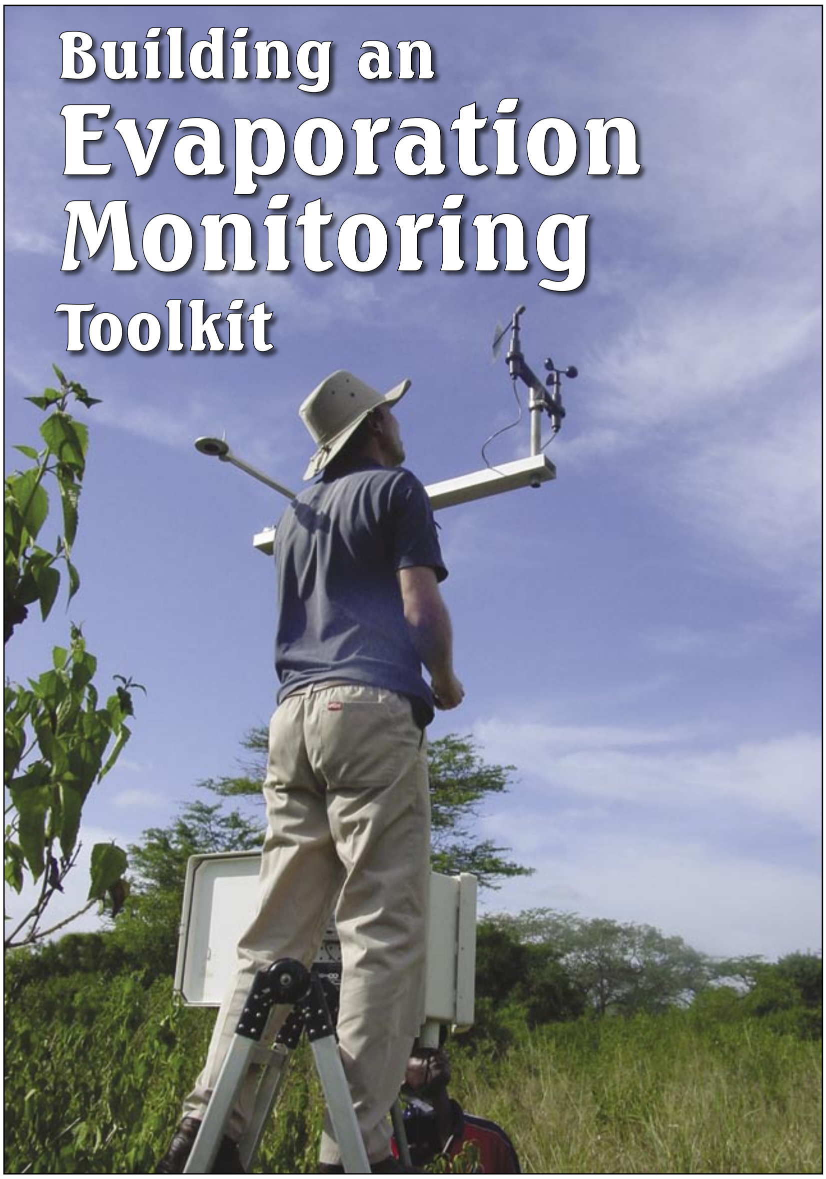
Building an Evaporation Monitoring Toolkit



Evaporation, one of the largest components of the hydrological cycle, remains one of the most challenging processes to quantify. Now a study funded by the Water Research Commission (WRC) is exploring ways of estimating evaporation with increasing precision. Lani van Vuuren reports.

The National Water Act, which proposes licensing of consumptive uses of water that result in streamflow reduction, implicitly requires that such uses be estimated with an acceptable degree of accuracy. Evaporation (including evaporation from open water surfaces, moist soil, wet foliage and transpiration by vegetation) is responsible for the majority of competitive uses of water, yet its exact quantification remains elusive.

Often required, evaporation estimation is usually estimated applying appropriate algorithms in numerical models in conjunction with the dynamic estimation of 'wetness' of evaporating media or surfaces through continuous simulation of the water balance. Most evaporation estimation techniques have been around since the 1940s, but only in the last 20 years or so has technology (including hardware and software) enabled these, together with more recent measurement techniques, to come into their own as reasonably affordable and practically applicable methodologies.

SUITE OF TECHNOLOGIES

The techniques applied in South Africa over the past two decades include energy balance, water balance and micrometeorological techniques, lysimetry, porometry, stem steady state and heat pulse velocity, cut stem technique, as well as semi-empirical and empirical methods. According to Dr Caren Jarmain of CSIR, leader of the WRC evaporation estimation project, the theoretical base of some of these techniques differs greatly.

In addition, these methods operate on different spatial and time scales. Time scales vary from two to 60 minute intervals or from daily or weekly intervals to longer time periods. They also differ in what they measure: evaporation, transpiration or evapotranspiration. "These issues of scale, difficulties relating to input data availability and problems of local validation may contribute to the lack of confidence in evaporation estimates," Dr Jarmain told *the Water Wheel*.

