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Linking climate and people
Agent-based simulation of Holocene precipitation and population dynamics in tropical semi-arid India

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SimulPast - www.simulpast.es

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Spanish Ministry for Science and Innovation (MICINN)
CONSOLIDER-INGENIO 2010 (CSD2010-00034, 2010-2015)
PI: M. Madella (CaSEs)

A region of extremes (1901-2010)

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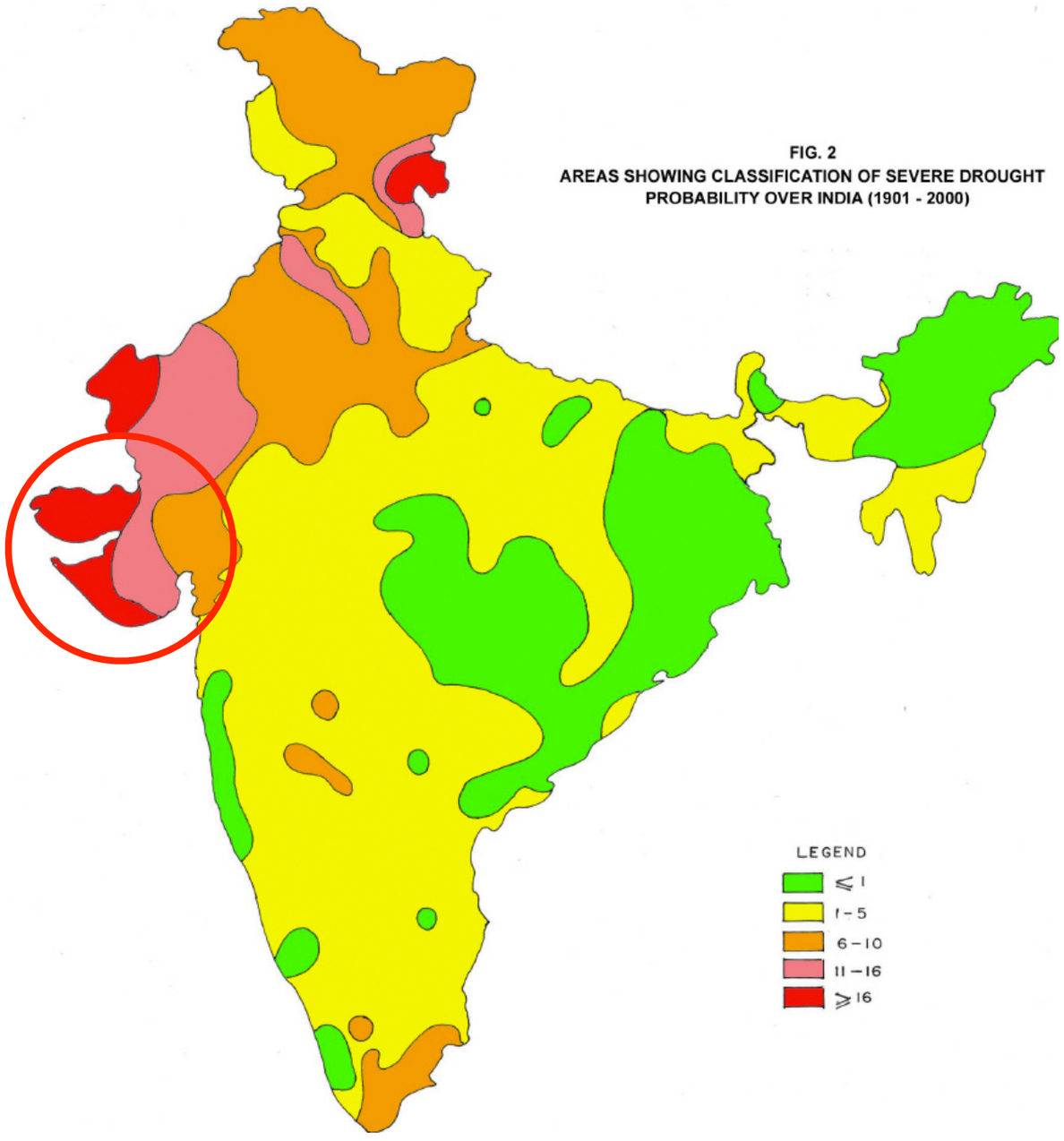
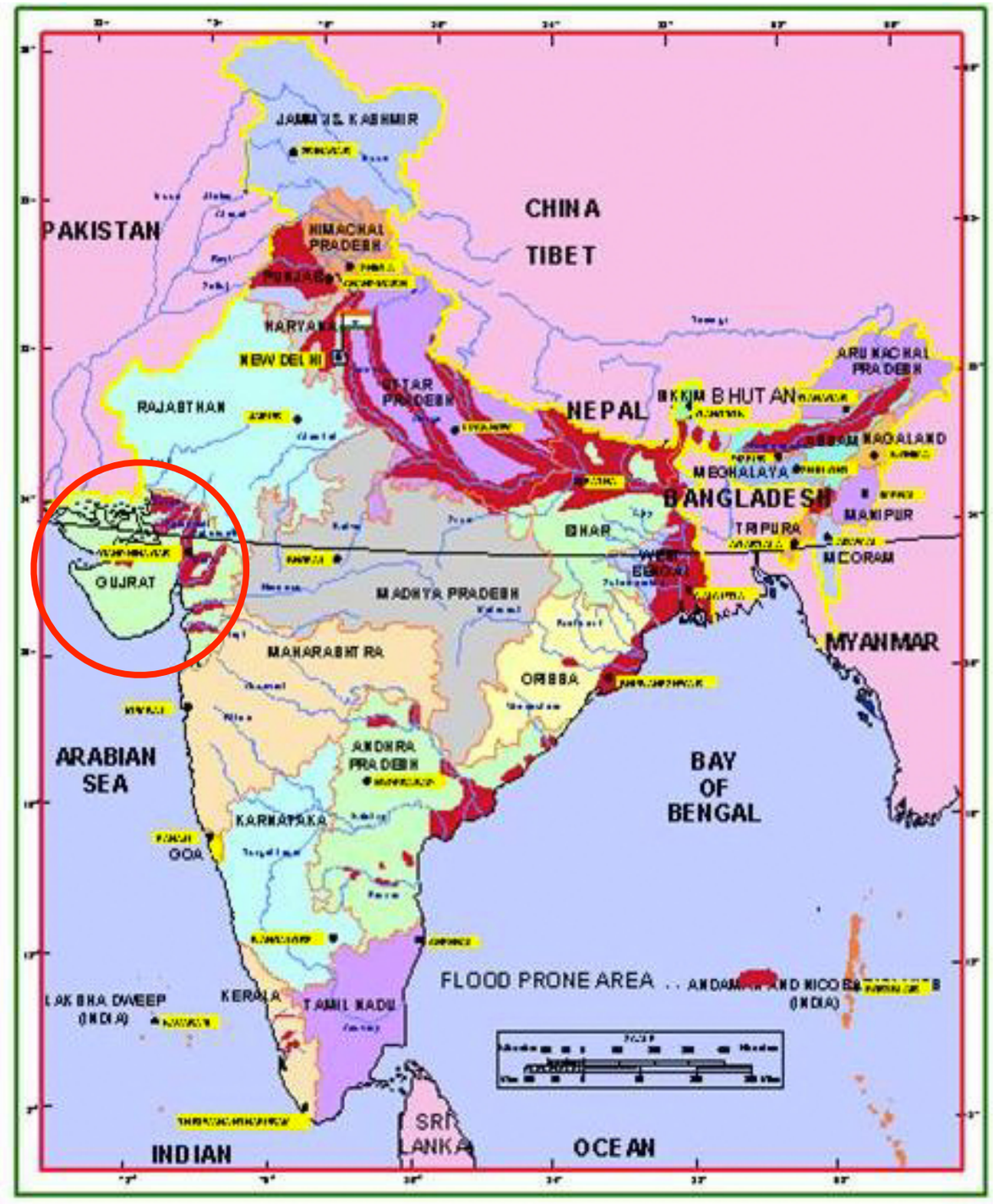
Severe draughts (c 1 in 7 y)



