Vulnerability assessment to select surface water scenarios for aquatic risk assessment in Brazil

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Helping Farmers Grow

Background:

- **2012: Brazilian environmental authority IBAMA started environmental risk assessment according to published guidance**
  - Simple screening models (e.g. GENEEC, ARAQUA SCI-GROW)
  - Only Tier 1 assessment, no procedure for higher tier
  - No mitigation measures included
  - No consideration of Brazilian specific pedoclimatic conditions
- **2014: Tripartite workshop of IBAMA with academia and industry**
  - Conclusion that more specific risk assessment is needed
  - Decision to initiate tripartite steering committee and working groups
- **2015: Start of two first working groups:**
  - Bees
  - Aquatic risk assessment
  - Other working groups foreseen (e.g. wild life, soil, groundwater)

Working group on aquatic risk assessment:

Composition of technical working group

- Brazilian scientists from Ibama (3), Academia (3), Industry (2)
- Further support from international scientists on request

Exposure related goals

- Selection of Brazilian surface water scenarios for important crops
- Identification of appropriate modeling system
- Implementation of scenarios into models
- Guidance on how to conduct exposure calculations

Risk assessment related goals

- Definition of specific protection goals
- Identification of relevant species
- Risk assessment principles (ETO versus ERO)
- Guidance on how to conduct risk assessment

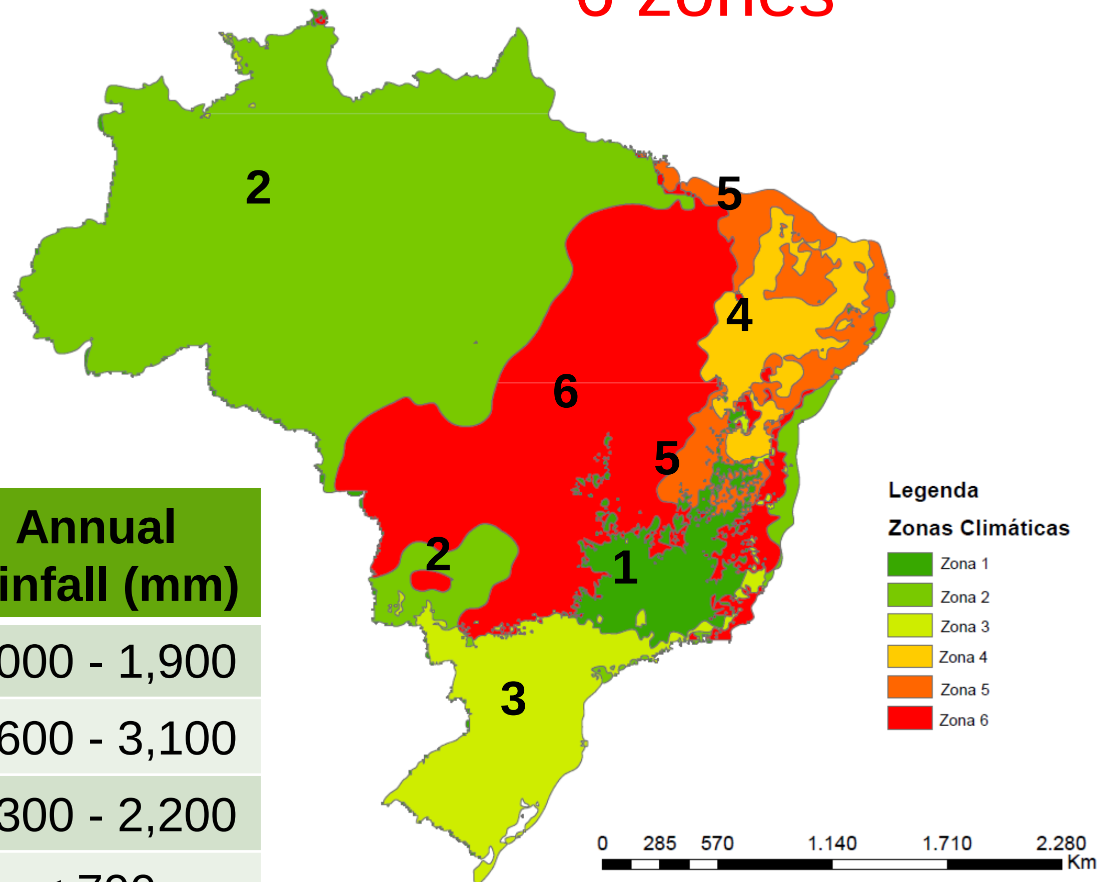
Pre-conditions for scenario selection defined by the core working group

