MODELING WATER TABLE DEPTH AND DRAINAGE DISCHARGE DYNAMICS IN PONGOLA, SOUTH AFRICA, USING DRAINMOD 6.1

Malota M & Senzanje A

UNIVERSITY OF KWAZULU-NATAL
INYUVESI YAKWAZULU-NATALI

WATER RESEARCH COMMISSION

Acknowledgements

- Johan van der Merwe – Dept Agric, Pongola

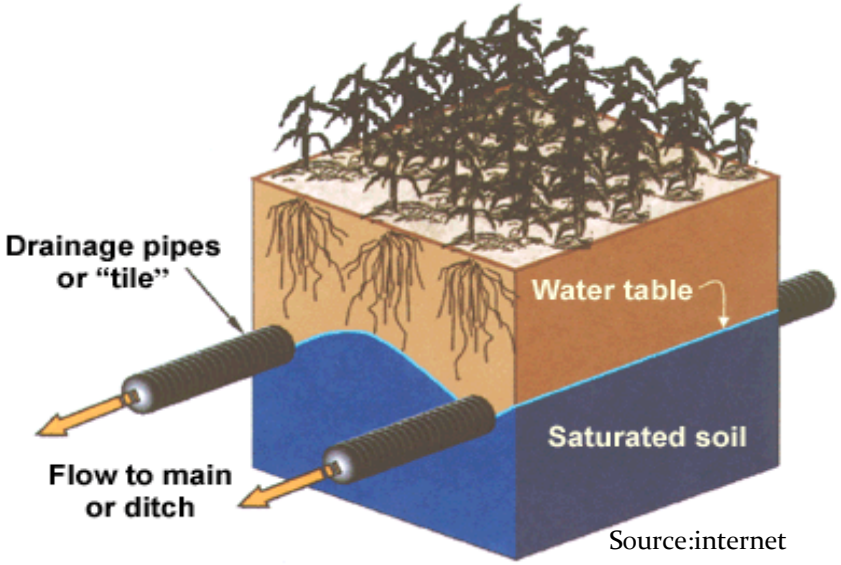
- WRC –**Project K5/2026//4 : *DEVELOPMENT OF TECHNICAL AND FINANCIAL NORMS AND STANDARDS FOR DRAINAGE OF IRRIGATED LANDS***
  - ***ARC – IAE (Lead)***
  - ***UKZN***
  - ***UoFS***
  - ***OABS***
  - ***Bioresources Consulting***
  - ***Depts of Agric - KZN, WC, NC***

Introduction…1

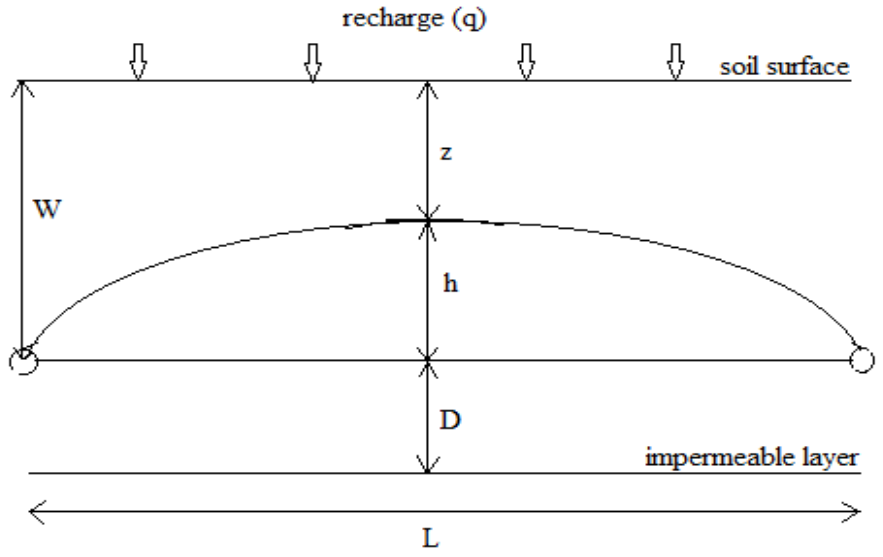
- **Irrigation & Drainage**
  - Should be an inseparable partnership
  - In reality drainage is (knowingly) ignored
- **Drainage**
  - *Removal and disposal of excess water (and salts) from agricultural land to create conditions suited to crop growth*.
  - Key factor is crop production

Introduction…2

- **Drainage systems & water table (WT) control**
  - Lower WT below root zone in shortest possible time (Young, 1999; FAO, 2007)
    - Steady state conditions (h_x) – WT constant
    - Non-steady state condition ($h_{x,t}$) – WT fluctuating

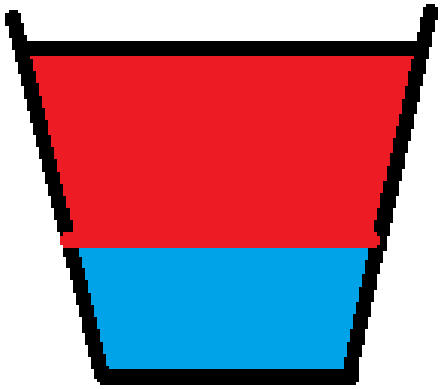


Source:internet



World Poor Drainage Statistics

275 million ha - irrigated



78% poorly drained

22% appropriately drained

- ≈500,000 ha deserted annually
- 90% in Asia and Africa

(Freisem and Scheumann, 2001)

Introduction…3

- **Drainage problems in RSA**
  - 18 000 000 cultivated, 1 300 000 ha irrigated
    - 240 000 ha affected by drainage problems (WT & salinisation)
- **Drivers of drainage problems**
  - Poor Agricultural Water Management (AWM)
  - Problem soils
  - Poor quality water
- **Why drainage is ignored**
  - Increases initial investment costs of I & D development
    - R70k – R80k/ha with drainage vs R35k/ha without! (Van der Merwe 2012)
  - Out of site…until crop performance suffers!

Introduction…4

- **Benefits of drainage of agricultural lands**
  - Increased crop yields
  - Improved returns for a cropping system
  - Improved workability of the land
  - Decrease in certain diseases incidences
  - Reduced compaction problems

South African Perspective

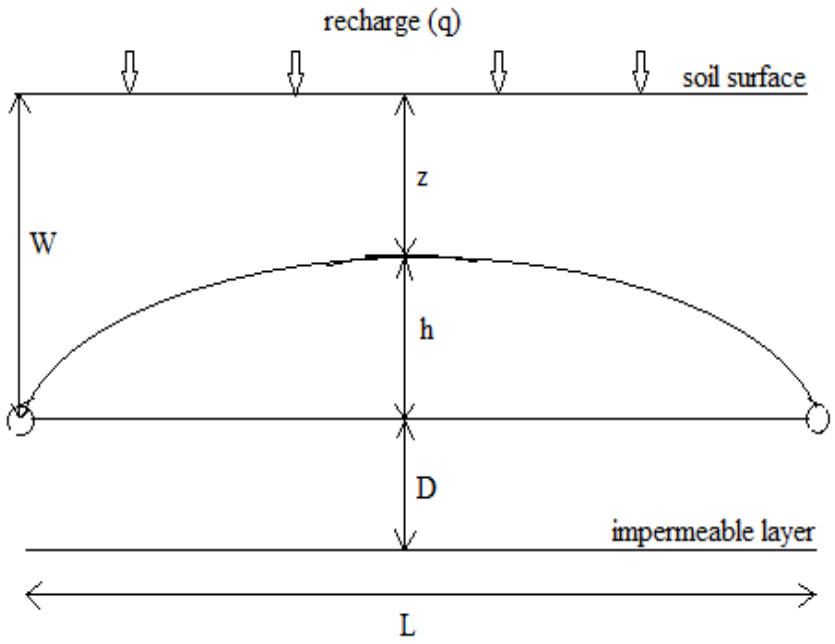
- **No concerted drainage research for the past 30 years**
- Climate change - affecting ground water dynamics
- Farmers must be assisted to adjust their farming systems
- Need for **technical & financial perspective to drainage design & implementation**

WRC Funded Research Project

- **Main Objective**
  - Develop technical & financial norms and standards for the assessment of feasibility of surface and sub-surface drainage systems in RSA.
- **Sub-objective 4**
  - Refine and develop technical standards for drainage with reference to soil types, crops, irrigation method, water tables, salinisation, water quality and management practices

