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The WRC operates in terms of the Water Research Act (Act 34 of 1971) and its mandate is to support water research and development as well as the building of a sustainable water research capacity in South Africa.

TECHNICAL BRIEF

Water and environment

Improving restoration of alien invaded riparian areas

A completed WRC-funded project sought to identify relationships between soil processes and biodiversity to improve restoration of riparian ecotones invaded by Black Wattle.

Background

Riparian zones exist at the nexus of high resource availability. High disturbance within these landscapes can severely affect hydrological ecosystem services.

In addition to natural disturbances, such as floods, fires and droughts, several anthropogenic stressors can affect riparian zones. In the fynbos biome, these stressors can range from impoundments, habitat destruction, urban development, agricultural activities and alien invasive species.

In the Western Cape, as in other parts of South Africa, the Australian tree *Acacia mearnsii* (or Black Wattle) has displaced many native riparian plants in some upper, but many middle and lower reaches, establishing populations with high stand density, which regenerate quickly following a natural disturbance, such as fire.

Where stands of *A. mearnsii* have established, evapotranspiration has been shown to be higher than where native riparian scrubs and forests are found, prompting a major restoration initiative, the Working for Water programme, which aims to clear the invasive species from riparian ecotones.

The Wit River, which is highly invaded by A. mearnsii.

Motivation for WRC-funded study

Thus far little information is available on the impact of invasive *Acacia* species in fynbos riparian ecotones on ecosystem function as it pertains to nutrient cycling and soil processes, some of which are central to riparian ecosystem services. Furthermore, it is unknown whether soil chemistry and processes return to pre-invasion levels after removal of the alien invasive *Acacia* species from fynbos riparian ecotones.

One of the objectives of the Working for Water programme is to clear riparian zones of invasive tree species, such as *Acacia*, which takes place with the expectation that both vegetation structure and ecosystem function will recover following clearing. However, while vegetation structure recover in some instances, it remains unclear whether ecosystem function will also recover.

The main objective of this project, therefore, was to investigate the impact of the invasive *A. mearnsii* on nitrogen (N), carbon (C) and phosphorous (P) stocks and cycling, as well as its impact on the soil bacterial and fungal communities structure within fynbos riparian ecotones and nearby upland areas.

The project sites were located mostly in upper reaches of catchments, which were dictated by the availability of reference sites. The project team also investigated the relationship between riparian soil processes and soil and plant diversity in pristine, invaded and cleared ecotones in order to improve the strategies for riparian repair after removal of alien invasive *Acacia* species.

Finally, aspects of N, C and P cycling were compared in soils at the main sites in the Western Cape, with measurements at sites in the southern and eastern Cape.

Major results

As the project team chose invaded sites in the Western Cape with *A. mearnsii* cover, both seeding and adult *A. mearnsii* cover was significantly higher in invaded compared to natural riparian ecotones. Cleared riparian ecotones had significantly lower *Acacia* cover, as can be expected from riparian ecotones where clearing operations are active and initial clearing has been followed up repeatedly.

In contrast, grass cover (especially in dry banks) increased in cleared sites, a trend which has been observed before in other studies. The grass species that were prominent in cleared riparian ecotones were *Briza maxima*, *Ehrharta calycina* and *Pennisetum clandestinum*. The project objectives only pertained to structural aspects of plant diversity; hence other aspects of plant biodiversity were not fully investigated.

Results were obtained from soils sampled from the first 10 cm of the topsoil of the sites in the Western Cape. Several soil properties were measured over the course of one year, while other properties were only measured once or twice over the course of one year.

Soils showed significant differences between sites with different invasion statuses, with lower coarse sand content in invaded areas. However, the content of finer material (silt and clay) was not significantly different between sites, with different invasion statuses.

As expected, gravimetric soil water content differed between different landscape positions, and seasonal interactions were apparent and prominent. The most prominent difference emerged in electrical conductivity where invaded riparian ecotones had significantly higher electrical conductivity compared to natural riparian ecotones.

One of the processes influenced by soil physical and chemical properties is N cycling. Nitrogen stocks were elevated in invaded riparian wet banks, and showed a trend towards the natural state when Acacia species were removed. Dry banks in the natural state did not show any differences with wet banks and terrestrial areas, which does not support the expectation that riparian topsoil is enriched in N and other nutrients.

In cleared riparian ecotones, especially dry banks, available N remained high more than seven years after removal of invasive Acacia species. Available N is the only soil property that remained relatively high after removal of alien species, and at the same time, riparian dry banks also showed high grass cover, especially the grass species *B. maxima*, *E calycina* and *P. clandestinum*, as noted above.

Available P was measured in riparian soils in natural, invaded and cleared riparian environments and uplands. Available P did not show significant differences when expressed by invasion status, however, wet banks had lower P concentrations than dry banks and terrestrial areas when the data was pooled over seasons.

