

Water and Sustainability

William Jury

Department of Environmental Sciences

University of California Riverside

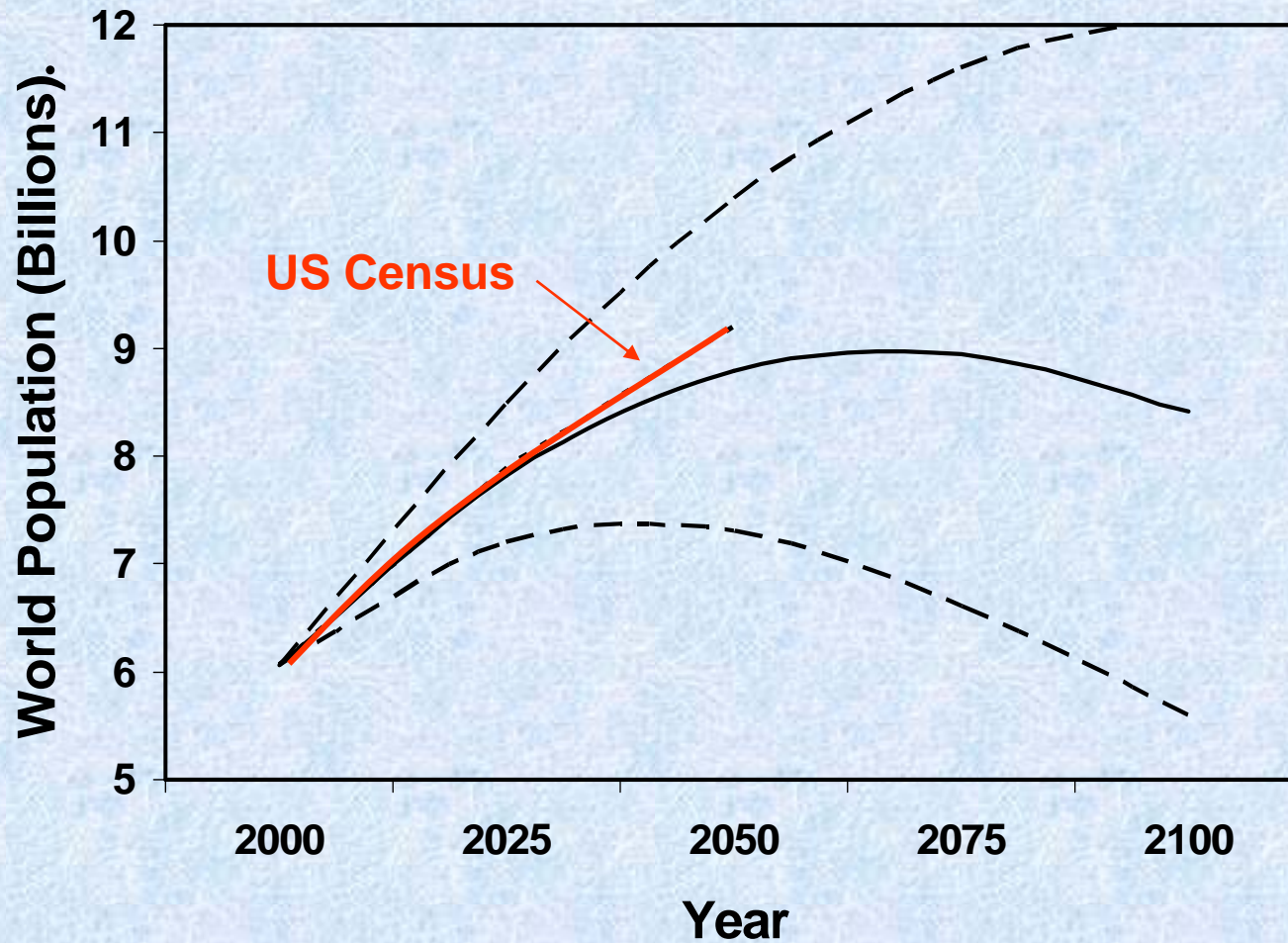
Overview of Presentation

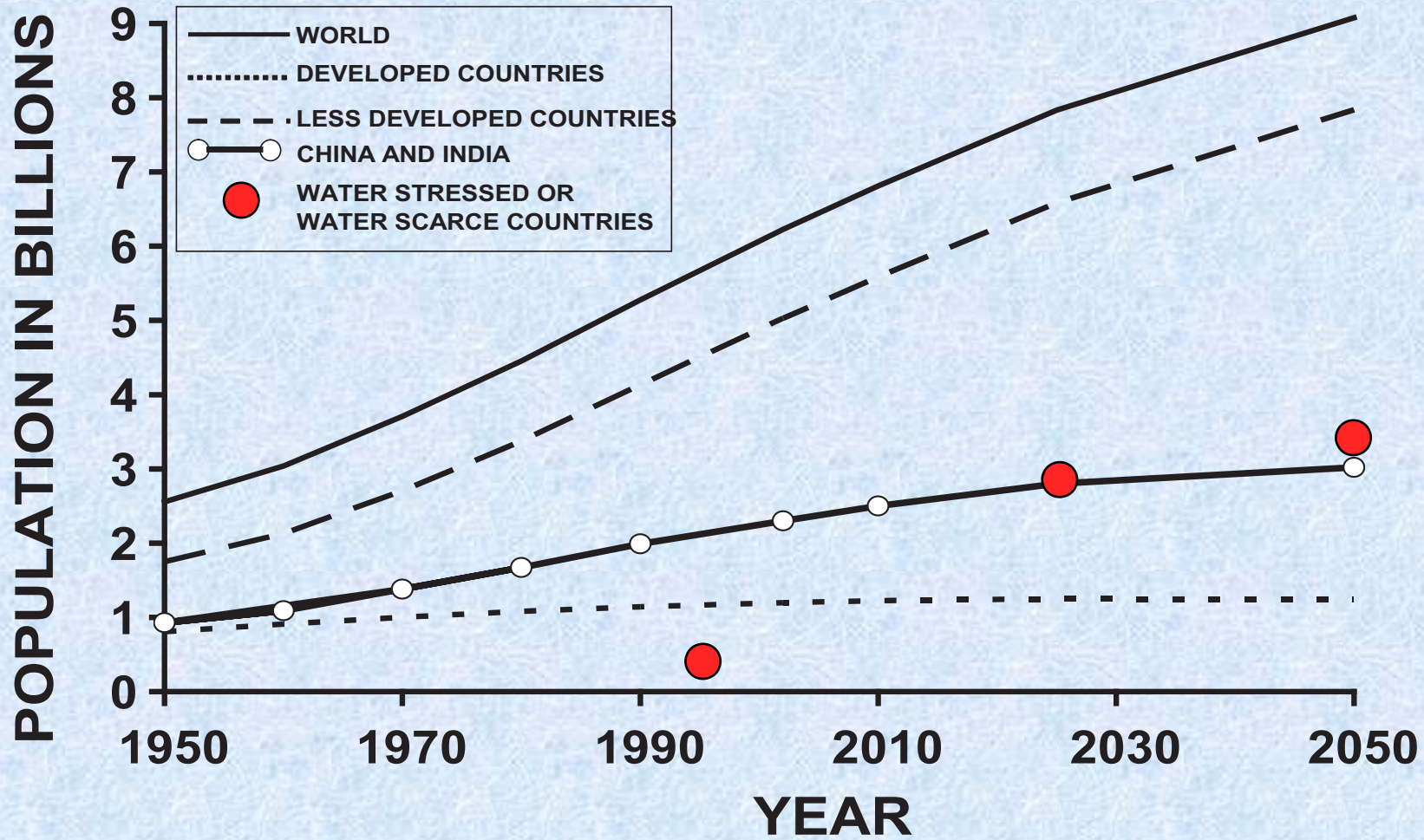
- **Population and Food Production Trends**
- **The Major Global Water Problems**
- **Significant US Problems**
- **China and India**
- **Ecological Needs**