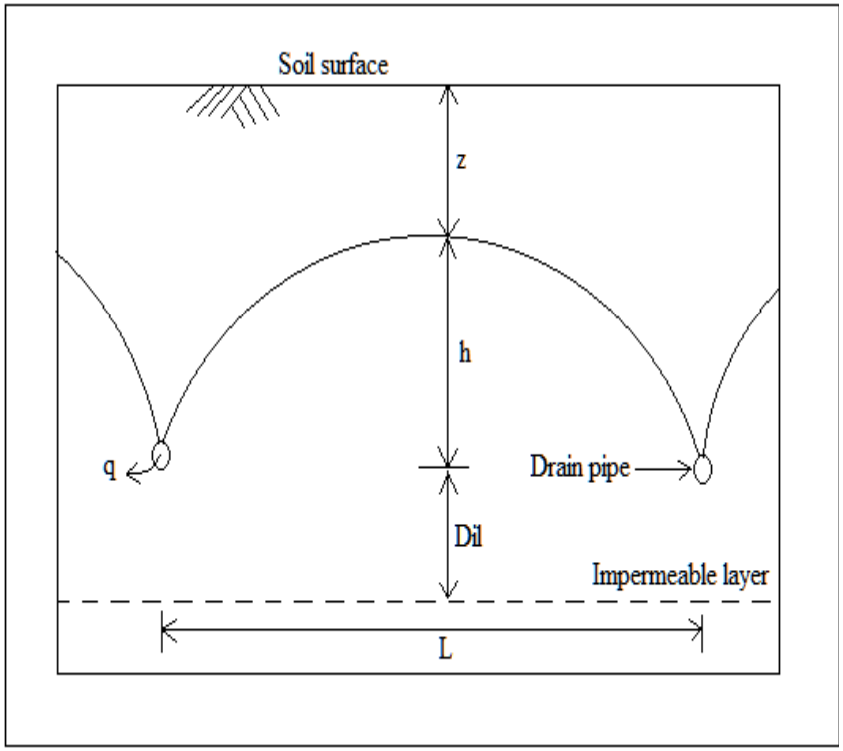
Drainage Design Problem

- **Drainage design criteria**
  - *"the essential specifications for conditions which must exist in a particular area for a drainage system to have an optimum level of water table control, required by the agricultural system to be practiced either under irrigation or rain-fed."* (SCS, 1971)
- **Key design parameters**
  - Drain depth (W)
  - Drain spacing (L)
  - Drain discharge (q)
  - Hydraulic head (h)
  - WT depth below soil surface (z)
  - Depth to impermeable layer (D)



Drainage Design Conditions

- **Steady state (non-transient)**
  - $q_{in} = q_{out}$ → **WT constant**
  - Hooghoudt's equation
  - $q = \frac{8k_2dh+4k_1h^2}{L^2}$
    - Implicit relationship
- **Non-steady state (transient)**
  - $q_{in} \neq q_{out}$ → **WT fluctuating**
  - Glover-Dumm equation



The Practical Problem

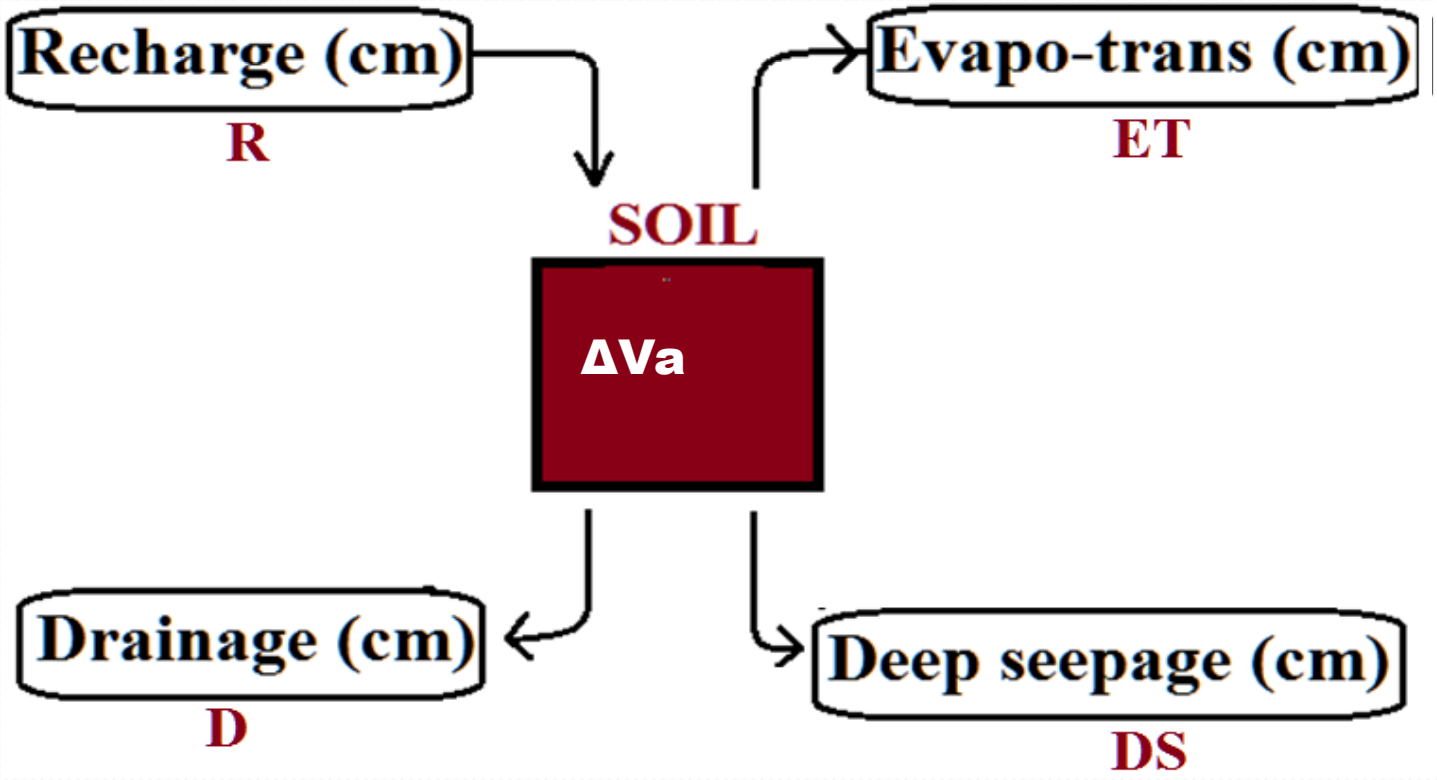
- **Combinations to be tested**
  - Climatic conditions
  - Soil types
  - Crop types
  - Irrigation methods
  - Management
  - Etc
- **WT monitoring**
  - Time consuming…
  - Expensive…

Role of Modelling

- **Simulation Modelling**
  - Allows testing of multiple scenarios
  - Cost effective – time and money
  - Requires calibration and validation
- **Drainage Models**
  - Drainmod
  - WaSim
  - SaltMod
  - etc

Drainmod…1

- **Drainmod (Skaggs, 1978)**
  - $\Delta V_a = D + ET + DS - R$ and $q = \frac{8k_2dh+4k_1h^2}{L^2}$



Drainmod…2

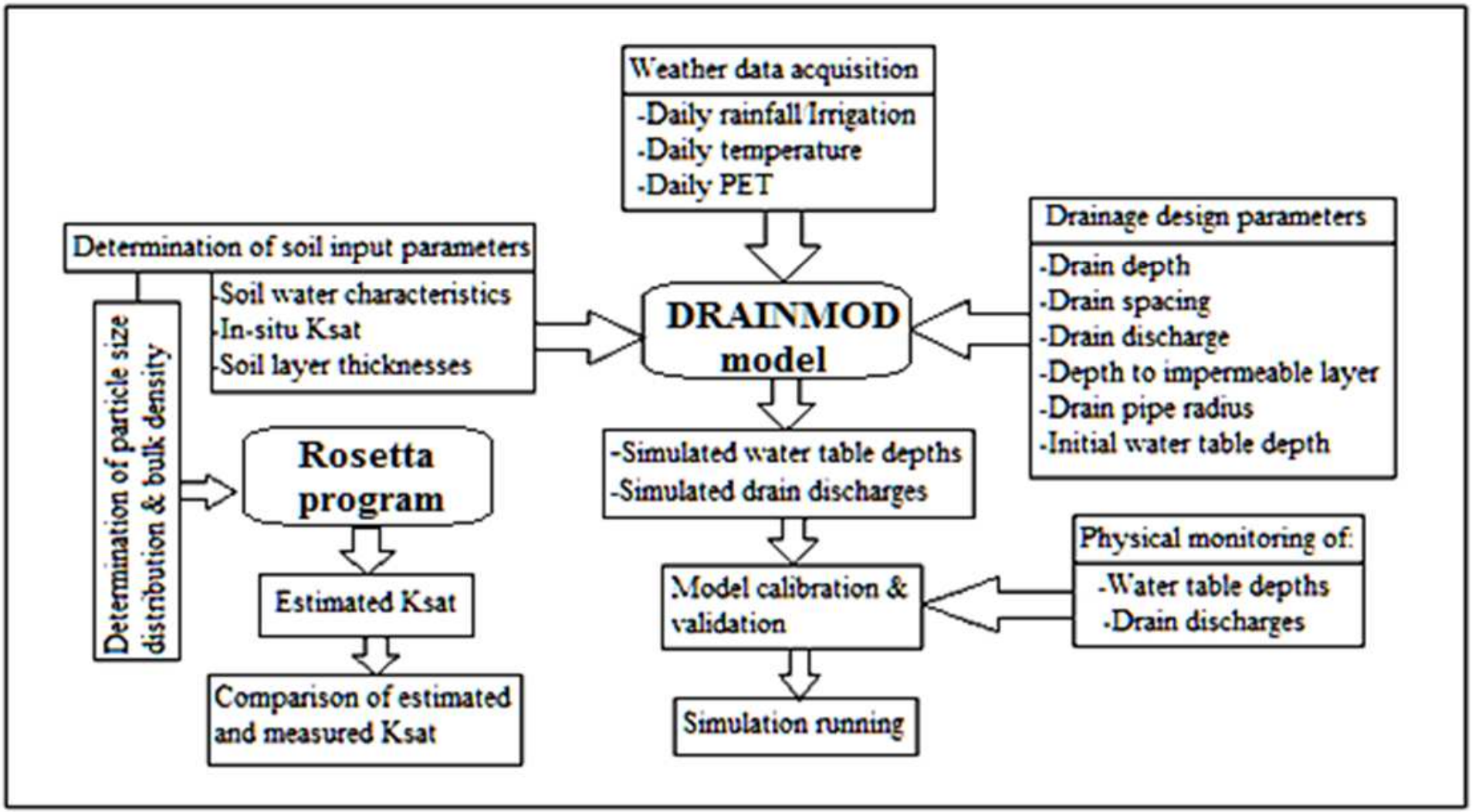
- **Input parameters**
  - Weather data (R, I, T, ETo)
  - Soils data (D or D_{il}, K, layering)
  - Drain systems data (L, W)
- **Simulation**
  - Water table fluctuations (h)
  - Drain discharge (q)