While available P did show some trends, more prominent differences emerged from analysis of acid phosphatase monoesterase (APME), an enzyme that can derive from plant roots or microbes, and is involved in transformation of organic P to available P. The presence of high APME is associated with low soil P availability to plants and microbes, and this suggests that APME may be a useful index of P.

Thus under invasive alien *Acacias* APME was expected to be high as P plays an important role in N fixation, hence is in high demand. Following this reasoning, invasion of usually low P fynbos riparian soils by N fixing woody species, any available P is taken up quickly by *Acacia* roots.

Indeed, in dry banks invaded by *Acacia* species, APME activity was double that of the comparative landscape position in natural riparian ecotones, and APME activity declined upon removal of the *Acacia* trees.

Parallel with N, soil total C concentrations were significantly higher in invaded dry banks, and were significantly lower in the wet bank compared to other landscape positions. Invaded dry banks also had higher soil respiration rates compared to natural and cleared riparian ecotones.

When *Acacia* individuals are removed from wet banks the soil respiration rate declined significantly. In fact, there were little differences in *in situ* soil respiration rates between natural and cleared riparian ecotones.

To answer the question of what drives soil respiration rates, especially in invaded dry banks, a small experiment was conducted where intact blocks of soil were trenched. Trends showed an immediate decline in soil respiration (first two seasons), although it later bounced back.

This does suggest, although it does not prove, that root respiration may be involved in the higher soil respiration rates in invaded riparian ecotones. The lack of differences between trenched and control plots later on may be due to elevated root decomposition.

Further support for this is found when soils, minus roots were incubated in the laboratory at constant temperature and moisture (potential soil respiration). Few differences were found between incubated soil from sites with different invasion statuses or landscape positions, suggesting that soil microbial activity is not the major driver of the higher *in situ* soil respiration rates in *Acacia*-invaded riparian dry banks.

Overall, soil bacterial diversity (Shannon diversity index) changed with invasion by *Acacia*. The Shannon diversity index was significantly lower in the invaded wet bank zones. The effect of the alien species on the bacterial diversity could thus only be observed within the wet bank, showing the influence of the river on structural differences between bacterial communities.

Soil bacterial and fungal diversity were driven by different soil properties. The soil bacterial community structure was driven by soil pH, and to a lesser extent, particle size and soil available P. It was noted during analyses for soil N dynamics that soil particle size was also important for N cycling. This suggests an important role for soil texture in riparian processes and soil microbial diversity.

When comparing sites in the southern and eastern Cape on the one hand, and the Western Cape sites on the other, some differences emerged. Denitrification enzyme activity appeared to show higher rates in invaded areas, compared to the natural and cleared riparian ecotones. This difference may be the result of differences in soil properties, however, little difference was found in physic-chemical soil properties when comparing the two regions.

Conclusions

The results point to changes in soil properties, soil processes and soil microbial diversity when invasive *Acacia* species establish in large numbers in fynbos riparian ecotones. Like the adjoining fynbos, topsoils of these mountain stream and mountain stream transition zone riparian ecotones are relatively nutrient poor.

However, with invasion, soil total N and total C increase, though not to the same magnitude that has been found in terrestrial sites in other studies. Invasion also affects soil processes – N availability increases, soil C efflux increases and soil phosphatase activity increases. Along with these changes in soil processes, the underlying microbial diversity also changes in terms of diversity and structure, though bacterial and fungal communities show different trends, and also different relationships with soil physico-chemical factors.

When the *Acacia* spp. are removed, soil properties, soil processes and soil microbial diversity recovers, suggesting that ecosystem function, as it pertains to these aspects also recover. A legacy effect does exist – soil available N levels remain elevated in cleared riparian ecotones. This may provide an opportunity for nitrophilus grasses to establish and thrive in these cleared riparian ecotones. The soil microbial community seems to be relatively resistant to invasive alien species and removal of these species.

The results support the contention that removal of *Acacia* species may assist in restoration of riparian ecotones. Major changes in soil functioning take place with or after invasion of riparian ecotones with exotic species, and these changes may impact ecosystem service delivery.

While plant structure and diversity have not been studied to a great extent in this research, aspects of ecosystem and soil function that received attention suggest a trajectory after removal of *Acacia* species back towards the natural state – an additional motivation for removing this alien invasive plant from watercourses.

However, more than seven years after removal of Acacia species, legacy effects still remain. These legacies (e.g. high available N) need to be carefully considered in managing clearing and follow-up activities. This may involve active treatment of certain areas to speed up removal of residual N and other resources that may be utilised by nitrophilous and other opportunistic plant species that may form persistent secondary invasions in riparian environments.

Further reading:
To order the report, *Identifying relationships between soil processes and biodiversity to improve restoration of riparian ecotones invaded by exotic acacias* (**Report No. 1927/1/13)** contact Publications at Tel: (012) 330-0340, Email: orders@wrc.org.za or Visit: www.wrc.org.za to download a free copy.