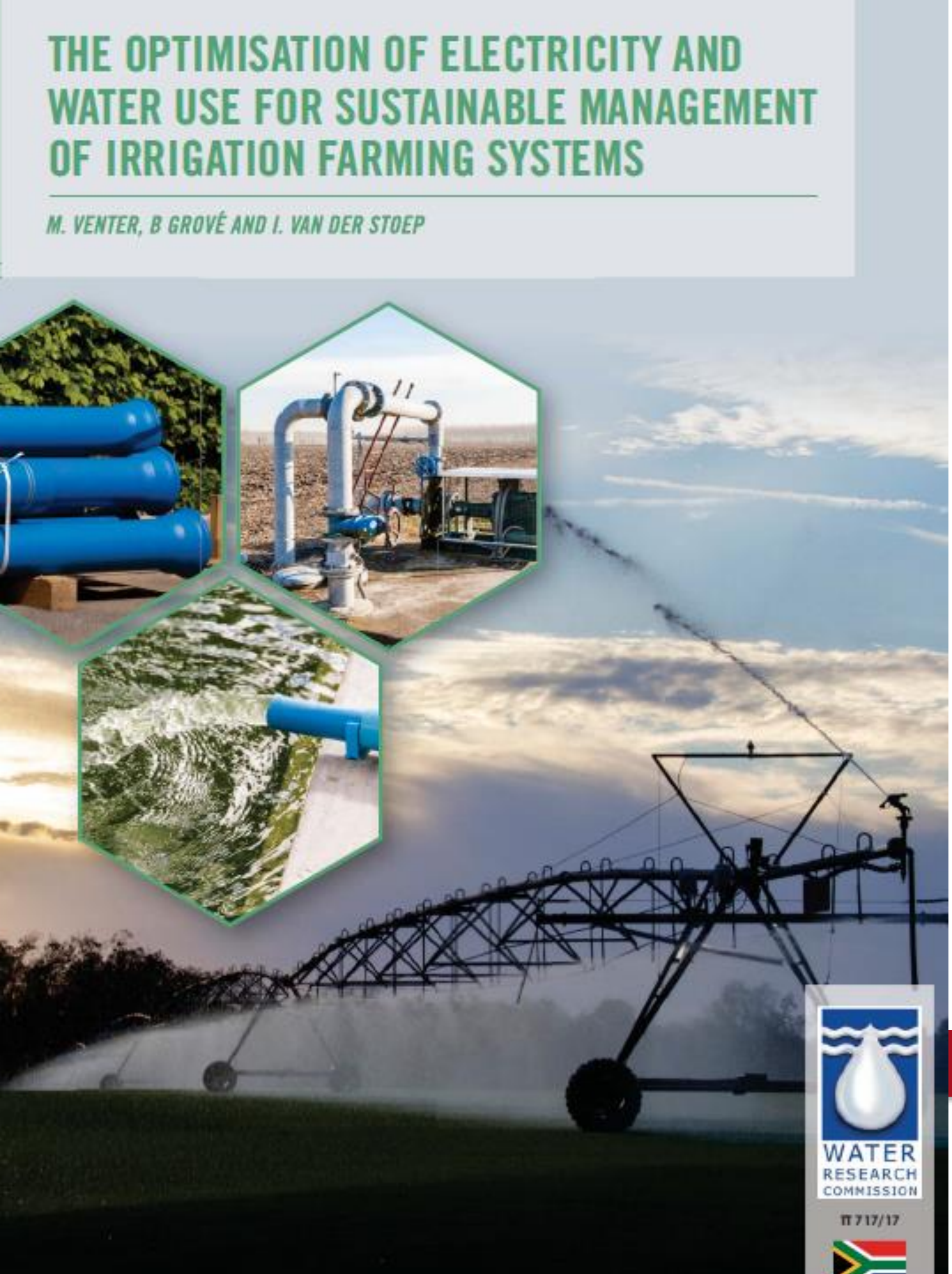


THE OPTIMISATION OF ELECTRICITY AND WATER USE FOR SUSTAINABLE MANAGEMENT OF IRRIGATION FARMING SYSTEMS

M. VENTER, B GROVÉ AND I. VAN DER STOEP

WATER
RESEARCH
COMMISSION

TT 717/17

Bennie Grové

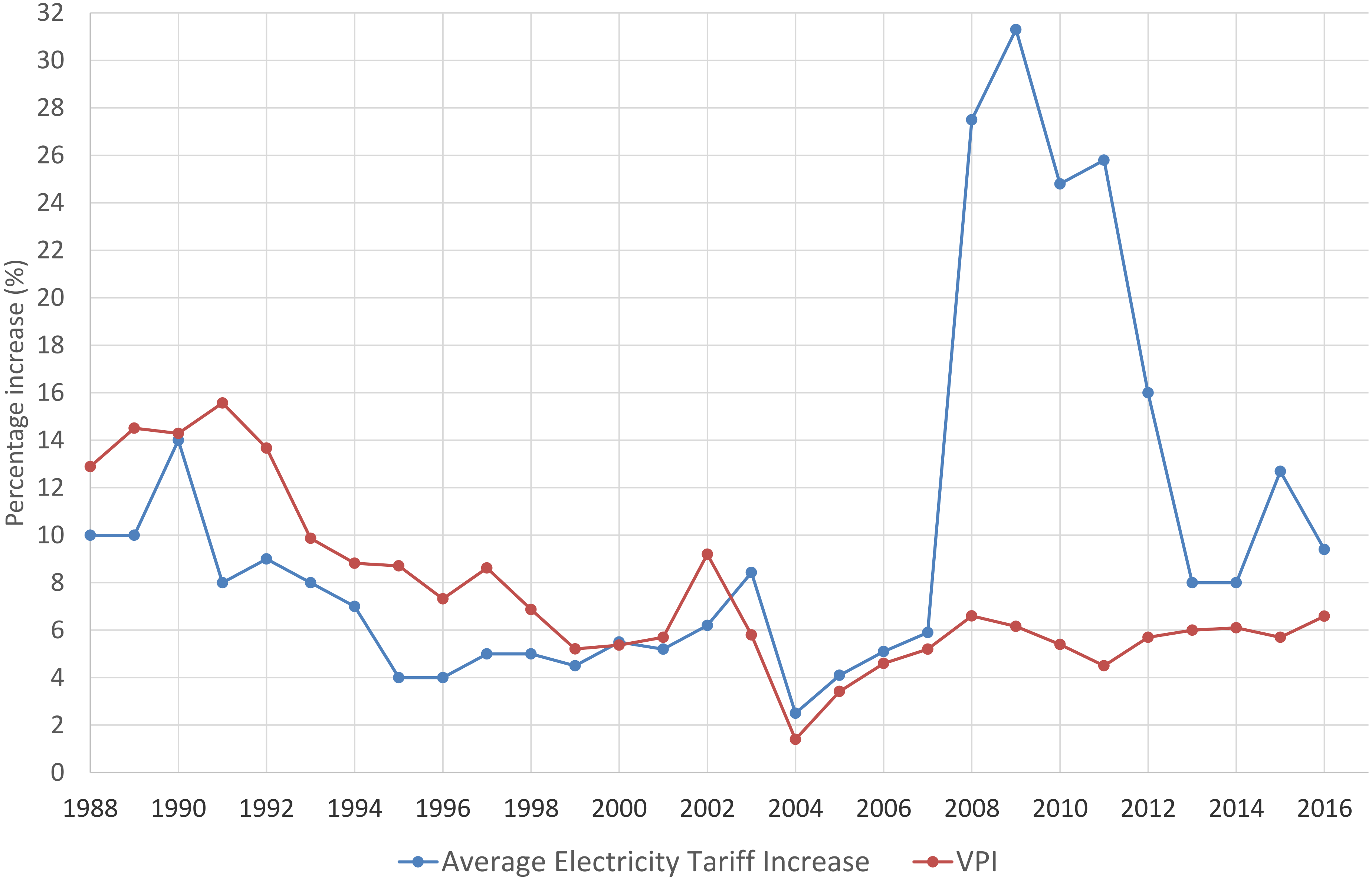
Isobel v/d Stoep

UNIVERSITY OF THE
FREE STATE
UNIVERSITEIT VAN DIE
VRYSTAAT
YUNIVESITHI YA
FREISTATA

UFS
UV

“The new normal”

- Previously: Water and Energy was cheap/abundant
  - minimise water applications with the aim of achieving maximum yield
  - buy irrigation systems with low investment costs and high energy demand
- Now: Water and Energy more costly/scarce
  - Economic value increases
  - WC/DM

