TESTING CROP COEFFICIENT CORRECTNESS WITH SAPWAT3 VER. 2

P S van Heerden, PICWAT
S Walker, UFS
LJ van Rensburg, UFS

SANCID, 2012

T: 051 401 9111 info@ufs.ac.za **www.ufs.ac.za**

© Copyright reserved
Kopiereg voorbehou

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

UFS·UV
NATURAL AND
AGRICULTURAL SCIENCES
NATUUR- EN
LANDBOUWETENSKAPPE

INTRODUCTION

- Estimation of irrigation requirements for planning comes a long way.
- Started through direct measurement and extrapolation
- Relating evaporation to crop irrigation requirement:
  - Class A pan
- Relating crop growth and development to weather data:
  - Penman-Monteith

© Copyright reserved Kopiereg voorbehou

INTRODUCTION

- Estimation or prediction of crop irrigation requirements are faced with a problem of credibility:
  - Green book – A-pan:
    - As long as calibrated and correctly placed;
    - Furthermore:
      - Heat exchange between pan and soil
      - Underground pans sensitive to environment
      - Maintain edge can cause wind break
      - Convective flows during night
  - Penman-Monteith:
    - Crop coefficients

- (Du Plessis & Wittwer, 1991; Green, 1985; Tanner, 1987; Riou, 1985; Doorenbos & Pruitt, 1977)

© Copyright reserved Kopiereg voorbehou

UFS UV

THEORETICAL BACKGROUND

- Growing plants contain about 90% water by weight.
- Transpires much more.
  - Maize plant contain 2l (2 kg) of water at maturity
    - 100000 plants/ha = 200 t/ha
    - Transpire 6000 t/ha during growing period.
- Water requirement need to be carefully planned and managed to ensure sustainability

- (Allen et al., 1998; Alois, 2007; DWA, 2004; Fairweather et al.,, undated)

© Copyright reserved Kopiereg voorbehou

THEORETICAL BACKGROUND

- FAO 56 crop coefficients based on semi-humid areas with warm summers
- Recent study found discrepancies between FAO 56 and crop coefficients.
  - -20% for citrus in Morocco
  - +20% for apples grown in cool, humid climate
- Crop coefficients used can vary significantly from actual observed data
  - Lysimeter, eddy covariance, soil and water balance, plant physiological
  - High air temperature and water deficit could lead to stomatal closure
    - lower than expected crop coefficients
- Some crops well researched:
  - Beans, cabbage, citrus, cotton, maize, onion, peas, peppers, potatoes, sugar cane, sunflower, wheat
- Some crops less well researched:
  - Berries, canola, gourds, granadillas, mangoes, papaws

- Need exists for continuous verification of crop coefficients

- (Lazarra & Rana, 2012; Allen, 2008; Raes, et al., 2009)

© Copyright reserved Kopiereg voorbehou

UFS UV

THEORETICAL BACKGROUND

- Existing models do not have built-in routines for testing crop coefficient correctness
- Shorter grass surface loses the similarity in aerodynamic exchange found in taller plants – lucerne (alfalfa) could be better
- Accepting default coefficients without considering influence of climate, planting data, cultivar characteristics, agronomic practices is wrong
- SAPWAT3 with 104 main crops and 2835 subgroups need to continuously update crop characteristics / coefficients
- Routine to verify crop coefficients has been built into SAPWAT3 version 2

- (Smith, 1992; Raes, et al., 2009; Allen, et al., 1998; Smith, 1994; Van Heerden, et al., 2001; Doorenbos & Kassam, 1986; Van Heerden, et al., 2008)

© Copyright reserved Kopiereg voorbehou

UFS UV

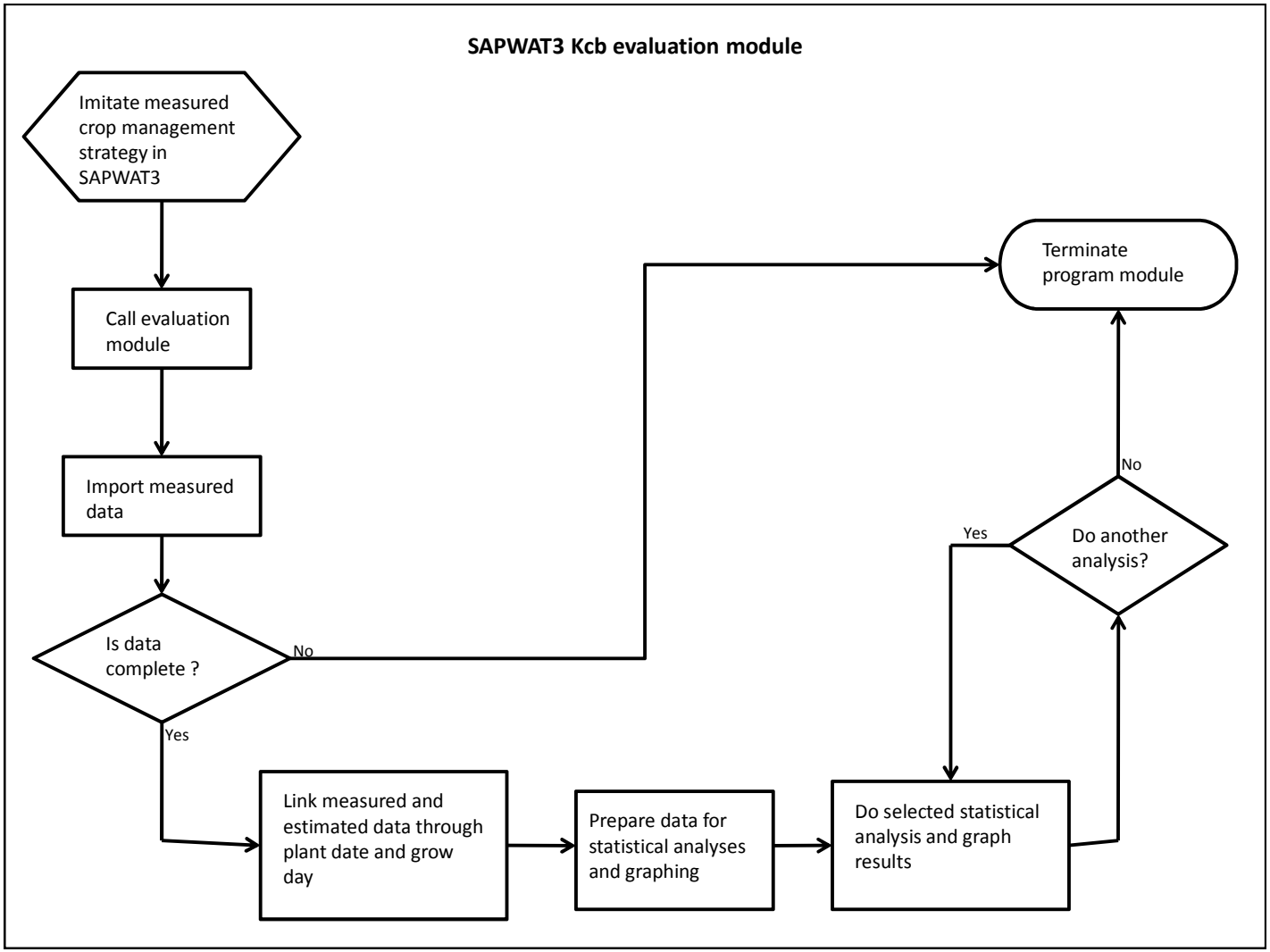
METHODOLOGY

- The approach to solving the problem for SAPWAT3
  - Crop observed ETc = SAPWAT3 estimated ETc
  - ETc is related to Kcb
  - Therefore:
    - If Crop observed ETc # SAPWAT3 estimated ETc
    - SAPWAT3 crop coefficient need to be adjusted
    - Adjustment within limits

- Allen, et al., 1998

© Copyright reserved Kopiereg voorbehou

UFS UV



© Copyright reserved Kopiereg voorbehou

METHODOLOGY

- ETc calculated with the soil water balance equation
- Calculate Kcb – basal crop coefficient
  - Kcb = Kc – Ke

- Display results supported by statistical analyses
  - SAPWAT3 ETc compared to observed ETc
  - SAPWAT3 cumulative ETc compared to observed cumulative ETc
  - SAPWAT3 Kcb compared to observed Kcb
  - SAPWAT3 Kcb curve compared to observed Kcb data