- **Technological and Institutional Fixes**
- **The Path to Sustainability**

Population Trends

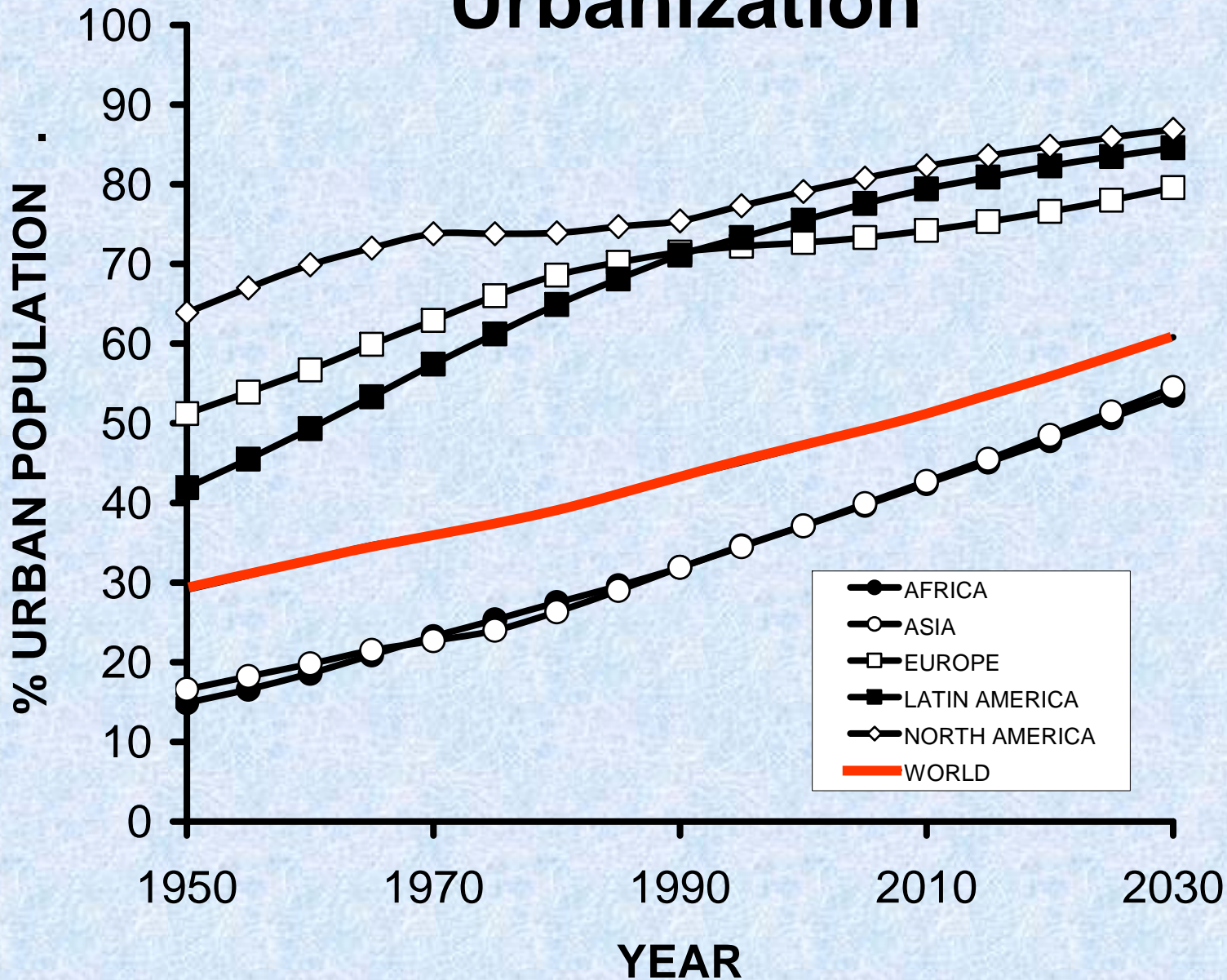
- **Between 9.0 and 9.5 billion people by 2050**
- **Almost all the increase will be in poor countries**
- **Almost all the increase will be in water-short countries**
- **There will be 2.5 billion more people living in cities by 2050**

