



What happens to soil water when savannahs burn?

A recently published study provides valuable insight into the relationship between water and fire in savannah landscapes. Article by Petro Kotzé.

Typically, the iconic savanna landscape is one of rolling grasslands scattered with shrubs and isolated trees. About 20% of Earth's land surface is covered by savanna, most of it in Africa. African Savanna make up 35% of South Africa's land area, but the most iconic representation of this landscape is probably the world-renowned Kruger National Park (KNP).

The savanna landscape is a complex one. Its structure and production are controlled by the availability of water over space and time, but fire, nutrients and herbivory are regarded as further primary drivers that control this dynamic system. Among these, fire is used extensively as a management tool in the

KNP in order to achieve the park's various ecological objectives. As such, research objectives are often geared towards finding out what type, frequency and intensity of fire should be implemented for the most ideal results, says Skukuza based fire ecologist, Navashni Govender, SANParks Programme Manager: Fire Ecology and Biogeochemistry.

There is a long history of fire research in the park, and experimental burning plots (EBPs) have been operated since the mid-1950s. Yet, a topic that has not received much attention in the KNP is the impact of long-term fire management on soil hydrology. This is particularly important for scientists and managers to understand in a fire driven landscape as is found in this park, and even more so in light of climate change and bush thickening.

Work that was done in the EBPs by Mills in 2003 showed that there was capping or soil crusting taking place with more frequent fires, says Govender,

but these soil samples were taken to a laboratory for analysis. “We wanted a field study. There was a big gap in our understanding of fire and soil properties,” she says. Consequently, the KNP’s scientists wanted to find out how fire should be varied over different soil types and rainfall zones, and what effect this would have on the soil properties, infiltration and run-off.

Govender and Dr Eddie Riddell, Manager: Water Resources, Kruger National Park, then applied for, and received, funding for such a project from the Water Research Commission (WRC). SANParks Junior Scientist, Tercia Strydom, subsequently completed her Masters on the project, through and with support from fellow Honours student, Thomas Rowe, at the Centre for Water Resources Research at the University of KwaZulu-Natal.

The resulting WRC report, ‘Pyrohydrology in African Savannas’ was published by the WRC late last year. It is the first time that the impact of fire on the hydrology of an African savanna has been documented. The results not only provide practical recommendations to the park’s existing fire management plan, but also valuable insight into the interaction between water, fire, soil, vegetation and herbivores within this complex system.

SETTING UP THE EXPERIMENT

In a very large nutshell, Kruger is divided into two main geologies, namely granite and basalt. The western half of the KNP is dominated by granite and gneiss soils, while the eastern half is dominated by nutrient rich basalt soils. A narrow band of Karoo sediment runs along the junction.

A concern on the basalts is the loss of large trees and forage, and fire is thus reduced in order to give vegetation the opportunity to escape the fire trap. On the granites, bush thickening is a concern, and hotter and more frequent fires are applied to combat this, says Govender. The EPB’s are spread over these landscapes, across high-rainfall and low-rainfall areas, as well as in a wilderness fire zone which is allowed to burn naturally.

The EBP’s are so well established, that there is a lot of data to work from, says Strydom, and they were thus employed for this study as well. The bigger question was unpacked in a number of objectives. Firstly, to understand the effects of varying long-term fire treatments (annual vs. no burn vs. a variable fire regime) on soil hydraulic properties on basalt and

Fire used extensively as a management tool in the Kruger National Park.



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granite. Secondly, to investigate the effects of long-term fire treatments on surface runoff and sediment yield. A last objective was to determine the effect on soil water balances.

From May 2012 to December 2013 the soil hydraulic properties in the EPBs were determined by measuring hydraulic conductivity at the soil surface and between 2 and 7 cm of the soil surface. Soil compaction was determined and organic matter (total carbon) measured. The water retention capacity was inferred and vegetation characteristics such as grass biomass and basal cover were measured.

Different rainfall intensity simulations were constructed in order to measure the effect of different fire regimes on surface runoff and sediment yields.

Below: Post-graduate students, Tercia Strydom and Thomas Rowe measuring runoff by simulating rainfall events in the field.

Bottom: Tercia Strydom measuring soil infiltration rates using an infiltrometer.



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The subsequent surface runoff was measured and sediment collected for analysis. The soil water balances on the different burn plots were measured by using remote-sensing analyses, which allowed researchers to determine evapotranspiration rates and water balances for the different fire regimes.

DOES FIRE AND SOIL WATER MIX?

The main finding was that soils are capable to recover relatively soon, says Strydom. “We were quite amazed to find no difference between the soil properties of plots that burned fifty years ago, and those that burned three years ago.” However, she notes, “This makes sense. This is how these systems have evolved.” Natural savanna systems would burn every four to seven years, which would give the soil enough time to recover between fires.

The study revealed that the slowest infiltration rates took place immediately after a fire, and that this was most noticeable at the soil surface. These effects would dissipate within approximately two-and-a-half years. So, the effect of fire frequencies on soil hydraulic properties was found to be negligible considering that it is actually the times following a fire which plays a significant role.

Strydom says another interesting finding was the relationship between soil compaction, fire and herbivores. The more compact soil is the less water can infiltrate. While herbivores have a direct impact on this when they trample over soil, fire contributes indirectly. When the soil is burnt bare, it is more exposed to elements such as rain, leading to raindrop impact and splash and compacting soil at the surface. If herbivores trample over the soil, it was compacted deeper down.

