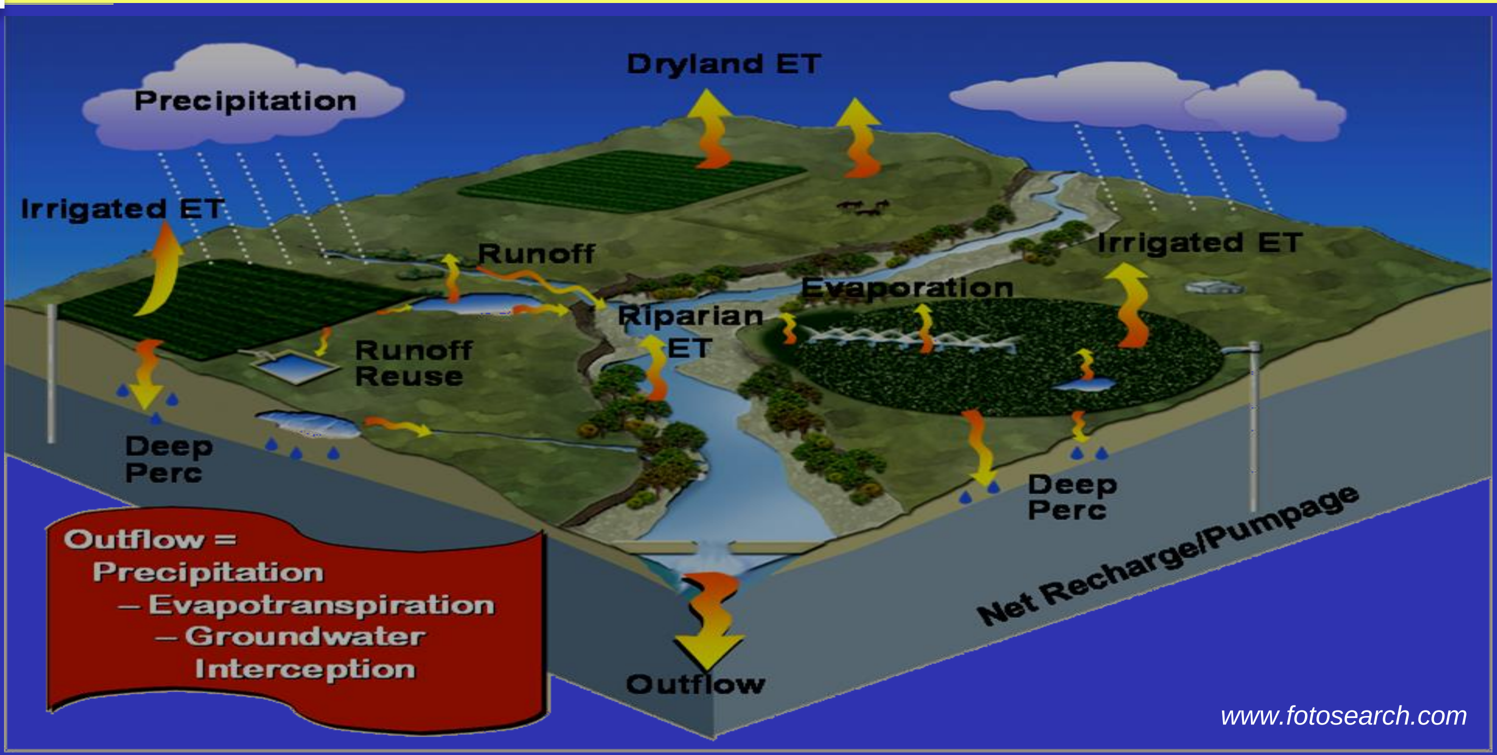
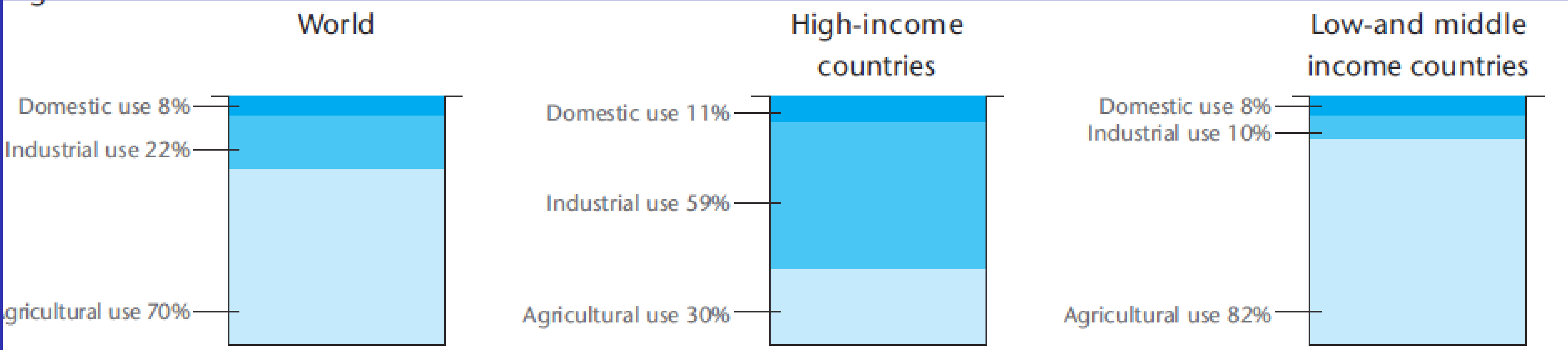
Some modifications to the simulation of Irrigation practices in rice paddy using SWAT



Dr. Balaji Narasimhan
Assistant Professor
Department of Civil Engineering
Indian Institute of Technology – Madras

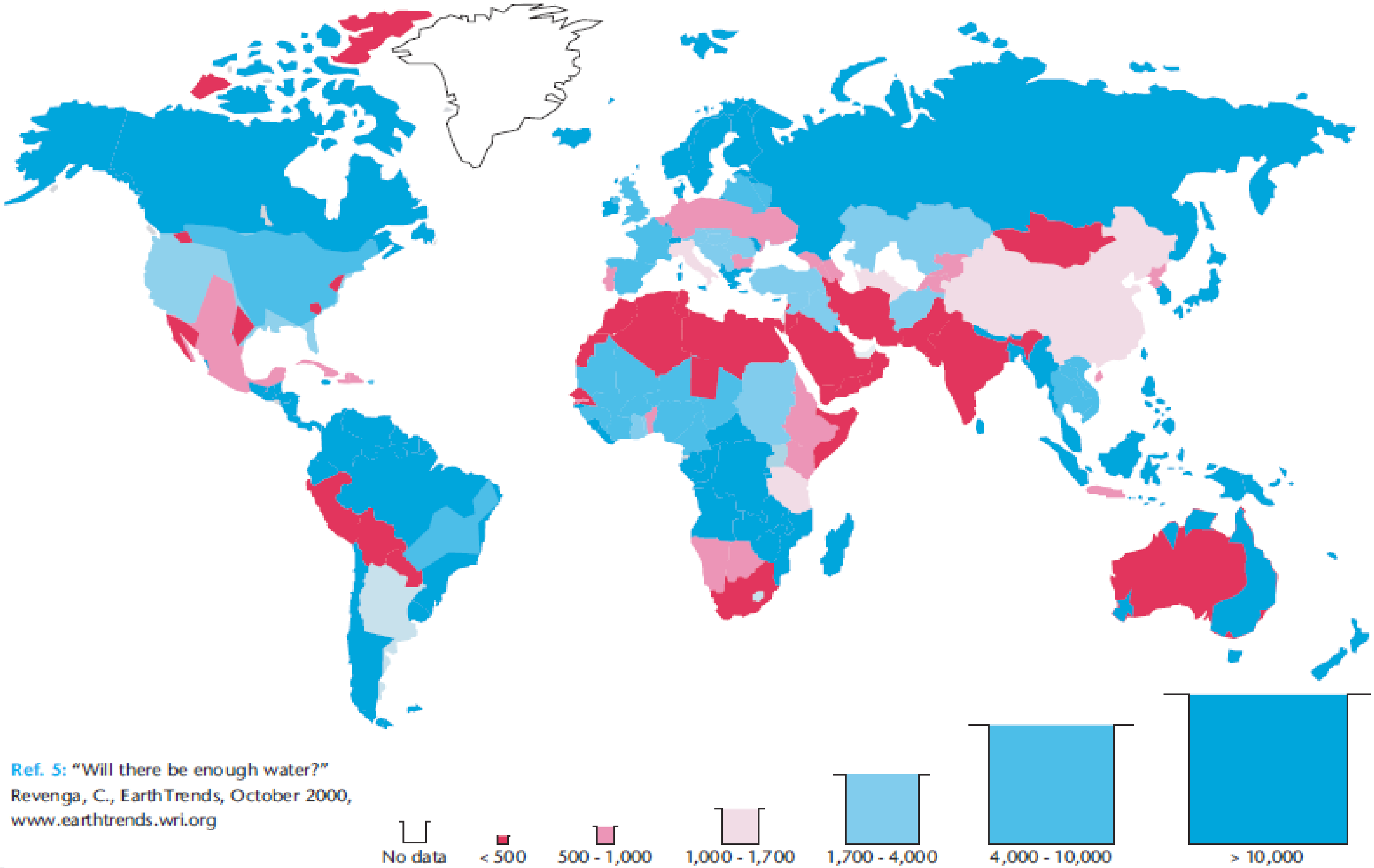
Water Use



Ref. 6: "Water for People, Water for Life" United Nations World Water Development Report, UNESCO, 2003
www.unesdoc.unesco.org

Annual Renewable Water

Annual renewable water (m3/person/year)[5]



Ref. 5: "Will there be enough water?"
Revenga, C., EarthTrends, October 2000,
www.earthtrends.wri.org

Irrigated Agriculture

Rank		Countries	Amount	Date
# 1		India:	558,080 sq km	2003
# 2		China:	545,960 sq km	2003
# 3		United States:	223,850 sq km	2003
# 4		Pakistan:	182,300 sq km	2003
# 5		Iran:	76,500 sq km	2003
# 6		Mexico:	63,200 sq km	2003
# 7		Turkey:	52,150 sq km	2003
# 8		Thailand:	49,860 sq km	2003
# 9		Bangladesh:	47,250 sq km	2003
# 10		Russia:	46,000 sq km	2003

Source: http://www.nationmaster.com

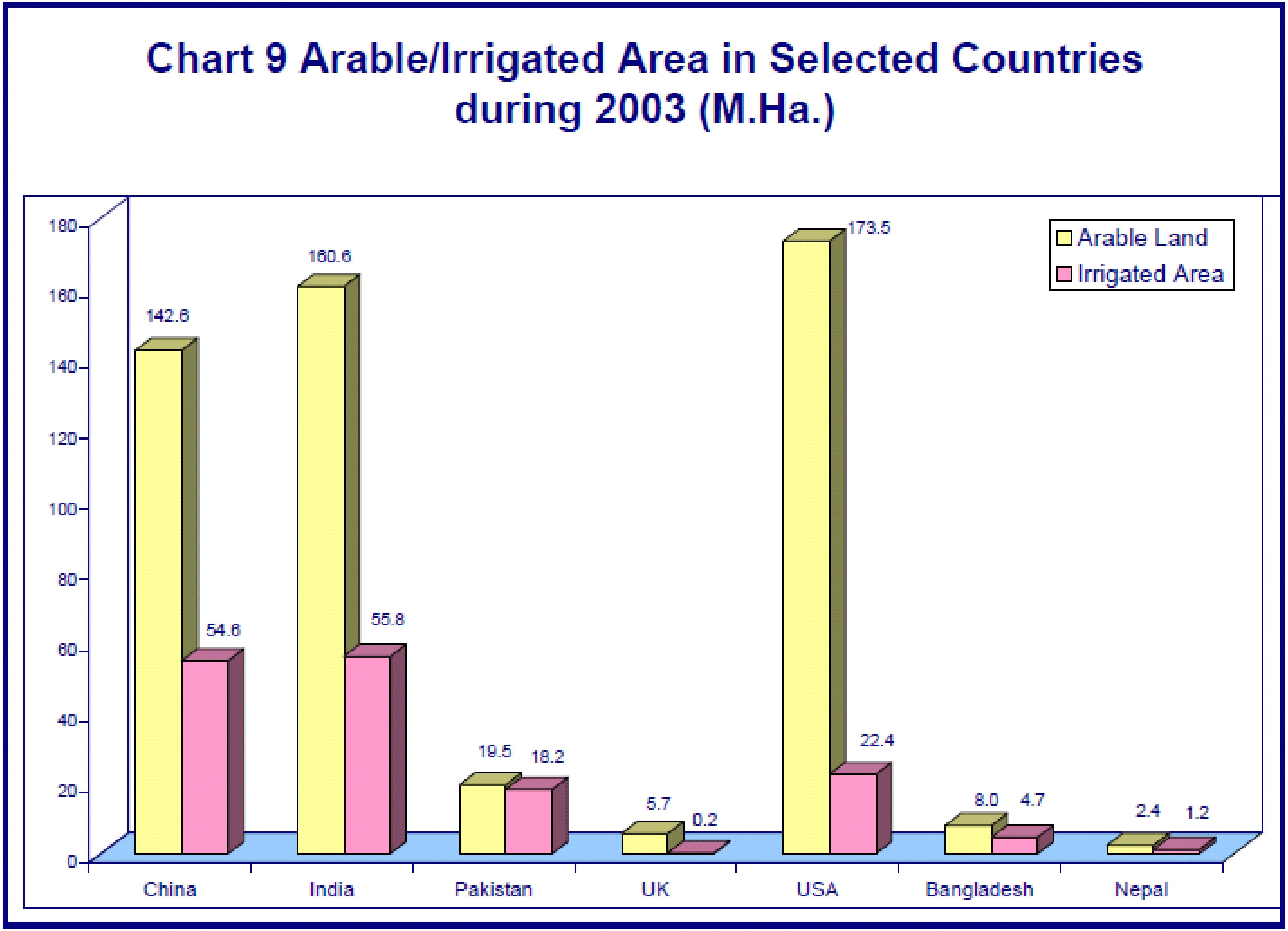


Chart 9 Arable/Irrigated Area in Selected Countries during 2003 (M.Ha.)
Arable Land
Irrigated Area
0
20
40
60
80
100
120
140
160
180
142.6
54.6
160.6
55.8
19.5
18.2
5.7
0.2
173.5
22.4
8.0
4.7
2.4
1.2
China
India
Pakistan
UK
USA
Bangladesh
Nepal