- Six climate zones => one scenario per crop per zone if relevant
- 90th percentile vulnerability represents a sufficient worst-case
- Runoff (+ erosion) as well as spray drift are the relevant entrance pathways that need to be considered
  - Spray drift dependent on machinery technique and highly variable wind conditions during application
  - Runoff (+erosion) dependent on pedoclimatic conditions
  - Runoff more important than erosion for PECsw

Runoff vulnerability drives the scenario selection

6 zones

The six climate zones for Brazil



Zone	Annual mean temperature (°C)	Annual rainfall (mm)
1	18 - 22°C	1,000 - 1,900
2	> 26°C	1,600 - 3,100
3	10 - 22°C	1,300 - 2,200
4	22 - 26°C	< 700
5	20 - 26°C	700 - 1,300
6	20 - 26°C	1,000 - 2,200

Considerations for the vulnerability assessment

- **PRZM will be the relevant model for runoff and erosion calculation**
  - Used in many parts of the world for regulatory (US, EU, China)
  - Well tested and many years of experience
  - Implemented in important regulatory systems (PWC, FOCUSsw)
- **The runoff curve number approach of PRZM should be used to estimate the relevant runoff**
  - RCN approach implemented into GIS
  - Calculation of daily runoff values for each spatial unit for 33 years
- **Overall vulnerability will be estimated with an index method**
  - Not possible to calculate mechanistic $PEC_{sw,runoff}$ for whole Brazil
  - Vulnerability index represents spatially resolved probability for substance runoff

Implementation of runoff curve number approach

- Calculation of daily runoff *R*

$$R = \begin{cases} 0 & ; P \leq 0{,}2 \cdot S \\ \frac{(P - 0{,}2 \cdot S)^2}{P + 0{,}8 \cdot S} & ; P > 0{,}2 \cdot S \end{cases}$$