Flood prone areas



maps from SD Attri A Tyagi Climate Profile of India 2010

Indian Summer Monsoon - ISM

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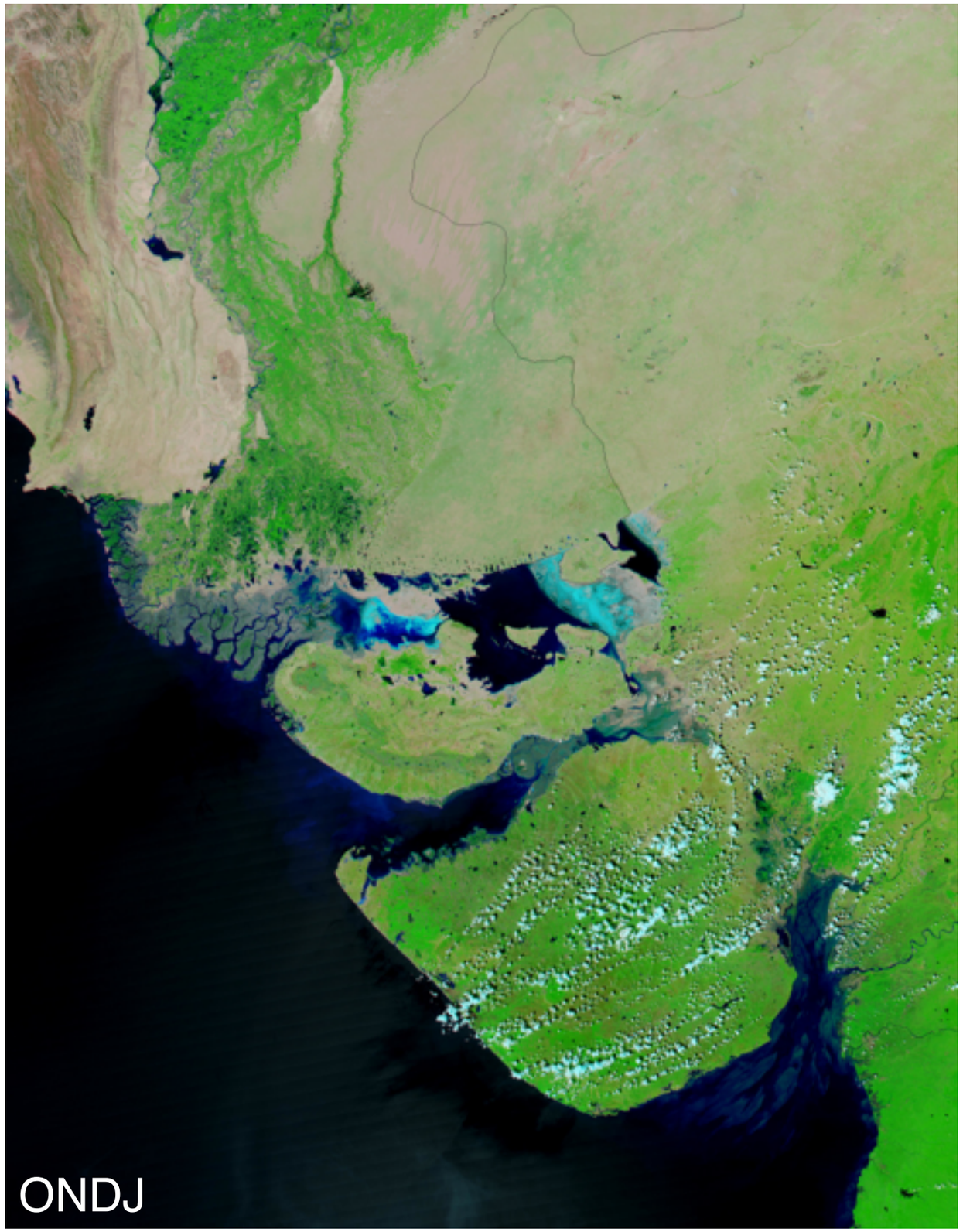

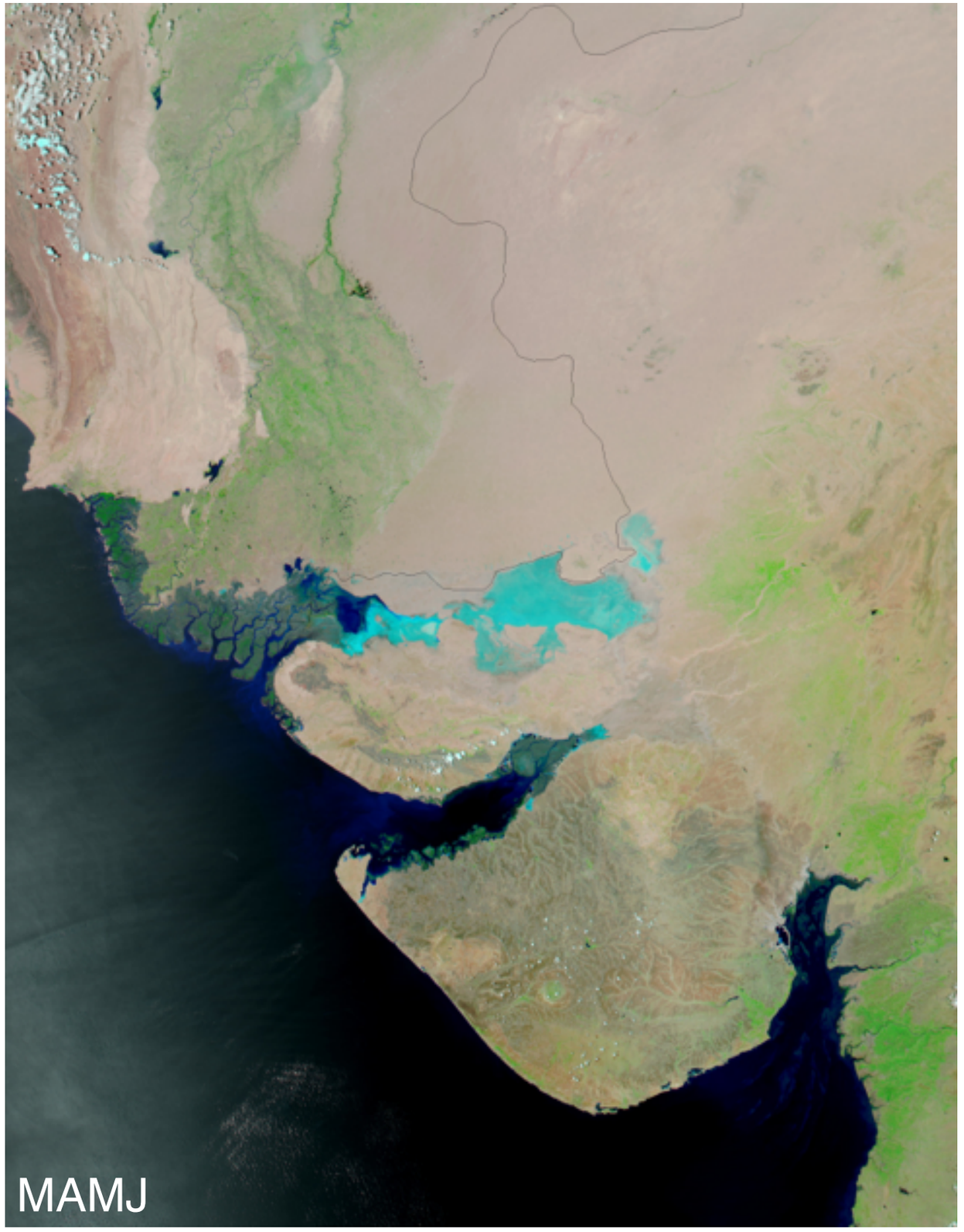

Aim and Rationale

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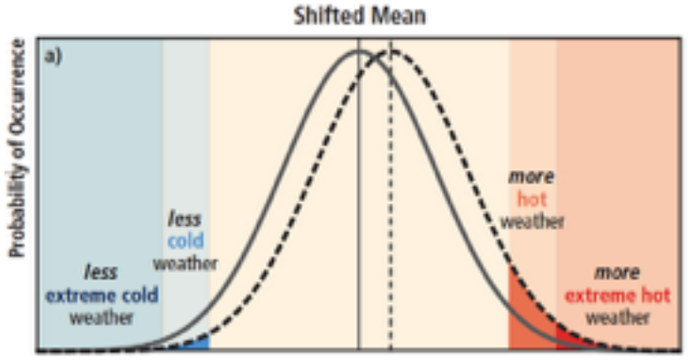
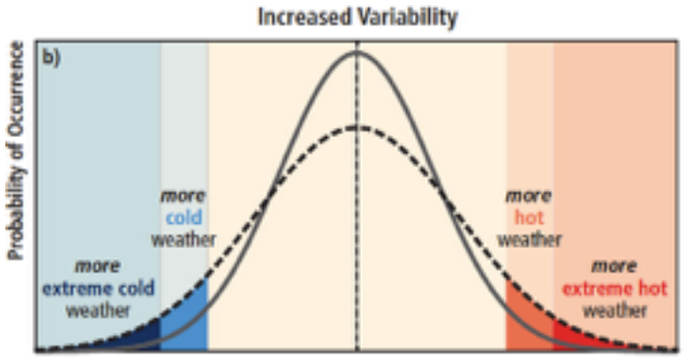
Explore dependencies between population dynamics (HGP) and resource availability driven by climate (ISM precipitation patterns)