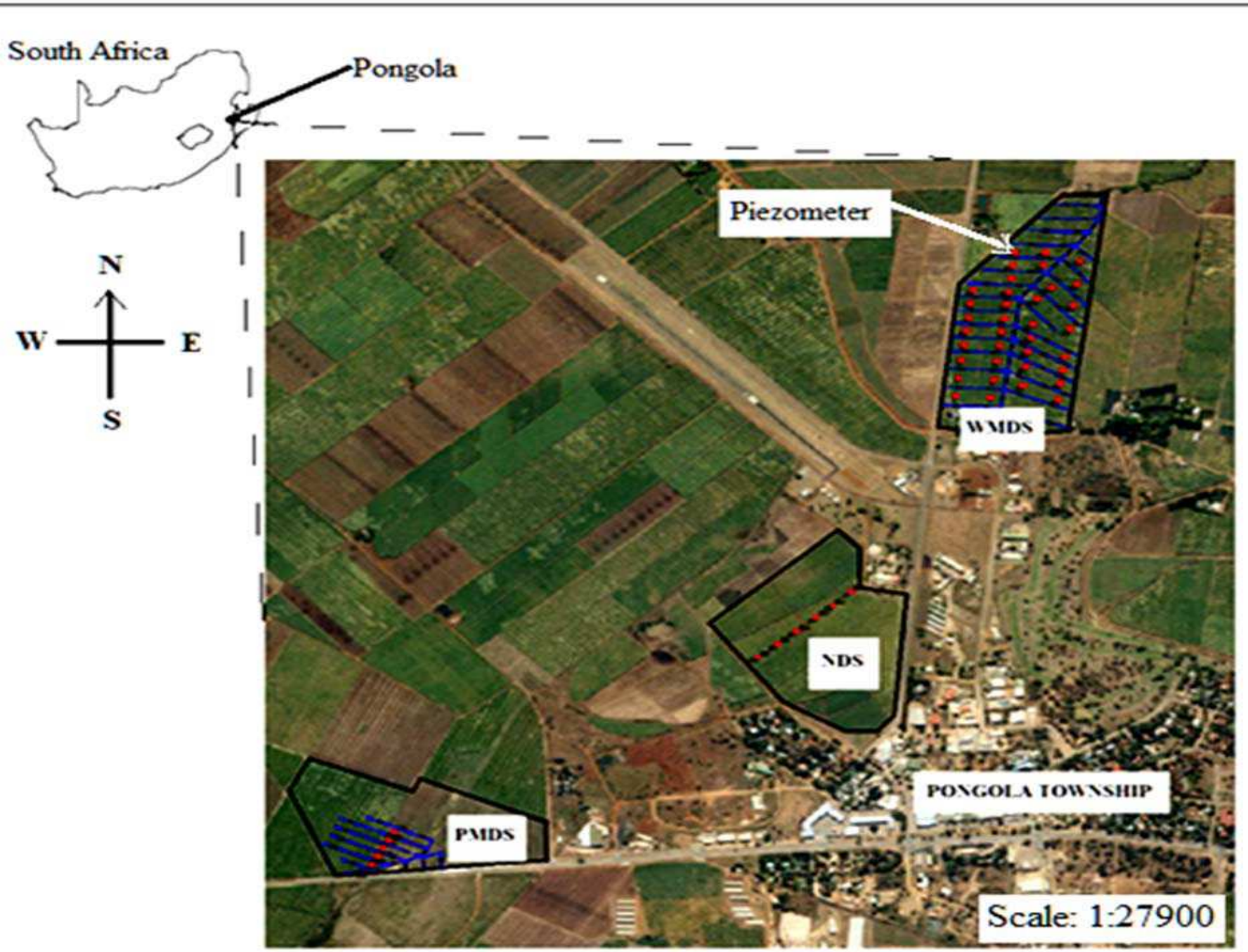
Research Objective (sub-obj4)

- **To test the applicability/reliability of DRAINMOD model, as a subsurface drainage design tool in Pongola, KwaZulu-Natal, RSA**

- **To determine optimum subsurface drainage design parameters for sugarcane grown in the area.**

Modelling Approach



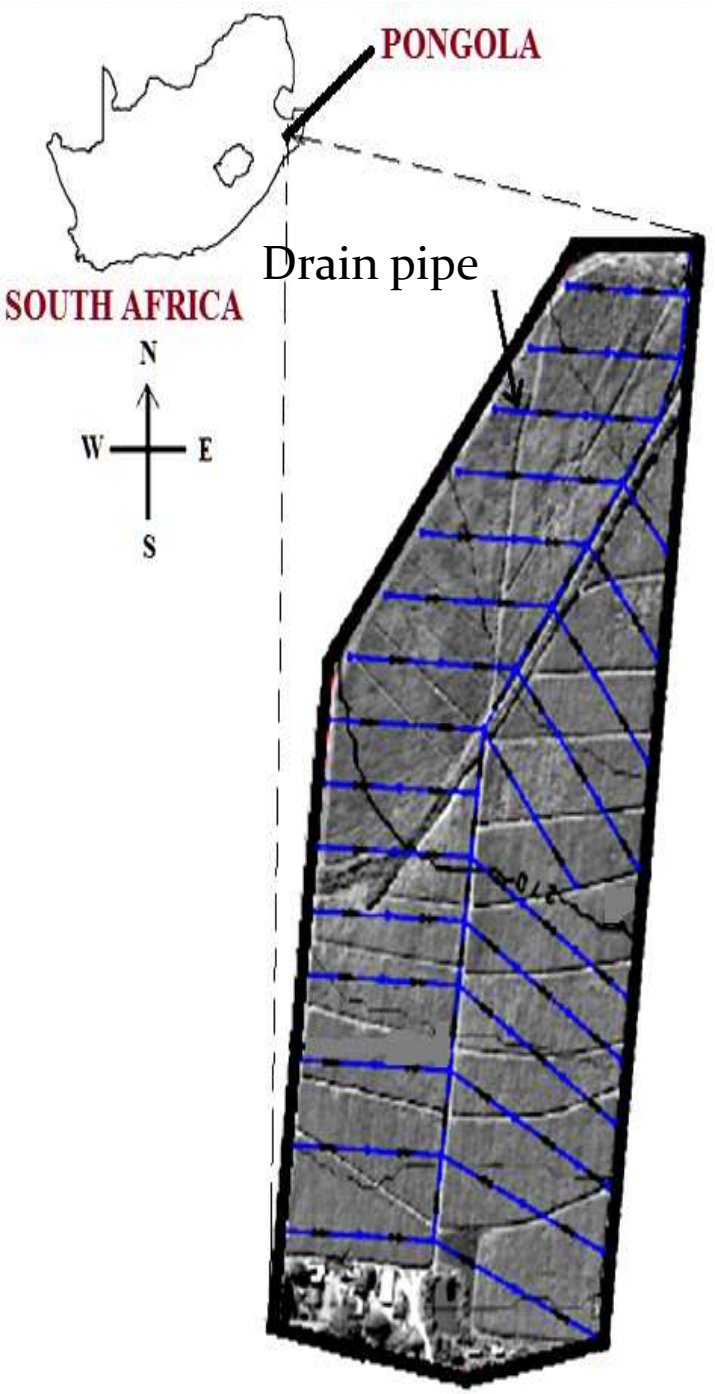

South Africa
Pongola
N
W
E
S
Piezometer
WMDS
NDS
PMDS
PONGOLA TOWNSHIP
Scale: 1:27900