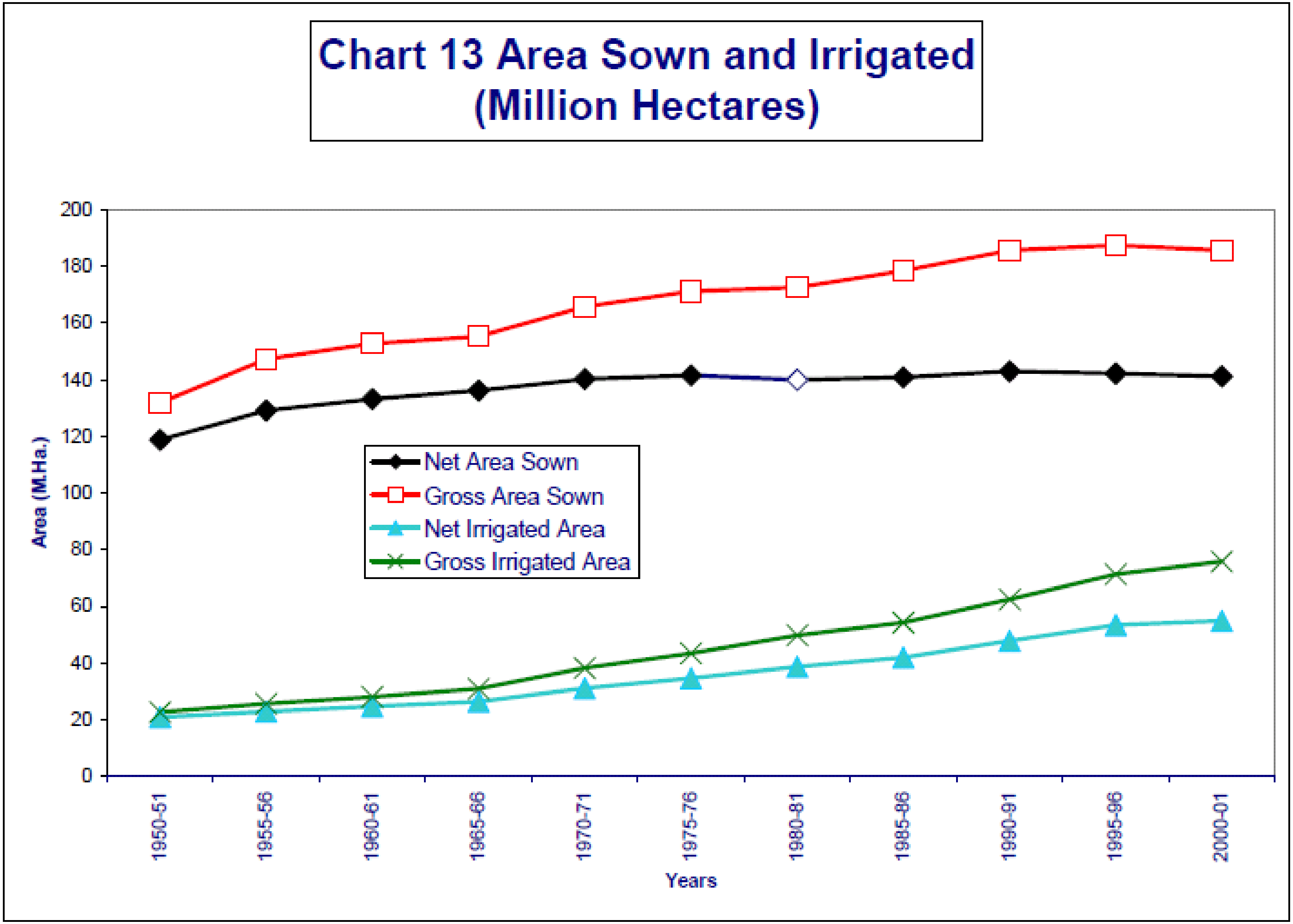
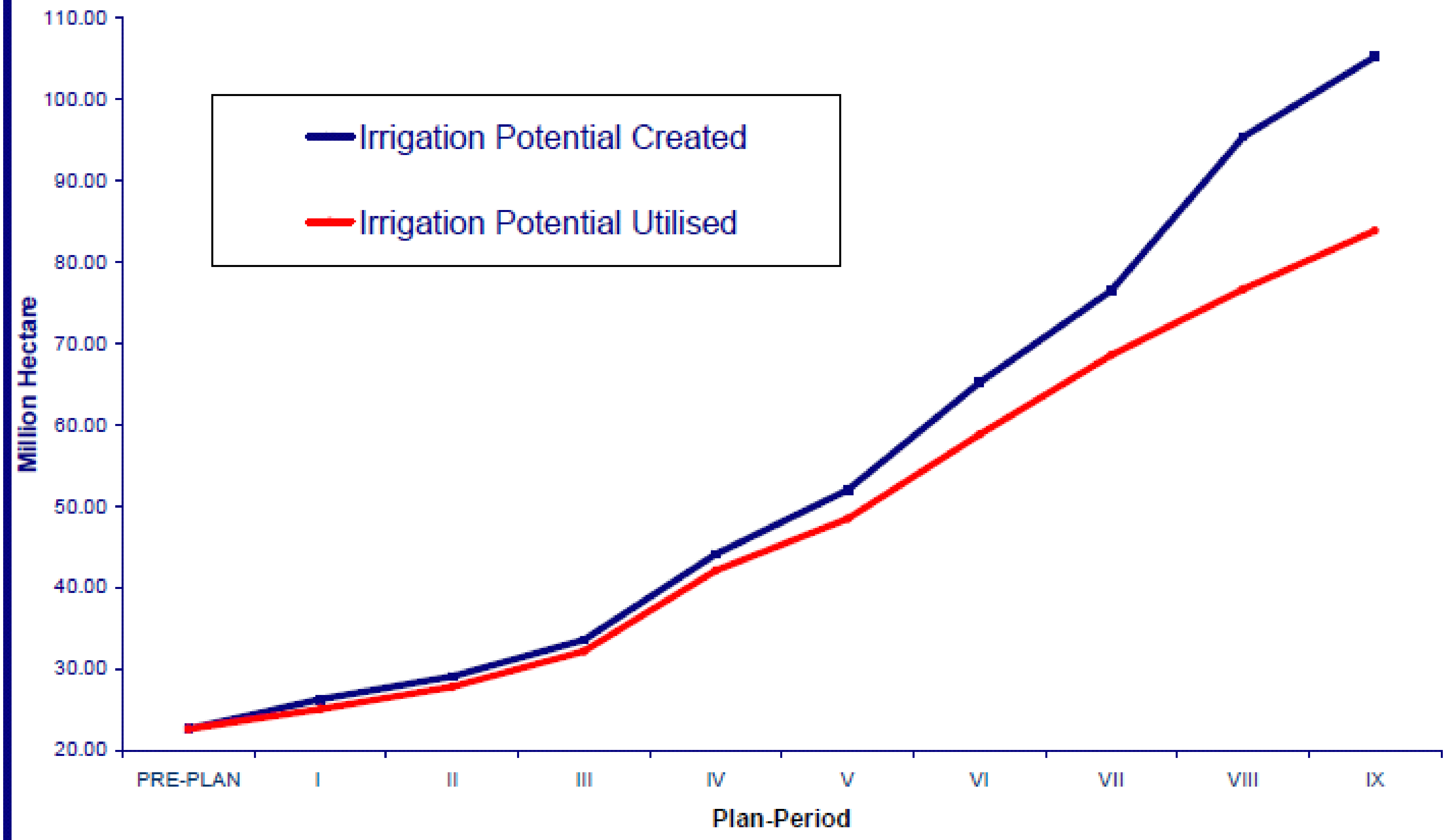


Chart 13 Area Sown and Irrigated
(Million Hectares)
Area (M.Ha.)
0
20
40
60
80
100
120
140
160
180
200
Net Area Sown
Gross Area Sown
Net Irrigated Area
Gross Irrigated Area
1950-51
1955-56
1960-61
1965-66
1970-71
1975-76
1980-81
1985-86
1990-91
1995-96
2000-01
Years

Chart 17 Planwise Irrigation Potential Created and Utilised (Cumulative)



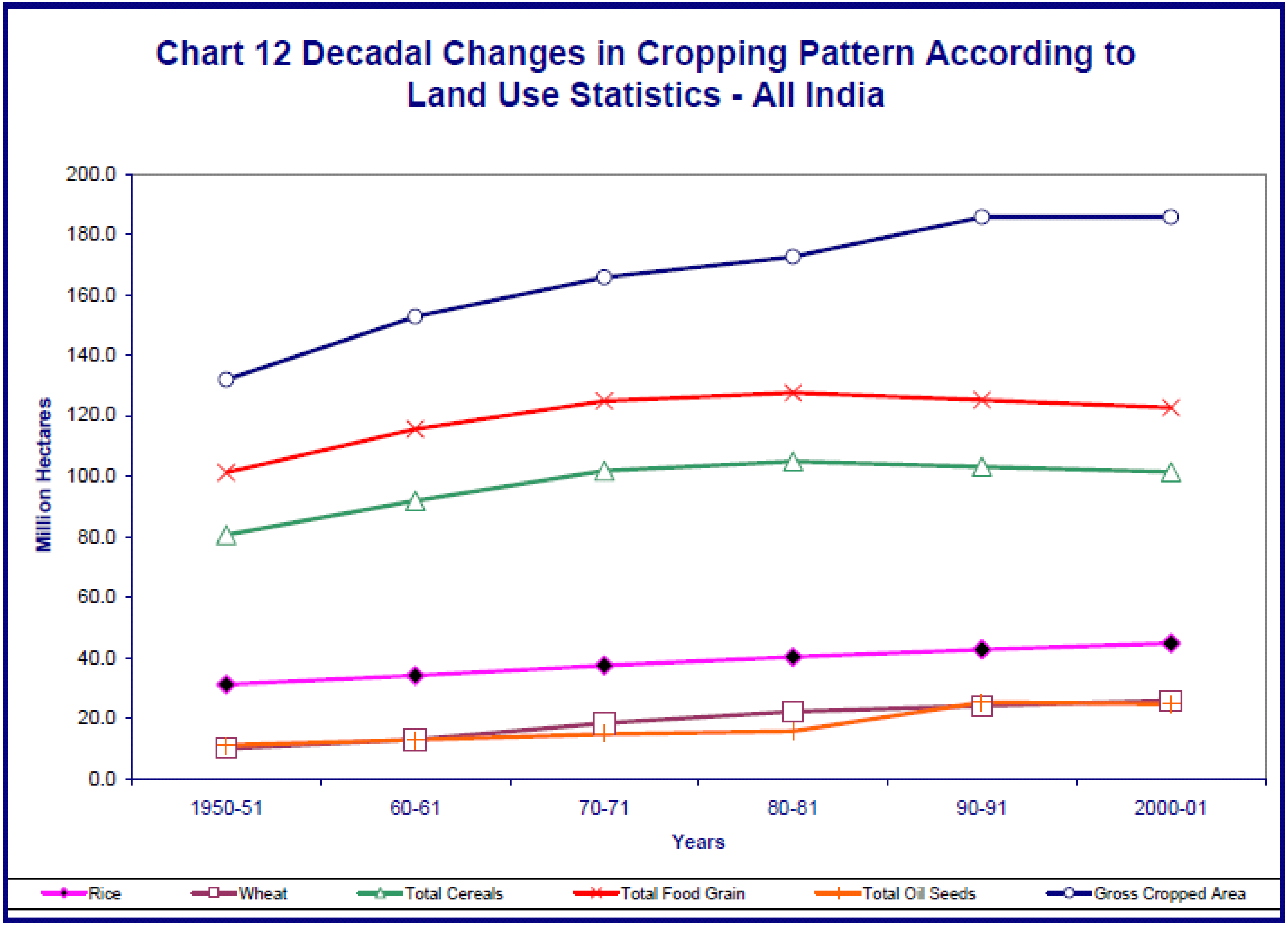


Chart 12 Decadal Changes in Cropping Pattern According to Land Use Statistics - All India
Million Hectares
200.0
180.0
160.0
140.0
120.0
100.0
80.0
60.0
40.0
20.0
0.0
1950-51
60-61
70-71
80-81
90-91
2000-01
Years
Rice
Wheat
Total Cereals
Total Food Grain
Total Oil Seeds
Gross Cropped Area

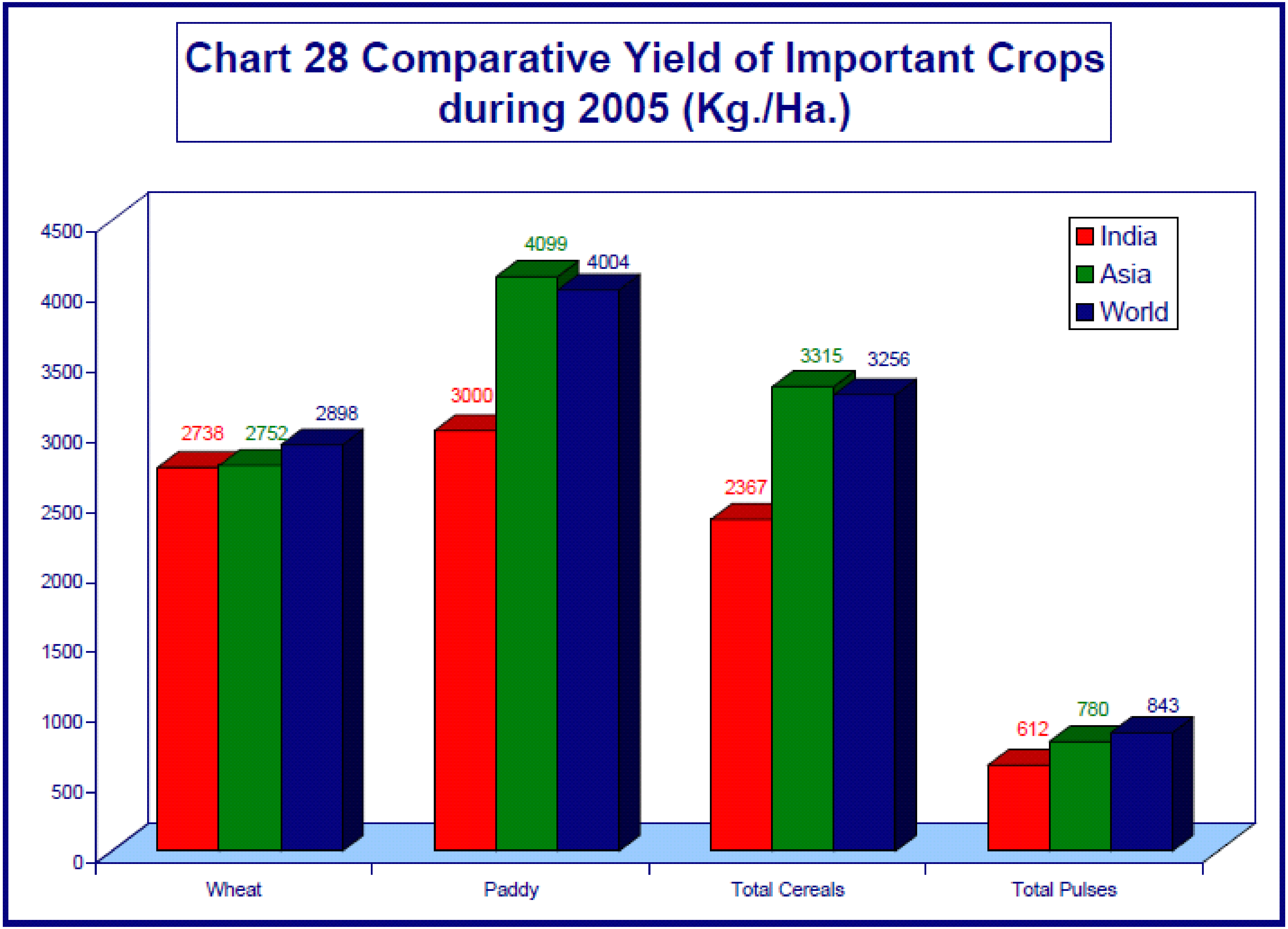


Chart 28 Comparative Yield of Important Crops during 2005 (Kg./Ha.)
India
Asia
World
0
500
1000
1500
2000
2500
3000
3500
4000
4500
2738
2752
2898
3000
4099
4004
2367
3315
3256
612
780
843
Wheat
Paddy
Total Cereals
Total Pulses

