

# ***Jatropha curcas*: Assessing the potential water resource impacts of large-scale production in South Africa**

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# Presentation Overview

- Background: Agro-fuels & Jatropha research
- *Jatropha curcas*: Description & SA situation
- Why research water resource impacts?
- First project: Sap flow (transpiration) measurements
- Second project: Water-use & growth trial
- Modelling: Needs, strengths & shortcomings
- Implications, conclusions & way forward

# Background

- Oil crisis, resultant agro-fuel initiatives, SA biofuel strategy
- Motivation: Energy security, business opportunities, rural upliftment / poverty alleviation, env. benefits (renewable, cleaner).
- Environmental impacts unknown (water use, invasiveness, yield).
- Global attention on bio-fuels and the potential for *Jatropha* to produce biodiesel from marginal land with low inputs has created a hype of attention
- Resultant planting of large areas of *Jatropha* in Asia, Africa and America. However little scientific substance to many of the claims made about *Jatropha*.
- No information worldwide on water-use aspects.

# *Jatropha curcas*

- **Origins and Distribution**

- Euphorbiaceae family, originally central America / Mexico, now pan-tropical (Africa, Asia)
- Limited RSA distribution, mainly KZN north coast, seed from Zimbabwe

- **Description**

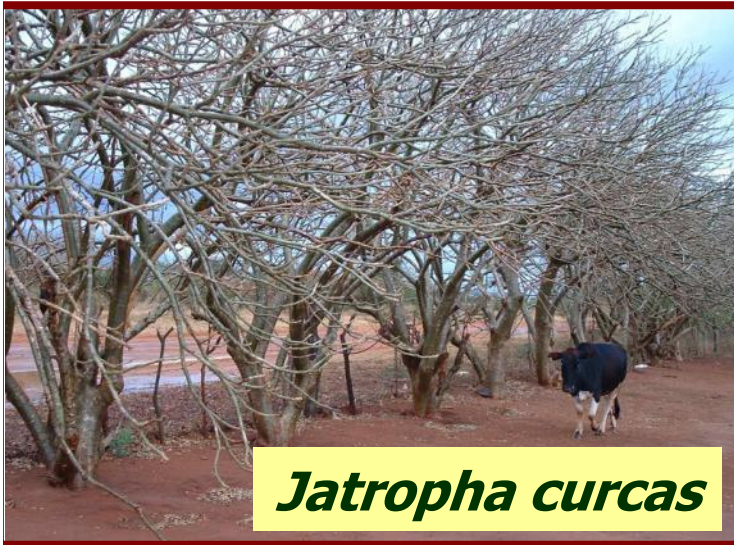
- Semi-deciduous (water stress), monoecious, small tree (<6m tall)
- Fruits with 3 seeds after de-husking, 35% oil, nitrogen-rich press-cake
- Seeds toxic to humans & animals (some non-toxic varieties)
- Stem exudes milky latex, often multi-stemmed

- **Bio-physical Requirements**

- Rainfall (250–1200mm MAP), drought resistant but affects yield
- Needs warm temperatures (20-28° C MAT), frost sensitive
- Tolerates marginal soils (well drained), mulching beneficial

- **Uses**

- Fuel and energy (Biodiesel, lamps, stoves?), Cosmetic (soap production), Medicinal, Environmental / Agricultural (erosion control, living hedge, fertilizer)



***Jatropha curcas***





## *Jatropha curcas* - Claims

- Low water-use
- Growth on marginal and degraded lands
- Potential energy crop – high oil yields
- Low maintenance (labour costs)
- Disease tolerance / pest resistance





# South African Situation

- SA Gov. has placed a moratorium on the planting of *Jatropha* due to fears of:
  1. Excessive water use
  2. Alien invasiveness and
  3. Lack of knowledge on its' economic potential (yield).
- Some aspects are the subject of on-going research by CSIR, UKZN & UP

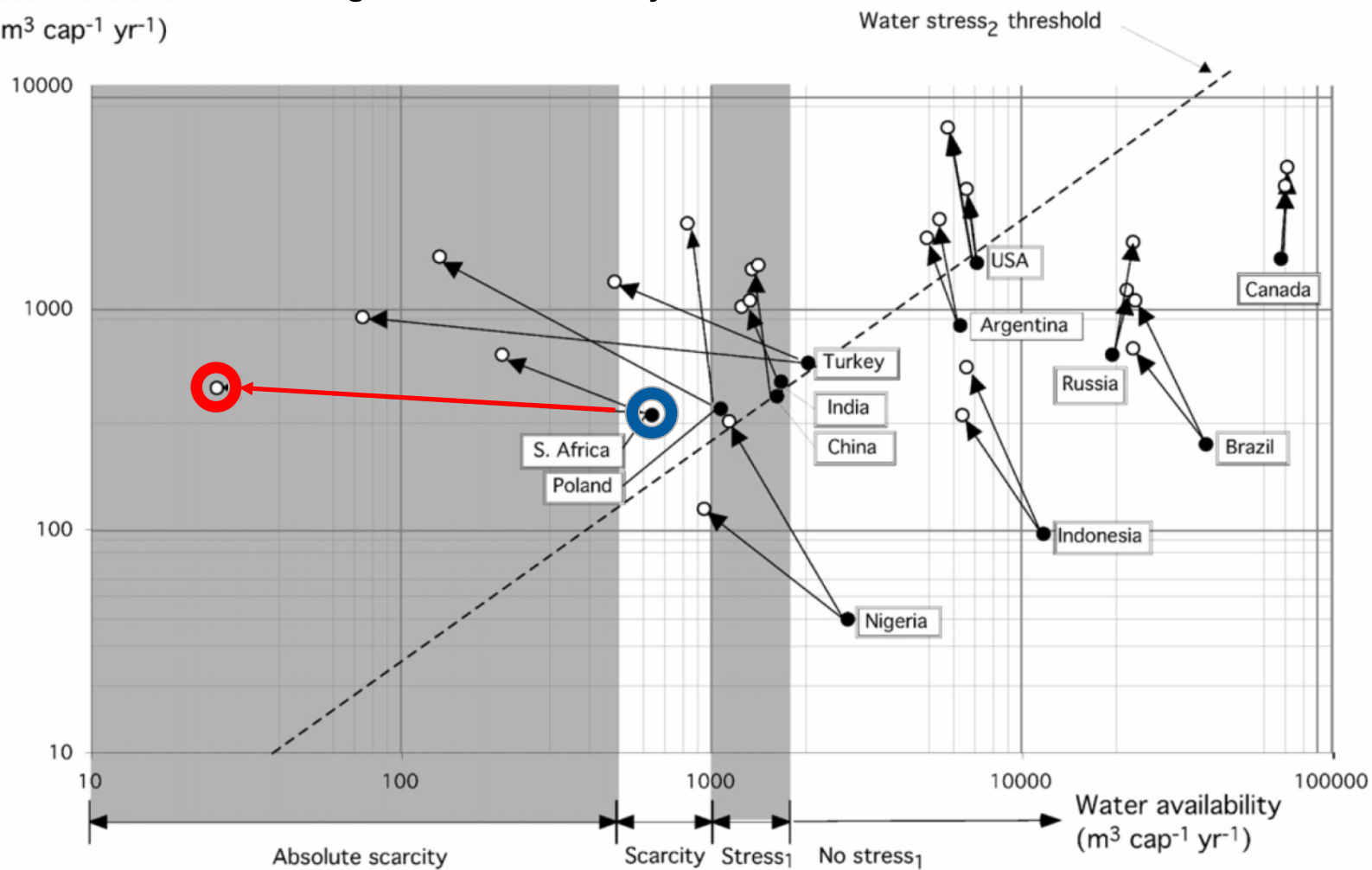


**Should we be concerned about agro-fuels and water-use?**



Water withdrawal  
( $\text{m}^3 \text{cap}^{-1} \text{yr}^{-1}$ )