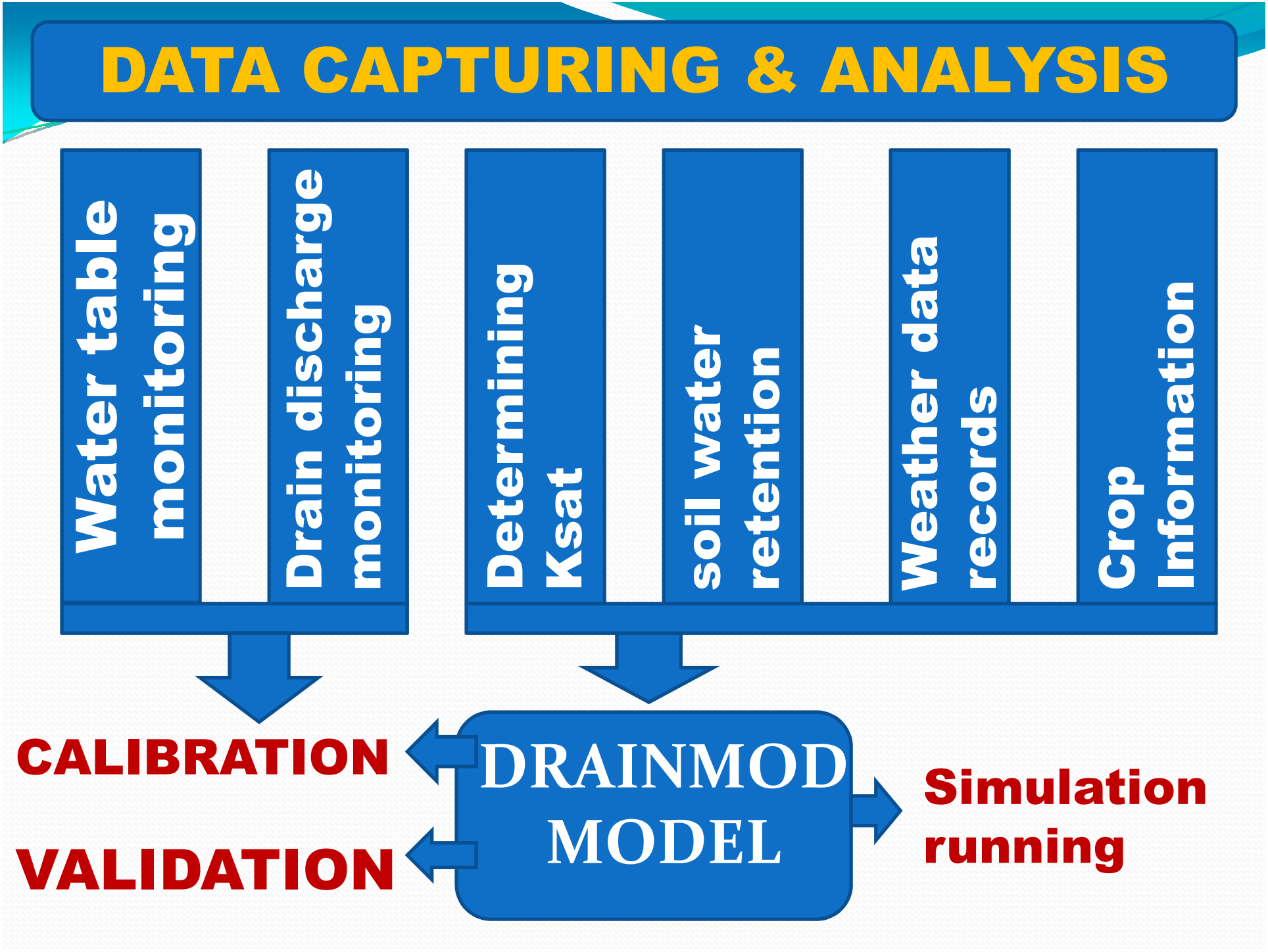
Study Site

- **Area**
  - Pongola area of KZN
- **Climate**
  - Semi-arid/Arid(Aridity index 0.12)
- **Crop**
  - Sugarcane
- **Soils**
  - Clay loam & clay
- **Irrigation**
  - Draglines & centre pivots

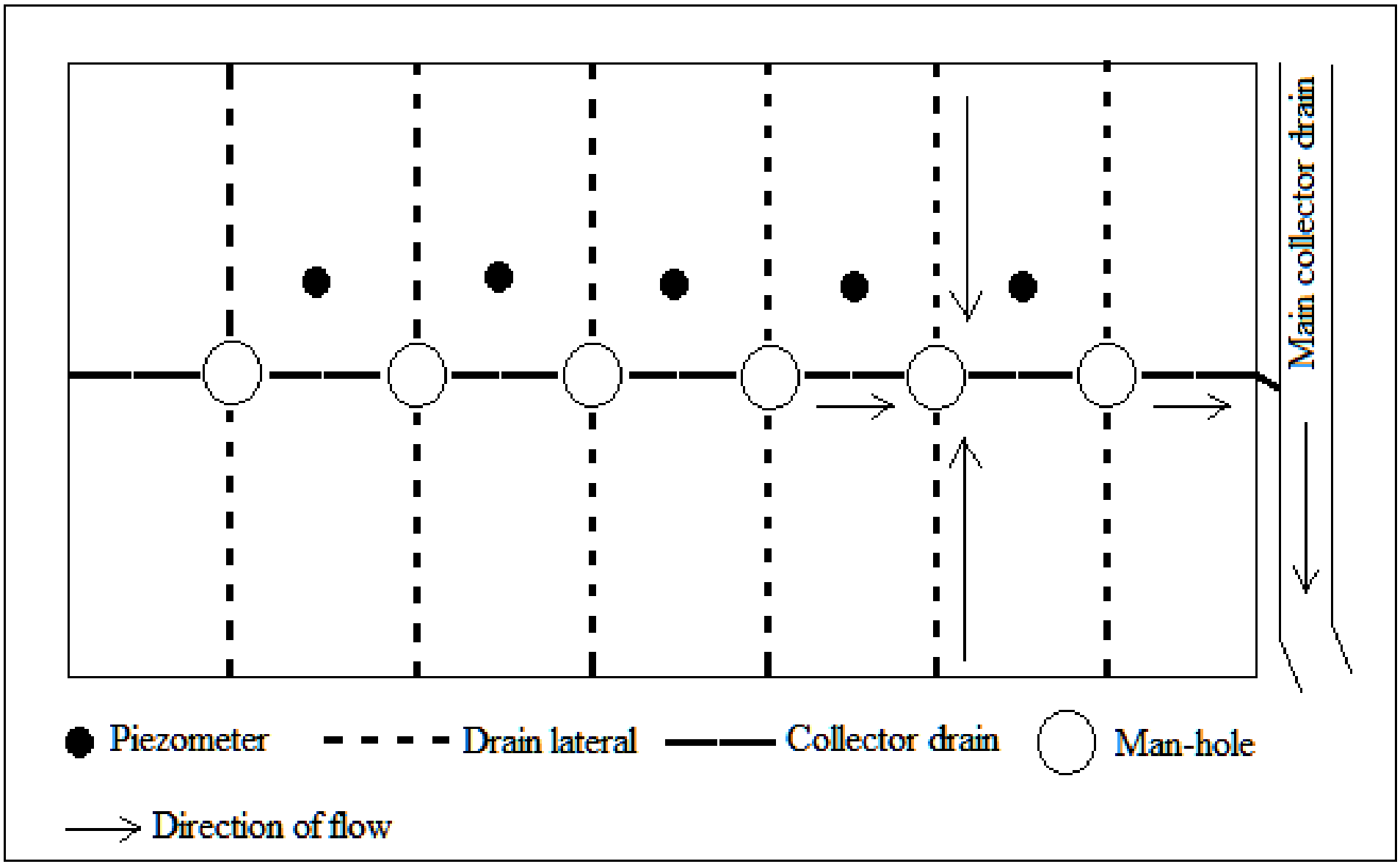
Instrumentation

- **Field**
  - 32 ha under sugarcane
- **Piezometers**
  - Installation details
    - 50 mm Ø Class 4 pipe
    - 1.7 m deep (30 cm top)
    - Perforated
    - Capped both ends
    - Coarse sand envelope
  - 36 (on 54 x 54 grid nodes)
  - FAO recommends 5 – 10 per 50 ha
- **Monitoring**
  - September 2011 to February 2012