© Copyright reserved Kopiereg voorbehou

UFS UV

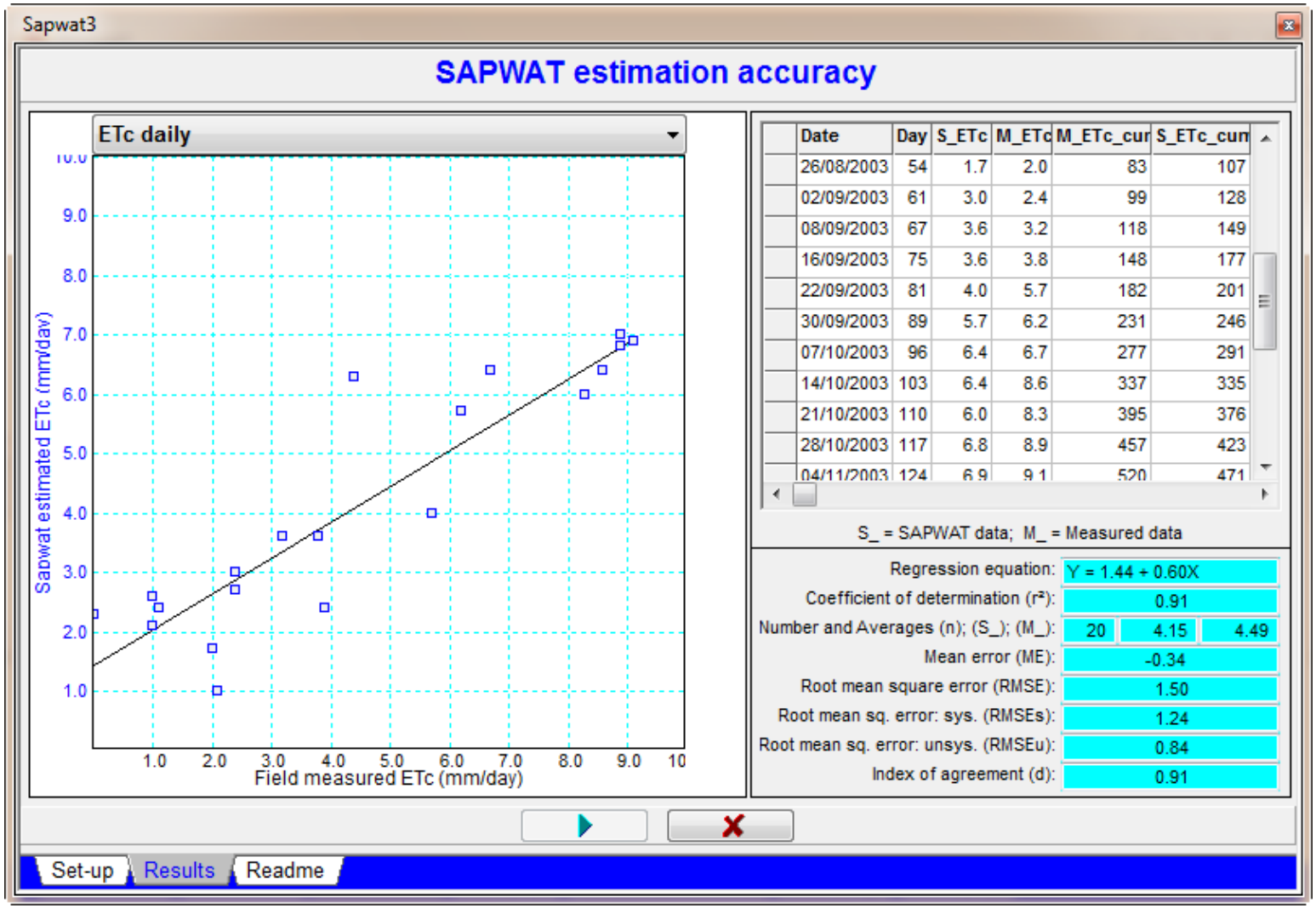
METHODOLOGY

- Three case studies:
  - Lysimeter at Bainsvlei (salinity project: control)
    - Wheat, planted mid June 2003
    - Centre pivot on sandy loam
    - Neutron probe about weekly
  - Lysimeter at Bainsvlei (water table project: control)
    - Wheat, planted mid June 1998
    - Centre pivot on sandy loam
    - Neutron probe about weekly
  - Field observed data near Hertzogville, NW (scheduling service)
    - Maize, planted End December 2008
    - Centre pivot on sandy loam
    - Decagon EC-20 probe, about daily
    - Percolation-Runoff not measured
    - “Good rain year”

