

Quantifying the environmental impact of irrigated cropping systems in South Africa using Life Cycle Assessment (LCA) with a focus on water resources

*M van der Laan, SR Perret, A Jumman,
JG Annandale and KL Bristow*



SANCID



UNIVERSITEIT VAN PRETORIA
UNIVERSITY OF PRETORIA
Water Institute



Introduction

- Irrigation uses ~60% of freshwater in South Africa
- Water scarcity in many catchments is leading to pressure to divert water from irrigation to other sectors
- Irrigated agriculture: greenhouse gas emissions, resource depletion, eutrophication, acidification....

Environmental impacts ??

- Rising input costs (electricity, nitrogen (N), water) motivating farmers to manage water and fertiliser more intensively

News

Intensive farming may ease climate change

Fri, Jan 19 2007

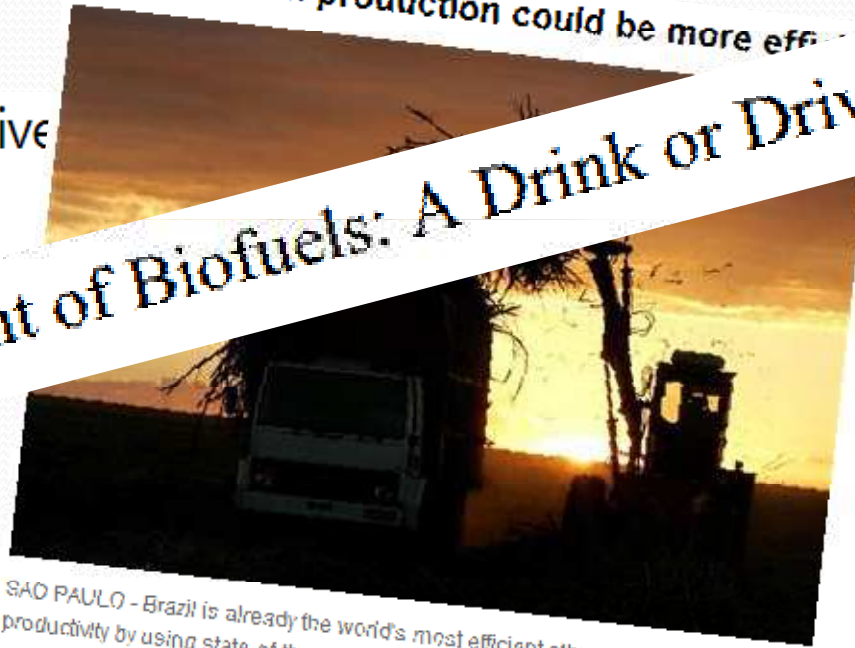
Ethanol use has environmental downsides

Brazil ethanol production could be more efficient

Is seaweed the future of alternative sources like biofuel?

Friday, March 16, 2012 by: J. D. Heyes

The Water Footprint of Biofuels: A Drink or Drive Issue?



SAO PAULO - Brazil is already the world's most efficient ethanol producer but could still greatly improve productivity by using state-of-the-art technology, a leading equipment supplier said on Wednesday.

Study suggests 'green' biofuels are more environmentally harmful than fossil fuels

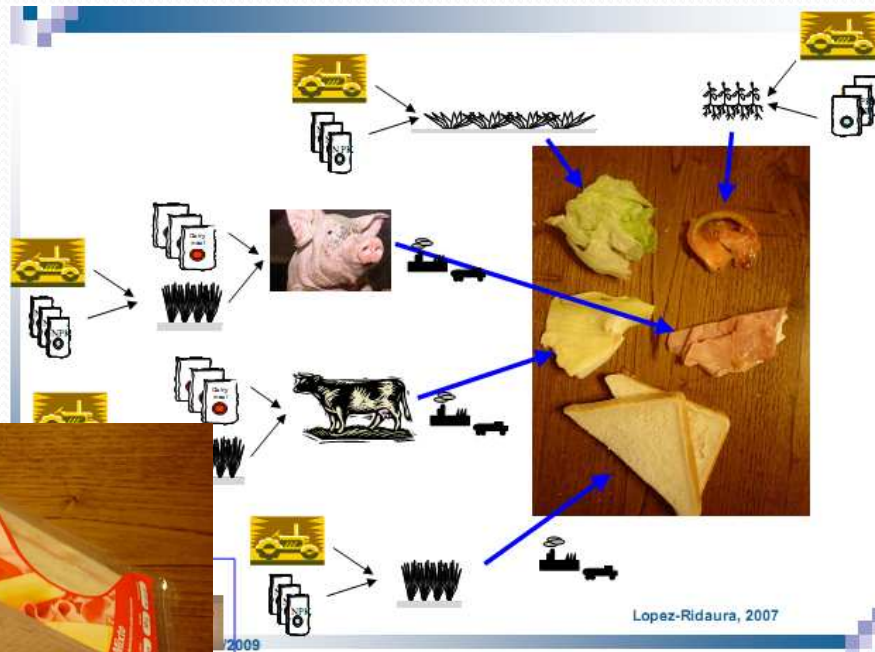
Tuesday, November 08, 2011 by Jonathan Benson, staff writer