World Population Forecast and 80% Confidence Limits





Urbanization



Mega Cities

YEAR	POPULATION		
	> 10 million	> 15 million	> 20 million
1985	9	2	1
2000	18	5	1
2015	22	11	4

Mexico City Water Supply

- **More than 70% of city supply comes from one underground aquifer**
- **Aquifer recharge of 700 km³/y is only about 1/2 of extraction**
- **Land subsidence is 7.5 m in center of city**
- **90% of municipal and industrial liquid wastes are discharged untreated into sewer systems**
- **Water supply is highly vulnerable to contamination**

Mexico City Water Supply

- **Land has sunk 7.5 m in the city center, damaging buildings and breaking pipes**



Food Production

- **Per capita food production peaked in 1983**
- **Grain stocks are at an all time low**
- **Water may become the major factor limiting food production in many parts of the world**

Human Water Requirements

- **Domestic Water Use:**
 - North America **250 m³/person/y**
 - Africa **25 m³/person/y**
- **Industry Water Consumption:**
 - North America **97 m³/person/y**
 - Africa **8 m³/person/y**
- **Food Production: 1000-1300 m³/person/y**

Countries Experiencing Water Stress

- Water stress at the national level is usually defined by per capita annual water supply or annual consumption as a percentage of water resources
- Countries with less than 1700 m³/pp/y are **Water Stressed**
- Countries with less than 1000 m³/pp/y are below the **Water Barrier**

Countries Under Water Stress

	1995		2025	
Category	Countries	Population (M)	Countries	Population (M)
Water Barrier	12	65	17	218
Water Stressed	29	460	47	2829

Countries Below Water Barrier

Algeria

Bahrain

Saudi Arabia

Burundi

Israel

Yemen

Cape Verde

Jordan

Libya

Kuwait

Barbados

Rwanda

Oman

Malta

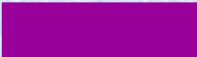
Tunisia

Qatar

Singapore

 African Nations

 Middle East Nations

 Island Nations

The Major World Water Problems

- **Unsafe drinking water**
- **Water Pollution**
- **Ground water overdraft**
- **Salinity**
- **Ecosystem destruction**
- **Transboundary water resources**
- **Future threat of climate change**

POPULATION LACKING ACCESS TO CLEAN DRINKING WATER (in millions)

Region	Rural	Urban	Total
Africa	256	44	300
Asia	595	98	693
Latin America and Caribbean	49	29	78
Europe	23	3	26
World	926	173	1099

Morbidity and Mortality for Various Water-related Diseases

Disease	Annual Cases (millions)	Annual Deaths (thousands)
Diarrhea	1000	3300
Malaria	400	1500
Schistosomiasis	200	20
Trypanosomiasis	0.275	130
Intestinal Helminths	1500	100
Dengue Fever	1750	20
Onchocerciasis	18	40

Percent Water and Sanitation Coverage by Region

Region	Water Supply	Sanitation
Africa	62	60
Asia	81	48
Latin America & Caribbean	85	78
Oceania	88	93
Europe	96	92
North America	100	100
World	82	60