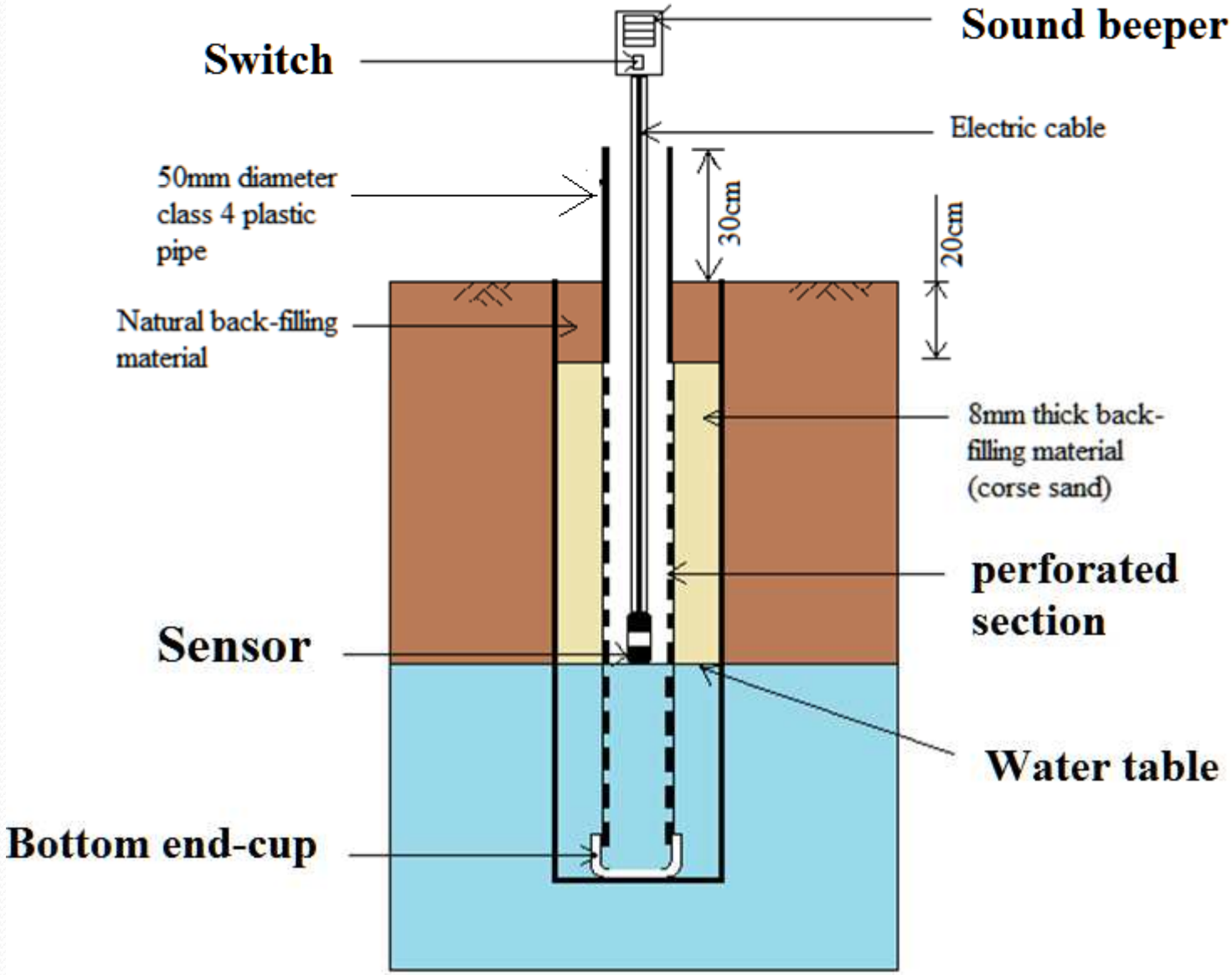



DATA CAPTURING & ANALYSIS
Water table monitoring
Drain discharge monitoring
Determining Ksat
soil water retention
Weather data records
Crop Information
CALIBRATION
VALIDATION
DRAINMOD MODEL
Simulation running