Study: Petrol better than biofuel

2012-10-02 06:40

Life Cycle Assessment (LCA)

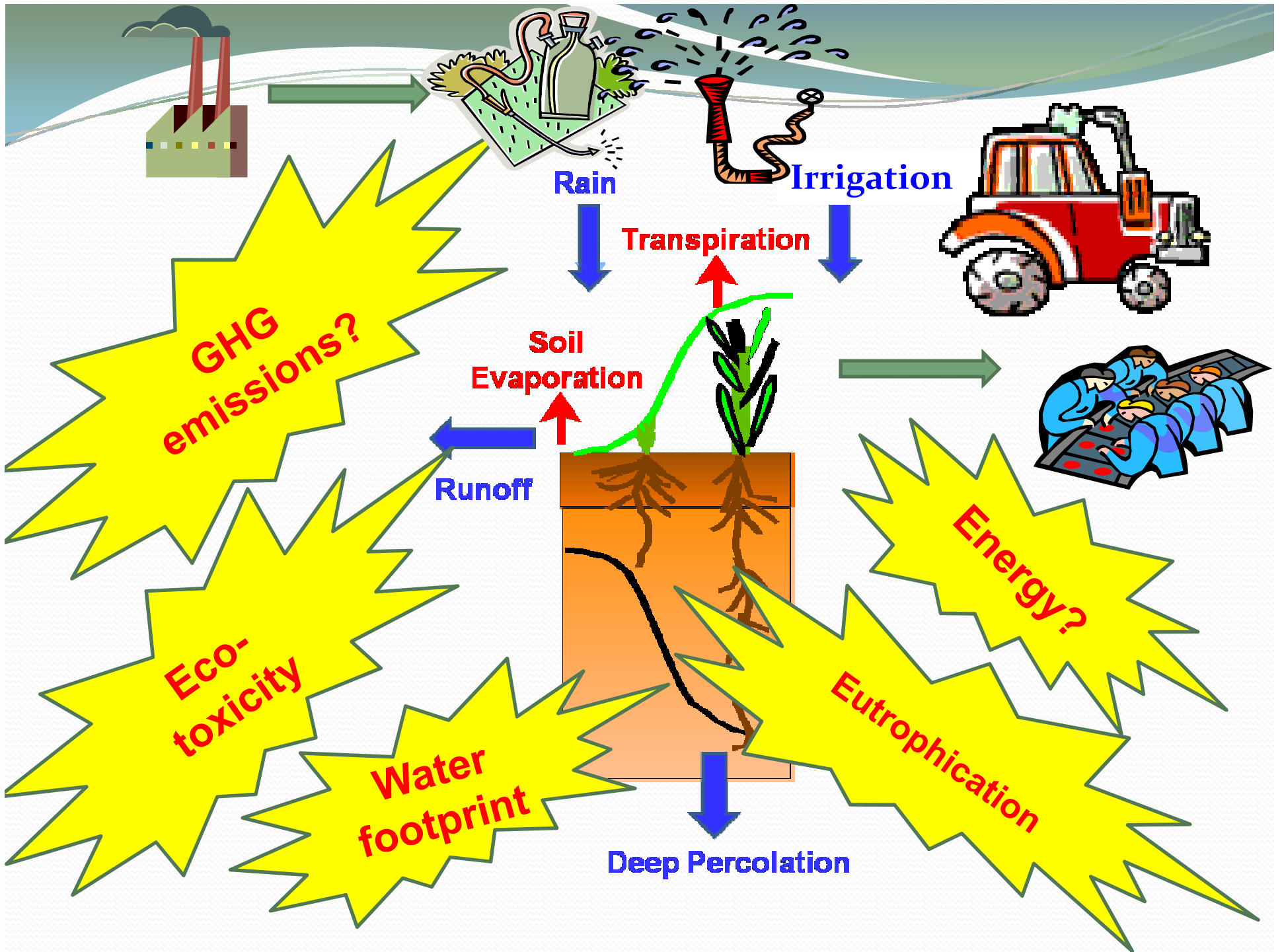
- A systematic assessment that aims to reveal and quantify environmental impacts and resource use along the complete supply chain of a product or service