### Regional water scarcity for 13 countries



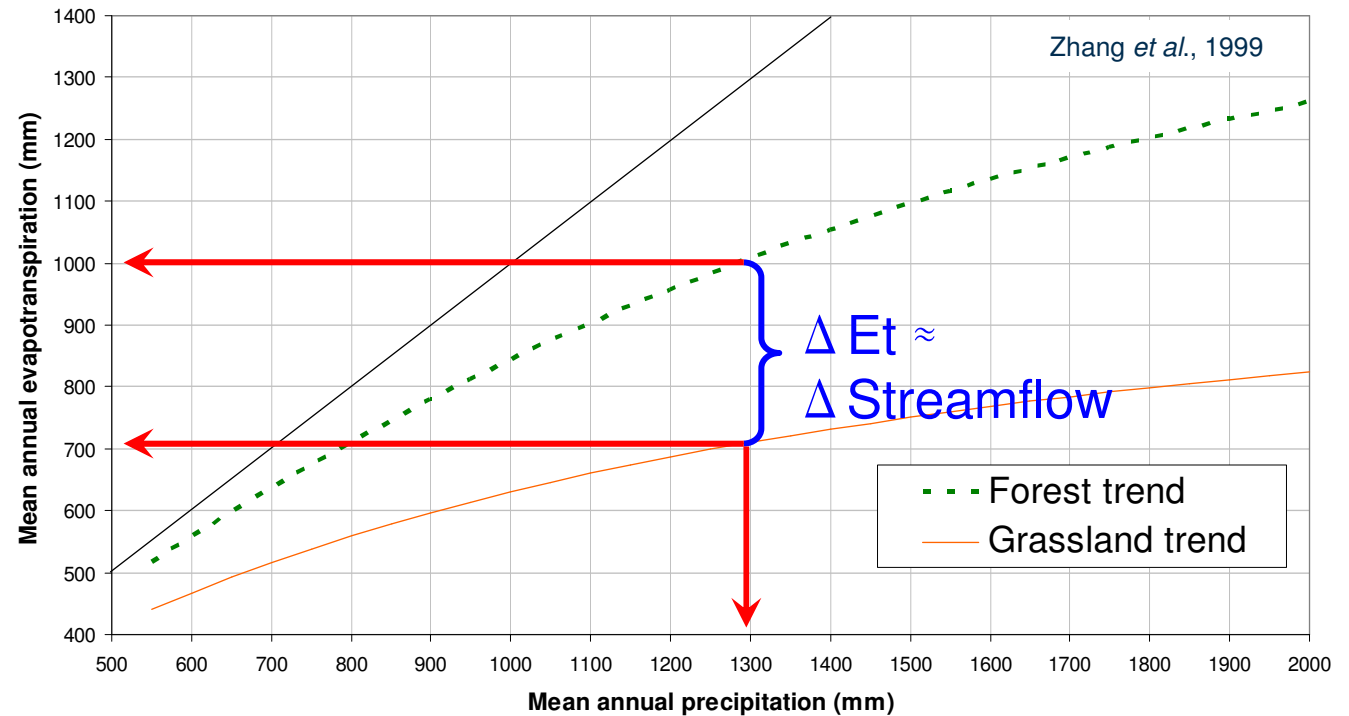
Per-capita water withdrawal and availability. Filled dots = 1995.

The two arrows that originate from each dot point to the situation in the year 2075.

After Berndes (2002). Global Environmental Change 12, 253–271.



# Implications of land-use change



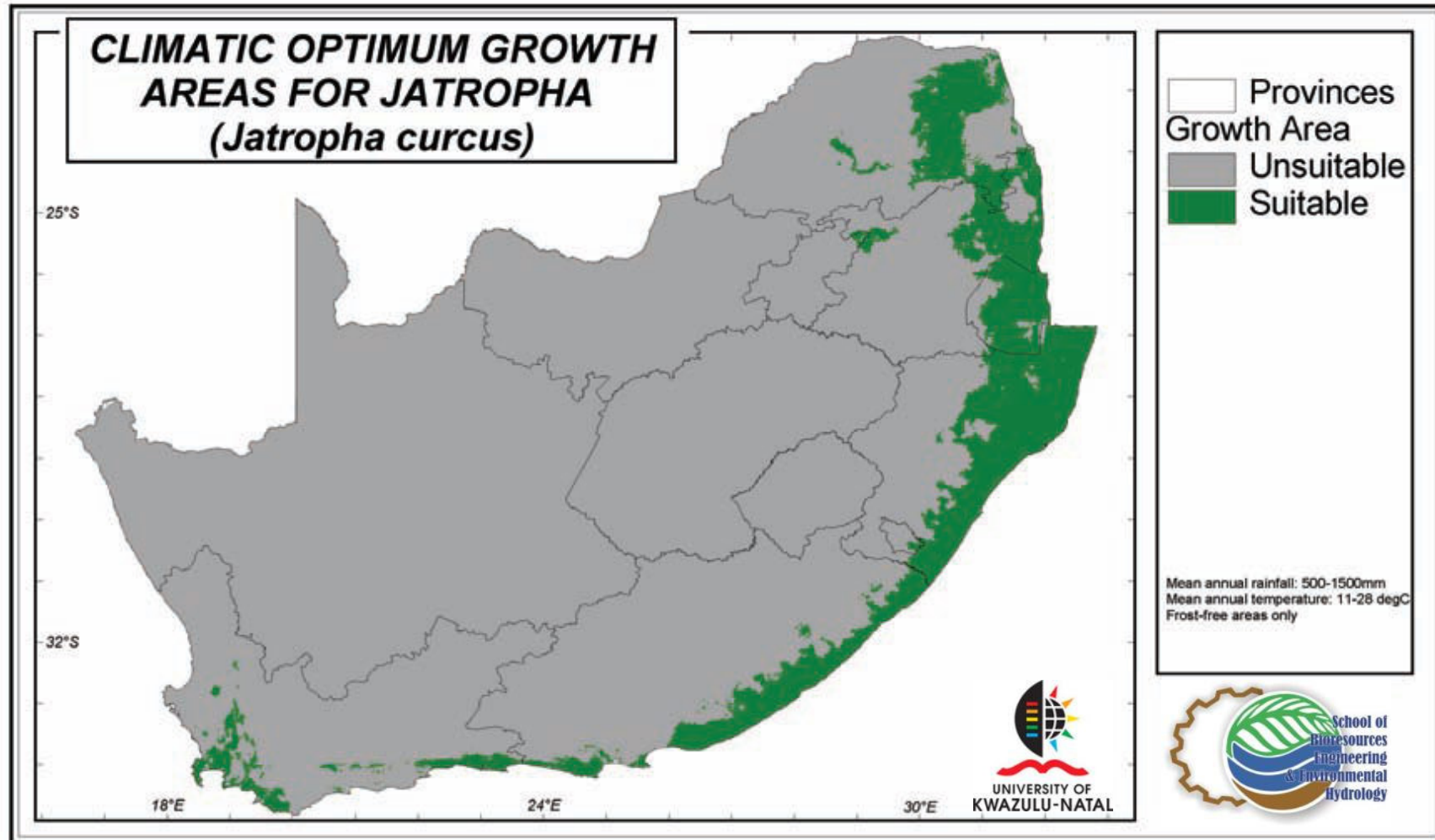
- Concept of baseline vegetation.
- DWA stance on bio-fuels water-use (dryland only)

# Project 1



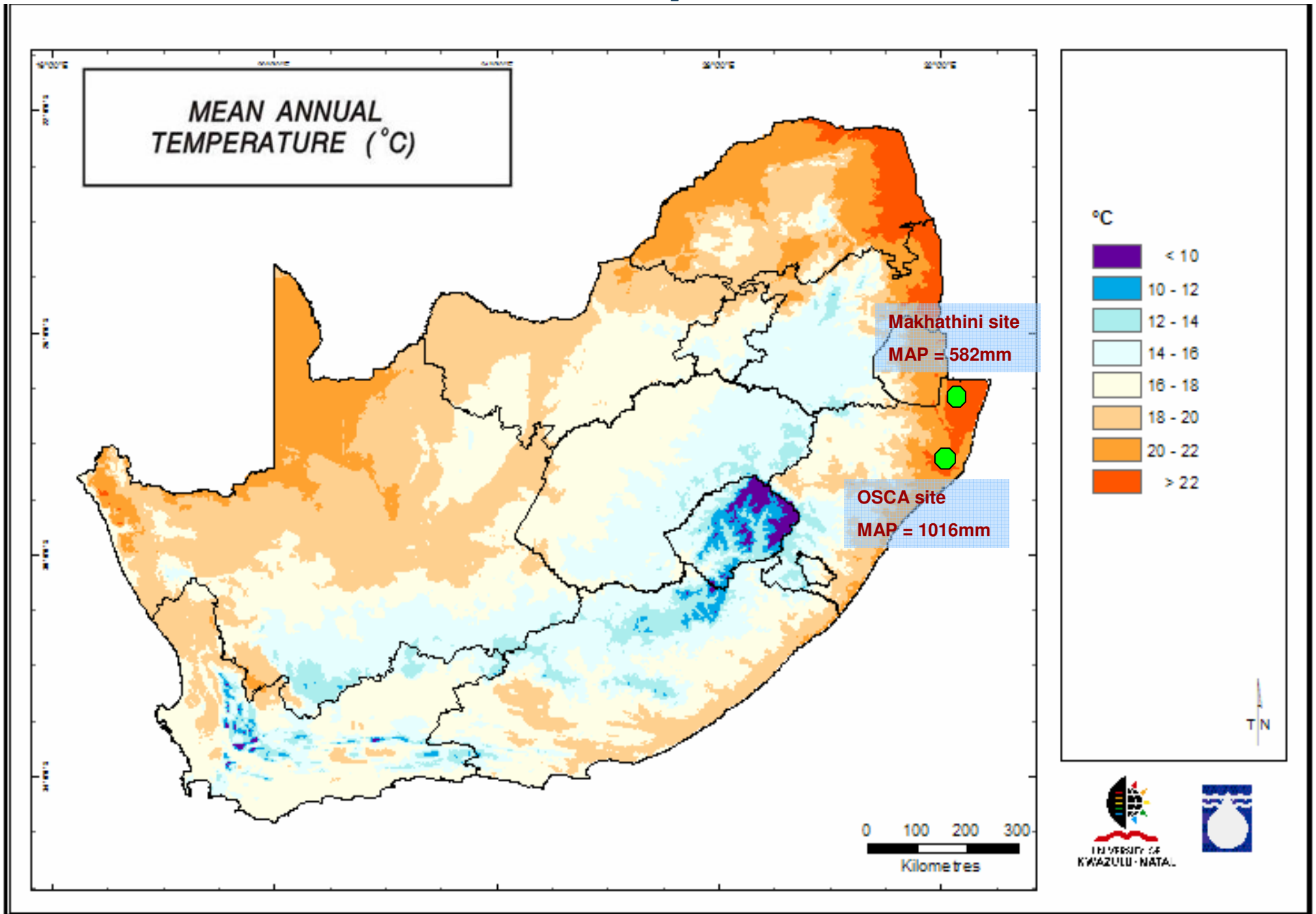
- Aim: To develop predictive capability with respect to the impacts of large-scale planting of *Jatropha curcas* on water resources in South Africa.
- Methodology: literature review, field measurements and modelling studies.
- Project Duration: Apr 2004 to Mar 2007 (3 yrs)
- Consortium (SDC, CSIR, CPH2O (DHI), Dirk Versfeld cc)
- Funded by the Water Research Commission of South Africa.