Ground Water Overdraft in Various Regions

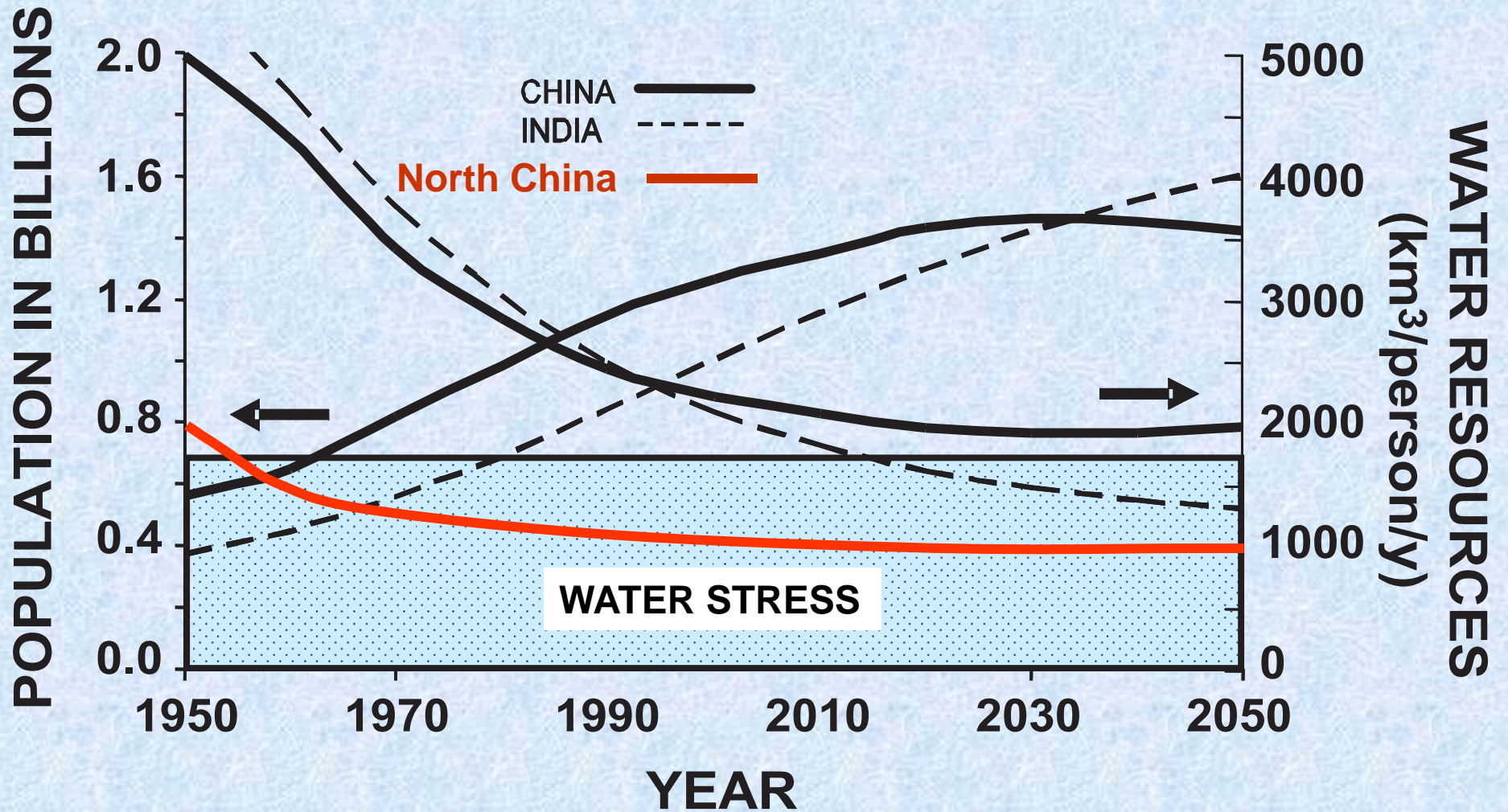
Country or Region	Annual Overdraft (km ³ /y)
India	104.0
China	30.0
United States	13.6
North Africa	10.0
Saudi Arabia	6.0
World (minimum estimate)	163.6

This transient water supply is providing food for nearly **500 million people**

China and India

- **China and India currently have 37% of the world's population**
- **Both have rapidly growing economies**
- **China has over 100 large water short cities**
- **Beijing will run out of water within 15-20 years**
- **Both are achieving food self-sufficiency through extensive ground water overdraft**

China and India



Worldwide Salt Damage

- **Nearly 1/3 of the world's land that is suitable for growing crops can potentially be damaged by salt**
- **About 77 million hectares of cropland has already been damaged by salt**
- **This is about 2.5% of the land under production**
- **Dry lands are especially vulnerable**

Water Supply to Ecosystems

- **As of 1995, humans appropriated 54% of the fresh water in lakes, lagoons, rivers, and streams.**
- **By 2025, that value could reach 70%.**
- **Rivers need about 30% of base flow to maintain ecological health.**
- **Few major rivers maintain that level.**

Water Supply to Ecosystems

- 15 of the 24 ecosystem services examined during the Millennium Ecosystem Assessment are being degraded or used unsustainably
- Up to half of the world's wetlands have been destroyed by humans in the last 100 years.
- Fresh water ecosystems have been estimated to provide **several trillion dollars** in annual services

Overuse of Rivers

- **The Colorado rarely reaches the Gulf of California**
- **The Ganges River is drying up before it reaches Bangladesh**
- **Since 1972, the Yellow River in China has run dry before reaching the sea**
 - **In 1997, it ran dry for 226 days and over 600km, and didn't reach a major agricultural region**
 - **Their grain output declined by 2.7 million tons**

1995 Global Water Use by Sector (in km³/y)

Sector or Use Category	Annual Withdrawal and % of Total	Annual Consumption and % of Total
Agriculture	2504 (66%)	1753 (84.5%)
Municipal	344 (9%)	50 (2.5%)
Industry	752 (20%)	83 (4%)
Reservoir Losses	188 (4%)	188 (9%)
Total	3788	2074

Water Use Increase 1995-2025 (in km³/y)

Water Use Category	Withdrawal Increase and % of Total	Consumption Increase and % of Total
Agriculture	685 (47%)	499 (72%)
Municipal + Industry	681 (47%)	111 (16%)
Reservoir Losses	81 (6%)	81 (12%)
Total	1447	690

The increase in municipal and industrial demand consumes enough water to feed 2 billion people

Transboundary Water Disputes

- **146 countries of the world share a river with at least one other nation**
- **There are 261 river basins whose drainage areas span more than one country, covering 45% of the land area of the planet**
- **Many of them have no treaties governing their use**