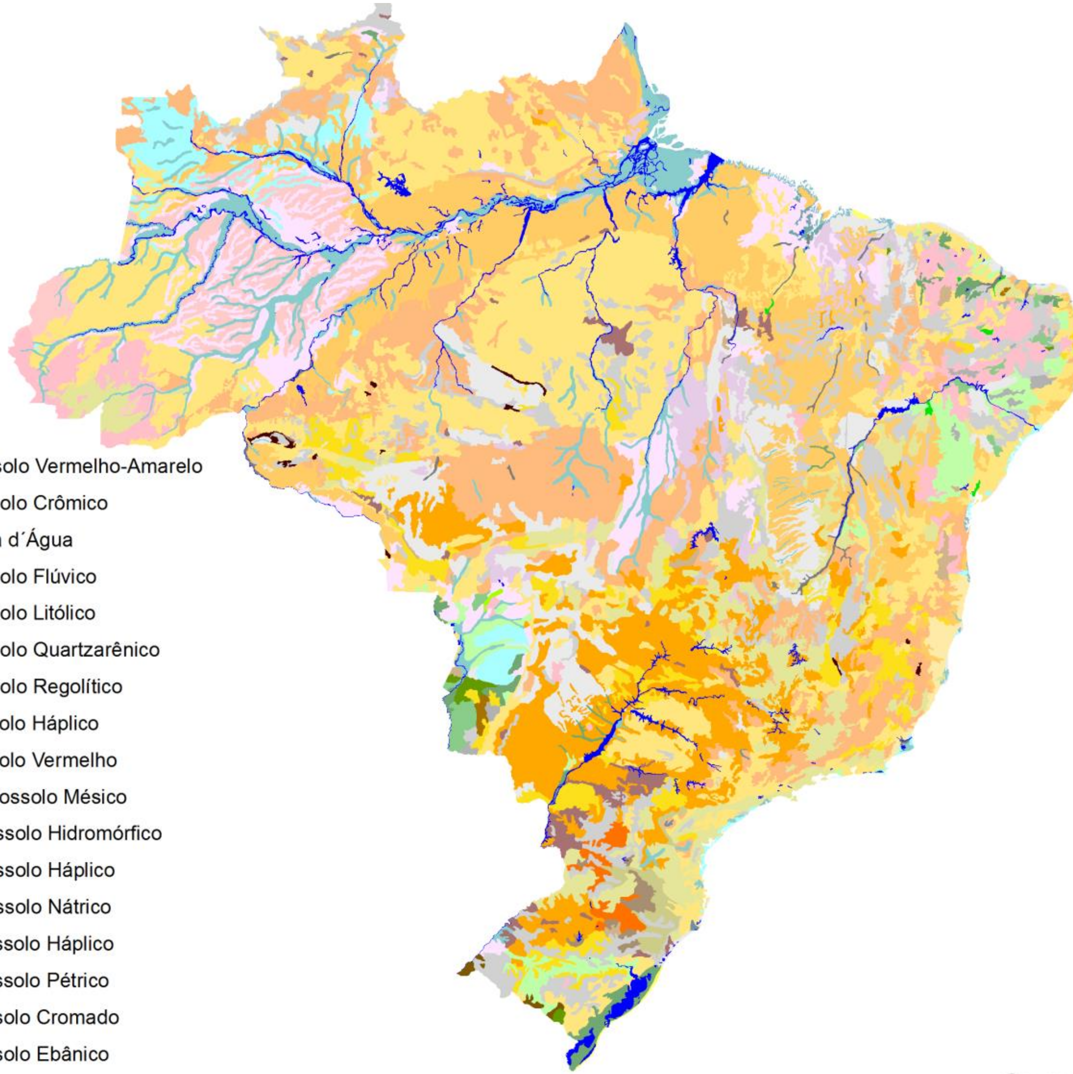
$$S = \frac{2540}{RCN} - 25{,}4$$

R = daily runoff (cm)
P = daily rainfall (cm)
S = potential maximum retention (cm)
RCN = runoff curve number (-)

- Databases:
  - Precipitation from daily gridded rainfall data from 1980-2013 (Xavier et., 2015, 0.25° , downscaled to 10km)
  - RCN = tabulated values depending from soil hydrological group and relevant crop type
  - Soil hydrological group derived from Brazilian soil map (Embrapa, 2011) according to Sartorius (2005)