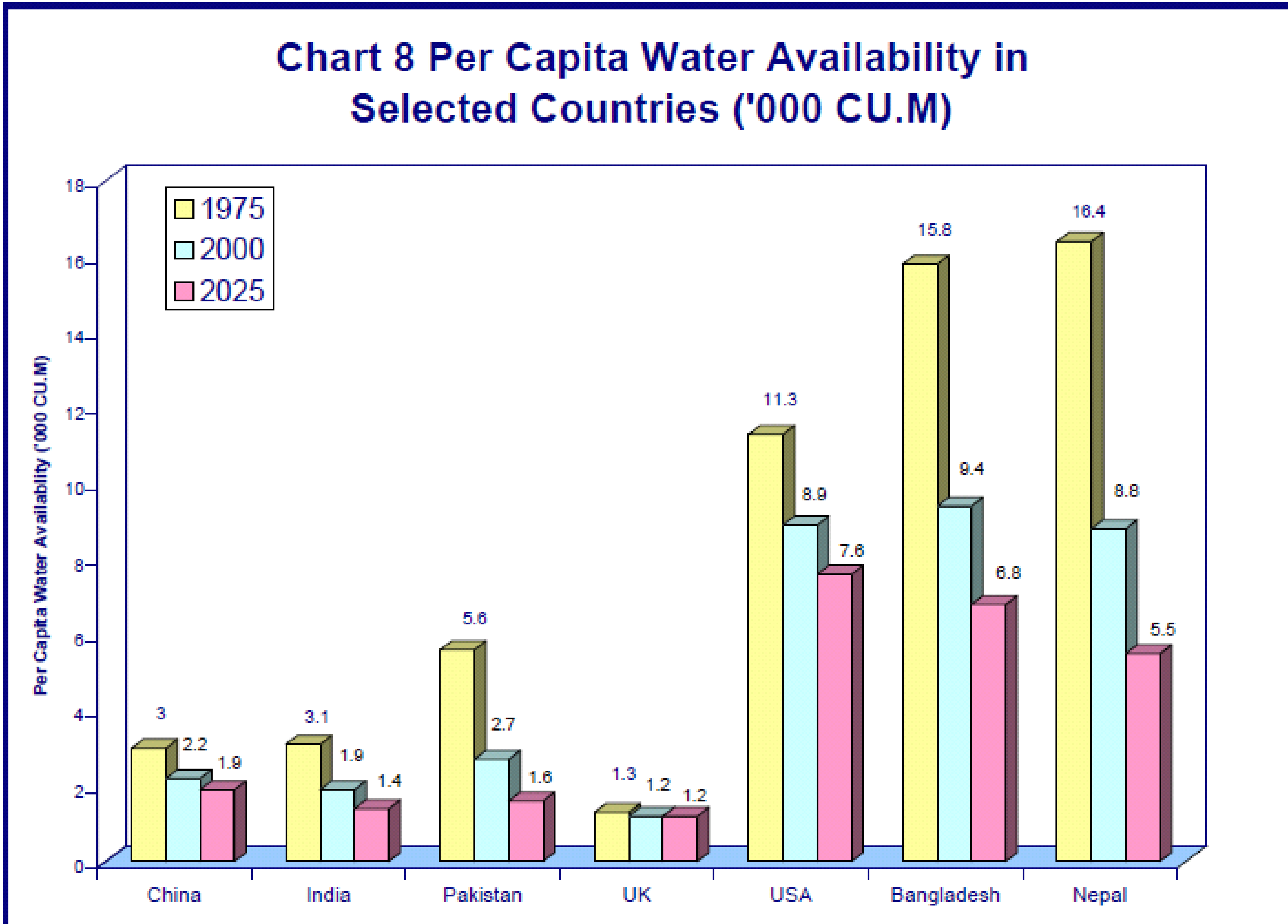
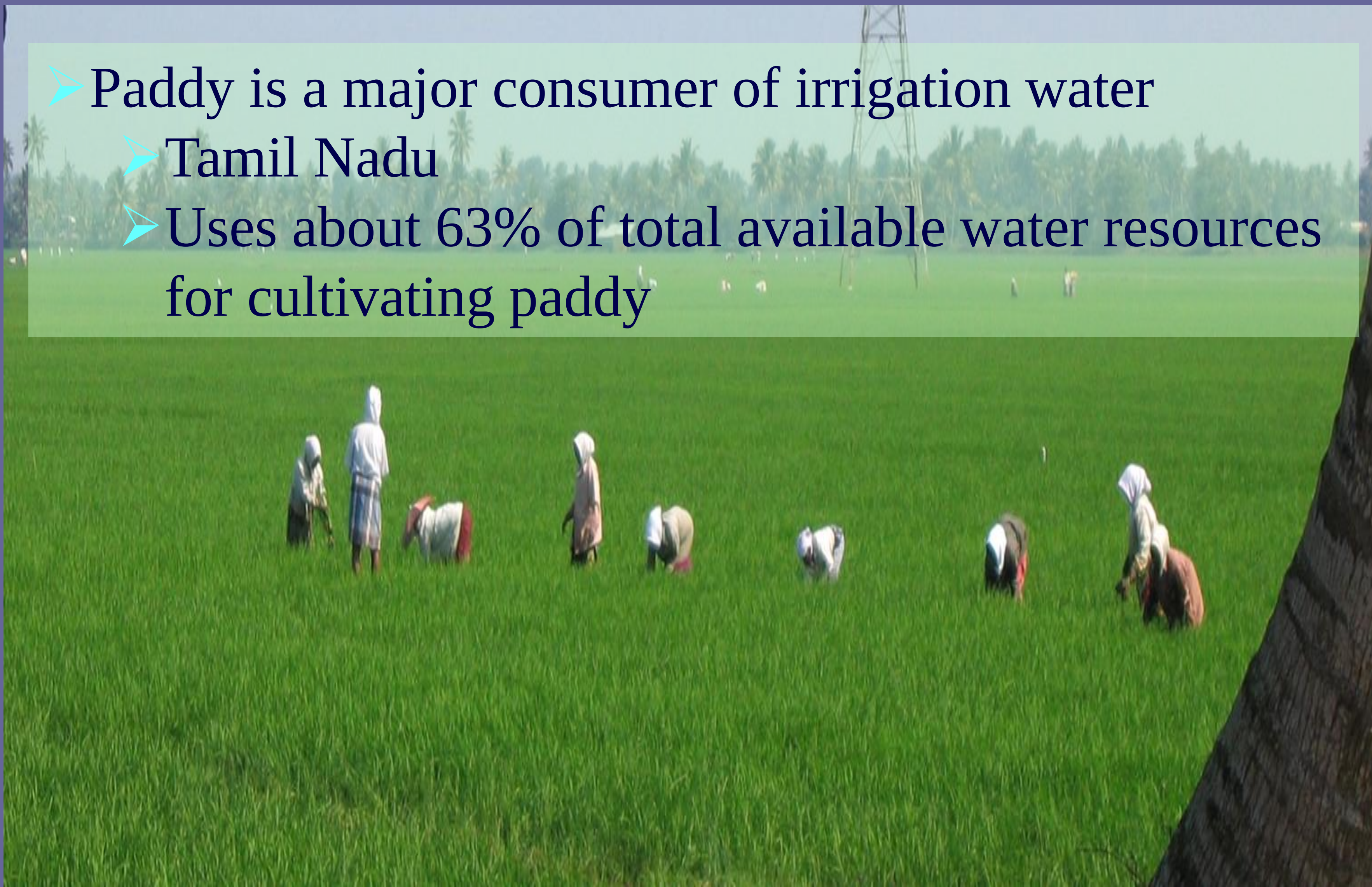


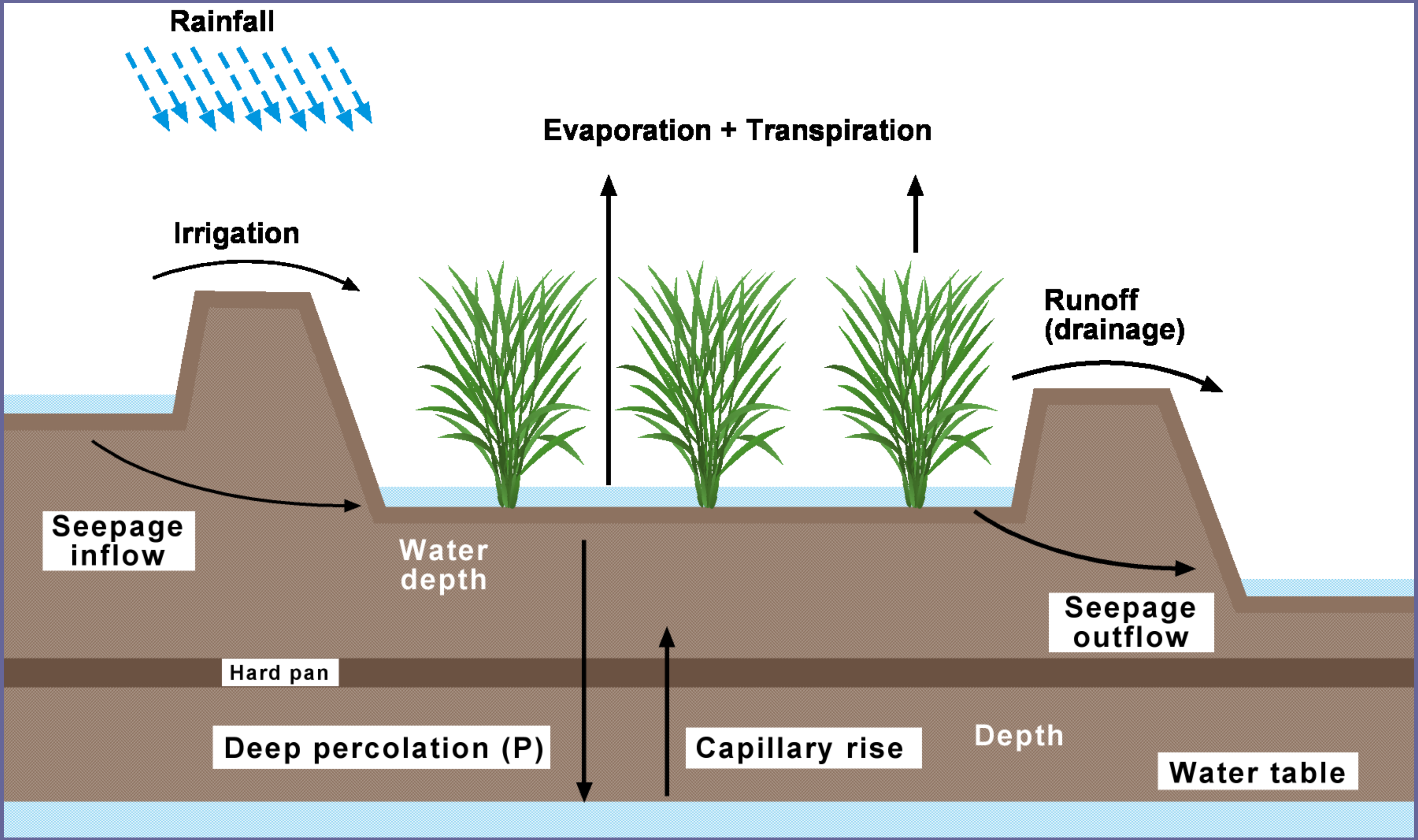
Chart 8 Per Capita Water Availability in Selected Countries ('000 CU.M)
Per Capita Water Availability ('000 CU.M)
0
2
4
6
8
10
12
14
16
18
1975
2000
2025
3
2.2
1.9
3.1
1.9
1.4
5.6
2.7
1.6
1.3
1.2
1.2
11.3
8.9
7.6
15.8
9.4
6.8
16.4
8.8
5.5
China
India
Pakistan
UK
USA
Bangladesh
Nepal

Significance

- Paddy is a major consumer of irrigation water
  - Tamil Nadu
  - Uses about 63% of total available water resources for cultivating paddy



Field water balance lowland rice



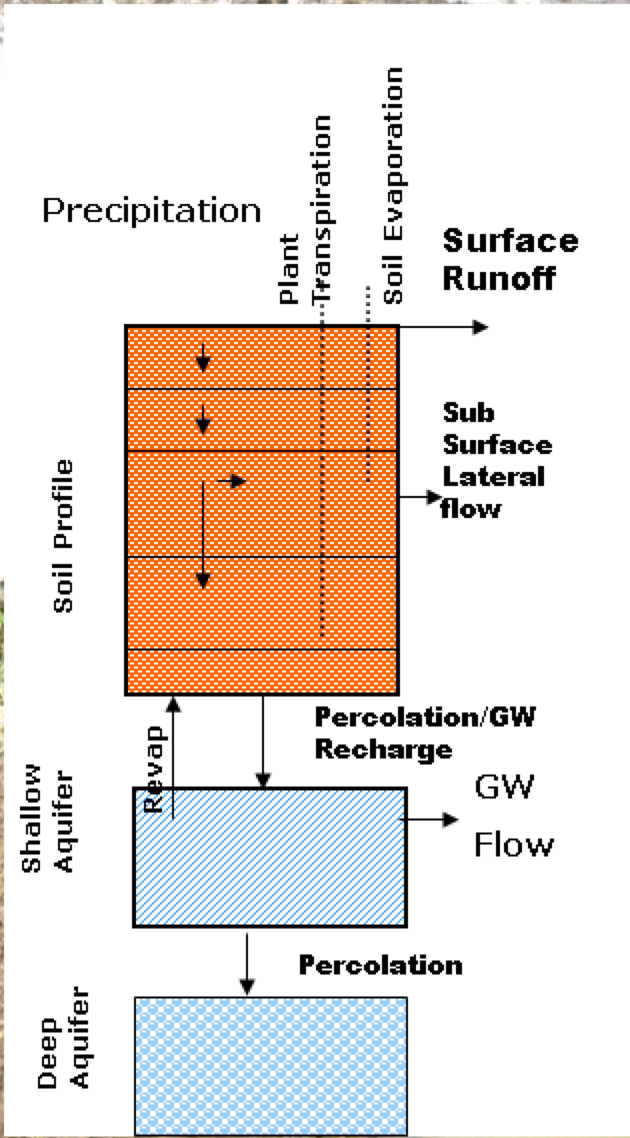
Source: IRRI

Irrigation efficiency $\underset{-}{\sim}$ (conveyance efficiency X field application efficiency)=40%

Water diverted from source = Irrigation requirement / Irri. Eff

Water applied in the field = Water diverted from source X Conv. Eff.

Water lost in conveyance = Water diverted – water applied



	Earthen canals			Lined canals
Soil type	**Sand**	**Loam**	**Clay**	
Canal length				
Long (> 2000m)	60%	70%	80%	95%
Medium (200-2000m)	70%	75%	85%	95%
Short (< 200m)	80%	85%	90%	95%

Source: FAO manual

Irrigation methods	**Field application efficiency**
Surface irrigation (border, furrow, basin)	60%
Sprinkler irrigation	75%
Drip irrigation	90%

$$e = \frac{ec \times ea}{100}$$

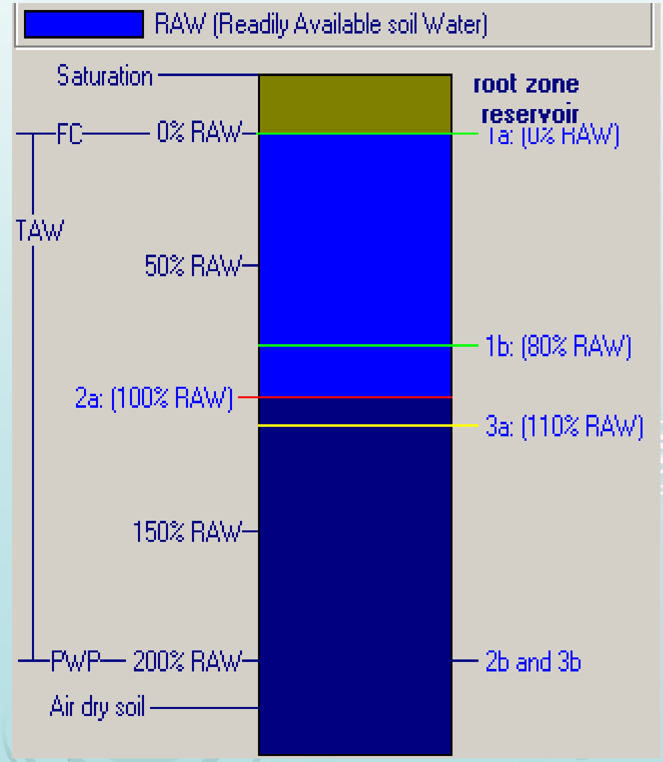
with

e = scheme irrigation efficiency (%)
ec = conveyance efficiency (%)
ea = field application efficiency (%)

A scheme irrigation efficiency of 50-60% is good; 40% is reasonable, while a scheme Irrigation efficiency of 20-30% is poor.