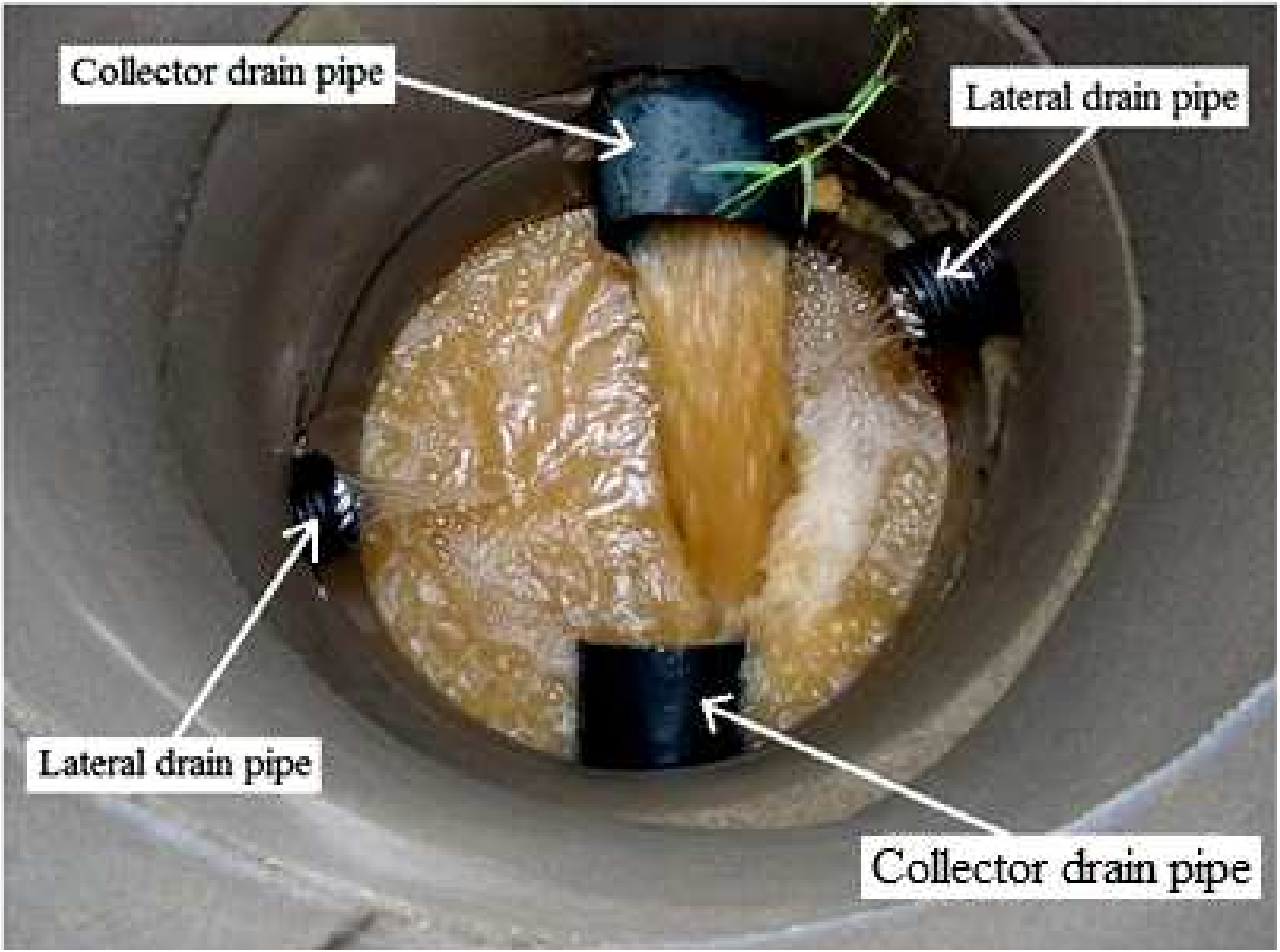
Observation locations



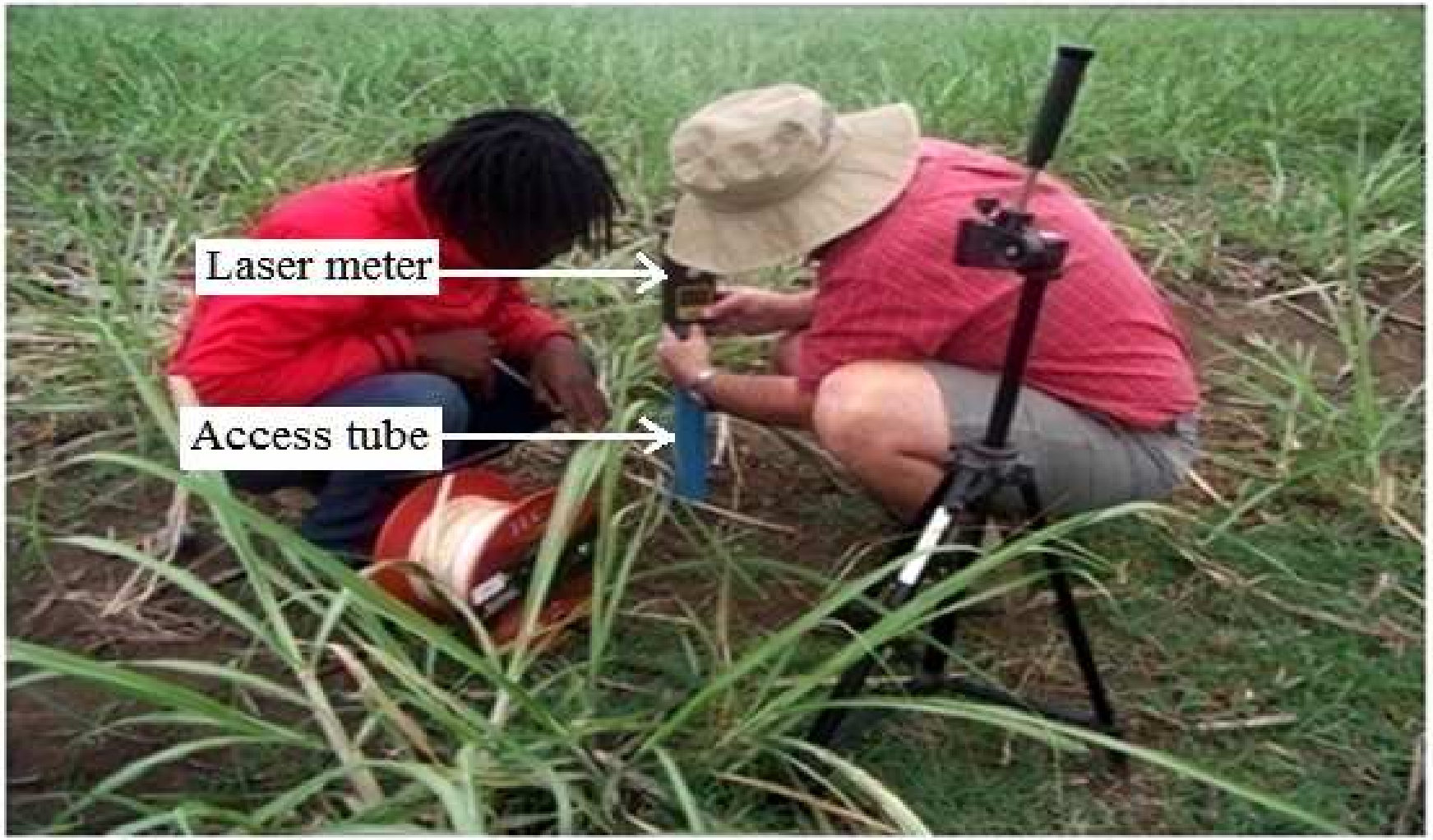
WT MONITORING



Drain discharge monitoring



Ksat determination



Other inputs

- Soil water retention – Pressure plate
- Weather data (1998 – 2012)
  - PET
  - RAINFALL
  - TEMPERATURE
- Crop information – From literature

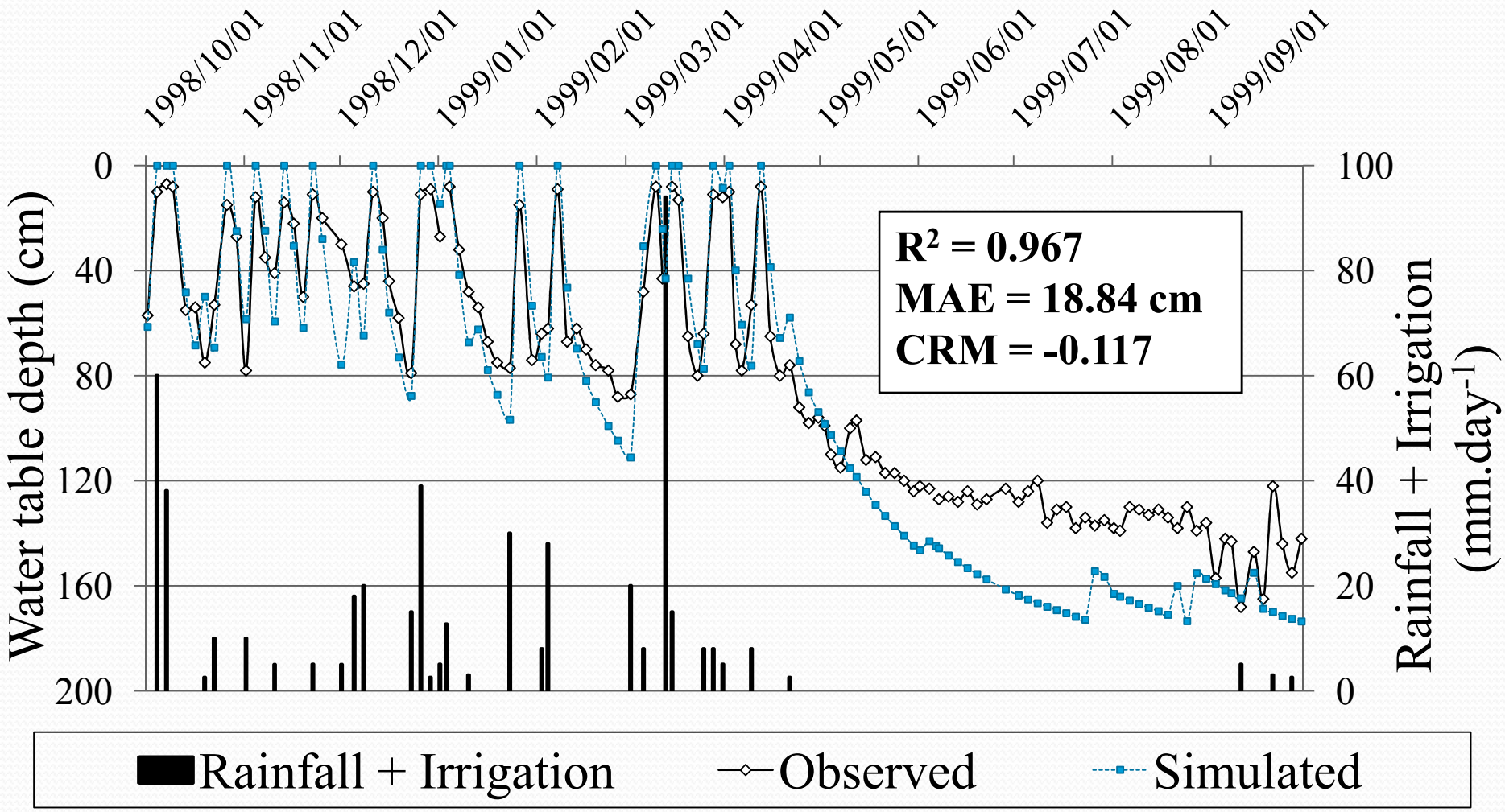
Model calibration & validation

Input parameter	Calibration	Calibrated Parameter
Top layer Lateral Ksat	1 x vertical Ksat	0.96 m/day
Bottom Layer Lateral Ksat	2 x vertical Ksat	0.48 m/day
Max surface storage depth	4 x the default 0.5 cm	2 cm

Results & Discussion

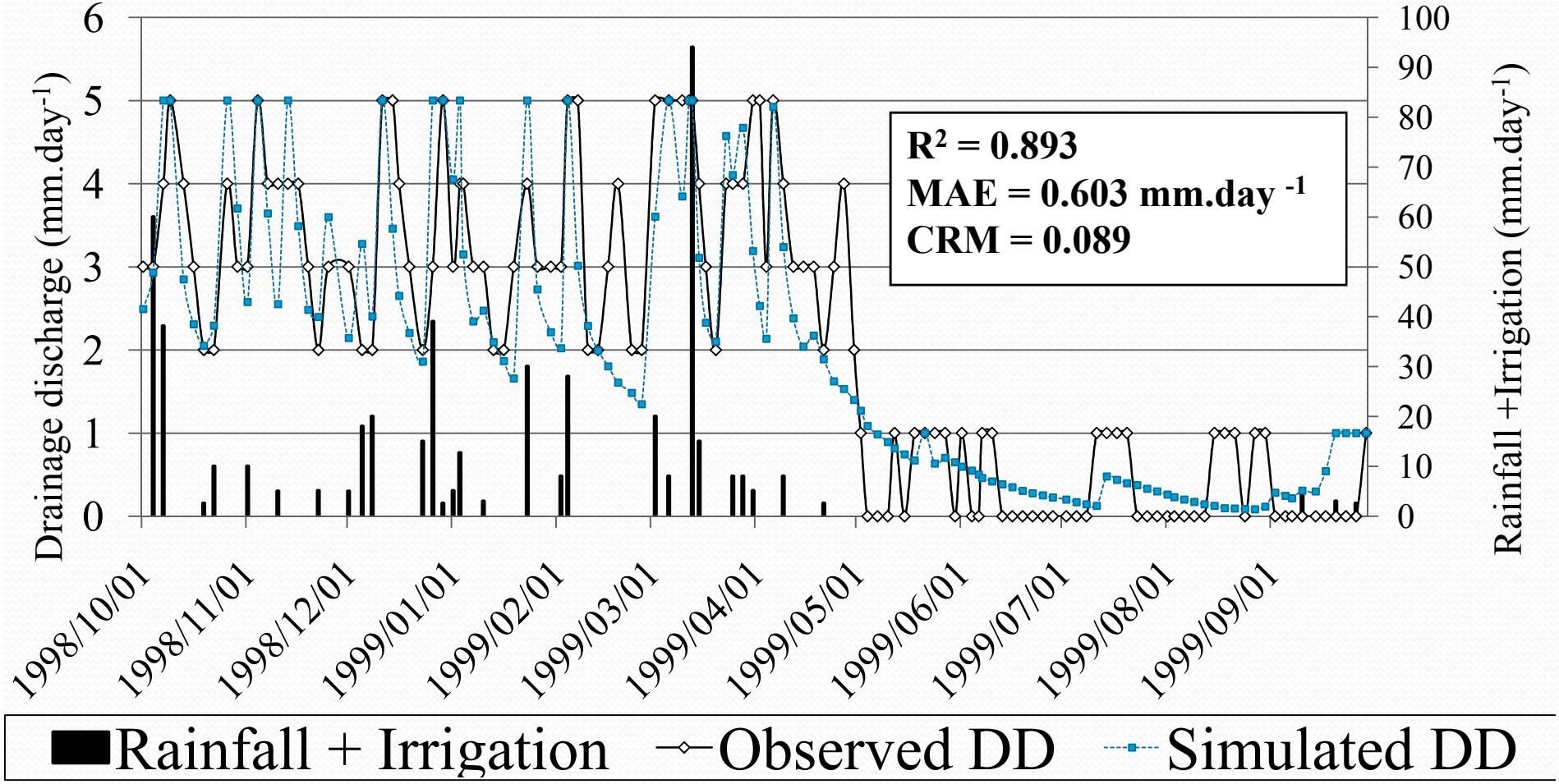
- **Bulk density**
  - Top = 1.45 g/cm^3
  - Lower = 1.88 g/cm^3
- **K_{sat}**
  - Clay = 0.24 m/day
  - Clay loam= 0.6 m/day

RESULTS & DISCUSSION



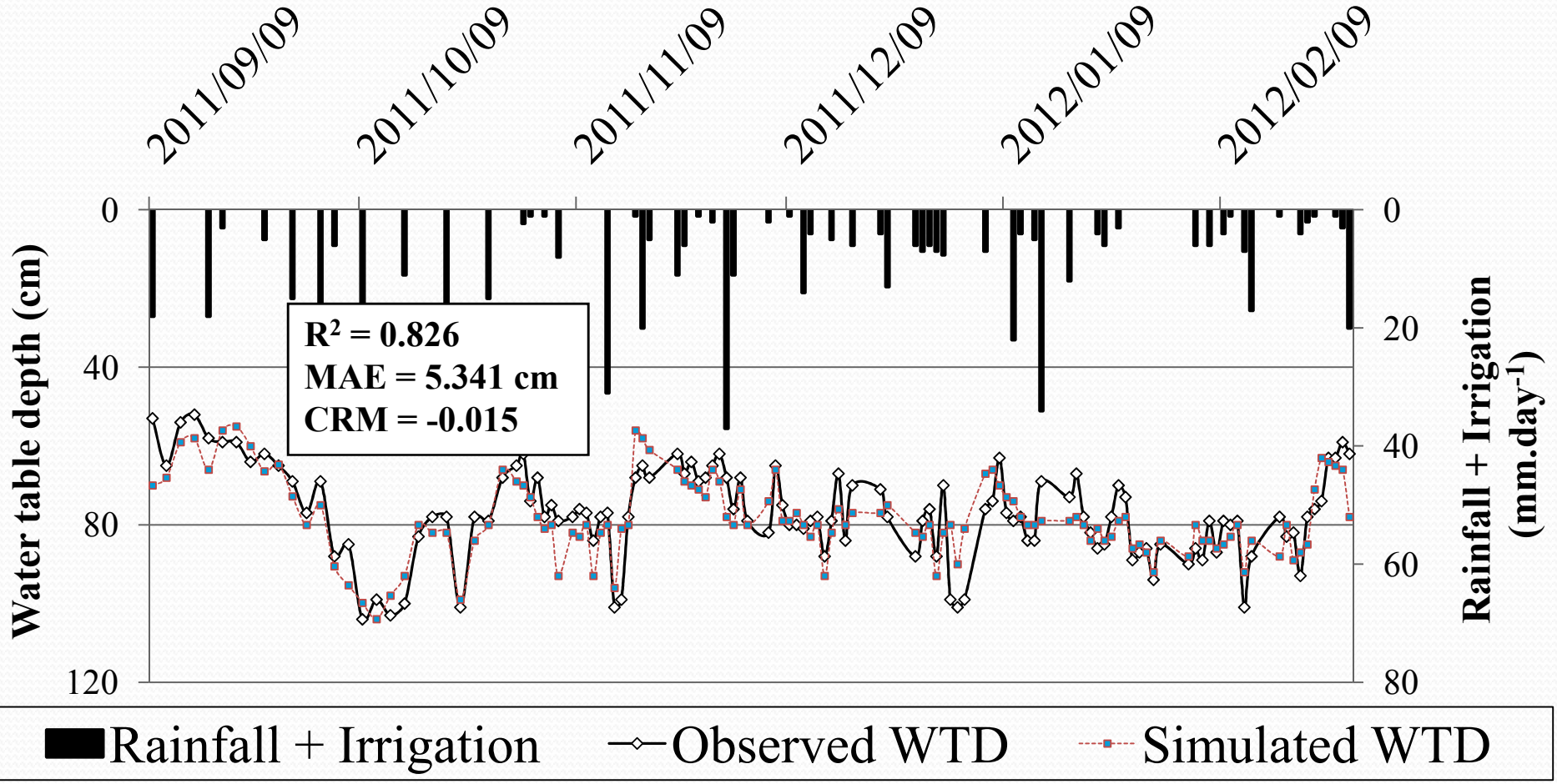
Observed and simulated WT fluctuation during the model calibration (better than Dayan et al 2009)

RESULTS & DISCUSSION...2



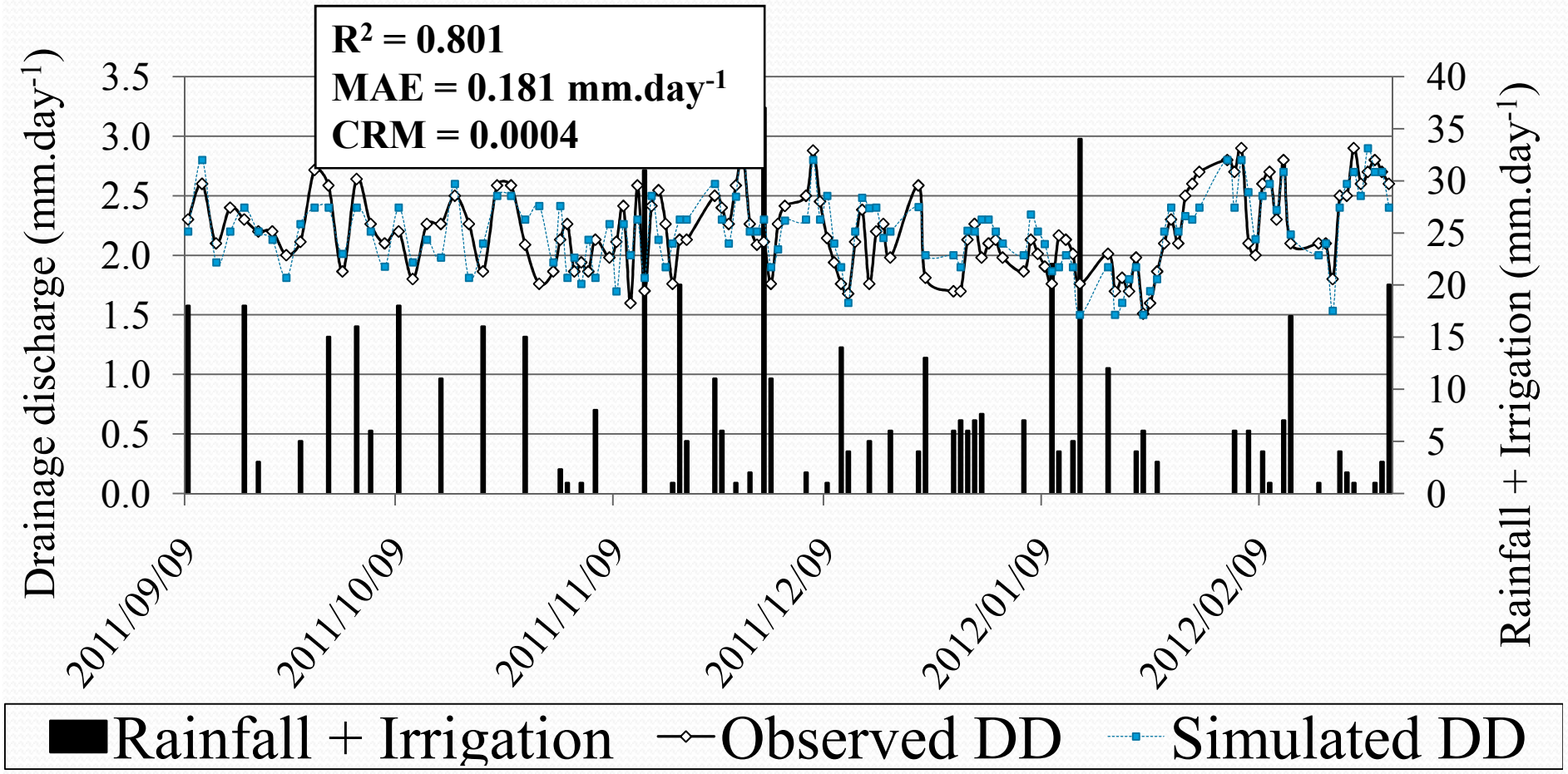
Observed and simulated drainage discharge hydrographs during calibration

RESULTS & DISCUSSION...3



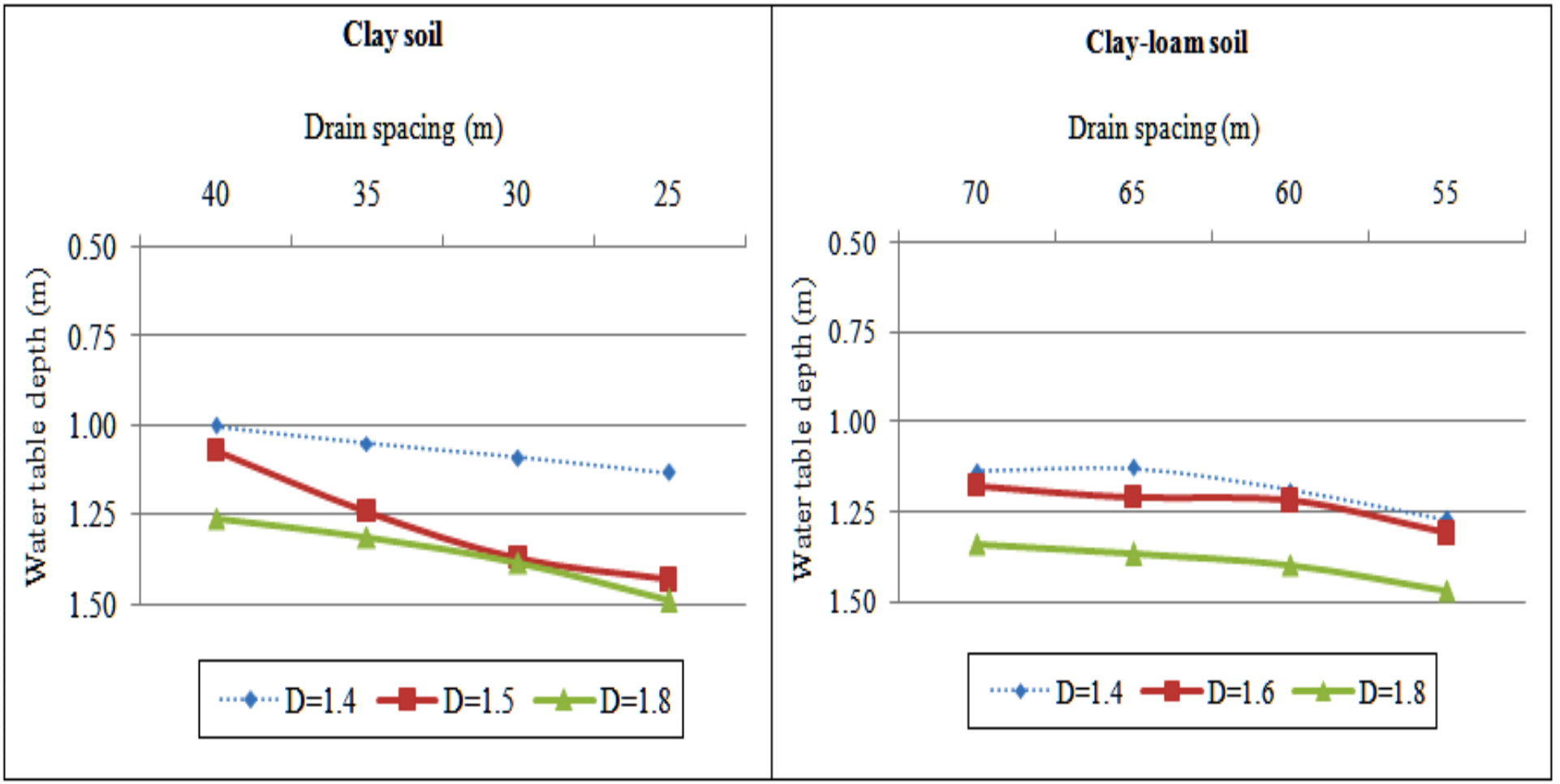
Observed and simulated WT fluctuation during the validation

RESULTS & DISCUSSION...4



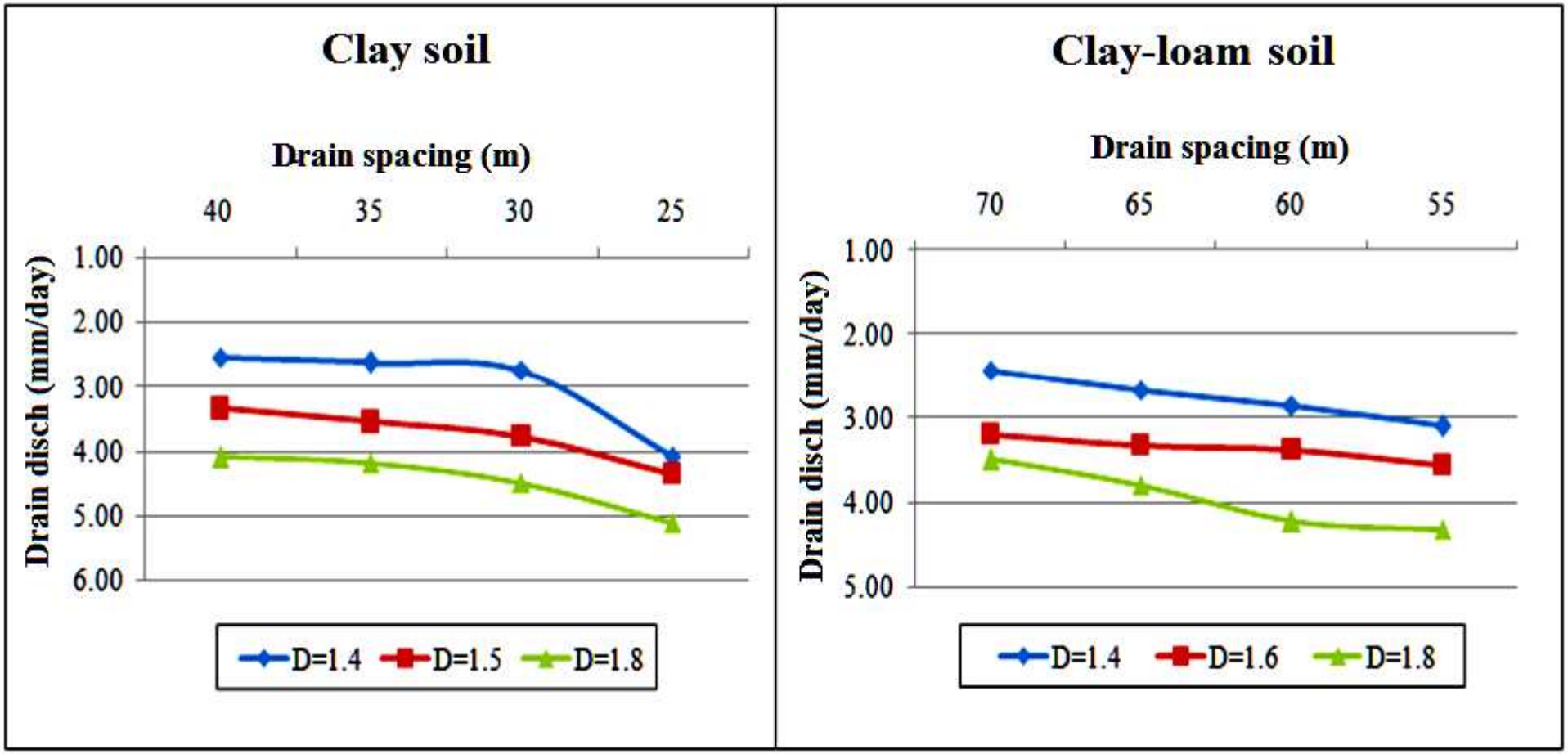
Observed and simulated drainage discharge hydrographs during the validation

Results - Simulation running



Mean WT depths in clay and clay-loam soils simulated at different drain depth W (m) and spacing L (m) combinations.

Drainage discharge



Mean drainage discharges in clay and clay-loam soils simulated at different drain depth W (m) and spacing L (m) combinations.

Concluding Remarks & Recommendations

- DAINMOD can be used as a drainage design tool
- It is recommended to use measured K_{sat} values, & PET
- Drain spacing must be reduced – to achieve recommended WT depths
  - But that increases costs
- The performance of the system must continuously be monitored

Acknowledgements

- **WRC for funding (via ARC)**
- **Mr J van der Merwe & Sfundo Nkomo**
- **Field Assistant**
- **Prof. K Mohammad – Tarbit Modares Univ, Iran**
- **Farmer in Pongola**

THANK YOU

LETS DRAIN IT!!!!