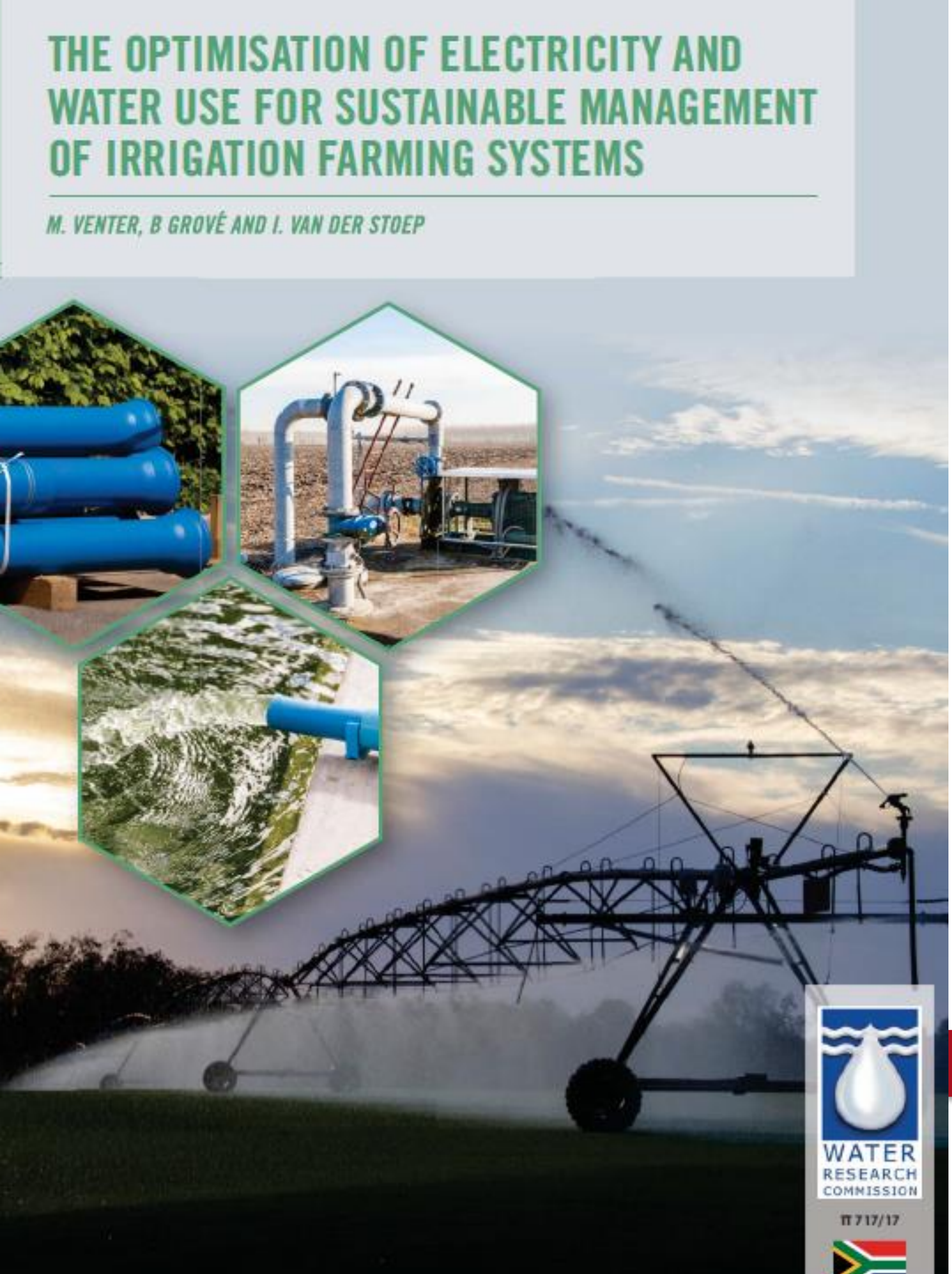

32
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
Percentage increase (%)
1988
1990
1992
1994
1996
1998
2000
2002
2004
2006
2008
2010
2012
2014
2016
Average Electricity Tariff Increase
VPI

What is the problem?

- The question, however, is not whether irrigators should adopt practises to improve energy and water management. Rather, the problem is how to evaluate the interrelated linkages between irrigation management, irrigation system design and choice of electricity tariffs simultaneously to improve energy and water management.

- Together these factors will determine the extent of water and energy savings in irrigated agriculture.

- A need exits for an integrated decision support model that include optimal irrigation management, irrigation system design in relation to the available electricity tariff choices and **energy source**.



THE OPTIMISATION OF ELECTRICITY AND WATER USE FOR SUSTAINABLE MANAGEMENT OF IRRIGATION FARMING SYSTEMS

M. VENTER, B GROVÉ AND I. VAN DER STOEP

WATER RESEARCH COMMISSION

TT 717/17

Overall:

Develop management approaches for reducing electricity costs, improving water use productivity and increasing profitability

Technology

$$P(kW) = \frac{Q \times H}{0.036 \times \eta_p \times \eta_m}$$

Q (discharge)

- Gross irrigation requirement
  - Crop