Auto Irrigation trigger

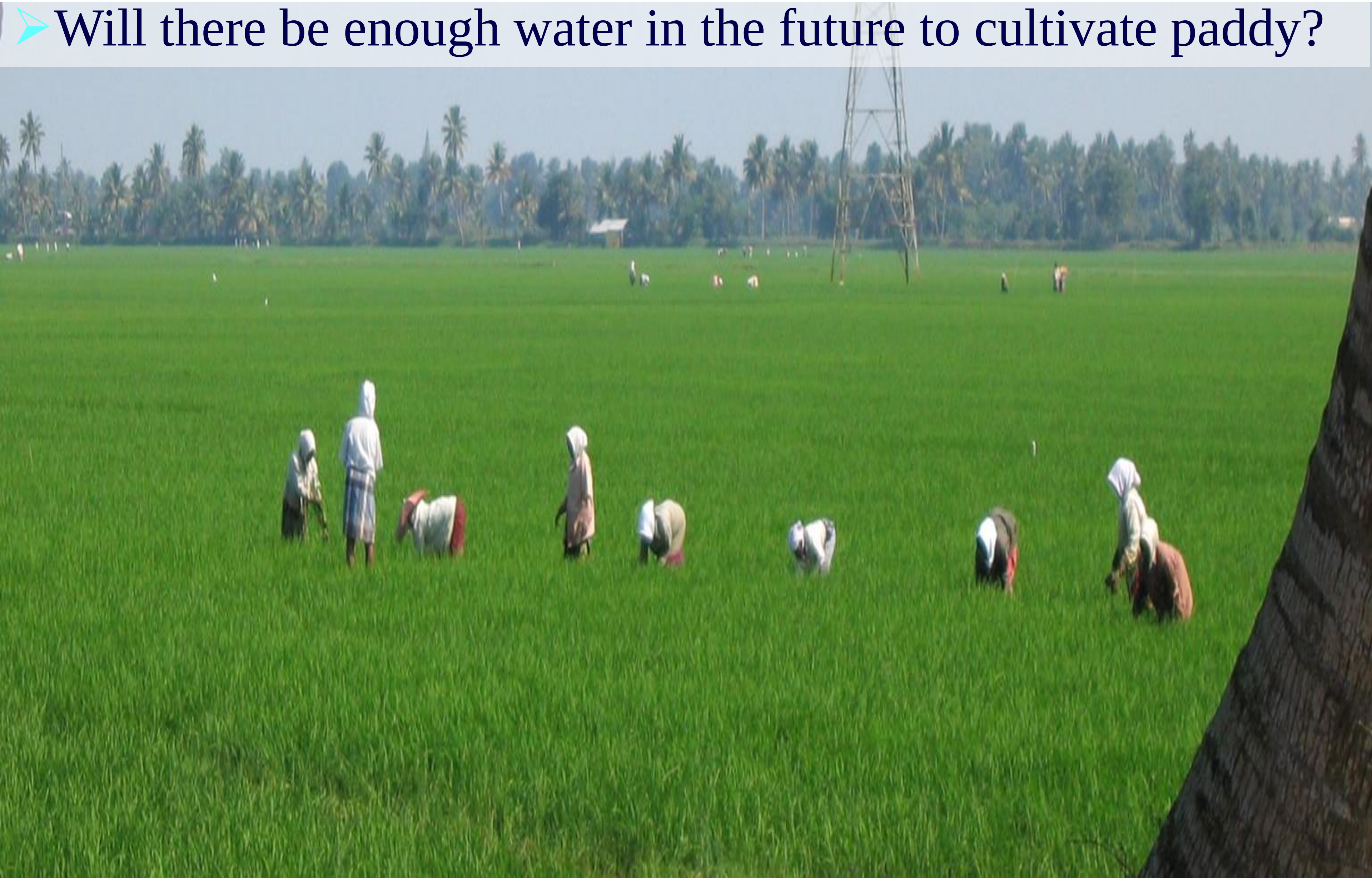
- Plant growth
  - Fraction of potential plant growth reduced due to water stress
- Soil water stress
  - 1 – Depletion. Fac
  - Depletion factor
    - SW/TAWC



Crop		Root zone depth (RZD)[1] (m)	Allowable soil moisture depletion (P)[2]
a. Small vegetables			
Broccoli		0.4-0.6	0.45
Brussels sprouts		0.4-0.6	0.45
Cabbages		0.5-0.8	0.45
Carrots		0.5-1.0	0.35
Cauliflowers		0.4-0.7	0.45
Celery		0.3-0.5	0.20
Garlic		0.3-0.5	0.30
Lettuce		0.3-0.5	0.30
Onions	– dry	0.3-0.6	0.30
	– green	0.3-0.6	0.35
	– seed	0.3-0.6	0.35
Spinach		0.3-0.5	0.20
Radishes		0.3-0.5	0.30
b. Vegetables – Solanum Family (*Solanacea*)			
Eggplant		0.7-1.2	0.45
Sweet peppers (bell)		0.5-1.0	0.30
Tomatoes		0.7-1.5	0.40
c. Vegetables – Cucumber Family (*Cucurbitaceae*)			
Cantaloupes		0.9-1.5	0.45
Cucumbers	– fresh market	0.7-1.2	0.50
	– machine harvest	0.7-1.2	0.50
Pumpkin, winter squash		1.0-1.5	0.35
Squash, zucchini		0.6-1.0	0.50
Sweet melon		0.8-1.5	0.40
Watermelon		0.8-1.5	0.40
d. Roots and tubers			
Beet, table		0.6-1.0	0.50
Cassava	– year 1	0.5-0.8	0.35
	– year 2	0.7-1.0	0.40
Parsnips		0.5-1.0	0.40
Potatoes		0.4-0.6	0.35
Sweet potatoes		1.0-1.5	0.65
Turnips (and Rutabaga)		0.5-1.0	0.50
Sugar beet		0.7-1.2	0.55[3]

FAO irrigation manual

- Significant quantum of water is used in the cultivation of paddy.
- Will there be enough water in the future to cultivate paddy?



ClimaRice

*www.**climarice**.org*

Partners

Bioforsk

IWMI
International Water Management Institute

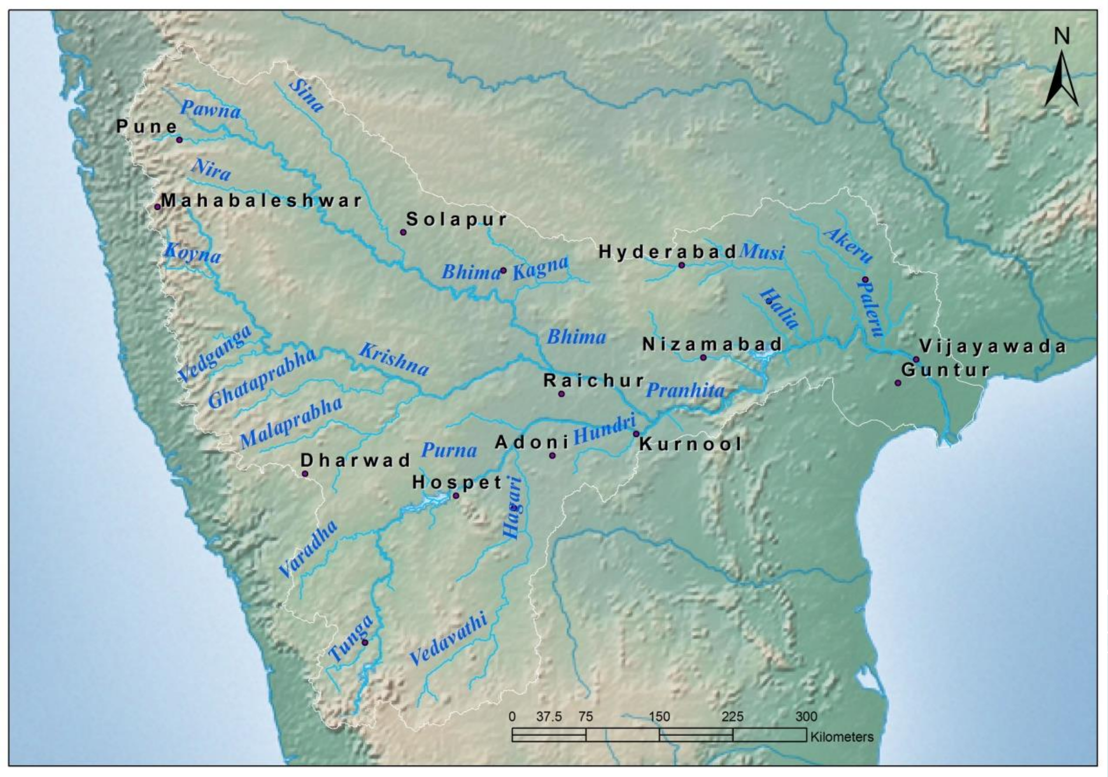
Tamil Nadu Agricultural University

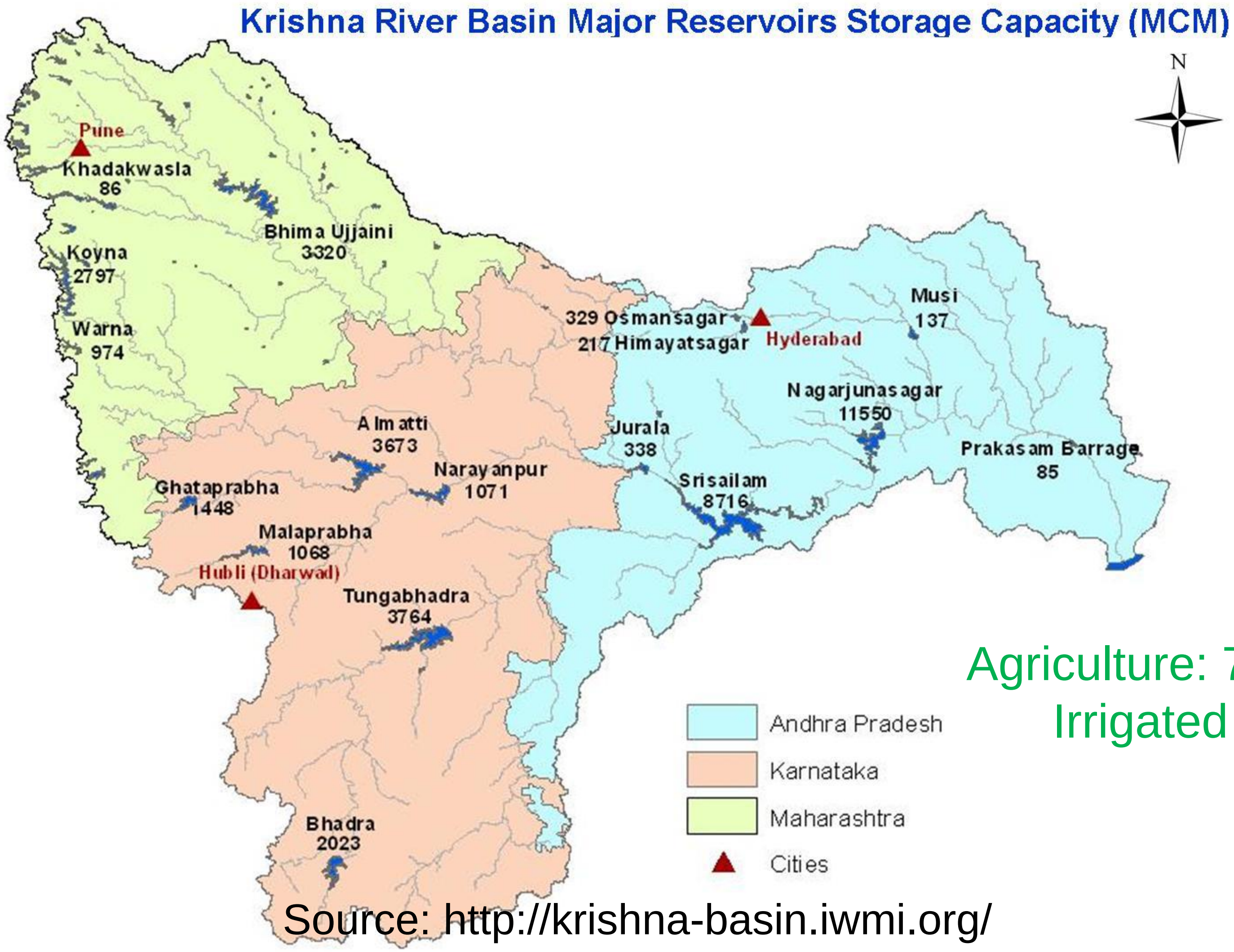
iprc
International Pacific Research Center

Indian Institute of Technology Madras

Krishna Basin

- Salient features
  - Length: 1,400 km
  - Drainage area: 258,948 sq.km
  - Population: 76.5 million
    - Density: 287/sq.km
  - Climate: Semi-arid
  - Rainfall: 800mm
    - 300 – 2000mm





Source: http://krishna-basin.iwmi.org/

Agriculture: 78%

Irrigated Agriculture: 40%

Surface Water potential 78.1 km^3

Ground Water potential 26.41 km^3

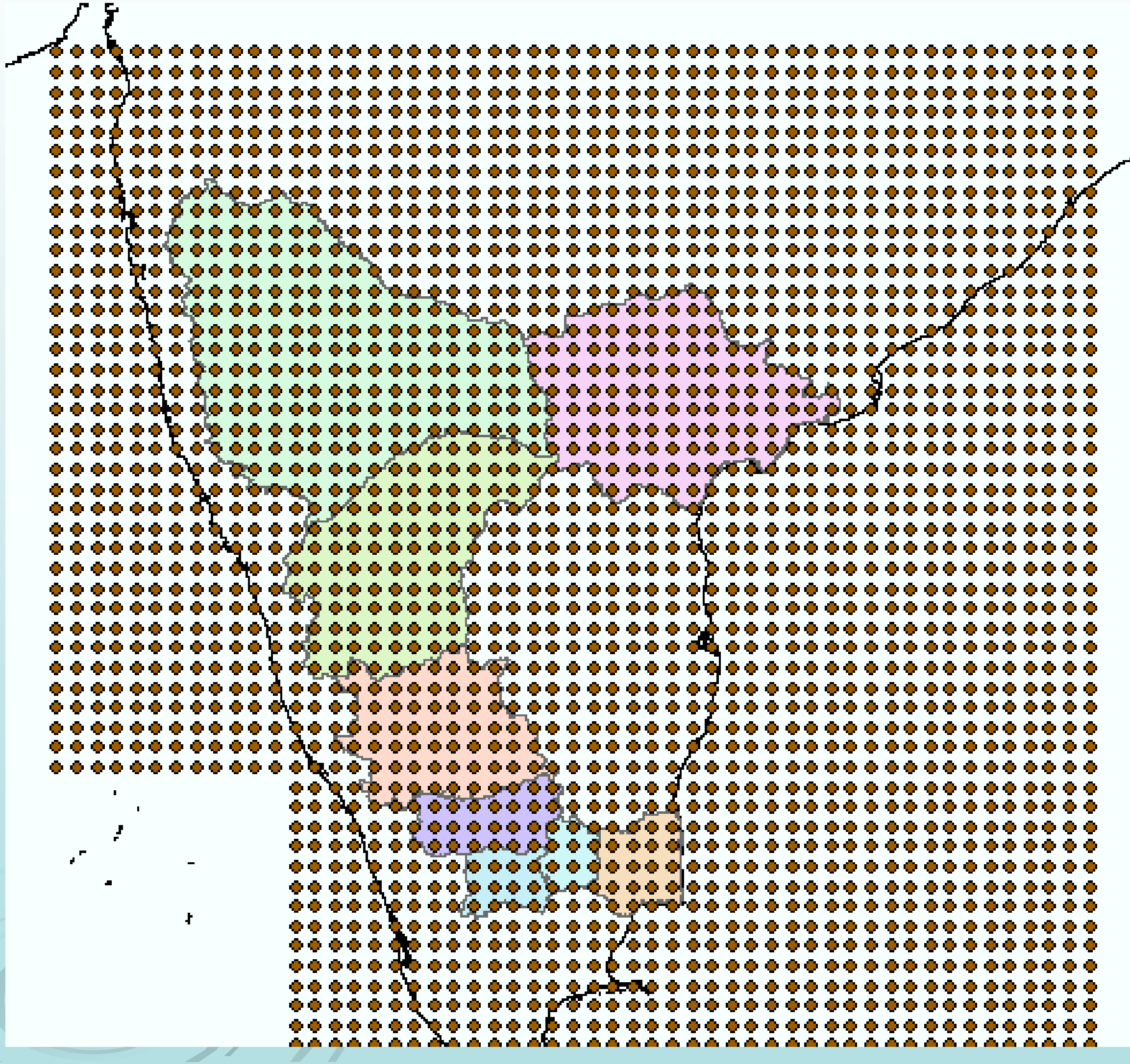
Close basin: All the water resources are allocated

Modeling Process

- Analysis of weather data inputs from climate model
  - Bias correction of precipitation
- Simulation of water availability at important control points
  - Major reservoir locations and diversions
- Irrigation water demand