# Potential Growth Area – *Jatropha curcas*



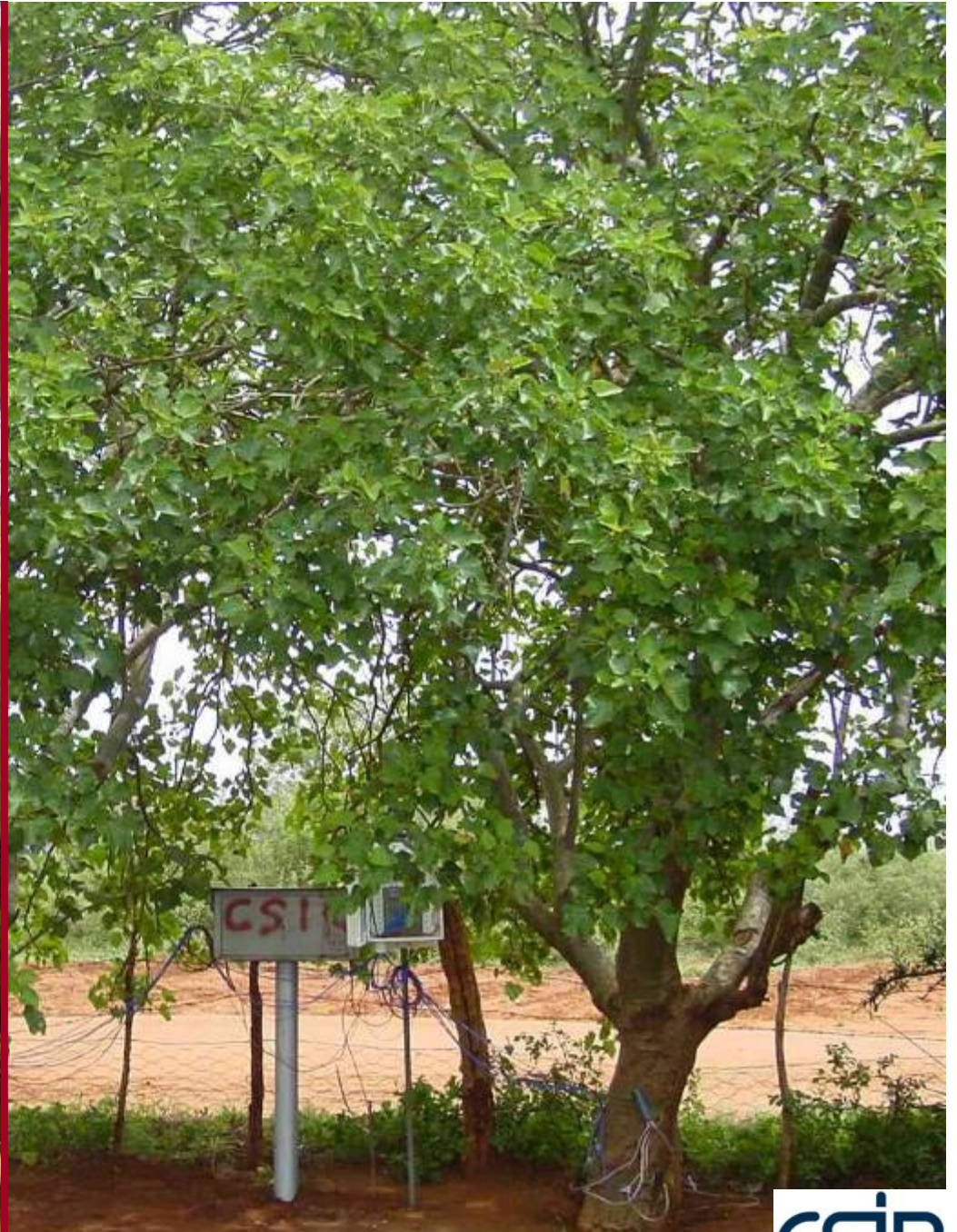
Jewitt, G.P.W., Wen, H.W., Kunz, R.P. and Van Rooyen, A.M., 2009. Scoping Study on Water Use of Crops/Trees for Biofuels in South Africa. Report to the WATER RESEARCH COMMISSION, WRC Report No. 1772/1/09 (ISBN 978-1-77005-884-2).