  - Climate
  - System efficiency
  - Leaching fraction
- Time available
  - Management (Tariff)
  - Automated/Manual system
  - Soil characteristics
- Size of the system (ha)

H (pressure requirement)

- System working pressure
- Static Height
  - Topography
  - Boreholes
- Friction loss
  - Type of pipe, Length, diameter
  - Flow rate (Q)

Pump station

- Single / Multiple pumps
- VSD
- Pump and motor efficiencies

X

Management

$$t(h) = \frac{1000 \times \sum_{crops} \left(\frac{NIR}{\eta_s} \times A \right)}{Q}$$

How much water and when?

- Crop choice
- Irrigation scheduling
  - Soil water holding capacities
  - Climate
  - Irrigation intervals
  - Deficit irrigation
- Irrigation system
  - Size (ha)
  - Application rate
  - Labour (move sprayers)
  - Repair and maintenance
- Energy source availability
  - ESKOM tariff structure
  - Alternative energy
- Water supply restrictions
- Pump station/Distribution network
  - Boreholes
  - Single / Multiple pumps
  - VSD
  - Balancing dams

X

Tariff

$$k_e \ (R/kWh)$$

Electricity tariffs

- Ruraflex
- Ruraflex CPD
- Landrate
- Nightsave
- Distance from Johannesburg

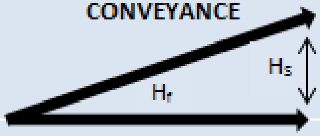
Alternative energy sources

- Solar
- Wind
- Water

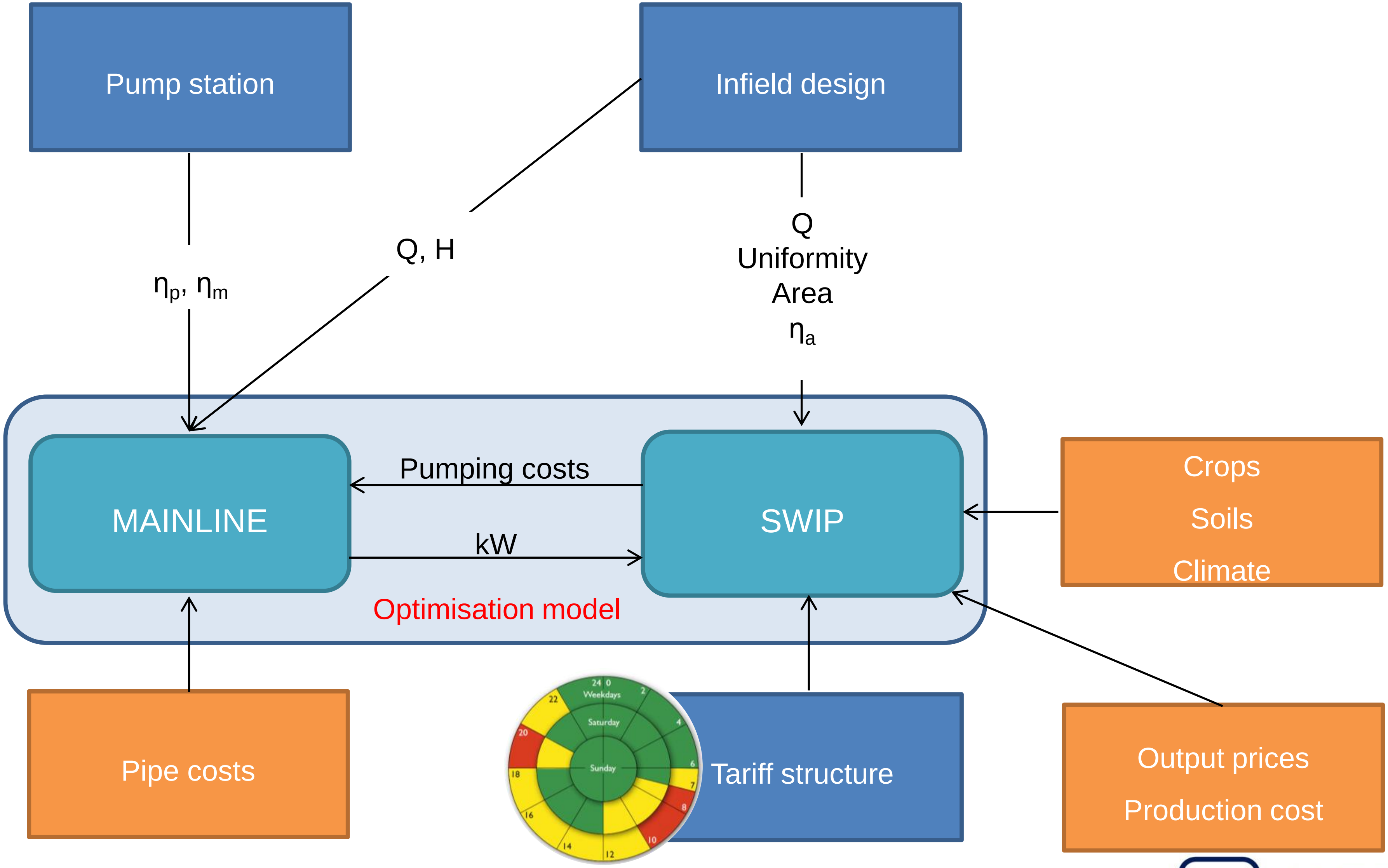
UNIVERSITY OF THE
FREE STATE
UNIVERSITEIT VAN DIE
VRYSTAAT
YUNIVESITHI YA
FREISTATA
UFS
UV

