



TECHNOLOGY IN FOOD AND ENERGY PRODUCTION SYSTEMS: ACHIEVEMENTS AND CHALLENGES

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SAIAE CPD
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Outline of Presentation

- ★ Technological achievements for food production systems
- ★ Impacts of technology and requirements for food and energy production systems
 - ★ Healthy and sustainable environment
 - ★ Secure and abundant supply of food, fiber and water
 - ★ Efficient use of energy
 - ★ Renewable sources of energy
- ★ Growing Bioresources Engineering
- ★ Conclusions

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Genealogy of Engineering

- ★ Three pillars of knowledge

- Medicine
- Philosophy
- Engineering

- ★ Imhotep (~2750 BC)

- 1st practicing engineer
- Step Pyramid at Saqqarah



- ★ Professional Societies of Engineering (in USA)

- 1716: Civil
- 1847: Mechanical
- 1884: Electrical
- 1907: Agricultural
- 1908: Chemical

Ten Agricultural and Biological Engineering Achievements that Changed the World

★ Development of agricultural Tractor (~1890)

- Significant increase in productivity

★ Rural electrification (1920s)

- Switch from animal and human power to electrical power

★ Development of self propelled combine harvester (mid-1920s)

- Used to harvest range of crops with 100 times increase in productivity



Ten Agricultural and Biological Engineering Achievements that Changed the World

- ☀ Centre pivot for irrigation (~1952)
 - ☀ First system capable of automatically, efficiently and uniformly irrigating a variety of crops, soils, sloping terrains, and field sizes
- ☀ Mechanical cotton picker (~1930)
 - ☀ Reduced need for farm labor and the end of sharecropping
- ☀ Milking Machine (early 1900s)
 - ☀ Dramatically improved the labor efficiency of collecting milk



Ten Agricultural and Biological Engineering Achievements that Changed the World

- ★ Conservation Tillage (~1960s)
 - Retains residue from the previous year's crop on the soil surface to prevent soil erosion



- ★ ASAE Standardization Procedure (1910)



Ten Agricultural and Biological Engineering Achievements that Changed the World

★ Rubber Tires on Tractors (~1930s)

- Providing enhanced traction performance
- Compatibility with paved roads
- Faster field and road travel speeds



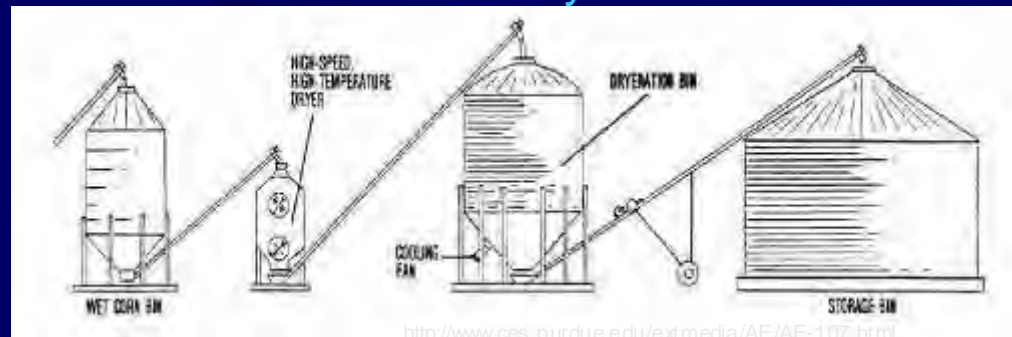
★ Refrigerated On-Farm Milk Storage (~1930s)

- Made significant improvements in both the quality and safety of raw milk supply



Other Outstanding Achievements

(Huggins and Cuello, 2000)



Grain Dyeration

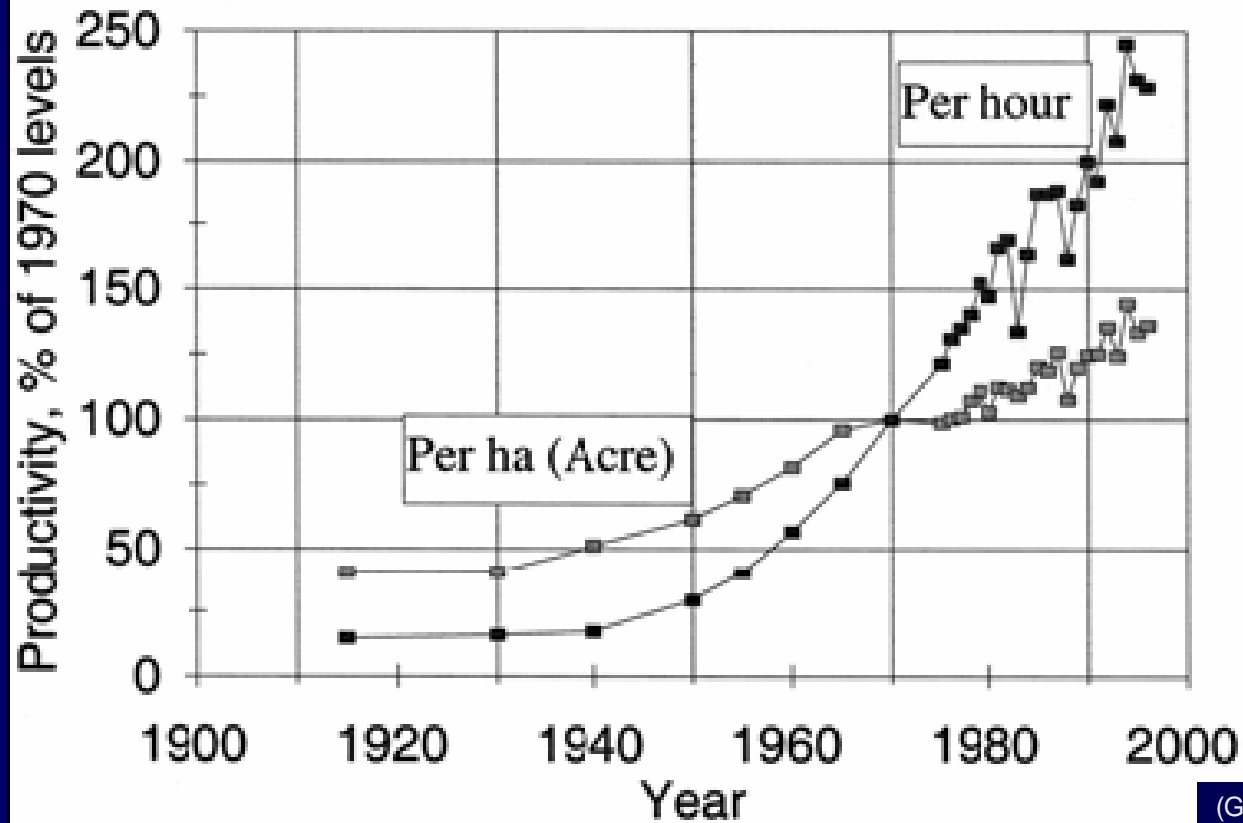
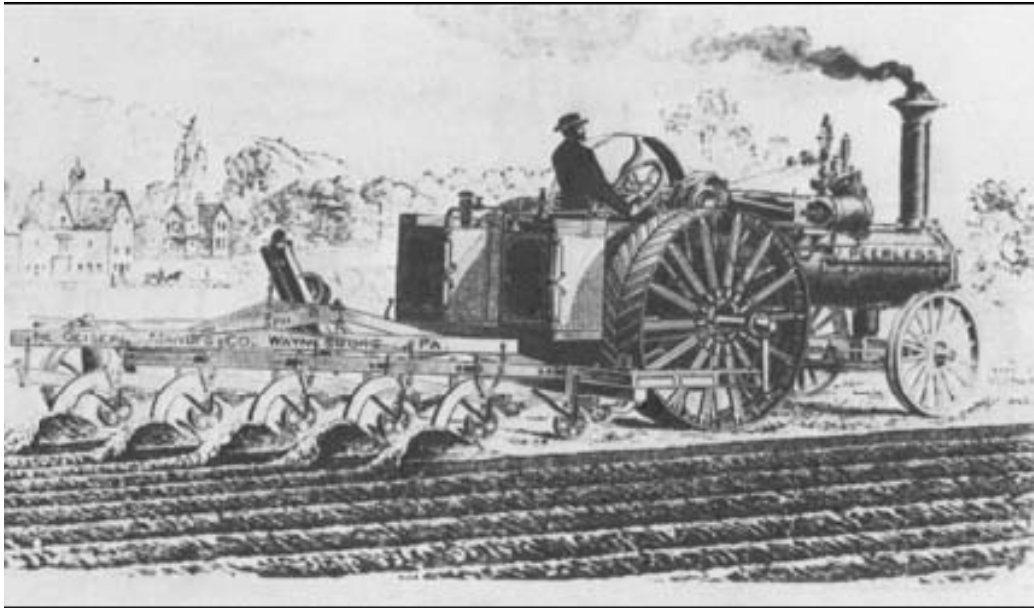


Agricultural Mechanisation



- ✦ Recognised as one of 20 Greatest Engineering Achievements in 20th Century (ASAE, 2000)
- ✦ Consequences
 - ✦ Significant increases in labour productivity in agriculture
 - 40% of labour force reduced to 2% to produce sufficient food to feed USA
 - 20% of ag. land in USA was needed to feed horses!
 - ✦ Significant increase in food production
 - Food production kept pace with population growth





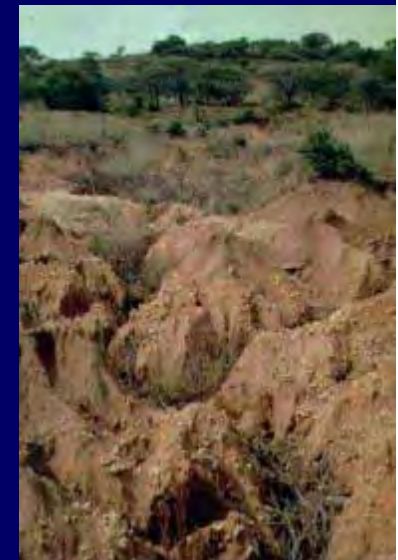
(Goering and Hansen, 2004)

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Impacts on the Environment

- ☀ Rate of food production > population growth
 - ☀ Over supply and shortages → Food Insecurity
- ☀ Production systems → Environmental contamination and degradation
 - ☀ Soil erosion, desertification
 - ☀ Pesticide runoff
 - ☀ Groundwater pollution
 - ☀ Climate change
 - ☀
- ☀ Mechanised agriculture (Cuello, 2002; Cuello, 2007)
 - ☀ USA
 - 90% of arable land eroded faster than soil generation
 - ☀ Globally
 - 70% of arable dry land production → desertification
- ☀ Unsustainable long term agricultural production systems



Is this the legacy we want to leave?



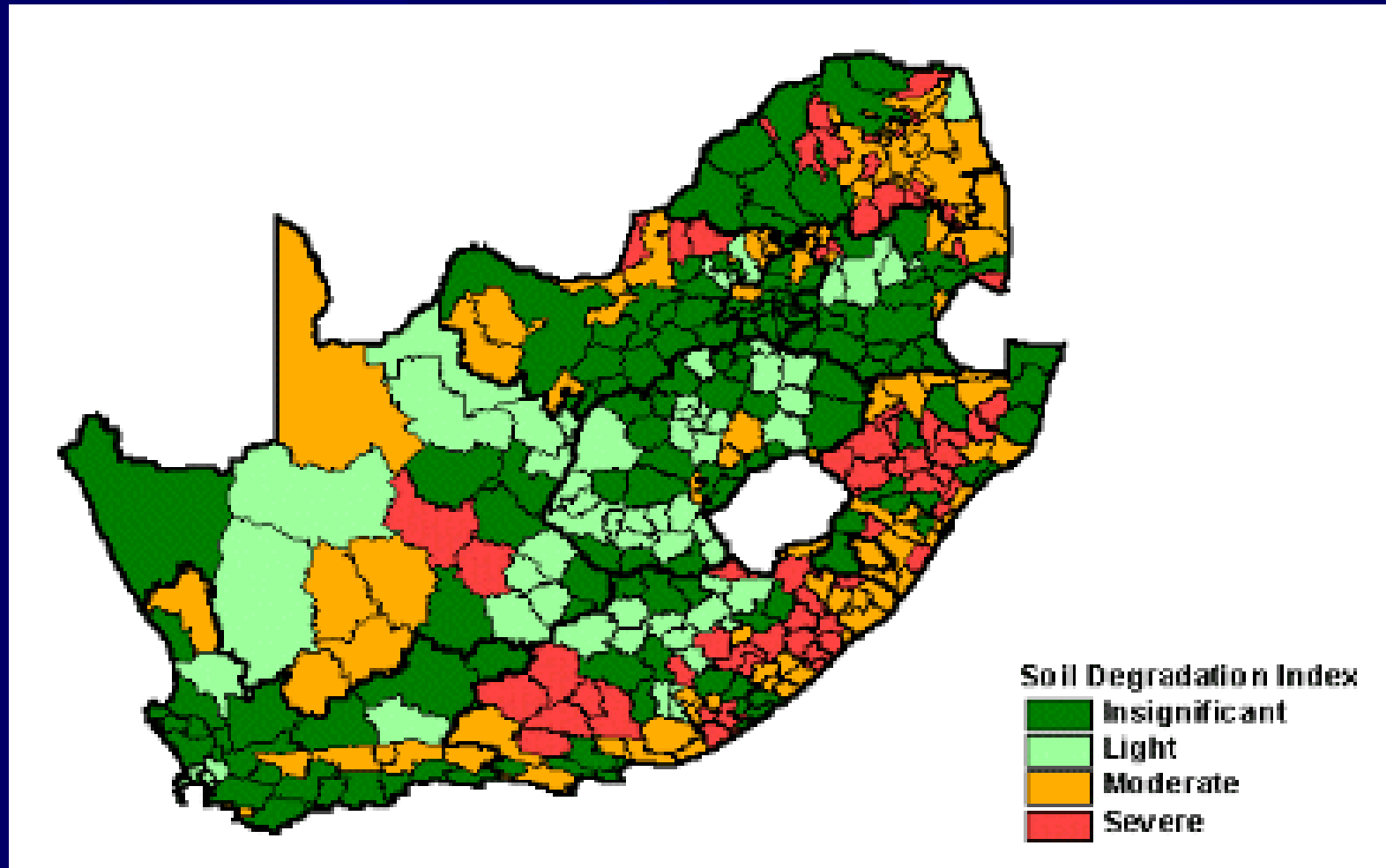
Or this?