IPCC 2012. Managing extreme events
WG2: Impacts, adaptations, vulnerability

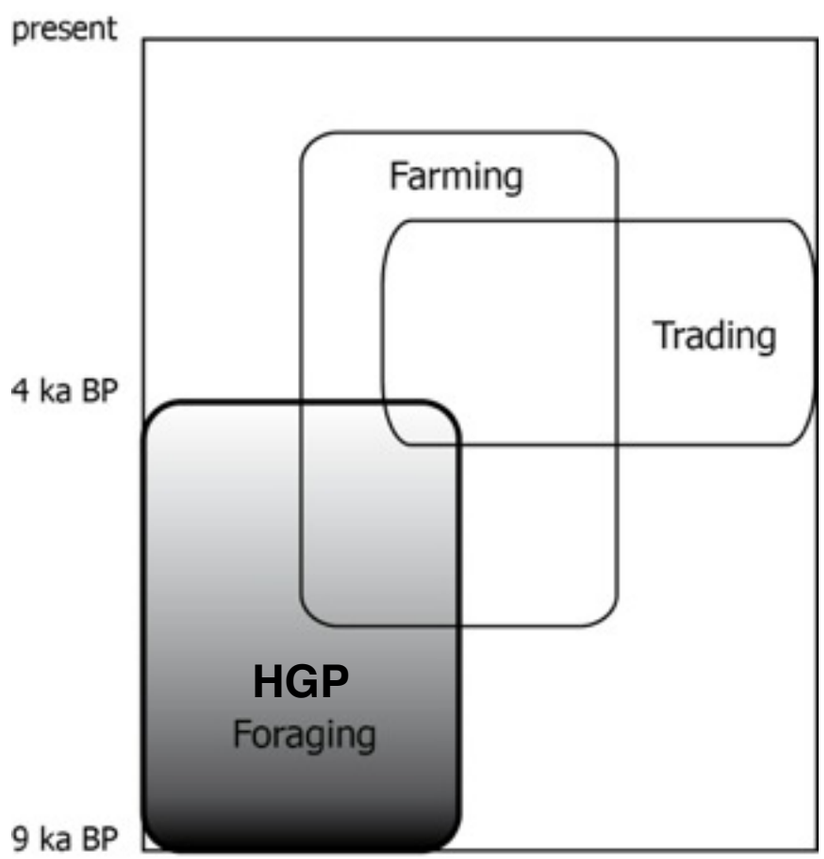
AYP - mean



VYP - sd



Holocene HGP adapted to strong seasonality in N Gujarat **9-4 ka BP**



Components of the model SES

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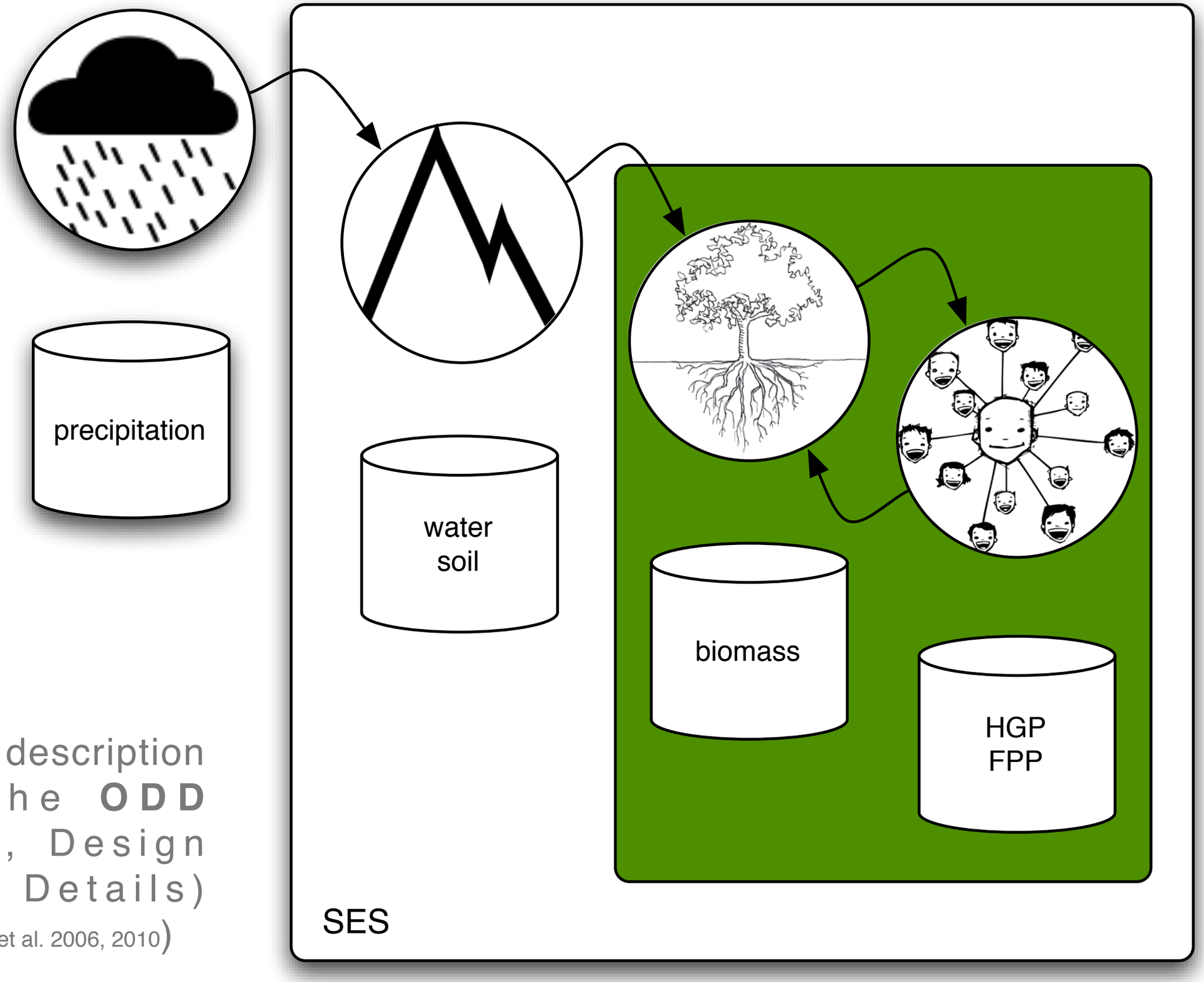

The model description follows the **ODD** (Overview, Design concepts, Details) protocol (Grimm et al. 2006, 2010)

