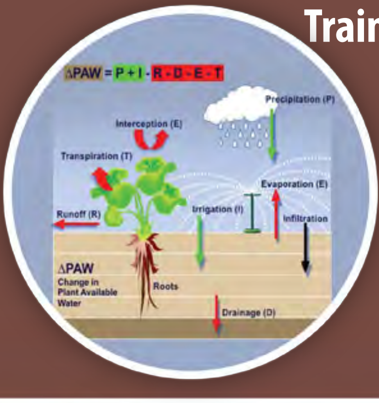

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Volume 2: Technical Learner Guide
Part 1: Soil-plant-atmosphere continuum

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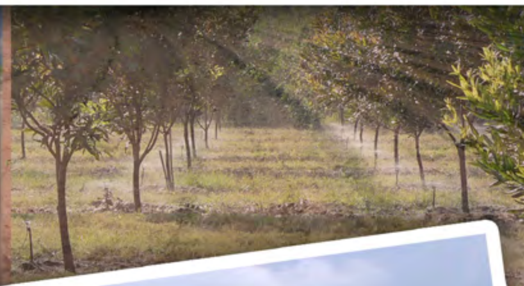



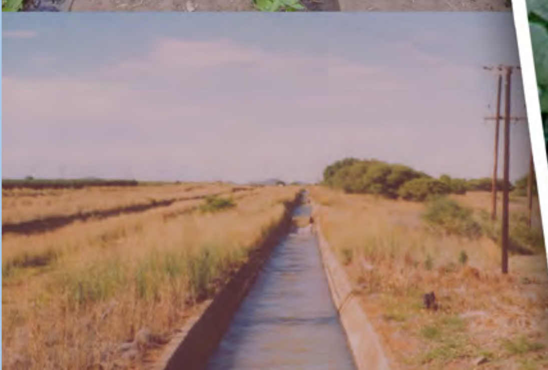


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WATER
RESEARCH
COMMISSION

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Part 1: Soil-plant-atmosphere continuum

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Report to the

Water Research Commission

University of Pretoria

NQF

Level 5

WATER RESEARCH COMMISSION

agriculture, forestry & fisheries

Department: Agriculture, Forestry and Fisheries REPUBLIC OF SOUTH AFRICA

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Before we start……………

Dear Learner ....this learner Guide contains information to acquire the basic knowledge and skills leading to the unit standard:

Title: Optimise and integrate various farming systems and trends within related enterprises

US No: 116337 **NQF Level: 5**

Title: Plan and maintain environmentally sound agricultural processes

US No: 116320 **NQF Level: 4**

Title: Monitor natural resource management practices

US No: 116263 **NQF Level: 3**

The full unit standards are available and can be cited on the SAQA website. Read the unit standards at your own time and if there are any questions or aspects that you do not understand, discuss it with your facilitator.

The unit standards are some of the building blocks in the qualification listed below:

Title	ID no	NQF Level	Credits
National Diploma: Plant Production	49010	5	120
National Certificate: Plant Production	49009	4	120
National Certificate: Plant Production	49052	3	120

Assessment.........

You will be assessed during the course of the study (formative assessment) through the expected activities that you are expected to do during the course of the study. At the completion of the unit standard, you will be assessed again (summative assessment).

Assessment therefore takes place at different intervals of the learning process and includes various activities - some will be done before commencement of the program, others during the delivery of the program and others after completion of the program.

How to attend to the activities.......

The activities included in the module should be handed in from time to time on request of the facilitator for the following purposes:

- The activities that are included are designed to help gain the necessary skills, knowledge and attitudes that you as the learner needs in order to become competent in this learning module.
- It is important that you complete all the activities and worksheets, as directed in the learner guide and at the time indicated by the facilitator.
- It is important that you ask questions and participate as much as possible in order to be actively involved in the learning experience.
- When you have completed the activities and worksheets, hand it in so that the assessor can mark it and guide you in areas where additional learning might be required.
- Please do not move to the next activity or step in the assessment process until you have received feedback from the assessor.
- The facilitator will identify from time to time additional information to complete. Please complete these activities.
- Important is that all activities, tasks, worksheets which were assessed must be kept as it becomes part of your Portfolio of Evidence for final assessment.