☀ Food and Energy Production Systems

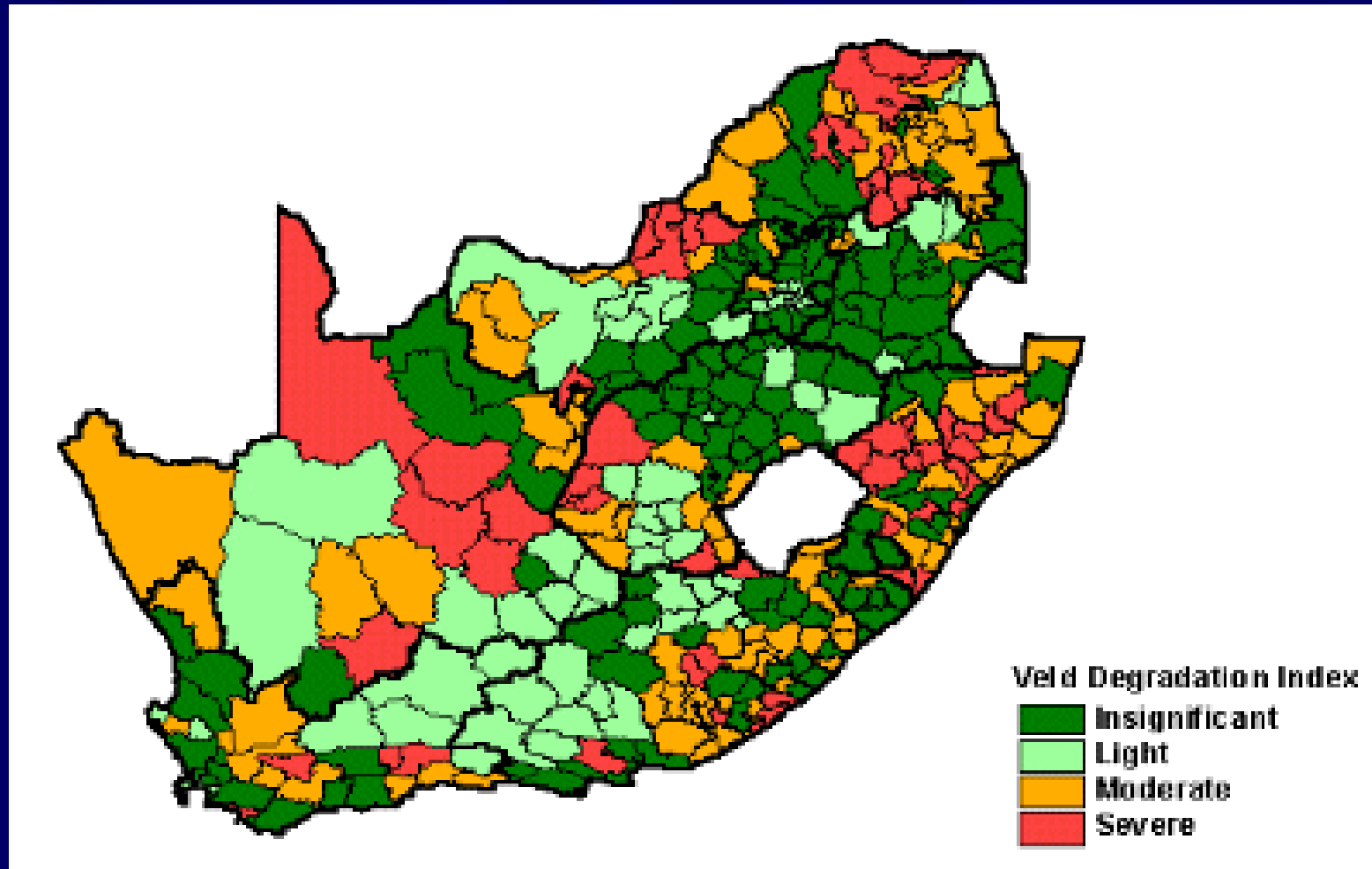
- ☀ Well planned
- ☀ Sustainable
- ☀ Efficient



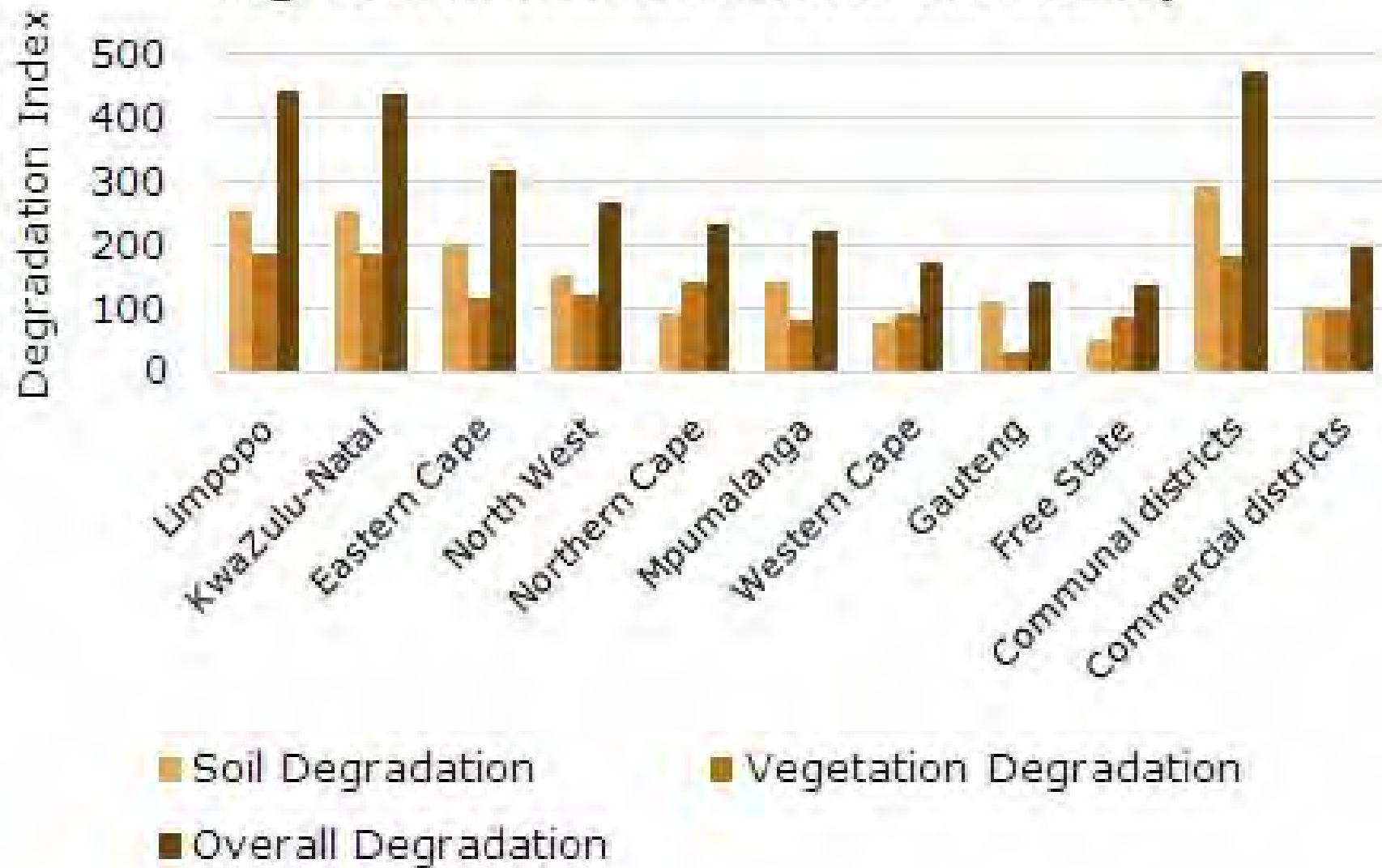
Soil Degradation in South Africa



Pasture Degradation in South Africa



Degradation variable accross the country



Ecologically Safe, Healthy and Sustainable Environment

- ✦ Design sustainable, locally adapted, engineering solutions
- ✦ Systems and technology needs to be “environmentally friendly”
- ✦ Mimic natural ecosystems with no wastes
- ✦ Economically viable, account for cost of degradation
- ✦ Utilise renewable energy sources
- ✦ Intelligent automated agricultural machines and sensors
- ✦ Further development and use of precision agriculture and information communication technology +
- ✦ Focus on both ends of production scales
 - ✦ Large commercial farmers
 - ✦ Emerging, small scale farmers

Precision Agriculture

☀ Site specific agriculture

- Response to spatial variability within individual fields
- Requires precise and reliable position computation

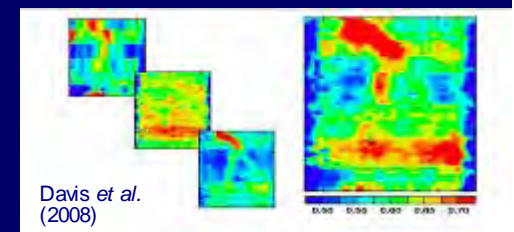
☀ Components

- Positioning by satellite navigation systems
- Real time mapping, e.g. crop yield, fertility, plant stress
- Control of field operations
 - Fertiliser and pesticide application
 - Irrigation



Improved, Affordable and Widely Applied Technology in Precision Agriculture

- Development of automated and rapid sensors of spatial variability, e.g.
 - soil moisture and acidity
 - plant stress from spectral reflectance from crop
 - discriminate between stress from disease, nutrient deficiency or insufficient moisture
 - weed/crop discrimination
- Precise applicators
- Concepts need to be developed, adapted, adopted for large and small scales
- Potential to reduce productivity gap



Production with Climate Variability and Climate Change

**MEAN ANNUAL
PRECIPITATION (mm)**
After Dent, Lynch & Schulze (1989)

mm



25°S



32°S

18°E

24°E

30°E

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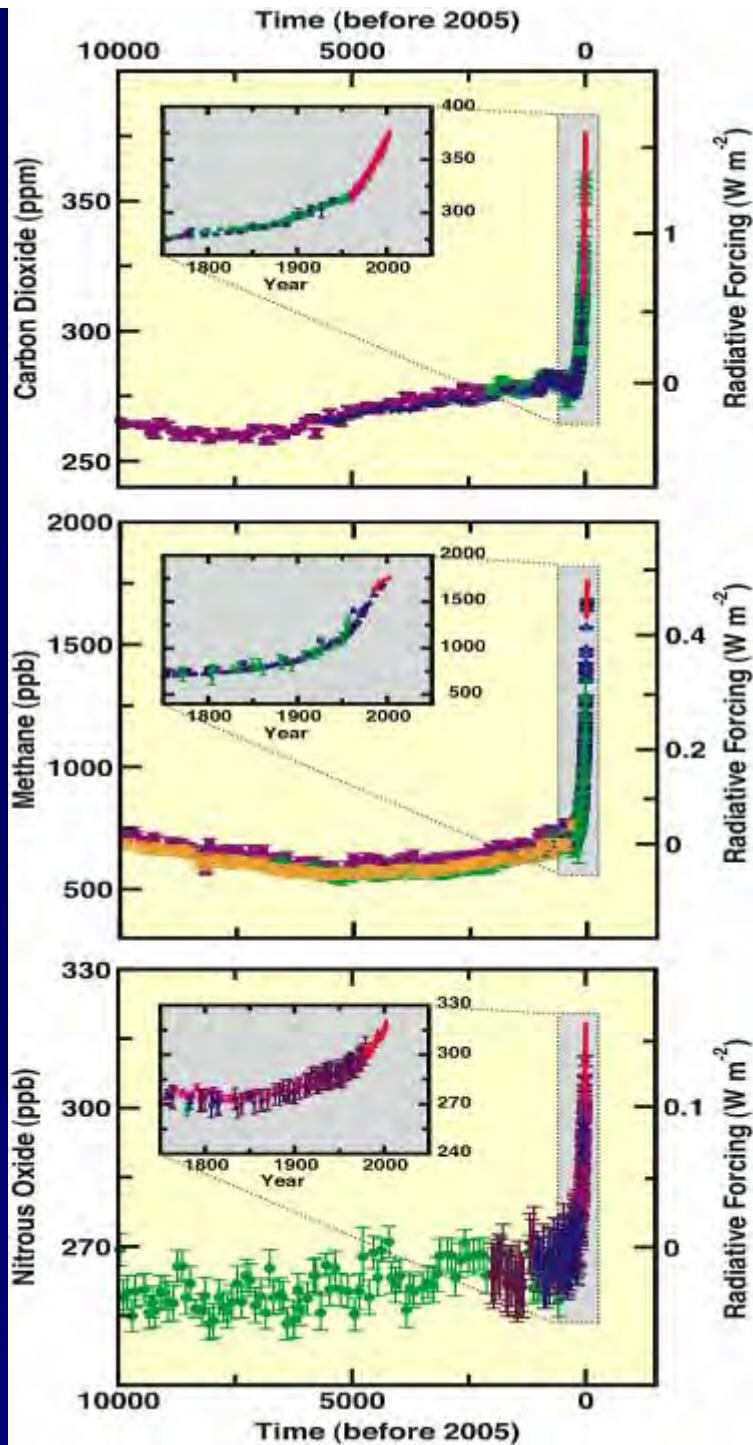




CO₂

CH₄

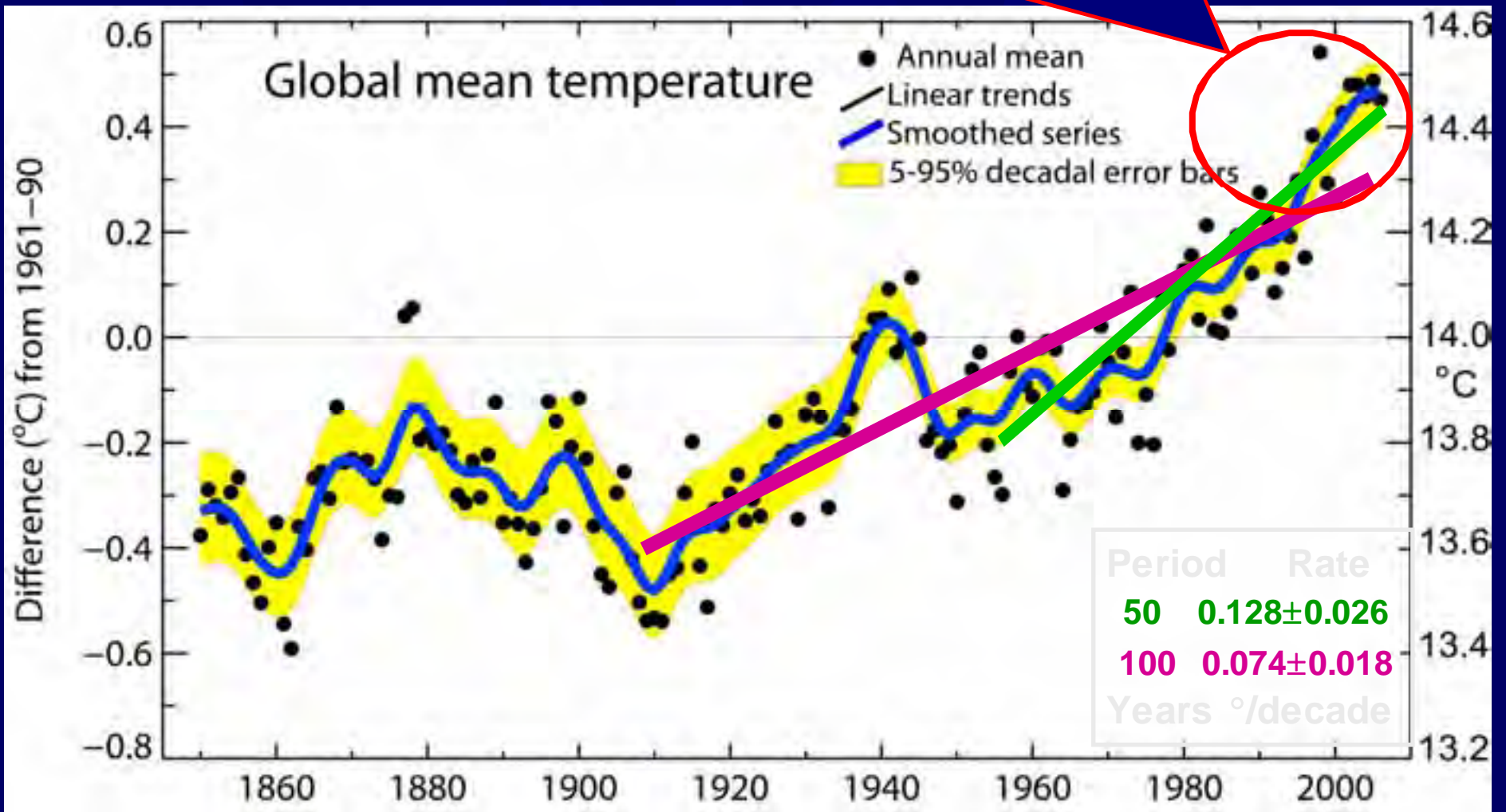
N₂O



Considerable changes have occurred since the industrial revolution

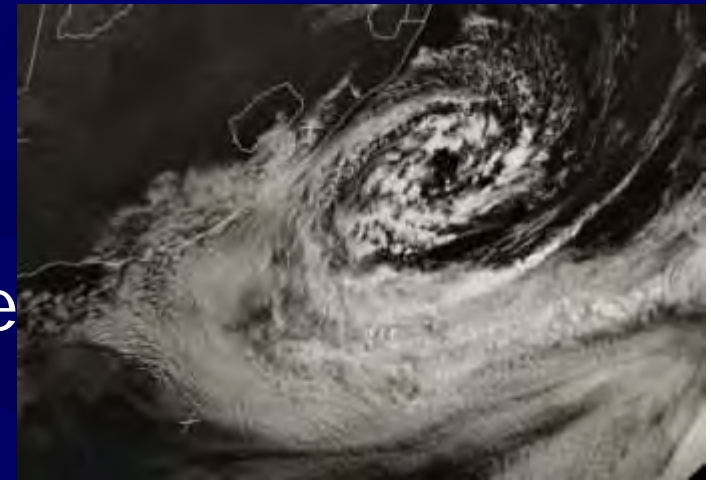
Global mean temperature from 1850 to 2005