Life Cycle Assessment (LCA)

- Widely applied worldwide, still developing in agriculture
- Carbon/water/energy footprint = reduced scope LCA
- System delineation, e.g. product/process
 - ‘Cradle to grave’, ‘field to farm gate’, ‘field to fork’
- Functional unit (FU), e.g.
 - 1 kg dry paddy rice (14% WC) delivered at farm gate
 - 750 ml bottle of wine on supermarket shelf
- Impact categories: Resource depletion, water consumption, eutrophication, land-use (mid-point indicators)
- End-point indicators: Human health, ecosystem health





Aim

Integrate biophysical crop modelling with LCA to assess the environmental impact of irrigated crop production

Test using a case study for sugarcane grown in Pongola, South Africa

Demonstrate the use of this LCA framework to study and quantify the environmental benefits of improved management

Methodology

- Calibrated DSSAT-Canegro model
- Case-study: Pongola
 - ‘Virtual farm’: 200 ha, pivot irrigation, 90% harvested annually, 1.8 m Hutton soil
 - Crop growth, soil water and C and N dynamics simulated for 16 seasons using actual weather data (1986-2001)
 - Farmers allocated 1000 mm irrigation water per season
 - Average yields for region approximately 89 tonnes cane ha⁻¹ >> *management gap*

Methodology

- Functional Unit (FU): metric tonne of extractable sucrose produced leaving the farm gate (in the form of fresh, recently burnt, sugarcane stems)
- Scenarios:

	Baseline scenario	Management scenario 1	Management scenario 2
Irrigation Scheduling	Fixed cycle	Optimised scheduling based on PAW depletion	
Nitrogen Management	150 kg N ha ⁻¹	150 kg N ha ⁻¹	Optimised site-specific rate 100 kg N ha ⁻¹