Realistic climate model

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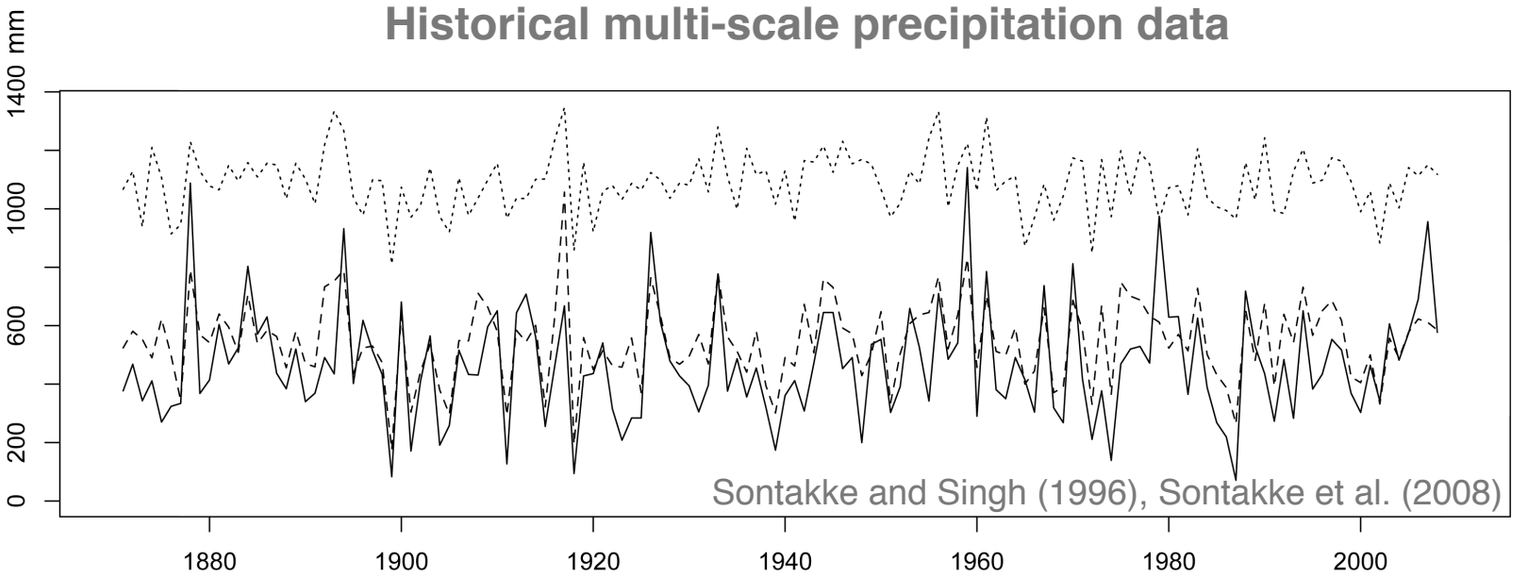
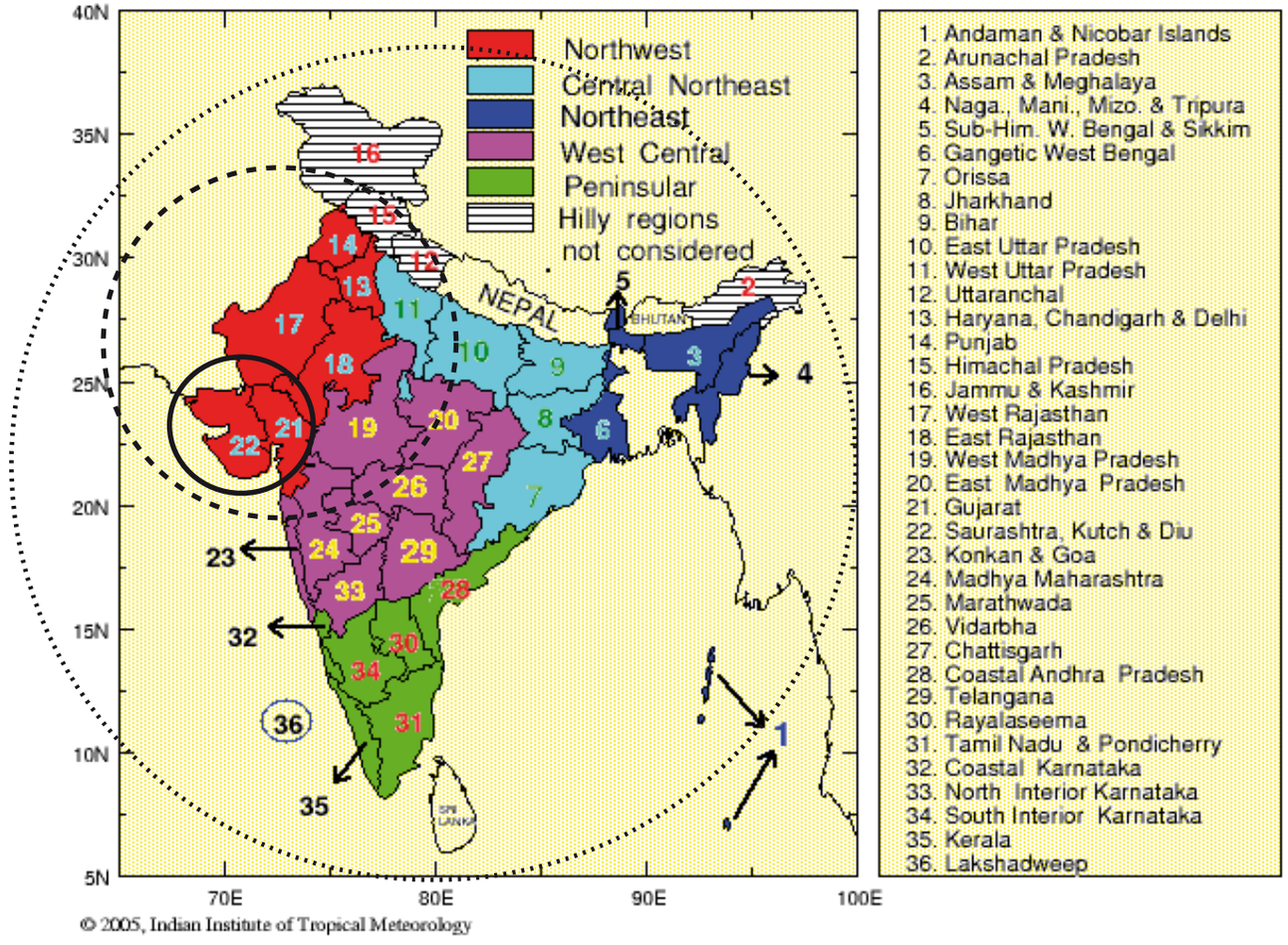
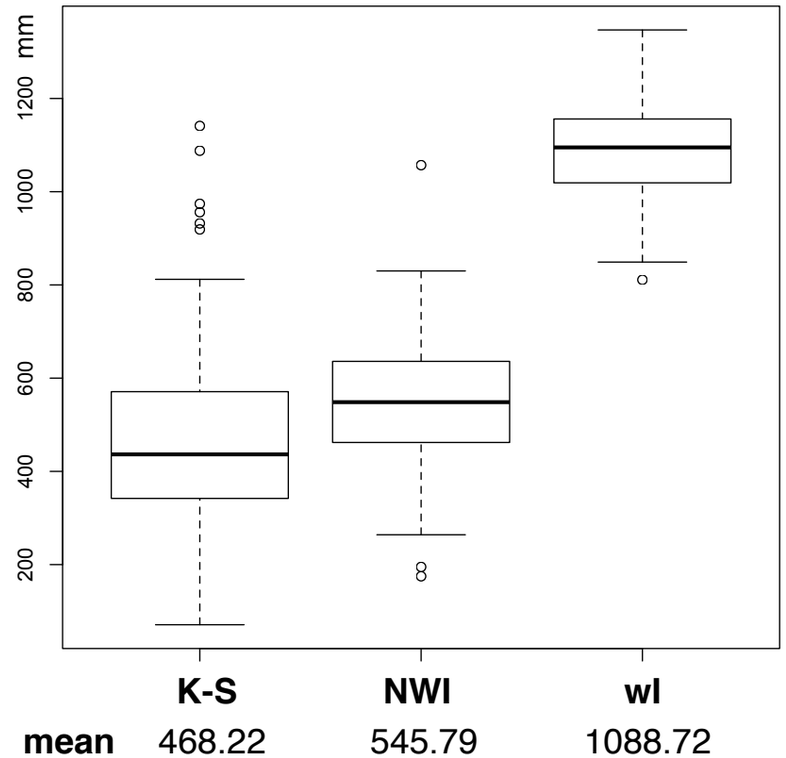
Historical multi-scale precipitation data



Homogeneous monsoon regions

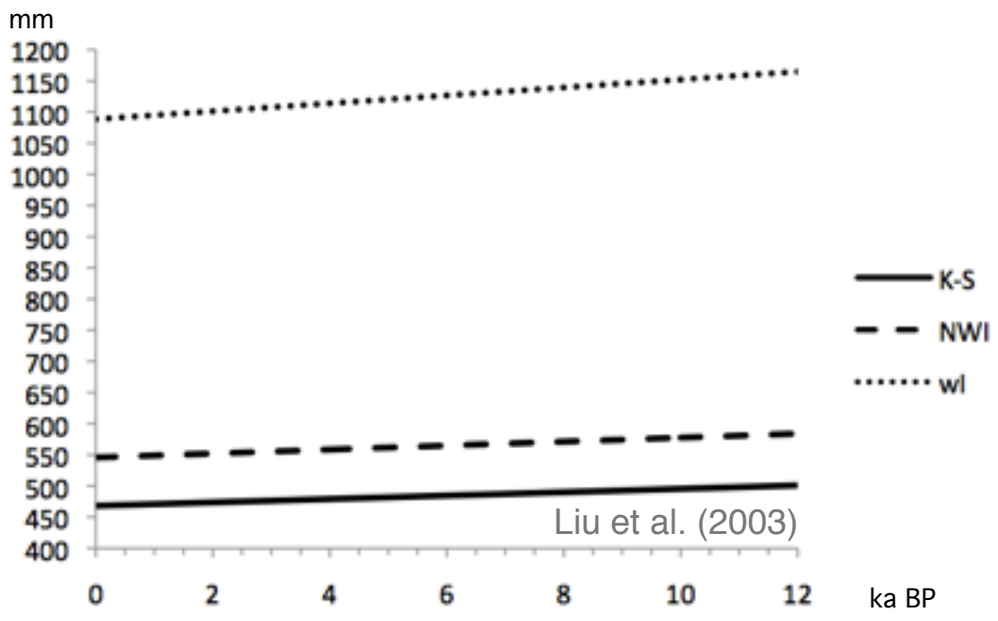


© 2005, Indian Institute of Tropical Meteorology



	K-S	NWI	wl
mean	468.22	545.79	1088.72
sd	193.46	136.55	101.12

Calibration of mean precipitation



Realistic ground model

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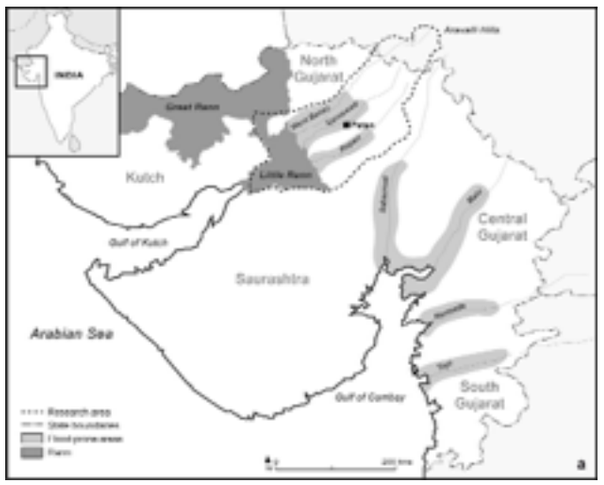