Warmest 12 years:
1998, 2005, 2003, 2002, 2004, 2006,
2001, 1997, 1995, 1999, 1990, 2000



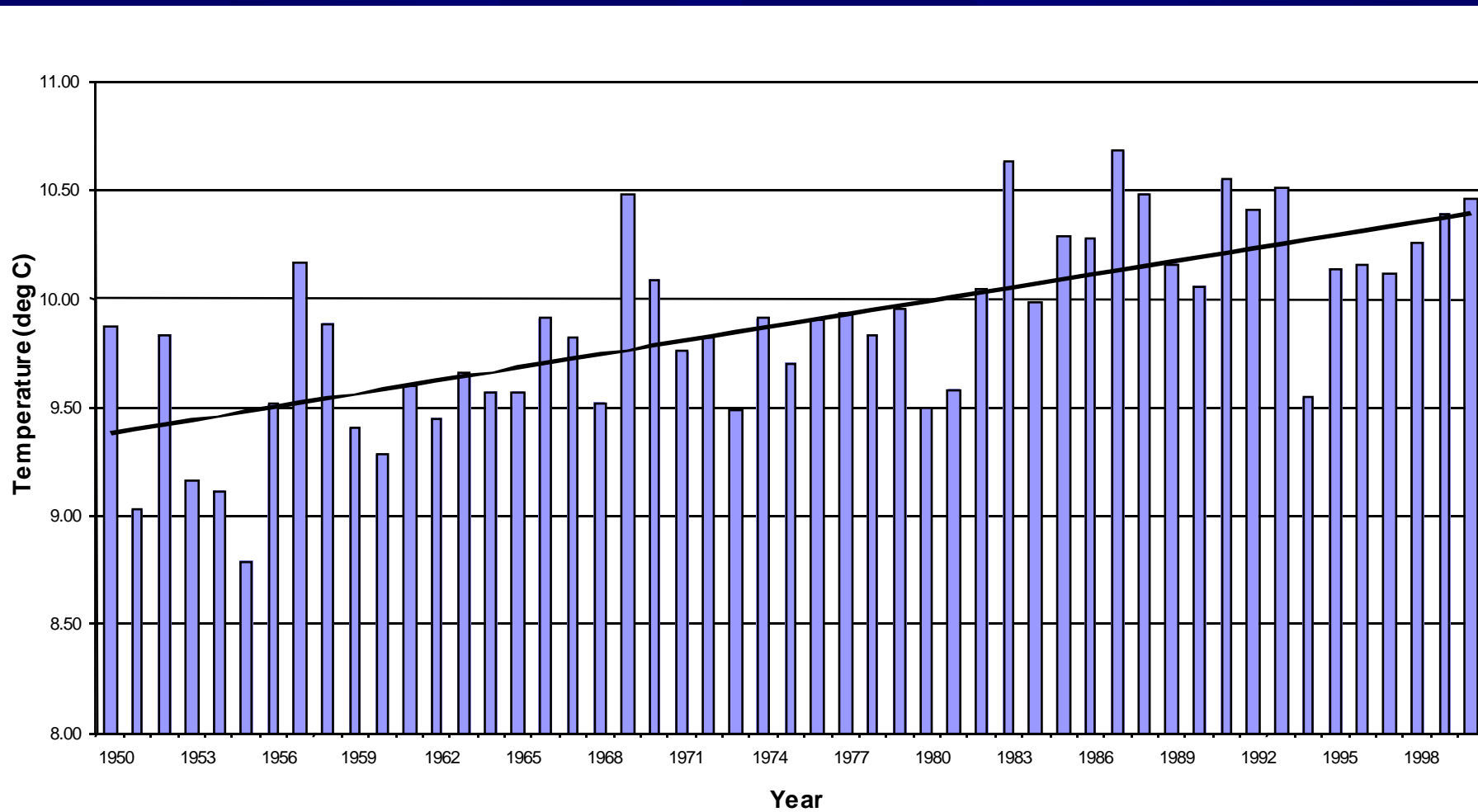
Impacts of Climate Change

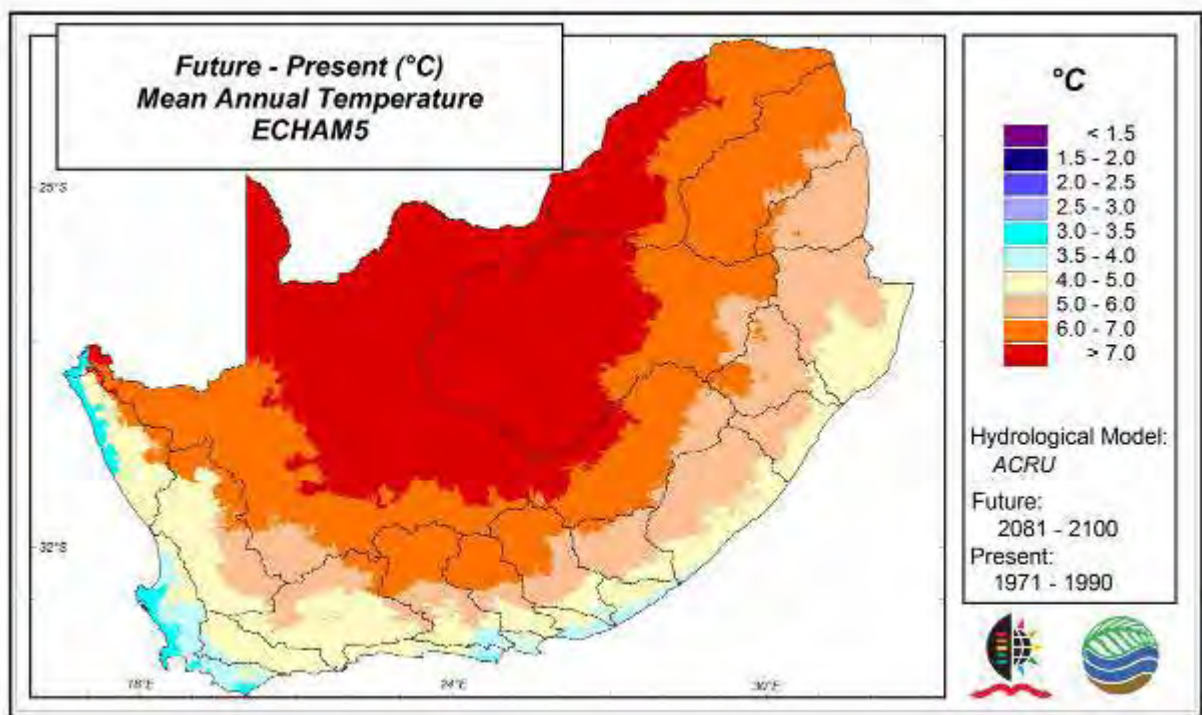
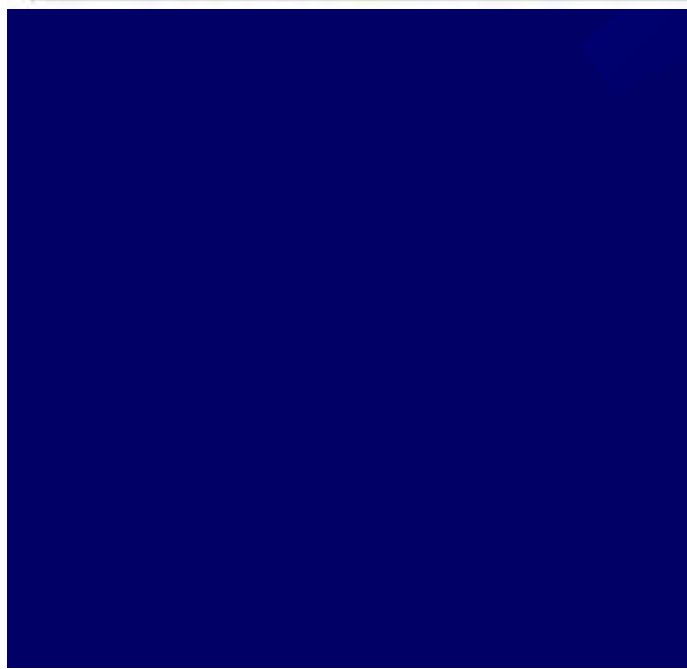
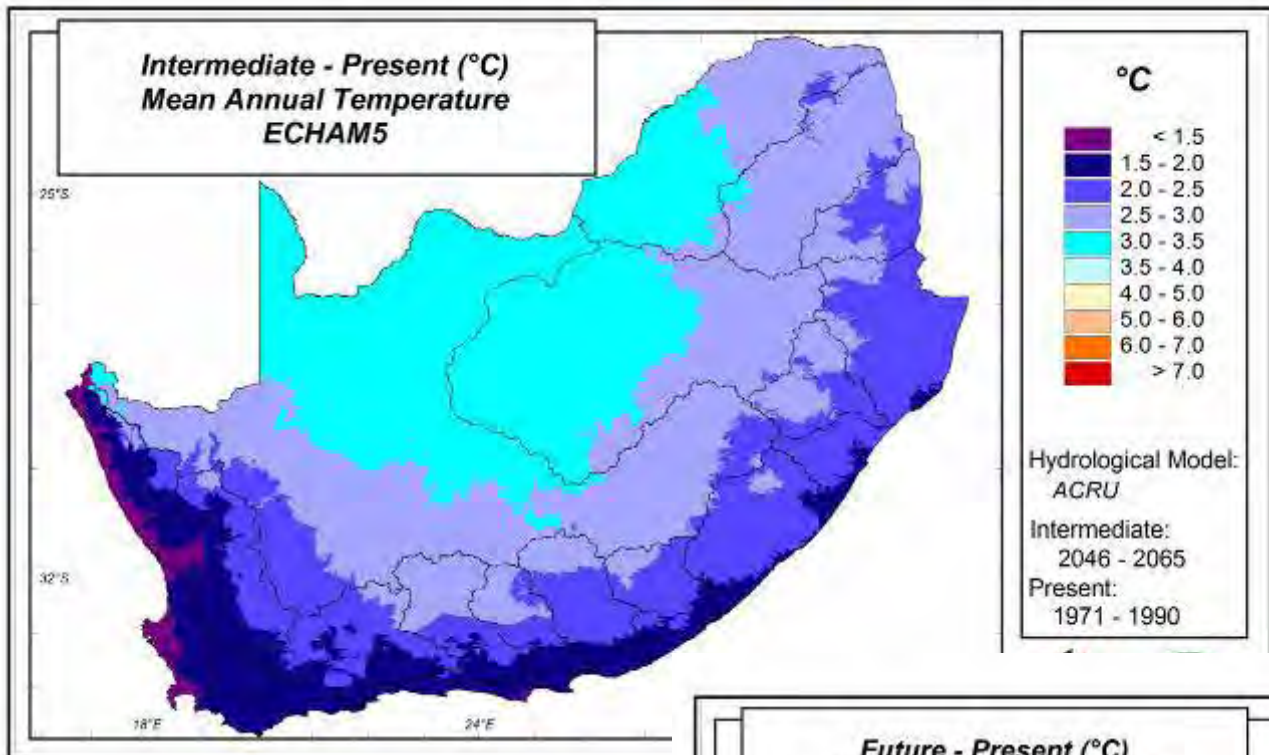
- ☀ Debate on degree and distribution
- ☀ Sea level and storm surges
- ☀ Frequency and magnitude of extreme climatic events
- ☀ Significant impact on agriculture
- ☀ Largest impact in poor and developing countries
 - ☀ Lack of capacity
 - ☀ Lack of technology
 - ☀ Limit poverty alleviation