Soil Map Brazil

Dominant Soil Types



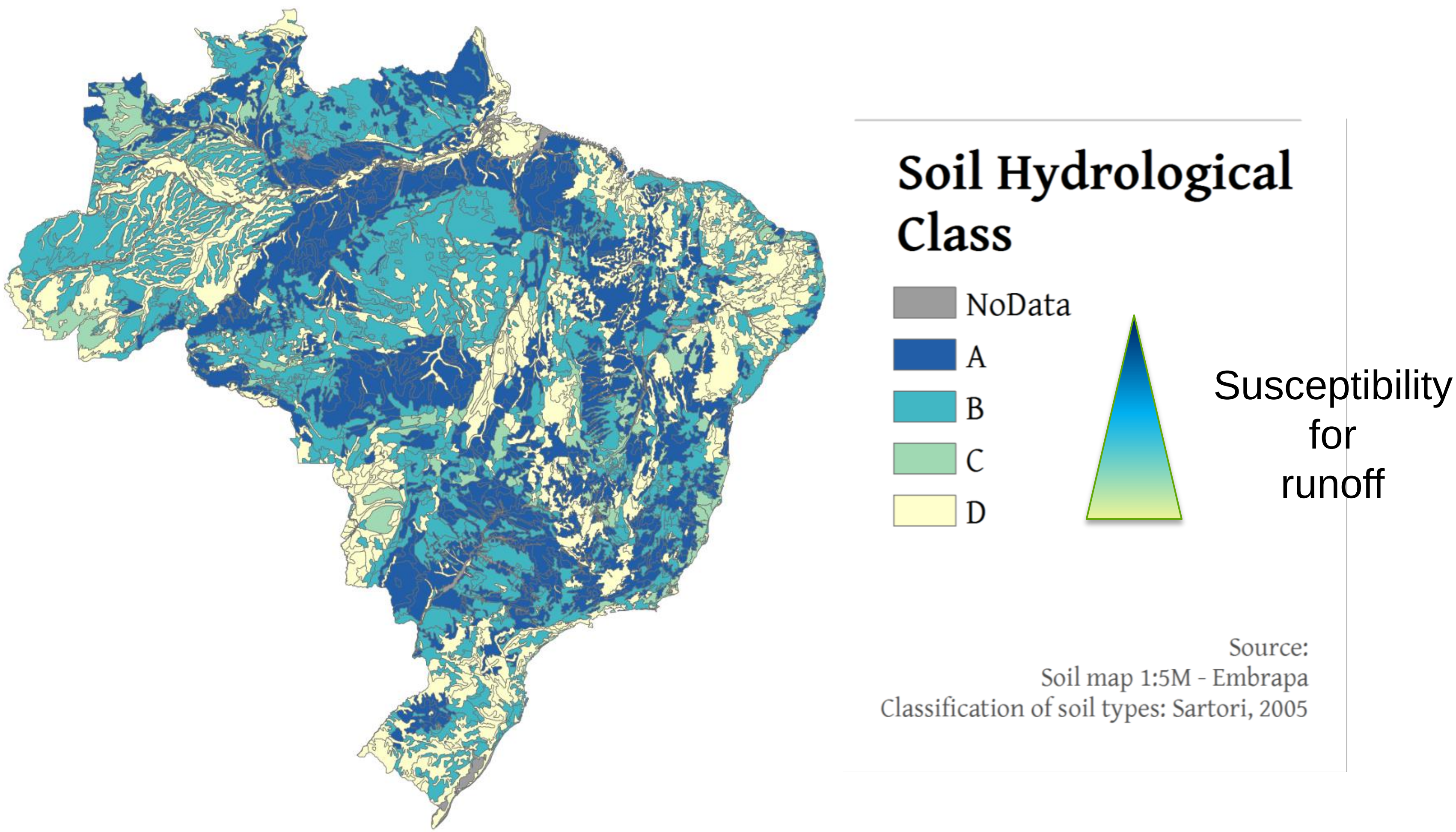
- Afloramentos de Rochas
- Alissolo Crômico
- Argilossolo Acinzentado
- Argilossolo Amarelo
- Argilossolo Vermelho
- Argilossolo Vermelho-Amarelo
- Cambissolo Háplico
- Cambissolo Húmico
- Chernossolo Argilúvico
- Chernossolo Ebânico
- Chernossolo Rêndzico
- Dunas
- Espodossolo Ferrocárbico
- Gleissolo Háplico
- Gleissolo Sálico
- Gleissolo Tiomórfico
- Latossolo Amarelo
- Latossolo Bruno
- Latossolo Vermelho
- Latossolo Vermelho-Amarelo
- Luvissolo Crômico
- Massa d´Água
- Neossolo Flúvico
- Neossolo Litólico
- Neossolo Quartzarênico
- Neossolo Regolítico
- Nitossolo Háplico
- Nitossolo Vermelho
- Organossolo Mésico
- Planossolo Hidromórfico
- Planossolo Háplico
- Planossolo Nátrico
- Plintossolo Háplico
- Plintossolo Pétrico
- Vertissolo Cromado
- Vertissolo Ebânico
- Vertissolo Hidromórfico

Source:
Embrapa Solos

Deriving hydrologic soil groups

- NRCS Handbook (2009): Description of four hydrological groups A to D
- Sartori et al. (2005): Classification of Brazilian soil types to hydrologic soil groups A to D under consideration of specific characteristics of Brazilian soils, e.g.
  - Soils with high clay content but high infiltration and low runoff because of aggregation and secondary pore system
  - Sandy soils with clayey low permeable subsoil layer with high susceptibility for runoff
- Attribution of hydrologic soil groups to soil types of Embrapa soil map (Santos et al., 2011) at a scale of 1:5,000,000

Hydrologic soil groups for Brazil



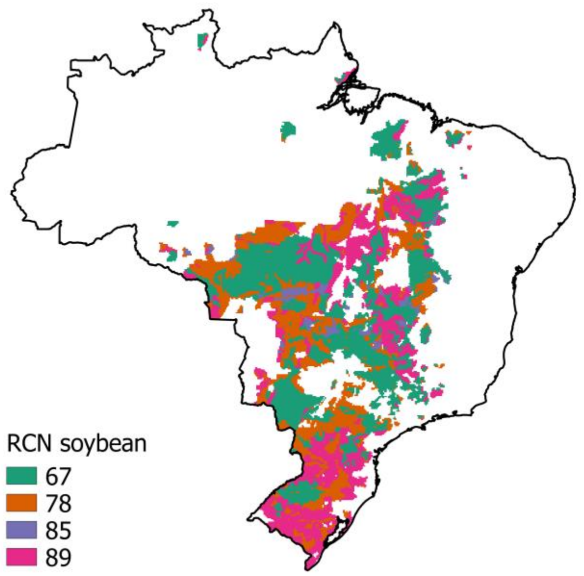
Tabulated RCN values for most important crops