© Copyright reserved Kopiereg voorbehou

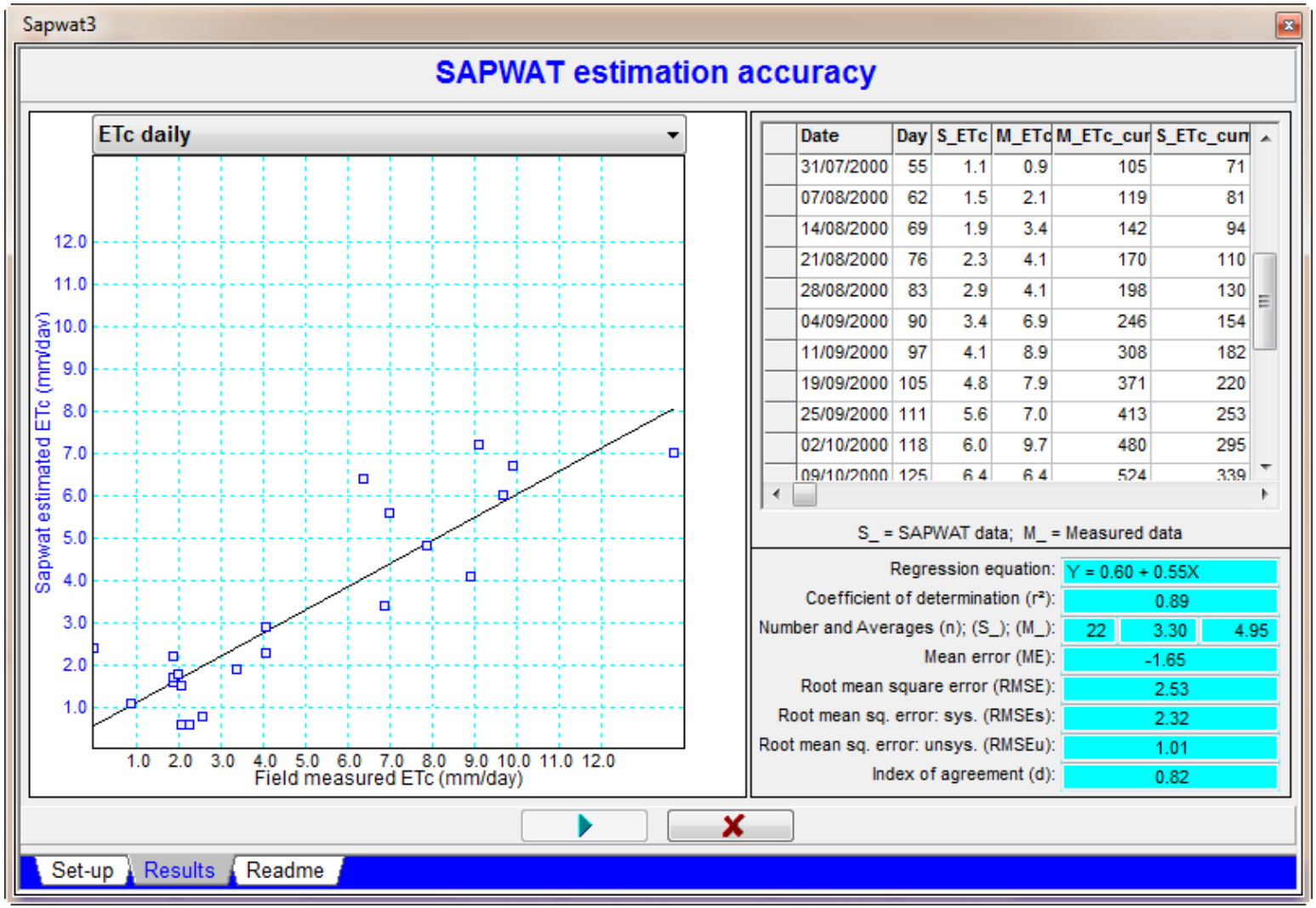
UFS UV

ETC DAILY: LYSIMETER 1



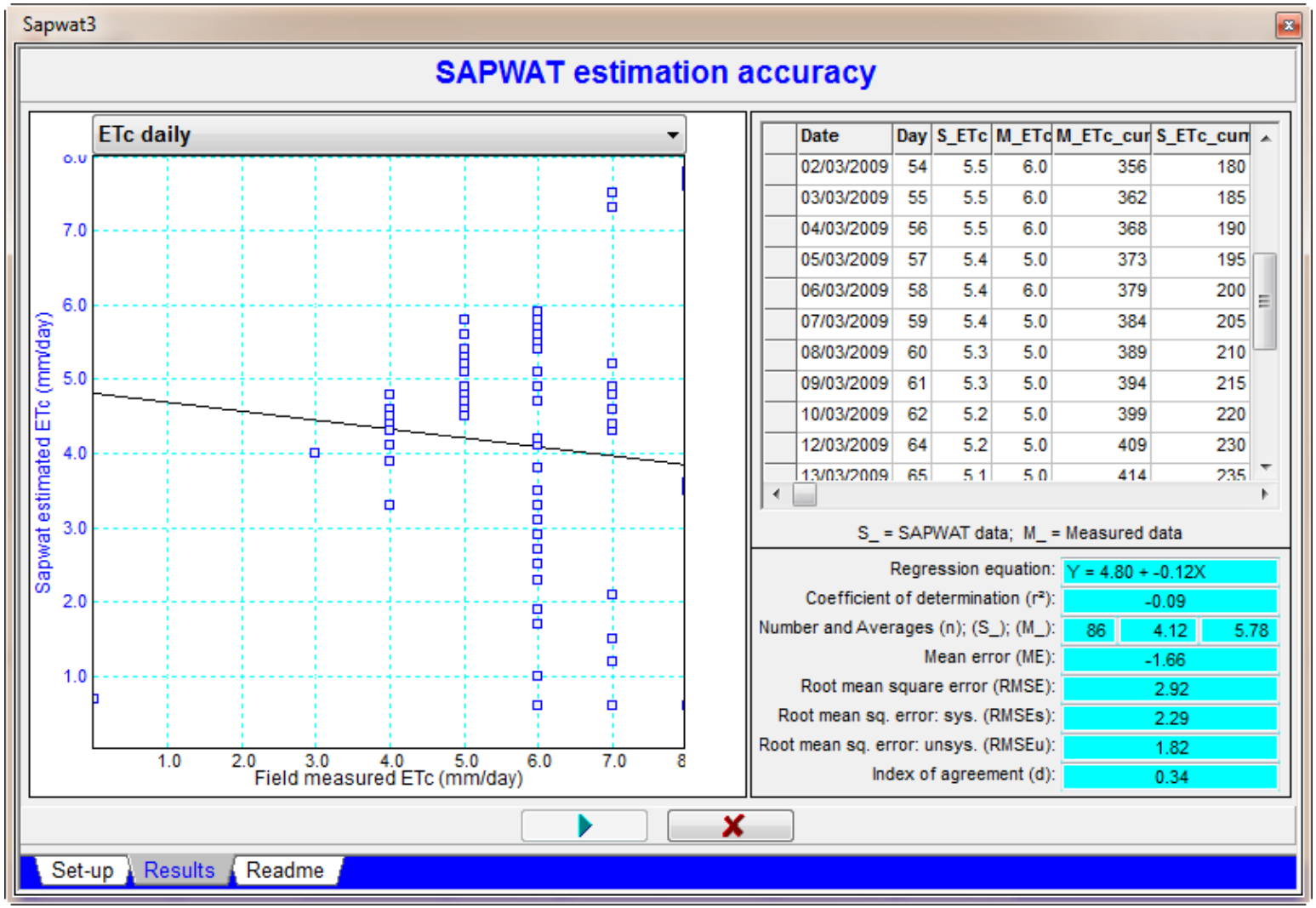
© Copyright reserved Kopiereg voorbehou

ETC DAILY: LYSIMETER 2



© Copyright reserved Kopiereg voorbehou

ETC DAILY: FIELD DATA



© Copyright reserved Kopiereg voorbehou

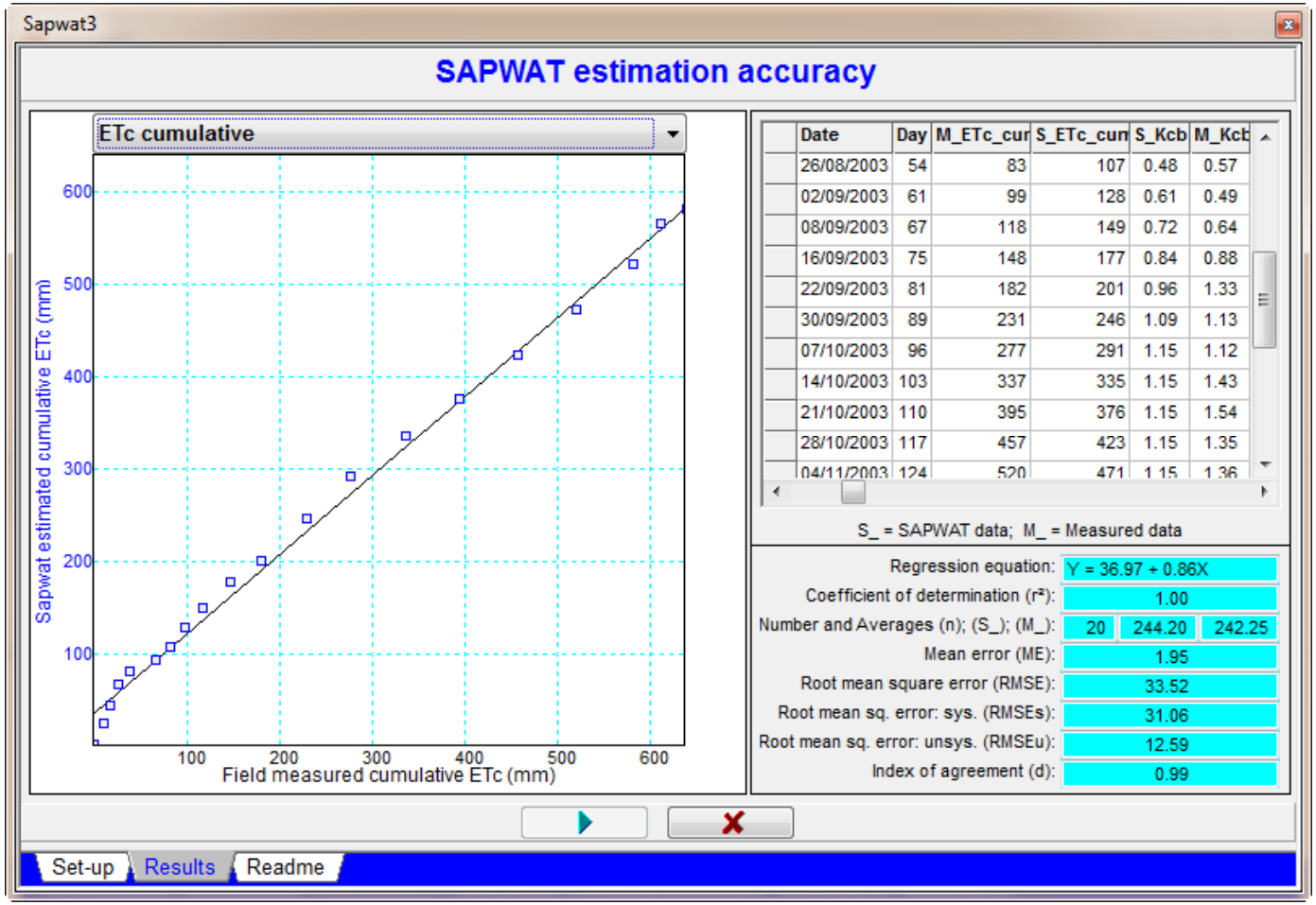
ETC DAILY RESULTS: DISCUSSION

- "Practical" acceptable slope 0.7 – 1.3
  - Lysimeter 1 is closest with slope = 0.6
  - Field observed data shows negative slope – no use
- Graph interpretation:
  - Lysimeter 1 = slope low;
  - Lysimeter 2 = slope too low;
    - Observed data substantially higher than estimated data;
  - Field data = not usable
    - Observed data rounded to nearest integer could have influence, but will not solve the problem
    - High observed data values at beginning of growth due to excessive water – lost through percolation but not picked up