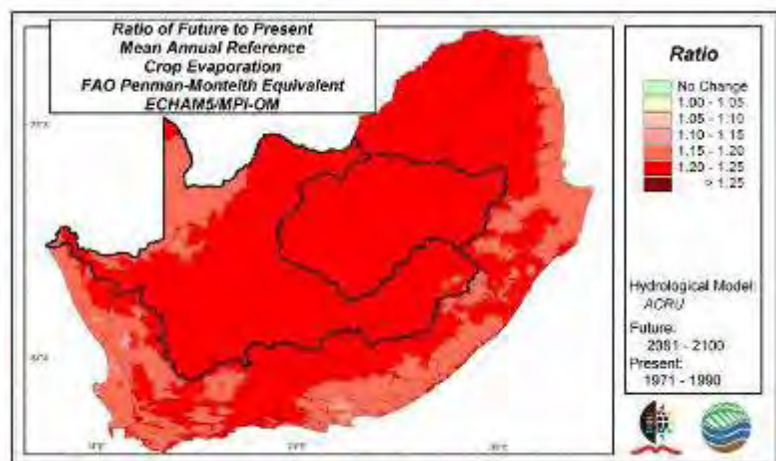
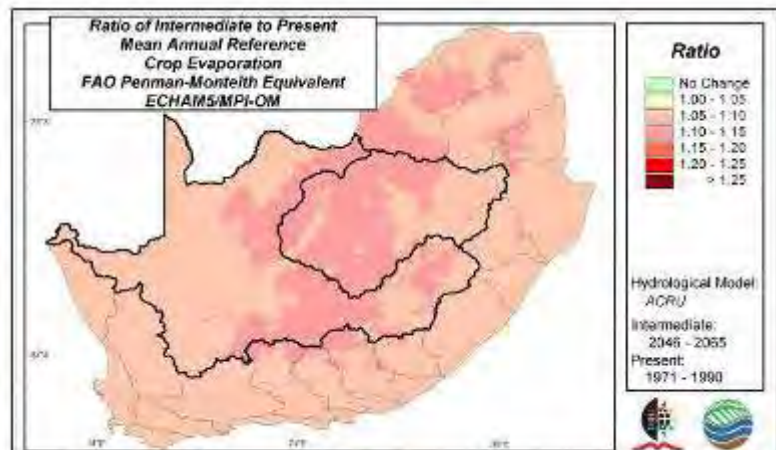
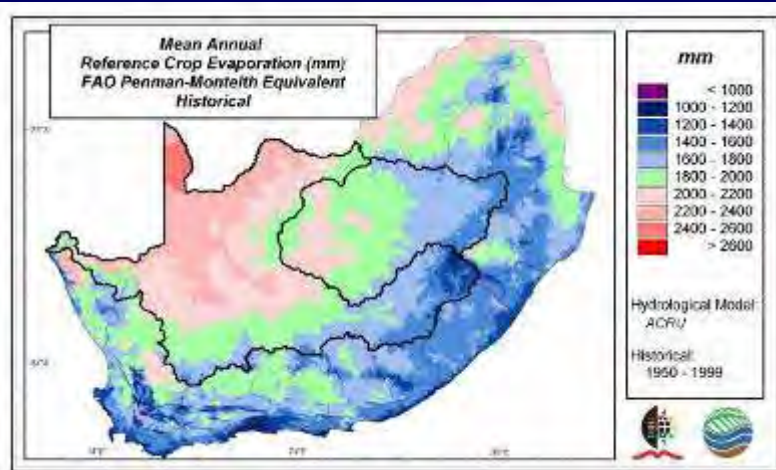
Potential Impacts of Climate Change in South Africa

Annual Means of Daily Minimum Temperature at Cedara





Acknowledgement: Schulze, 2009

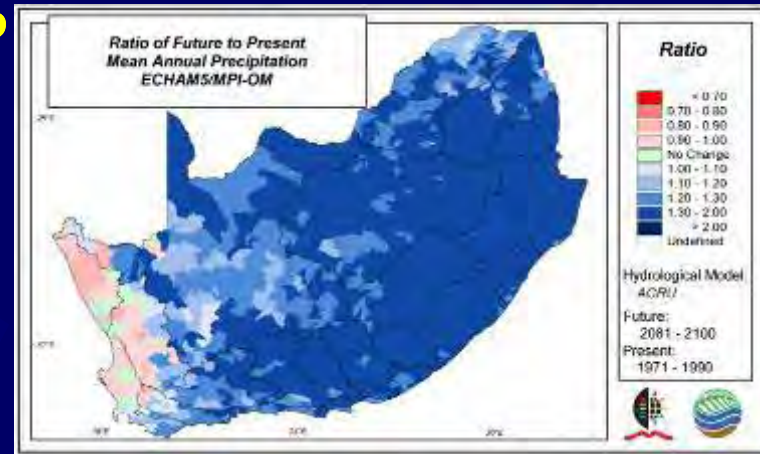
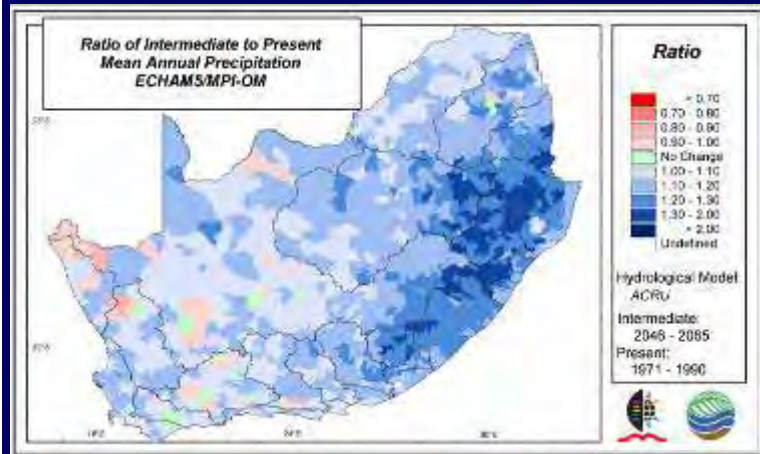


*Potential Evaporation
is Projected to
Increase by

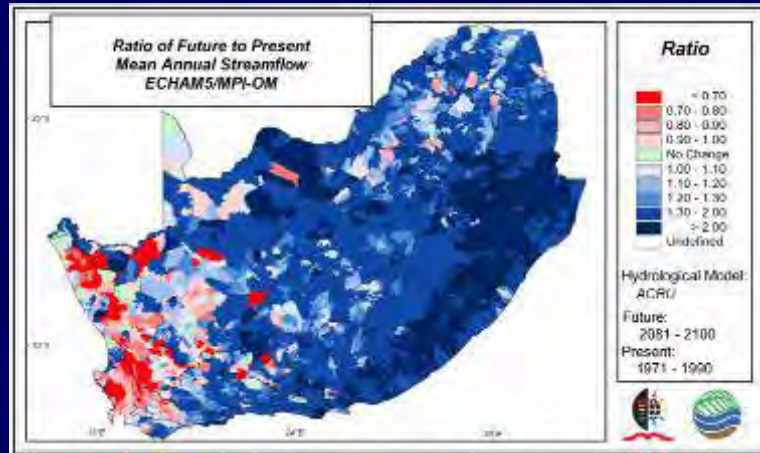
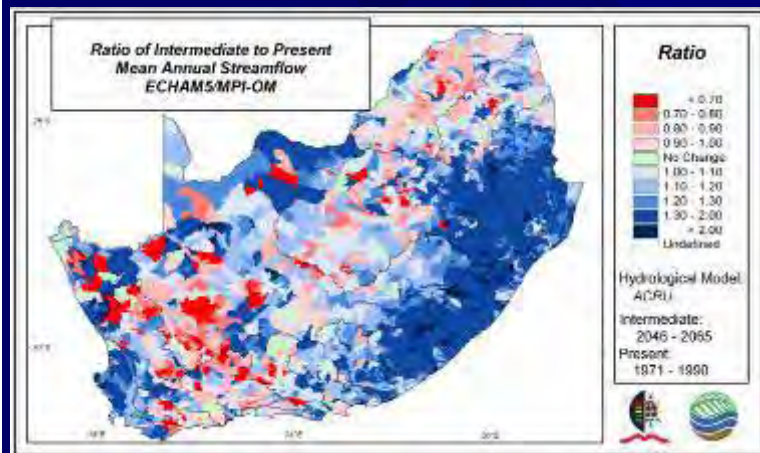
~ 5 - 15% in the
Intermediate Future
and by ~ 20 - 25% in
the More Distant
Future*

I:P

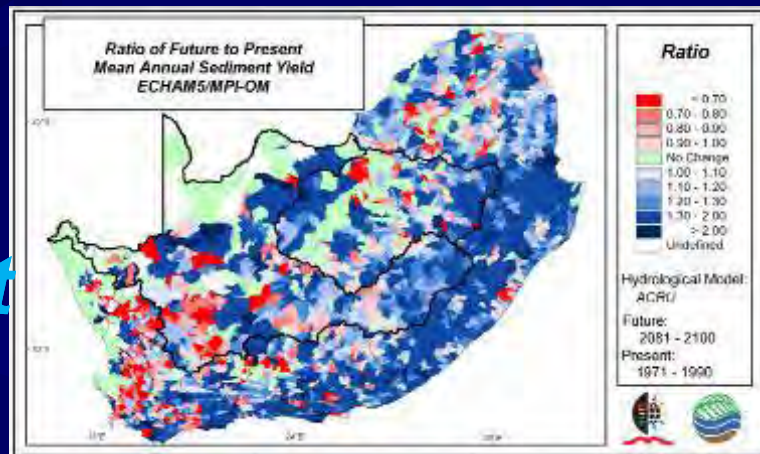
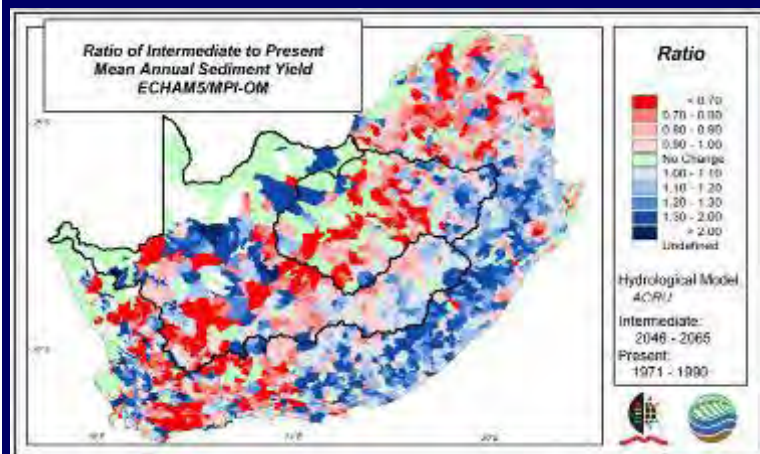
F:P



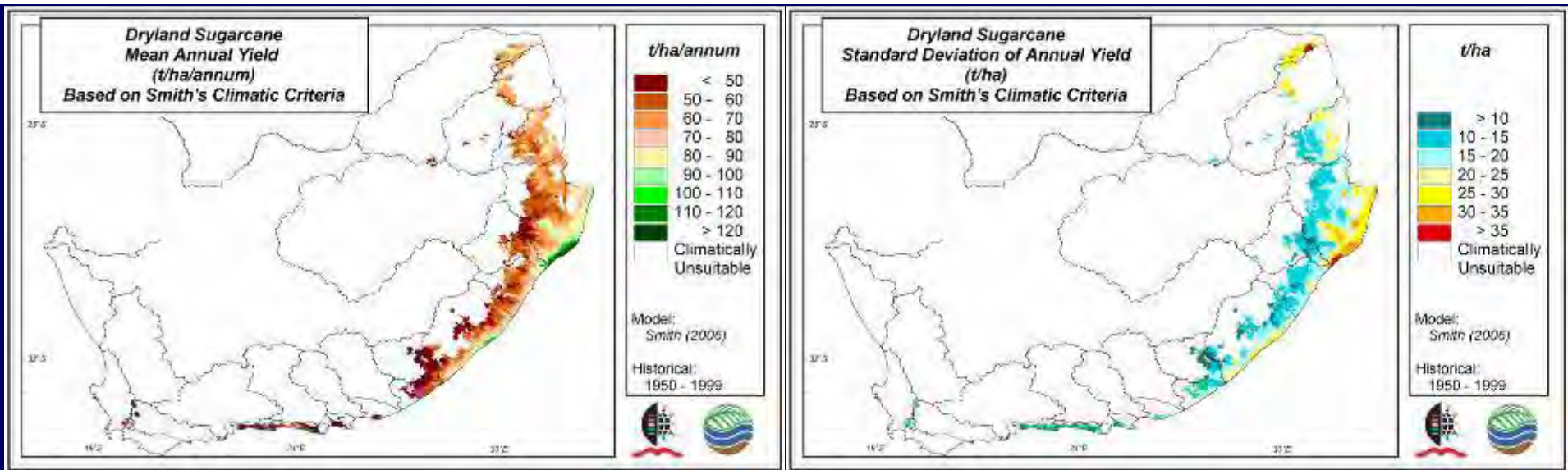
Rainfall



Runoff

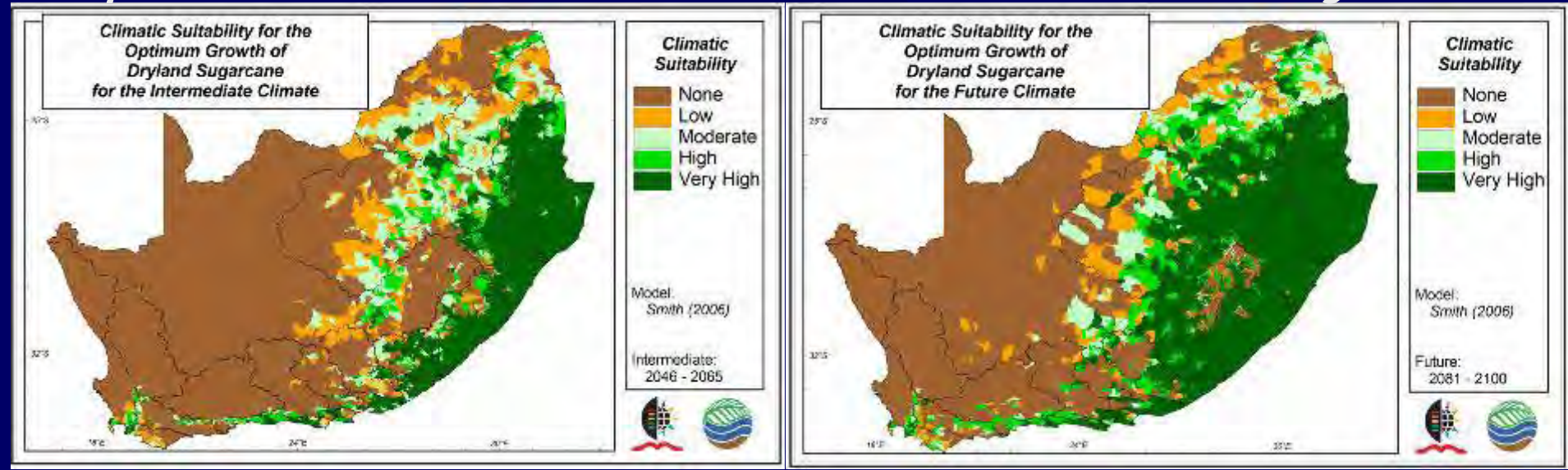


Sediment Yield



Sugarcane Yields Under Present Climatic Conditions

Optimum Growth Areas Under Future Climate Projections



Technology to Mitigate Impact of Climate Change

- ☀ Need adaptive & flexible management strategies
- ☀ Predict/forecast future climates and impacts
 - ☀ Optimum growing regions
 - ☀ Irrigation demands for water
 - ☀ Pests and diseases
 - ☀ Production practices to minimise GHGs
 - ☀
- ☀ Optimum use and retention of water – critical growth periods
- ☀ Renewable energy and energy efficiency
- ☀ Strengthen local capacity – mitigation measures
- ☀ Develop research capacity
- ☀

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Food and Water Security and Sustainability

- ✦ Increase in hunger despite increase in global food production
- ✦ 84% of global population live in water stressed region
- ✦ 1/6 of world has inadequate & unsafe drinking water
- ✦ Food insecurity is a consequence of
 - ✦ Limited fresh water supplies
 - ✦ Limited fossil fuels
 - ✦ Environmental degradation
 - ✦ Climate variability and climate change
 - ✦ Production economics
 - ✦ Increasing world population