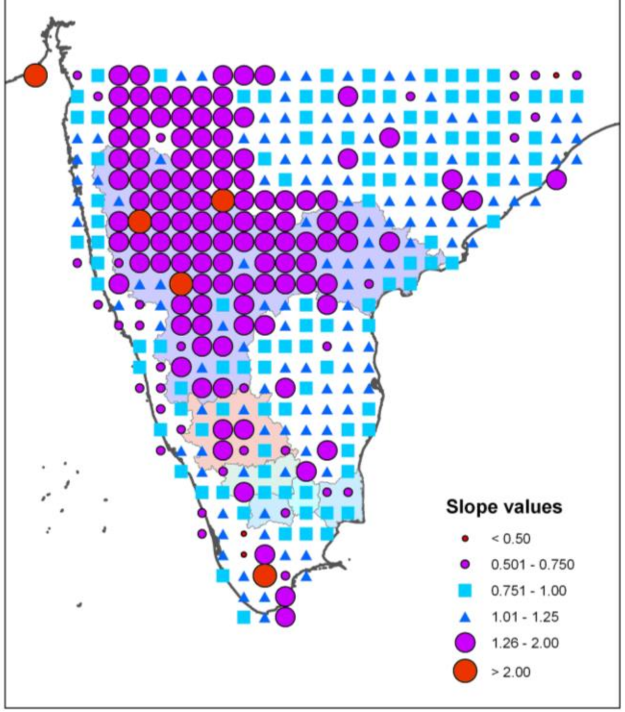
Climate Model

- GFDL
  - Baseline, A1B and Y1B
    - IPRC-RegCM
      - – 0.25º × 0.25º



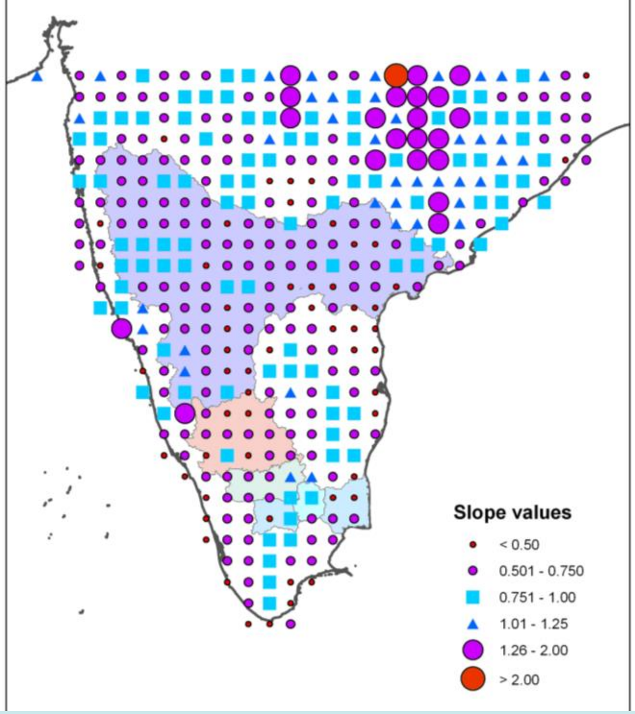
Slope Values of the regression fit for JJAS

(Orderd series of original baseline data with IMD 0.5 deg gridded data)



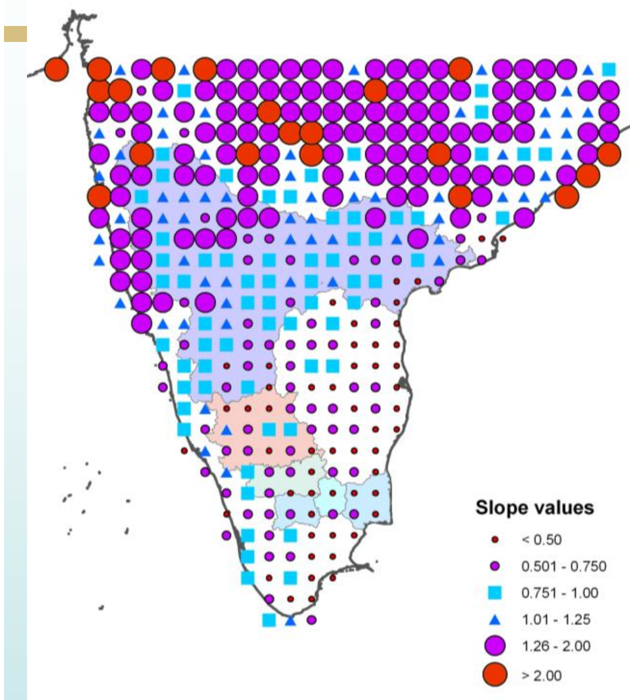
Slope Values of the regression fit for ONDJ

(Orderd series of original baseline data with IMD 0.5 deg gridded data)



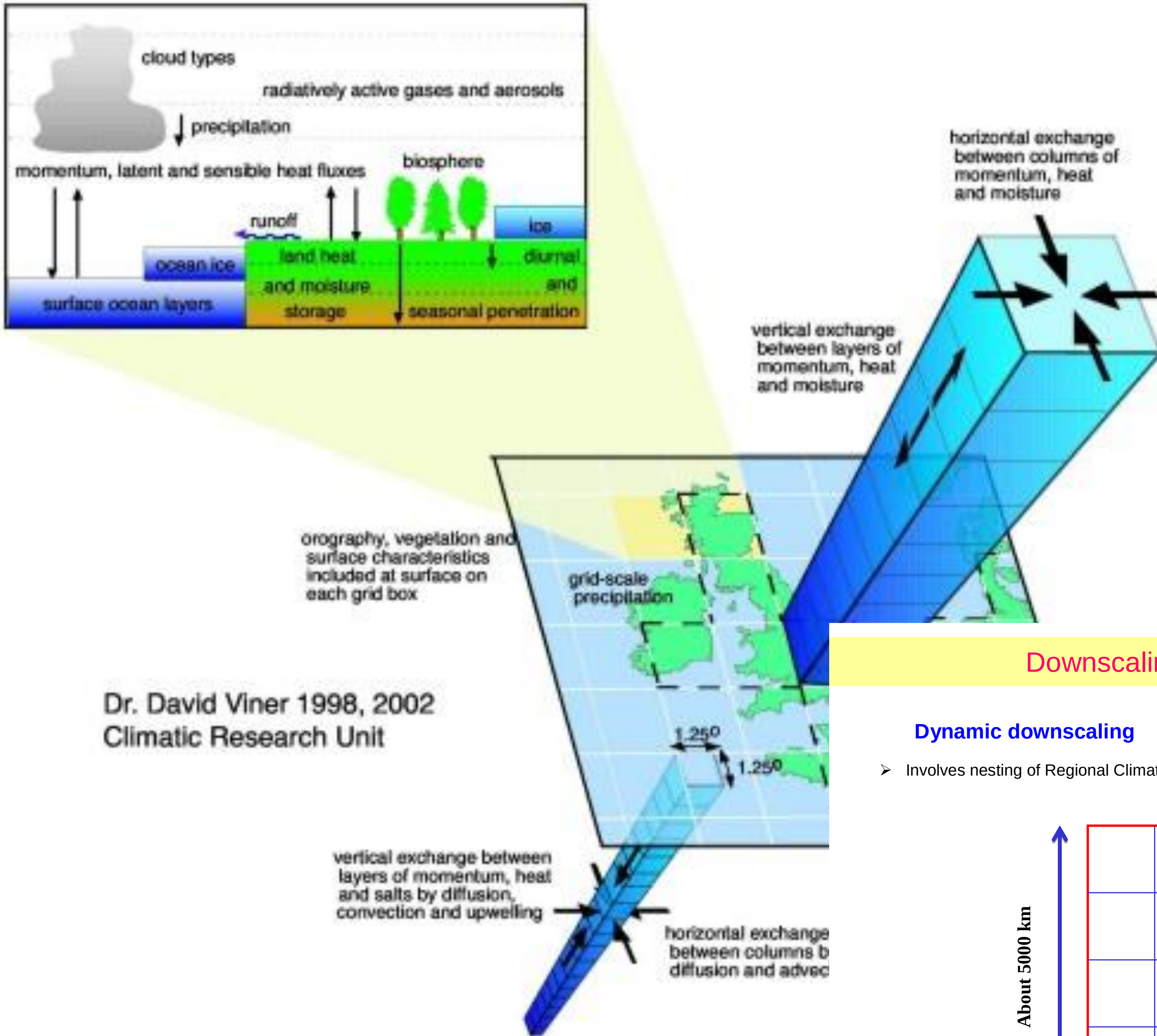
Slope Values of the regression fit for FMAM

(Orderd series of original baseline data with IMD 0.5 deg gridded data)



Reason for Bias in RCM

- Systematic model errors
  - Imperfect conceptualization
    - Model physics is quite complicated
  - Discretization and spatial averaging within grid cells

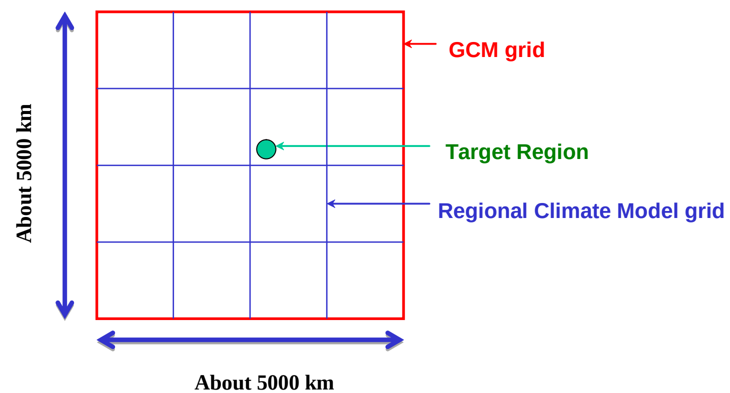


Dr. David Viner 1998, 2002
Climatic Research Unit

Downscaling Models – An Overview

Dynamic downscaling

- Involves nesting of Regional Climate Model (RCM) in GCM



Source: VVS, IISc

Need for Bias correction

- Rainfall underestimated
  - May not have enough water for irrigation
  - Irrigation demand cannot be predicted correctly
- Rainfall overestimated
  - May indicated more water is available
  - Irrigation demand cannot be predicted correctly
- Flood and drought assessment

Bias adjustment

- Baseline scenario
  - Equi-probability transformation
    - The simulated rainfall of a given probability of exeedance was made equivalent to the IMD rainfall of same exceedance

Distribution transfer

- Probability mapping or quantile-quantile mapping

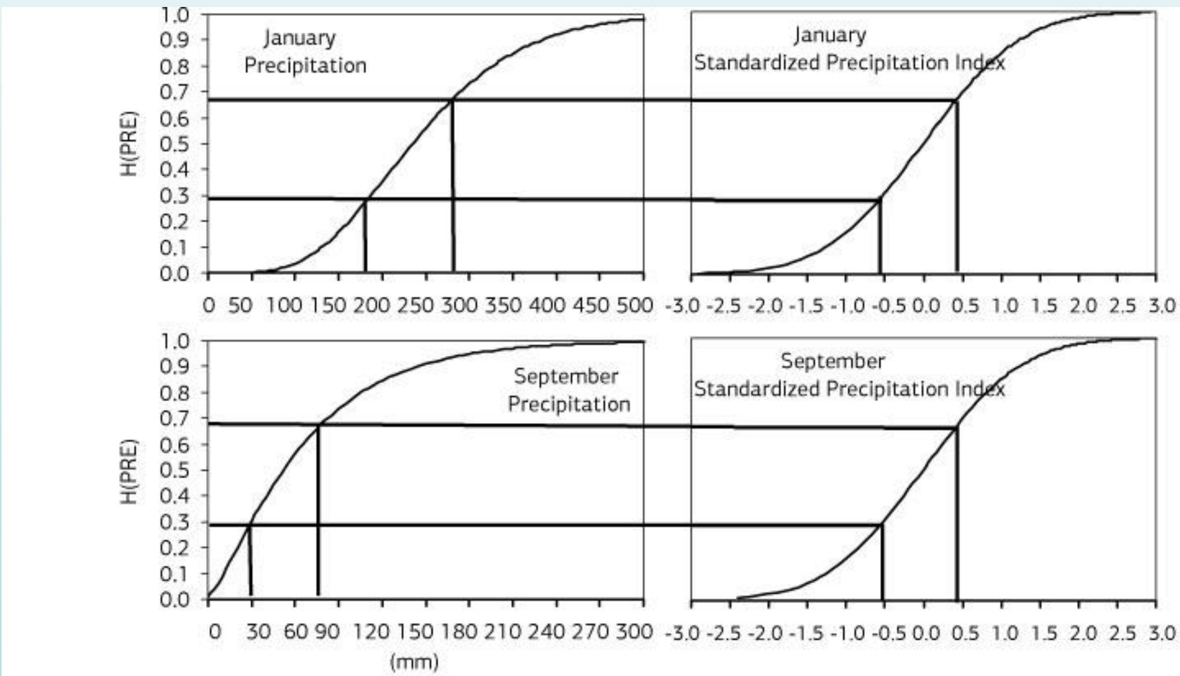
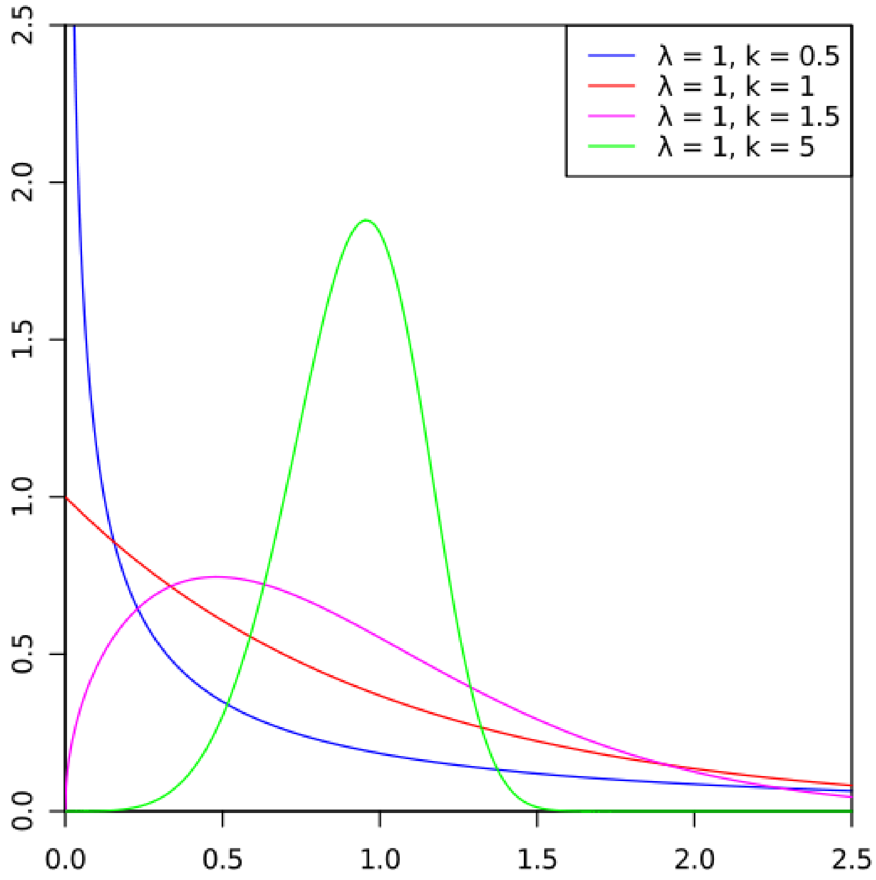
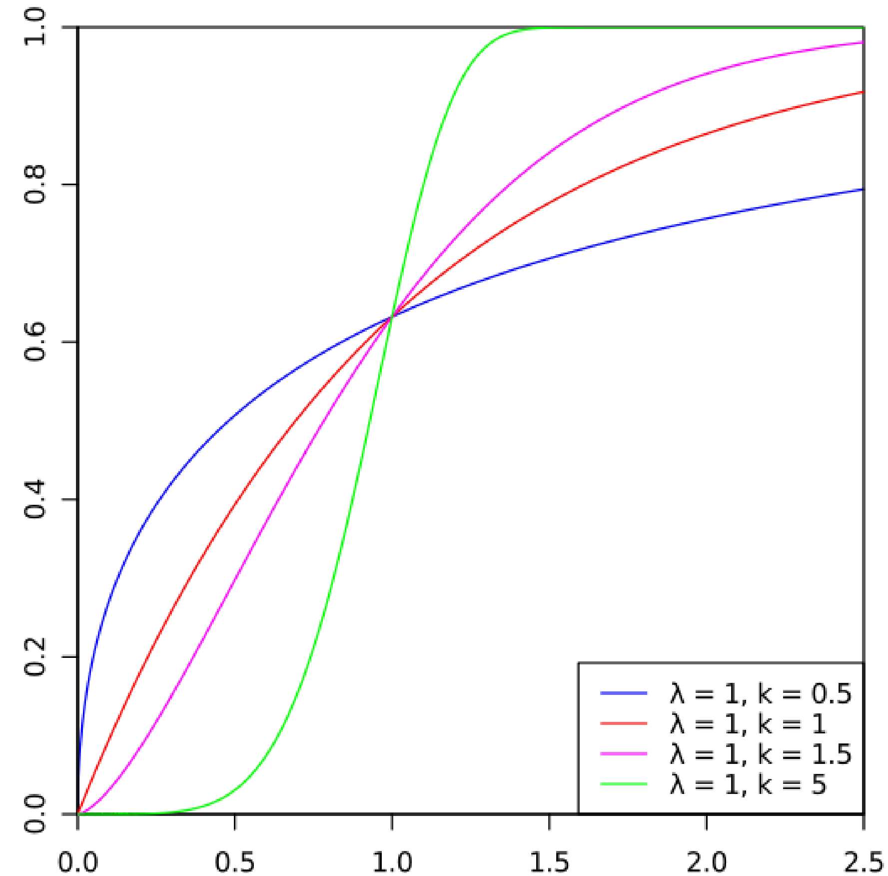


Figure 2. Equiprobability transformation of precipitation amounts obtained from the weather station of Campinas (22°54'S, 47°05'W; Instituto Agronômico).