Achieving more accurate evaporation estimates is crucial. When using rainfall and evaporation estimates to deduce rates of surface runoff, streamflow and groundwater recharge, for example, a 10% error in evaporation estimates could easily translate to errors of 85% and 170% in streamflow and recharge estimation, respectively.

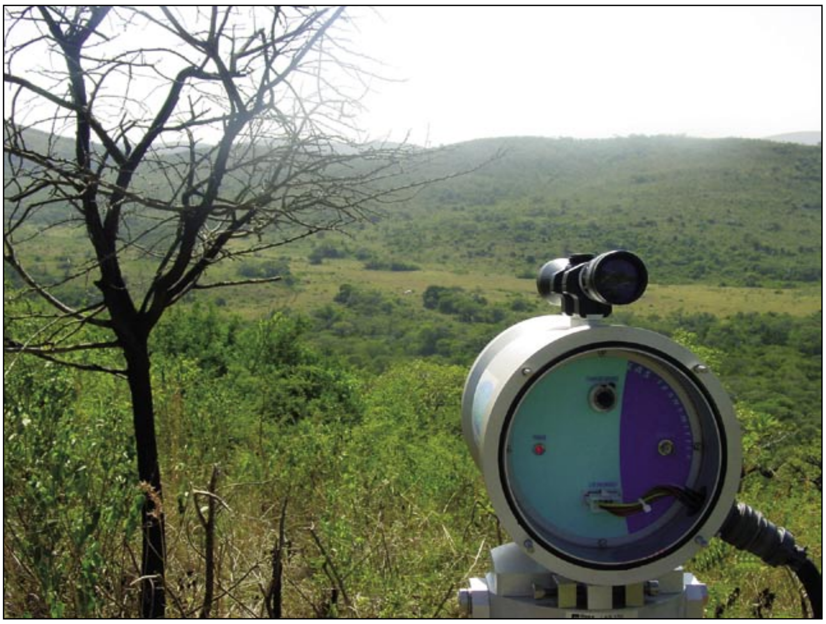
Dr Jarmain noted that it was not a question of whether a technique in itself was accurate or not. Rather the accuracy element lies in whether the technique has been applied correctly and under suitable conditions, as each technique has certain requirements that need to be met for accurate measurement.

A possible solution is the complementary use of modelling and measurement techniques. In this project, a collaborative effort between CSIR, the School of Environmental Sciences at the University of KwaZulu-Natal (UKZN), and the Department of Soil, Crop and Climate Sciences at the University of the Free State (UFS), different ways of estimating evaporation are being assessed, and the application of these to different land uses investigated. Ultimately, the project team hopes to develop and test guidelines on estimating evaporation accurately from different land uses or for different water resource management applications, in cases combining different technologies.

TESTING THE TOOLS

Initially, the project team used literature reviews and the results from an inception workshop to select land uses and vegetation types that could be used in the research. It was decided to focus on complex vegetation types, characterised by heterogeneous, species-rich and sometimes multi-layered vegetation.

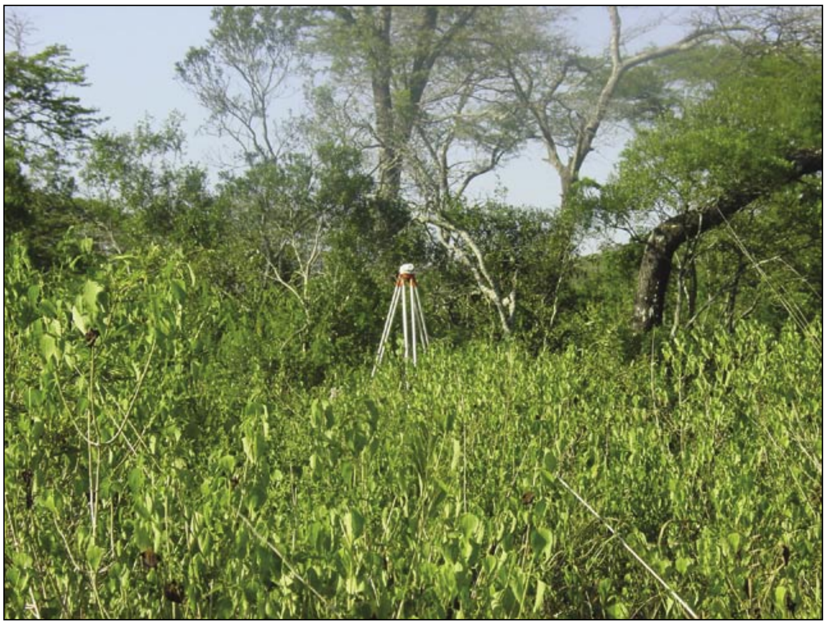
To date, three research sites have been used. The first is a tall riparian *Podocarpus falcatus* (yellowwood) plantation located in Limpopo, while the second is a young stand of *Jatropha curcas* trees as part of an agroforestry trial in KwaZulu-Natal. The third is a Coastal bushveld/ grassland infested with *Chromolaena odorata* (triffid weed or 'paraffienbos') stand also situated in northern KwaZulu-Natal.