Growing World Population

☀ Projections

☀ 2000 - 2050

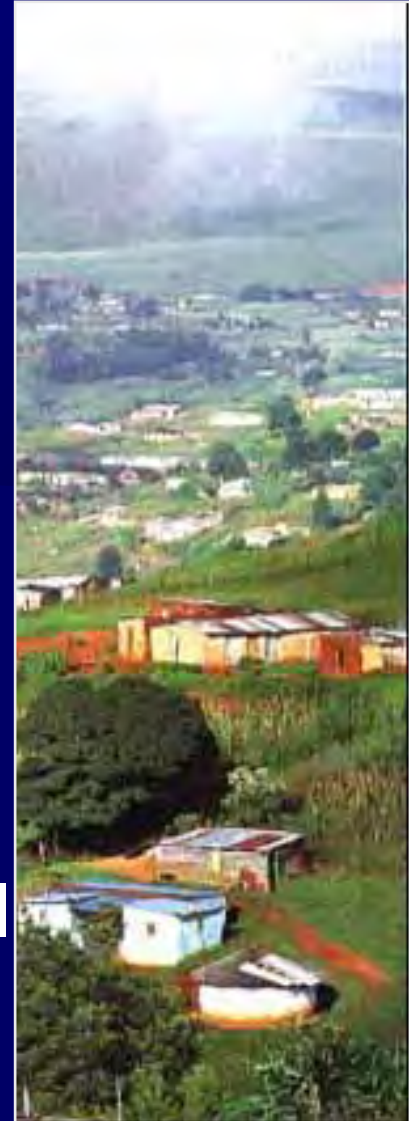
- 50% projected increase in world population

☀ by 2050

- 7.3-10.5 billion
- At current rates: 14 billion

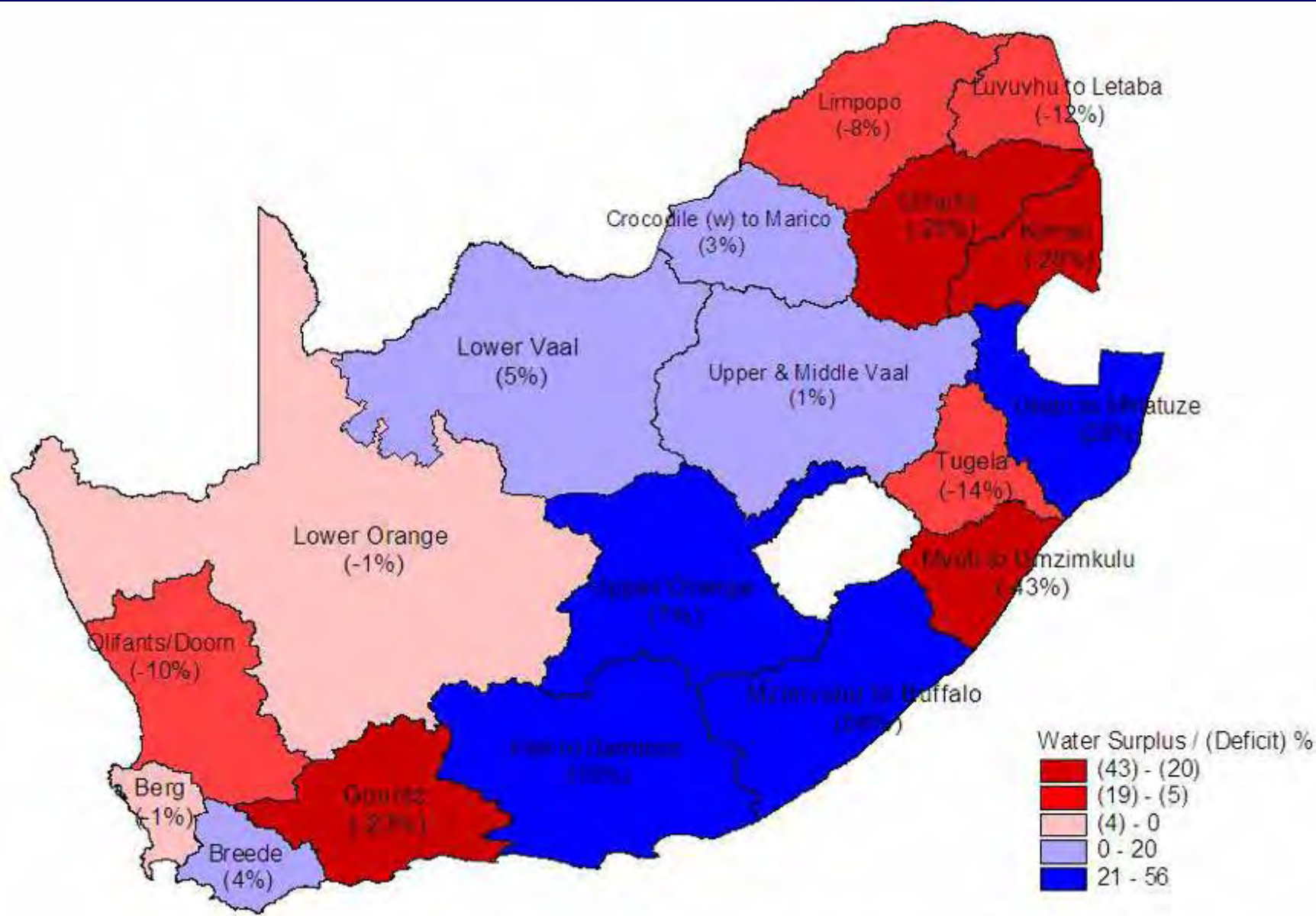
☀ Requires more food, water, energy, goods

☀ Limited resources demand we do more with less, without degrading our natural environment



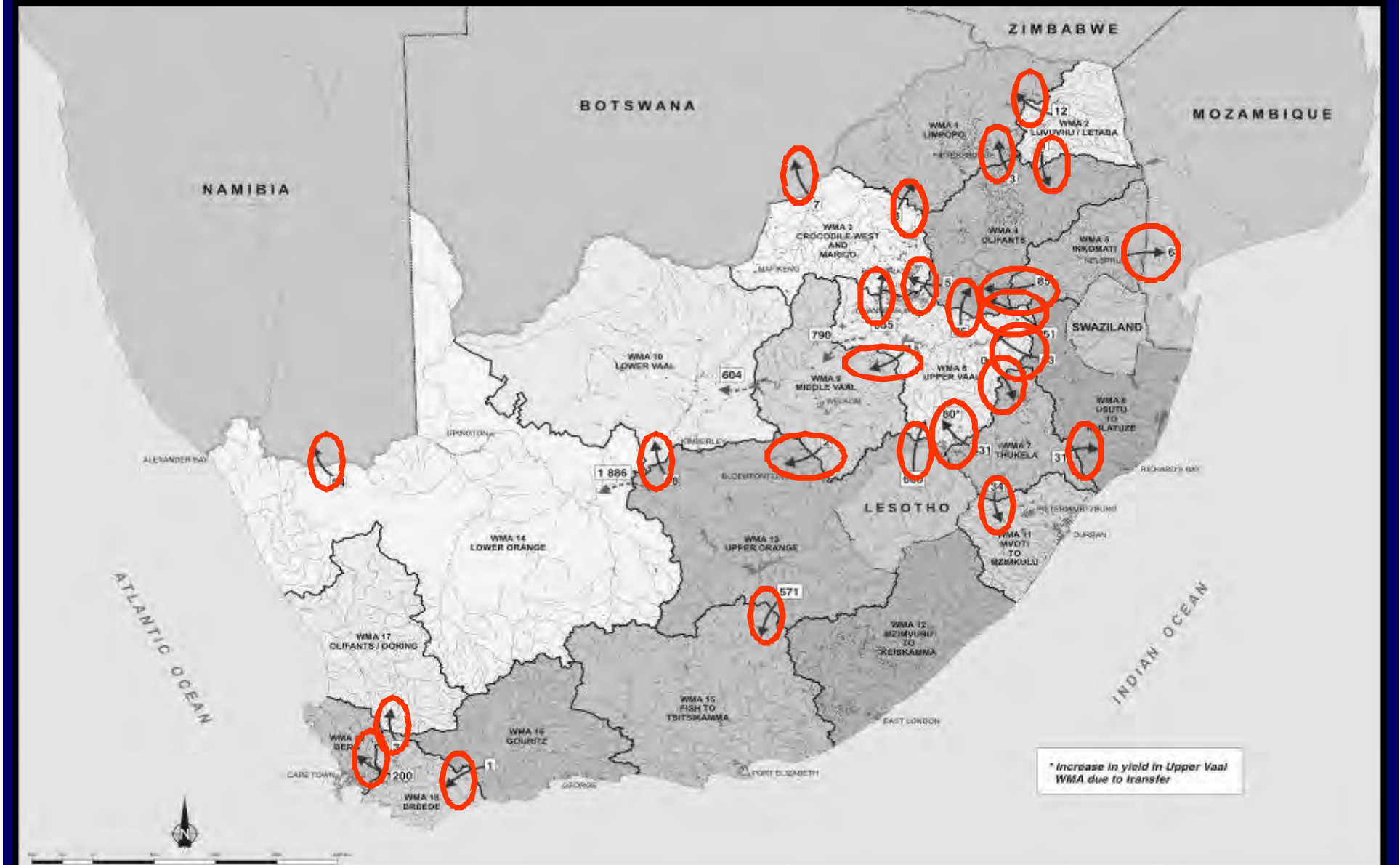
Global Water Supply

- ✦ By 2050: **two thirds** of global population
 - ✦ Inadequate access to safe drinking water
 - ✦ Inadequate water for food production
- ✦ Growing demand > Supply
 - ✦ Potential for conflict
- ✦ Current global usage
 - ✦ 71 % used for irrigated agriculture
 - ✦ 20 % for industry, and
 - ✦ 9 % for municipal and domestic purposes



Water Management Areas percentage surplus/deficit for the year 2000 (Source: NWRS)

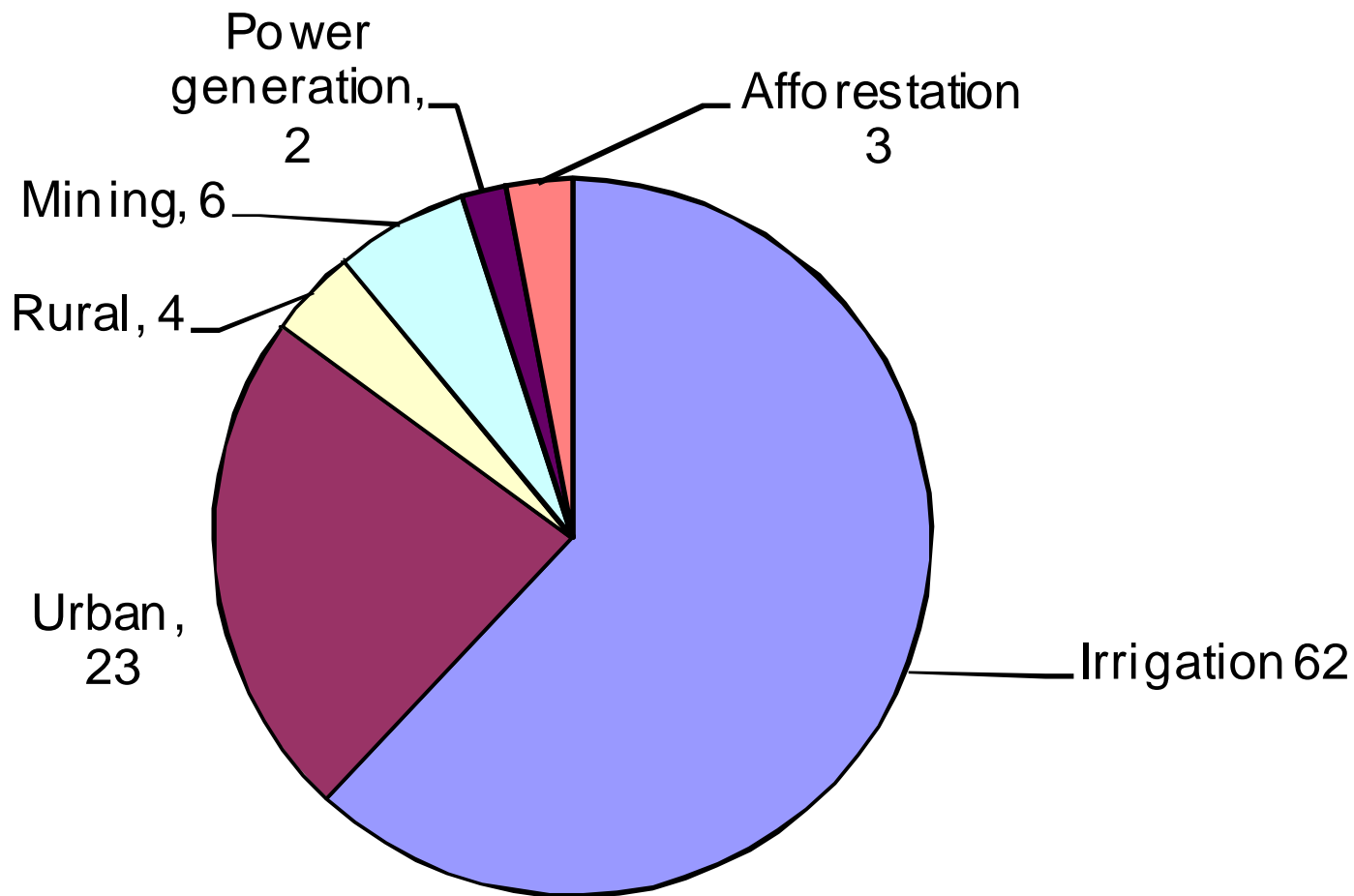
Inter-Catchment Transfers



National Water Act (Act 36 of 1998)

- ✦ Fundamental change to management of water and water use rights
 - ✦ From riparian rights system
 - ✦ Permit (licensing) system
- ✦ Establishes priority of allocation
 - ✦ Provision for the Reserve
 - ✦ International agreements and obligations
 - ✦ Water for social needs
 - ✦ Strategically important to the national economy
 - ✦ Water for general economic use, which includes commercial irrigation and forestry
- ✦ Licence for water use required
- ✦ Trading of water is envisaged
- ✦ Resources and knowledge to implement?

Water Use (%) in South Africa in 2000



Design and Maintenance of Irrigation Systems



Furrow



Sprinkler



Drip



Micro



Mobile

Improve WUE in Irrigation

★ How?

