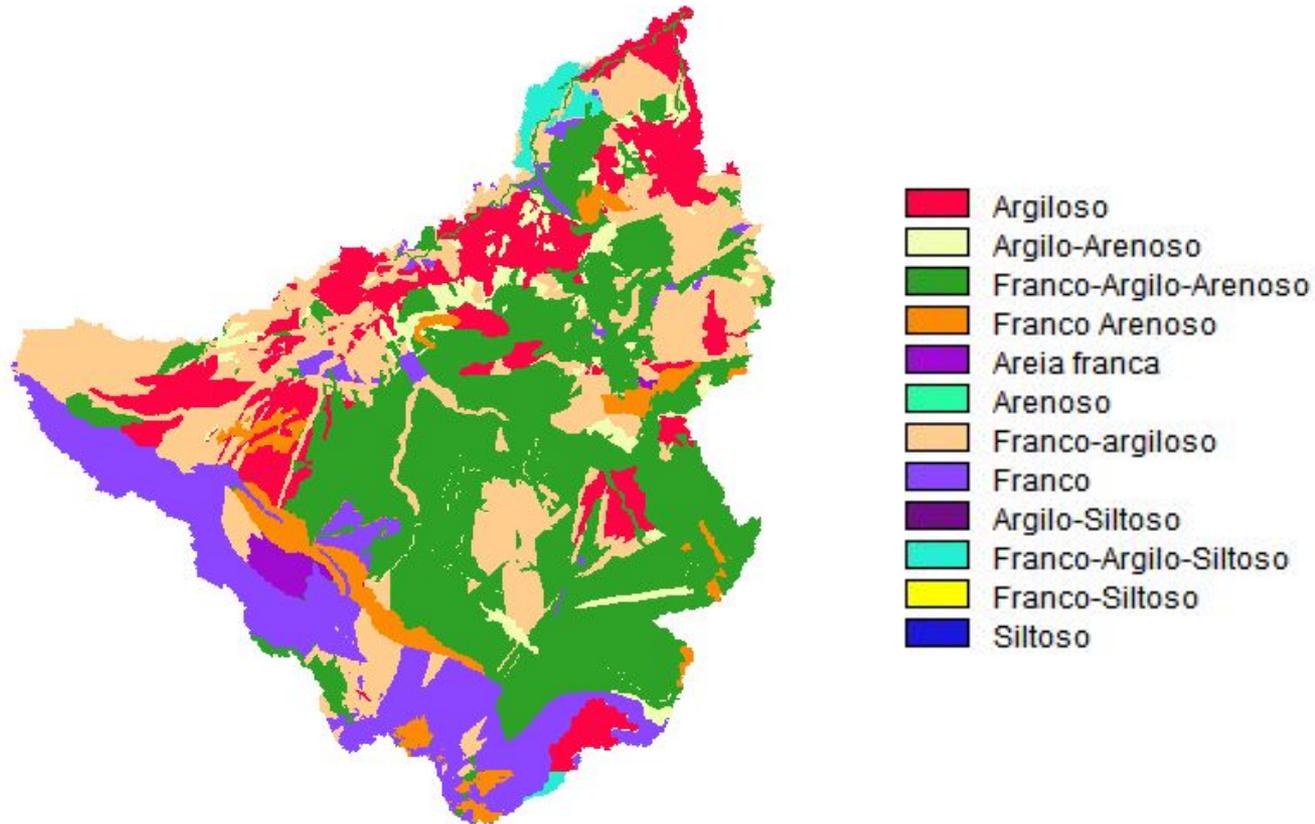
MHD-INPE: Vegetação

Obtido do projeto ProVeg (SESTINI, et al, 2002), disponível na resolução de 1 km no site <http://proveg.cptec.inpe.br/index.shtml>. Neste projeto, foi utilizado como mapa base a classificação do RADAM e foram atualizados os usos da terra usando dados de desmatamento do Prodes digital de 1997.



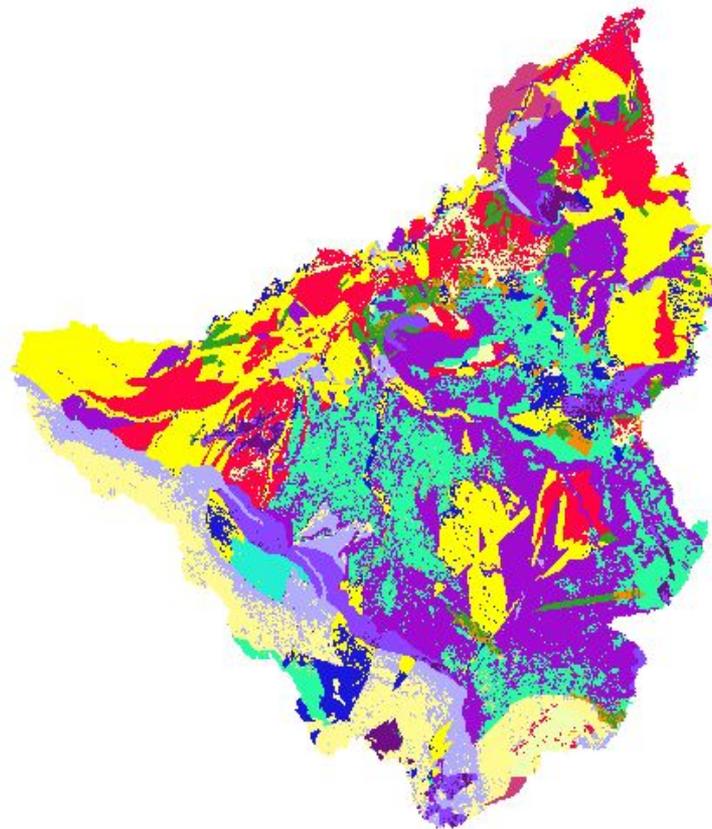
MHD-INPE: Solos

A classificação dos tipos de solo na bacia do rio Madeira foi derivado a partir dos mapas de solo fundação independente ISRIC - World Soil Information - SOTERLAC (Dijkshoorn; Huting; Tempel, 2005); resolução de 2 km.



MHD-INPE: Unidades de Resposta Hidrológica

Os grupos de solo (8 classes) foram combinados aos tipos de vegetação (3 classes) para gerar os blocos com os quais são subdivididas as células do modelo hidrológico distribuído, resultando em 15 blocos .



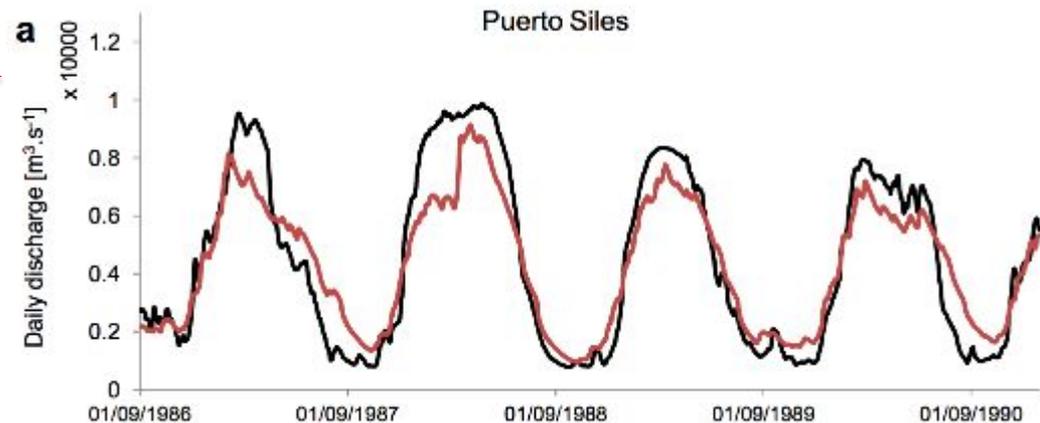
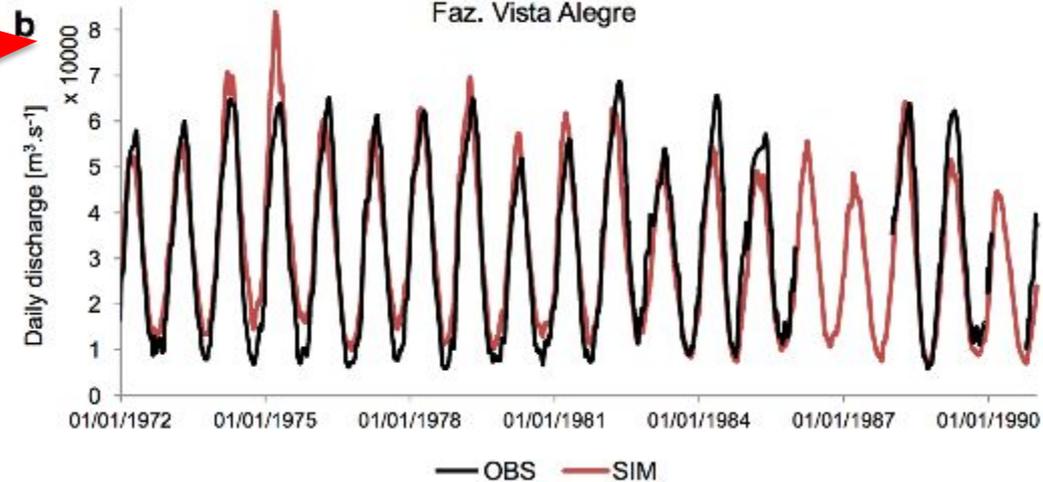
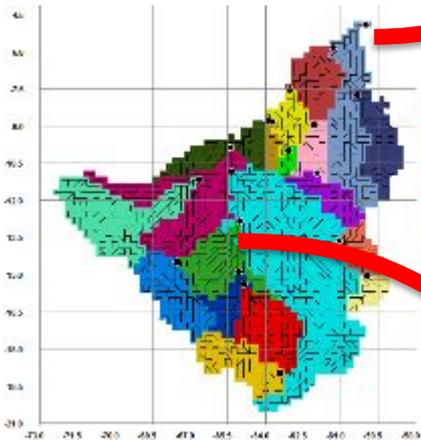
- Argiloso + Floresta
- Argiloso + Pastagem
- Argiloso Arenoso + Floresta
- Argiloso Arenoso + Pastagem
- Franco Argiloso Arenoso + Floresta
- Franco Argiloso Arenoso + Pastagem
- Franco Argiloso Arenoso + Cultivos
- Franco Arenoso + Floresta
- Franco Arenoso + Pastagem
- Areia Franca + Floresta
- Franco Argiloso + Floresta
- Franco Argiloso + Pastagem
- Franco + Floresta
- Franco + Pastagem
- Franco Argiloso Silteoso + Floresta