- Snedecor & Cochran, 1991; Wilmot, 1981

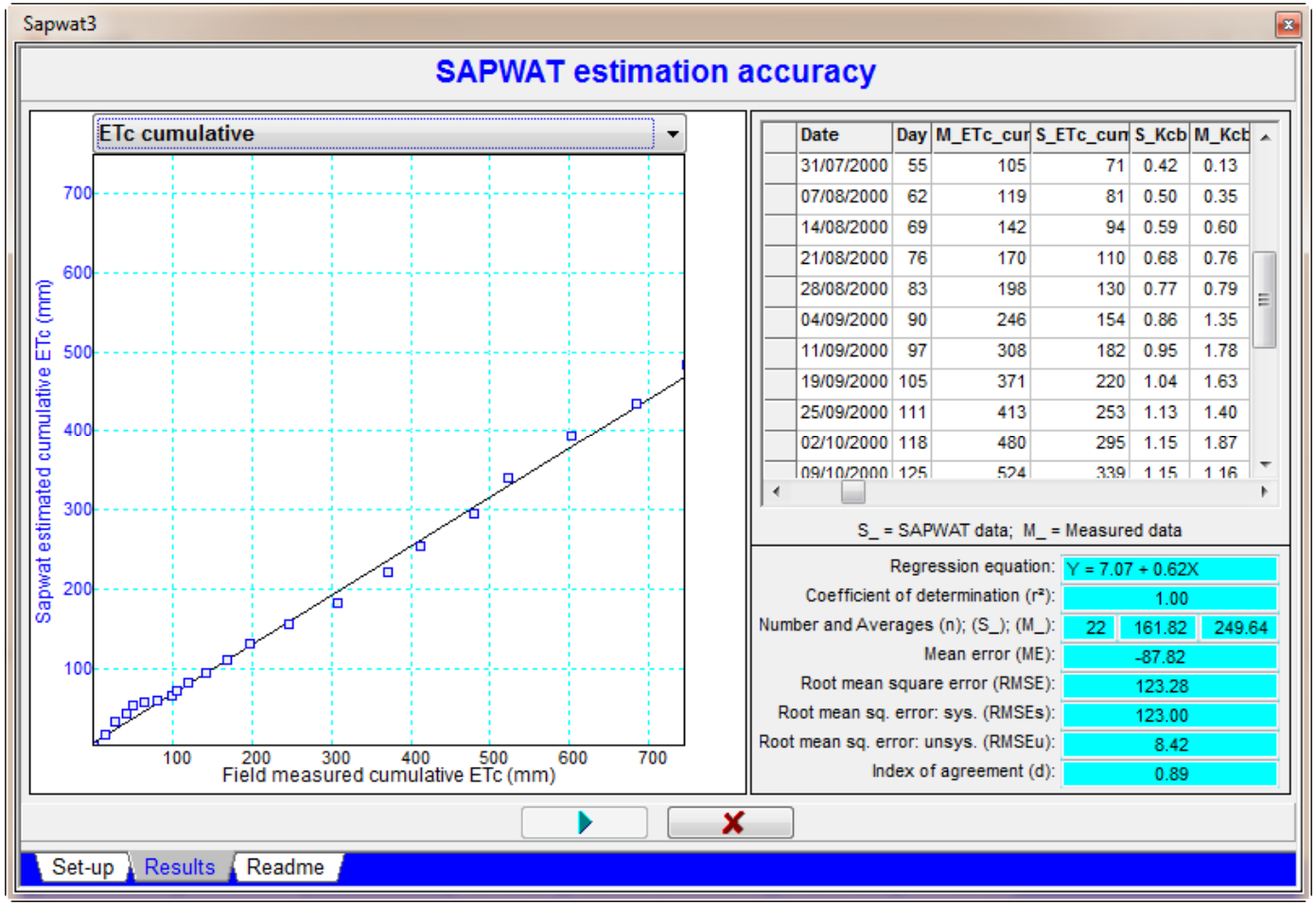
© Copyright reserved Kopiereg voorbehou

ETC CUMULATIVE: LYSIMETER 1



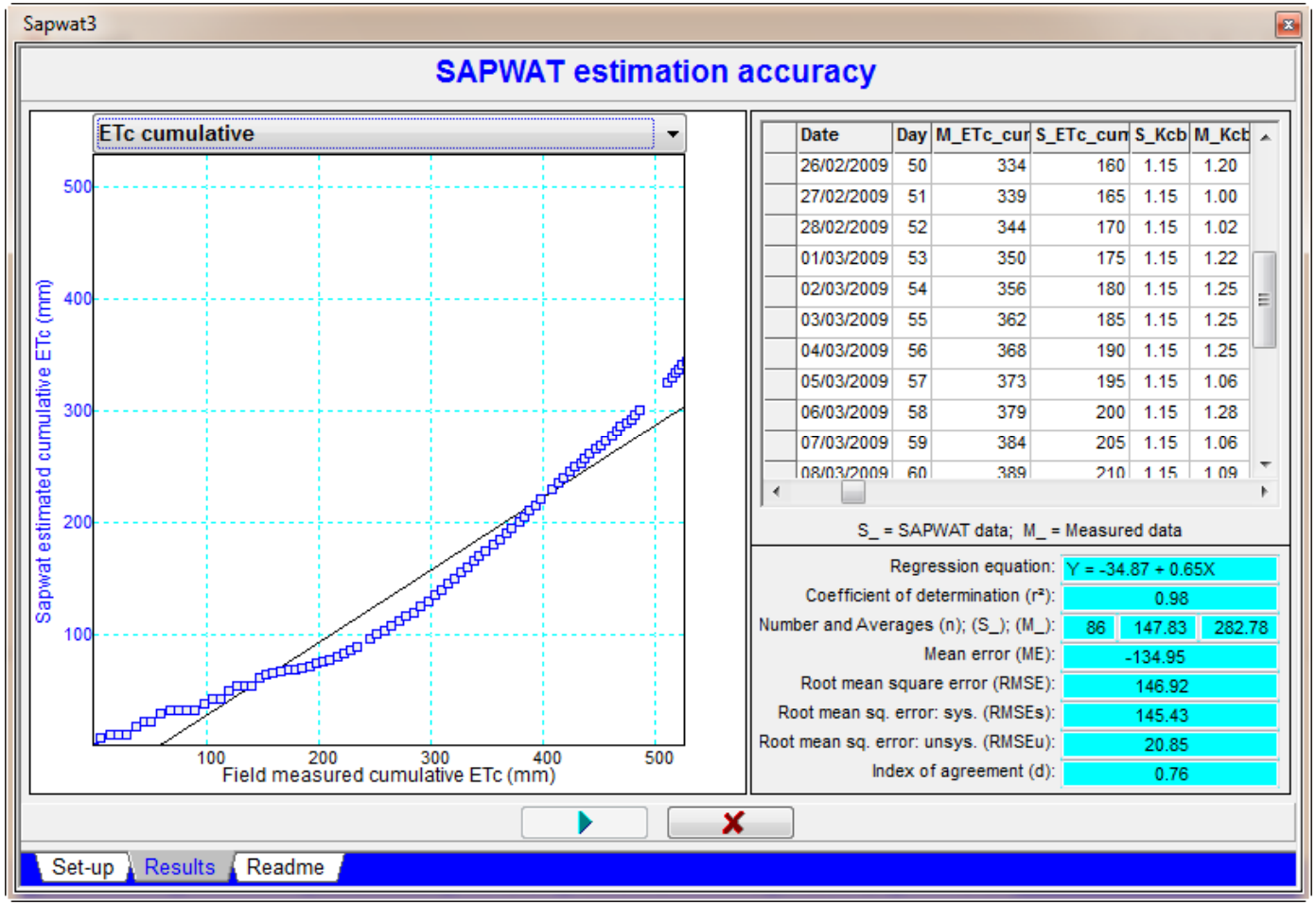
© Copyright reserved Kopiereg voorbehou

ETC CUMULATIVE: LYSIMETER 2



© Copyright reserved Kopiereg voorbehou

ETC CUMULATIVE: FIELD DATA



© Copyright reserved Kopiereg voorbehou

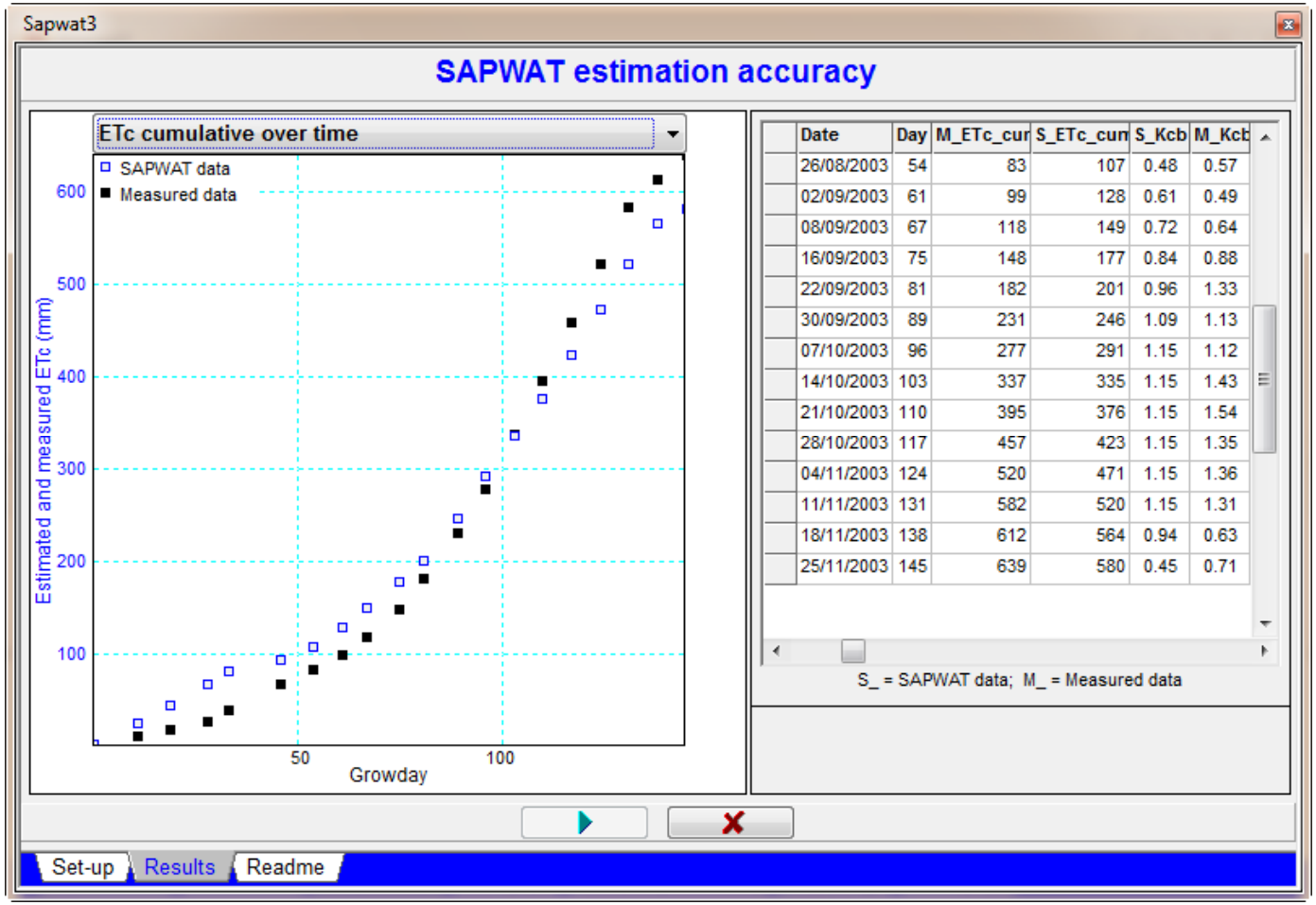
ETC CUMULATIVE RESULTS: DISCUSSION

- Lysimeter 1 shows a slope within acceptable values range at 0.86
- Slope of lysimeter 2 is too shallow at 0.62,
  - Observed cumulative ETc of 700 compared to 450 for estimated cumulative ETc
- Slope of field data 16 too shallow at 0.65,
  - Observed cumulative ETc of 500 compared to 300 for estimated cumulative ETc
  - Excessive rain with no measurement of percolation could be the cause
- Graph interpretation:
  - Lysimeter 1 = good;
  - lysimeter 2 = predicted and observed data on line, slope too shallow,
  - field data = predicted and observed data approximately on line, slope too shallow