- ★ Automatic irrigation control systems using soil moisture sensing
- ★ Automated short furrow irrigation
- ★ Near on-demand water supply with vastly improved overall distribution efficiency (e.g. Victoria, Australia)
- ★ Improved field application technology and management to raise efficiency of water use
- ★ Develop low-energy, precise application systems
- ★ Conservation tillage production systems
- ★ Plan for climate change
- ★

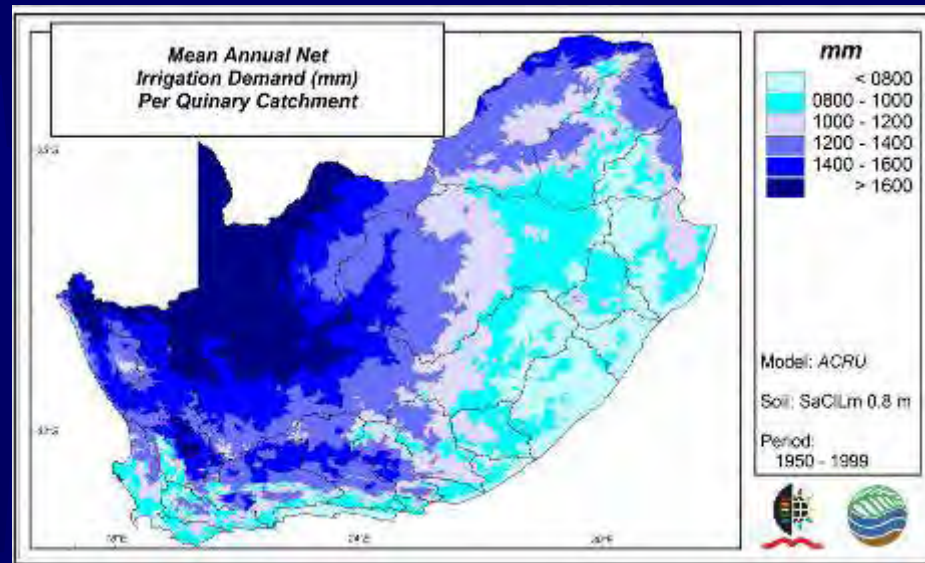


Irrigation and Climate Change



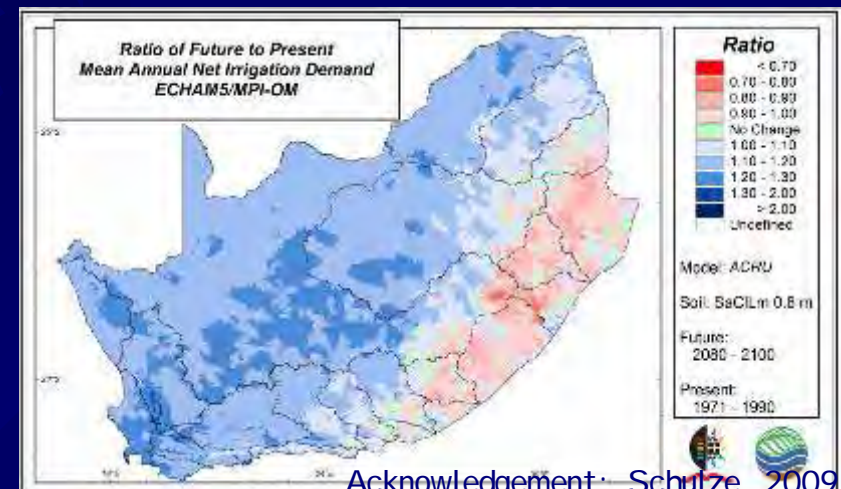
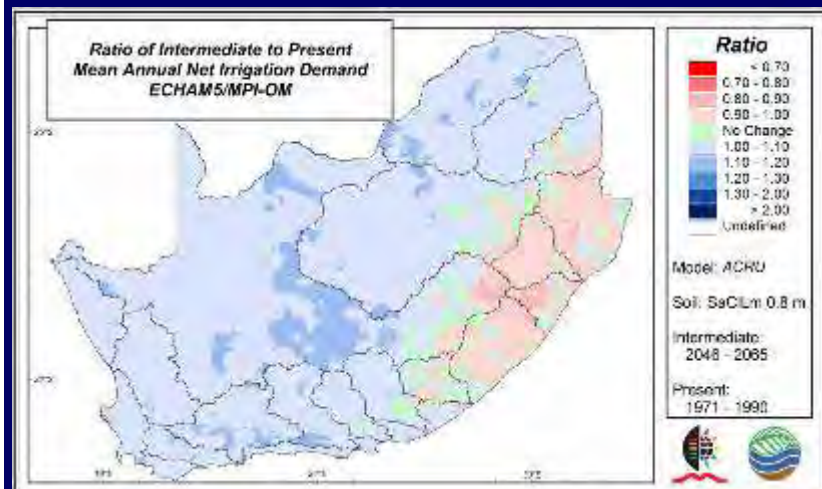
Acknowledgement: Schulze (2009)

Present



Irrigation Demands Will Change

Changes in the Intermediate Future *Changes in the Distant Future*



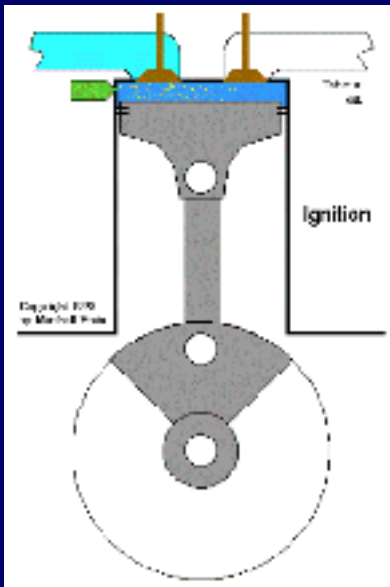
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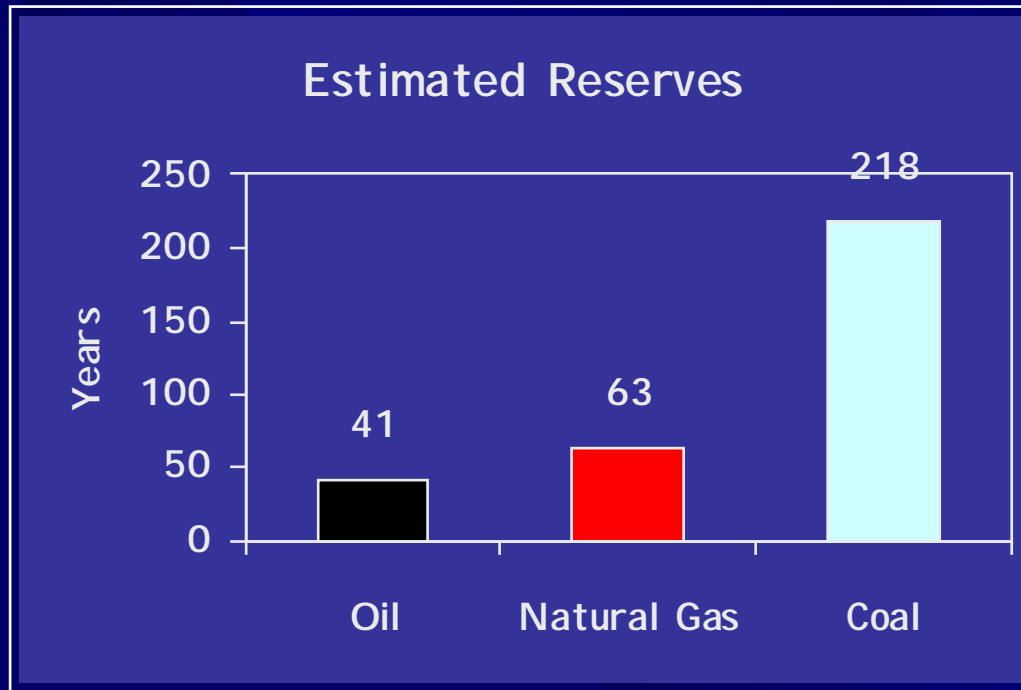
Energy in Food Production Systems

- ✦ Current production systems dependent on fossil-based energy
- ✦ Dwindling supply of fossil-based energy and products
- ✦ Fossil fuels → GHG → Climate Change



Fossil Fuel Reserves

- ☀ Rate of depletion of (limited) fossil fuel reserves exceeds supply
- ☀ Estimated reserves (under a business-as-usual scenario)



- ☀ Demand for fossil fuel projected to triple from 1990-2020

Technology for Efficient Use of Energy

- ★ Energy efficient and regenerative controlled environment systems
- ★ Design Zero Energy Buildings (ZEB)
 - ★ combine energy-efficient design and technology
 - ★ with solar energy and other on-site energy generation technologies
- ★ Energy efficiency and savings in production systems
- ★ Renewable energy from biomass and waste sources
- ★



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Renewable Sources of Energy

- ✦ Power from wind
- ✦ Solar
- ✦ Geothermal
- ✦ Biomass
- ✦ ...

Bio-Energy

- ★ Energy from biomass
 - Renewable
 - Carbon neutral
 - Sustain the environment
 - Economically viable?
 - Competition with food supply?
 - Energy balance?



Can We Grow All Our Energy Requirements?

- ★ "To replace 10% of fossil based transport fuel in USA will require 30-70% of current crop land" (Rajagopal, 2007)
- ★ "Biodiesel from oil crops, waste cooking oil and animal fat cannot realistically satisfy even a small fraction of the existing demand for transport fuels" (Chisti, 2007)
- ★ Ebrahim Patel (Minister of Economic Development, RSA), 2010
 - biofuels production target = 400-million litres
 - 3 South African biofuel projects, each producing 100-million litres a year
 - sugar beet and grain sorghum-to-ethanol project in E. Cape
 - sugarcane-to-ethanol project in Limpopo & KwaZulu-Natal

Comparison of Selected Biodiesel Feedstock

Crop	Oil yield (L/ha)	Land area needed (M ha) ^a	Percent of existing US cropping area ^a
Corn	172	1540	846
Soybean	446	594	326
Canola	1190	223	122
Jatropha	1892	140	77
Coconut	2689	99	54
Oil palm	5950	45	24
Microalgae ^b	136,900	2	1.1
Microalgae ^c	58,700	4.5	2.5

^a For meeting 50% of all transport fuel needs of the United States.

^b 70% oil (by wt) in biomass.

^c 30% oil (by wt) in biomass.

Bio-Energy Technology Requirements

- ☀ Biomass production, harvesting & transport
 - ☀ Engineering solutions for biomass feedstock production and harvesting systems
 - ☀ Biomass feedstock supply chain logistics
- ☀ Biomass processing
 - ☀ Production of transportation fuels and electrical power
 - ☀ Conversion and processing of cellulosic feed stocks (crop residues, wood, etc)
- ☀ Development bio-based products
- ☀ Alternative feedstocks (e.g. algae)
- ☀ Biodiesel fuel properties & performance
- ☀ Bio-energy is necessary to sustain food production, not challenge it!



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Growing Agricultural Engineering: USA

- ✦ Decline in AE student population in 1980s
 - ✦ Agriculture not attractive to school leavers
 - ✦ Many AE academic departments
 - Merged with other programs
 - Shut down or
 - Restructured and transformed
- ✦ One response has been to change names
 - ✦ ASAE → ASABE in 2005
 - ✦ J. of Ag Eng Research → Biosystems Engineering
- ✦ More focus on “Biological Engineering”
 - ✦ ASAE launched Biological Engineering Technical Division in 1999

Name Change: Academic Departments in USA and Canada

- ★ 50 Agricultural Engineering academic departments were surveyed in 1995
 - 61%
 - had modified their department names
 - 49%
 - had changed their bachelor degree titles to mirror their Biological Engineering interests
 - 52%
 - had either significantly reworked their undergraduate curricula or expanded their research areas to include Biological Engineering

University of Illinois

- ☀ Top ranked UG programme



The graphic features a central text area on a light beige background. At the top left is a red line drawing of three people in a classroom setting. To the right is a vertical grid of small, colorful images related to agriculture and engineering. The text is centered and includes a website URL, several engineering sub-fields, a main title, a tagline, and contact information for the department at the University of Illinois.

www.abc.uiuc.edu

SOIL & WATER RESOURCE ENGINEERING

OFF-ROAD EQUIPMENT ENGINEERING

BIOENVIRONMENTAL ENGINEERING

PRECISION AGRICULTURE

Agricultural and Biological Engineering
It's about individuals who make life better.

FOOD & BIOPROCESS ENGINEERING


GRAIN QUALITY & MILLING PROPERTIES

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UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Agricultural and Biological Engineering
206 Agricultural Engineering Sciences Building
1304 W. Pennsylvania Avenue
Urbana, Illinois 61801
Telephone: (217) 244-0870
Fax: (217) 244-0829
Email: age@uiuc.edu

Cornell University

☀ 2nd ranked UG programme



Cornell University
Ithaca, New York

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Texas A&M University – College Station

☀ 3rd ranked UG programme



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... In the Department of Biological and Agricultural Engineering at Texas A&M University, the best agricultural engineering department in the country, as ranked by *U.S. News & World Report*.

With degree programs in biological systems engineering and agricultural engineering, you can study

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- Food engineering
- Water and environment engineering
- Air quality engineering
- Soil and water resources engineering

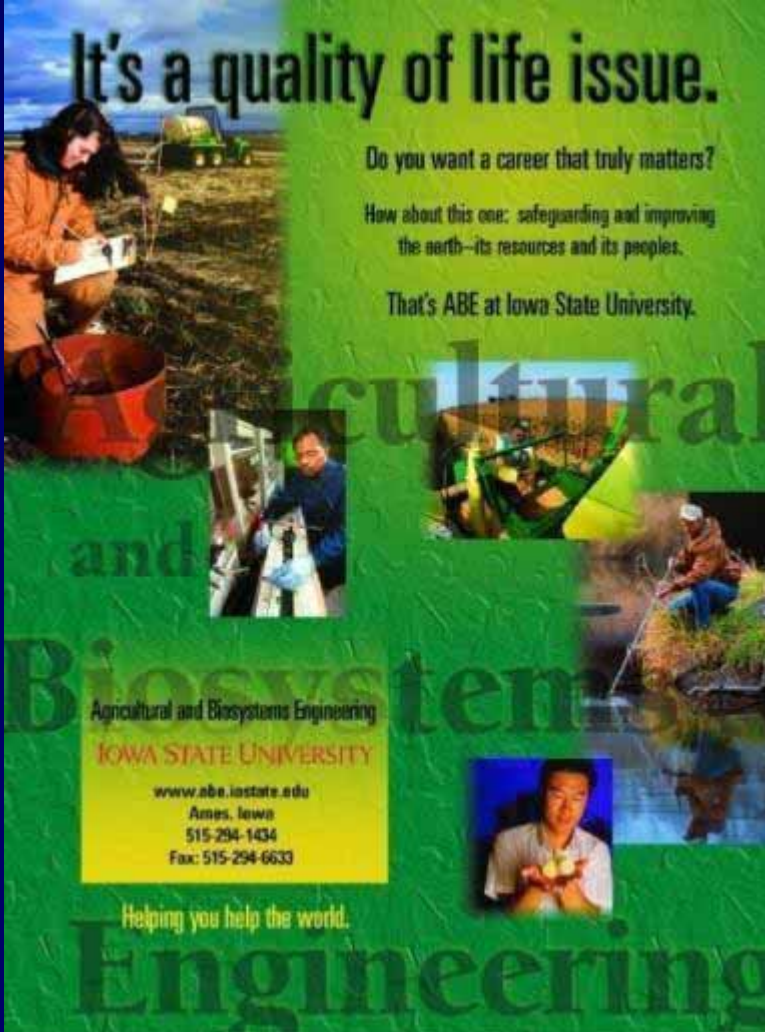
Biological and Agricultural Engineering at Texas A&M

Department of Biological and Agricultural Engineering
Texas A&M University
201 Scoates Hall
2117 TAMU
College Station, TX 77843-2117
info@baen.tamu.edu
979/845-3931

<http://baen.tamu.edu>

Iowa State

☀ 4th ranked UG programme



It's a quality of life issue.

Do you want a career that truly matters?