Another important facet for researchers to understand was the soil’s water holding capacity. The effect of fire on this is integral to understand seeing as it is essential in order for the veld to recover after a fire. While fire intensities are probably not substantial enough transfer heat deep into the soil and consume organic matter on the granite plots, it is believed that the huge contrast in above-ground biomass between the basaltic burn plots is responsible for the contrast in organic matter contents in the soil. As organic matter retains water, soil water retention was found to be the best on plots with no fires.

It was also concluded that long-term fire management undisputedly affects the amount of runoff generated

Shaping a science career with the helping hand of the WRC

Tercia Strydom was thrown right from the deep blue sea into the deep end when she started her career at SANParks, having to move out of her parental house in Cape Town “to the middle of nowhere” when she was accepted in the SANParks Junior Scientist Programme. This is an initiative to train, empower and mentor young scientists from previously disadvantaged groups. It allows students the opportunity to work with SANParks Scientific Services and gain practical experience while studying full-time.

She completed her undergrad studies at the University of the Western Cape in Environmental and Water Science. This was followed by her Masters in Hydrology through the University of KwaZulu-Natal's Centre for Water Resources Research, relocating to the Kruger National Park for the project. “It took me three months to realise that I don't want to go back to the big city,” she says. Funded by the WRC, Strydom has now completed her Masters on pyrohydrology in African savannas, the first on the topic.

Yet, the achievements do not stop there. She was recently invited by the WRC to speak at the launch of the prestigious book, *Celebrating Twenty Years of Excellence in Water and Sanitation Research in South Africa*, which reflects on and conceptualises the last 20 years of research within the water and sanitation domain.

To *the Water Wheel*, she lists the “incredible” freedom that she was given by her supervisor, Dr Eddie Riddell and SANParks coordinator, Navashni Govender. “Initially I was overwhelmed, but I learned that I was capable of things that I didn't think I could do.” She says that she has learnt that it is important to give students enough freedom while you are nurturing them, as they are likely to take on more challenges that way. “Supervisors should not be afraid to give us more scope to find ourselves,” she says.

She also lists her time in Kruger as a high point. The amount of time you spend doing your



research is much greater than if you are at a university, and you are surrounded by scientists that have done it all before,” she says.

She is, however, not done with Kruger yet. Strydom recently located to the park's Phalaborwa office for her PhD, again with the support of WRC funding. Her work will entail monitoring where water gets 'lost' in the Letaba River from where it is released from the Tzaneen Dam until it reaches the Kruger National Park.

The river's flow is measured in Kruger, and when it gets too low to meet the Reserve, operators in Tzaneen release more water from the dam. The amount of water that needs to be released is worked out according to the SPATSIM model, yet, when it reaches the park, it is not enough. Transmission loss is estimated to be as much as 30%.

“So, where is it going?” asks Strydom. Scientists will be investigating if it is natural loss, to the riparian vegetation and groundwater for example, or due to extraction by small-scale farmers next to the river. “Once we know how much water naturally gets lost, the dam operators can compensate,” she says.

“The study results not only provide practical recommendations to the park's existing fire management plan, but also valuable insight into the interaction between water, fire, soil, vegetation and herbivores within this complex system.”

from the savannas of the KNP. This is due to a number of factors. The frequency of fires will affect the amount of water lost through vegetation (via evapotranspiration). Reduced vegetation cover will also result in less rainfall interception and thus exposing

the soil surface to direct raindrops which, as mentioned, inhibit infiltration because soil is compacted. Less vegetation cover is believed to be responsible for the increased runoff rates observed on the annual burn plots in the granitic region of Pretoriuskop.

In conclusion, the impact of fire on soil water balances was found to be significant in both the granitic Pretoriuskop area, characterised by sandy soils and higher rainfall, as well as the basaltic Satara area, characterised by clayey soils and lower rainfall.



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Top right: The Limpopo River forms the border between the Kruger National Park and Zimbabwe. Questions are now being asked about the impact of fire on catchment processes.

Middle right: Measuring hydraulic conductivity in the field.

Below: Charred soil providing evidence of veld burning.



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These impacts may have knock-on effects on large-scale catchment processes. “Even though what we measure might only be on a plot scale, it automatically has a cascading effect,” reports Strydom. You might have more runoff after a fire because water is not infiltrating. This runoff will go into a stream and into a larger river, as a result of the fire. Because water moves, the impacts are bigger.”

THE IMPLICATIONS FOR MANAGEMENT

A recommendation from this study is that management must actively ensure that the veld does not burn as often as every two years, says Govender. Soil properties require a minimum of two years to return to pre-fire conditions on both the granitic and basaltic regions of the park in order to ensure that catchment hydrological properties are not adversely affected by unsuitable burning regimes. She adds that management must also consider the trampling effect on infiltration, and the impact of different intensities of rain and run-off on possible erosion.

An interesting element to keep in mind is that the loss of water through transpiration and evapotranspiration has an impact on water delivery in catchments, says Govender. How then, would bush densification effect this, and how must fire be used as a management tool?

According to the final report, these results could need to be extrapolated and confirmed at a catchment scale, considering that the park management policies are designed for large-scale areas. A further recommendation is that they work in fire catchment zones, instead of fire management zones. “Even though it would seem quite impractical in a place like Kruger, it is something that we must think about,” notes Govender.

Accordingly, they have already started a project to look at the landscape across ‘supersites’ – large areas across granite and basalt geologies and low and high rainfall areas. According to Govender, “we need to upscale to understand what is happening in the landscape over a larger area.”

To order the report, *Pyrohydrology in African Savannas* (Report No. 2146/1/14) contact Publications at Tel: (012) 330-0340; Fax: (012) 331-2565; Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a digital copy. 