Check your progress.......

Use the following checklist to determine your competency regarding this specific learning module.

Confidence level	I am sure	Still unsure	Do not understand and need help	Motivate your answer
Can you identify problems and troubleshoot correctly?				
Are you able to work well in a team?				
Are you able to collect the correct and appropriate information required for decision making?				
Will you be able to perform the observation expected in an organised and systematic way while performing your task as an extensionist?				
Are you able to communicate the information and newly gained knowledge well to experts?				
Can you base your tasks and answers on scientific knowledge that you have learned?				
Are you able to show and perform the activities required in this learning module correctly				
Are you able to link the knowledge, skills and competencies you have learned in this module of learning to specific duties in your job?				

How to use this guide ....

Throughout the learner Guide you will come across certain re-occurring notifications. These notifications each presents a certain aspect of the learning process, containing information, which would help you with the identification and understanding of these aspects. The following will be found in the learning material:

Study objective	What are the study objectives for a specific module? This provides an idea of the knowledge, skills and competencies that are envisaged to be
Activity	You will be requested to complete activities, which could either be group or individual activities. Please remember that the completion of these activities is important for the facilitator to assess, as it will become part of your ***Portfolio of Evidence.***
Definition	What does it mean? Each learning field is characterised by unique terminology and concepts. Definitions help to understand these terminology and concepts and to use it correctly. These terminology and concepts are highlighted throughout the learner guide in this manner.

My notes..................................

You can use this box to jot down some questions or notes you might have, concepts or words you do not understand, explanations by facilitators or any other remark that will help you to understand the work better.

What are we going to learn?

For each of the learning modules included in this learning area specific learning outcomes were set, which you need to be able to demonstrate a basic knowledge and understanding of.

Contents

Module 1

Soil-Plant-Atmosphere Continuum (SPAC)

Study objective

After completion of this module, the learner should be able to have a basic understanding of:

- The dynamics of SPAC
- How these hydraulic resistance and balances change with soil and

The *soil-plant-atmosphere relationship* recognizes that all components of the irrigation field environment (the soil, plant and atmosphere) when taken collectively form a physically integrated and dynamic system (Figure 1). The water movement inside the system is known as a soil-plant-atmosphere continuum (SPAC)[4]. Water generally moves from the soil to the plant and then into the atmosphere. When the soil is dry and the atmosphere is near saturation, water may move in small quantities from the plant into the soil[6,11]. The water flow through SPAC is complex with a series of resistances offered by different components of the system.

The flow path of water through SPAC is complex with a series of resistances offered by different components of the system. Traditionally, the treatment of soil resistances has been much more mechanistically based than the corresponding description of plant hydraulics. Although complex, the physical nature of flow through soil makes it more open to quantitative treatment than flow through the plant. Plants usually offer little resistance when the soil has enough soil water and the atmosphere conditions are moderate[10)]. When the soil dries, water deficits develop in plants and the stomata either close partially or completely. Under these conditions, plants offer great resistance to water movement[1)]. Plant resistance dominates the total hydraulic resistance of the continuum under moist soil conditions [1,2,4)]. Even under dry conditions when soil resistance increases the plant resistance also increases — thus continuing to exert a major influence on water movement even during drought[3,7,9,10,14)]. The content of the water in the soil affects the way the energy flux reaching the field is partitioned or utilized. The water balance and the energy balance are interchangeably linked, since they involve the same process within the same environment[15].