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That's ABE at Iowa State University.

and

Biosystems

Agricultural and Biosystems Engineering
IOWA STATE UNIVERSITY


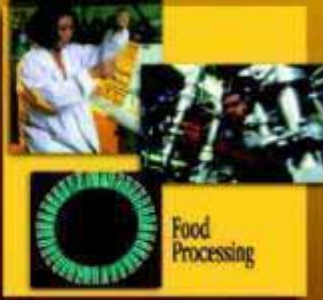
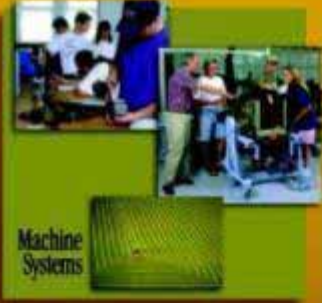

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Engineering

Purdue

- ★ 5th ranked UG programme



PURDUE UNIVERSITY

Machine Systems

Food Processing

Environmental & Natural Resources

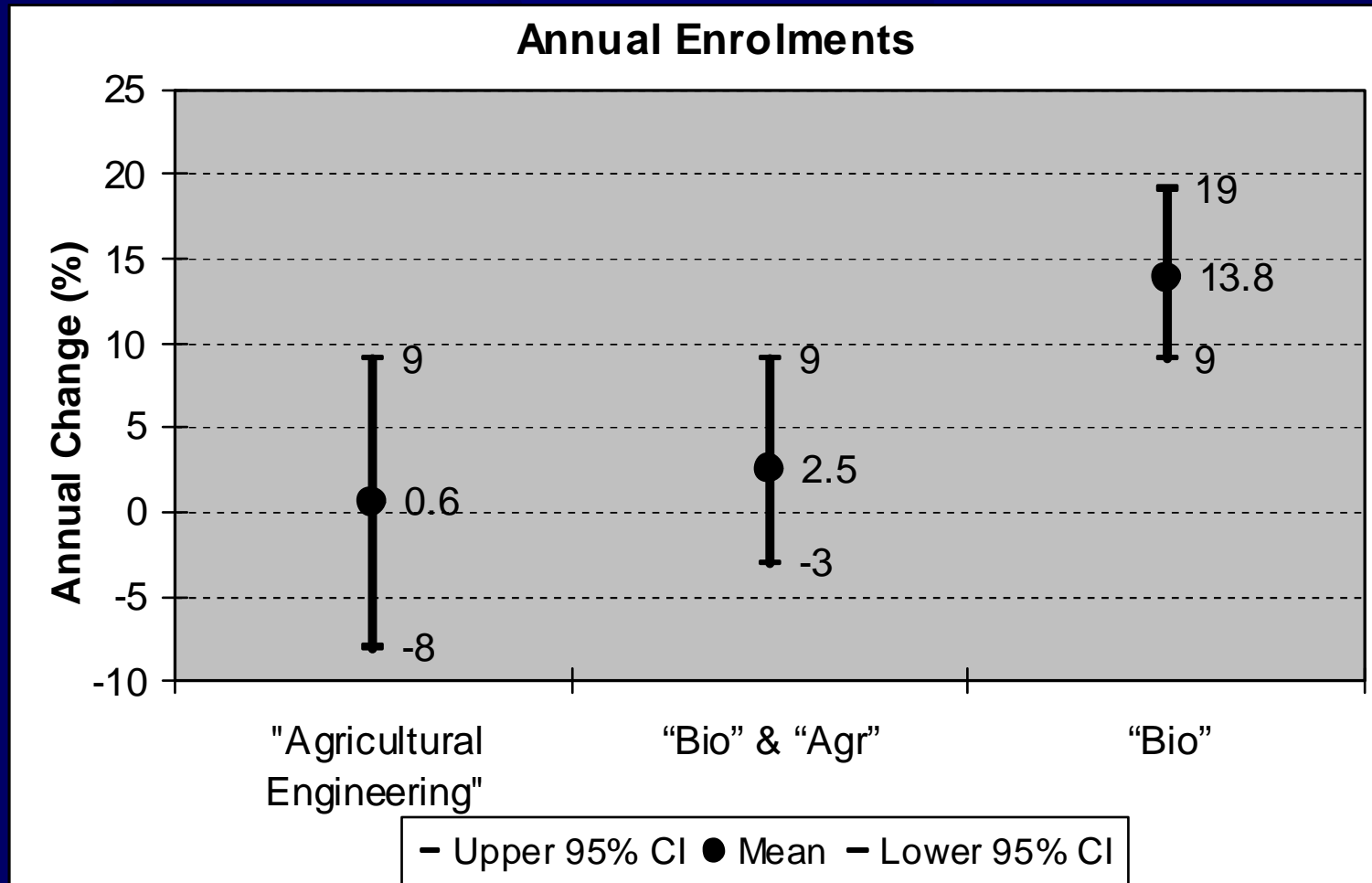
*Preparing students, citizens,
and industry for the future...*

<http://www.purdue.edu/abe>

Purdue University is an equal opportunity, equal access employer.

Impact of Name Change

- Enrolment changes at 37 universities

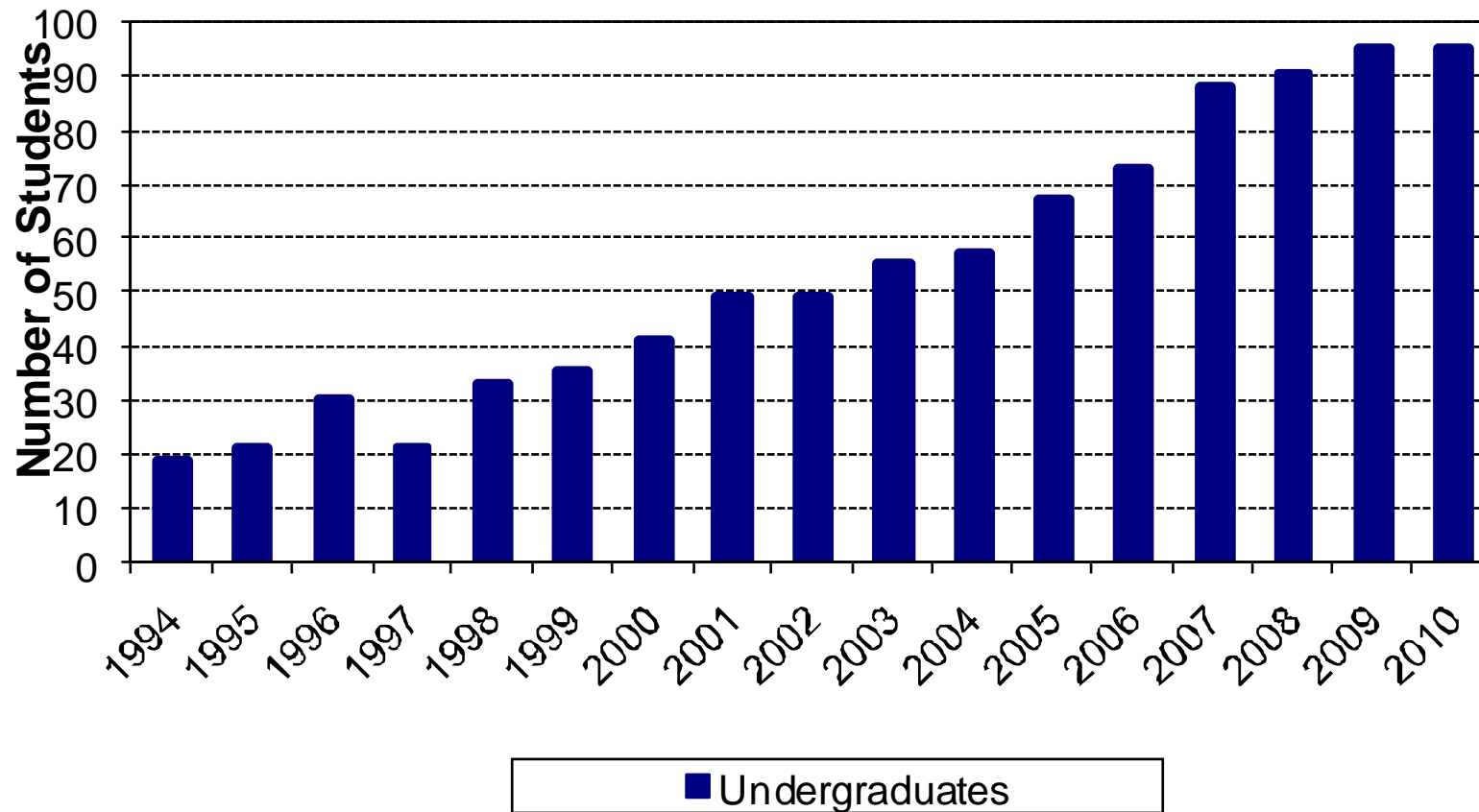


University of Natal

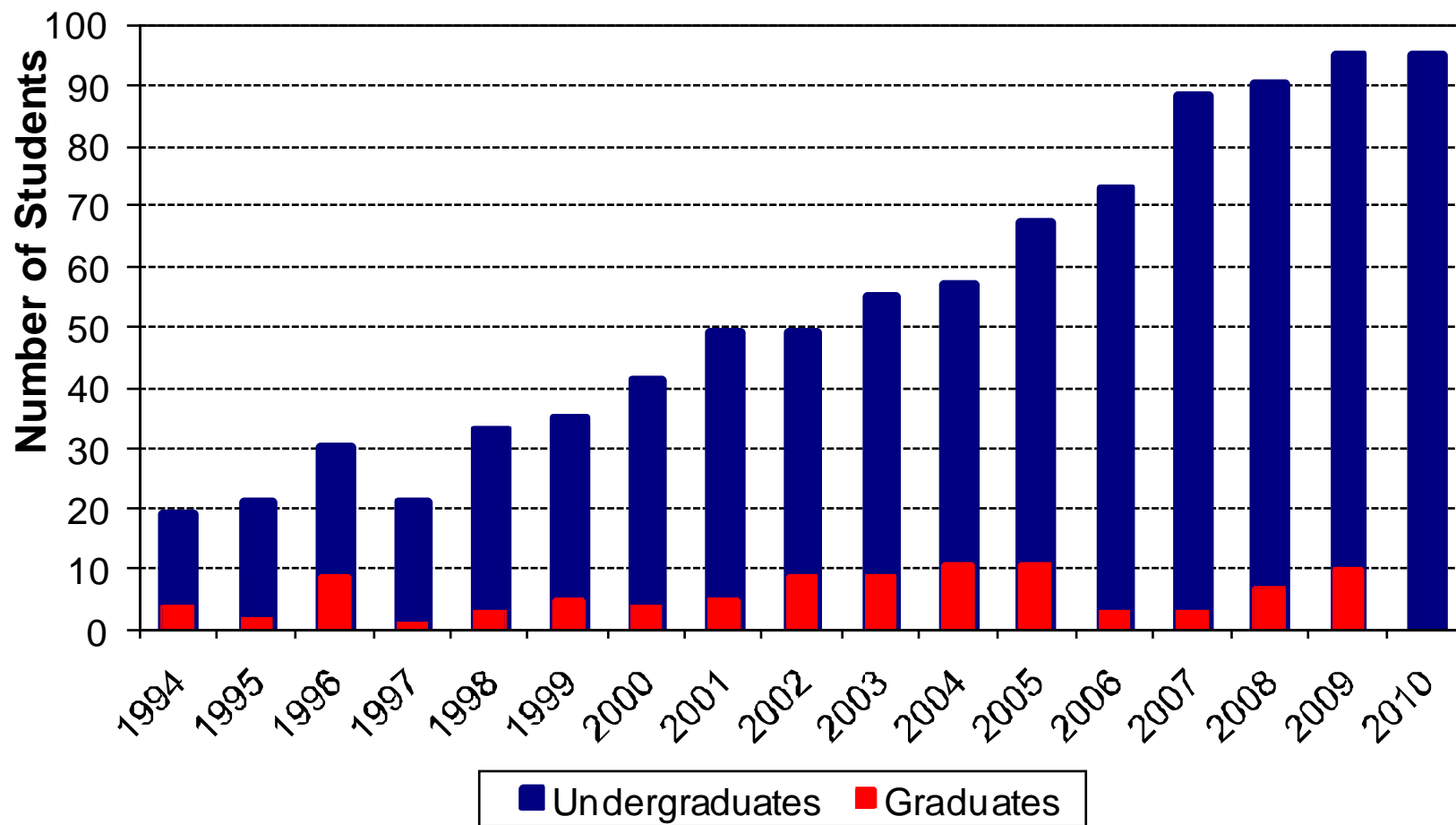
- ✦ Name change: 1999
 - ✦ Department of Agricultural Engineering
 - ✦ School of Bioresources Engineering and Environmental Hydrology



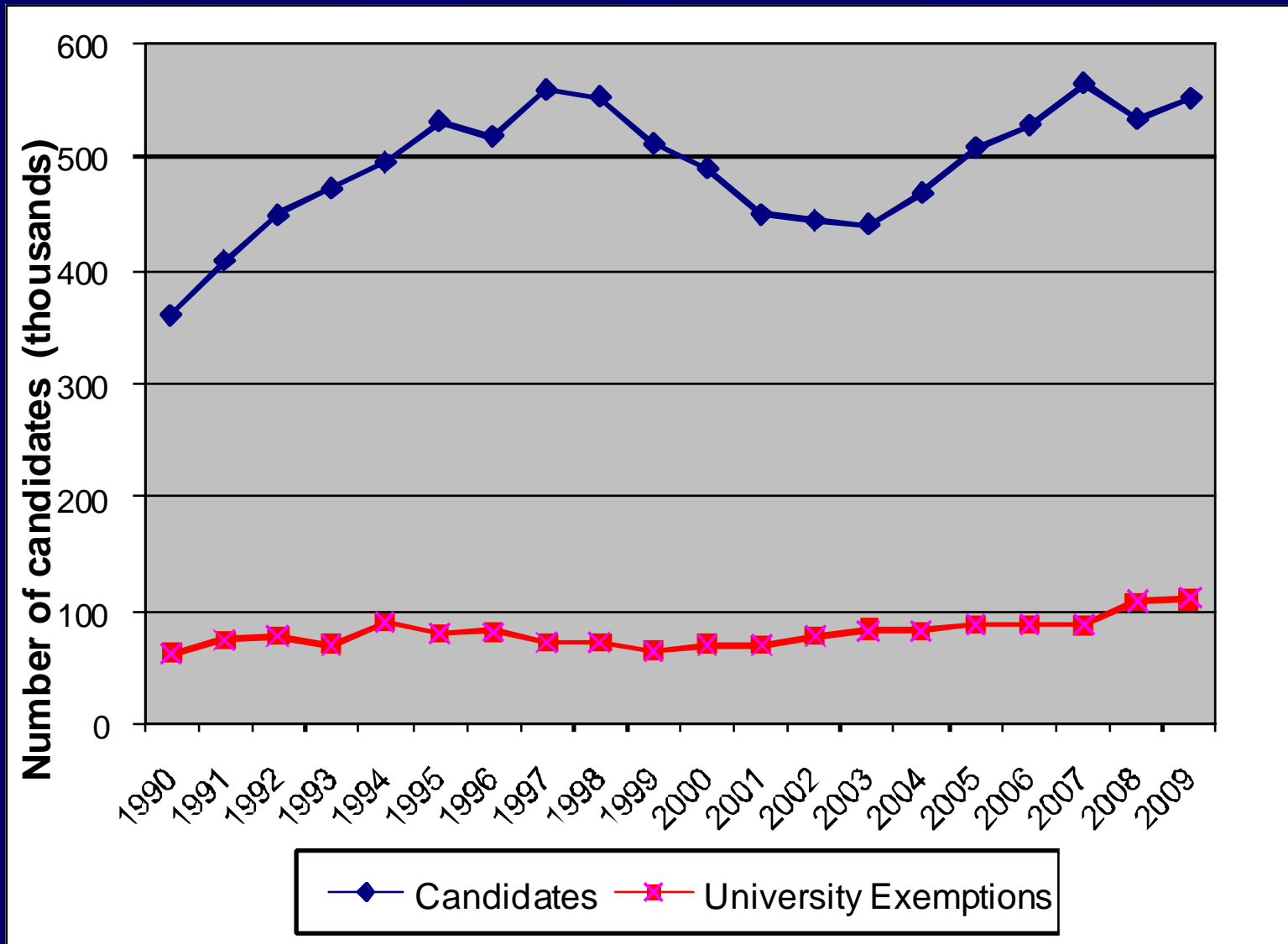
Bioresources Engineering Students at UN/UKZN