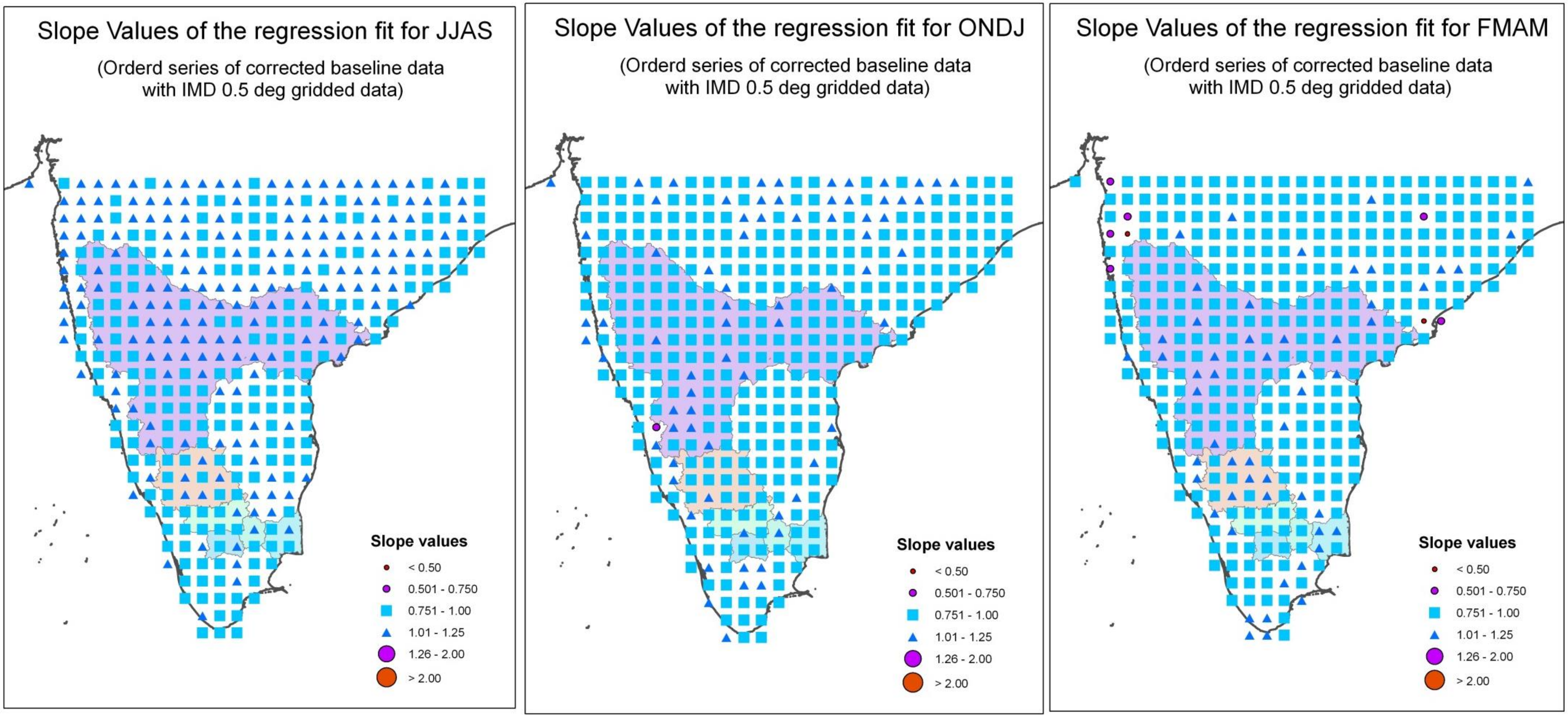
Weibull Distribution

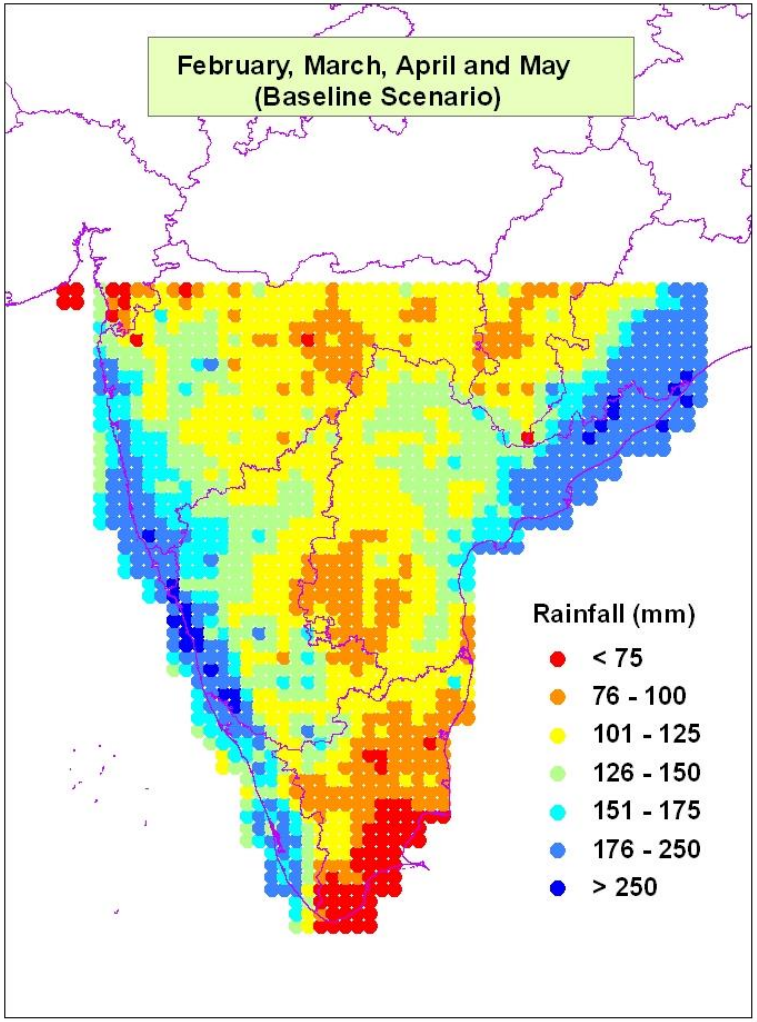
Parameters	$\lambda > 0$ scale (real) $k > 0$ shape (real)
Support	$x \in [0; +\infty)$
PDF	$f(x) = \begin{cases} \frac{k}{\lambda}\left(\frac{x}{\lambda}\right)^{k-1} e^{-(x/\lambda)^k} & x \geq 0 \\ 0 & x < 0 \end{cases}$
CDF	$1 - e^{-(x/\lambda)^k}$