- Snedecor & Cochran, 1991; Wilmot, 1981

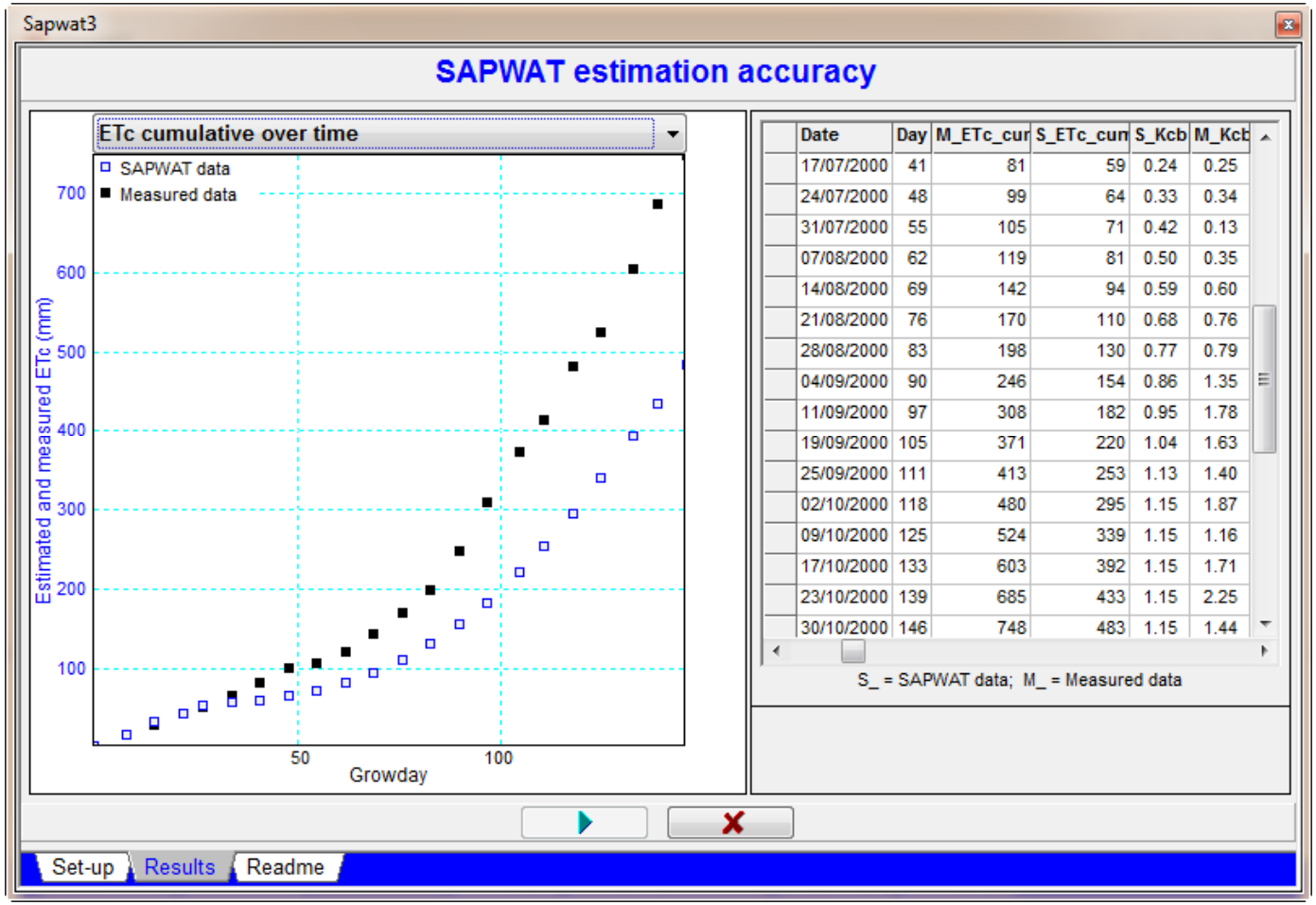
© Copyright reserved Kopiereg voorbehou

ETC OVER TIME: LYSIMETER 1



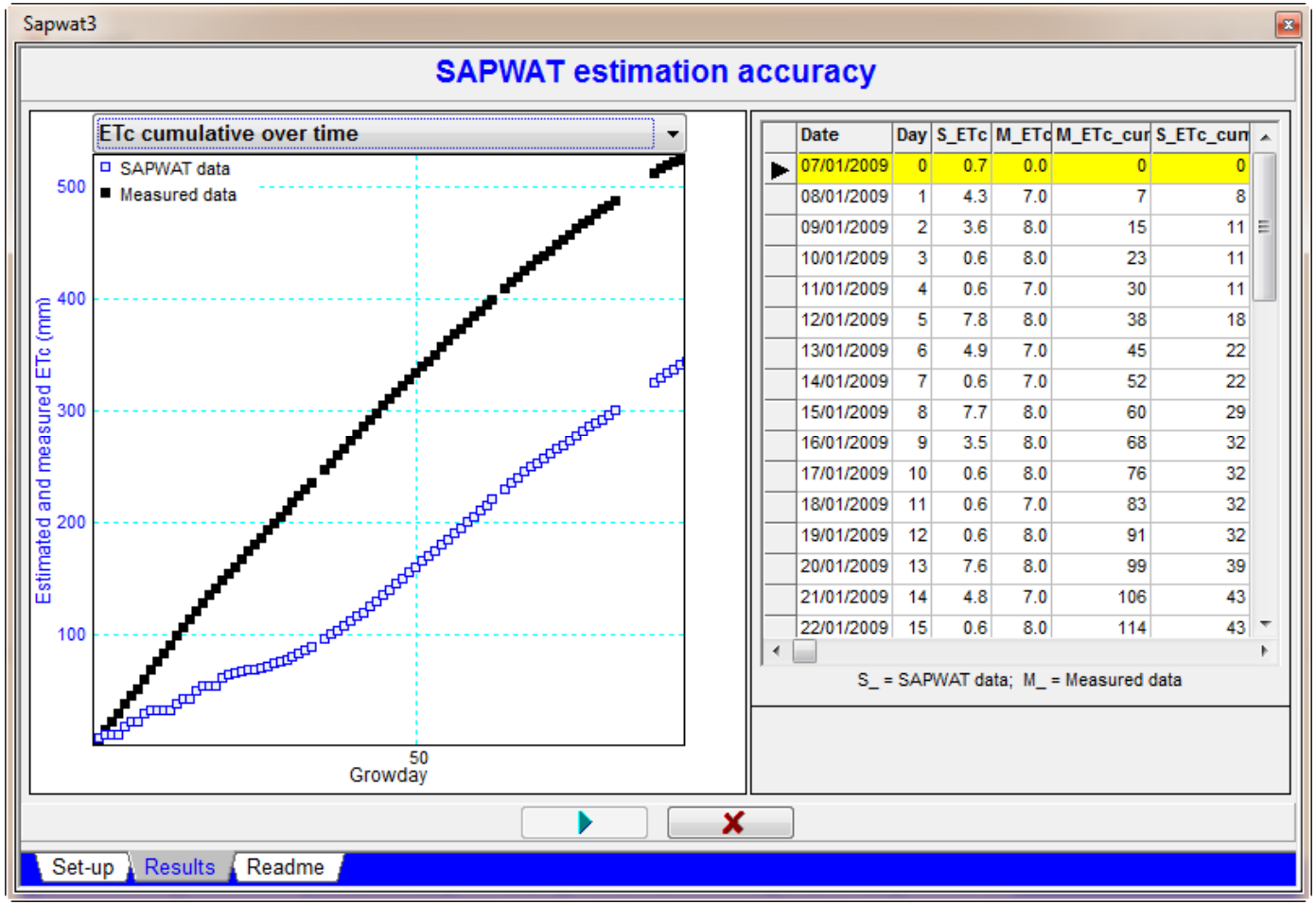
© Copyright reserved Kopiereg voorbehou

ETC OVER TIME: LYSIMETER 2



© Copyright reserved Kopiereg voorbehou

ETC OVER TIME : FIELD DATA



© Copyright reserved Kopiereg voorbehou

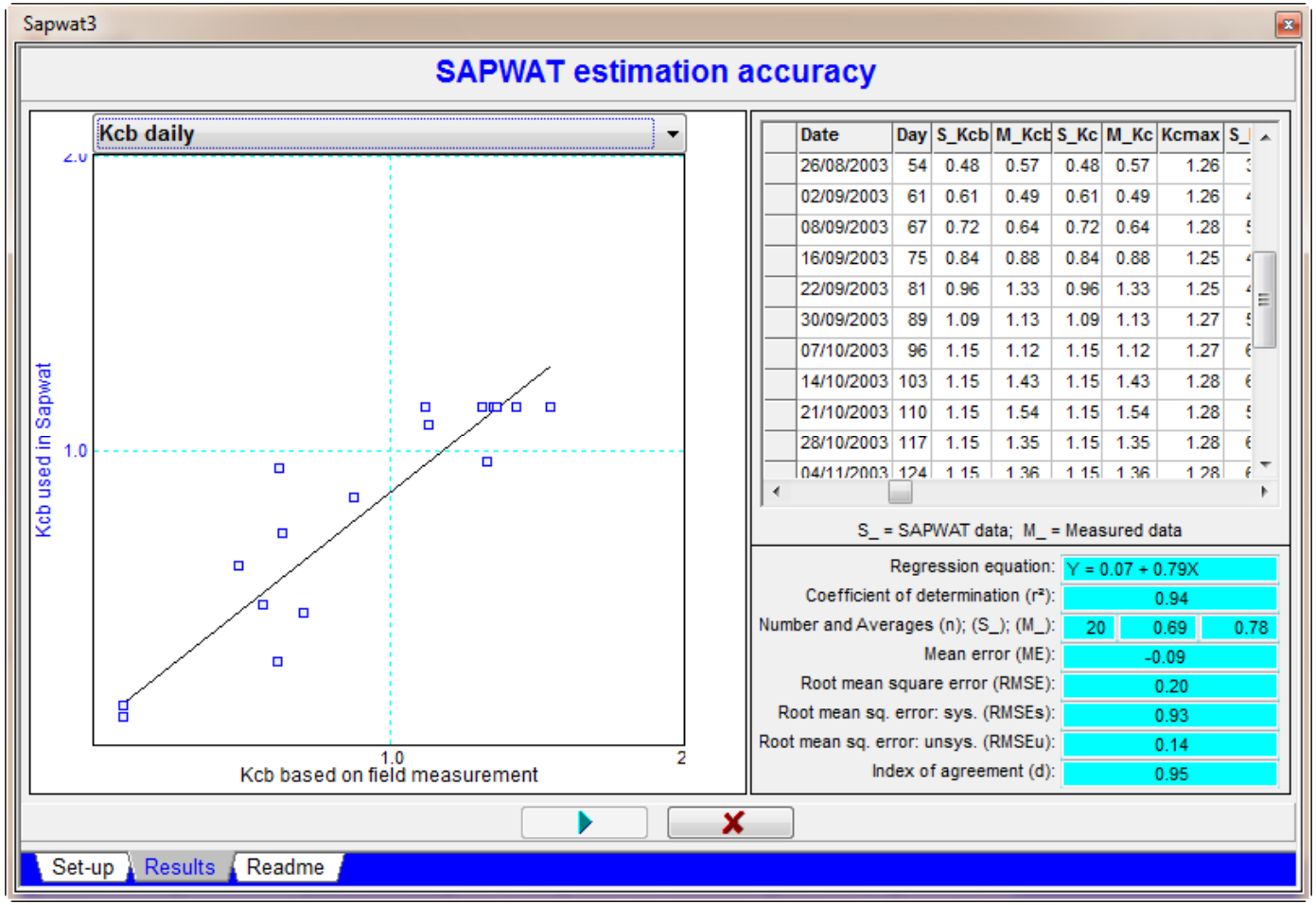
ETC OVER TIME RESULTS: DISCUSSION

- In Lysimeter 1 the cumulative ETc curves of estimated and observed data follow a similar line – indicating an acceptable degree of similarity
- The estimated and observed curves of lysimeter 2 is divergent
  - Excessive observed ETc?
  - Under-estimation of cumulative ETc?