Serious River Basin Conflicts

River

Countries Involved

Jordan

Israel, Jordan, Lebanon, Syria

Tigris-Euphrates

Iraq, Syria, Turkey

Nile

Egypt, Ethiopia, Sudan

Indus

India, Pakistan

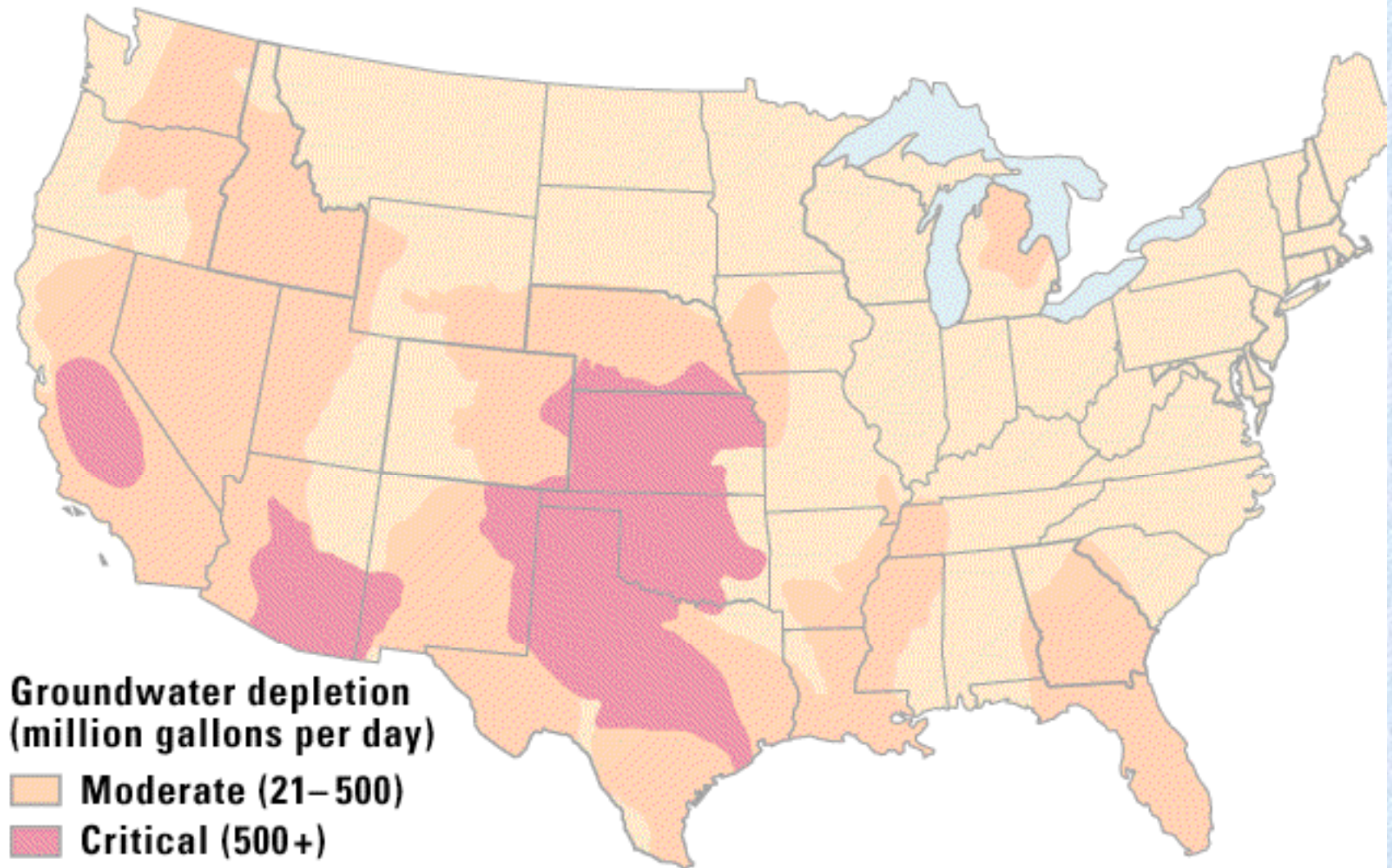
Ganges

India, Bangladesh

Major US Water Problems

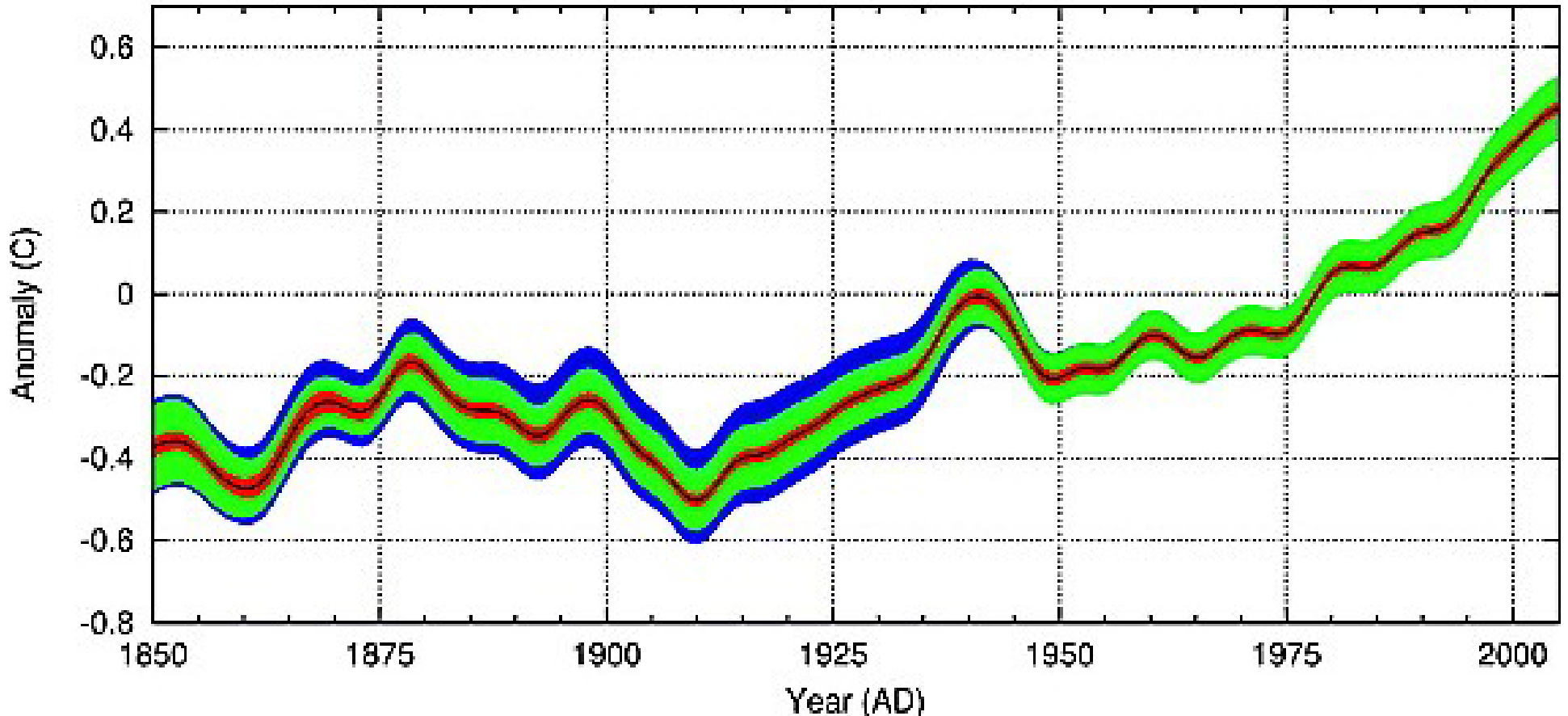
- **Ogallala aquifer is drying up (20% of all US irrigation)**
- **Salinity is a huge problem in the Central valley**
- **The Southwest is water short**
- **The Colorado is over-allocated**
- **The Rio Grande is in serious trouble now**