			Hydrological class			
Crop	Acreage (ha)	% of total field crop area (2014)	A	B	C	D
Soybean	30273763	40%	67	78	85	89
Maize	15432909	20%	62	83	89	93
Sugar cane	10419678	14%	70	80	87	90
Beans, dry	3185745	4%	67	78	85	89
Wheat	2834945	4%	54	70	80	85
Coffee	1997827	3%	36	60	73	79
Cotton	1129399	1%	67	78	85	89

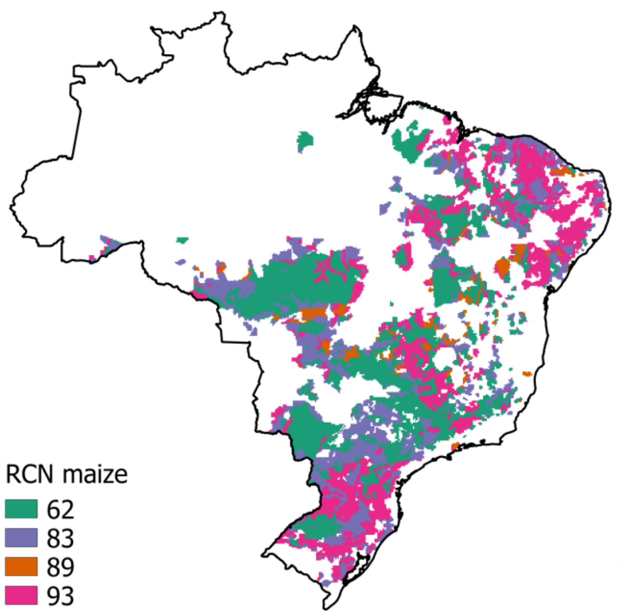
RCN geographical maps of most important crops

- Crop statistics available on administrative level => municipalities (361 – 15.9 Mio ha size, median: 42 378 ha)
- Runoff calculations were carried out for all municipalities where more than 1% of the total area is cropped with the respective crop