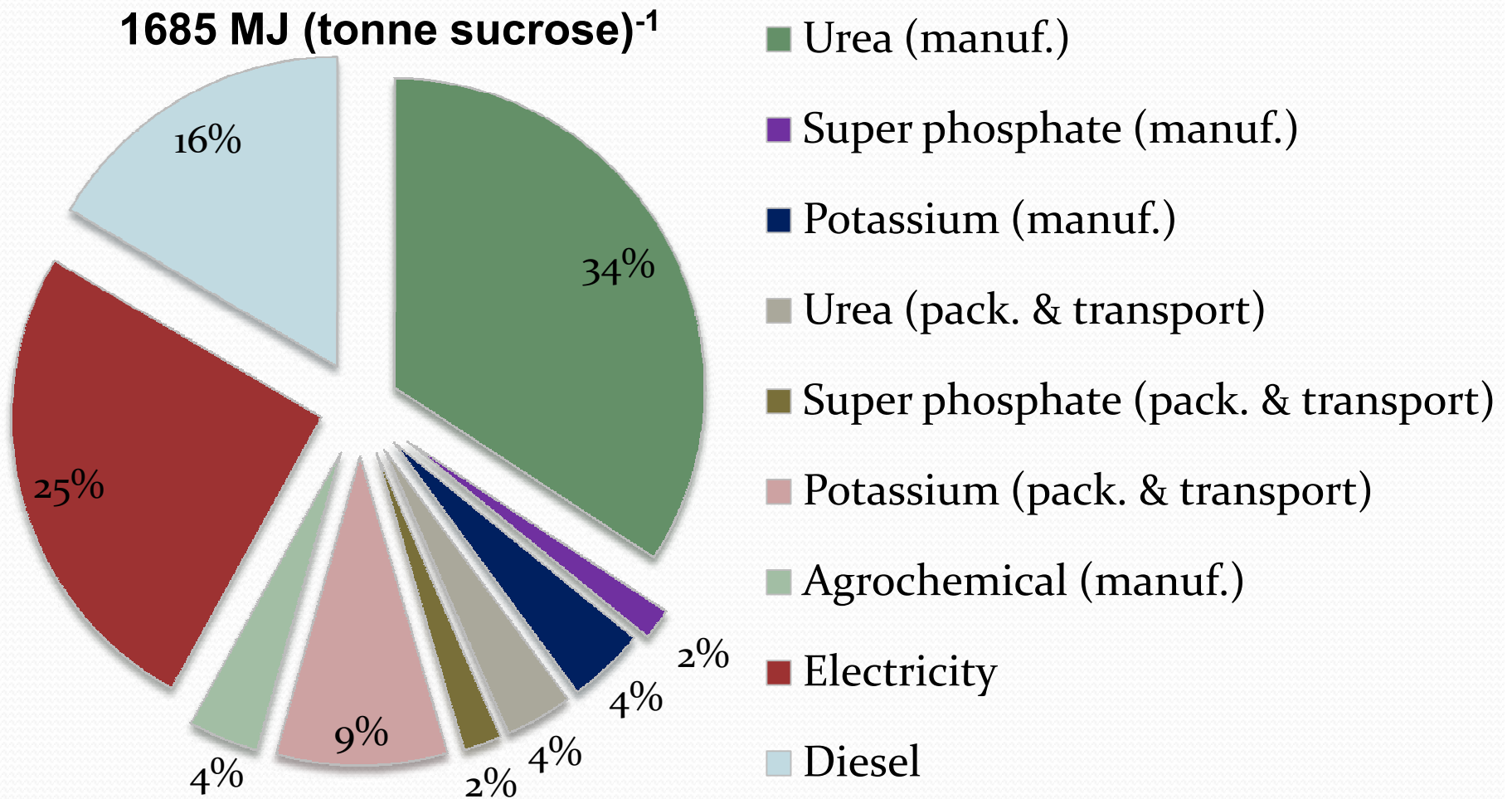
Results

DSSAT-Canegro simulation outputs presented as growing season averages over the 16 year simulation period

SIMULATION OUTPUTS	Unit	Baseline scenario	Management scenarios 1 & 2*
Green cane mass	t ha ⁻¹	116.9	121.8
Extractable sucrose yield	t ha ⁻¹	17.8	18.5
Trash mass (dry mass)	t ha ⁻¹	22.1	23.2
Evapotranspiration	mm	1173	1211
Irrigation	mm	1000	825
Rainfall	mm	758	758
Deep drainage	mm	432	236
Runoff	mm	155	122