Aquifer depletion in the U.S.



Harcourt Brace & Company items and derived items copyright ©1998 by Harcourt Brace & Company

Climate Change and Water Resources: Observed Temperature



Climate Change and Water Resources: Probable Implications

- **More rainfall at high and mid-latitudes**
- **Greater variability with more floods and droughts**
- **Changes in timing of rainfall and streamflow**
- **Less snow and storage in snowpack**
- **Increase in species endangerment and extinction**

Future Water Requirements Under Business as Usual (km³/y)

Time Period	Food Production	Municipal and Industrial	Hunger Eradication	Total
1995-2025	2740	760	1,100	4,600
2025-2050	1560	430	1,100	3,090
1995-2050	4,300	1,190	2,200	7,690

All of Agriculture in 1995 = 2504 (km³/y)

Where will the Water Come From?

- **World has a limited capacity for expansion of irrigation (~800 km³/y)**
- **Rainfed agriculture must become much more efficient**
- **Conservation must become more widespread**
- **If other means fail, the water will come at the expense of the environment**

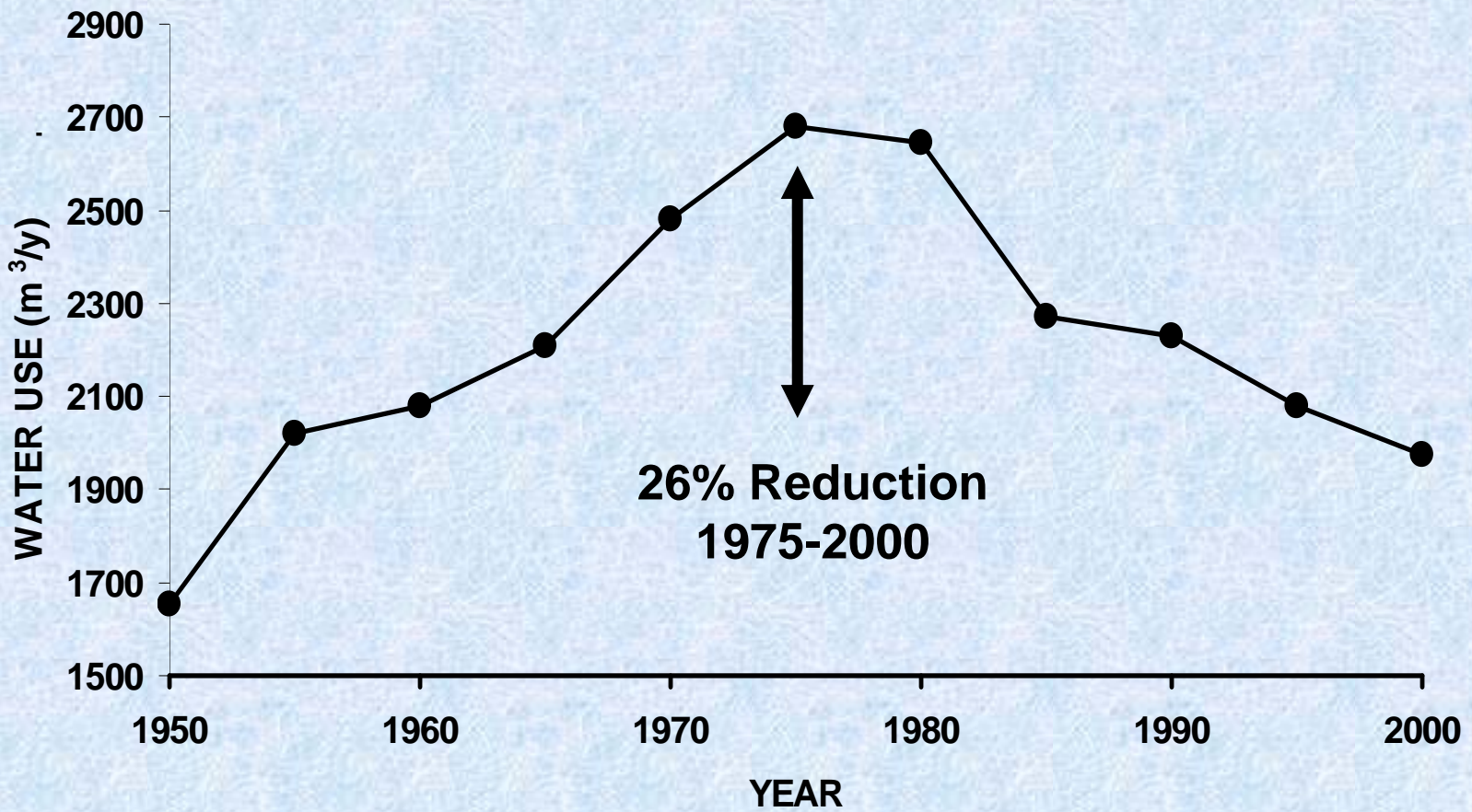
Urban Water Saving Strategies

- **Water reuse**
- **Educational programs**
- **Strengthened water codes (metering)**
- **Retrofitted plumbing**
- **Dual water supply systems**
- **Landscaping modifications**

Per Capita Water Use in USA

Category	Daily Use (L/d)	Percent of Total
Outdoor Use	362	58.0
Indoor Use	263	42.0
• Toilet	70	11.2
• Clothes washer	57	9.1
• Shower	44	7.0
• Faucet	41	6.6
• Leaks	36	5.8
• Bath	5	0.7
• Dishwasher	4	0.6
• Other	6	1.0
All uses	625	

Per Capita US Water Use



Irrigation Efficiency Improvements

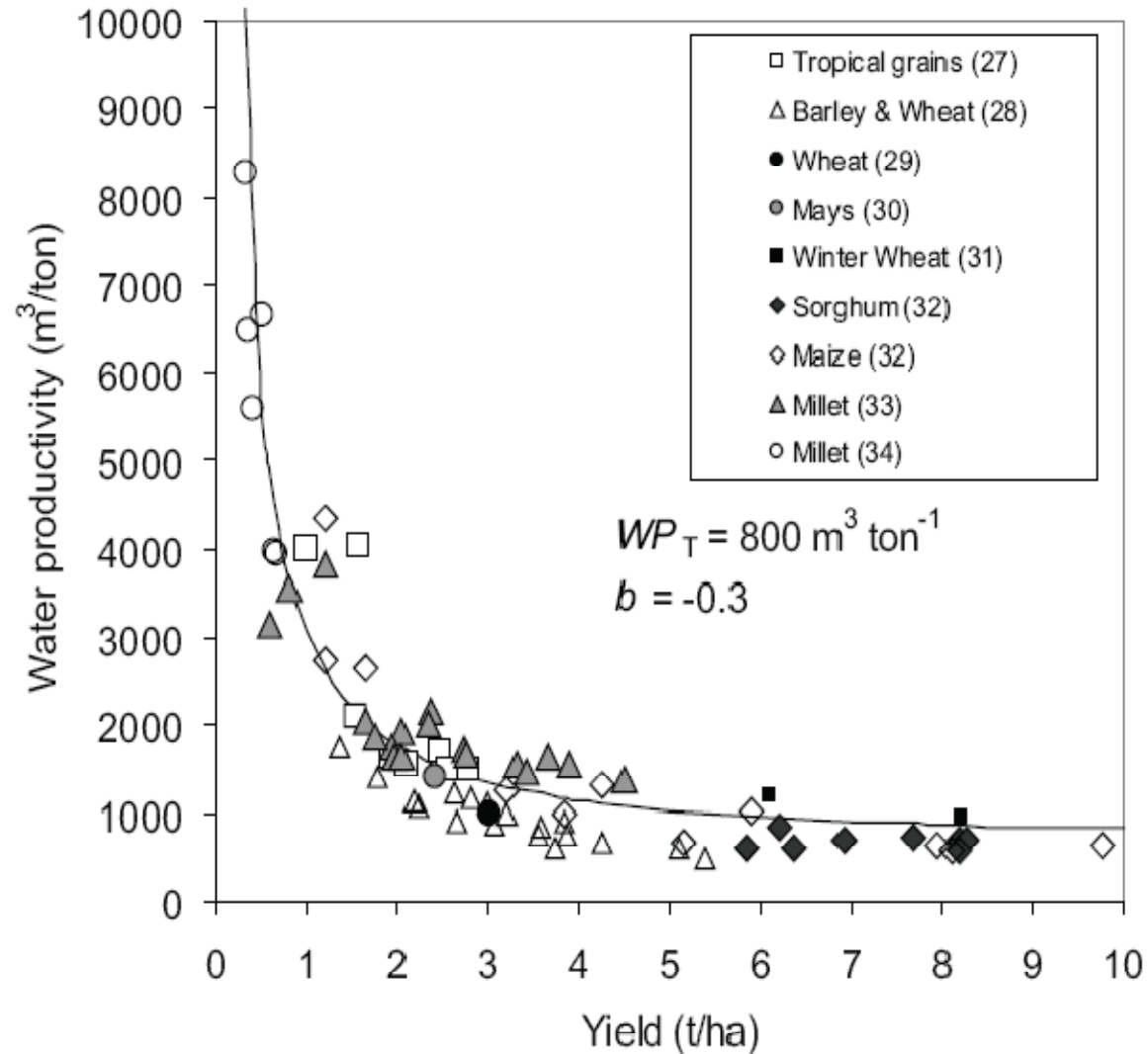
- **Average irrigation efficiency of 118 countries of the world in 1990 is 43%**
- **Could save nearly 1000 km³/y by raising this to 70%**
- **This could be achieved through technical, agronomic, managerial, and institutional improvements**
- **Deficit irrigation may be an option in water-short regions with available land**