- The estimated and observed curves of field data is very divergent
  - Excessive observed ETc?
  - Under-estimation of cumulative ETc?

© Copyright reserved Kopiereg voorbehou

UFS UV

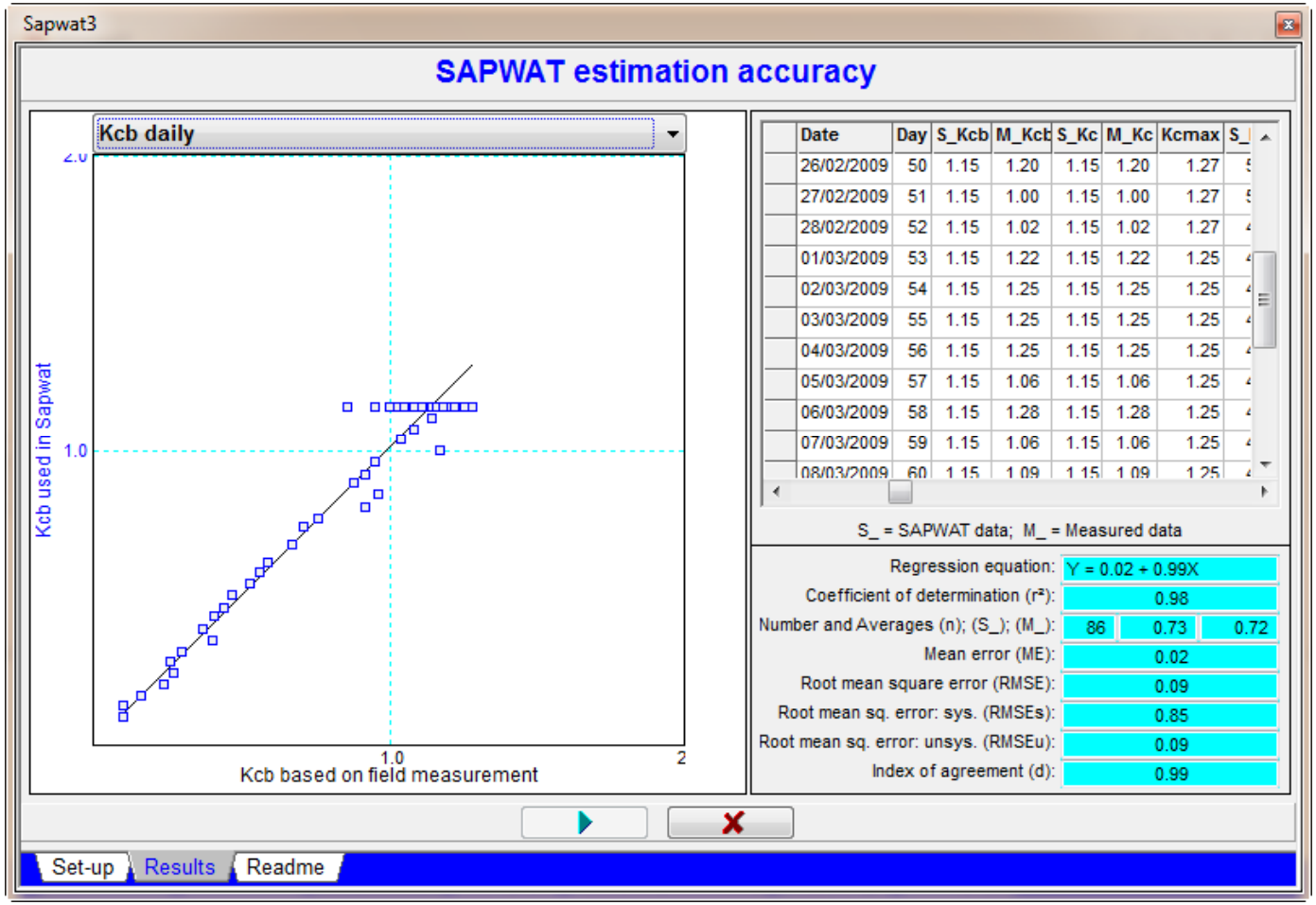
KCB DAILY: LYSIMETER 1



Date	Day	S_Kcb	M_Kcb	S_Kc	M_Kc	Kcmax	S_
26/08/2003	54	0.48	0.57	0.48	0.57	1.26	
02/09/2003	61	0.61	0.49	0.61	0.49	1.26	
08/09/2003	67	0.72	0.64	0.72	0.64	1.28	
16/09/2003	75	0.84	0.88	0.84	0.88	1.25	
22/09/2003	81	0.96	1.33	0.96	1.33	1.25	
30/09/2003	89	1.09	1.13	1.09	1.13	1.27	
07/10/2003	96	1.15	1.12	1.15	1.12	1.27	
14/10/2003	103	1.15	1.43	1.15	1.43	1.28	
21/10/2003	110	1.15	1.54	1.15	1.54	1.28	
28/10/2003	117	1.15	1.35	1.15	1.35	1.28	
04/11/2003	124	1.15	1.36	1.15	1.36	1.28	