PLANNING & DESIGN

LIFE CYCLE COST ANALYSIS

		Investment costs	Economic Tradeoff	Maximise uniformity
PROCESS		**POWER SUPPLY** P(kW) Pumping Station	**CONVEYANCE**  	**DEMAND (H_i,Q)** Irrigation System
				LAYOUT
INVESTMENT COSTS	Tax deduction	$P(kW) = \frac{Q \times H_t}{0.036 \times \eta_p \times \eta_m}$ Pump selection (η_p) Motor selection (η_m) VSD	<-------------------- <---------- H_s & H_f <-------------------- Balancing dams	Irrigation system layout Working pressure (H_i) • Infield design Discharge (Q) • Irrigation requirement • Leaching fraction • Time (Electricity Tariff) • Area • Uniformity & η_a
OPERATIONS				
	$R/(kWh)$			Fixed during planning • Landrate / Ruraflex • Alternative energy
VARIABLE ELECTRICITY COSTS	$\times\ t(h) = \frac{1000 \times \sum_{GT\ mpd}\left(\frac{NIR}{\eta_a} \times A\right)}{Q} \times$			Crop choice (Area) Irrigation application • Objective / Strategy • Crop / Climate Balancing dams RESTRICTIONS • Discharge (Q) • η_a • TOU Electricity tariff • Soil water holding capacity • Labour (move sprayers) • Water supply restrictions • Water Quality
	$p(kW)$	Fixed by design Sequencing Maintenance	Maintenance	Fixed by design Maintenance
OTHER	$o(R/h)$	Maintenance Labour	Maintenance Labour	Maintenance Labour

Modelling framework



Pump station

Infield design

η_p, η_m

Q, H

Q
Uniformity
Area
η_a

MAINLINE

Pumping costs

kW

SWIP

Optimisation model

Crops
Soils
Climate

Pipe costs

Tariff structure

Output prices
Production cost

UNIVERSITY OF THE FREE STATE
UNIVERSITEIT VAN DIE VRYSTAAT
YUNIVESITHI YA FREISTATA
UFS UV

Conclusions

- Higher electricity costs resulted in mainline design changes
- Landrate results in a higher margin above specified costs
  - Ruraflex – Higher fixed costs
- Pivot size effect choice of pipe diameter
  - Higher flow rate
    - Higher friction
- 30,1 hectare
  - Ruraflex: 14 mm/day
  - Landrate: 14 mm/day
- 47,7 hectare
  - Ruraflex: 12 mm/day
  - Landrate: 12 mm/day