# Research sites – *Jatropha curcas* water use



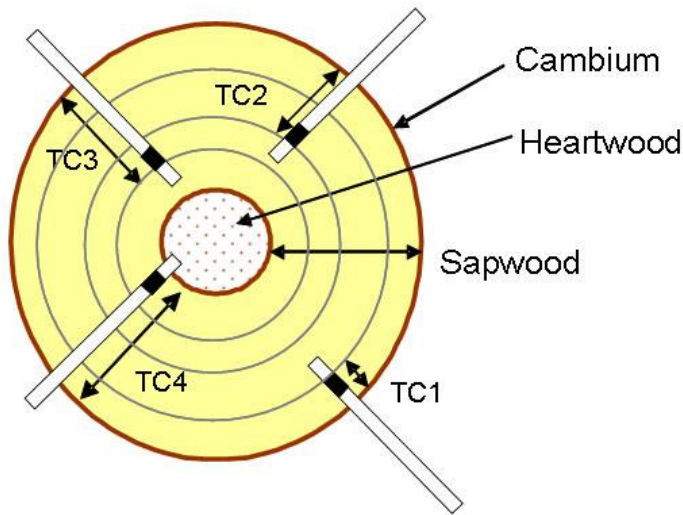


**4-year old *Jatropa curcas* trees – OSCA**



**12-year old *Jatropha curcas* trees – Makhathini Flats**

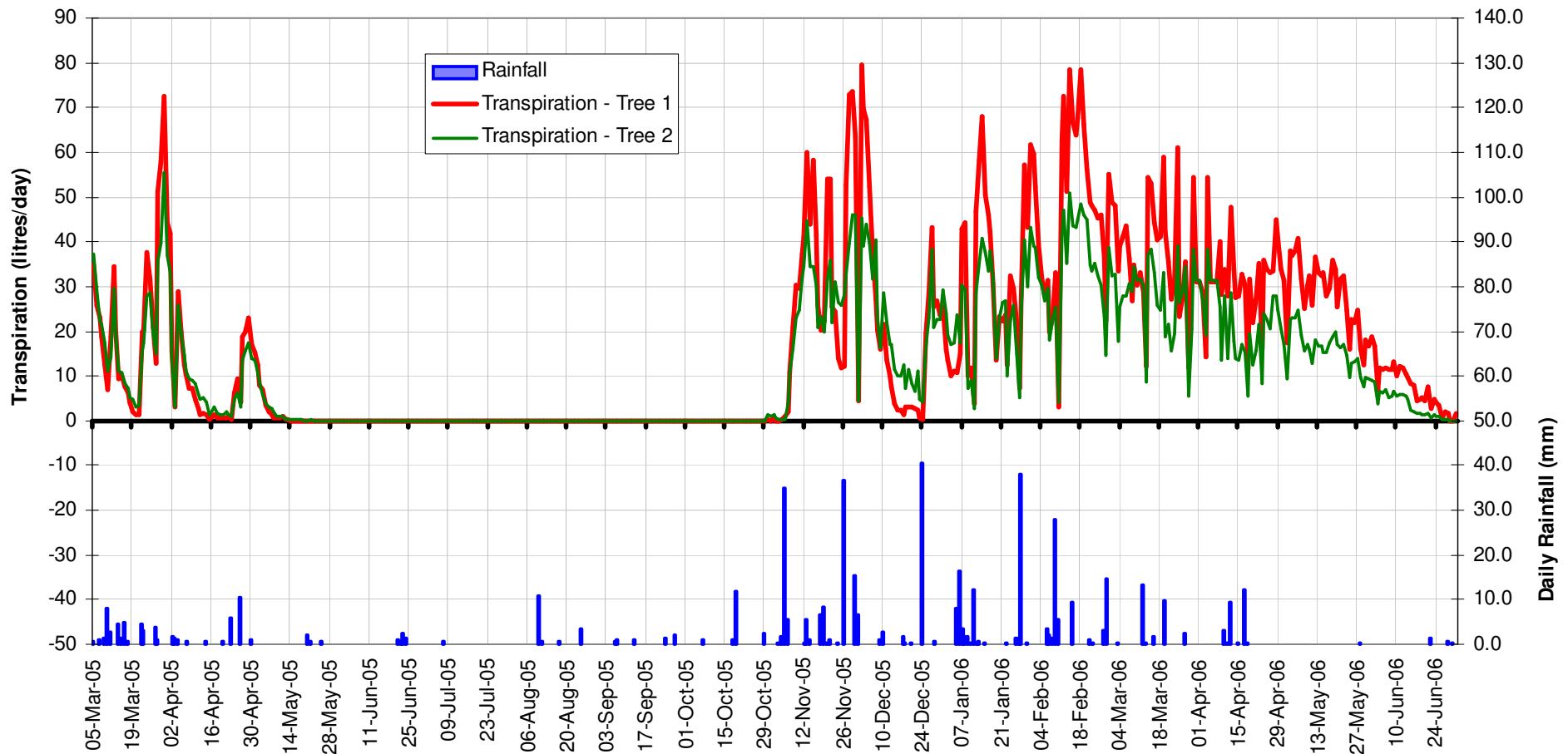
# Heat pulse velocity technique: Sap Flow (water-use)





# Results (Makhathini) – HPV Data

Daily Transpiration (litres) for 2 *Jatropha curcas* trees, with Rainfall (Makhathini site)



- Highest daily sap flow = 79.6 litres
- Daily Ave = 13.4 litres (over 12-months)

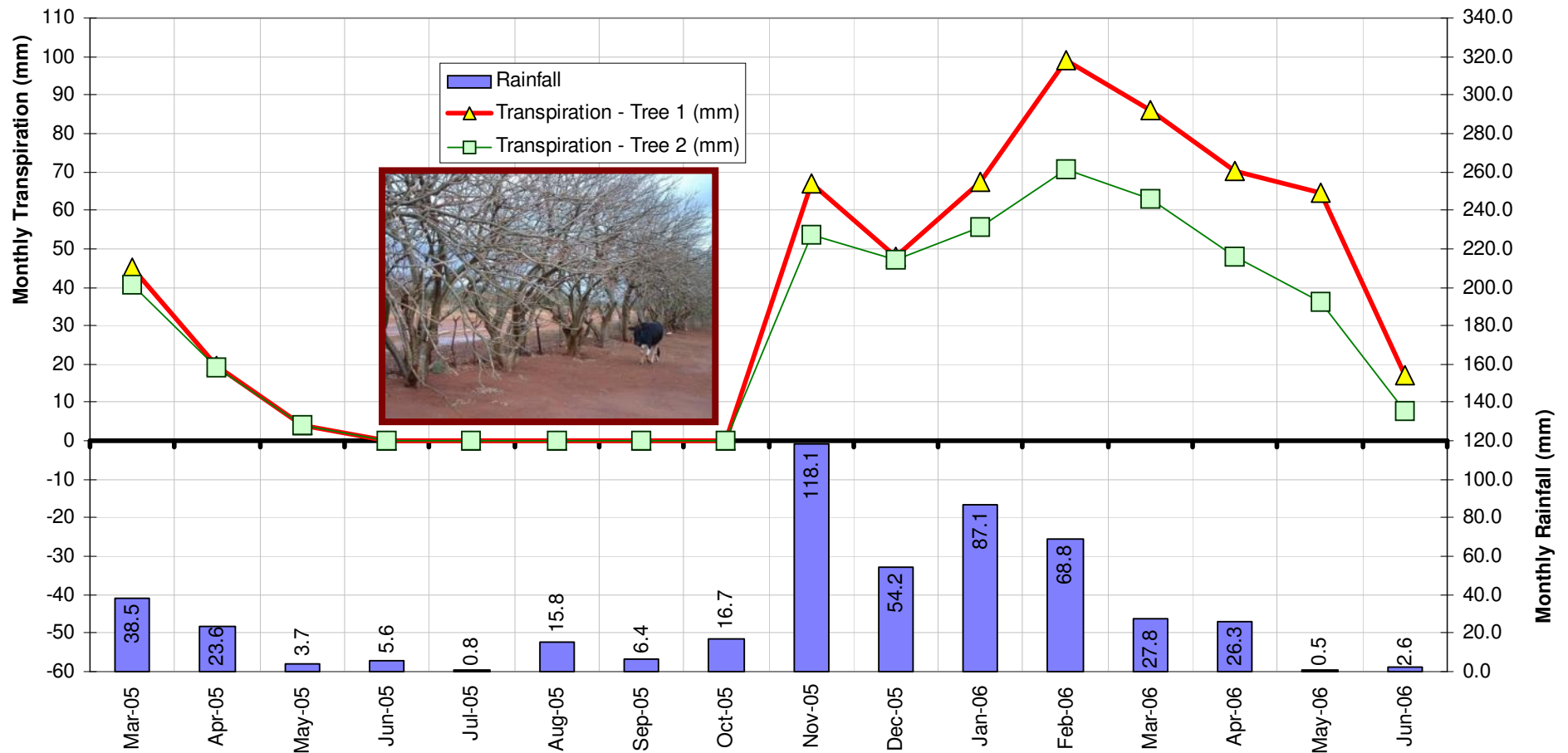


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# Results (Makhathini) – HPV Data

Monthly Totals of Transpiration (mm) for 2 *Jatropha curcas* trees, with Rainfall (Makhathini)



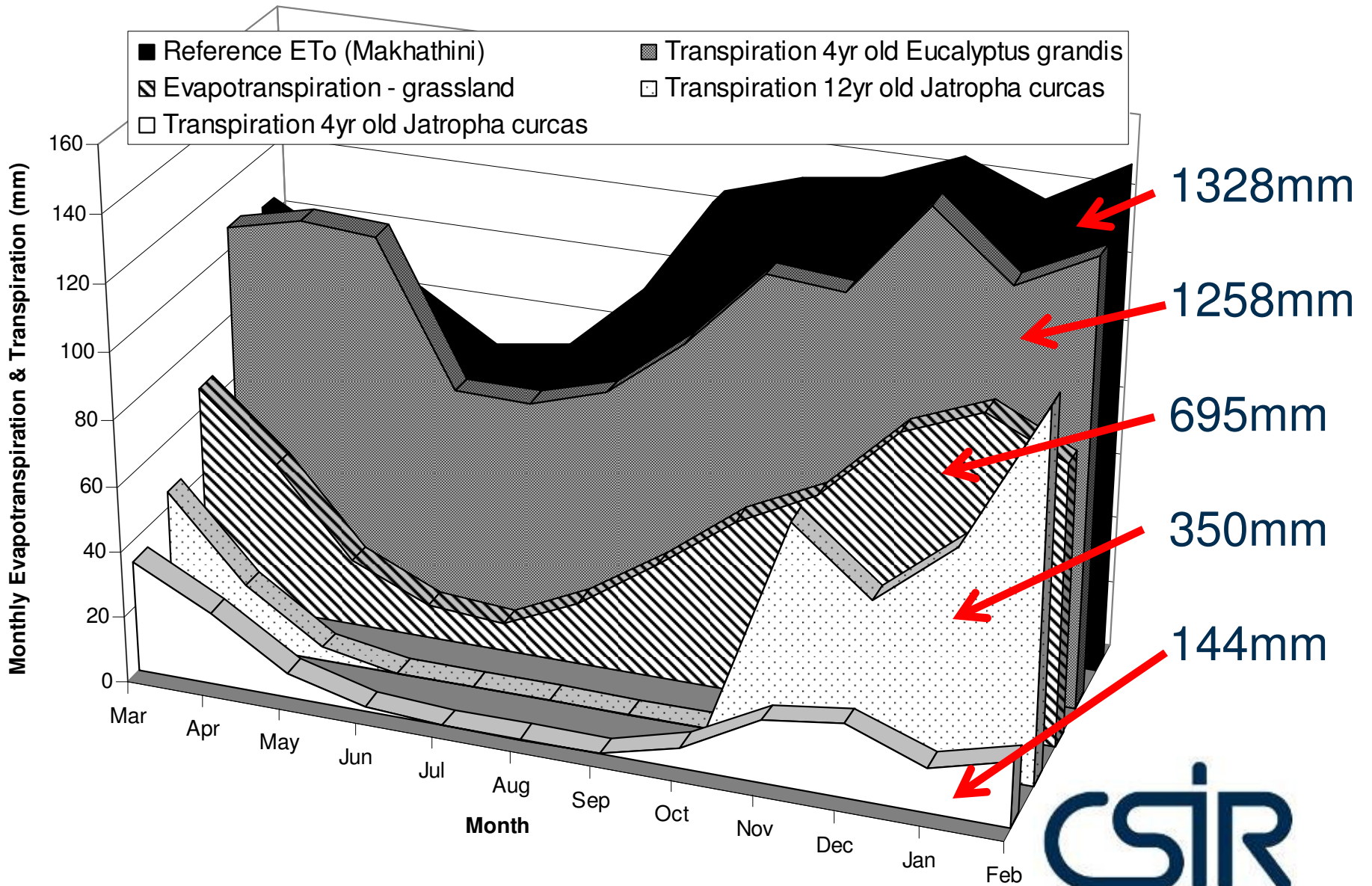
- Single tree totals scaled up to plantation scale
- Water use of 12-yr old trees = 350mm  
(4-year old trees = 144mm)