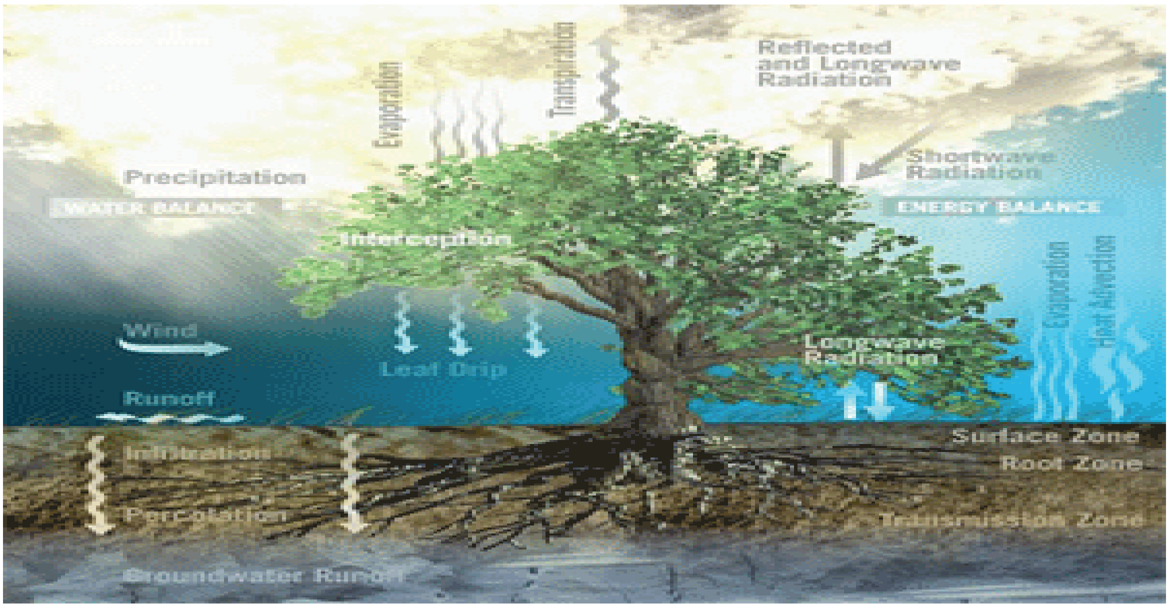

Figure 1. The soil-plant-atmosphere continuum[7]

Any attempt to control the quantity and availability of soil water to plants must be based on a thorough understanding and a quantitative knowledge of the dynamic balance of water in the soil – *the field water balance*. Irrigation management is not only about starting the irrigation system, letting it operate for a while and then turn it off again. The *field water balance,* like a financial statement of income and expenditures, is an account of all water quantities added to, subtracted from, and stored within a given volume of soil during a given period of time[10, 7,3)]. Various soil-water processes like infiltration, drainage, evaporation, water uptake by plants are in fact strongly interdependent, because they appear simultaneously or sequentially.

The field water balance is based on the *law of conservation of mass*, which states that matter can neither be created nor destroyed, but can only change from one state or location to another. Since no significant amounts of water are normally decomposed or recomposed in the soil, the water content of a soil profile of finite volume cannot increase without addition from the outside (as by infiltration or capillary rise) nor can it diminish unless transported to the atmosphere (by evapotranspiration) or to the deeper zones (by drainage)[4)].

The field water balance is intimately connected with **energy balance,** since it involves processes that require energy. The energy balance is an expression of a classical **law of conservation of energy**' which states that in a given system, energy can be absorbed from or released to the outside, and

along the way it can change from form, but it cannot be created or destroyed[4)]. The content of water in the soil affects the way the energy flux reaching the field is distributed and utilized. The water balance and the energy balance are inextricably limited, since they are involved in the same processes within the same environment. A physical description of the SPAC must be based on a good understanding of both balances together.

The evaporation process is often the largest component of the water balance, because most of the water added to the field is normally evaporated, and this therefore forms the principle consumer of energy in the field. Evaporation therefore depends in a combined way, on the supply of both water and energy[12)].