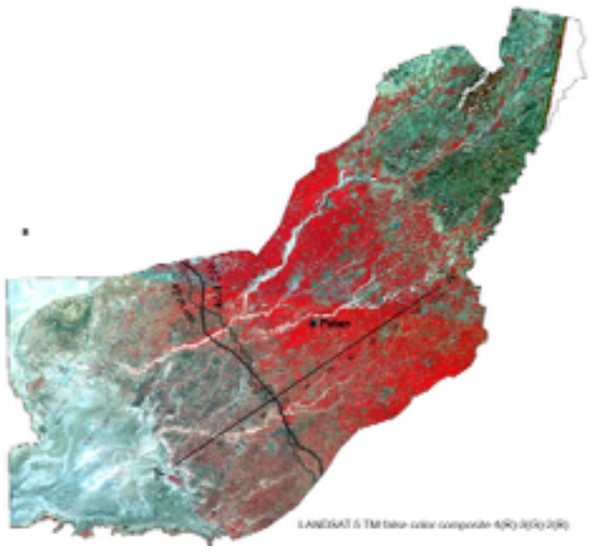

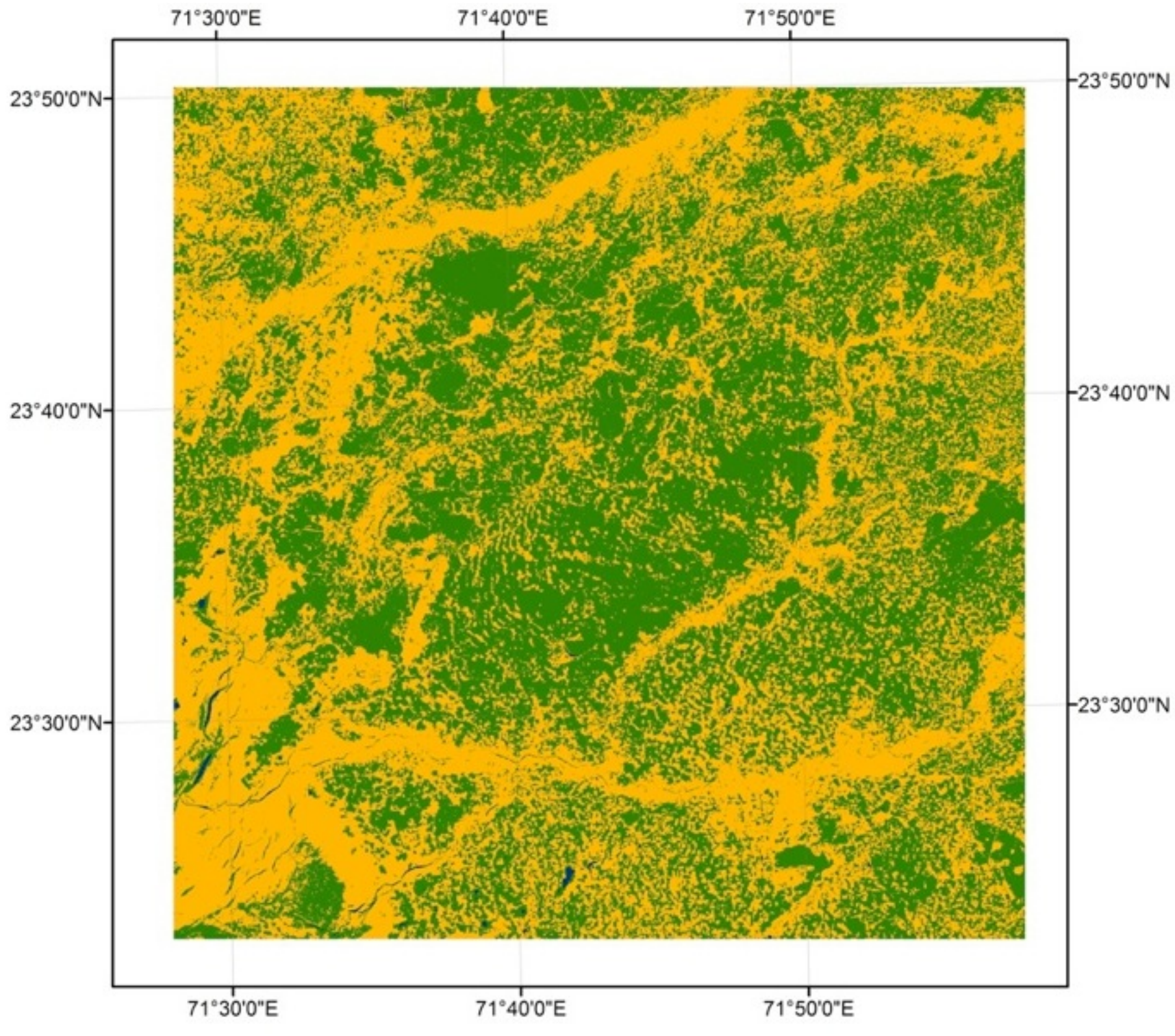

Ground model covers 800*800 cells, c. 625 km2 and is made of: Dune (yellow), Interdune (green), Water (blue)

Resources (biomass)