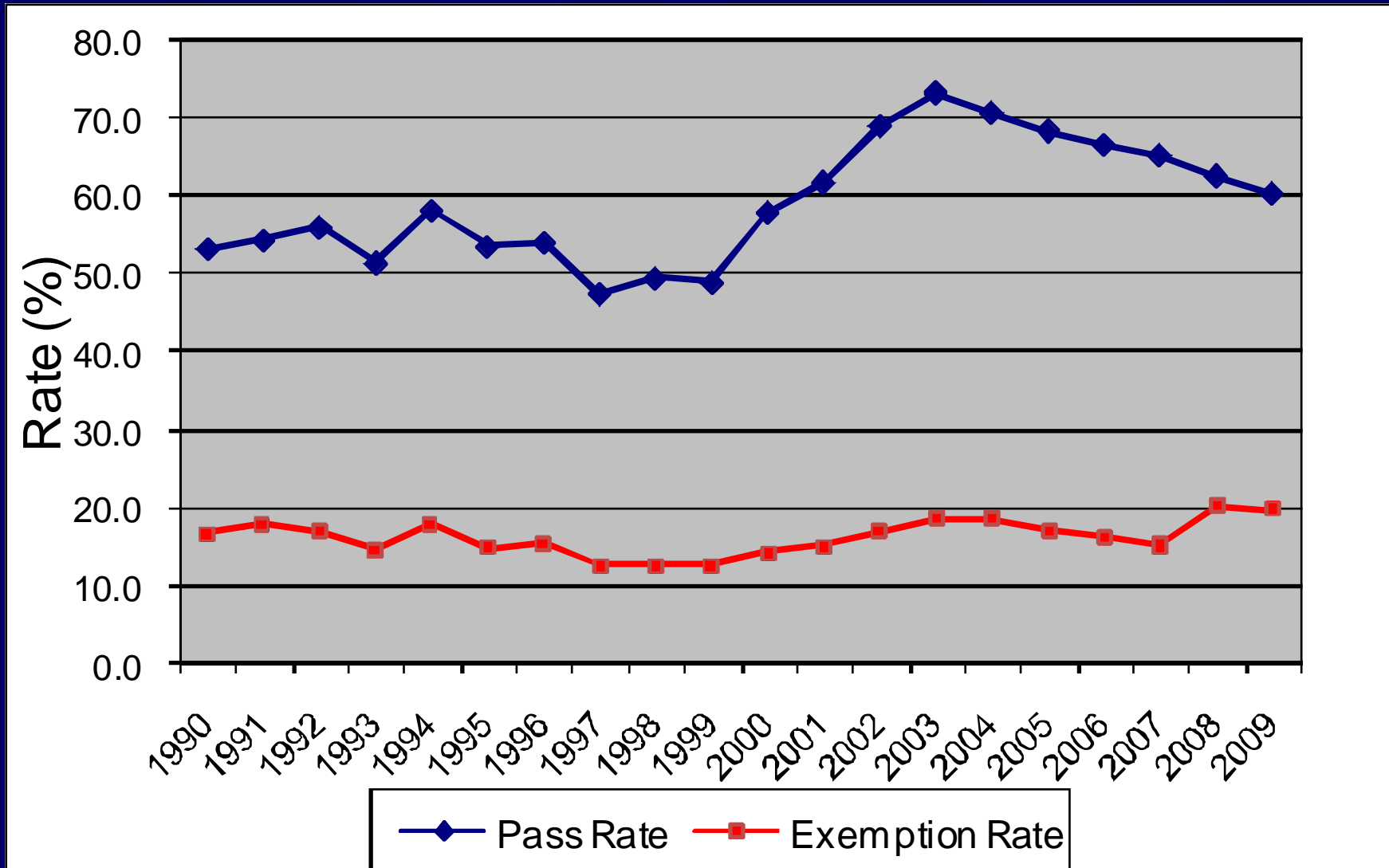
Bioresources Engineering Students at UN/UKZN



Senior Certificate Examination in South Africa

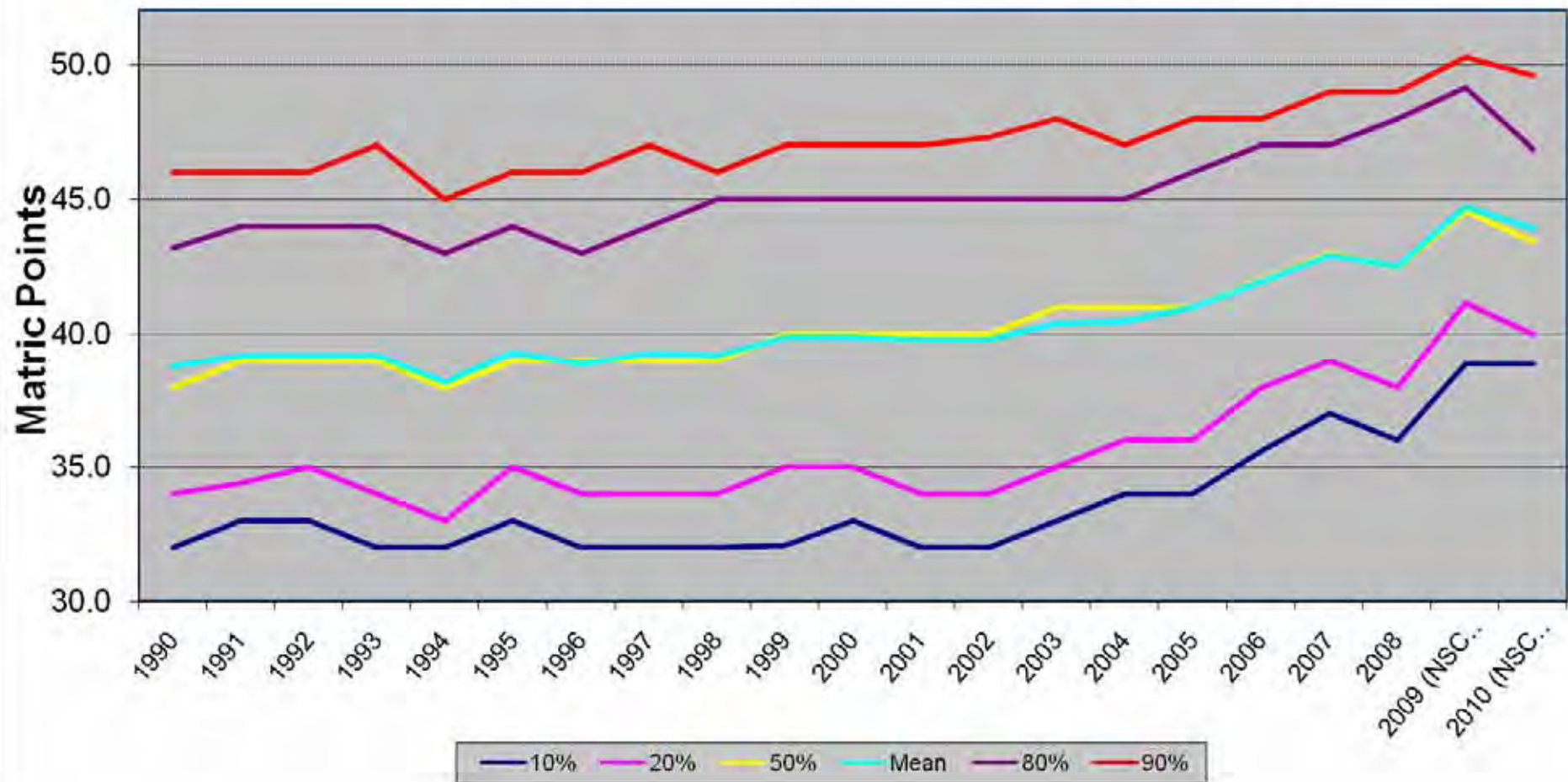


Senior Certificate Examination in South Africa



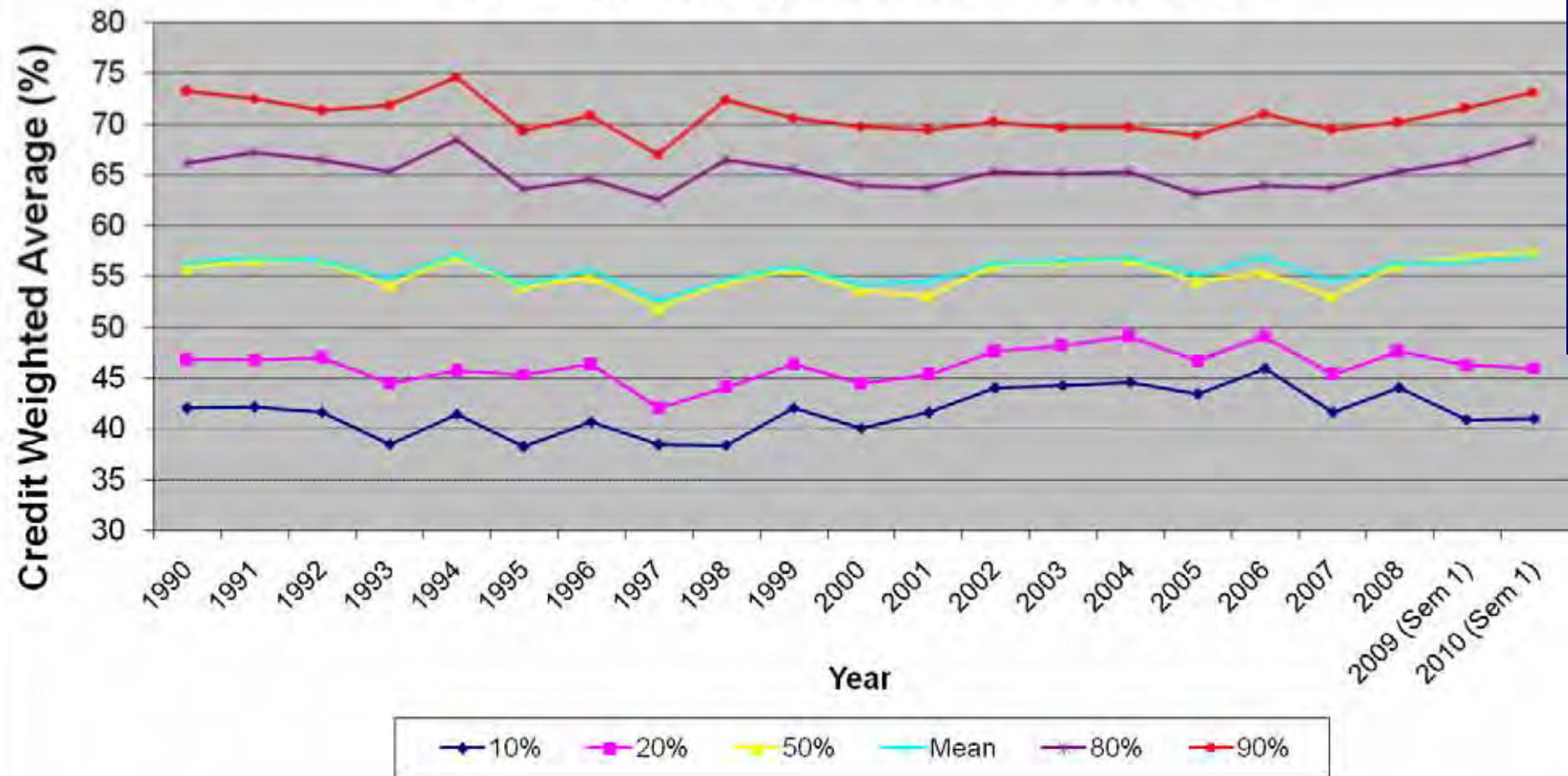
Matric Points

First Year BSc Engineering at UN/UKZN



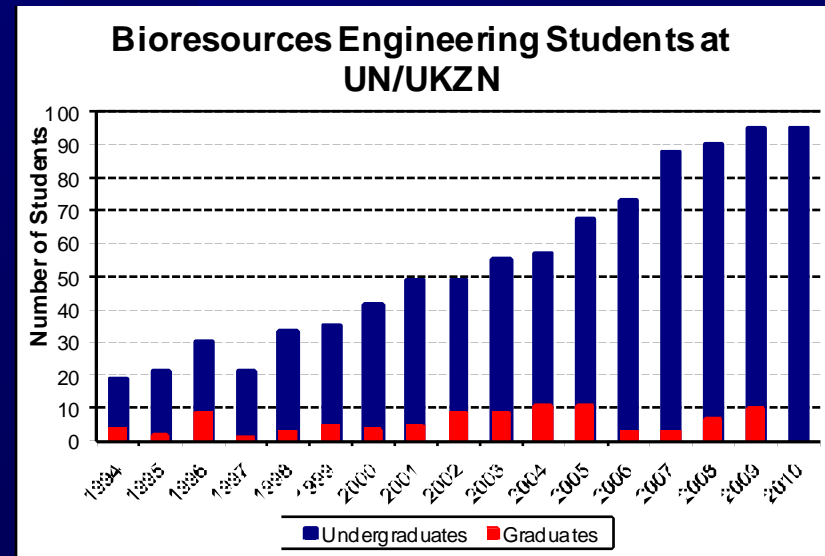
Students Performance

BSc Engineering: First Year at UN/UKZN



Growing Bioresources Engineers: Educational Challenges

- ☀ Schooling system?
- ☀ Delivery of programme?
- ☀ Interventions
 - ☀ ASAP
 - ☀ ADO's
 - ☀ Technical tutor
 - ☀ SI and extra tutorials
 - ☀ Mentors
 - ☀ Extended programme?
- ☀ Mentoring of candidate engineers



Conclusions

- ✦ Development and application of technology
 - ✦ Increased productivity of food and energy production systems
 - ✦ Reduced environmental impacts (e.g. wind erosion)
 - ✦ Unintended environmental impacts (e.g. CC, water quality)
- ✦ Social consequences
 - ✦ More food, yet more hunger
 - ✦ Developed vs developing countries - disparity in technology
 - ✦ Equal access to production resources and appropriate technology to increase productivity of poor farmers
- ✦ Many global challenges
 - ✦ Food and water
 - ✦ Sustainable environment
 - ✦ Increased water use efficiency
 - ✦ Renewable energy
 - ✦ Climate variability and climate change
 - ✦

Conclusions

- ★ South Africa – significant challenges
 - Water and food security
 - Impacts of politics
 - Progressive legislation without adequate resources
 - Poverty and disparity in income
 - Skills shortage
 - Education system – particularly schooling
- ★ Challenges all require development and adaptation and transfer of appropriate technology
 - Large scale commercial farmer
 - Small scale emerging farmer
- ★ Global and local challenges will drive demand for Bioresources Engineers!

Bioresources Engineering ... Engineering in and with the environment