Resultados da Calibração MGB-INPE aplicado na Bacia do Rio Madeira 1970- 1990

Climatic Change
DOI 10.1007/s10584-015-1338-x

Impacts of future climatic and land cover changes
on the hydrological regime of the Madeira River basin

J. L. Siqueira Júnior · J. Tomasella · D. A. Rodriguez



COEFICIENTES DE PERFORMANCE

$$NSE = 1 - \frac{\sum_{i=1}^n (QS_i - QO_i)^2}{\sum_{i=1}^n (QO_i - \overline{QO})^2}$$

$$ENSLog = 1 - \frac{\sum_{i=1}^n \left(\text{Log}(QO_i) - \text{Log}(QP_i) \right)^2}{\sum_{i=1}^n \left(\text{Log}(QO_i) - \text{Log}(\overline{QO}) \right)^2}$$

$$R2 = \frac{\sum_{i=1}^n (QS_i \cdot QO_i) - \sum_{i=1}^n (QS_i) \cdot \sum_{i=1}^n (QO_i)}{\sqrt{\left[n \cdot \sum_{i=1}^n (QS_i)^2 - \left(\sum_{i=1}^n (QS_i) \right)^2 \right] \cdot \left[n \cdot \sum_{i=1}^n (QO_i)^2 - \left(\sum_{i=1}^n (QO_i) \right)^2 \right]}}$$

$$LR2 = \frac{\sum_{i=1}^n (QS_i \cdot QO_i) - \sum_{i=1}^n (QC_i) \cdot \sum_{i=1}^n (QO_i)}{\sqrt{\left[n \cdot \sum_{i=1}^n (QS_i)^2 - \left(\sum_{i=1}^n (QS_i) \right)^2 \right] \cdot \left[n \cdot \sum_{i=1}^n (QO_i)^2 - \left(\sum_{i=1}^n (QO_i) \right)^2 \right]}}$$

$$KGE = 1 - \sqrt{(r-1)^2 + (\alpha-1)^2 + (\beta-1)^2}$$

$$\alpha = \frac{\sigma_s}{\sigma_o}$$

$$\beta = \frac{\mu_s}{\mu_o}$$

$$\beta = \frac{\mu_s}{\mu_o}$$

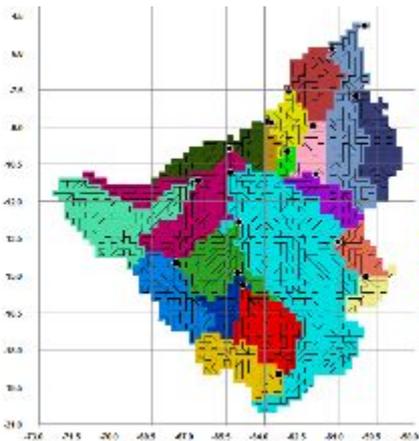
$$BIAS = \frac{\sum_{i=1}^n QS_i - \sum_{i=1}^n QO_i}{\sum_{i=1}^n QO_i}$$

Resultados da Calibração MGB-INPE aplicado na Bacia do Rio Madeira 1970- 1990

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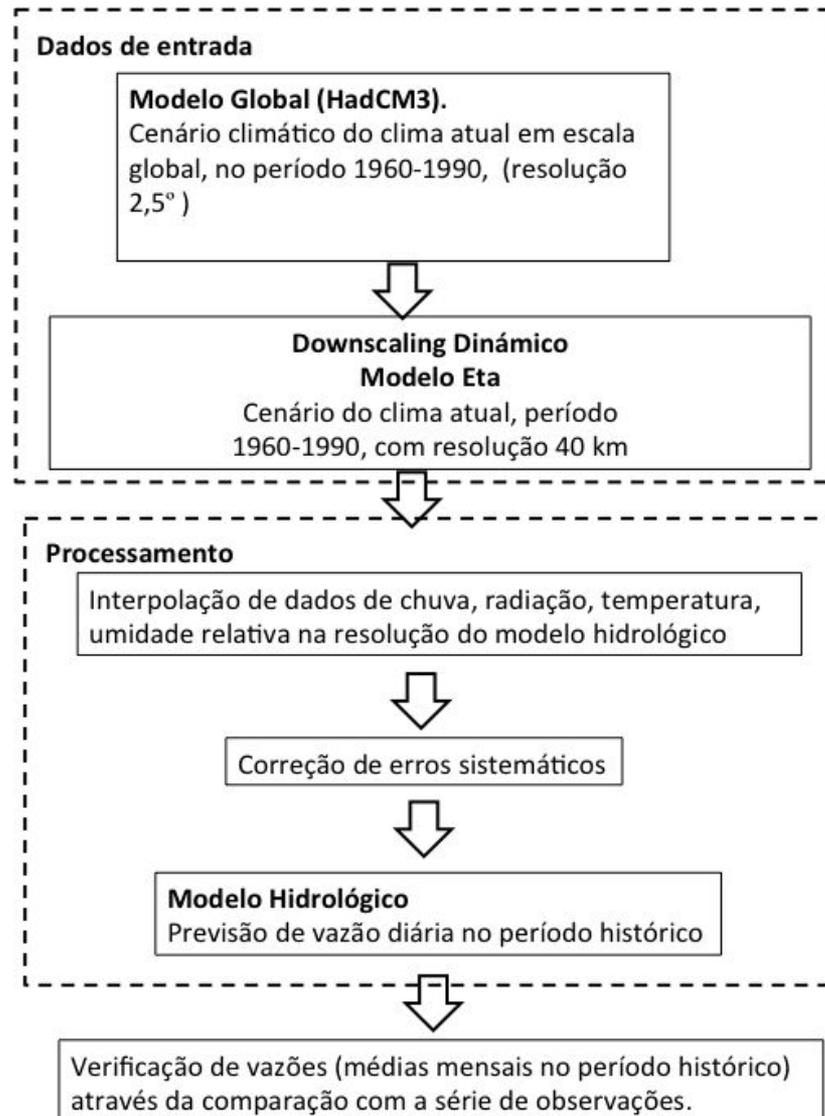


1970 - 1990

Sub-bacia	Rio	Codigo	Nash	NashLog	R2	Errv
Mira Flores	Rio Madre de Dios	1	0.53	0.63	0.73	13.8%
Rurrenabaque	Rio Beni	2	0.74	0.70	0.76	-7.2%
Abapo	Rio Grande	3	0.72	0.72	0.72	3.9%
Camiaco	Rio Mamoré	4	0.78	0.75	0.80	-3.5%
Puerto Varador	Rio Mamoré	5	0.79	0.80	0.82	0.7%
Puerto Siles	Rio Mamoré	6	0.80	0.78	0.86	-7.1%
Mato Grosso	Rio Guaporé	7	0.84	0.85	0.86	6.2%
Pimenteiras	Rio Guaporé	8	0.77	0.84	0.82	2.6%
Guajara-Mirim	Rio Mamoré	9	0.71	0.75	0.72	-6.7%
Abunã	Rio Madeira	10	0.89	0.86	0.89	1.1%
Porto Velho	Rio Madeira	11	0.83	0.85	0.84	3.5%
Santa Isabel	Rio Candeias	12	0.79	0.79	0.81	0.3%
Ariquemes	Rio Jamari	13	0.58	0.76	0.68	7.5%
Ji Paraná	Rio Ji-Paraná	14	0.79	0.87	0.80	-5.2%
Tabajara	Rio Ji-Paraná	15	0.84	0.88	0.86	-10.4%
Humaitá	Rio Madeira	16	0.79	0.82	0.80	3.7%
Manicoré	Rio Madeira	17	0.77	0.80	0.78	-0.1%
Boca da Guariba	Rio Aripuanã	18	0.93	0.92	0.93	-5.0%
Fazenda Vista Alegre	Rio Madeira	19	0.87	0.85	0.87	-0.4%