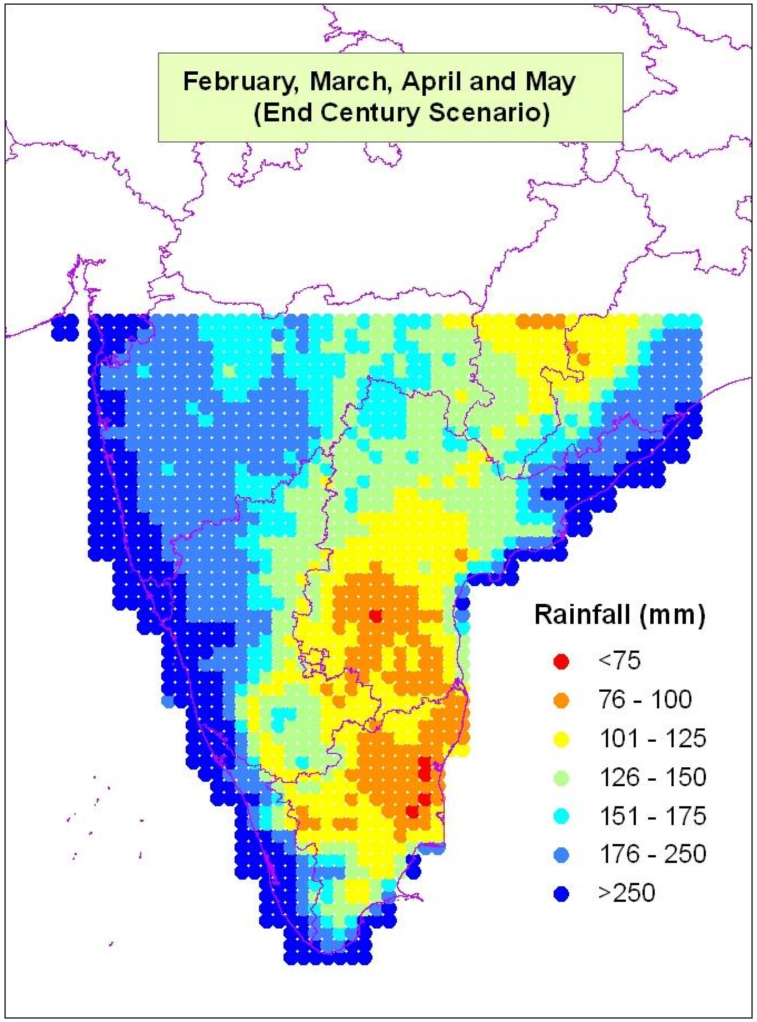


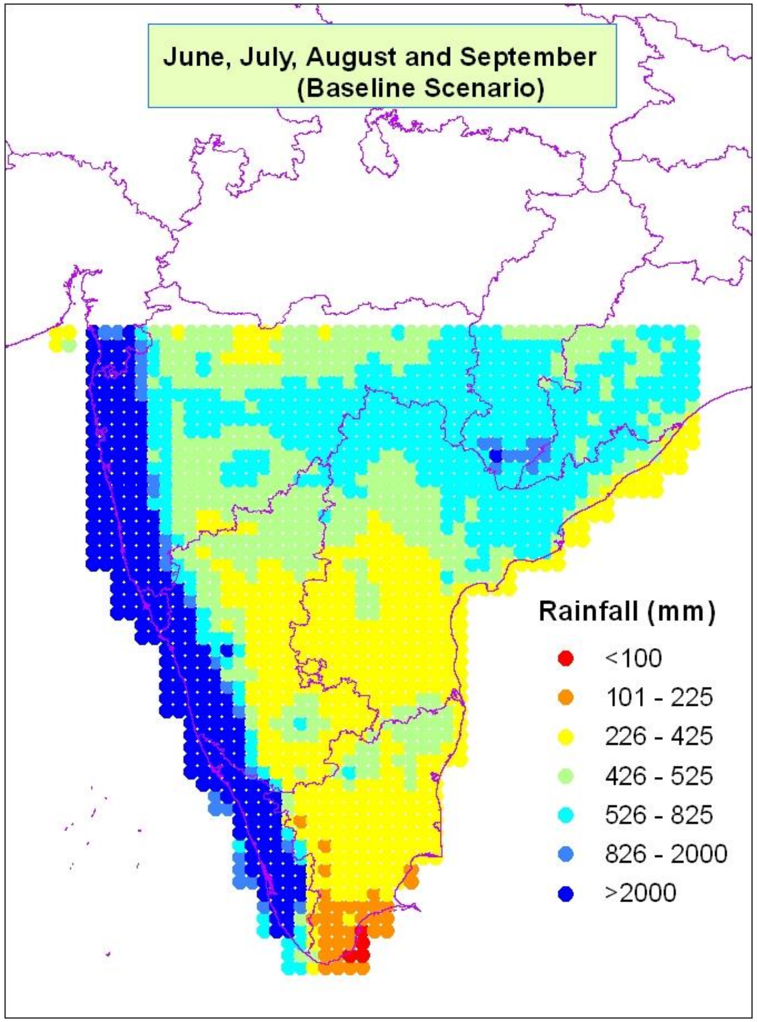


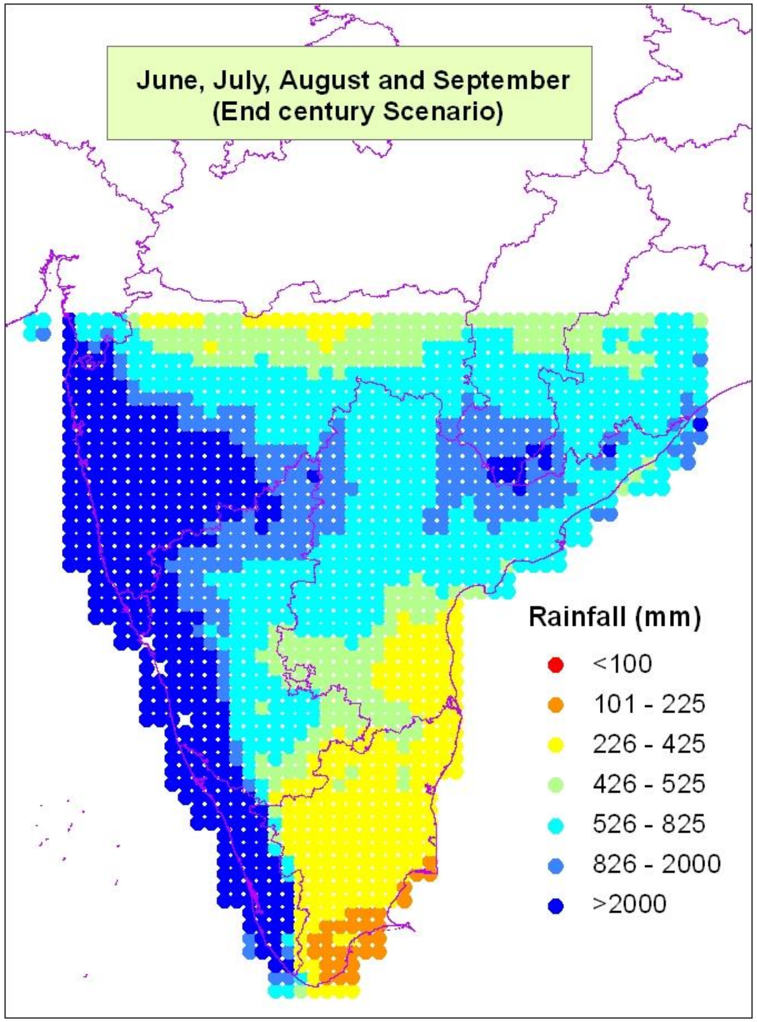
Source: Wikipedia

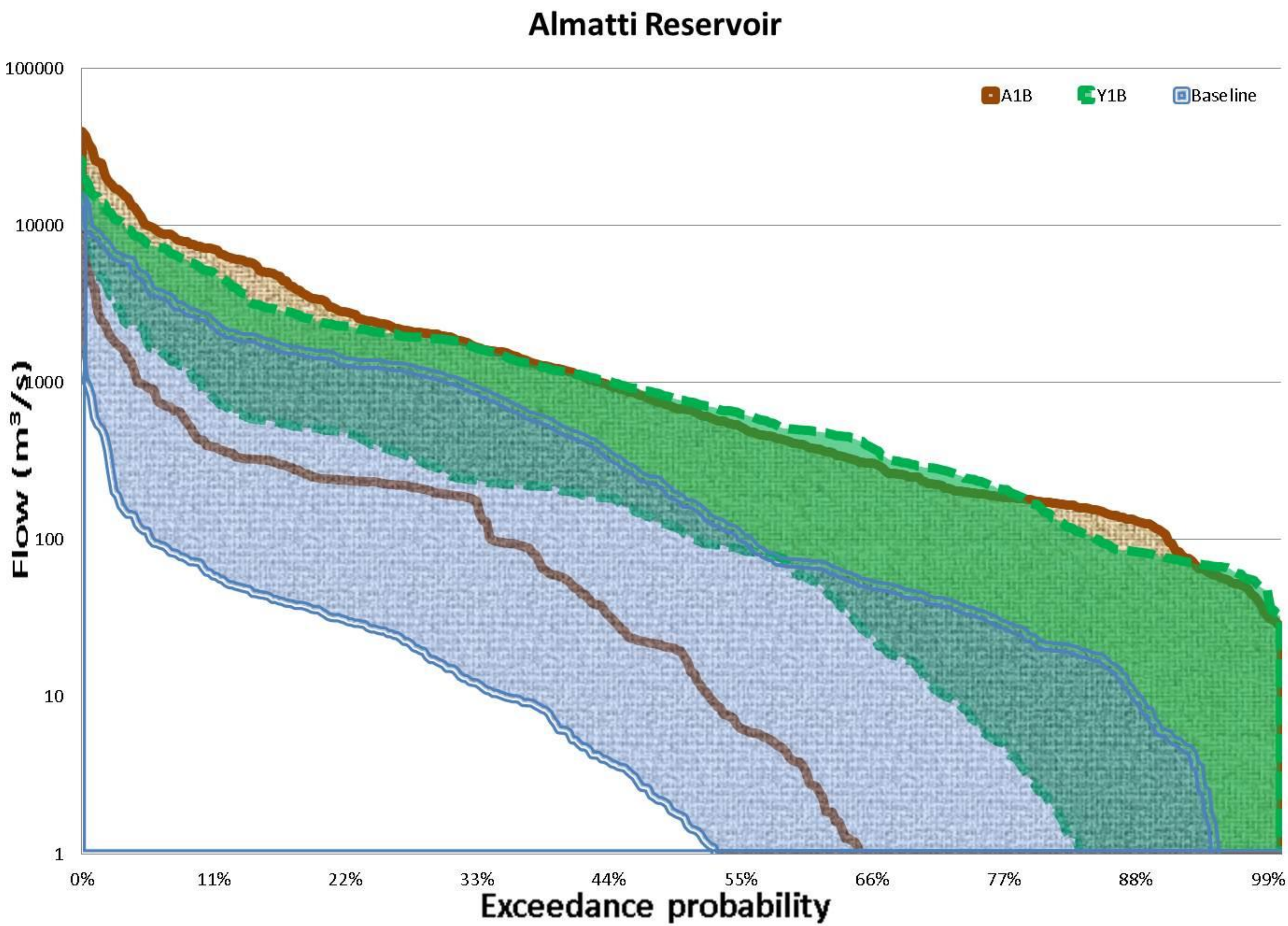

Slope Values of the regression fit for JJAS
(Orderd series of corrected baseline data
with IMD 0.5 deg gridded data)
Slope values
< 0.50
0.501 - 0.750
0.751 - 1.00
1.01 - 1.25
1.26 - 2.00
> 2.00
Slope Values of the regression fit for ONDJ
(Orderd series of corrected baseline data
with IMD 0.5 deg gridded data)
Slope values
< 0.50
0.501 - 0.750
0.751 - 1.00
1.01 - 1.25
1.26 - 2.00
> 2.00
Slope Values of the regression fit for FMAM
(Orderd series of corrected baseline data
with IMD 0.5 deg gridded data)
Slope values
< 0.50
0.501 - 0.750
0.751 - 1.00
1.01 - 1.25
1.26 - 2.00
> 2.00


February, March, April and May
(Baseline Scenario)
Rainfall (mm)
< 75
76 - 100
101 - 125
126 - 150
151 - 175
176 - 250
> 250


February, March, April and May
(End Century Scenario)
Rainfall (mm)
<75
76 - 100
101 - 125
126 - 150
151 - 175
176 - 250
>250

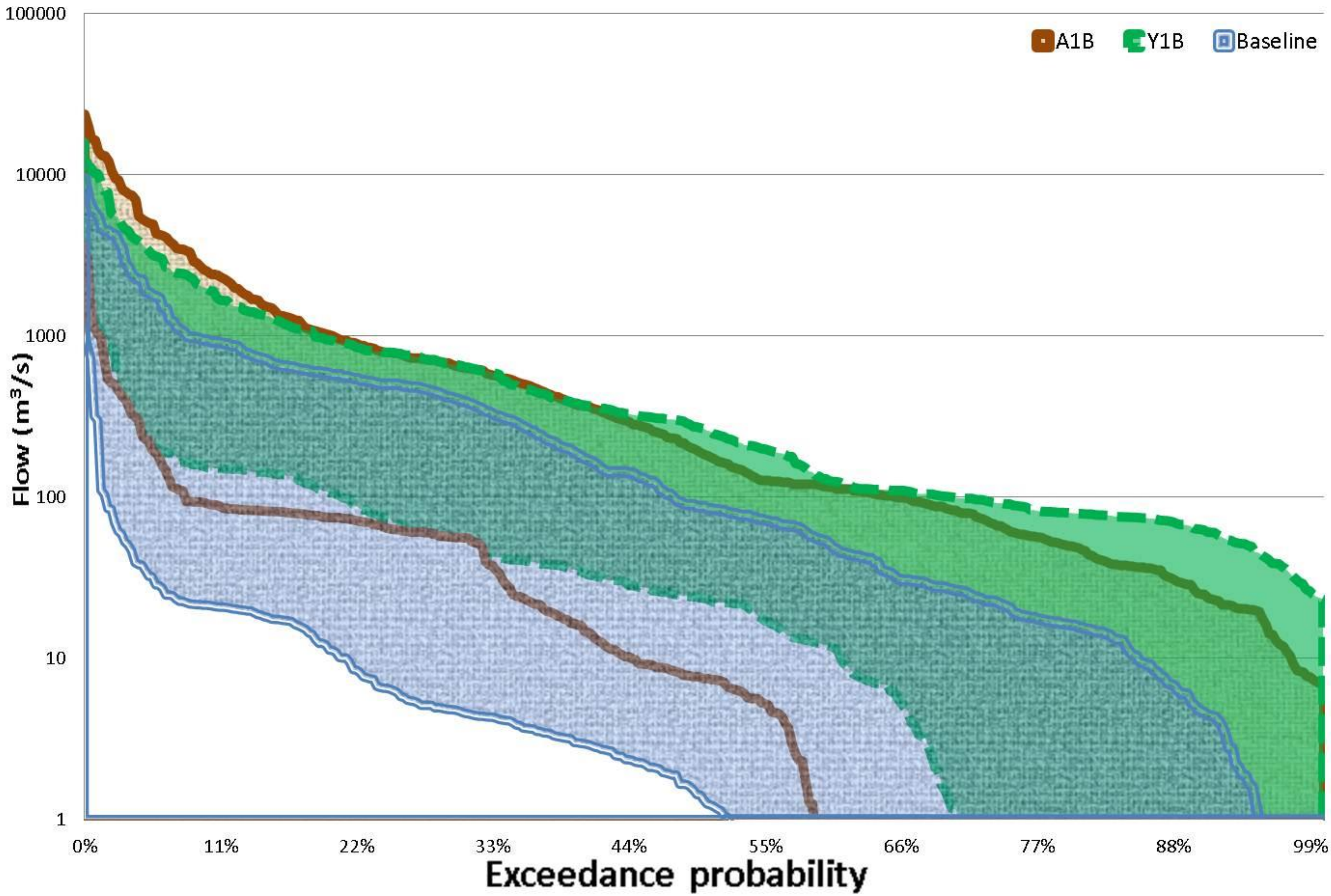

June, July, August and September
(Baseline Scenario)
Rainfall (mm)
<100
101 - 225
226 - 425
426 - 525
526 - 825
826 - 2000
>2000

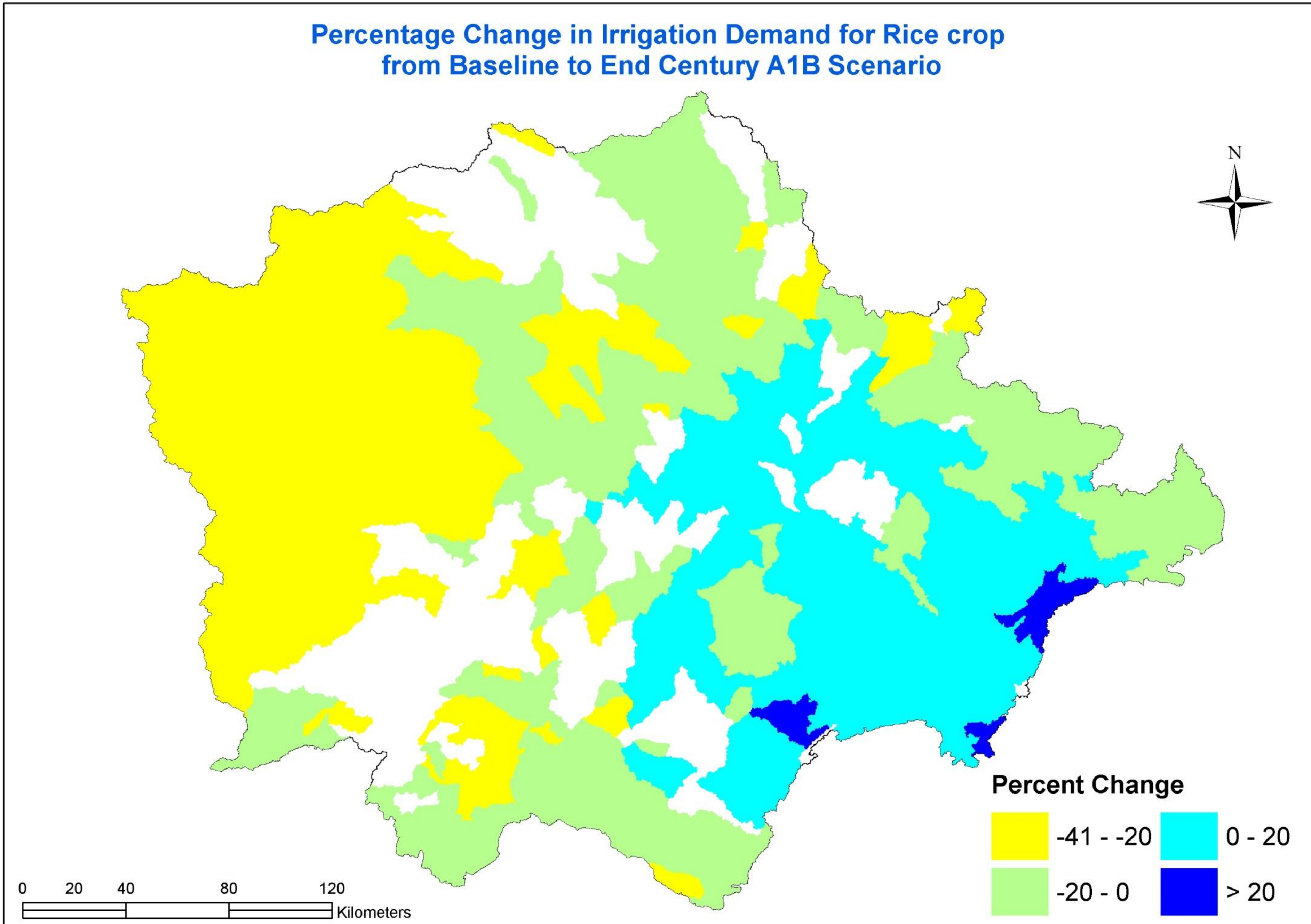

June, July, August and September
(End century Scenario)
Rainfall (mm)
<100
101 - 225
226 - 425
426 - 525
526 - 825
826 - 2000
>2000



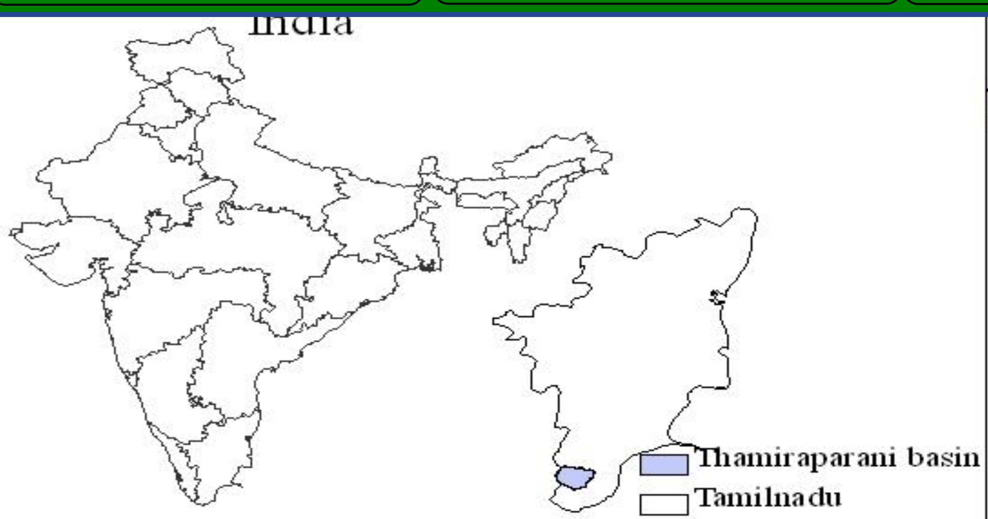
Almatti Reservoir
A1B
Y1B
Baseline
100000
10000
1000
100
10
1
Flow (m³/s)
0%
11%
22%
33%
44%
55%
66%
77%
88%
99%
Exceedance probability

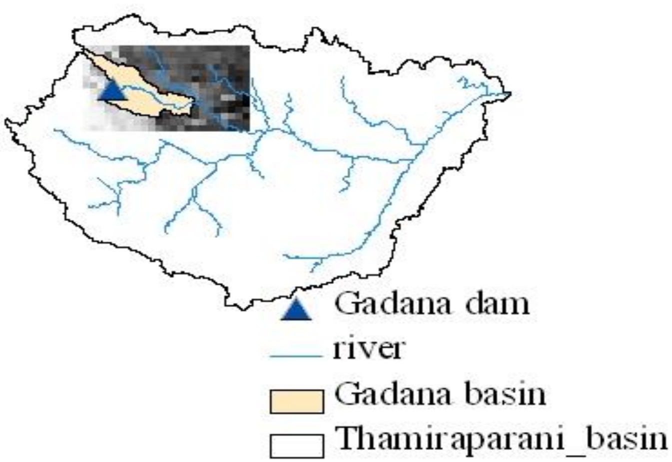
Ujjaini Reservoir

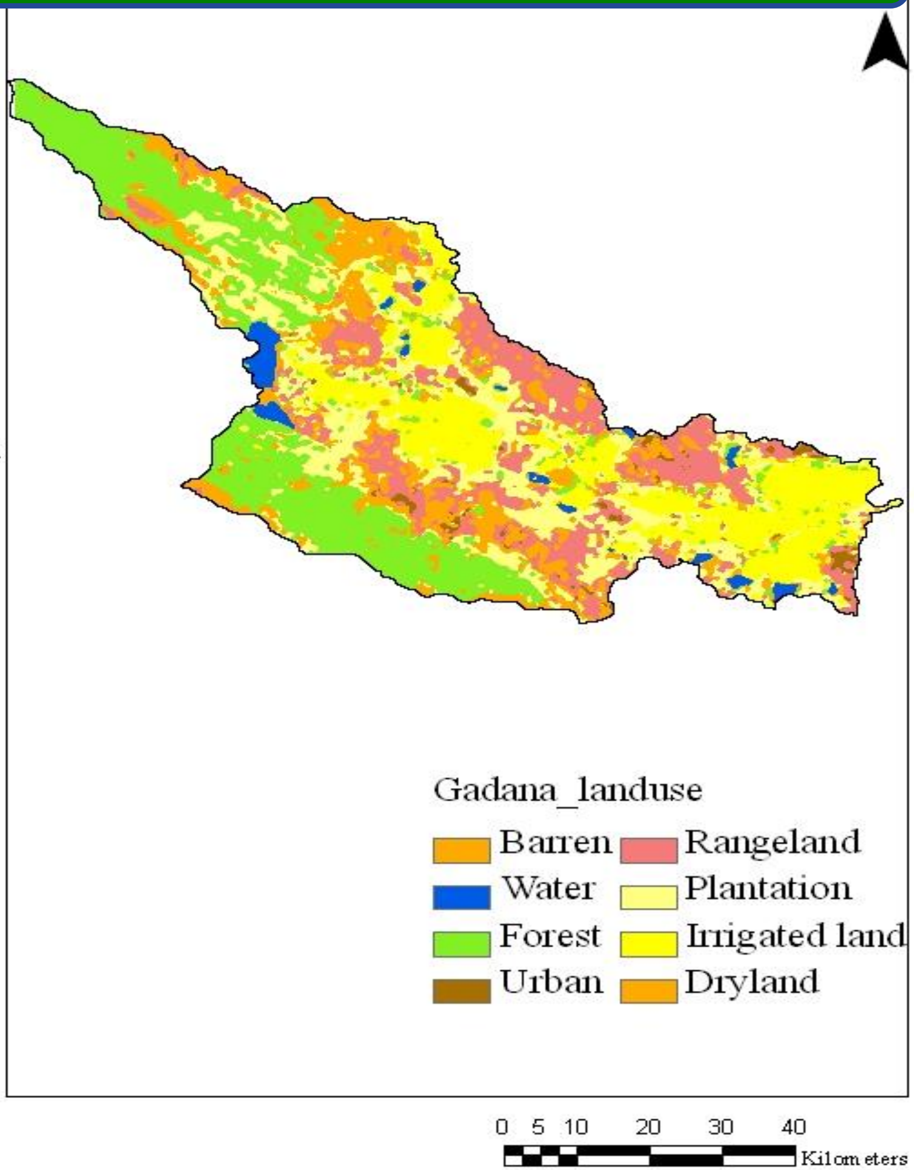



Percentage Change in Irrigation Demand for Rice crop
from Baseline to End Century A1B Scenario
N
Percent Change
-41 - -20
0 - 20
-20 - 0
> 20
0 20 40 80 120
Kilometers