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# Results – *Jatropha curcas* water-use



# Project 1 - Conclusions



- Strong seasonal effect (deciduous nature).
- Good correlations with climate data (air and soil moisture).
- Differences in water use between sites were related to tree age (stem size / leaf area) and water availability (rainfall).
- Water use of *Jatropha curcas* appears to be low when deciduous.
- Single tree totals scaled up to plantation scale gave the annual water use of 4-year old trees = 144mm and 2-year old trees = 350mm. Less than other vegetation.

# Project 2



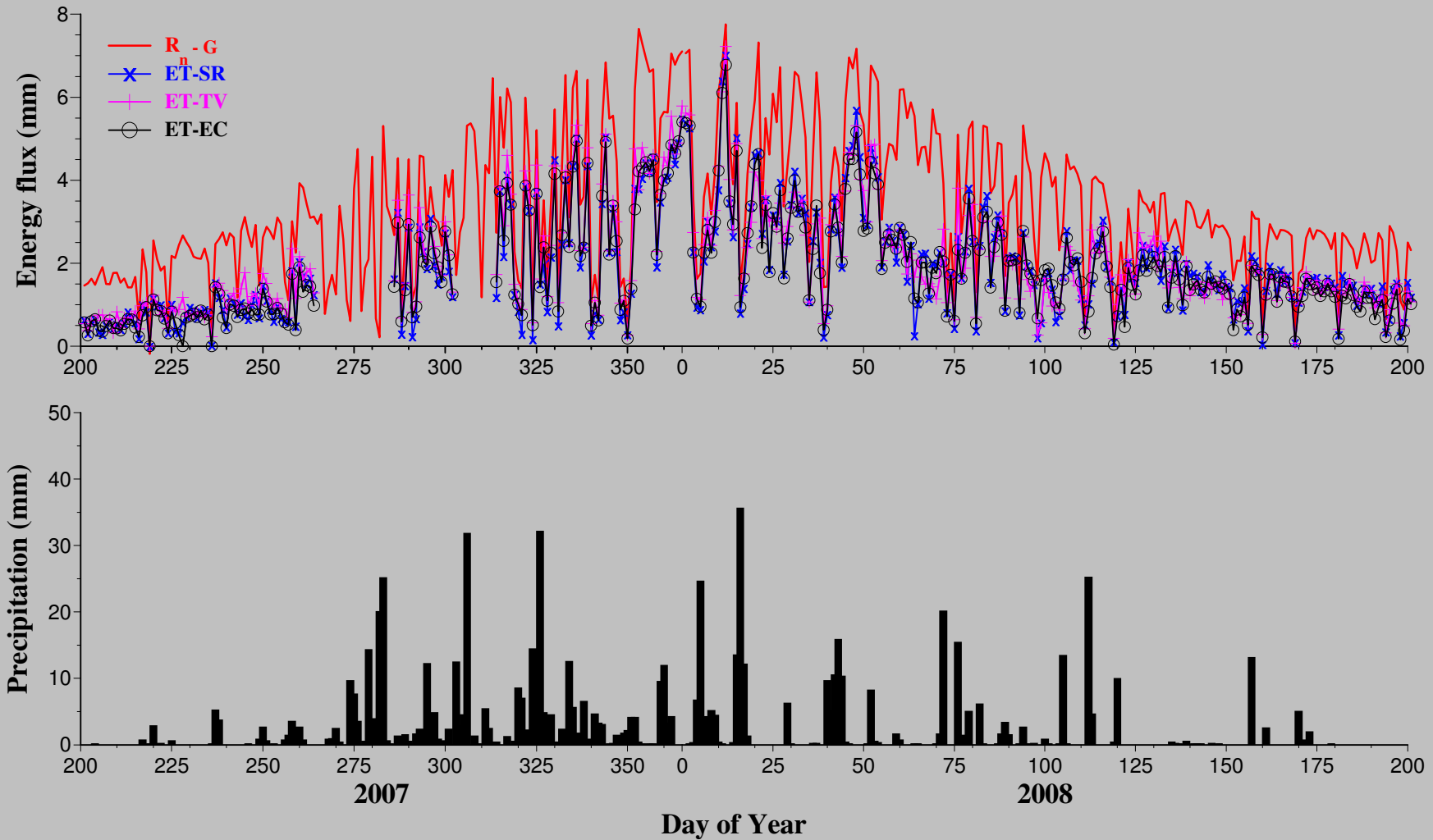
- Aim: To measure changes in water-use, growth and yield of a *Jatropha curcas* / kikuyu agro-forestry system over time.
- Methodology: Establish and maintain a 3ha trial, conduct field measurements and modelling studies, gain practical experience.
- Project Duration: Apr 2004 to present
- Consortium (CSIR, UKZN, UP)
- Funded by the Water Research Commission of South Africa.

## Project 2 - *Jatropha* grown in a silvopastoral (Kikuyu) agro-forestry system



**Total evaporation measurements -  
Ukulinga Research Farm (UKZN)  
Pietermaritzburg.**

# Project 2 – Total evaporation of *Jatropha curcas*

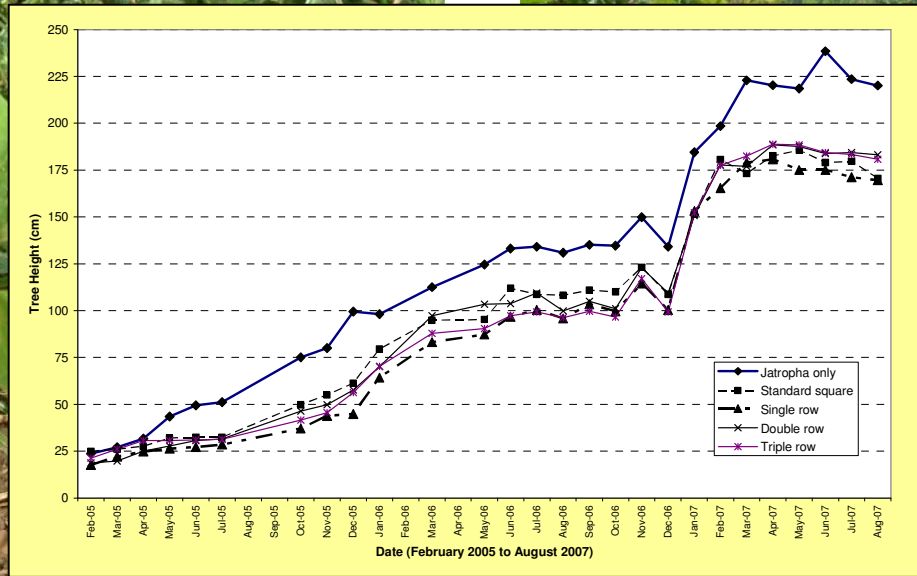
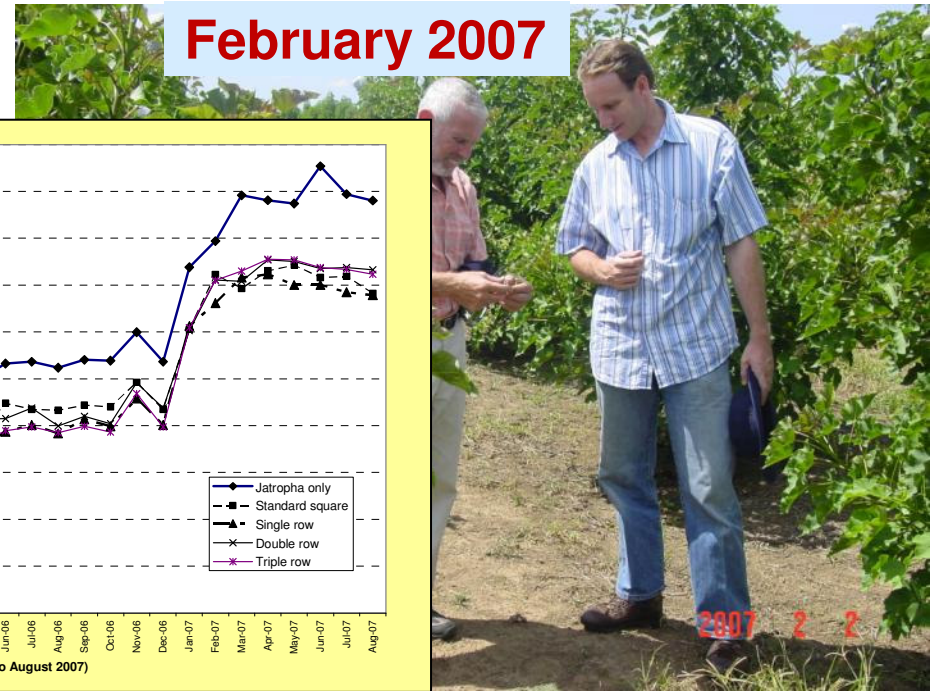