METODOLOGIA

Impactos das Mudanças Climáticas nos Recursos Hídricos



Correção de erros sistemáticos: Precipitação ETA

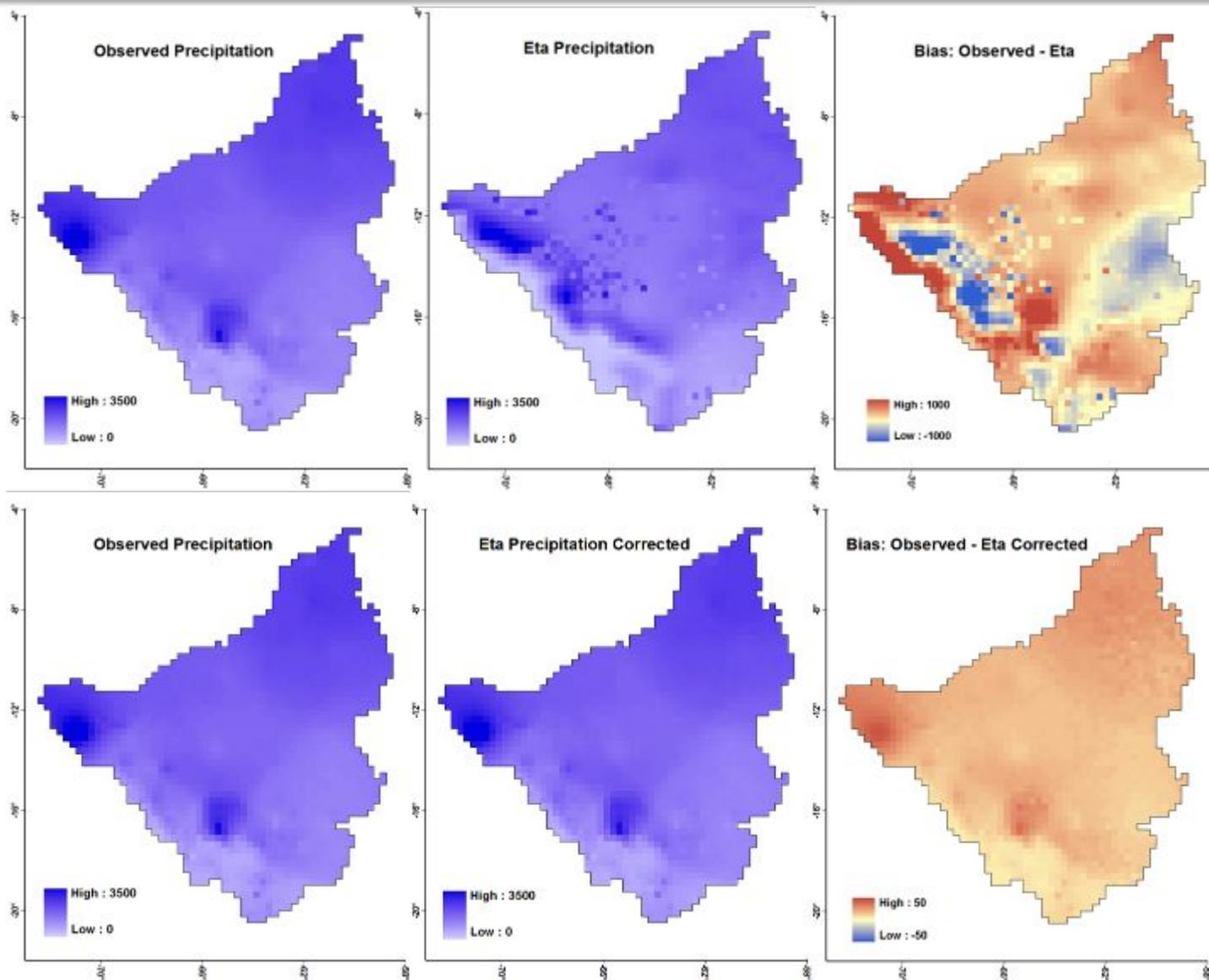
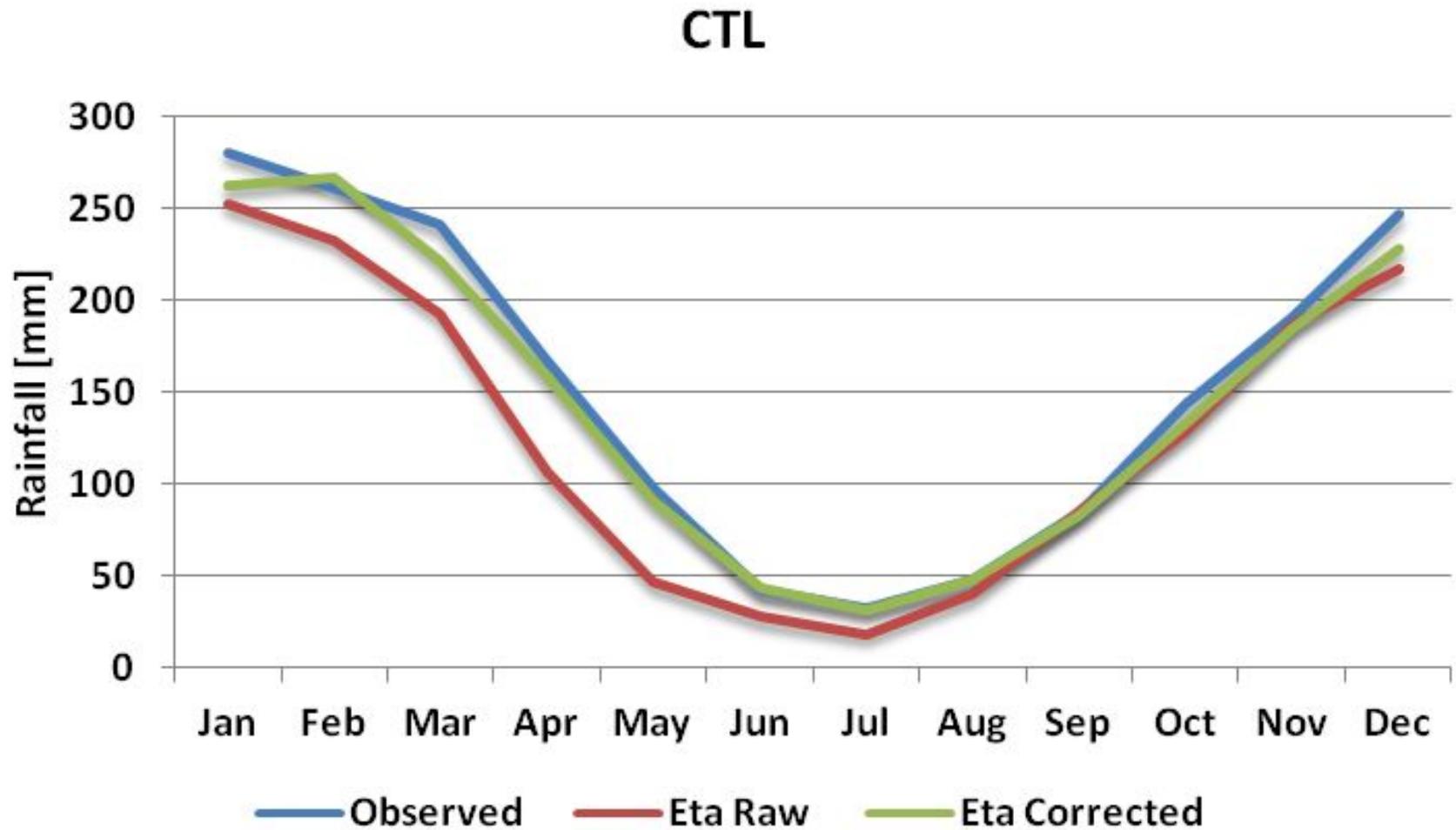


Figura 4 - Médias anuais de precipitação(milímetros) observada, modelo Eta(controle) para o período 1970 a 1990 e a diferença entre as médias(erro sistemático).