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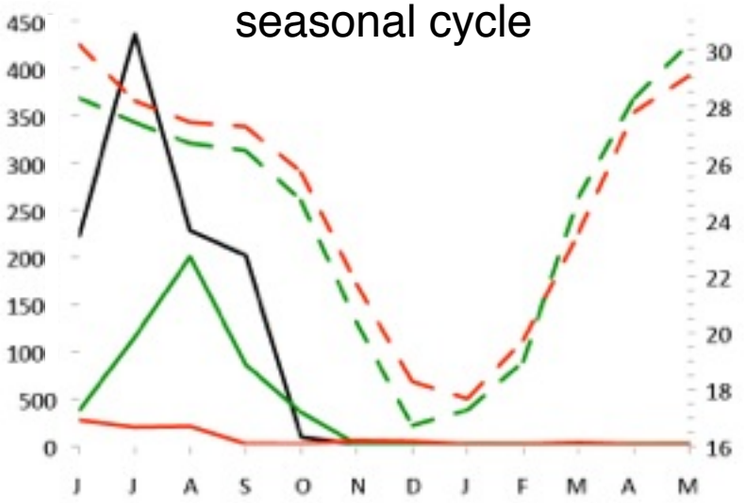
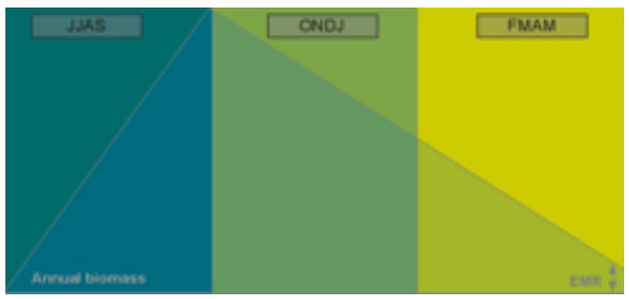
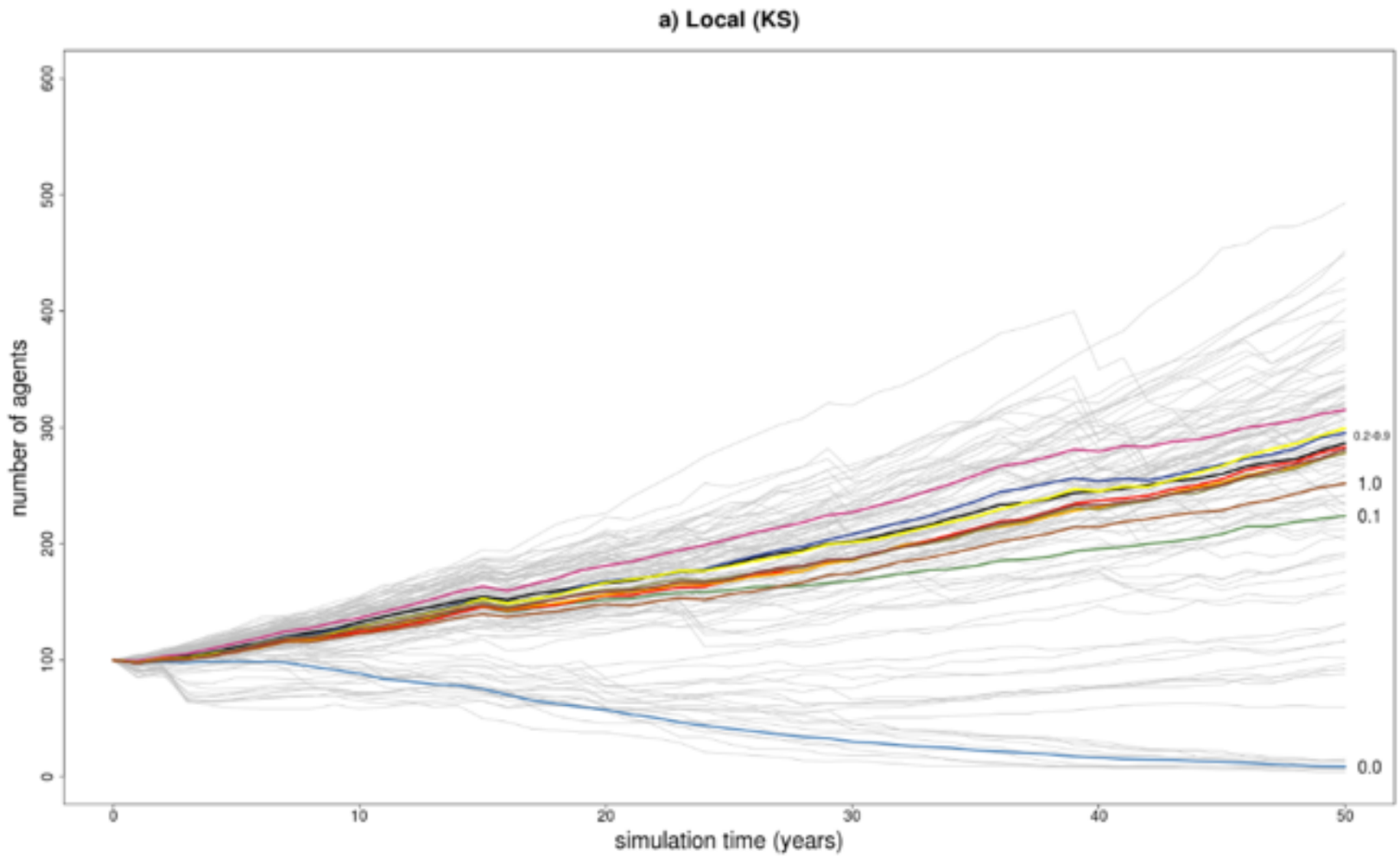
- Calculated from present-day tropical semi-arid regions
- Decrease linearly as distance from water increases
- Increase linearly to maximum through the rainy season (JJAS), then decrease linearly until the end of the dry season (FMAM)
- **EMR** '**end-of-year minimum residual resources**' is defined as a % of the overall biomass for the year, under which resources are not allowed to decrease
- Low EMR = high seasonality, and viceversa







Agents sources

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Archaeological data are incomplete and limited in terms of derivable behavioural patterns. HG behaviour for the model was derived from published studies of historical and present-day populations in similar ecological settings:

- The **Van Vargis** Groups of HGP live near N Gujarat (Nagar 2008) but have a high degree of interaction with and dependency from settled agricultural communities

- The **San** (especially the G/wi and G//ana of Botswana) represent the best-fitting parallel in terms of SES (Tanaka and Sugawara 1996):

  - ***Landscape***: flat plateau in the Kalahari with fossil rivers and dunes
  - ***Rainfall***: concentrated in the summer with c. 400 mm average precipitation
  - ***Vegetation***: grasses and shrubs also found in N Gujarat

Agents attributes (households)

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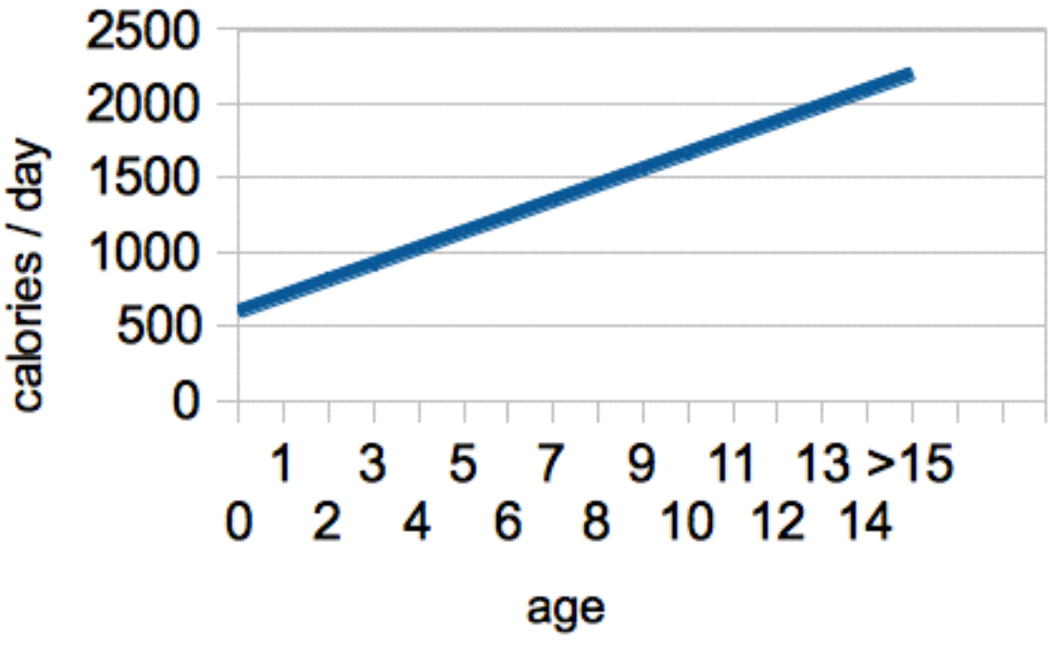
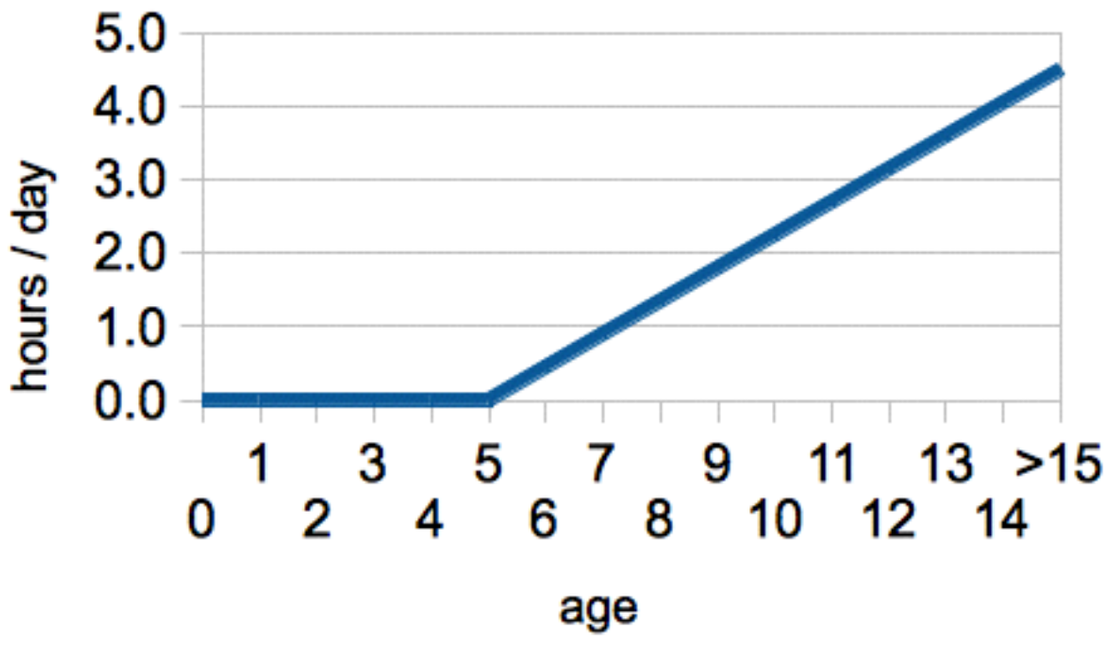
- **Age** - Number time steps a given agent has been active in the simulation
- **Children** - Number of children per agent. Birth/mortality bound to resource availability
- **Home location** - The cell where the agent resides
- **Home range** - Maximum distance an agent may travel in one day
- **Social range** - Maximum distance within which an agent with individuals coming of age will seek suitable matches to mate and generate a new agent
- **Food needs** - Minimum calories a given individual needs in each time step in order to survive. Total for an agent is the sum of the individuals
- **Available forage time** - Daily time that an agent can spend on foraging. Total for an agent is the sum of the individuals. Foraging time increases from infancy to adult life, modelling learning processes