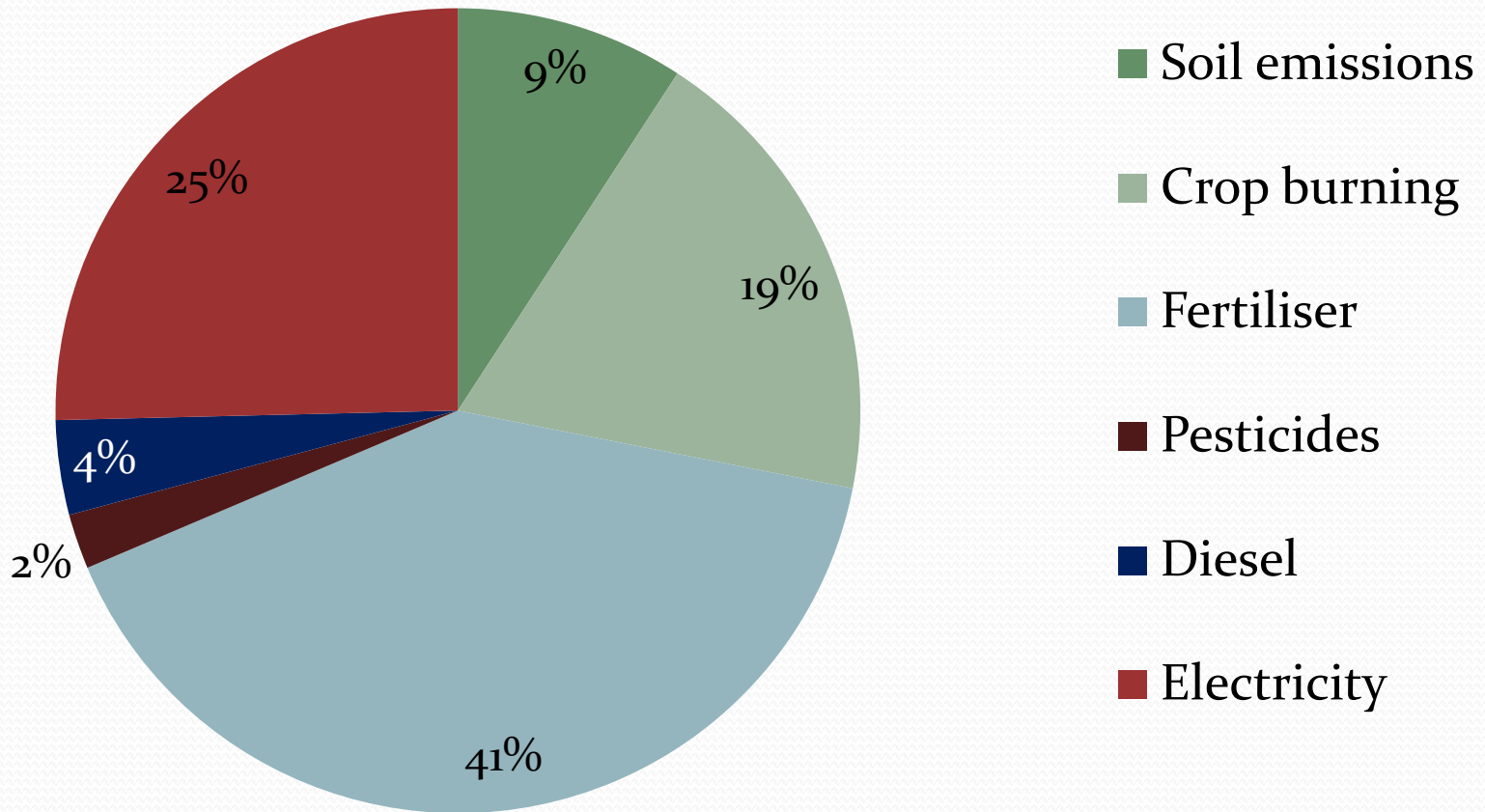
* Simulated crop yield and water balance outputs were the same for management scenarios 1 and 2

Relative contributions non-renewable energy consumption for the baseline scenario



Relative contributions to total global warming potential (GWP) for the baseline scenario

485 kg CO₂-e (tonne sucrose)⁻¹



Environmental impact indicators per functional unit (FU) according to management scenario

IMPACT CATEGORY	Unit/FU	Baseline scenario	Management scenario 1	Management scenario 2
Energy input	MJ	1685	1553	1349 ↓ 20%
Global Warming Potential (100)	kg CO ₂ -e	485	438	370 ↓ 25%
Acidification potential	g SO ₂ -e	7.8	7.6	7.6
Eutrophication potential	g PO ₄ -e	23.1	13.4	12.7 ↓ 45%
Water consumption	m ³	659	655	655

Water consumption

Blue water refers to surface water (rivers, lakes, dams) and groundwater available to multiple users

Green water is water originating from rainfall that is stored in the soil and available for vegetation growth only

IMPACT CATEGORY	Unit/FU	Baseline scenario	Management scenarios 1 & 2
Blue water consumption	m ³	562	446
Green water consumption	m ³	97	209