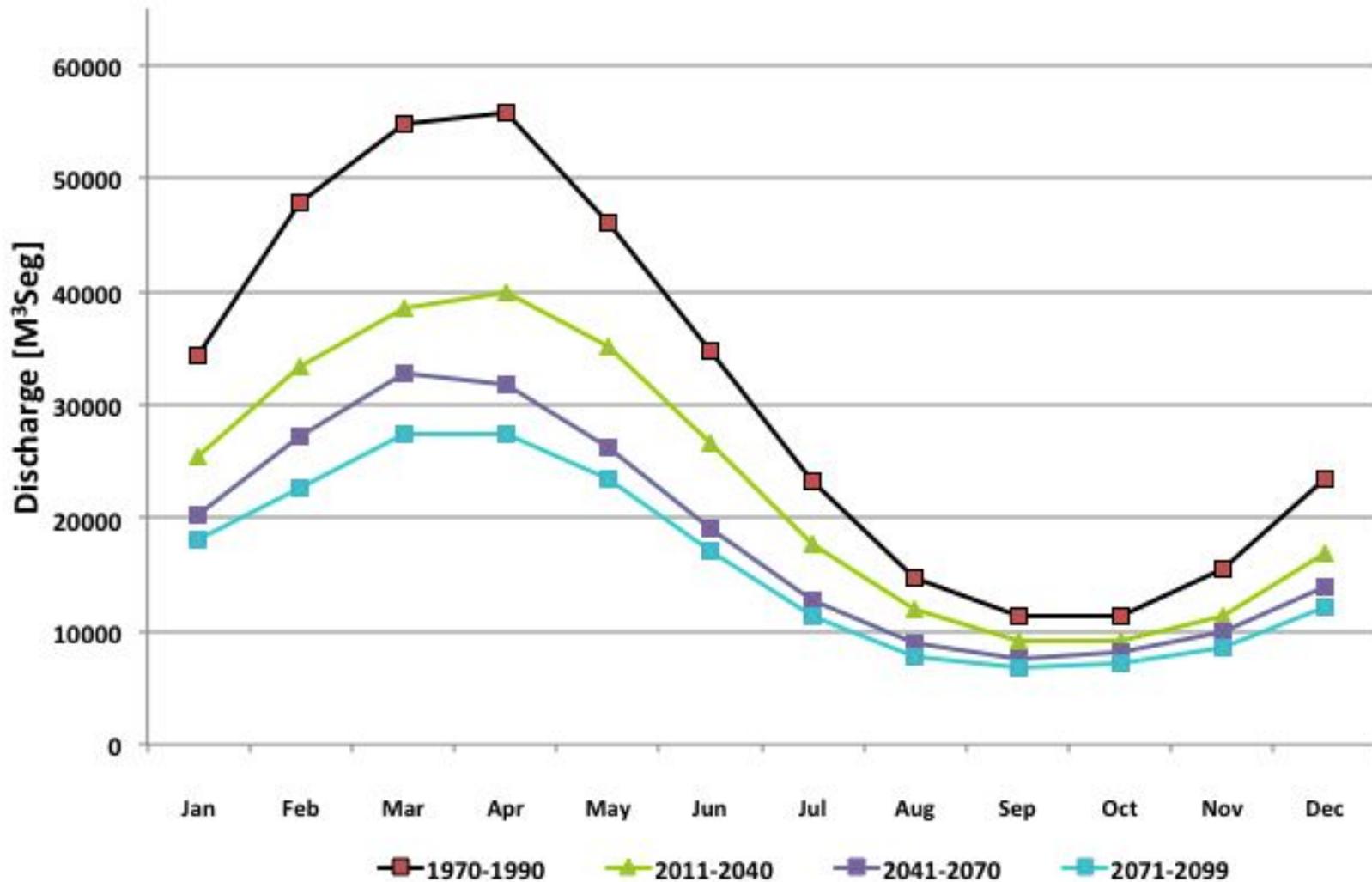
Correção de erros sistemáticos: Precipitação ETA



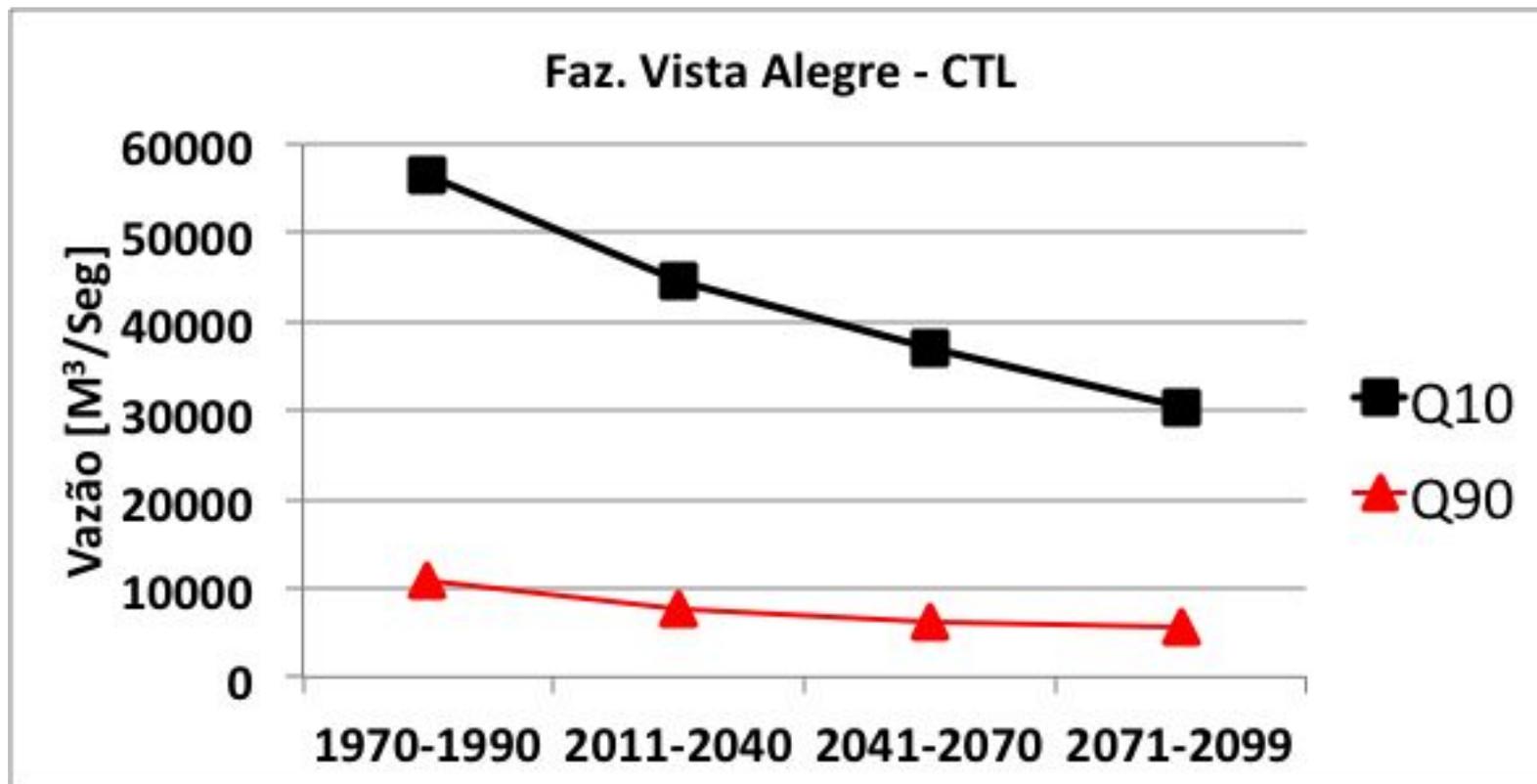
ANÁLISES DOS IMPACTOS POTENCIAIS DAS MUDANÇAS CLIMÁTICAS NAS VAZÕES

Impactos das Mudanças Climáticas nas Descargas

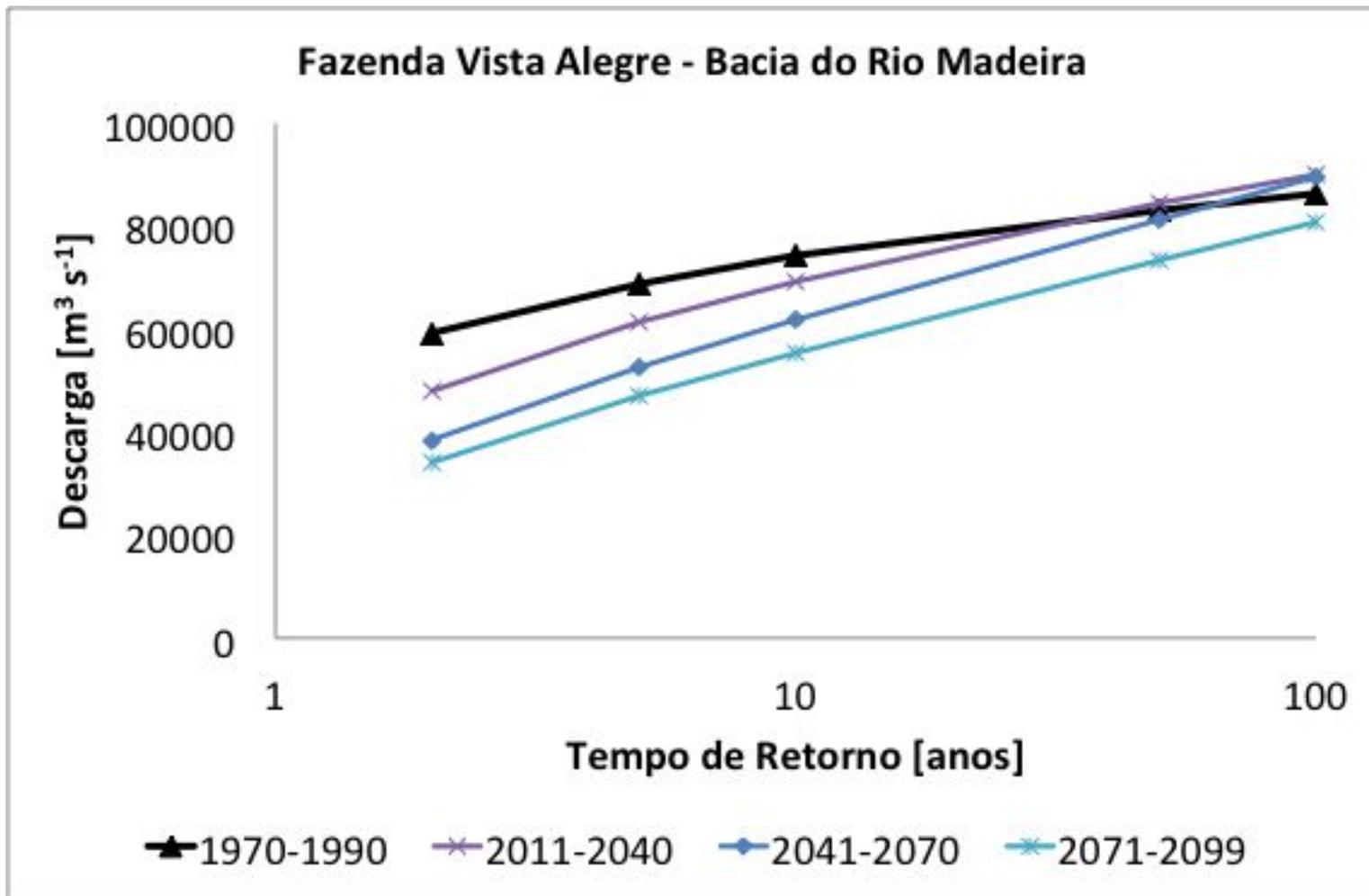
Mean Discharge in the Madeira River - CTL



Impactos das Mudanças Climáticas nas Descargas



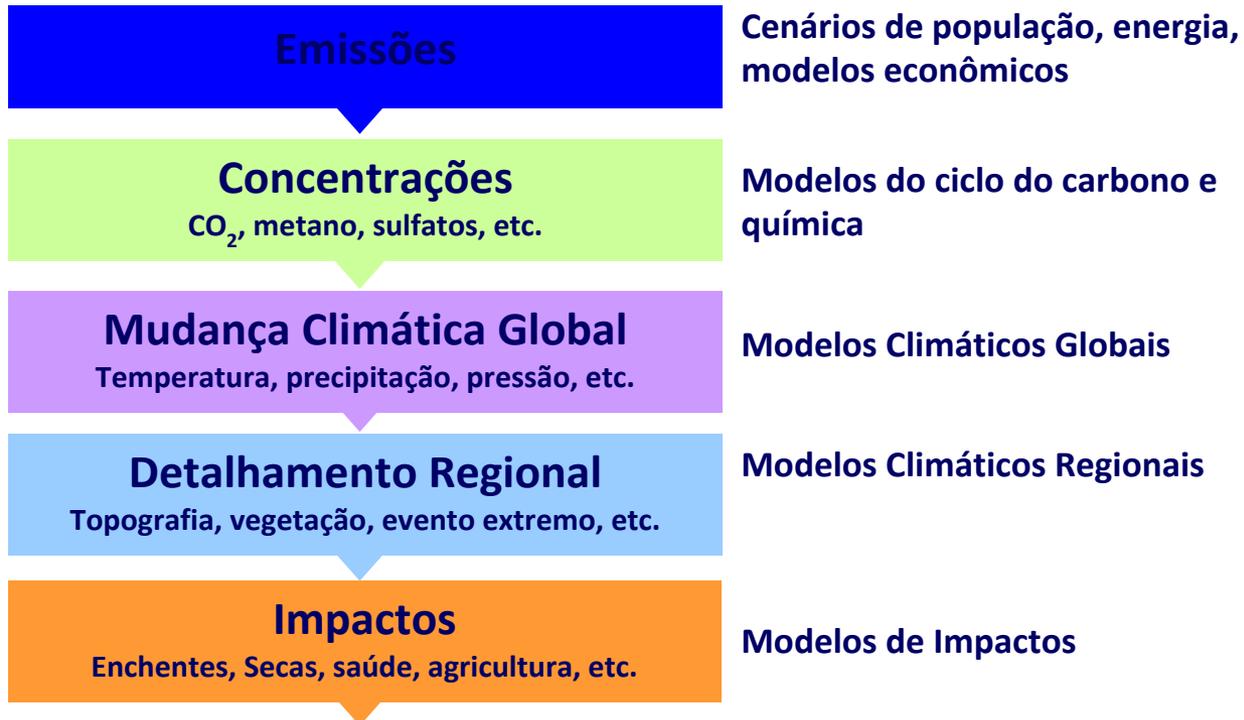
Impactos das Mudanças Climáticas nas Descargas



INCERTEZAS

Cadeia de incertezas na modelagem climática

Projetar os Impactos da Mudanças Climáticas



INCERTEZAS

- As incertezas representam limitações para a tomada de decisões com respeito à mitigação dos impactos, baseadas num paradigma de otimização.
- Não obstante, diante deste contexto de incertezas, tomadores de decisão precisam da integração de conhecimentos que considerem os múltiplos fatores de stress que condicionam o ambiente de decisão.
- Aplicação de análises exploratórias, que consideram múltiplos cenários, explorando sistematicamente as implicações de um amplo intervalo de condicionantes e políticas.

Projeções climáticas

Cenários socioeconômicos

- Uso do solo
- População
- Desenvolvimento
- Indústria
- Energia
- Meio ambiente
- ...

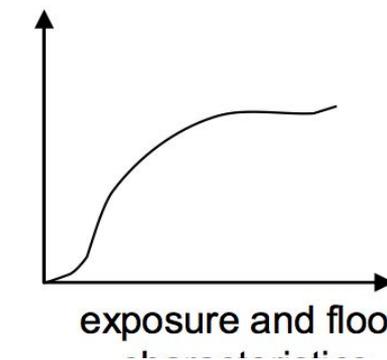
expected damage



expected damage



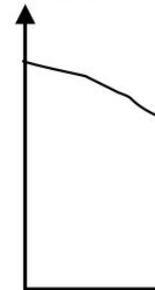
expected damage



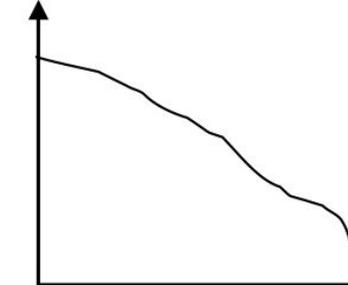
expected damage



expected damage



expected damage

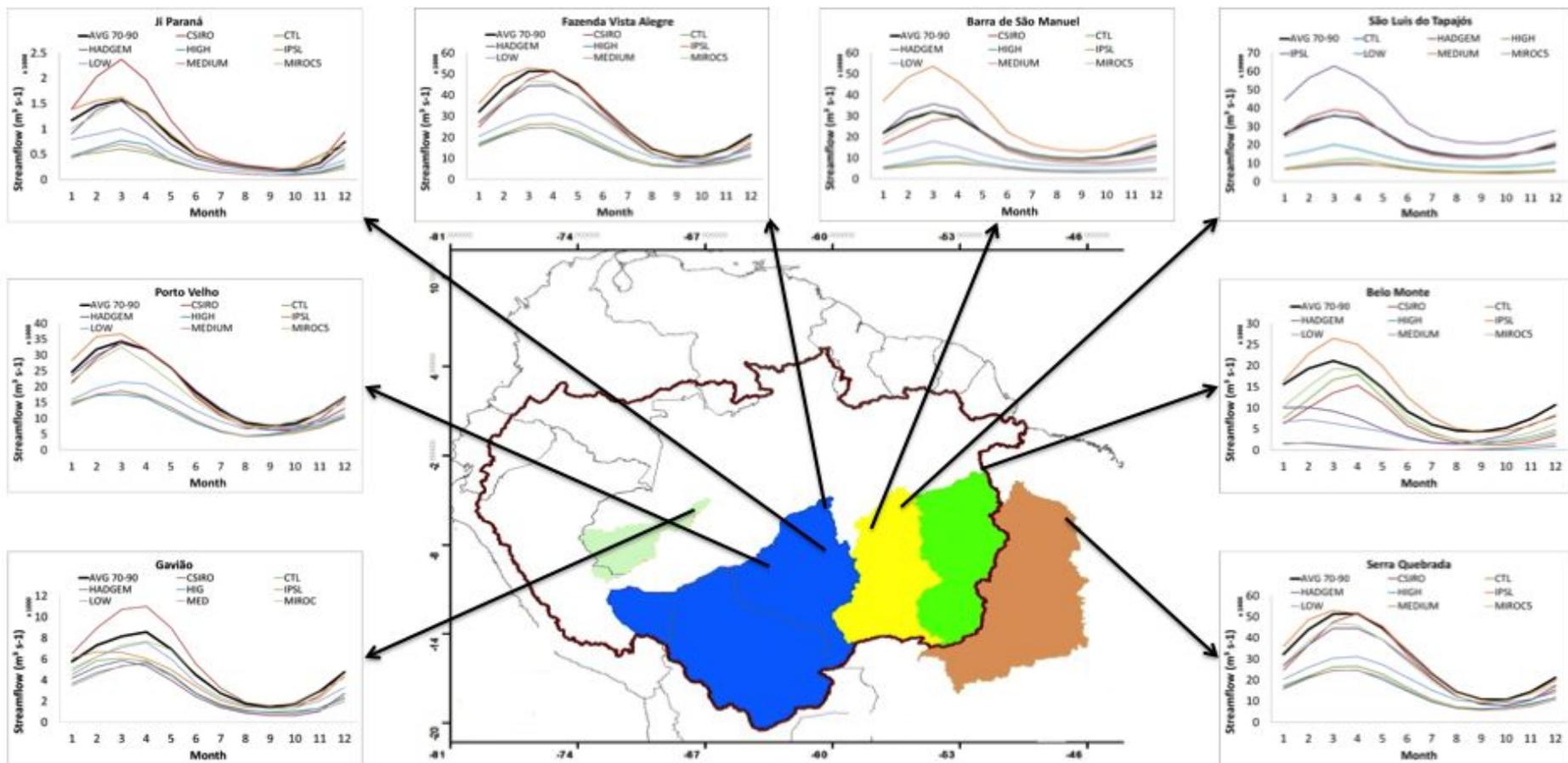


susceptibility characteristics

MHD-INPE

Mudanças Ambientais Globais

Grande escala



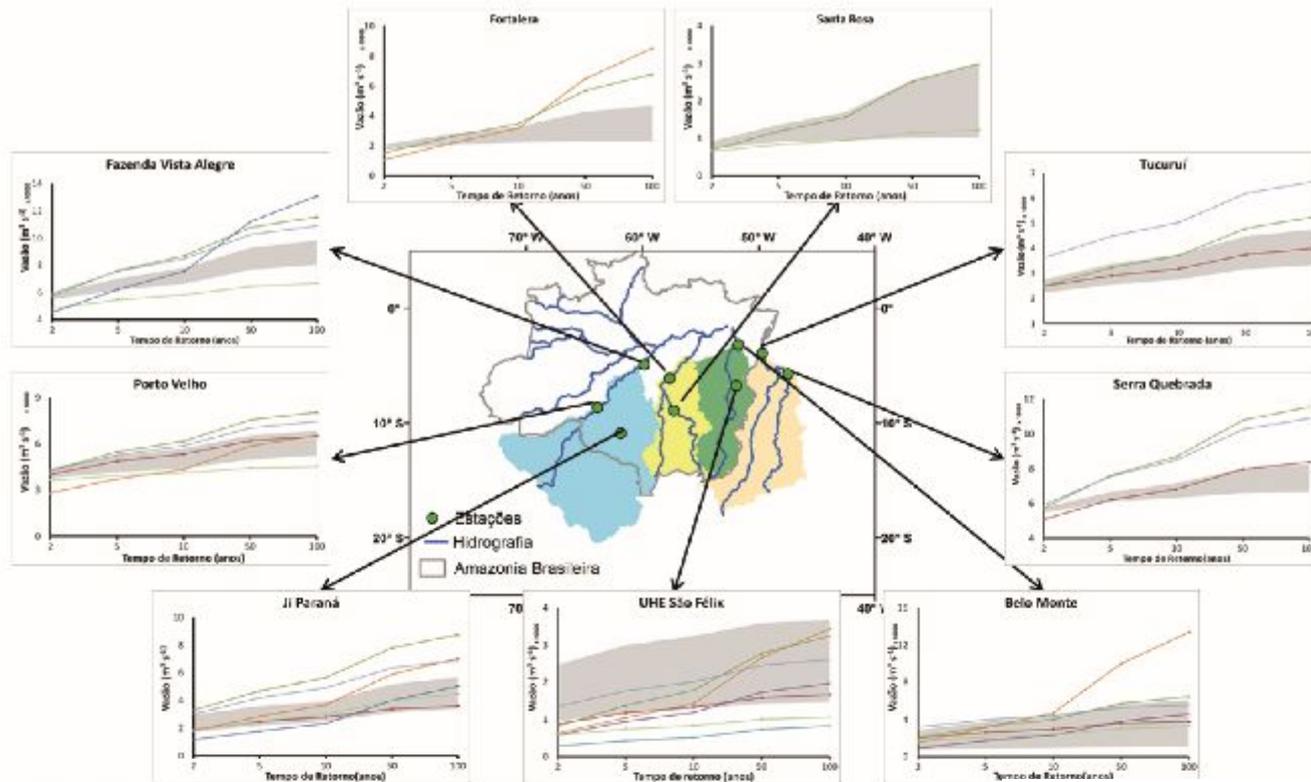
2071-2100

Tocantins
 Juruá
 Amazonas
 Madeira
 Xingú
 Tapajós

MHD-INPE

Mudanças Ambientais Globais

Grande escala



GEV 2041-2070

PROJEÇÕES DE DESCARGAS EXTREMAS SOB IMPACTOS DAS MUDANÇAS CLIMÁTICAS NA REGIÃO AMAZÔNICA

Projections of extreme streamflows under climate change scenarios in Amazonia

Lucas Garófalo Lopes¹

Daniel Andrés Rodríguez²

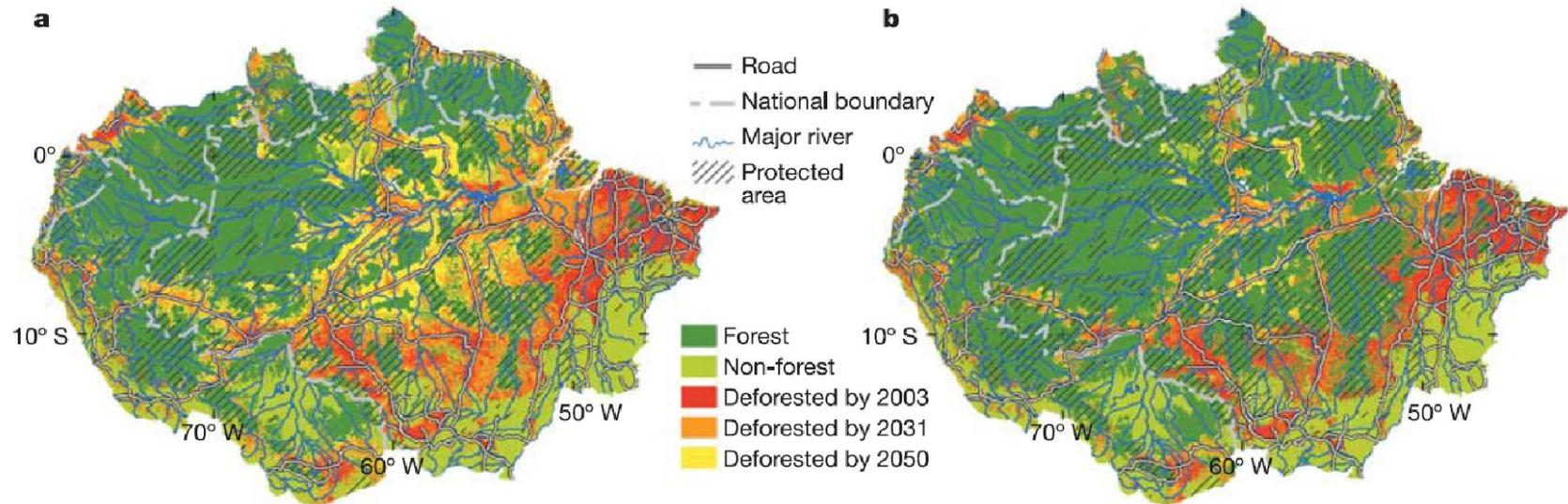
José Lazaro Nogueira Júnior¹

Guilherme Sacramento Mohor¹

**ANÁLISES DOS IMPACTOS POTENCIAIS DAS
MUDANÇAS CLIMÁTICAS E DAS MUDANÇAS NO
USO DA TERRA**

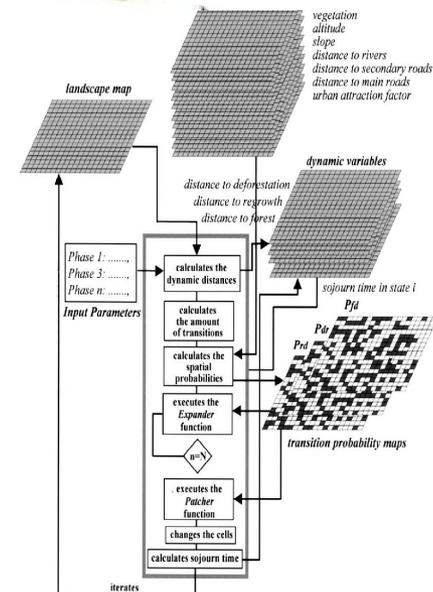
METODOLOGIA

Impactos das Mudanças Climáticas nos Recursos Hídricos



Modelling conservation in the Amazon basin

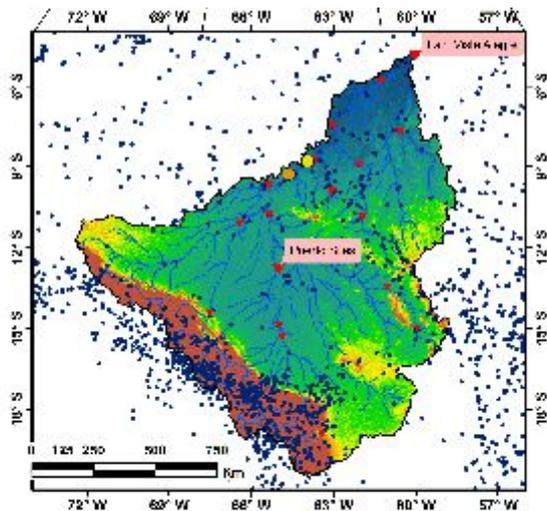
Britaldo Silveira Soares-Filho^{1,2}, Daniel Curtis Nepstad^{3,5,6}, Lisa M. Curran⁴, Gustavo Coutinho Cerqueira¹, Ricardo Alexandrino Garcia², Claudia Azevedo Ramos⁵, Eliane Voll¹, Alice McDonald⁴, Paul Lefebvre³ & Peter Schlesinger³



MHD-INPE

Mudanças Ambientais Globais

Grande escala

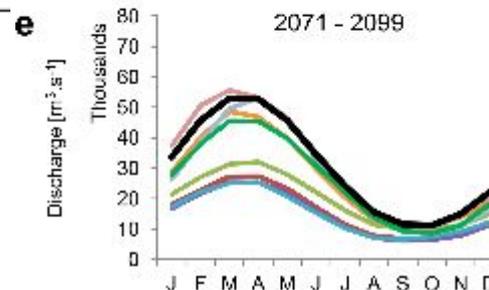
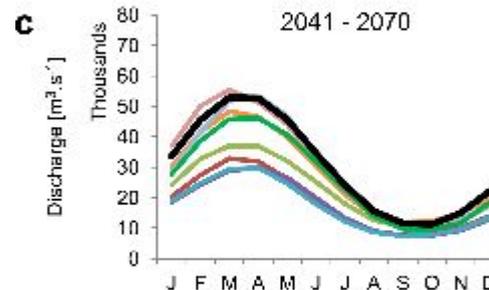
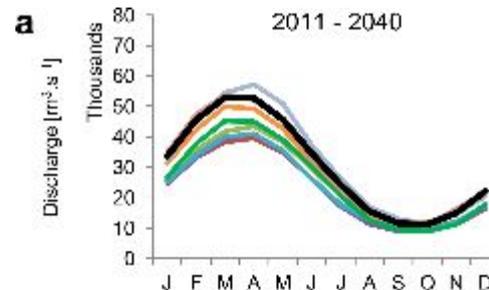


Climatic Change
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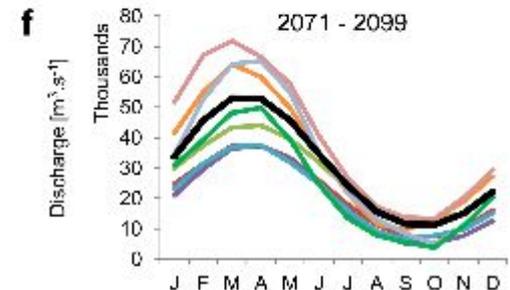
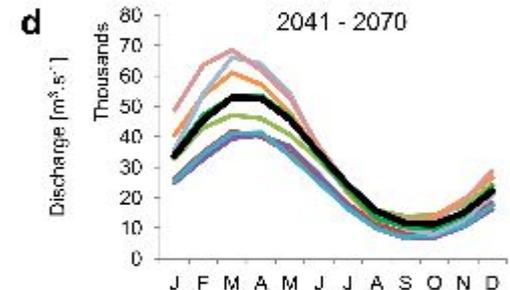
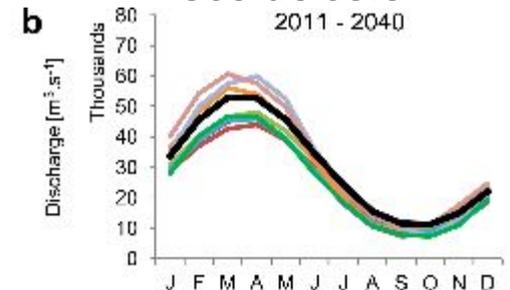
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Mudanças Climáticas



Mudanças Climáticas Uso do solo



— M1 — M2 — M3 — M4 — MR5 — CSR — IPS — HD2 — Base Line

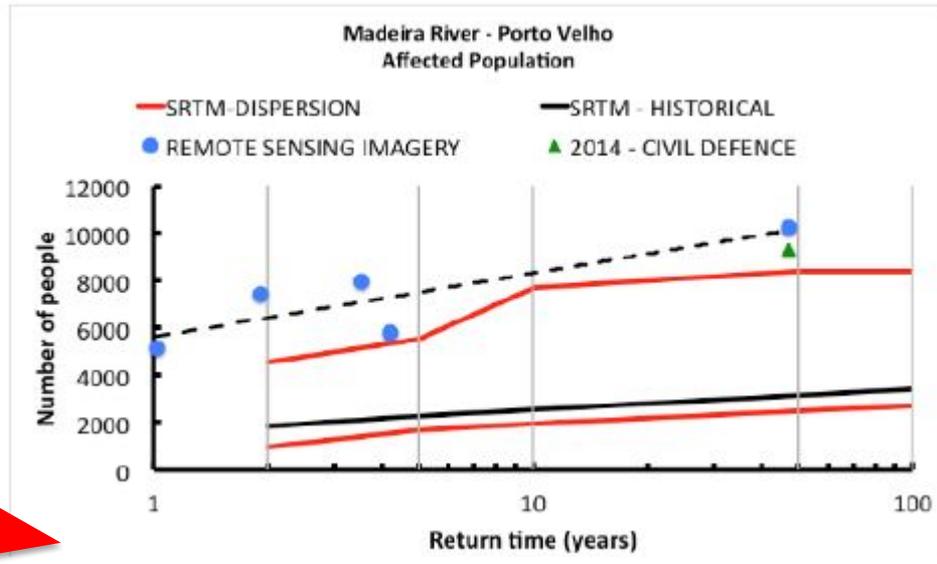
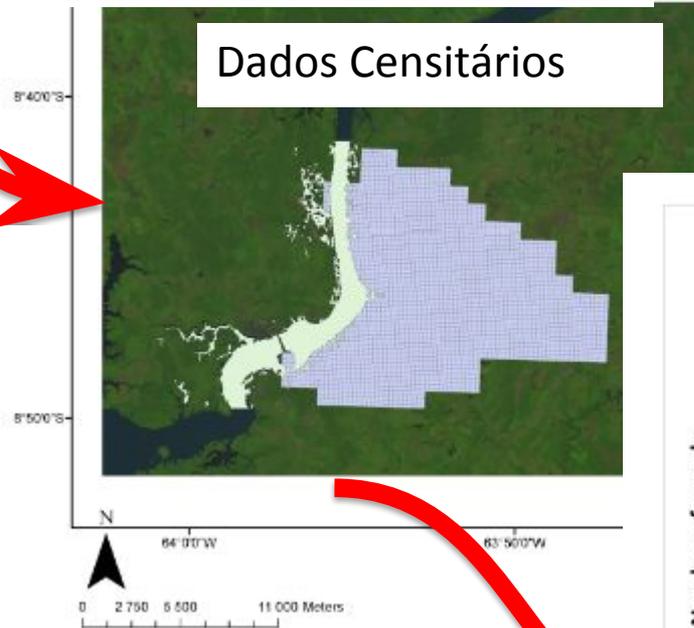
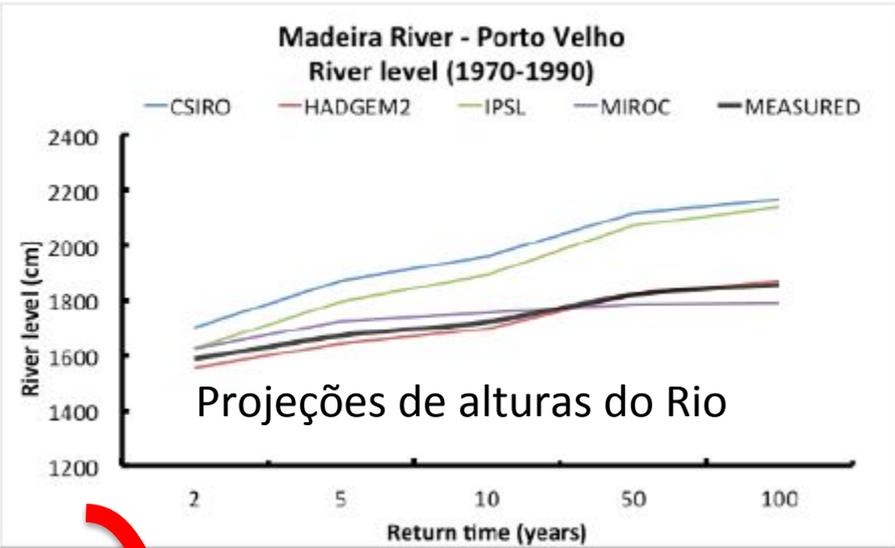
ANÁLISES DE VULNERABILIDADES

ASSESSMENT OF FLOODED AREAS PROJECTIONS AND FLOODS POTENTIAL IMPACTS APPLYING REMOTE SENSING IMAGERY AND DEMOGRAPHIC DATA

D. A. Rodriguez^{a*}, F. Carriello^b, P. J. F. Fernandes^b, L. Garofolo Lopes^a, J. L. Siqueira Júnior^a

^a Earth System Science Center, National Institute for Space Research, 12630-000 Cachoeira Paulista, São Paulo, Brazil - (daniel.andres, lucas.garofolo, jose.lazaro)@impe.br

^b Geosciences Institute, Universidade Federal Fluminense, Av. Litorânea s/n, 24030-346, Niterói, Rio de Janeiro, Brazil – (felix-carriello@vm.uff.br, pjf_fernandes@yahoo.com.br)