Field Water Balance

In its simplest form, the water balance states that any change that occurs in the water content (ΔW) of a soil profile during a specific period must equal the difference between the amount of water added to the soil profile (W_{in}) and the amount of water withdrawn from it (W_{out}) during the same period. When gains exceed the losses, the water content change is positive. However, when water losses exceed the gains, the water content change is negative. Therefore one can treat the soil volume of interest as a "bank account".

To understand this soil water balance better, one needs to understand the depletions and accumulations from the soil storage reservoir:

- Rain and irrigation water applied to a specific land may in some cases infiltrate the soil as fast as it arrives or it may pond over the soil surface. Depending on the specific slope of the field, a portion may exit from the area as *surface runoff*.

  Some of the water that infiltrate the soil, may evaporate directly from the soil surface, some is taken up by the plants for growth or transpiration and some may drain downwards beyond the root zone of the plant. The remainder may accumulate around the rootzone and adds to the soil water content.

  Additional water may reach the defined soil volume from either runoff form a higher area or by upward flow from a rising water table or from wet layers present at the same depth (capillary flow into the rootzone).

- To compute the water balance of a rootzone it can be expressed as:

Change in storage = Gains - Losses

$$(\Delta S+\Delta V) = (P+I+U) - (R+D+E+T)$$

ΔS = change in rootzone soil water content

ΔV = increment of water incorporated in the vegetative biomass

P = Precipitation

I = Irrigation

U = Capillary flow into the rootzone

R = Runoff

D = Downward drainage out of the rootzone

E = Direct evaporation from the soil surface

T = Transpiration by plants

**All quantities are expressed in terms of volume of water per unit land area during the period considered*

- The largest component of losses in the equation is generally *evapotranspiration (E+T)*. This can also be referred to as the potential evapotranspiration (E_{tp}), which represents the climatic demand for water. The *potential evapotranspiration* for a well irrigated field depends on:
  - The energy supplied to the surface of the field by solar radiation, which is a climatic characteristic of each location (depending on the latitude, season, slope, aspect, cloudiness, etc.)
  - It also depends on the atmospheric demand, which is related to the size and the orientation of the field and the nature of the upwind “fetch” of the surrounding area.
  - It also depends on the surface roughness and soil thermal properties (like for instance soil colour), which also vary in time[13].

The actual evapotranspiration (E_{ta}) is generally a fraction of E_{tp}, depending on the degree and density of plant coverage of the surface as well as on the soil water and root distribution. E_{ta} of a well growing crop and well watered field will approach E_{tp} during the active growing stage of the specific crop, but it may fall below it during the early growth stage prior to full canopy coverage, and again towards the end of the growing stage as the matured plants start to dry out[14)]. For the entire season, E_{ta} may total 60-80% of E_{tp}, depending on the water supply. The drier the soil water regime-the lower the actual ET.

- Another component of losses in the system is internal drainage. (D). Internal drainage out of the bottom of the root zone is important in terms of the field water balance. The function of drainage is to release excess water from the soil profile that may otherwise limit aeration and also to leach excess salts. In the absence of adequate drainage- water logging as well as salt accumulation occurs in the root zone.

An understanding of these balances and hydraulic resistances are fundamental to any treatment of the SPAC. Without knowing these resistances and how they change with soil and plant water content, the irrigator cannot understand and predict the response of plant water use to environment and irrigation.

The factors that determine the field water and energy balances (like evapotranspiration, evaporation, transpiration, water infiltration, radiation of energy, transport of heat and vapour into the atmosphere, and advection) are discussed in more detail in the learning material, but facilitators should pay special attention to ensure that learners understand the whole picture and where each of these factors fit into the dynamic balance of energy and water in the field.

Activity

Activity 1

Individual activity

1. Explain “soil-plant-atmosphere continuum” in your own words
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2. Define what you understand under the following:
   a. Energy balance
   b. Field water balance
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3. Which factors influence field water and energy balances?
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4. Define E_{tp} and elaborate on the factors that may influence it in an irrigation field.
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5. What do you understand with the concept "actual evapotranspiration (E_{ta})? Which factors influence E_{ta} of a well growing crop?
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My notes............

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