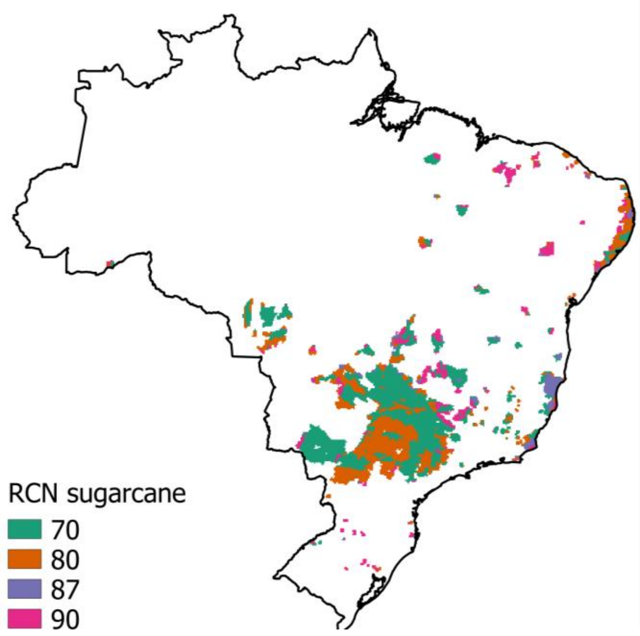
Soy bean



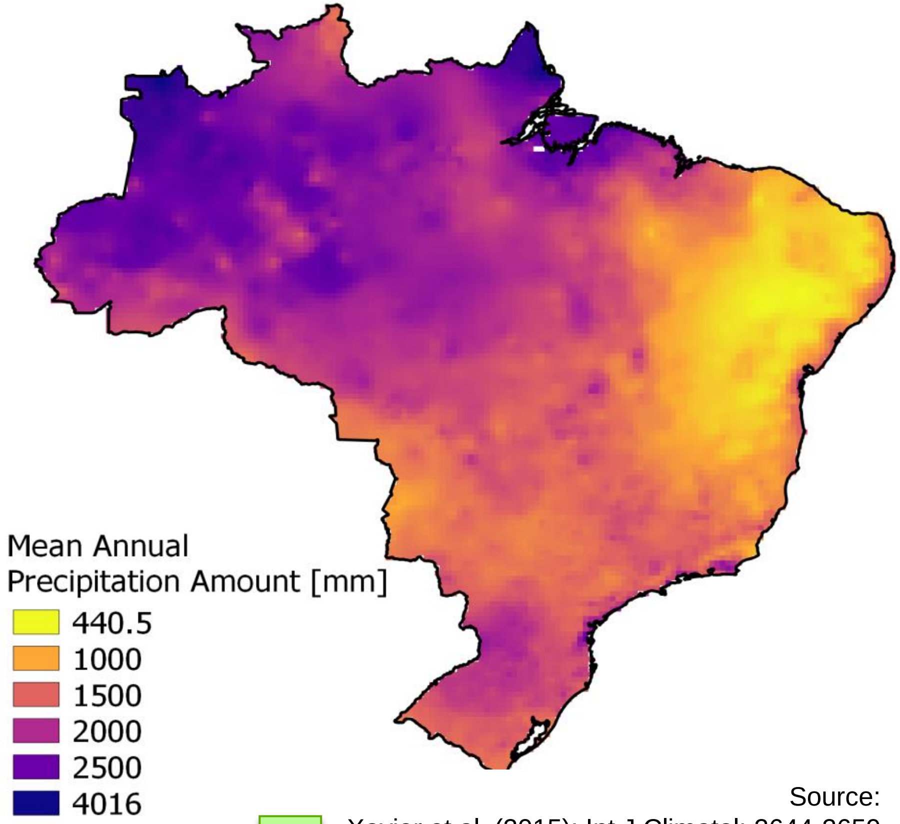
Maize



Sugar cane



Mean annual precipitation in years of calculation from 1980-2013



Source:
Xavier et al. (2015): Int J Climatol: 2644-2659

Calculation of daily runoff during main vegetation period from September to April

Vulnerability index as basis for scenario selection

- Feasibility showed that indices and selected scenarios should be independent from
  - Application date of product (GAP)
  - Substance properties

- Selected drivers which are assumed to have largest impact on maximum substance runoff and PEC_{sw}
  - **Average annual maximum runoff (AAMax)**

    => The higher the water runoff the higher the potential substance load in runoff
  - **Average annual number of runoff events (AANum)**

    => The higher the number of runoff events the higher the temporal proximity of substance application and runoff events => more available substance for runoff
  - **OC-content (OC)**

    => The lower the OC content the higher the substance concentration in the runoff water

Vulnerability index as basis for scenario selection

- In order to combine indices normalization of values needed
  - Indices should be in a similar range to avoid that one factor dominates VI_{runoff}
  - After testing several methods values were normalized by their mean value
  - Resulting indices were in a similar range between 0 and 4.2 for all factors
- Formula for vulnerability index

$$VI_{runoff} = AAMax_{norm} + AANum_{norm} - 2 * OC_{norm}$$

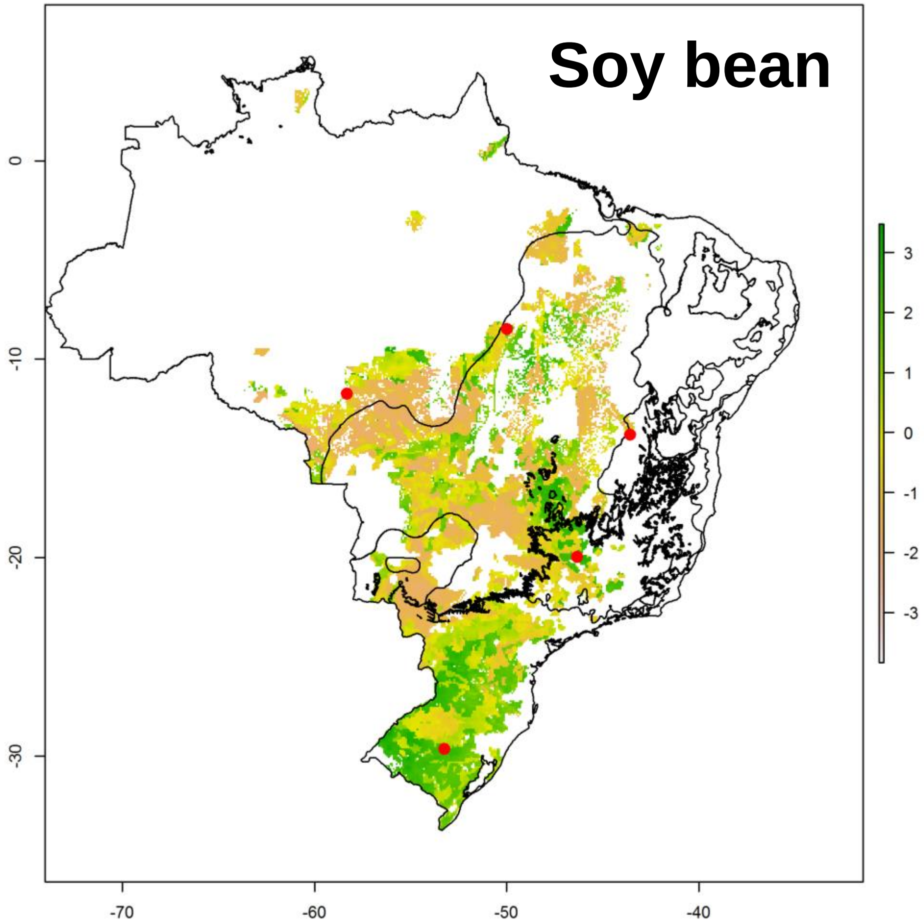
with: $AAMax_{norm}$ = index for normalized average annual maximum runoff