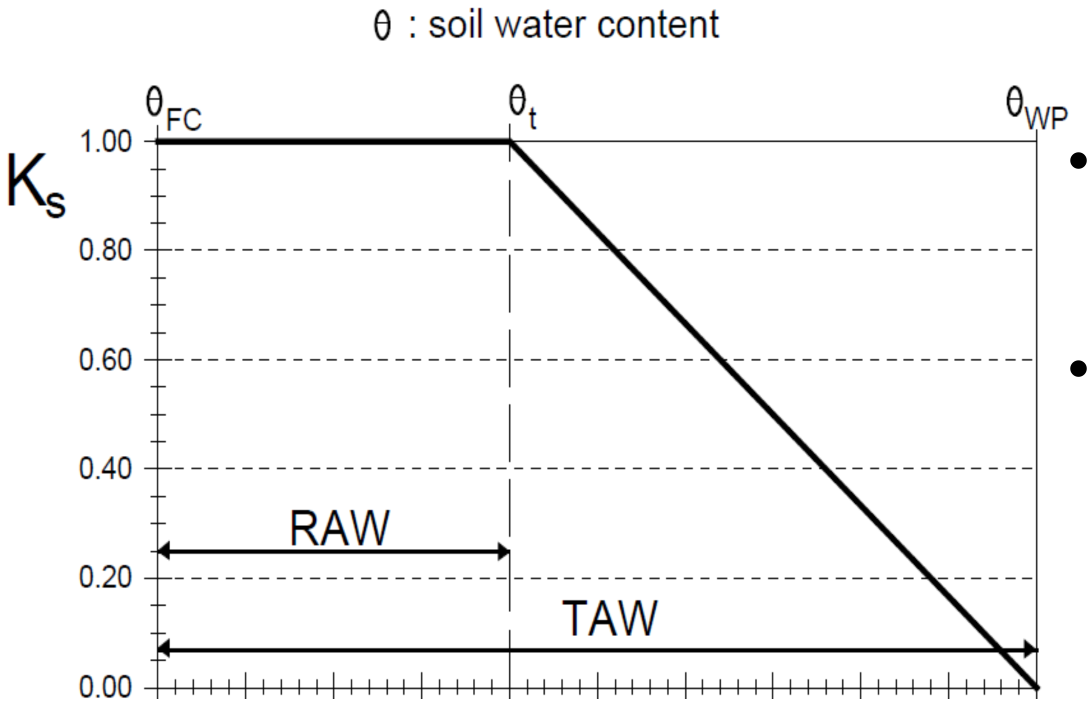
WATER
RESEARCH
COMMISSION

Dual Kc Approach

$$ET = (K_r K_e + K_s K_{cb})ET_0$$

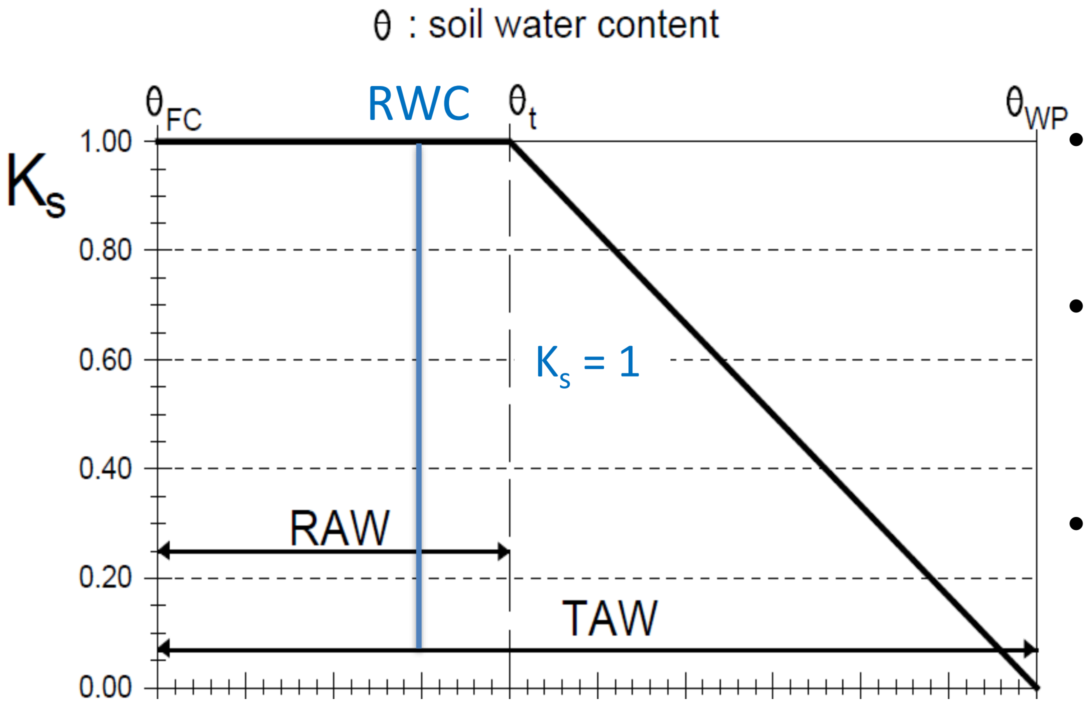
K_r	adjustment factor for evaporation
K_e	evaporation coefficient
K_s	adjustment factor for transpiration
K_{cb}	transpiration coefficient

K_r-adjustment factor



- **TAW**: amount of water that a crop can extract from its root zone
- **RAW**: fraction of TAW that a crop can extract from the root zone without suffering water stress

