Determining the water use of indigenous trees used to rehabilitate riparian zones

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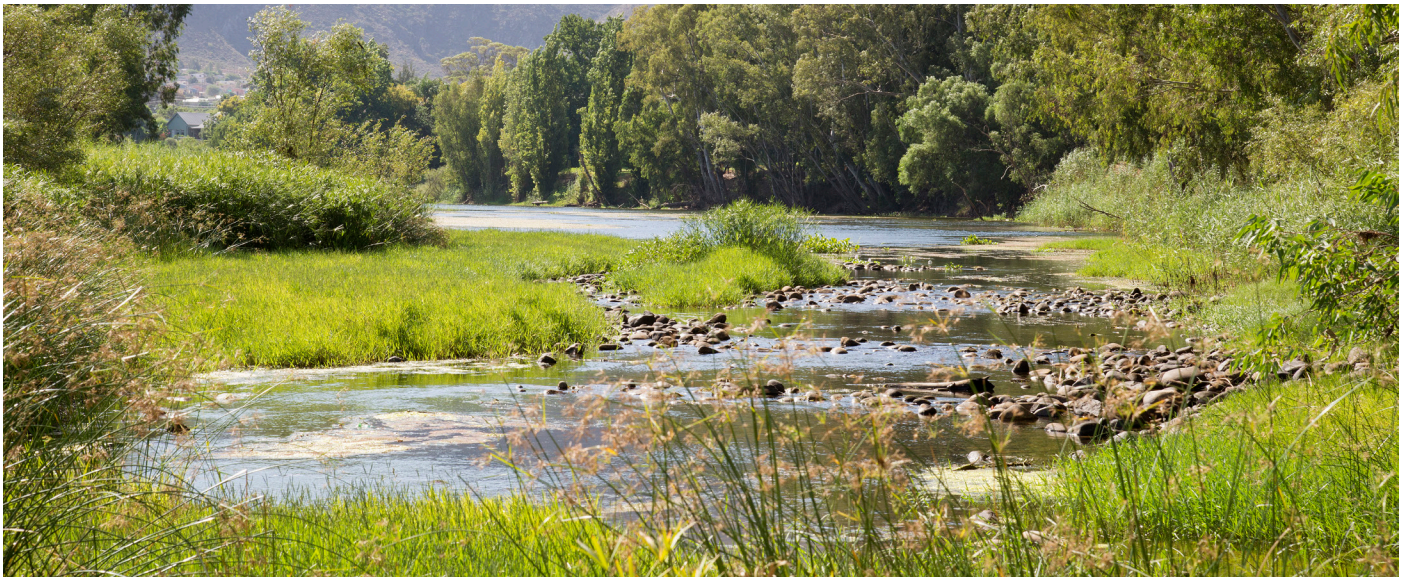
A newly-completed Water Research Commission (WRC) study has provided crucial knowledge and guidance on the rehabilitation of alien invaded riparian zones and catchments using indigenous trees.



Background

Natural forests are receiving worldwide recognition as it has the potential to make an impact in many diverse areas such as poverty alleviation, global climate change, carbon sequestration, tree domestication and payments for environmental services. Trees can be used for catchment rehabilitation and riparian zone management as well as to combat global climate change. In order to use trees for these purposes it is necessary to find alternatives to the use of fast growing exotic tree species which are high water users.

A common practice to facilitate indigenous forest recovery after removal of alien trees is through selective thinning of the invader plant stand to stimulate the growth of natural forest seedlings. An alternative is to plant relatively fast-growing indigenous forest pioneer and early regrowth species to promote establishment of late successional species.

The question then is whether these indigenous species use less water than the fast growing invader plant stands? There is a widespread belief in South Africa that indigenous tree species, in contrast to the exotic trees, are water efficient and should be planted more widely in land restoration programmes. This is based on observations that indigenous trees are generally slow growing, and that growth and water-use are broadly linked. However, tree water-use is technically difficult and expensive to measure, and so there is scant evidence of low water-use by indigenous trees.

This is even more so for pioneer tree species more suited to the rehabilitation of degraded lands and those found re-colonising riparian zones previously invaded with exotic trees (e.g. wattle). The main aim of this project was to investigate the water-use (transpiration rates) of a selection of pioneer indigenous tree species suitable for forest expansion, rehabilitation programmes and riparian zone restoration following invasive alien clearing or manipulation.

The project had two main components – a hydrological component to compare the water use of indigenous tree species versus introduced tree species; and an ecological component to determine how natural forest species become established within invader plant stands.

Methods

Various climatic regions were considered for this study. The following sites were selected: Western Cape Afro-temperate forest (Buffeljagsriver), Eastern Mistbelt Forest (New Forest) and Maputaland Coastal Belt (Vasi pan). The selection of priority species for this project was motivated by a combination of expert advice (workshops), gaps in past research, and a short-list of species selected based on a previous WRC study into the water-use and economic value of the biomass of indigenous trees (WRC project no. K5/1876).

The primary aim was to select species that occurred in the forest biome and over various climatic regions. In addition to plant water-use measurements, additional information on the size and age of both the alien and indigenous trees were collected in order to compare both within and between the different tree species. Measurements included height and diameter as well as soil moisture, rainfall, temperature and relative humidity in order to support the sap flow measurements.

To determine the ecological objectives, the study conducted intensive sampling of both natural forest and invasive alien plant stands at all three sites. In addition the project conducted intensive measurements of individual tree water-use using heat energy balance techniques, weather variables, soil water dynamics as well as modelling the

potential impact of the rehabilitation of invaded riparian ones using the SWAT and ACRU hydrological catchment models.