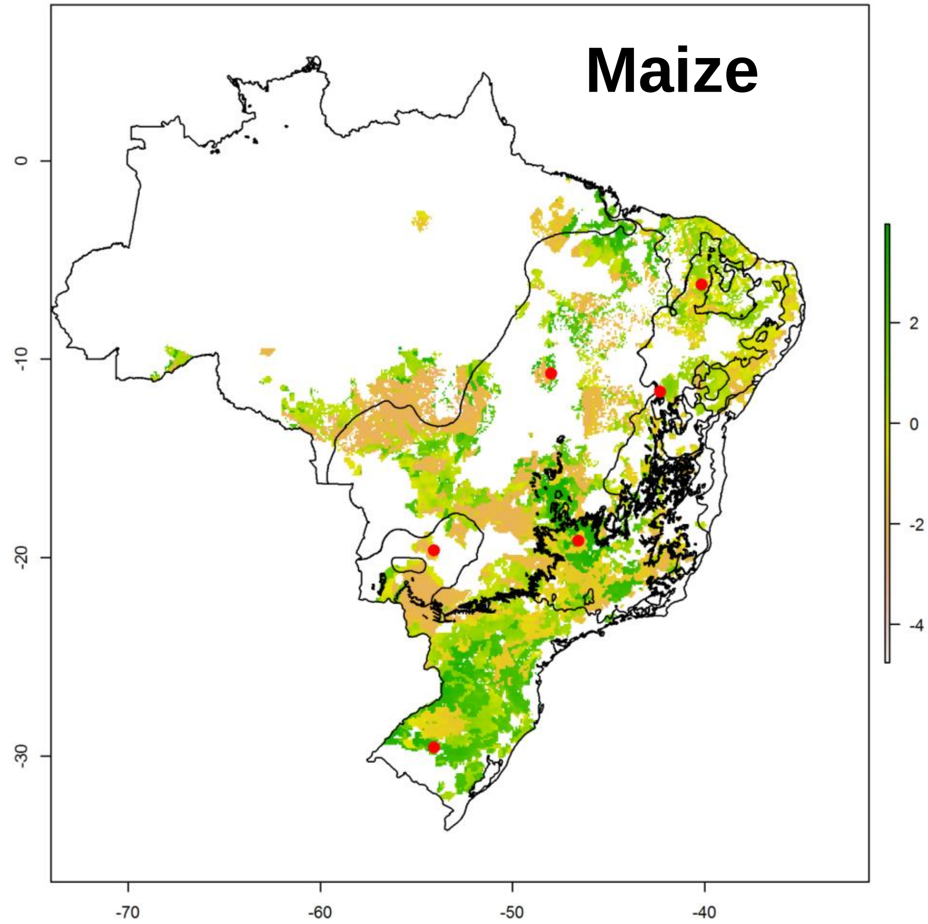
$AANum_{norm}$ = index for normalized average annual number of runoff events

OC_{norm} = index for normalized organic carbon content

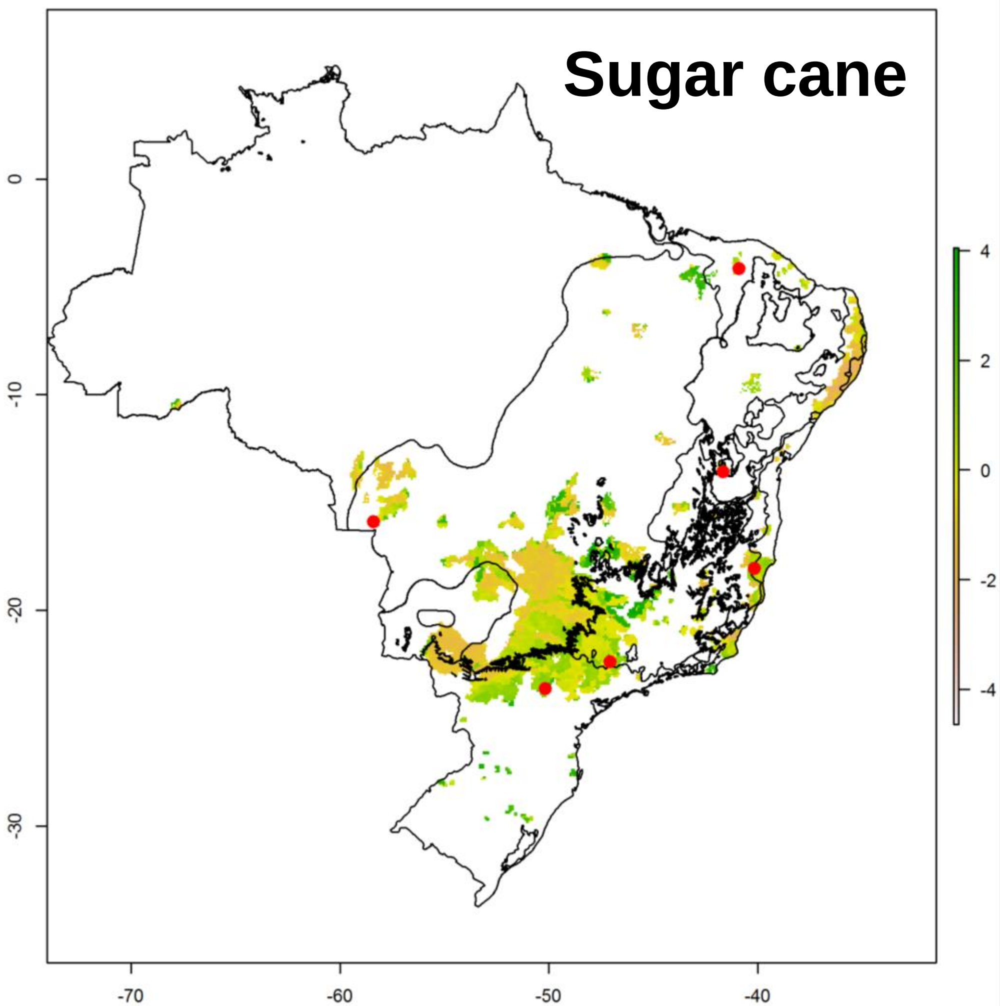
- Role of OC in vulnerability index
  - Minus sign: The higher the OC the lower the concentration in runoff water
  - Factor of two applied to get equal weighting between water runoff and substance concentration in runoff water

Vulnerability index and selected 90th percentile as scenario proposal for each climate zone





Vulnerability index and selected 90th percentile as scenario propsal for each climate zone



Conclusions

- **The proposed VI_{runoff} approach represents a scientifically based pragmatic approach for selection of surface water scenarios in Brazil**
  - Selected indices directly influence the substance runoff into surface waters
  - Use of runoff routine of PRZM consistent with model that will be used for PEC_{sw} calculation
- **Crop specific scenarios for three major crops that cover 75% of the field crop area available**
- **Decision about acceptance of the presented approach to be taken by regulatory authority IBAMA**

Outlook

- **Still a huge amount of work to do**
  - Scenarios for some more important crops (crop grouping, less scenarios for smaller crops)
  - Definition of relevant surface water bodies (ponds and streams that are *permanent* and *natural* => dimensions?)
  - Selection of appropriate models (IBAMA favorizes US-EPA PWC)
  - Deriving necessary parameters for scenarios
  - Implementation of scenarios into modelling system

- **Guidance development**
  - Normative expected in late 2017 / early 2018
  - Manual in 2018

Stakeholder workshop at Brasilia in Oct 2016

Per telecon

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