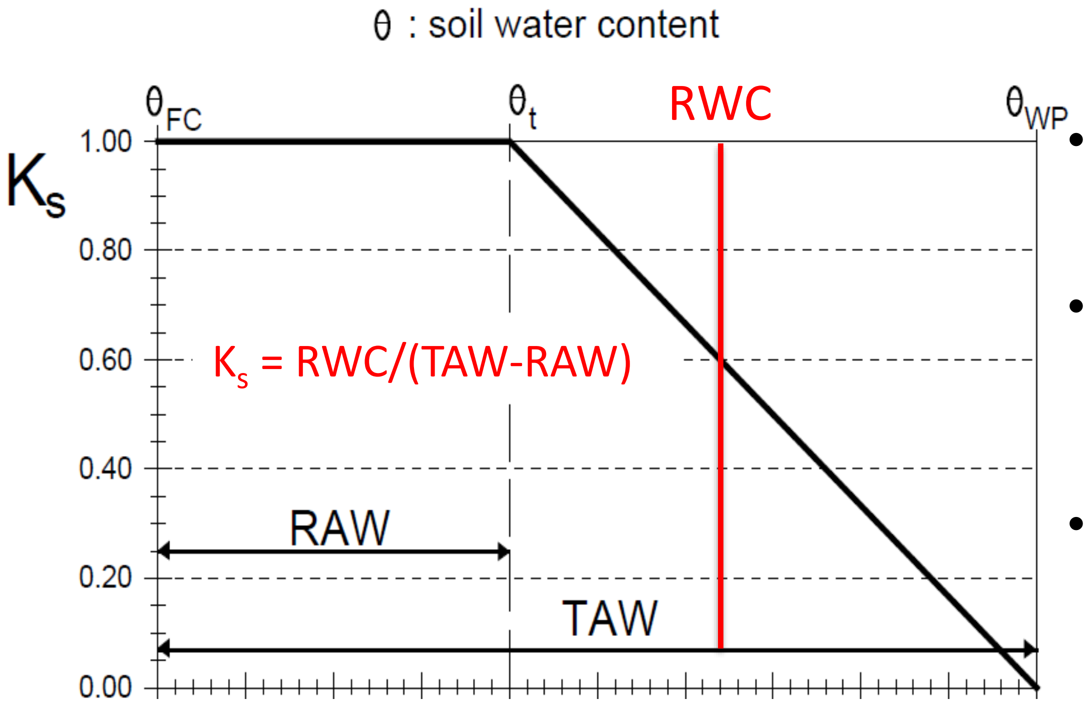
K_s-adjustment factor



- **TAW**: amount of water that a crop can extract from its root zone
- **RAW**: fraction of TAW that a crop can extract from the root zone without suffering water stress
- **RWC**: water content of the root zone

WATER
RESEARCH
COMMISSION

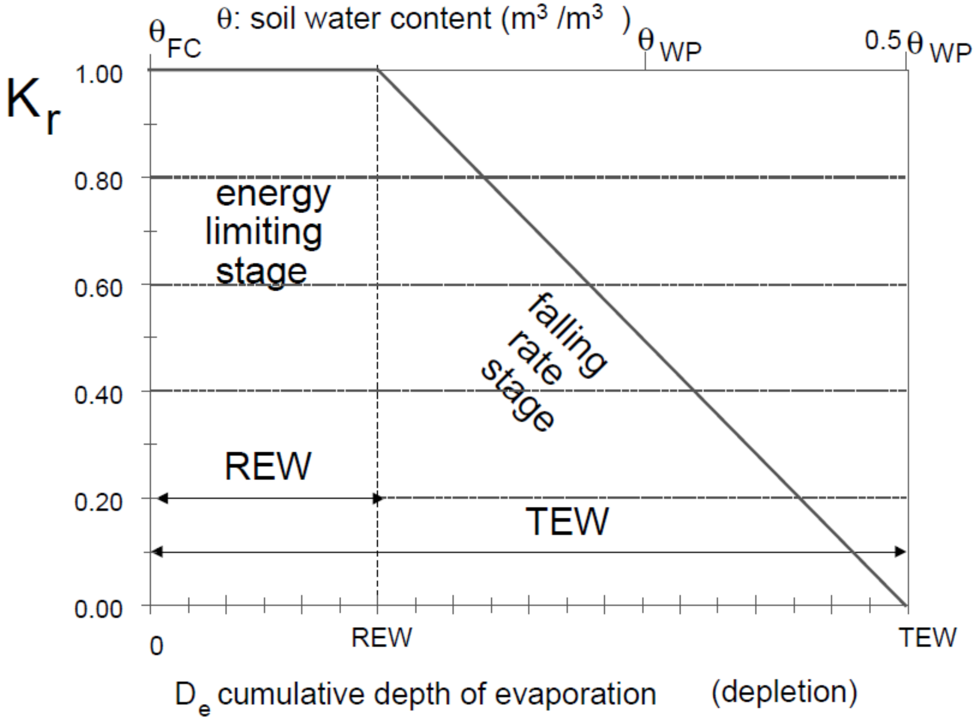
K_s-adjustment factor



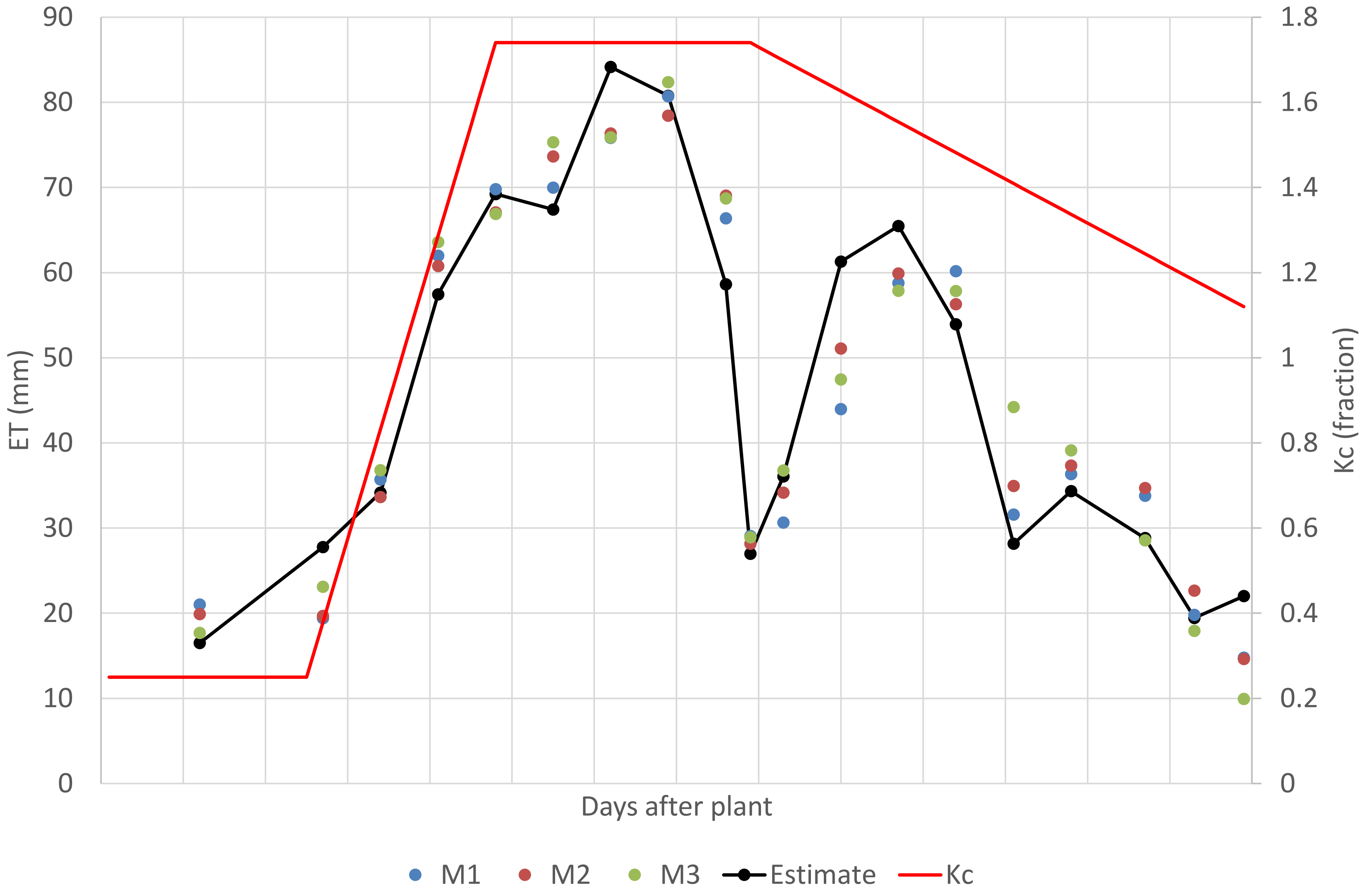
- **TAW**: amount of water that a crop can extract from its root zone
- **RAW**: fraction of TAW that a crop can extract from the root zone without suffering water stress
- **RWC**: water content of the root zone