Improvements in Rainfed Agriculture

- **Irrigated agriculture is 325% as productive as rainfed agriculture**
- **Evaporation losses are as high as 65% in Africa**
- **Three strategies for improving productivity**
 - **Water harvesting**
 - **Strategic supplements of irrigation water**
 - **Improved land management**

Nonlinear Yield Gains

Rockstrom et al. PNAS 2007)

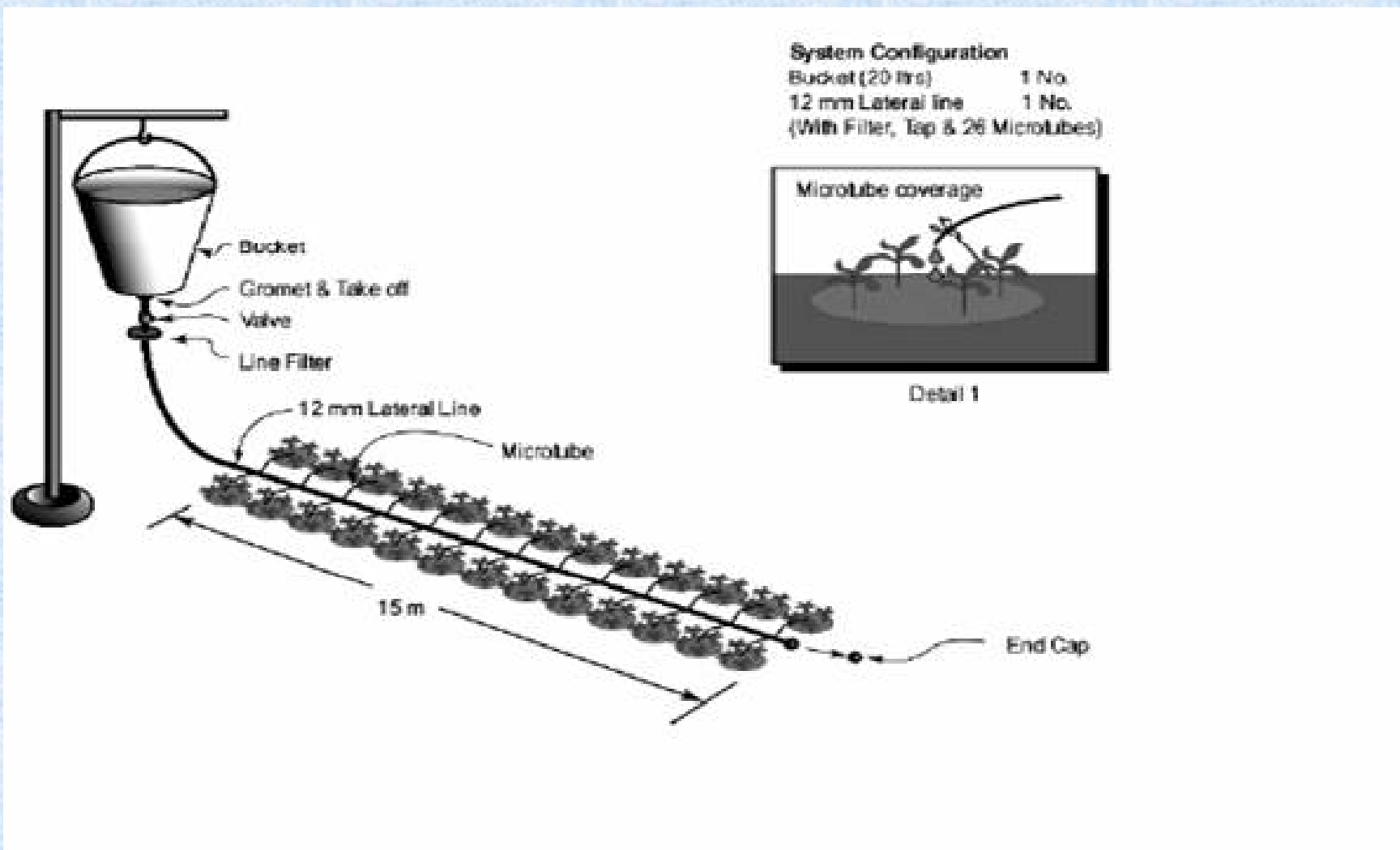


The Treadle Pump



- Human powered
- Can raise 5-7 m³/h up to 7 m
- Inexpensive to buy and maintain
- Over 1.2 million sold in Bangladesh
- Growing demand in India

Drip Irrigation Bucket Kit



Desalination

- **Energy costs make desalinating seawater for potable use economically unattractive unless water is very expensive**
- **Not a feasible supplement for irrigation water**
- **Desalination may play a valuable role in transforming brackish water for non-potable use**

Desalination Costs

Supply Type	Unit Cost (\$/1000m ³)
Existing Traditional Supply	\$240-660
New Desalted Water	
- Brackish	\$400-800
- Seawater	\$800-2100
- 50% brackish water mix	\$320-730
- 10% seawater mix	\$290-800

Paths to Sustainability

- **End unsustainable practices that deplete or damage water resources**
- **Adopt conjunctive management of surface and ground water**
- **Water agreements**
- **Societal changes**
- **Global management of food and water**