# Project 2 – Growth (tree height) of *Jatropha curcas*

**February 2005**



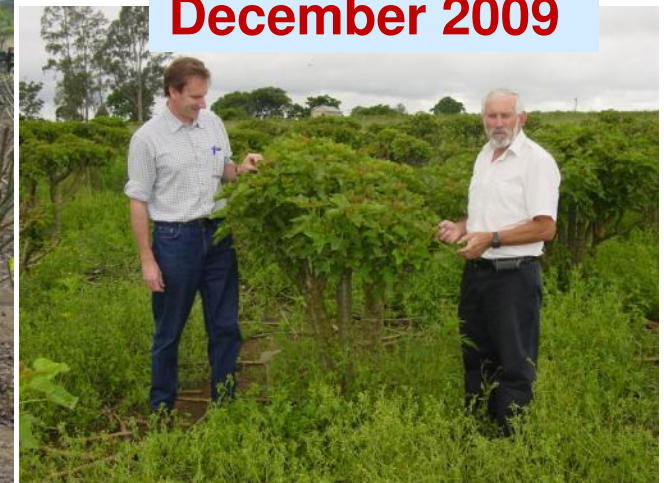
**February 2007**



**October 2007 - Pruned**

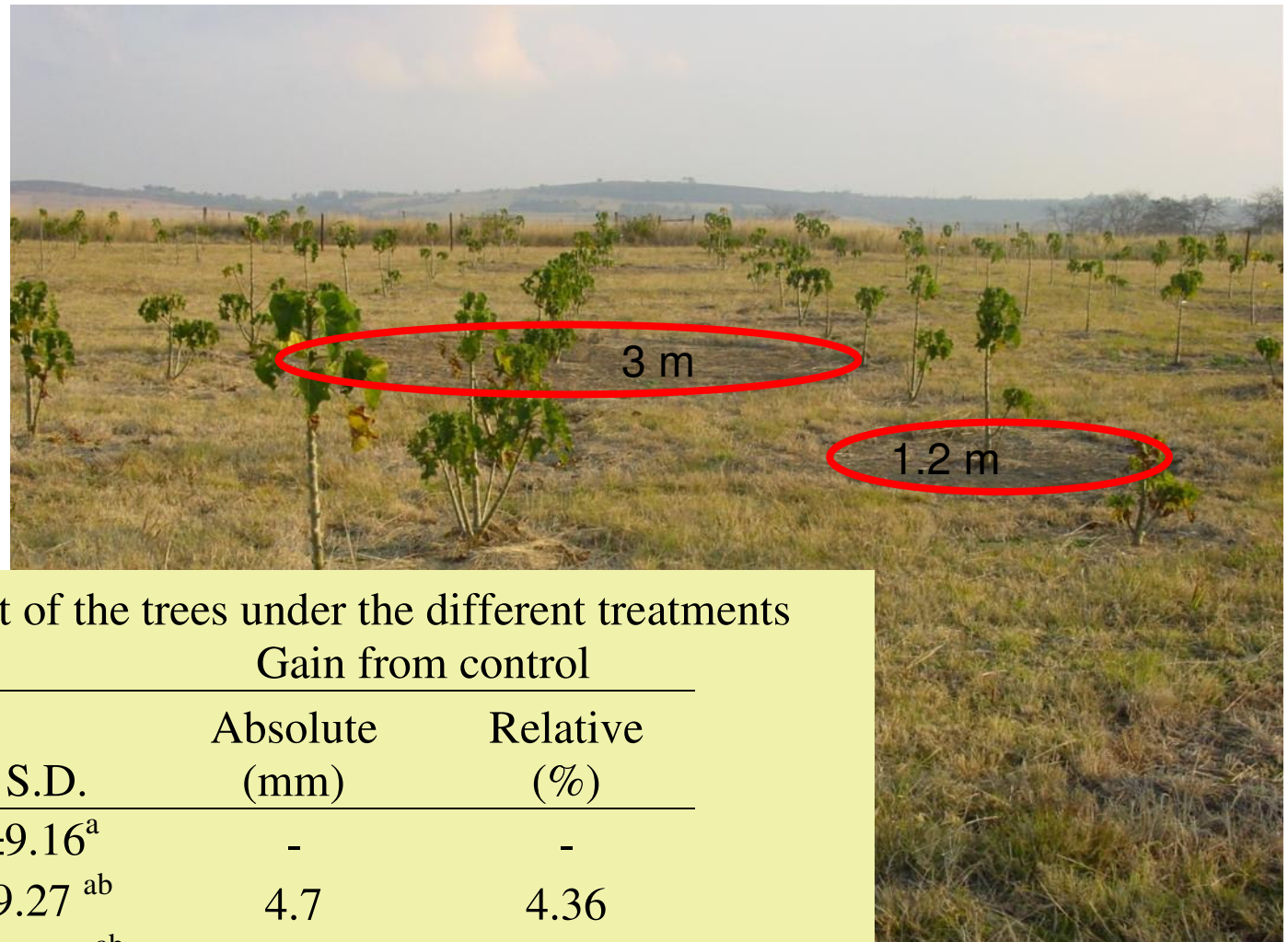


**December 2009**





## Project 2 – Competition trials with *Jatropha curcas*



The final average height of the trees under the different treatments  
Gain from control