WATER
RESEARCH
COMMISSION

K_e-adjustment factor



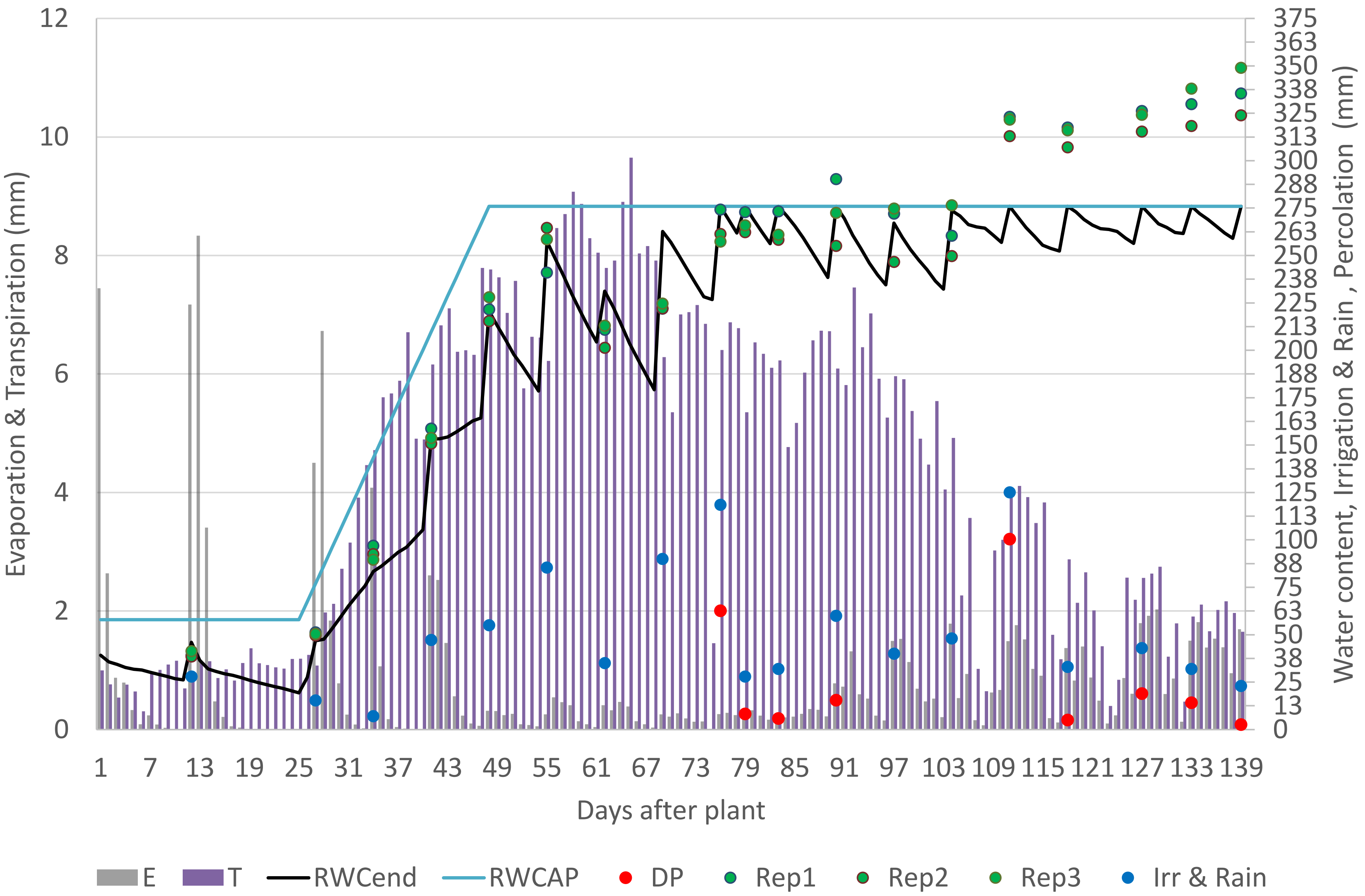
- **TEW**: maximum depth of water that can be evaporated from the soil when the topsoil has been initially completely wetted
- **REW**: maximum depth of water that can be evaporated from the topsoil layer without restriction