© Copyright reserved Kopiereg voorbehou

KCB DAILY: FIELD DATA



© Copyright reserved Kopiereg voorbehou

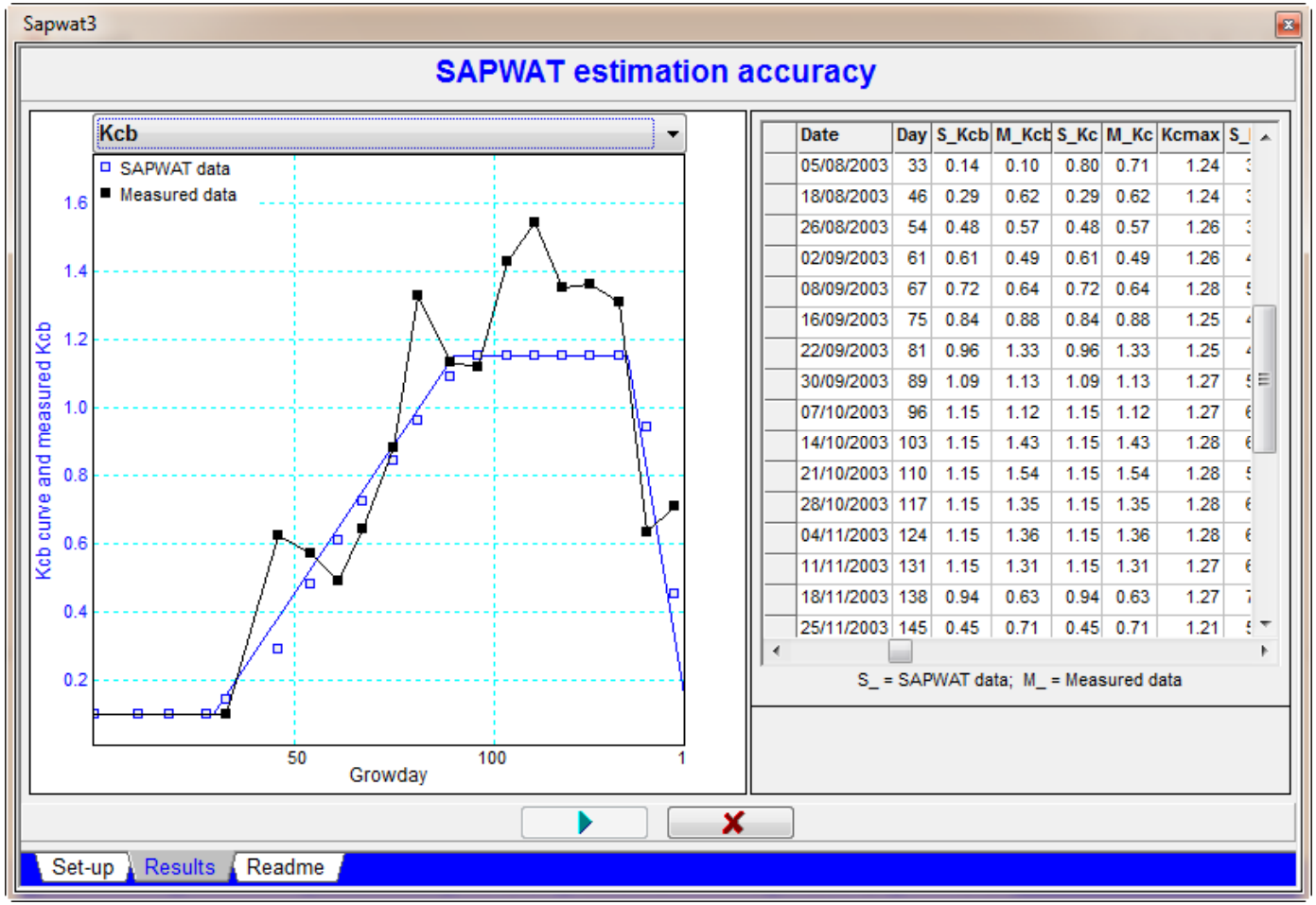
KCB DAILY RESULTS: DISCUSSION

- Acceptable slope 0.7 – 1.3
  - Lysimeter 1 and field data is within the acceptable range with slopes of 0.79 and 0.99 respectively
- Graph interpretation:
  - Lysimeter 1 = acceptable
  - field data = acceptable