Main results

This study provided long-term water-use for three different forest types, each at differing levels of rehabilitation.

Water use of indigenous trees

The results showed that indigenous trees in an established riparian stand in a Western Cape Afro-temperate forest can use high volumes of water throughout the year (little seasonal rainfall change in this region). The variability of water-use between species and tree size was large as this variable is largely dependent on location, tree condition and light dynamics.

This further highlights the need for measurement replication. The comparison between individual trees indicated that the largest trees (***Celtis*** and ***Vepris***) used the most water. However, when extrapolated by stem density, the alien species (***Acacia mearnsii***) used significantly more water per unit area (up to five times more water in certain stand locations).

The modelling results revealed that a significant amount of water can be conserved if alien invaded forest stands are rehabilitated. Of particular importance, during the wetter season (May to August), the deciduous trees in the winter rainfall region were not using any water. This is in contrast to the deciduous species in the Eastern Mistbelt region and the Maputaland coastal belt that are dormant during the dry season when water is most scarce.

In the Western Cape area, it is recommended that evergreen species be used for forest rehabilitation as they use less water than the deciduous trees during the drier months when water is needed the most.

The results for the Eastern Mistbelt forest, which had a highly disturbed/invaded stand, showed very low water-use volumes in comparison to the Western Cape site. The alien species used significantly more water than the indigenous species, which had approximately the same stem density in the measurement area.

A key finding from this site was that the smaller trees (up to 2.5 m) in the understorey of pioneer species such as ***Buddleja*** (indigenous), ***Solanum*** and ***Acacia*** (introduced) used up to four litres a day individually. It is recommended that deciduous species in addition to low consumptive evergreen species be used for forest rehabilitation as they use very little water during the drier winter months when water is needed the most.

The results from the Maputaland Coastal belt revealed that the alien species (***Eucalyptus grandis*** and ***Pinus elliottii***) used significantly more water than the short forest that it invaded. A key recommendation for this site is that more detailed research be undertaken given the environmental, political, social and hydrological importance of the site.

Although modelling was not the primary focus of this study, unique input attributes for mixed riparian forests were derived for the ACRU and the SWAT models. This is an important step forward for future modeling (upscaling) as it allows users to accurately model these riparian systems that have constant access to water.

The SWAT model is not commonly used in South Africa as the input parameters are not easily available nor are they easily transferable from one model to another. This model was run successfully using entirely site specific inputs and used to test various scenarios at each site. The model showed that it has the potential to provide a powerful tool for understanding the impact of various land-use scenarios.

Regeneration of natural forests

The study investigated the influence of alien plant stand conditions (i.e. distance from seed source) and the development processes (i.e. cluster expansion) in which forest growth occurred. This challenged the perception that invasive plants nullify the capacity of native species to grow within invasive alien plant (IAP) vegetation systems.

There were two distinct ways in which natural forest establishes within alien plant stands, namely edge expansion and cluster development. Importantly, the study found that clusters (which contained mature individual trees) were self-regenerating and thus did not require the seed source from the initial forest patches to expand.

The New Forest study investigated how invasive plant stand structure might affect the establishment of the natural forest. The study showed that the IAP stands which were sampled were self-thinning, i.e. their density decreased with an increase in the age or mean stem diameter of the stand.

This finding supported the theory outlined in the knowledge review of the project. Analysis of the results indicated that distance may have had a stronger influence on forest development than IAP stand structure.

It is important to understand the genera of plant species within the forest, particularly with reference to the characteristics of the dominant pioneer species. Some species functioned as both pioneer and old growth forest species, e.g. ***Celtis Africana*** and ***Rapanea melanophloeos*** (Cape Beach) which were recorded as dominant pioneer species and old growth forest species at New Forest and Buffeljagsrivier.

Such species become established in large gaps or degraded forest and then persist into the canopy where they then nurse the regeneration and establishment of more shade-tolerant forest species. This trend was also noted at Vasi Pan, for example, with ***Hymenocardia ulmoides*** (Redheart Tree).

From a hydrological perspective, understanding the water-use of such widespread species would be important for choosing suitable species for regeneration programmes. The study showed that the forest expansion processes (i.e. edge expansion and cluster development) were similar throughout the three study sites. The study revealed the dominant pioneer genera within each site, and where they are most likely to occur during the forest development process.

This is critical from a water-use perspective as these data can be synthesized with the hydrological data and incorporated into models of the water-use for riparian catchments. The conversion from invader plant stands into natural regrowth forest is a process which can occur naturally, but can also be facilitated by manipulation to benefit the developing natural forest.

Guideline document

A practical guideline document was provided as part of this project to guide natural resource managers on this process. The guideline document provides insights into the ecological and hydrological findings of the study. It then provides guidelines for forest regeneration through IAPs and nurse stands.

- The document deals with the following components of a regeneration plan:
- Initial planning
- Mapping the vegetation by potential land use management categories
- Developing specific management guidelines by vegetation zones
- Finding agreement between relevant stakeholders on a plan of action
- Implementation of relevant regeneration actions
- Monitoring

Further reading:

To obtain the report, *Rehabilitation of alien invaded riparian zones and catchments using indigenous trees: An assessment of indigenous tree use Volume 1 (Research Report)* (**Report No. 2081/1/16**), and *Volume 2 (Guidelines Report*) (**Report No. TT 677/16**) contact Publications at Tel: (012) 761 9300, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy