DRAINAGE

FOR IMPROVED SOIL HEALTH AND PRODUCTIVITY

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Acknowledgement

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DEVELOPMENT OF TECHNICAL AND FINANCIAL NORMS AND STANDARDS FOR DRAINAGE OF IRRIGATED LANDS

Project

Initiated and Funded by the
Water Research Commission

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Project details

- **WRC-KSA**
  - Water Utilisation in Agriculture
- **Thrust**
  - Water resources protection and reclamation in agriculture
- **Title**
  - Development of technical and financial norms and standards for drainage of irrigated lands
- **Duration**
  - Start date: 1 April 2011
  - End date: 31 March 2015

Organisation details

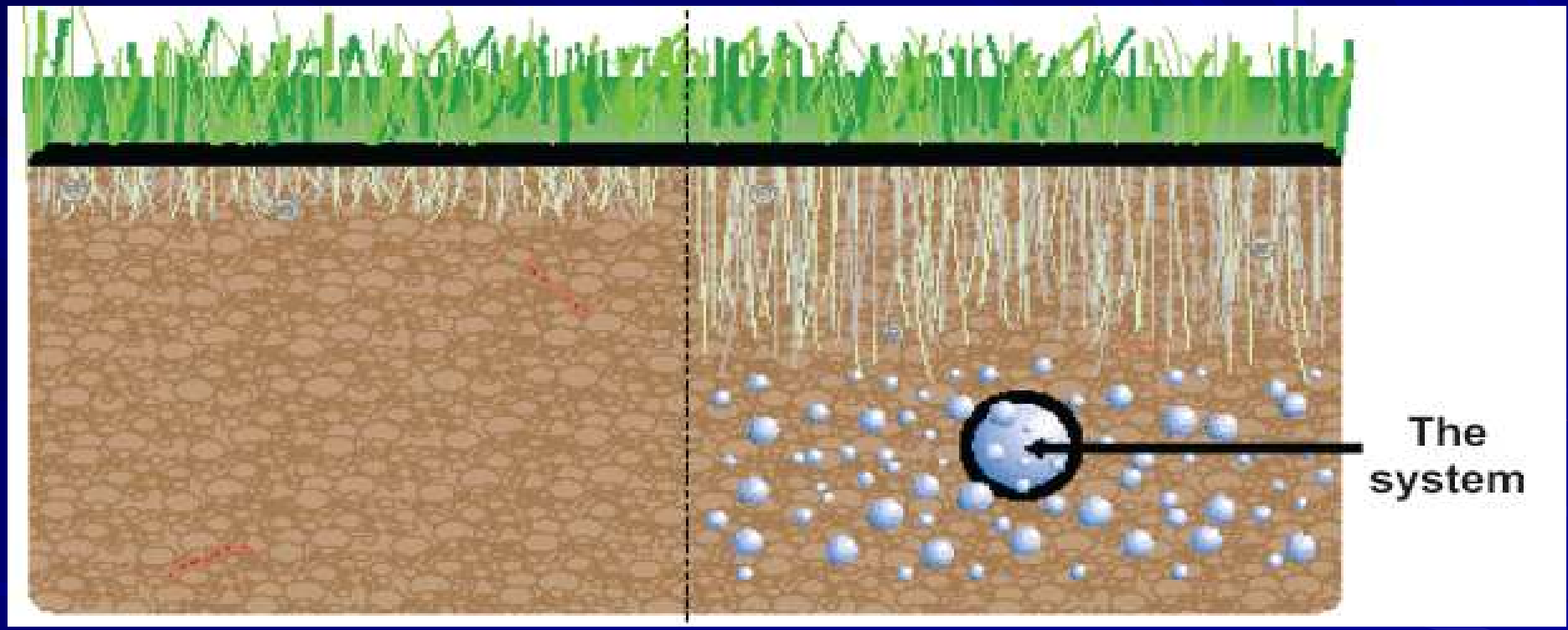
- Lead organisation
  - Agricultural Research Council,
    Institute for Agricultural Engineering
- Collaborating organisation
  - University of KwaZulu-Natal, School of Bioresources Engineering and Environmental Hydrology
  - OABS
  - University of the Free State
  - Bioresources consulting
- Supporting organisations
  - Directorate sustainable resource management
  - Directorate sustainable resource utilization
  - Directorate engineering – north region

Introduction

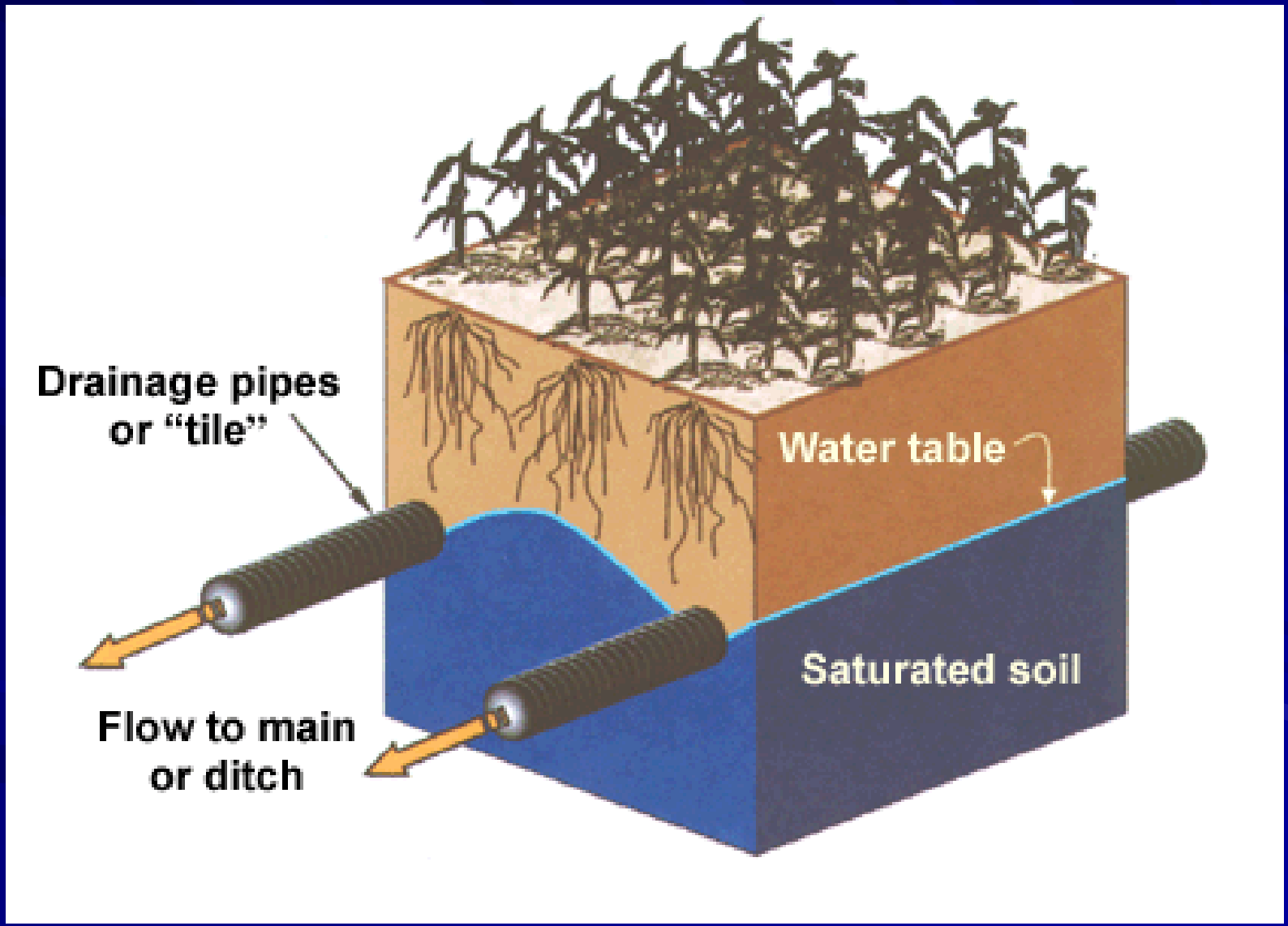
- In South Africa an area of 18 000 000 ha are been cultivated and 1 500 000 ha are been irrigated.
- It is estimated that 240 000 ha is affected by rising water tables and salinisation and problems appear to be expanding.
- There is also an indication that costs of drainage have increased quite significantly.
- Various approaches and techniques have been used and are still been used to drain agricultural fields in South Africa.

- There is therefore a need to revise and publish up to date norms and standards for South Africa that could form the basis for training of students at tertiary level and provide guidance for practitioners.
- Internationally and locally available research output and modelling approaches are been assessed for applicability in South Africa
- New ways of managing drainage should be introduced in stead of only a narrow focus on the present solutions.

Subsurface drainage



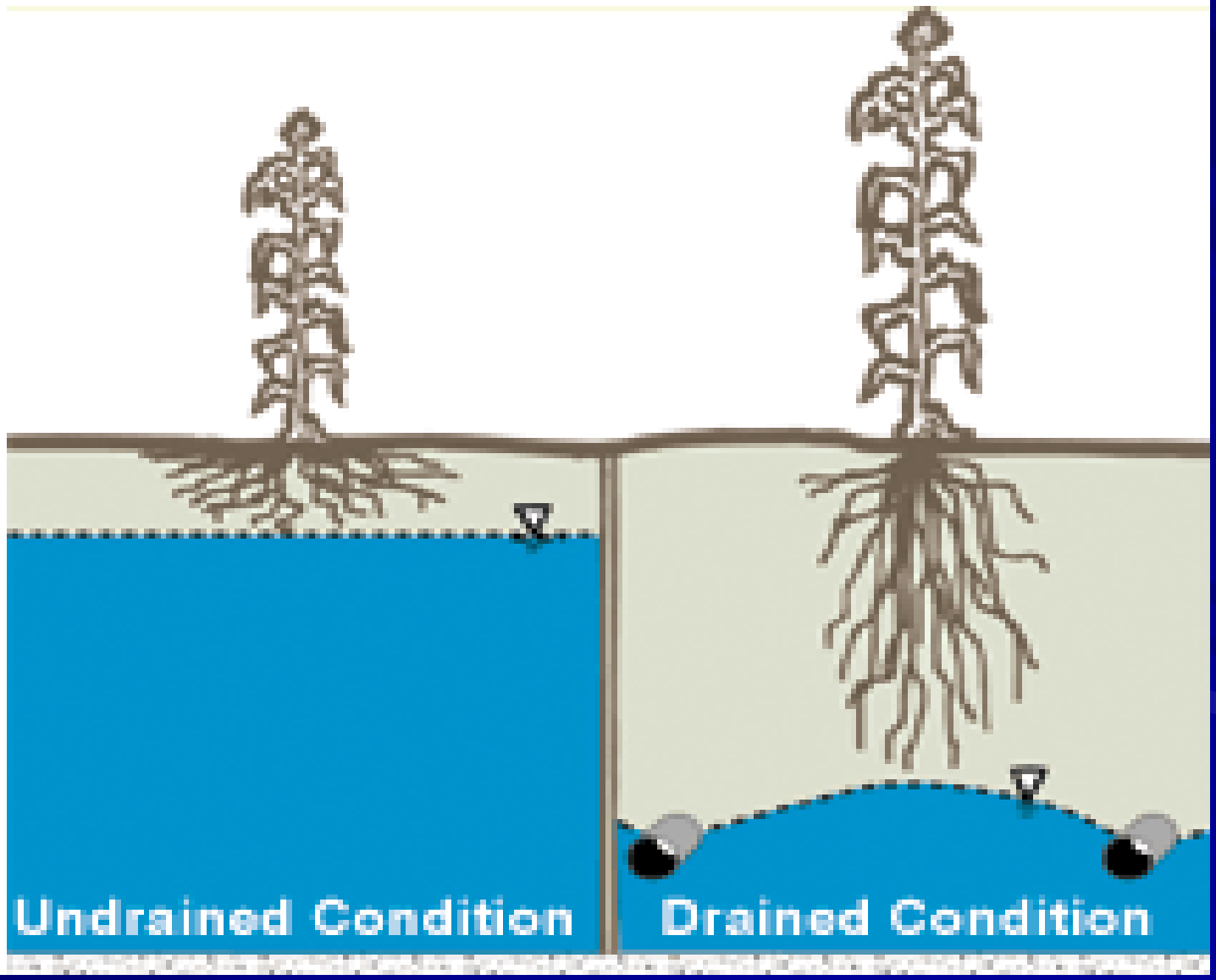
Principles of drainage



Improved root growth and plant health

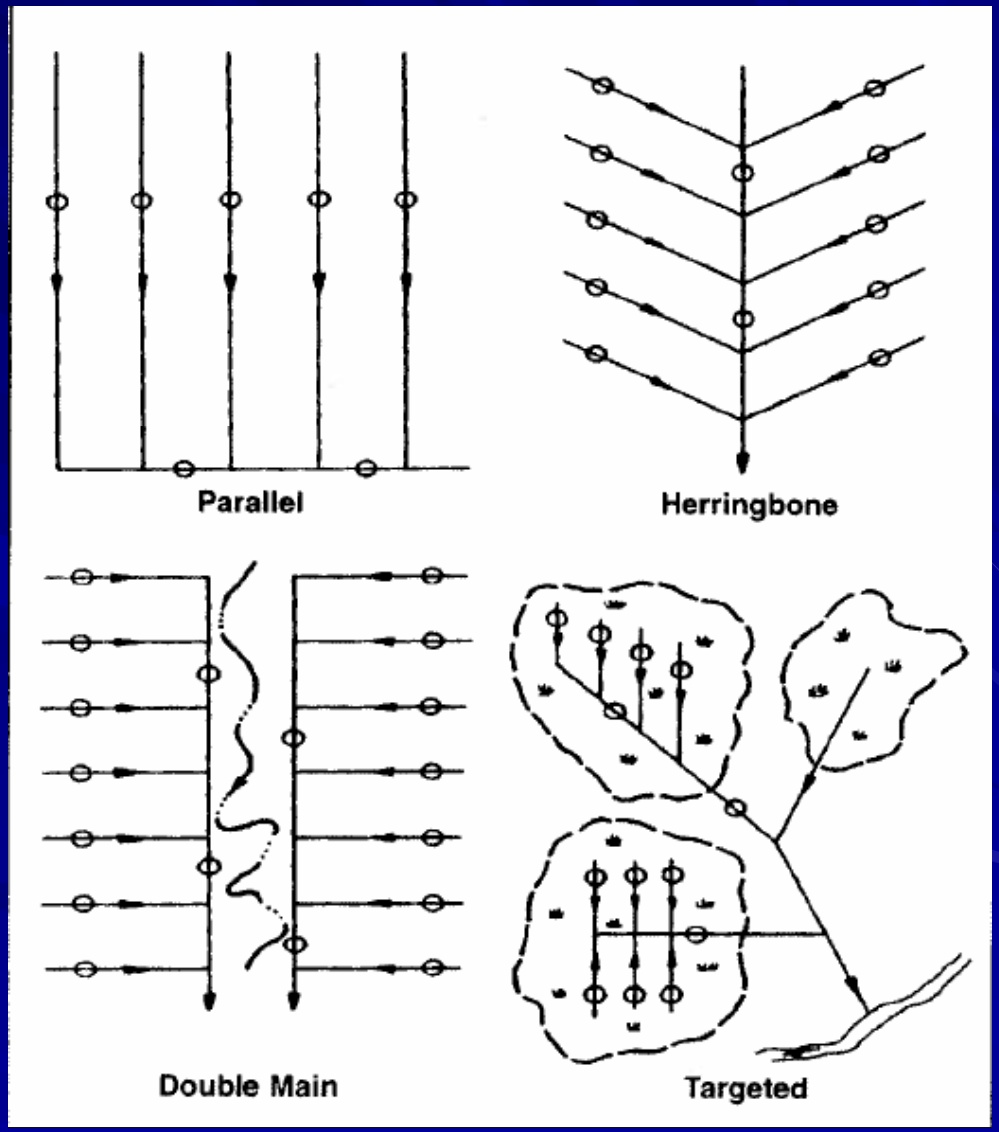
- The demand for the use of irrigation water and technologies to improve efficiency is a **derived demand** from the whole farm profitability of farming with irrigation crops.
- The major reason for installing drainage is to **improve the productivity** of the farmland.
- Reduced productivity of farm land = **waterlogged soils – anaerobic microbial activity (bad bugs)**
- Improved land productivity = **aerated soils stimulate aerobic microbial and fungi activity (good bugs)**
- **Higher yields translate into more returns.** So the investment decision is based on whether the higher crop returns will justify the investment in drainage

Subsurface drainage promotes better root growth and plant health when soils have poor internal drainage



Drain types

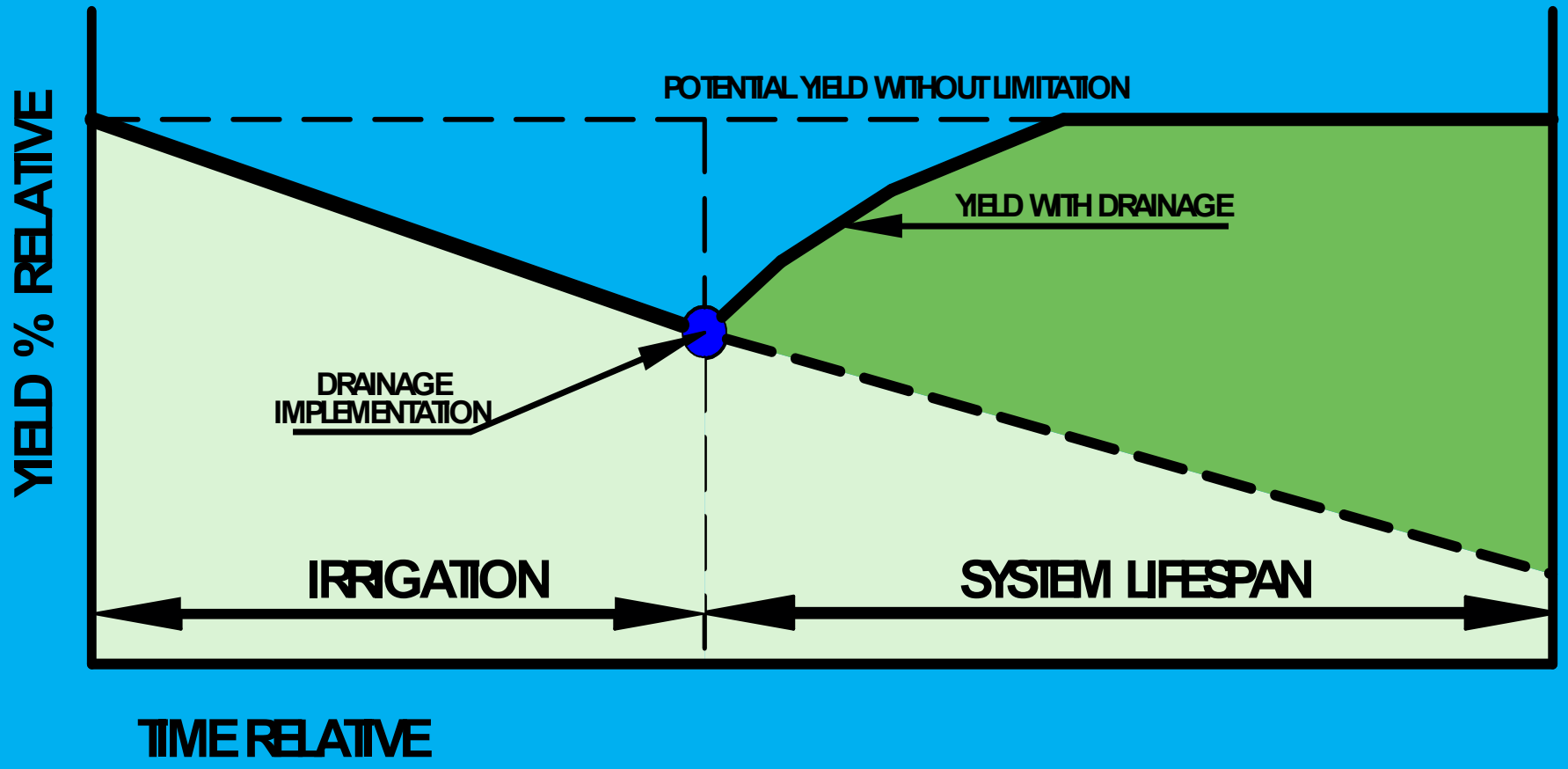
- System of drains
- Cut off drains
- Targeted drains



The main centres where we have drainage problems are:

- The areas along the Orange River, especially at Vaalhartz, Douglas and Upington.
- Winter Rainfall area at Robertson, Worcester, Swellendam, Ceres and Wellington
- KwaZulu Natal Region – Pongola and Nkwalini
- Eastern Cape – Gamtoos valley, Sunday River valley and Fish River valley.
- Limpopo– Loskopdam and Hartbeespoortdam Irrigation schemes
- And mainly where there is a concentration of irrigation going on.

Yield trends with and without Subsurface drainage



J vd Merwe, 2008

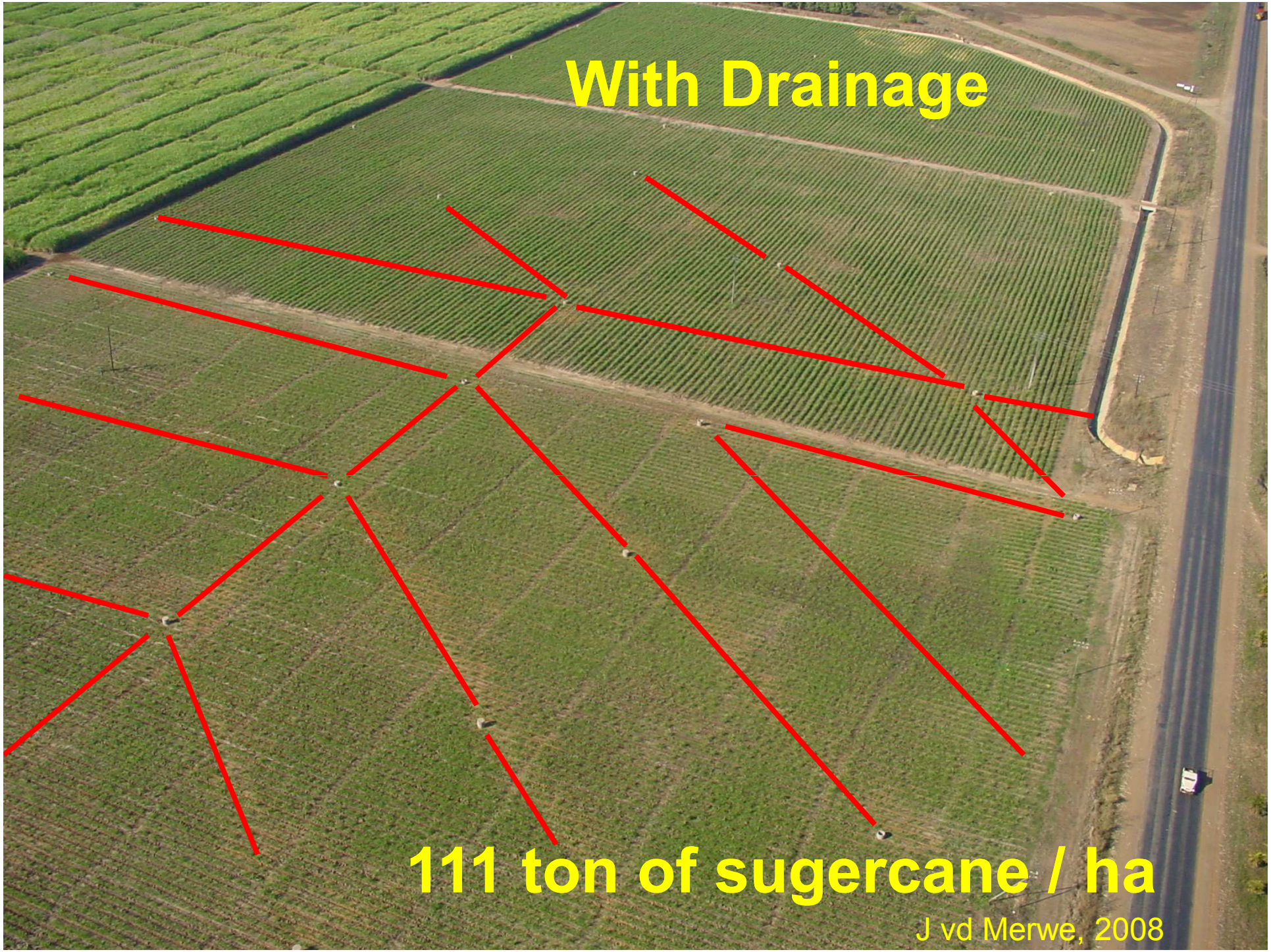
Irrigation without Drainage

- **Non-effective irrigation application.**
- **Shallow root development.**
- **Field operations more difficult.**
- **Greater control of weeds is required.**
- **Rise of the water table.**
- **Salt accumulation.**
- **Reduction in plant available water.**
- **Development of bad patches in the field.**
- **No or limited yield.**

Irrigation with Drainage

- **Initial high implementation cost.**
- **Lowering of the water table.**
- **Reduce soil compaction and destruction.**
- **Leaching of accumulated salts.**
- **Field operations without water logging.**
- **Extended growing season.**
- **Increased root development.**
- **Improved yields.**
- **Better drought resistance.**
- **Sustainable long-term Irrigation.**


No Drainage
70 tons of sugercane/ha
J vd Merwe, 2008


With Drainage
111 ton of sugercane / ha
J vd Merwe, 2008

Objective

- To develop technical and financial standards and guidelines for assessment of the feasibility of surface and sub-surface drainage systems under South African conditions.

Specific objectives

1. To review internationally and nationally available norms and standards and to give an overview of current drainage systems, practices and technology;
2. To evaluate the interaction between irrigation, drainage practices and impact on the natural environment;
3. To describe technical/physical/biological/financial requirements for drainage;

Specific objectives

4. To refine and develop technical standards for drainage with reference to soil types, crops, irrigation method, water tables, salinisation, water quality and management practices;
5. To refine and develop financial standards for drainage with reference to capital investment, financing methods, operation and maintenance expenditure and management practices;
6. To evaluate the technical and financial feasibility of drainage based on selected case studies;
7. To develop guidelines for design, installation, operation and maintenance of drainage systems.

Methodology

1. Conduct a desktop study to synthesise the terminology, definitions, practices and technology of drainage (Objectives 1, 2 & 3)

2. Evaluating and measuring of drainage in selected areas for the refinement and development of standards (Objectives 4 & 5)

3. Apply the tools at selected locations to finalise the technical and financial standards (Objective 6)

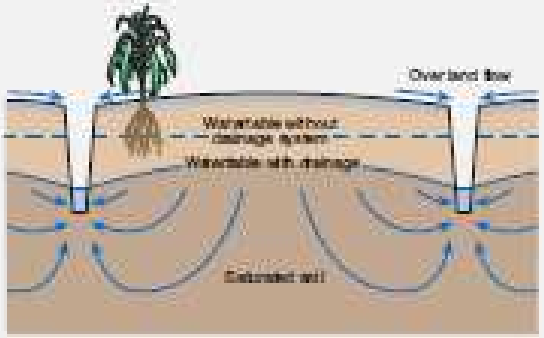
4. Compile guidelines for proper drainage approaches.

Product

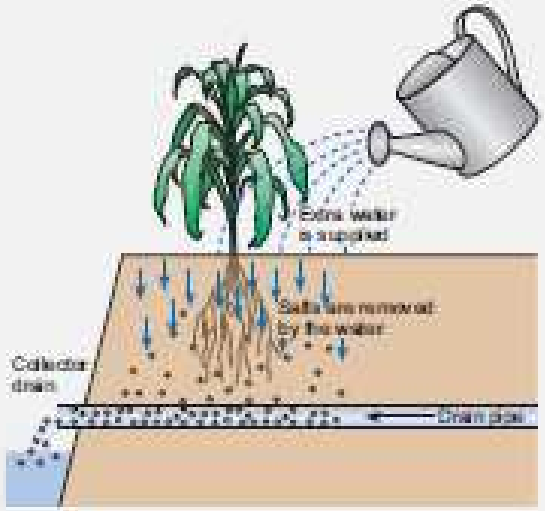
Guidelines and manual for design, installation, operation and maintenance of drainage systems.

OVERVIEW OF SUBSURFACE DRAINAGE

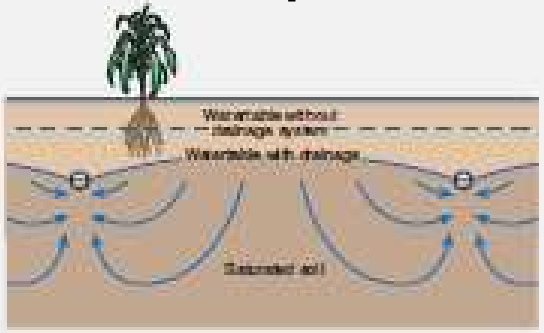
- Introduction
  - Theory of Agricultural Drainage
  - Drainage in agricultural lands
  - Drainage system design parameters
- Drainage decision support tools
  - Hydrological modeling
  - DRAINMOD model
  - WaSim model
  - SaltMOD model



a. **To remove excess water from the surface**



b. **To remove excess salts from the profile**

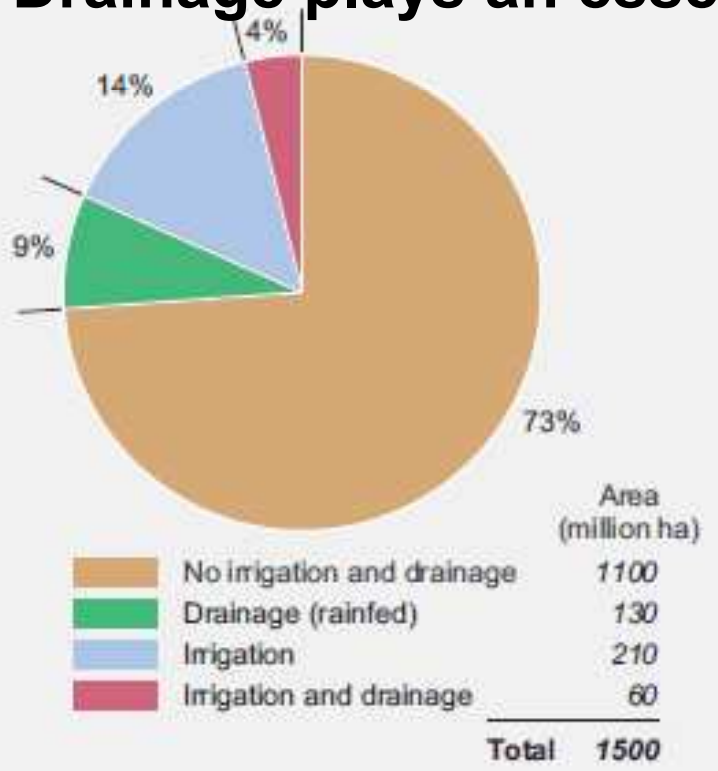


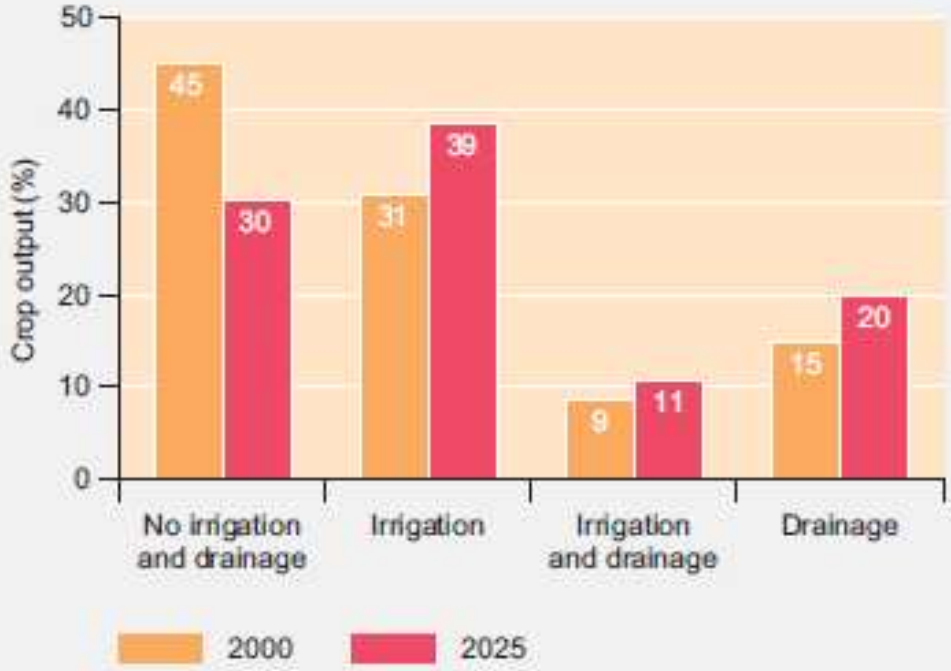
c. **To maintain groundwater at a desired level**

- 500,000 ha of the total world‘s agricultural land are being lost out of production every year due to poor drainage
- South African Government installed subsurface drainage systems on 54,000 ha of the total irrigated land and another 150,000 ha with surface drainage systems
- Drainage models have been developed e.g. DRAINMOD, WaSim and SaltMOD to aid in the design of new drainage systems and evaluation of already installed drainage systems.

- The extent of cultivated area worldwide is estimated at 1500 million ha, out of which about 390 million ha are said to be provided with sustainable water management systems, being irrigation, drainage, or both

Drainage plays an essential part to sustain food production





- Salinisation and water logging are still reducing the crop production potential of irrigated arid and semi-arid lands claiming 250,000 - 500,000 ha out of production every year

Observed irrigation efficiency as calculated for a 12 months period for an irrigation field along the Breede River in South Africa

Crop/irrigation method combination	Irrigation depth (mm)	Actual depth of water drained		Water use efficiency (%)
		(mm)	% of irrig	
Vines/drip	435	181	41.6	56.8
Vines/micro	665	260	39.1	66.5
Vines/sprinkler	699	313	44.8	67.8
Vines/flood	507	371	73.2	64.1

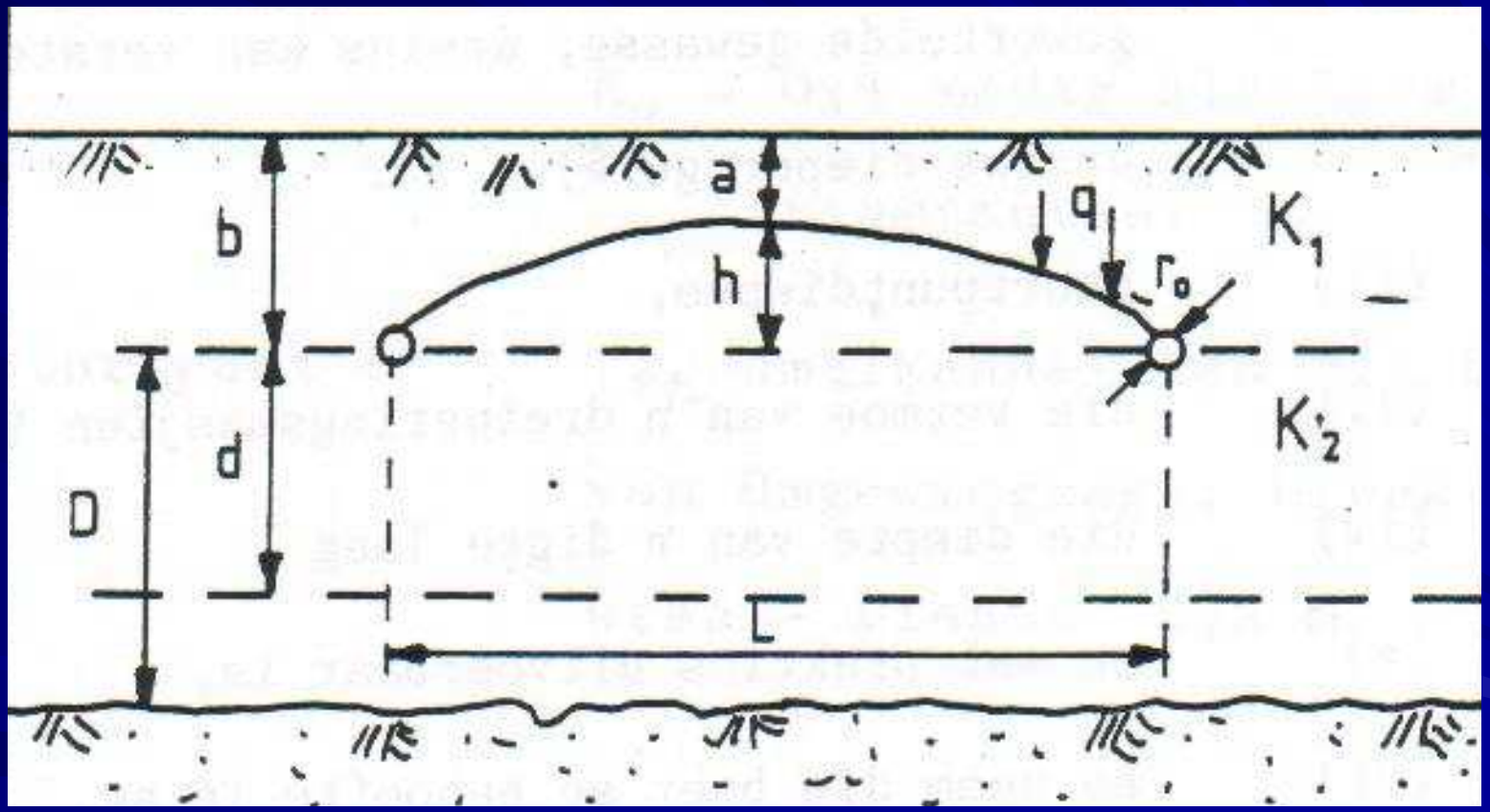
Drainage % of total irrigated area (%) in different countries

Country	Area irrigated (ha)	Area drained (surface drainage) (ha)	Drainage % of total irrigated area (%)
Egypt	3,246,000	3,024,000	93
India	90,000,000	5,800,000	12
The Philippines	1,530,000	1,500,000	96
South Africa	1,500,000	150,000	10

Basic design criteria for groundwater drainage in a humid climate zone

Condition	Drain discharge q (m/day)	Design water table depth z (m)	Hydraulic head h (m)	h/q (day)
Low value crops (most grasslands)	0.007	0.30 - 0.40	0.60 - 0.70	85 - 100
Sensitive & high value crops	0.007	0.50 - 0.60	0.40 - 0.50	55 - 70
Average conditions	0.007	0.5	0.5	70

Main variables in groundwater drainage design



Drainage decision support tools

- **Hydrological modeling**

  The soil system is one of the highly complex natural systems due to greater variations and non-linear processes occurring within it. Interestingly, crop production both under rain fed and irrigation is dependent on these processes, which require a good understanding of such processes in order to make effective decisions on water management systems.

DRAINMOD model

DRAINMOD is a hydrological model developed at the North Carolina State University (NCSU) in the department of Biological and Agricultural Engineering. The model is reported to have been initially developed for analyzing field scale watershed management scenarios for poorly drained soils, but it has now been updated and used on both field- and watershed-scale management sites.

DRAINMOD model is one of the most widely applied of the water balance models in subsurface drainage system design

$$\Delta V_a = D + ET + DS - F$$

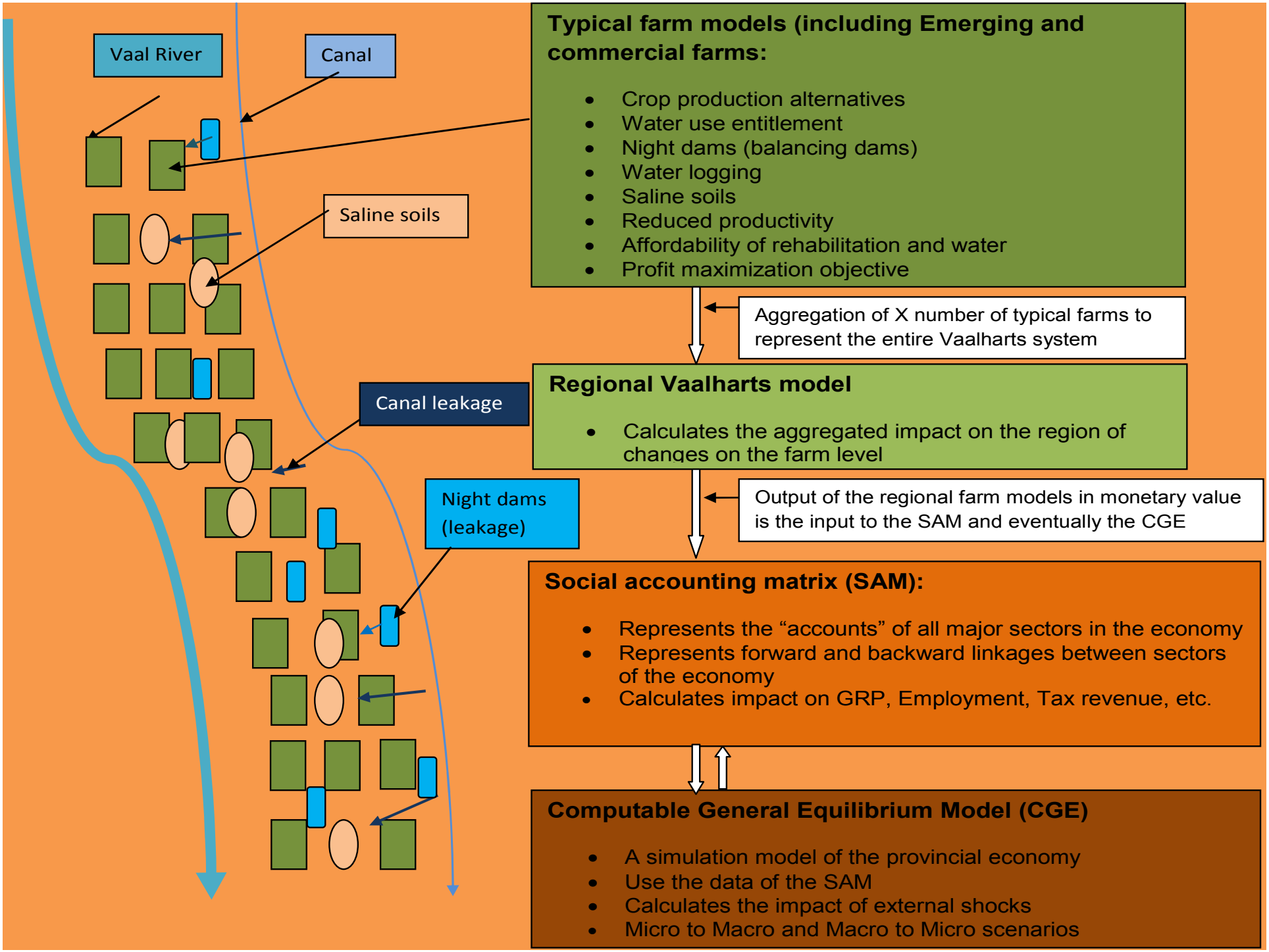
Where:

ΔV_a is the change in the water free pore space or air volume, cm; D is the drainage from the section, cm; ET is the evapotranspiration, cm; DS is the deep seepage, cm; F is the infiltration entering the soil section, cm.

FINANCIAL APPROACHES

Drainage financing models

- World Bank
- Bank determination of repayment ability
- Benefit Cost Analysis
- Armour and Viljoen, economic Models to determine the financial feasibility of drainage at farm level.

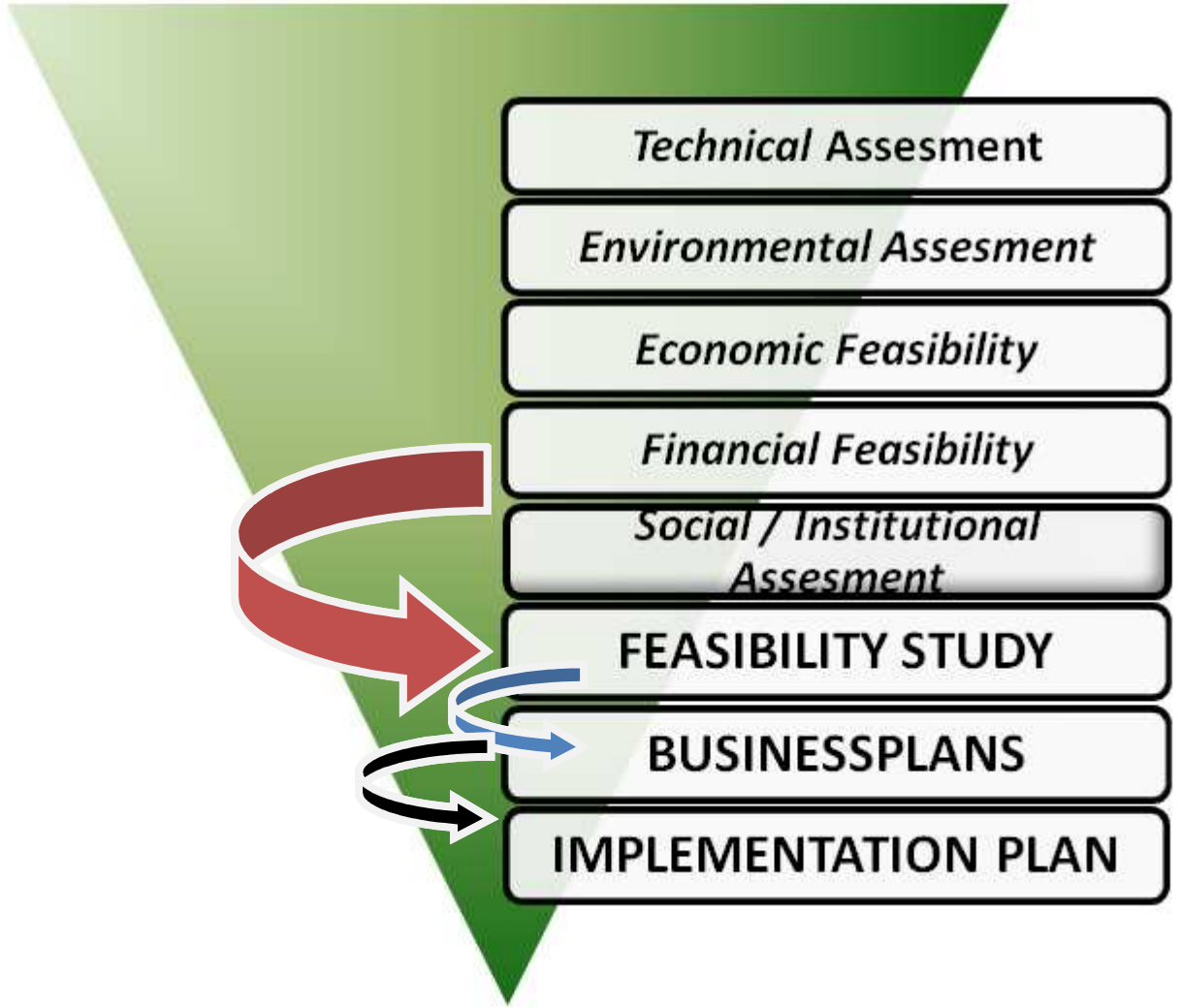

Vaal River
Canal
Saline soils
Canal leakage
Night dams (leakage)
Typical farm models (including Emerging and commercial farms:
Crop production alternatives
Water use entitlement
Night dams (balancing dams)
Water logging
Saline soils
Reduced productivity
Affordability of rehabilitation and water
Profit maximization objective
Aggregation of X number of typical farms to represent the entire Vaalharts system
Regional Vaalharts model
Calculates the aggregated impact on the region of changes on the farm level
Output of the regional farm models in monetary value is the input to the SAM and eventually the CGE
Social accounting matrix (SAM):
Represents the "accounts" of all major sectors in the economy
Represents forward and backward linkages between sectors of the economy
Calculates impact on GRP, Employment, Tax revenue, etc.
Computable General Equilibrium Model (CGE)
A simulation model of the provincial economy
Use the data of the SAM
Calculates the impact of external shocks
Micro to Macro and Macro to Micro scenarios

Feasibility concept

The concept of feasibility is often misunderstood – it consists of five key elements:

- Technical feasibility – engineers, soil scientists, agronomists etc
- Economic feasibility - micro (farm level and regional) and macro (provincial and national) economy
- Financial – to finance the capital requirements. Economic feasibility is not equal to financial feasibility
- Institutional/social feasibility
- Environmental feasibility

Project methodology



Technical assessment: Aims

- Status quo of all relevant technical issues (consideration of issues such as water logging, salinity, structural failures and so forth);
- To establish feasible alternatives to address the issues identified from the status quo situation;
- To determine the associated cost of addressing water logging, salinity and infrastructure issues – drainage systems and specifications.
- To present the designs of proposed alternatives;
- To consider and establish best practices with respect to the operations and management of alternative drainage systems;
- To consider and establish best practices with respect to water management;

Environmental: Aim

– Guidelines on possible environmental impact and the implications for drainage systems.

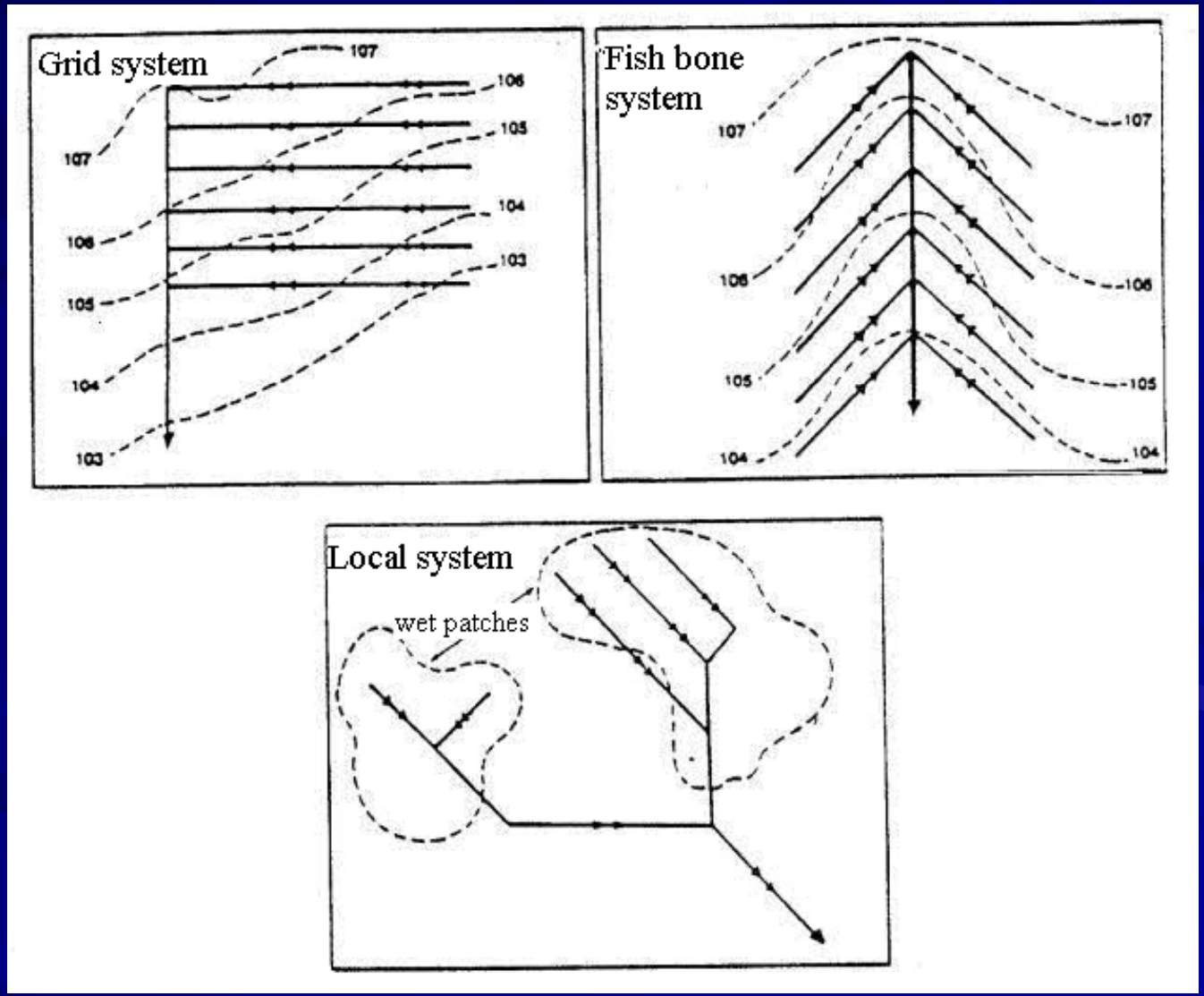
Economic and financial assessment:

- To establish the current drainage efficiency and costs on selected case studies
- Quantify the costs and benefits of alternative drainage systems
- Use the Armour (2008) model to quantify the net benefit on a case study basis and to extrapolate to the scheme level;
- Develop criteria to determine the affordability of drainage systems
- Test the financial feasibility including the possible impact of government subsidies
- To model the macro economic impact by using existing economic multipliers – if available; The economic multipliers of the proposed intervention in terms of GDP, employment, value adding, government revenue.

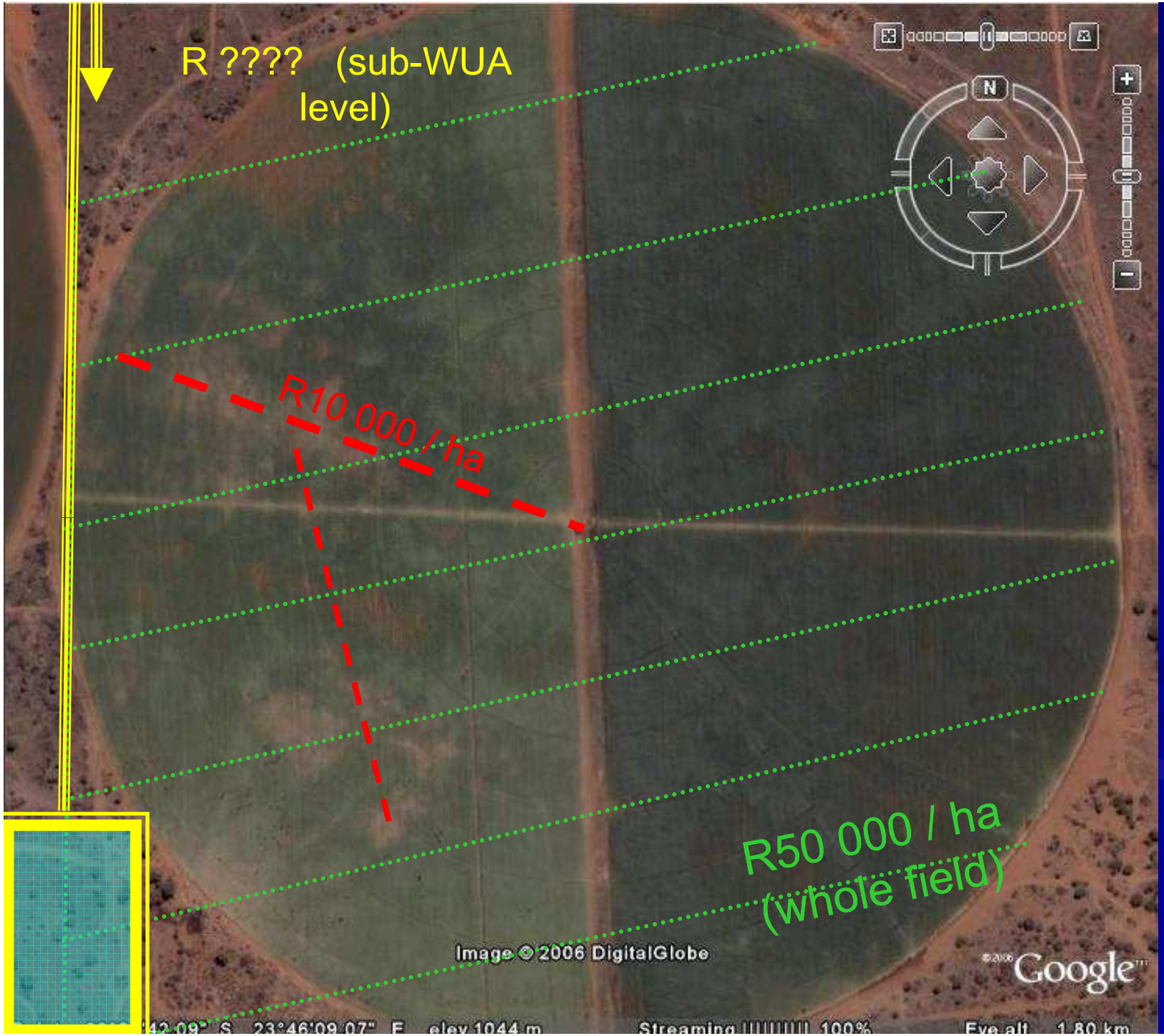
Institutional assessment aims

– Guidelines for the coordination, management, implementation and monitoring of drainage;

CURRENT DRAINAGE SYSTEMS, PRACTICES AND TECHNOLOGY



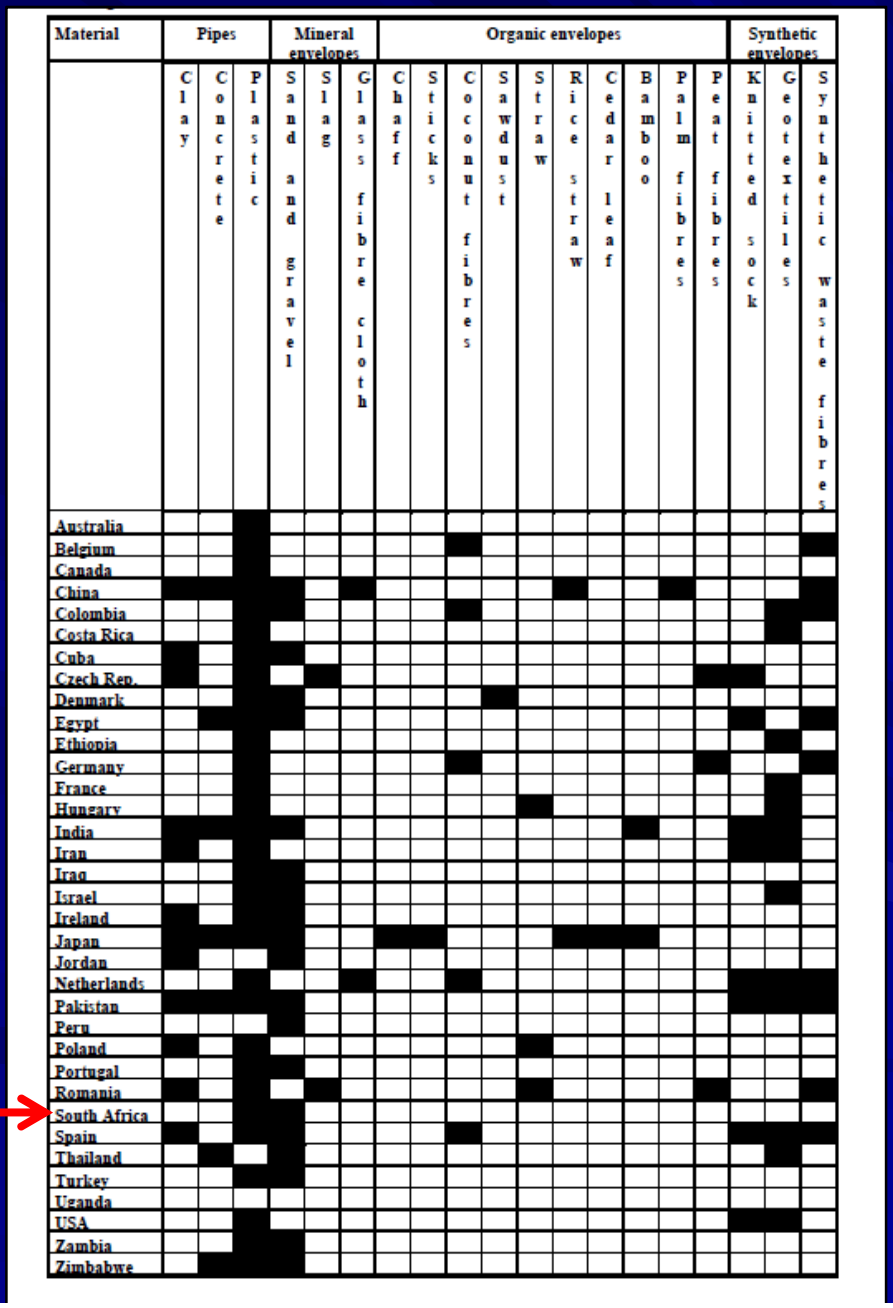
SPATIAL VARIABILITY



Different drainage systems and materials used

ITEM	TYPE OF SYSTEMS OR MATERIALS
Systems	Open channel Stone drains Pipe drains
Materials for pipe drains	Unglazed earthenware pipes Glazed earthenware pipes Cement pipes (for soils with no SO_4^{2-} in the soil water) Smooth uPVC pipes with grooves (6 m lengths) Pitch fibre pipes Fluted uPVC pipes with grooves (in rolls)
Cover materials (Especially for finely textured soils)	Gravel or coarse river sand Coal slate Stone breaker dust Fibreglass “Styromull” (Synthetic small granules)

Drainage materials used in a number of Countries



Material	Pipes			Mineral envelopes			Organic envelopes									Synthetic envelopes		
	Clay	Concrete	Plastic	Sand and gravel	Slag	Glass fibre cloth	Chaff	Sticks	Coconut fibres	Sawdust	Straw	Rice straw	Cedar leaf	Bamboo	Palm fibres	Peat fibres	Knitted sock	Geotextiles	Synthetic waste fibres
Australia			■																
Belgium			■						■										■
Canada			■																
China	■	■	■	■		■						■			■				■
Colombia			■						■										■
Costa Rica			■															■	
Cuba	■		■	■															
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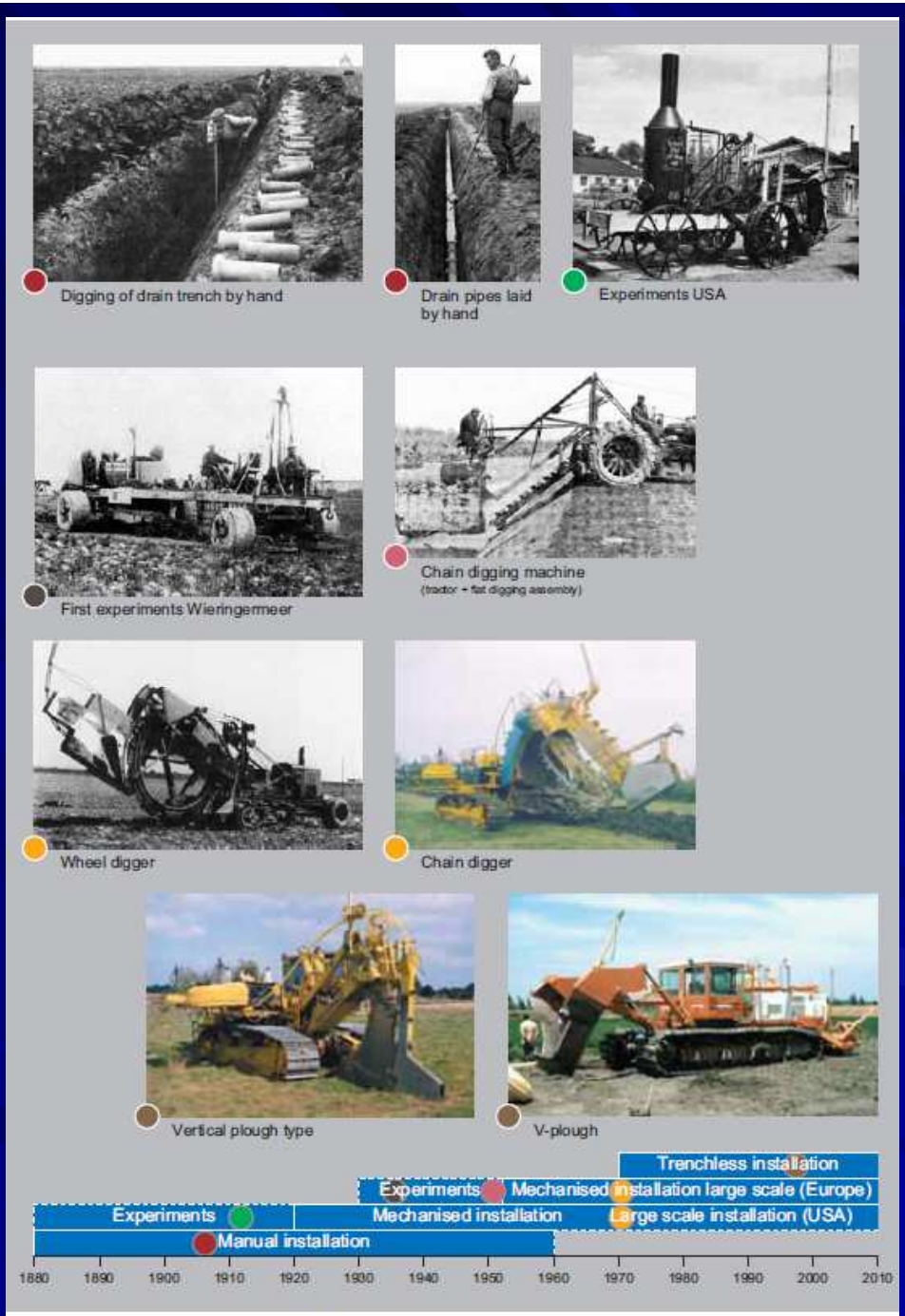
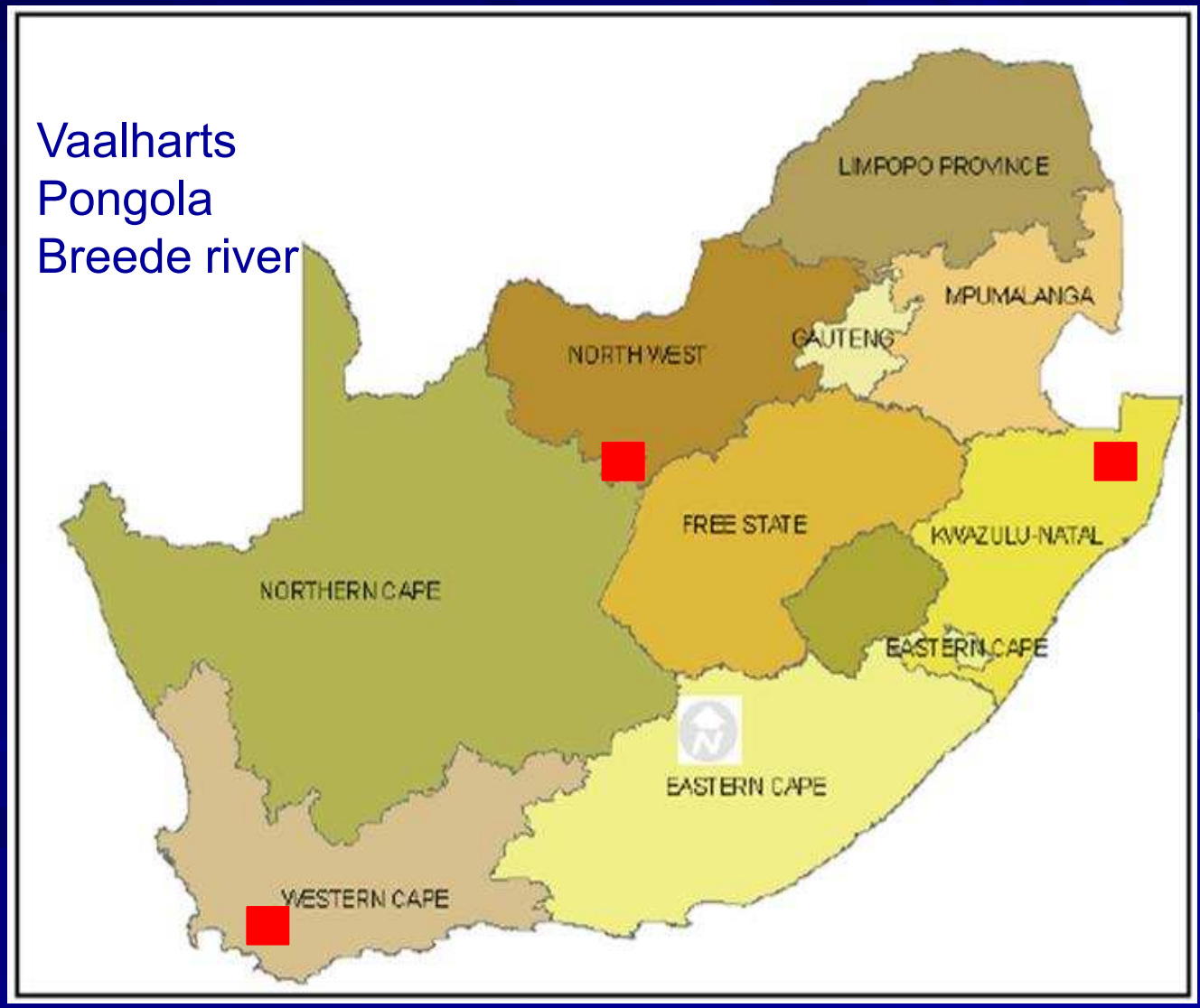