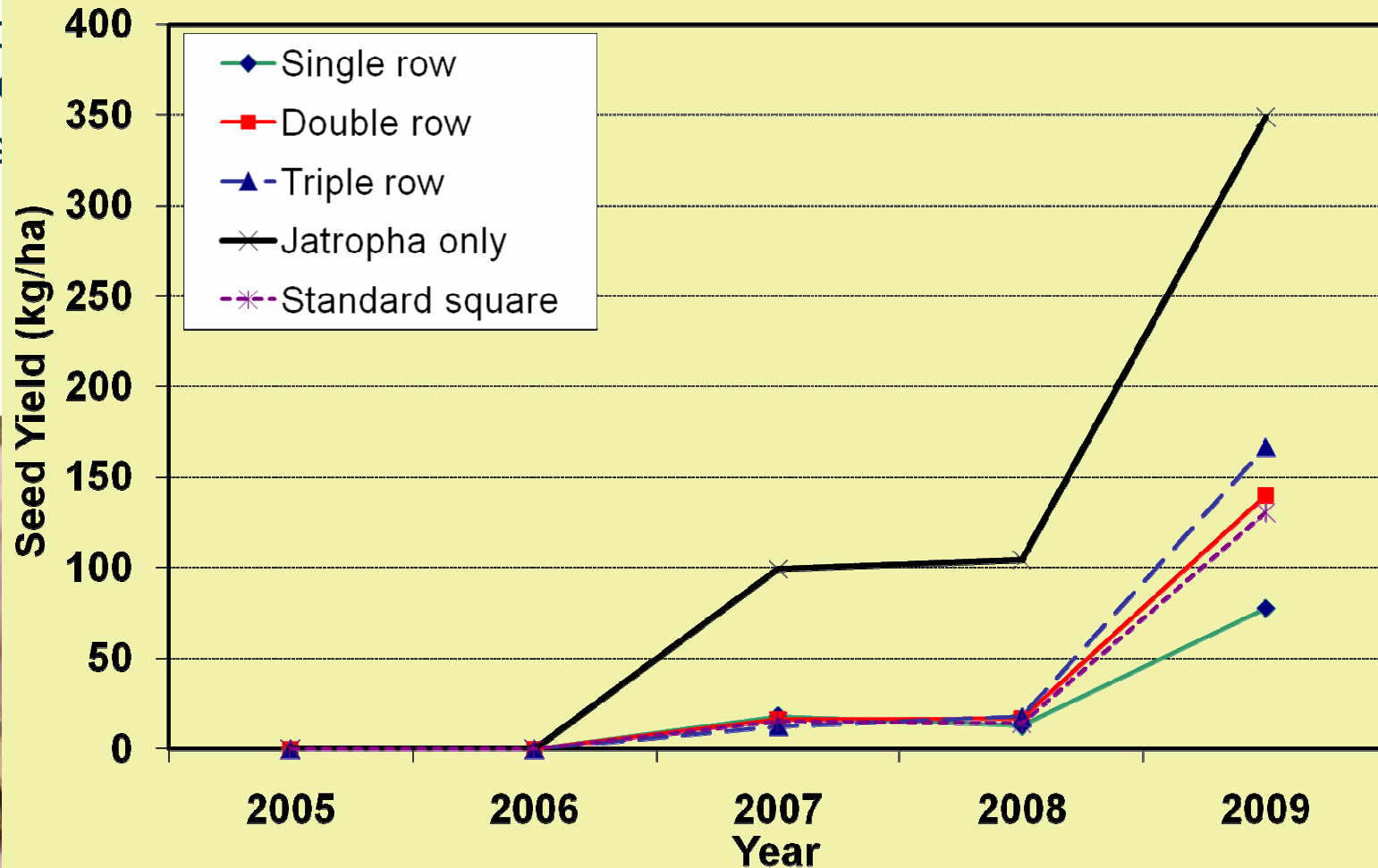
Treatment	Mean $\pm$ S.D.	Absolute (mm)	Relative (%)
Control	107.28 $\pm$ 9.16 <sup>a</sup>	-	-
60	111.95 $\pm$ 9.27 <sup>ab</sup>	4.7	4.36
120	115.27 $\pm$ 13.98 <sup>ab</sup>	8.0	7.45
300	117.97 $\pm$ 13.54 <sup>b</sup>	10.7	9.97

a, b: Significantly different groups using Scheffe Post Hoc test (SPSS)

## Project 2 – Yield (*Jatropha curcas* as an energy crop)

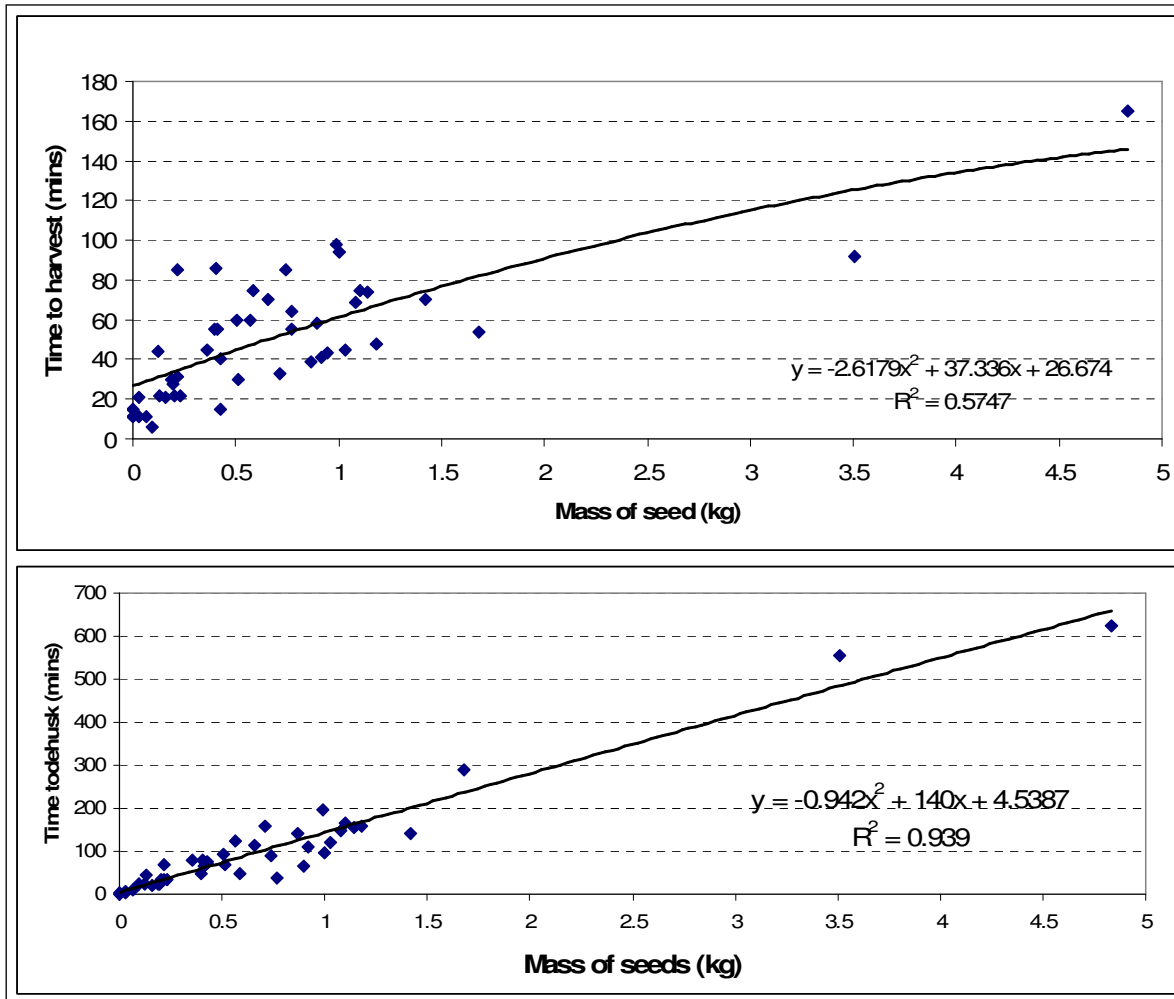
- Harvested part is fruit containing 3 seeds.
- Seed fruit
- Gross

Effect of  
Drainage



## Project 2 – Labour costs?

Relationship between the mass of *Jatropha* seeds and the time to harvest and to dehusk



Conclusion:  
Harvesting will require large labour inputs

## Project 2 – *Jatropha curcas* tolerance to pests and disease

Assumed tolerance based on single trees - does not apply to *Jatropha* plantations.

In plantations serious problems have been reported with fungi, viruses and attack by insects. This has also been our experience at Ukulinga



Insect Damage



Fungal Damage



# Project 2 - Conclusions



- Claims of low water use appear to be true. However, water use measurements need to be made in tropical regions where the plant remains green all year.
- High oil yields have not been observed. Major constraint - lack of knowledge under different conditions (marginal vs. fertile)
- *Jatropha* has potential to be exploited in semi-arid & arid conditions for soil water conservation, erosion control, living fences, green manure, soap production and many others. For these the claims are verifiable.

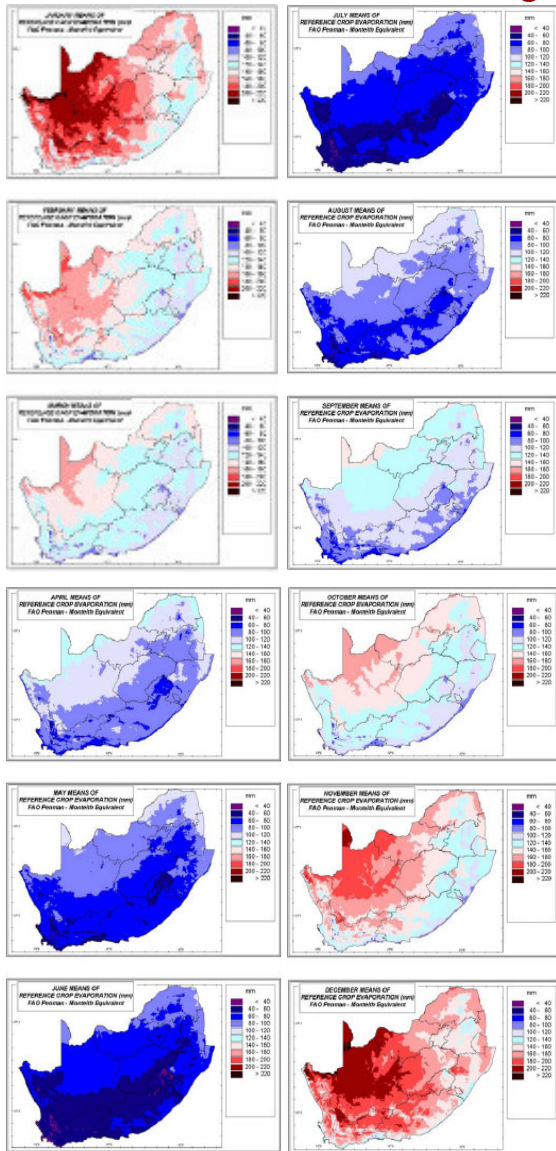


## Project 2 – Conclusions (cont.)

- Silvicultural practices (limiting competition, mulching, pruning) important for tree production – will effect economic viability.
- Claims of low labour input not true. Problems with mechanical harvesting due to sequential flowering.
- Tolerance to pests and diseases not true in plantations. Increases input costs due to need for insecticides and fungicides.
- No information on alien invasiveness
- Economic viability may be improved by growing in an agro-forestry system.