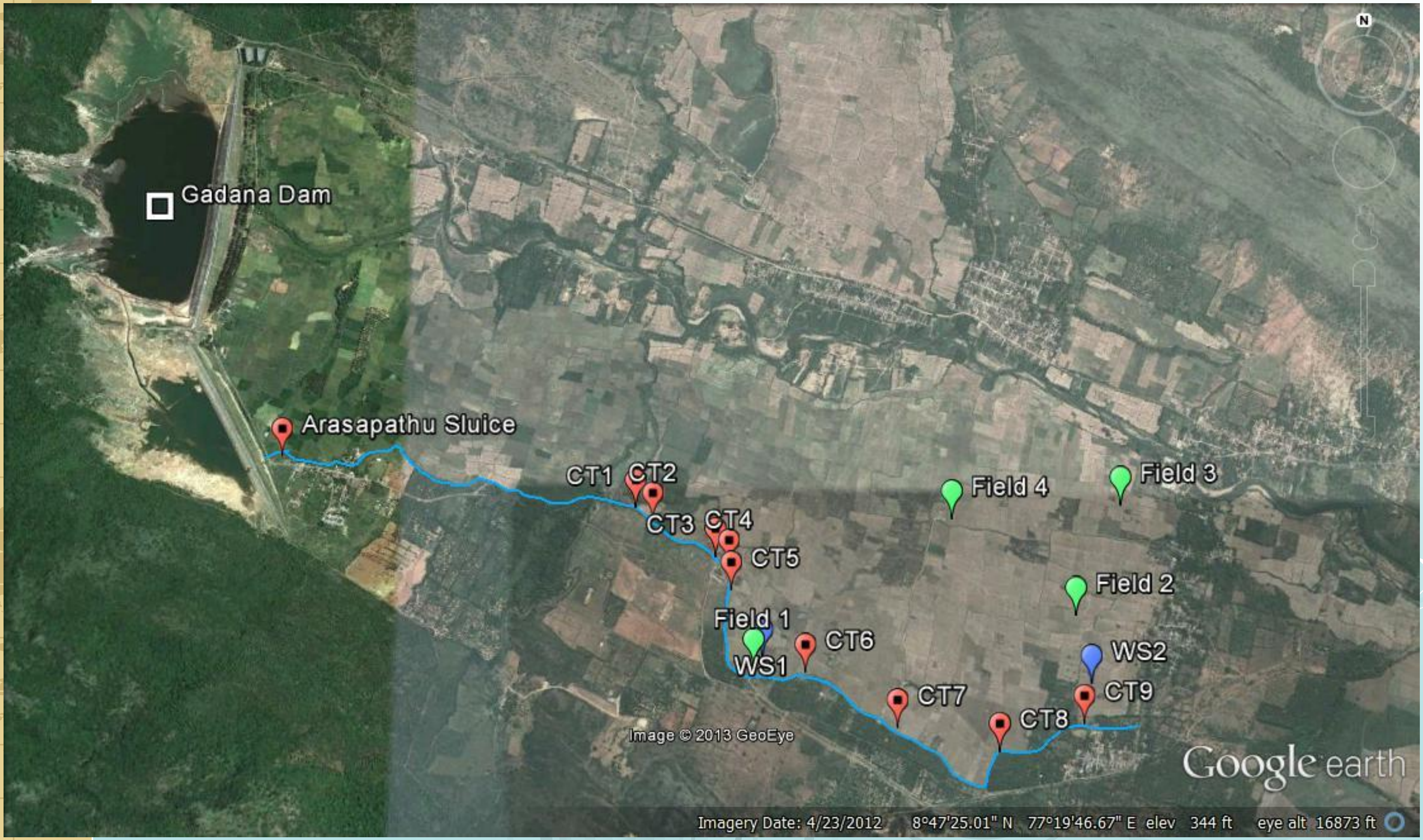
ONGOING STUDIES


India
Thamiraparani basin
Tamilnadu

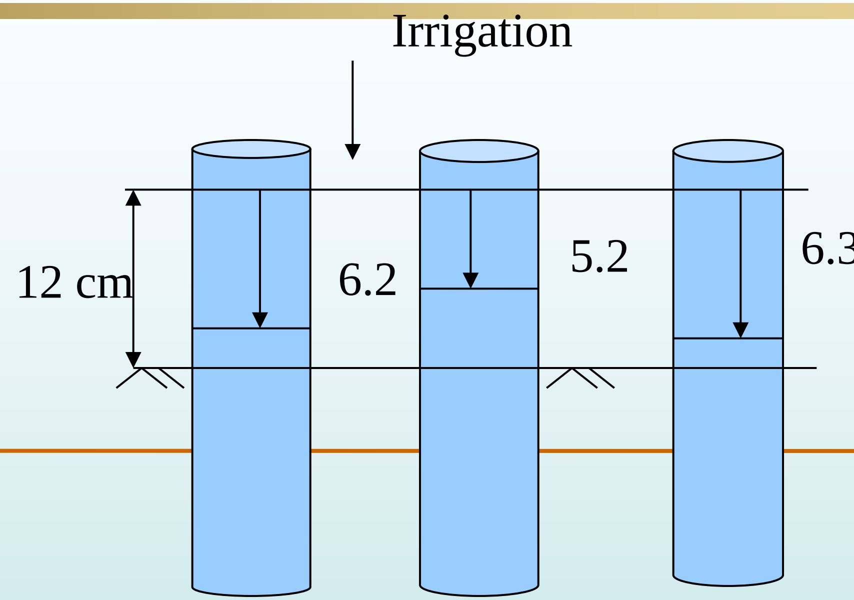

Gadana dam
river
Gadana basin
Thamiraparani_basin


Gadana_landuse
Barren
Rangeland
Water
Plantation
Forest
Irrigated land
Urban
Dryland
0 5 10 20 30 40
Kilometers

Field Instrumentation



Record daily measurements in the field water tube and percolation tube in order to estimate the field water balance based evapotranspiration.



Field water tube

Aquacrop – water productivity based crop growth model

FAO 33 Yield response to water

(Doorenbos & Kassam, 1979)

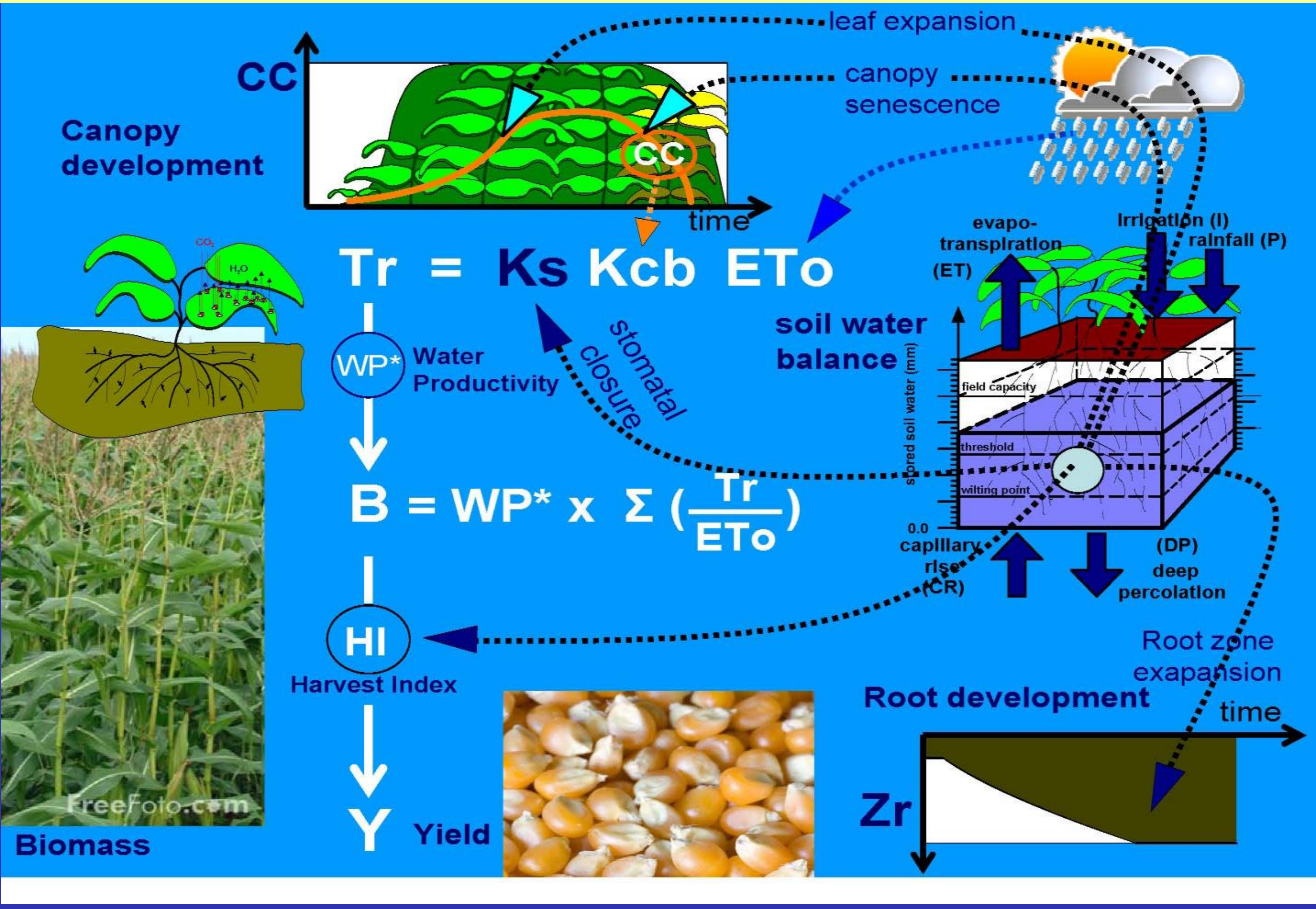
Solar Radiation

↓

Crop Evapotranspiration

↓ Ky

Crop Yield



Source: Raes et al., 2009

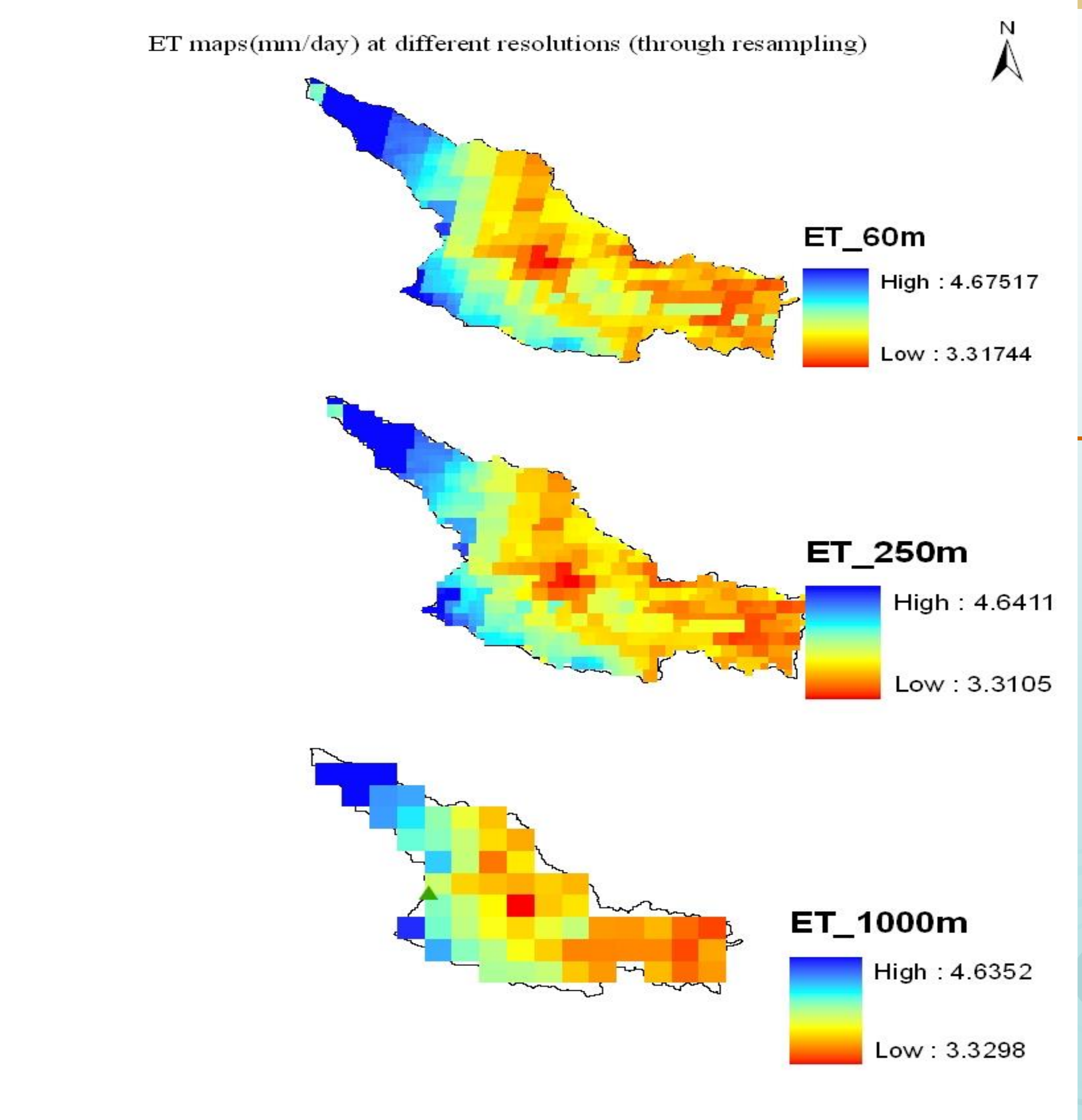
FAO AquaCrop

Solar Radiation → Crop Evapotranspiration

Solar Radiation → Canopy Transpiration

Canopy Transpiration → (WP) → Biomass

Biomass → (HI) → Crop Yield


ET maps(mm/day) at different resolutions (through resampling)
N
ET_60m
High : 4.67517
Low : 3.31744
ET_250m
High : 4.6411
Low : 3.3105
ET_1000m
High : 4.6352
Low : 3.3298

- Improve the rice paddy irrigation routine within SWAT
  - AQUACROP, ORYZA, and field observations
- Improve SWAT parameterization using thermal remote sensing based ET