The large aperture scintillometer receiver sensor installed above a mixed stand of Chromolaena odorata *and Coastal bushveld/grassland.*

Right: *Post-graduate students Michael Mengistu of the University of KwaZulu-Natal and Angelo Mockie of the University of the Free State install a RM Young sonic anemometer on to a mast at the* Chromolaena odorata *site in the Hluhluwe Nature Reserve.*

Several methods are being applied at each site, including eddy covariance (a method measuring water vapour, carbon dioxide and heat flux); surface renewal (measuring the change in heat content of air by expressing evaporation as the change in the heat energy content of air with time per unit area); sapflow measurements (using the heat pulse velocity technique); and scintillometry (measuring atmospheric optical disturbances or



The surface layer scintillometer for the first time ever in South Africa installed above a complex vegetation type in South Africa: a Chromolaena odorata *and Coastal bushveld/grassland mix in the Hluhluwe Nature Reserve.*

Most of the equipment requires high frequency measurements. Data is either stored on a datalogger, laptop or desktop computer. Seen here are the desktop computer and other electronics controlling evaporation measurements by the in situ *Flux eddy covariance system.*

TERMINOLOGY

Evaporation: This is the physical process by which a liquid or solid is transferred to the gaseous state.
Transpiration: This can be defined as evaporation of water that has passed through the plant. Transpiration comprises vaporisation of liquid water contained in the plant tissues and vapour removal to the atmosphere.
Total evaporation: This can be defined as the total process of water movement into the atmosphere. Soil surface evaporation and transpiration occur simultaneously and are determined by the atmospheric evaporative demand, soil and canopy characteristics. Also referred to as **evapotranspiration**.

scintillations caused by fluctuations of the relative index of air).

In the near future the team will also be undertaking field work in a grassland or shrubland and at a species-rich tree site. As part of this study the team will investigate a method for determining heat storage within tree canopies, which is normally not accounted for in the shortened energy balance equation used in several evaporation estimation techniques. Field work will also be carried out at a sugarcane site, where the team will have the opportunity to test micrometeorological techniques against lysimeters, providing an independent measure of evaporation.

"Based on the results from the present project's field work, combined with results from research conducted over the last 20 years around evaporation estimation we will develop an expert system aimed at aiding in the selection of the correct technique for an application, the correct use of the technique as well as rigorous data analysis," said Dr Jarmain.

According to Dr Renias Dube, research manager at the WRC, this project will improve the quantification of evaporation in most hydrological models as well as water resource assessment models. "Evaporation is currently one of the most poorly quantified components of the water budget," he noted.

Due to the lack of expertise in this specialised field in South Africa the project also features a strong

Gill Sonic anemometer and Li-Cor gas analyser (dominant white, left) as part of an eddy covariance system installed at the top of a telescopic mast at the Podocarpus falcatus *research site in Tzaneen, in addition to the thermocouple and net irradiance sensors (right).*

A telescopic mast is used to install the equipment high enough above the Podocarpus falcatus *canopy at Tzaneen. Here project team members Drs Colin Everson, Caren Jarmain and Peter Dye can be seen in action, mounting sensors to the mast.*

capacity building focus. Post-graduate students from the universities of KwaZulu-Natal and the Free State have been involved in the field work under the supervision of Prof Mike Savage, head of UKZN's School of Environmental Sciences and Prof Sue Walked from UFS. In addition, a University of Zululand Honours student, Dumisani Shezi, has been appointed as an intern to the project and is registered for an M.Sc degree at UKZN. Two training workshops around evaporation estimation technologies and terminologies have also been presented to date.

The research project should be completed in 2008.

- For more information, visit the project website, http://fred.csir.co.za/extra/project/evapmon/

EVAPORATION MEASURING TECHNIQUES

Scintillometer: This is a scientific device used to measure atmospheric optical disturbances called scintillations, which are caused by fluctuations of the refractive index of air. The air's refractive index is influenced by temperature, humidity and pressure. The device thus allows measurements of the transfer of heat between the Earth's surface and the air above it called the "sensible heat flux". Both the large aperture scintillometer and surface layer scintillometer have been used in South Africa.

Lysimeter: This device collects water from the pore spaces of soils and determines the soluble constituent removed in the drainage. A lysimeter is often regarded as the standard for evaporation measurement.

Eddy covariance: This is a statistical method measuring water vapour, carbon dioxide and heat flux.

Surface renewal: This method involves measuring the change in heat content of air by expressing evaporation as the change in the heat energy content of air with time per unit area.

Cut-stem technique: This is mainly useful for determining the transpiration from a single tree or part of a plant. This technique has been applied mainly in forestry.

Empirical methods: Many empirical and semi-empirical methods exist for estimating evaporation, mainly from bare soil. Of these the Penman-Monteith method is the most well known.

Sonic anemometry: Measures wind speed via sound pulse travel-time differences.