# Modelling - Spatial Extrapolation

## Monthly P-M ET<sub>0</sub>



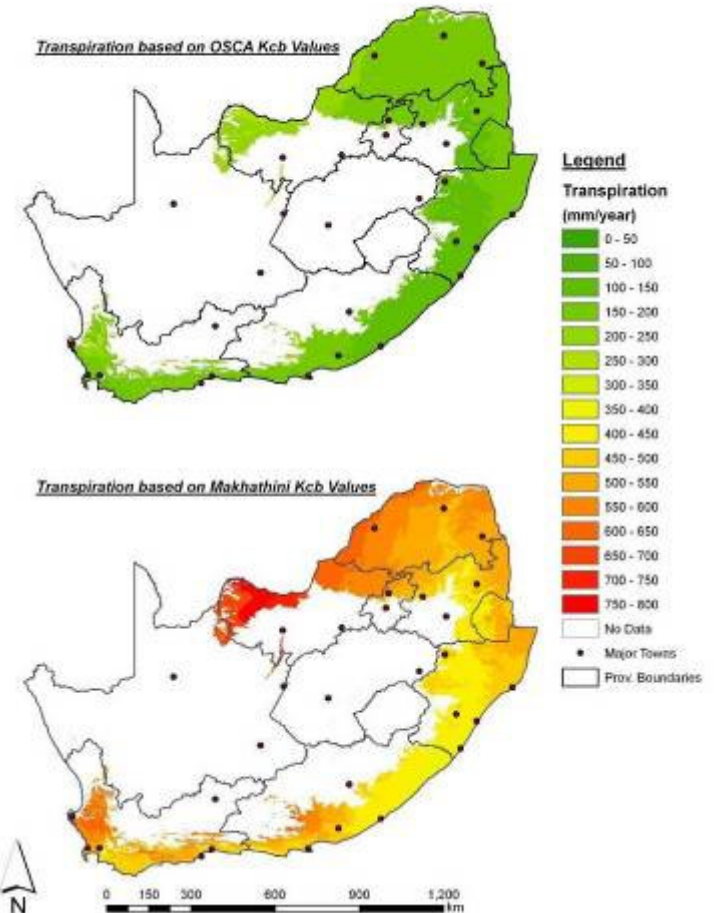
**X**

	K <sub>cb</sub>	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
OSCA	0.18	0.18	0.26	0.21	0.14	0.06	0.00	0.00	0.00	0.00	0.04	0.14	0.15
Makh.	0.55	0.76	0.56	0.47	0.46	0.15	0.00	0.00	0.00	0.00	0.00	0.50	0.50

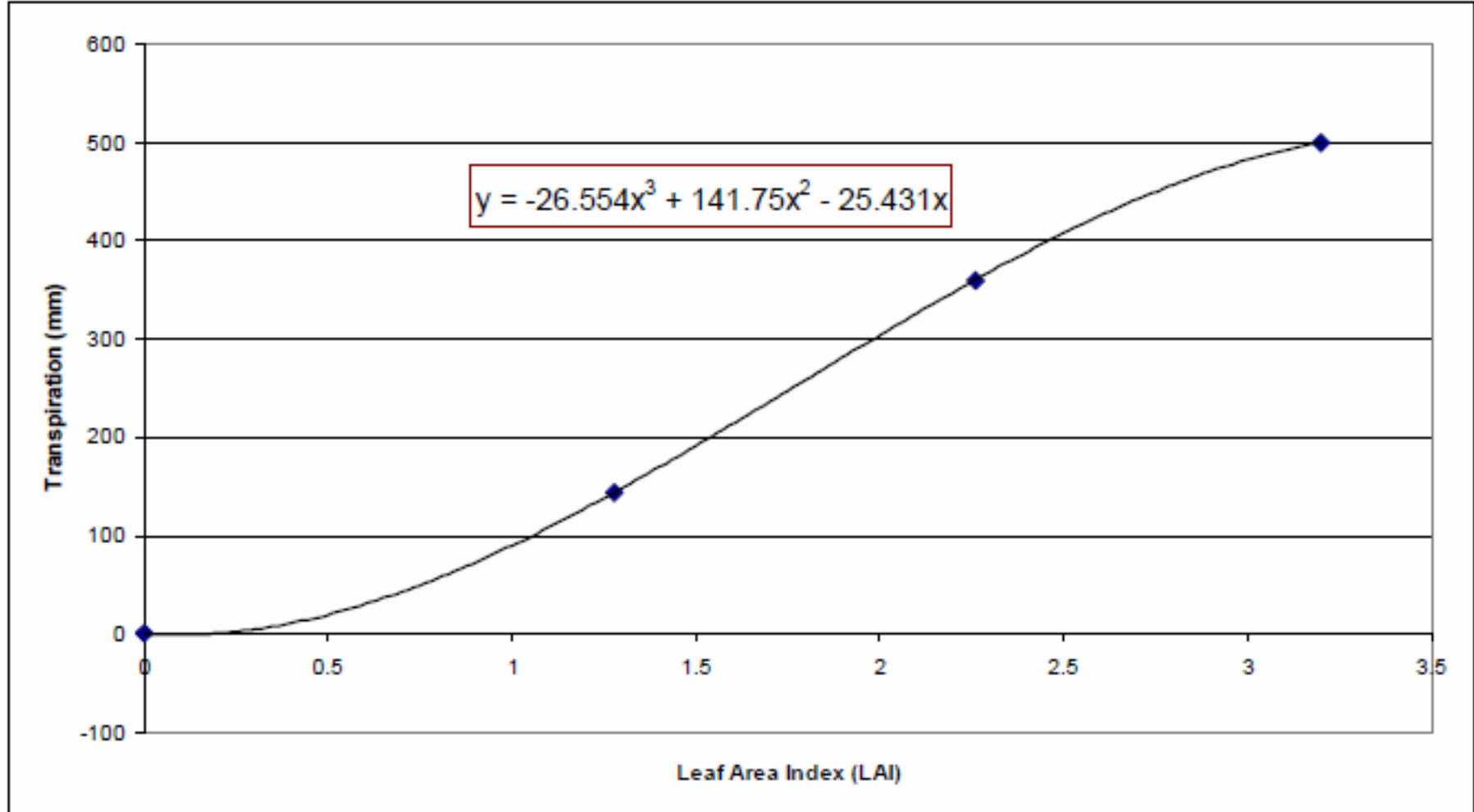
**=**

## Jatropha curcas Transpiration in South Africa

Transpiration based on OSCA K<sub>cb</sub> Values



# Modelling – Temporal Extrapolation



- Limitations of input data (few measurements)
- Account for varying bio-physical conditions.



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Gush, M.B. and Moodley, M. 2007. Water use assessment of *Jatropha curcas*. In: Holl, M., Gush, M.B., Hallows, J. and Versfeld, D.B. (Eds). 2007. *Jatropha curcas* in South Africa: an assessment of its water use and bio-physical potential. WRC Report 1497/1/07, Chapter 4.





## General Conclusions & Way Forward

- Dry-land water-use of *Jatropha curcas* is low
- Useful additional information (growth, yield & management) being collected from existing trial
- Calculation of “water footprint” or “virtual water” WUE possible from this kind of study
- Expand concept to bio-fuels water-use atlas (WRC, UKZN, CSIR, UP project - **WATER USE OF CROPPING SYSTEMS ADAPTED TO BIO-CLIMATIC REGIONS IN SOUTH AFRICA AND SUITABLE FOR BIO-FUEL PRODUCTION**)
- Other environmental issues

# Acknowledgements

- Water Research Commission for funding the projects
- Fellow Project Consortium Members:
  - Siyaphambili Development Consulting
  - CPH20 / DHI
  - Dirk Versfeld cc.
  - University of KwaZulu-Natal
  - University of Pretoria
- CSIR Project Team:
  - Dr. Michael Mengistu, Mr. Lelethu Sinuka, Mr. Alistair Clulow, Mr. Joshua Xaba



**Thank you**

**CSIR**  
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