Agents actions

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Each day an agent update their environmental knowledge and execute an action:

- **Forage** - The agent takes multiple walks during available foraging time.within their Home range. Resource reward is retrieved based on biomass of visited cells. The agent will halt the walk when reward achieves food needs
- **Move home** - The agent moves from its current home location to a new one within Home range. The new home settlement is chosen randomly within the sectors with the highest amount of resources. Afterwards, a Forage Action is executed using half the available daily foraging time

Adjustment of agent population size:

- **Age** - Increment human objects age
- **Death** - At the end of the year individuals have a probability of:
  - ***Natural death*** - 1.5% for adults, 10% for the first four years of life
  - ***Starvation*** - Capability of an agent to fulfil its caloric requirements. 'Starvation value' is accumulated through the year
  - ***Removal*** - When all individuals are dead, agent is removed from simulation
- **Reproduction** - At the end of the year every agent where both adults are still alive will have a 50% chance of having a new child.
- **Emancipation** - An agent with individuals coming of age will seek suitable matches among agents within its social range and originate a new agent. **Fission** is the only interaction between agents considered in this model

Experiments ABM @ BSC

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Experiments

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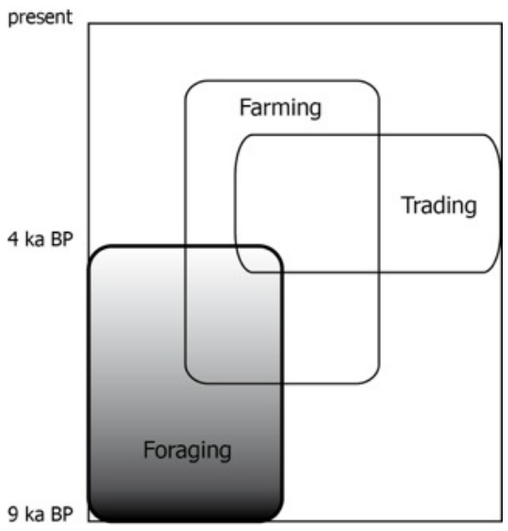
Experiments were run at three scales. Results for K-S only are presented here

Mean

- Test absolute thresholds for HGP disappearance dependent on variability in mean precipitation
- Test if the progressive reduction in mean precipitation in the Holocene explains the disappearance of HGP in N Gujarat 4 ka

Standard deviation

- Test population performance with increasing short-term variance in precipitation
- Test if higher short-term variance explains the disappearance of HGP in N Gujarat 4 ka



Time	Precipitation increment rate (%)	AYP KS (mm)
0 ka	0	468.20
4 ka	2.33	479.11
10 ka	5.83	495.50
12 ka	7	500.98
VYP		193.47

Liu et al. (2003), Sontakke and Singh (1996), Sontakke et al. (2008)

Exp. 1: shifted mean

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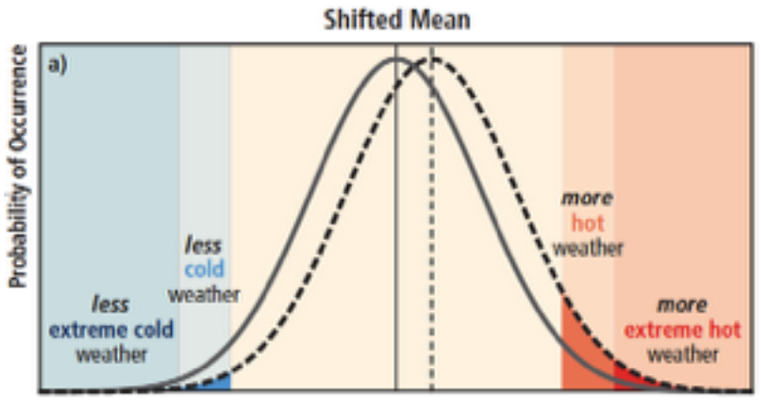
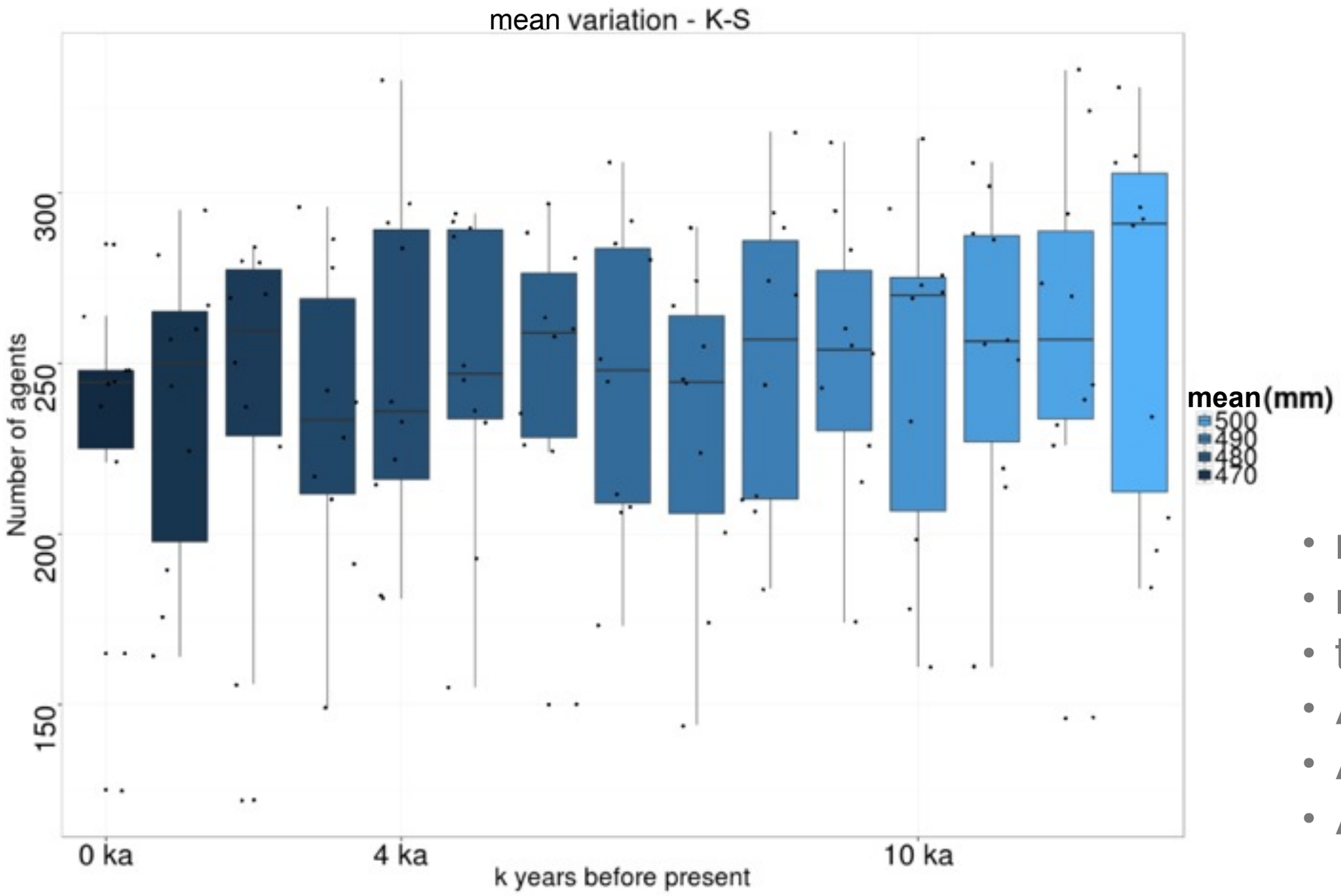


A reduction in mean c. **8** times larger than that attested 12-4 ka is necessary to explain HGP disappearance of in N Gujarat 4 ka



- mean 12 ka = 500.98
- mean 4 ka = 479.1
- threshold = 300
- Δ 12-4 ka = 21.9
- Δ th-4 ka = 179.1
- Δ th-4 ka/Δ 12-4 ka = **8.2**

Exp. 2: increased variability (sd)

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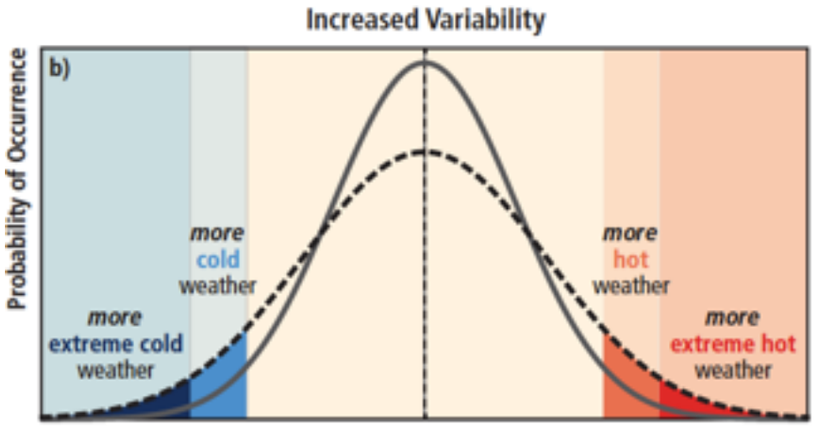
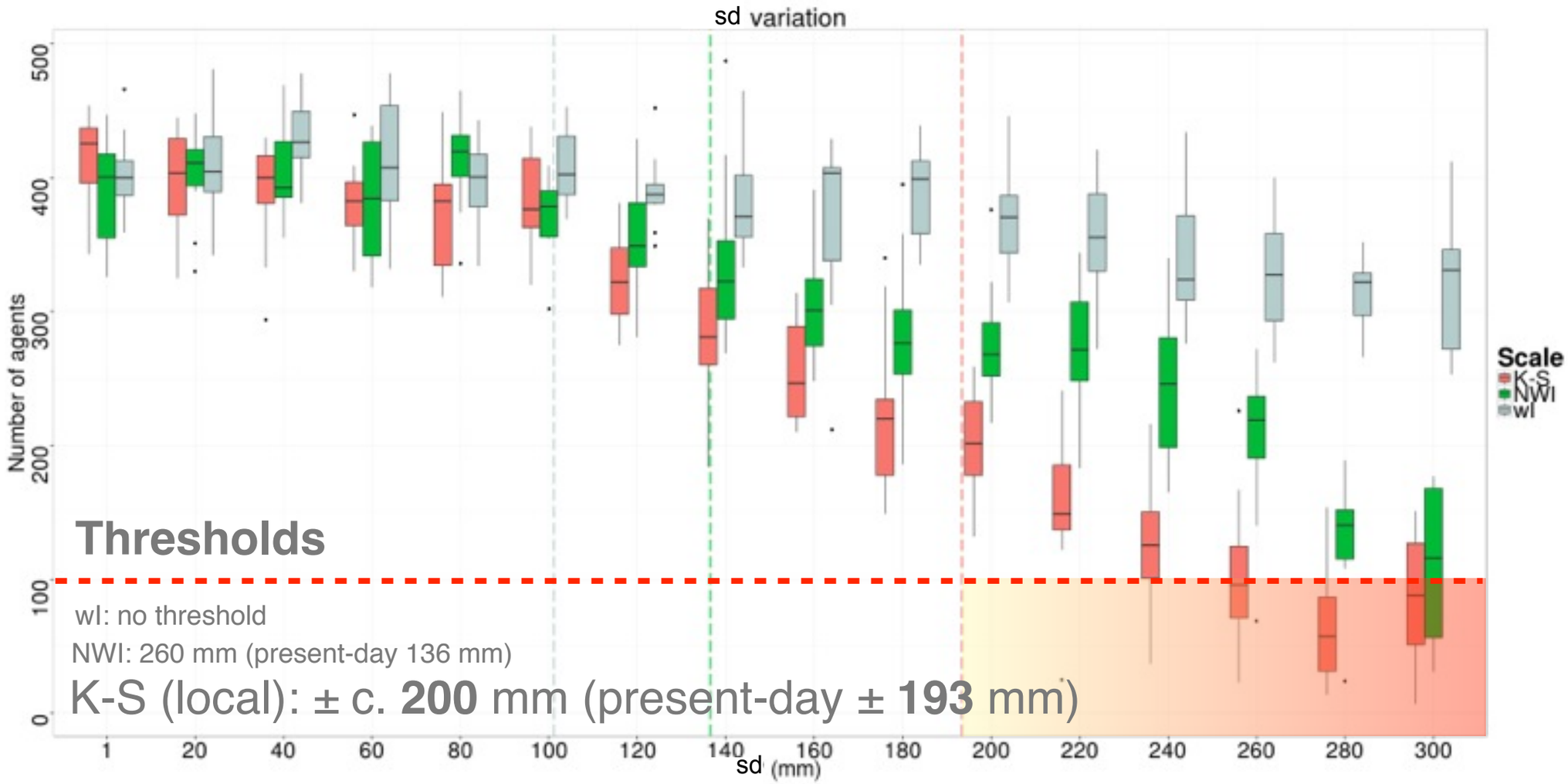


Threshold in sd for HGP viability 4 ka is ± c. **200** mm. This is just above (**+ 5%**) present-day sd (**193** mm). Hence: even a minor increase in the recurrence of severe droughts (>1 every 7 y) would potentially have led to HG disappearance



Summary

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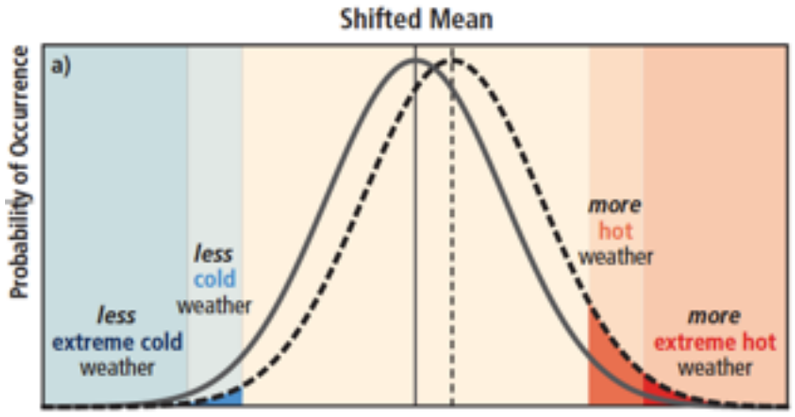
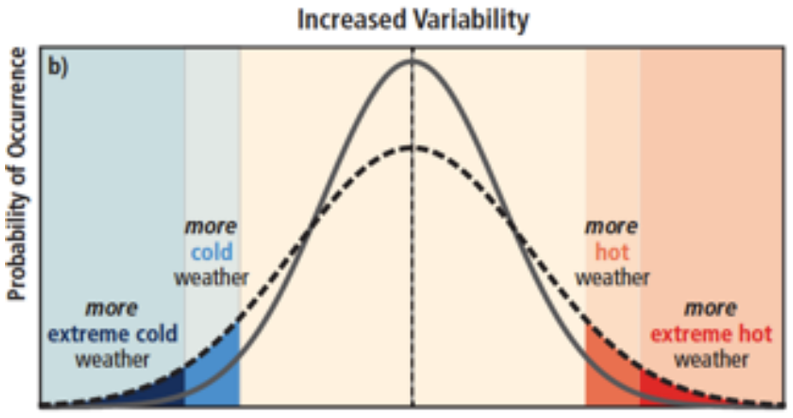


mean: Holocene changes in mean precipitation for the Asian monsoon do not explain the disappearance of HGP in K-S 4 ka.



sd: Short-term variance in precipitation is the main parameter affecting population performance.

- A slight increase (+ 5 %) in in precipitation variability (sd) 4 ka compared to the present would have contributed to HGP disappearance in K-S
- Severe droughts recurring more frequently than 1 every 7 y (present day) potentially explain HGP disappearance in K-S 4 ka
- Palaeoclimatic reconstructions (Clift and Plumb 2008; Anderson et al. 2010) suggest increased frequency of dry episodes locally c. 4 ka

Conclusions

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Global and continental models of precipitation for the Asian monsoon may not be representative of conditions found at the tail of the Asian monsoon trajectory

In the transitional areas of tropical semi-arid India short-term inter-annual variance (sd) is the strongest climatic parameter affecting population dynamics in our model

More SimulPast models

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http://link.springer.com/journal/10816/21/2/page/

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