Figure 3 History of mechanised installation of subsurface pipe drainage systems

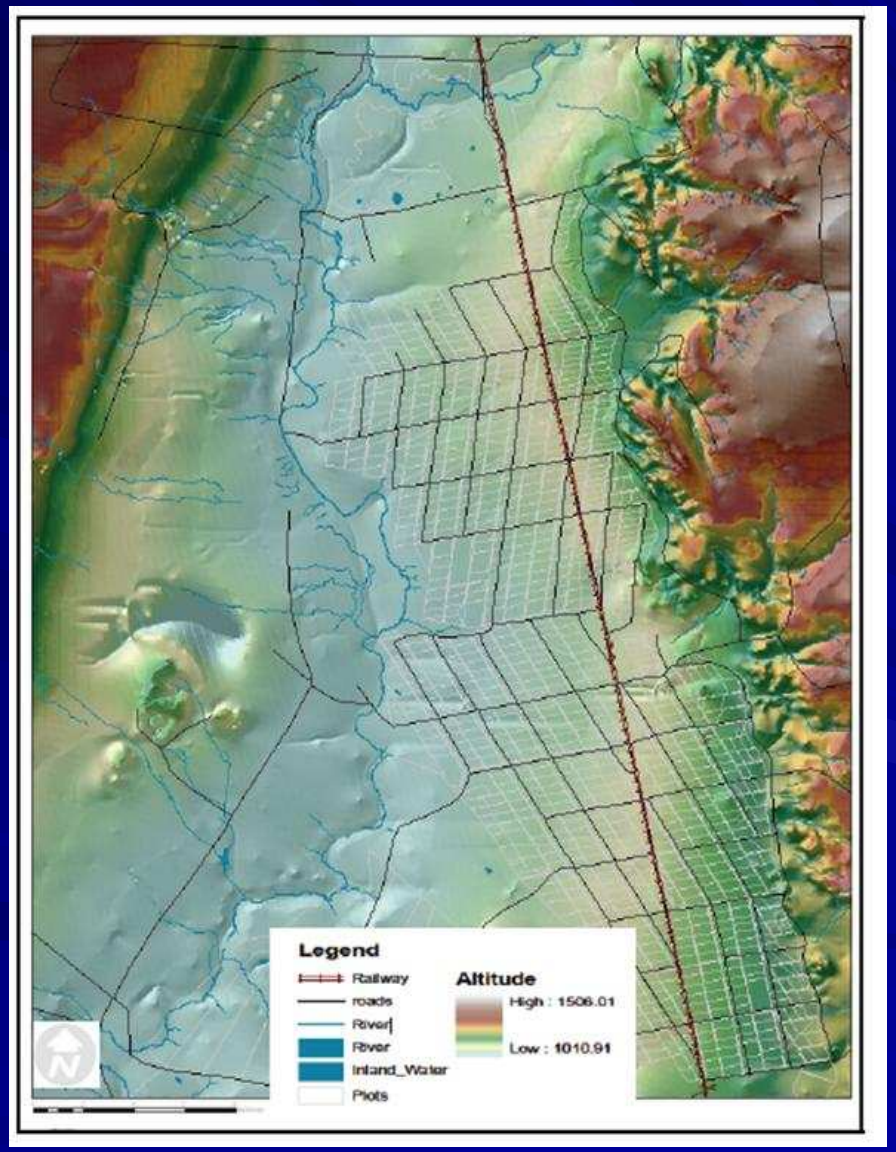
SITES FOR DRAINAGE INVESTIGATIONS

Vaalharts
Pongola
Breede river

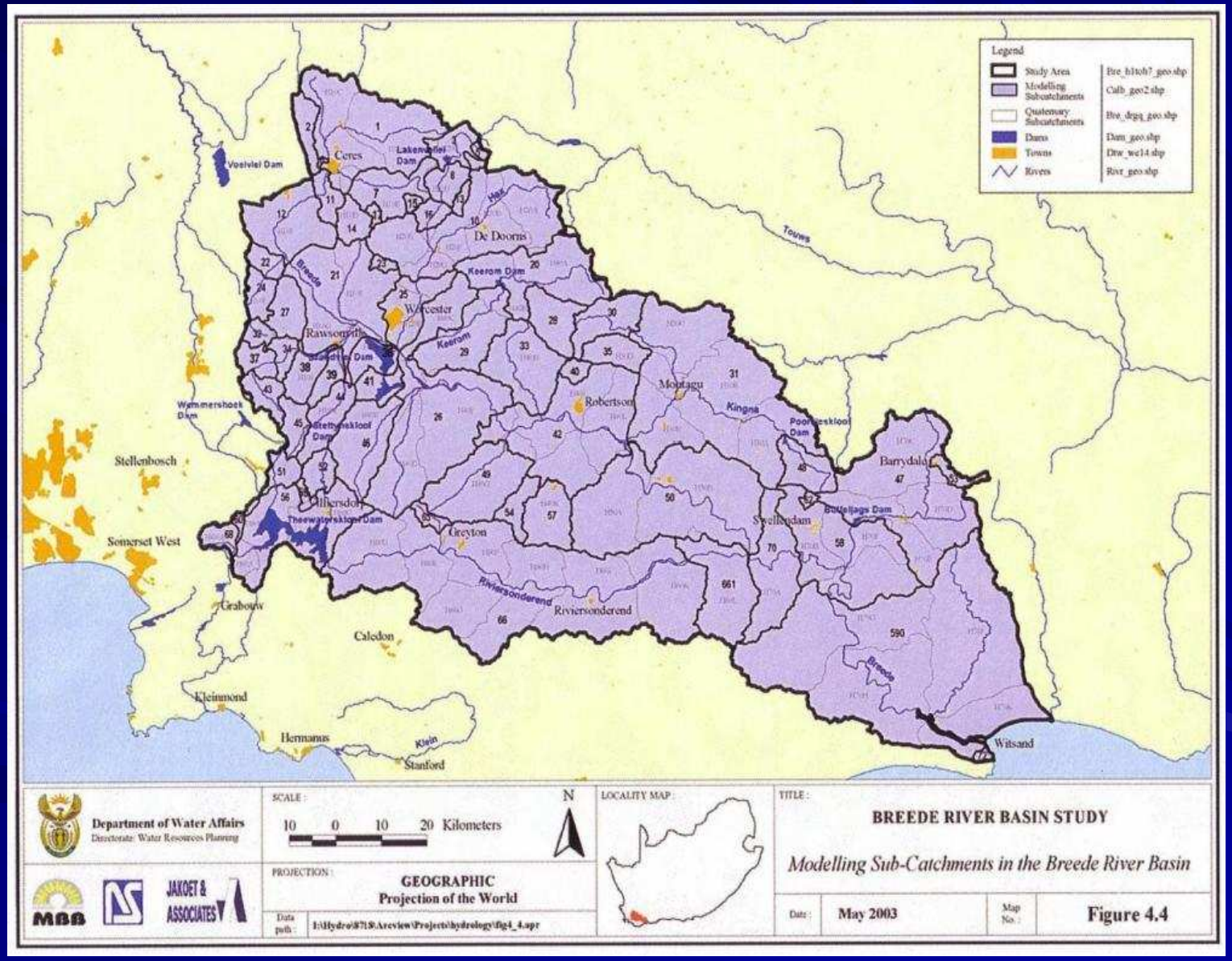


Aerial view of farm lay-out at Vaalharts scheme

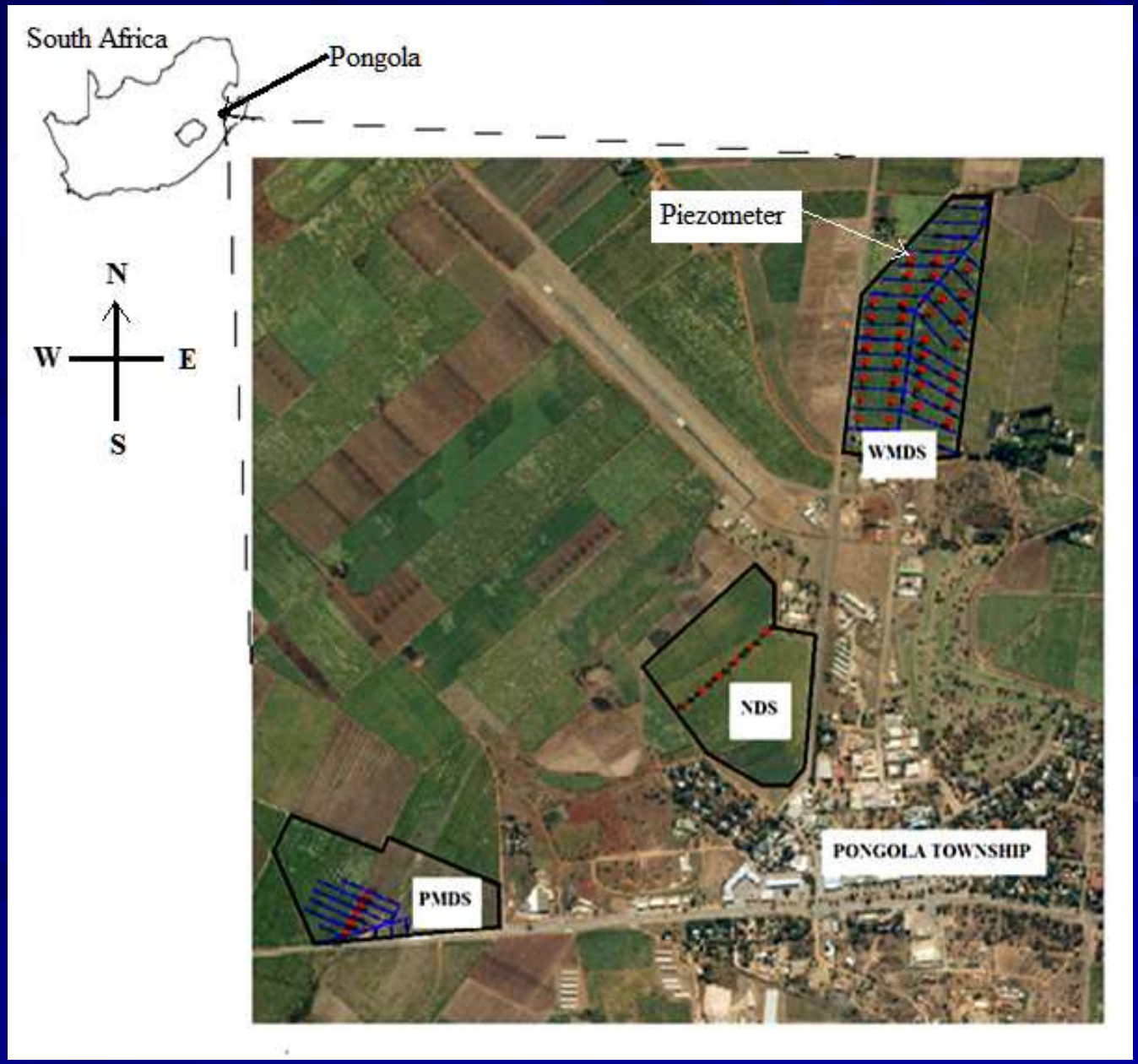
Topographic map of the Vaalharts scheme



Breede river irrigation scheme



Impala irrigation scheme




Thank you