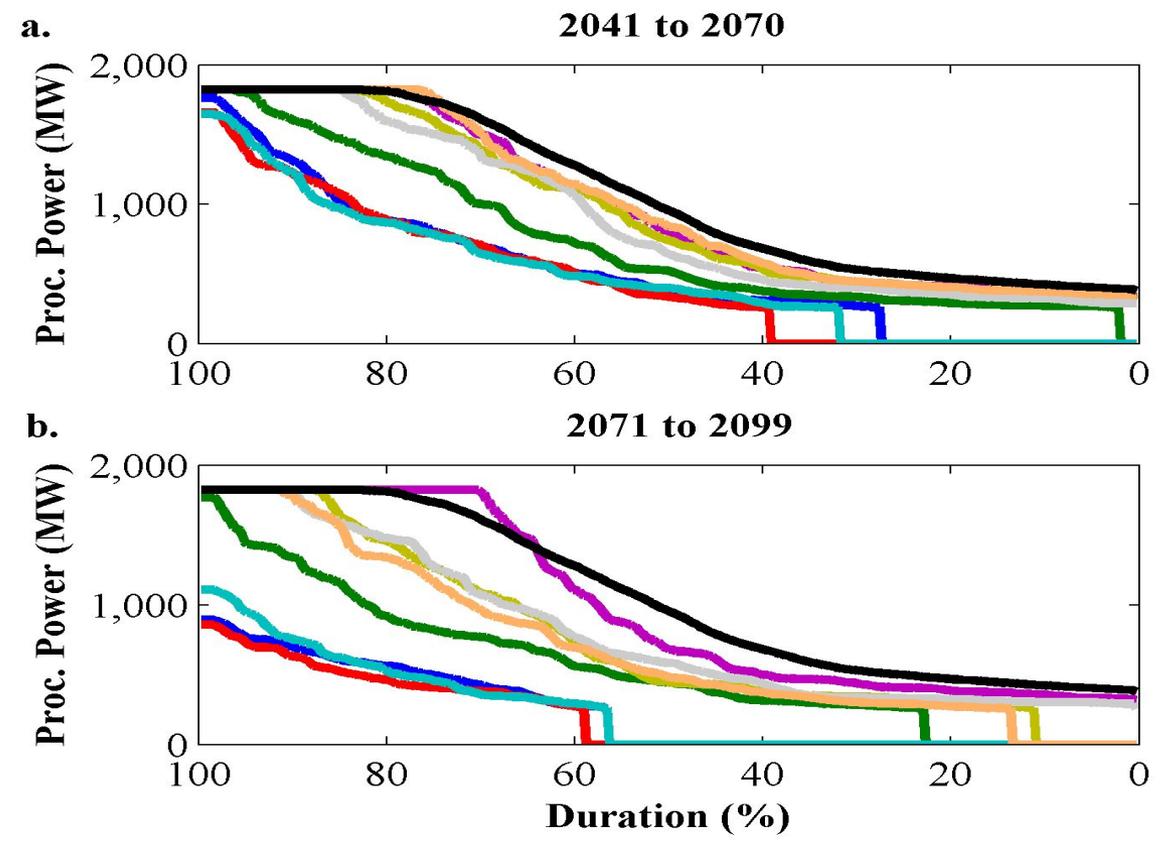
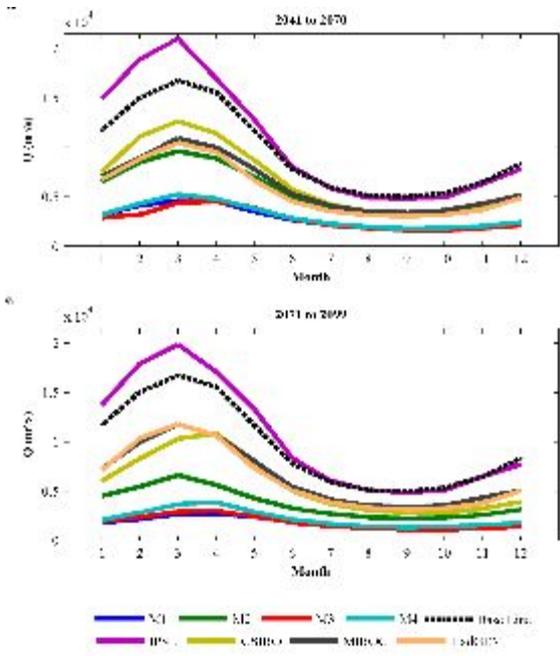
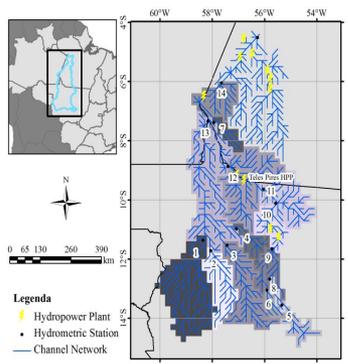


Impactos Potenciais na População

MHD-INPE

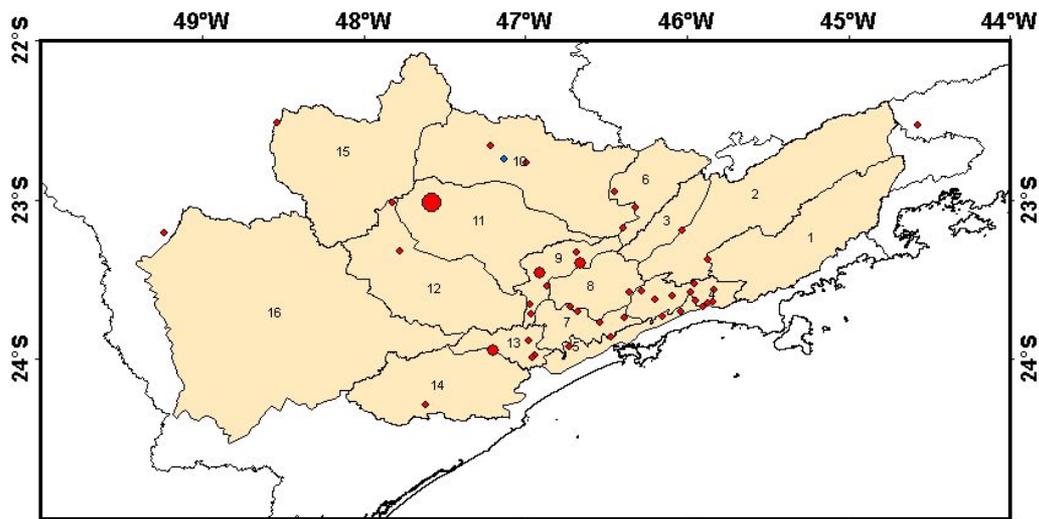
Mudanças Climáticas

Vulnerabilidade na produção de hidroenergia

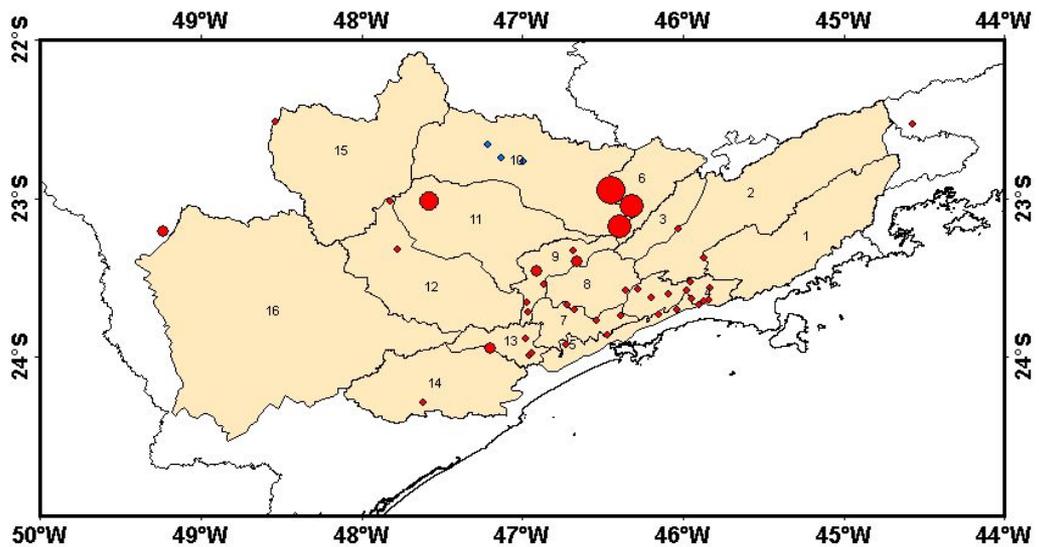


- M1
- M2
- M3
- M4
- Base Line
- IPSL
- CSIRO
- MIROC
- HadGEM

Mudança nas Vazões Médias Anuais em 2041-2070 em 2041-2070



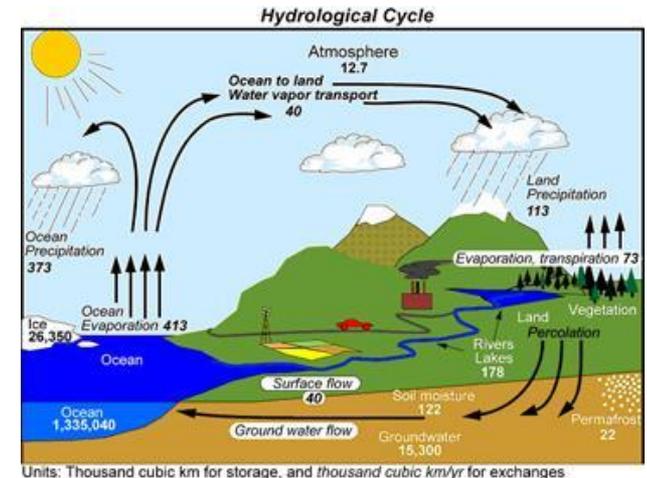
RCP 4.5



RCP 8.5

MUDANÇAS AMBIENTAIS GLOBAIS NA HIDROLOGIA

OBRIGADO!!



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