UNIVERSITY OF THE
FREE STATE
UNIVERSITEIT VAN DIE
VRYSTAAT
YUNIVESITHI YA
FREISTATA
UFS
UV

KC Calibration

	ET mm	E mm	T mm	Biomass Kg/ha
M1	860			34472
M2	872			36803
M3	879			35006
Estimate	873	286	586	36875
Avg Error (%)	0.75			4.17



UNIVERSITY OF THE
FREE STATE
UNIVERSITEIT VAN DIE
VRYSTAAT
YUNIVESITHI YA
FREISTATA

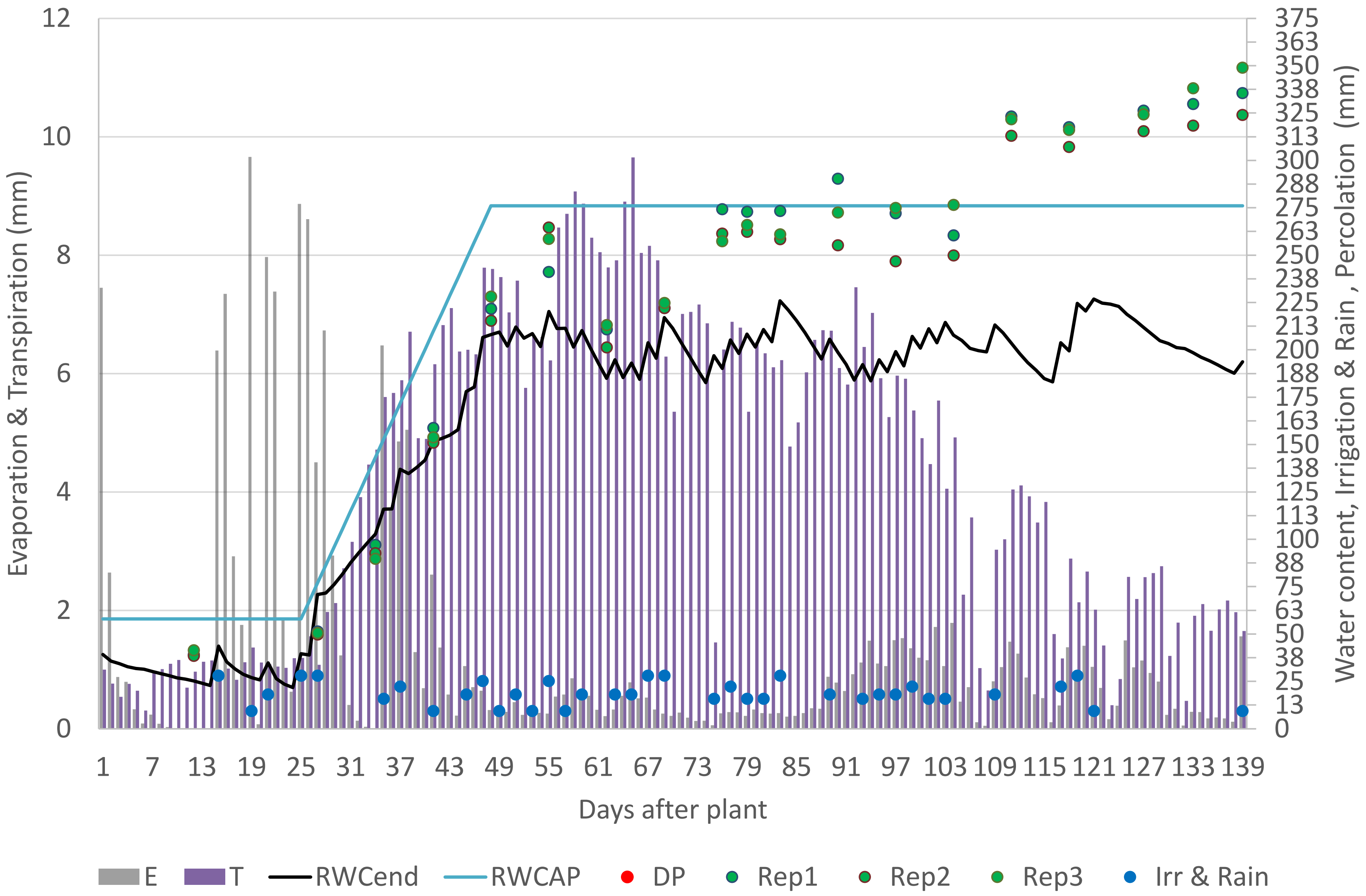
UFS
UV

Results

	Kc & Kcb	Ke	Optimal
Transpiration	586	586	?
Evaporation	286	116	?
ET	872	702	?
Irrigation		945	?
Percolation		233	?
Avg Error RWC (%)		9.32	

UNIVERSITY OF THE
FREE STATE
UNIVERSITEIT VAN DIE
VRYSTAAT
YUNIVESITHI YA
FREISTATA

UFS
UV



UNIVERSITY OF THE
FREE STATE
UNIVERSITEIT VAN DIE
VRYSTAAT
YUNIVESITHI YA
FREISTATA

UFS
UV

Results

	Kc & Kcb	Ke	Optimal
Transpiration	586	586	586
Evaporation	286	116	177
ET	872	702	763
Irrigation		945	691
Percolation		233	4
Avg Error RWC (%)		9.32	

Conclusion

- Calibration procedure with optimisation is promising
- More “computer farming” necessary to research evaporation losses