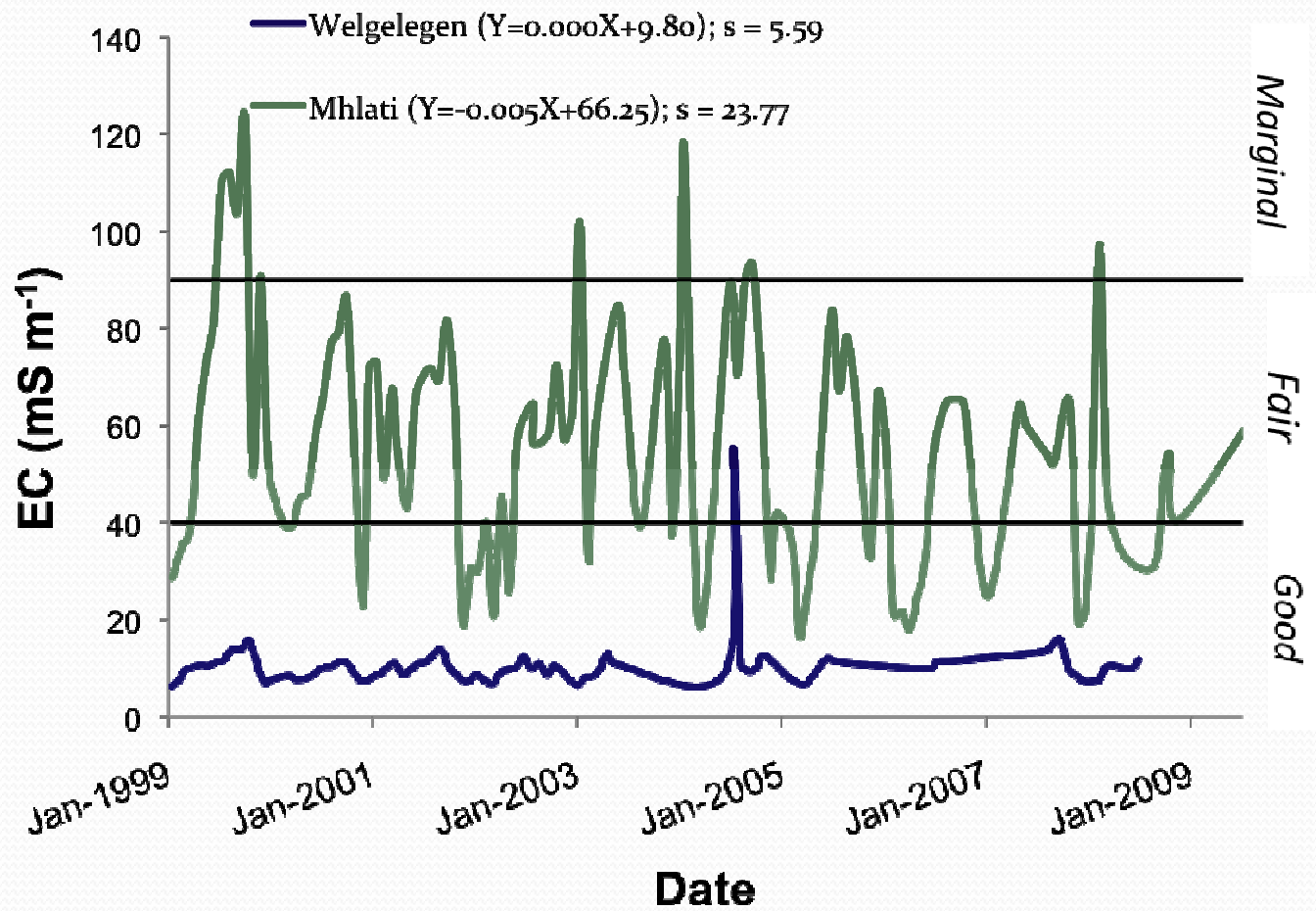
15% → 32%



What about impact on water quality?

LCA → eutrophication potential ($\text{PO}_4\text{-e}$)
→ eco-toxicity potential (pesticides)

Salinity??





What about impact on water quality?

LCA → eutrophication potential ($\text{PO}_4\text{-e}$)
→ eco-toxicity potential (pesticides)

Salinity??

Water Footprint Assessment Manual (Hoekstra et al. 2011):

Grey water refers to the volume of water required to dilute emitted pollutants to ambient levels

Applying the grey water concept

- Eutrophication potential: 23.1 g PO₄-e

- Baseline scenario: NO₃-N leaching conc = 15 mg l⁻¹
- Standard = 10 mg l⁻¹ (DWAF, 1996)
- Will take 288 mm for dilution ~ grey water footprint

Geographic context

Pfister et al. (2009) >>>



water stress index. South Africa – more specific characterisation of watersheds required

Conclusions

- Generic framework has now been developed combining mechanistic crop modelling with LCA
- Farmer management can significantly reduce environmental impacts ~~ human health implications??
- LCA effective in monitoring for 'problem shifting' or 'pollution swapping'
- LCA results are additive – further investigations for transport, milling, packaging
- Data very scarce for impact on human health
- Biofuel & electricity co-generation application
- LCA could benefit from applying grey water footprint methodology.....open research question

Conclusions

- Other potential LCA applications:
 - Environmental stewardship incentives?
 - Carbon credit trading opportunities in agriculture?
- Sustainability of nation/big companies/industries etc
(economical vs ecological)

Final thoughts