- Snedecor & Cochran, 1991; Wilmot, 1981

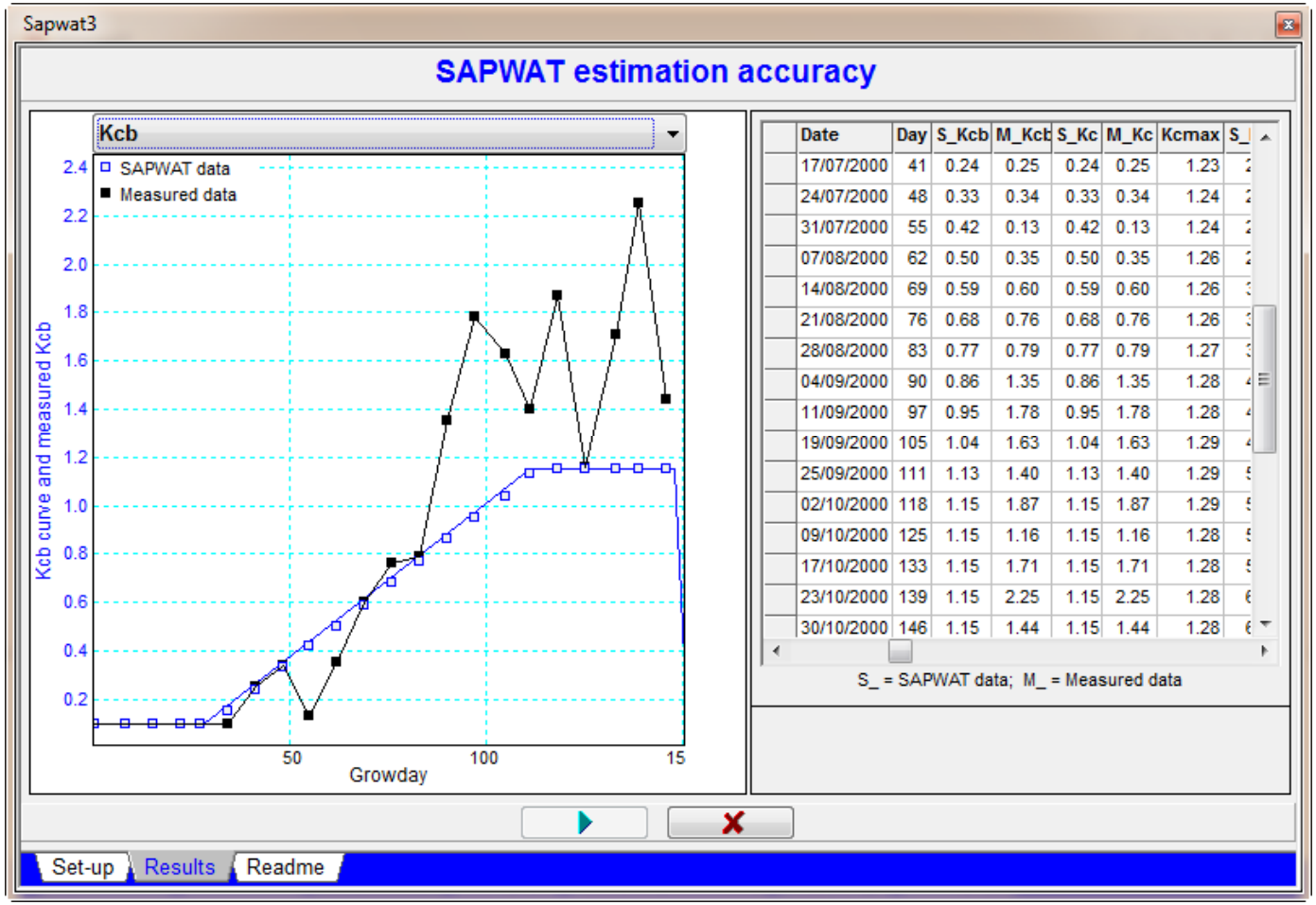
© Copyright reserved Kopiereg voorbehou

KCB CURVE: LYSIMETER 1



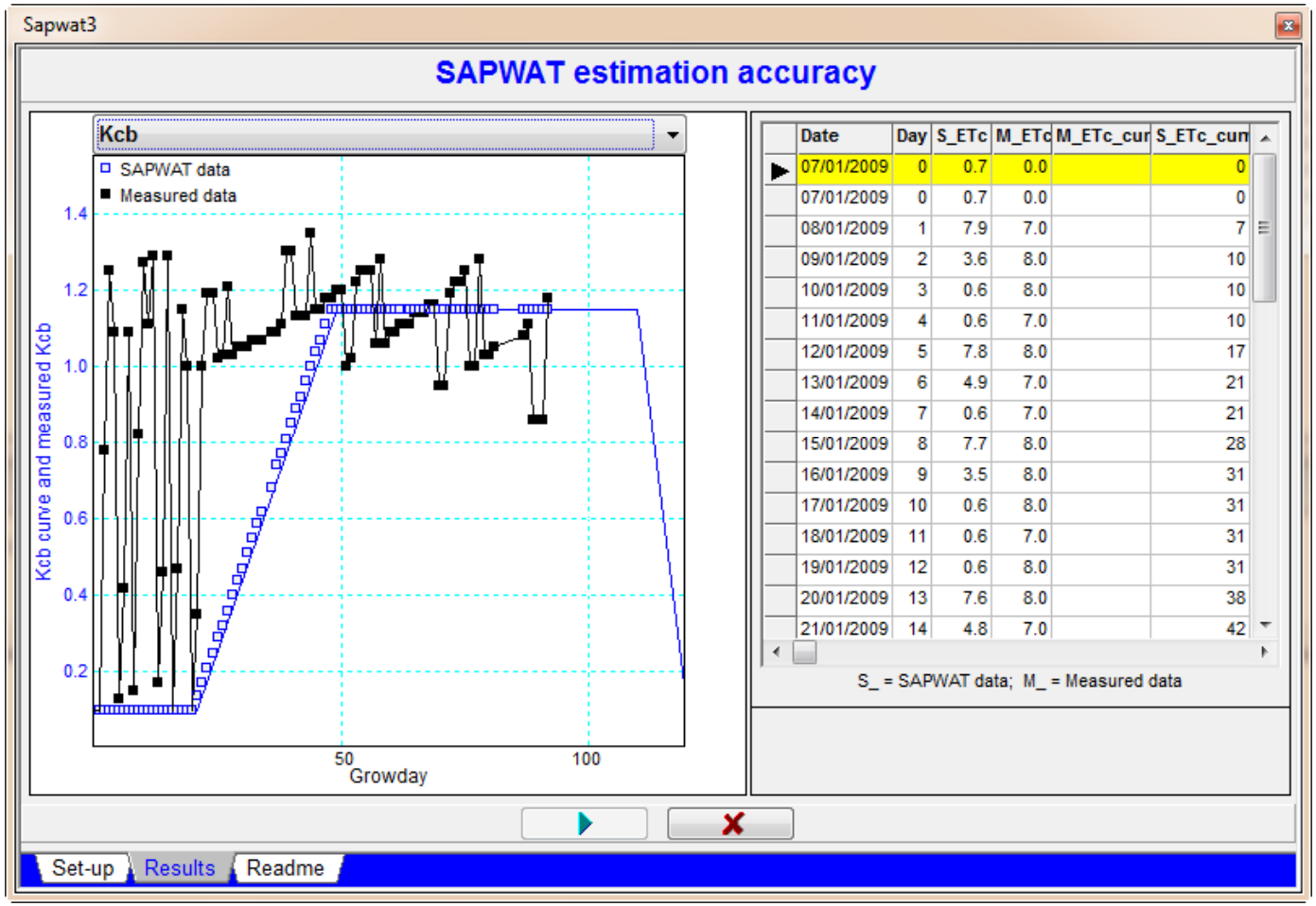
© Copyright reserved Kopiereg voorbehou

KCB CURVE: LYSIMETER 2



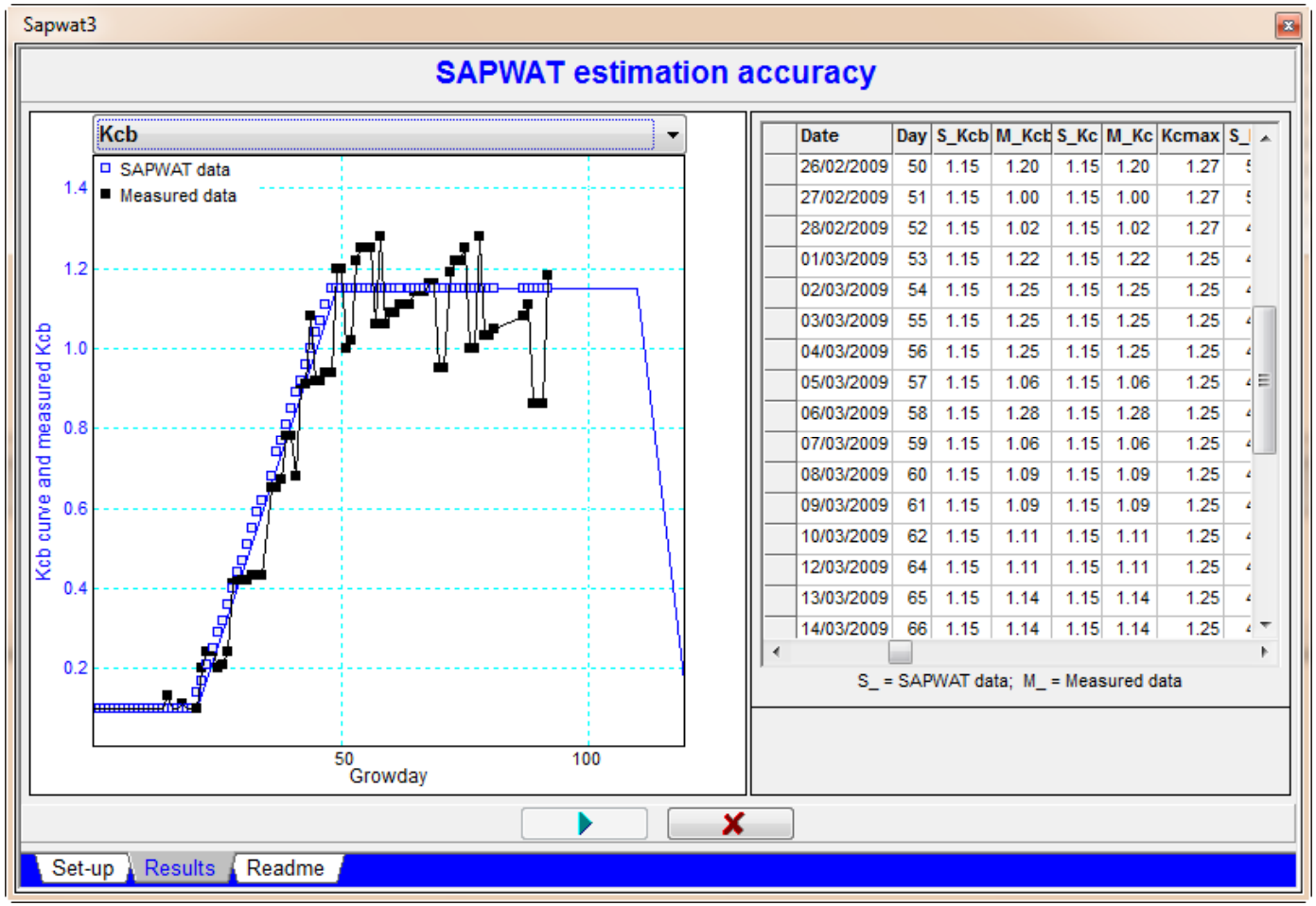
© Copyright reserved Kopiereg voorbehou

KCB CURVE: FIELD DATA WITHOUT CANOPY DEVELOPMENT



© Copyright reserved Kopiereg voorbehou

KCB CURVE: FIELD DATA WITH CANOPY DEVELOPMENT



© Copyright reserved Kopiereg voorbehou

KCB CURVE RESULTS: DISCUSSION

- Lysimeter 1
  - Predicted and observed Kcb values follow a similar curve
    - Good comparison, though observed values are higher for mid-season stage
- Lysimeter 2
  - Predicted and observed Kcb values follow a similar curve
    - Not a good comparison, observed values are much higher for mid-season stage
    - Observed Kcb values beyond 1.5 – 1.6 for grass reference are unexpected
- Field data
  - Too high values for initial and development stages, even allowing for soil evaporation
  - Mid-season stage values show good comparison
- Field data with incorporation of canopy development
  - Good comparison between observed and predicted values

- Allen, et al., 1998

© Copyright reserved Kopiereg voorbehou

UFS UV

CONCLUSIONS

- Lysimeter 1
  - Graphs and analyses data show that this case can be used for verification of crop Kcb values.
    - Accurate measurement at all levels required.
- Lysimeter 2
  - Graphs and analyses data show that this case should not be used for verification of crop Kcb values.
    - Analyses gives Kcb values higher than expected maxima.
    - The result: data is skewed at all levels of analyses.
- Field data
  - Graphs and analyses show that the use of this data can only be used if:
    - Rainfall and irrigation is limited so that over-extension of soil water capacity is limited.
    - Canopy development data also be noted and used in the analyses.

- The module could be extended to include observed sap flow data as input.

- The inclusion of remote sensing data in this module need to be investigated.

© Copyright reserved Kopiereg voorbehou

UFS UV

ACKNOWLEDGEMENT

- To my co-presenters, prof Sue Walker and prof Lean van Rensburg for guidance and for making data available.

- James Kennedy who supplied the concept and data for the original development and testing of the verification module.

- To the Water Research Commission who have funded the development of SAPWAT3.

© Copyright reserved Kopiereg voorbehou

UFS UV

- Thank you

T: 051 401 9111 info@ufs.ac.za **www.ufs.ac.za**

© Copyright reserved
Kopiereg voorbehou

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

UFS·UV
NATURAL AND
AGRICULTURAL SCIENCES
NATUUR- EN
LANDBOUWETENSKAPPE