
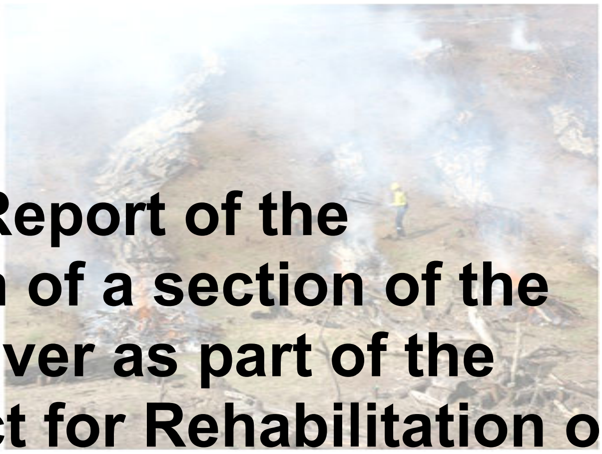

Technical Report of the Restoration of a section of the Witteklip River as part of the Pilot Project for Rehabilitation of the Kouga River

Master's Final Report

Master Oficial en Restauración de Ecosistemas

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ABSTRACT

Black Wattle (*Acacia mearnsii,* Fabaceae) represents one of the most important invasive alien species that have spread over large catchment areas in South Africa, with well documented effects on reducing water yield and in altering indigenous plant structure. Nationwide measures are being applied to eliminate this species, and different protocols are being evaluated for restoring heavily invaded areas, such as the rehabilitation site at the Lower Witteklip River in the Eastern Cape Province.

As a part of the Kouga River Rehabilitation Pilot Project, this study described four topics: (a) the degradation state of the area which was concluded that it was related to the presence of Black Wattle, (b) revegetation practices which were established as an experiment to evaluate the guilds which could be used to rehabilitate similar areas, defining as a priority from the early state of the experiment, to use a vast mix of species and densities as treatments, (c) effects of different biomass loads on burning and on the temperature to which soil was exposed in which it was observed that values dependent on the biomass load and not on the sampling site and (d) an assessment of the effects of fire and transformation of wood to chips, as methods to remove biomass left from clearing from the site which from the data available, there were not a definitive conclusion on which one of the treatments influenced on the results, mainly because of the lack of time for the soil seedbank to be fully germinated, and due to a mistake in the methodology by not segregating between the indigenous species group. This technical report also includes an assessment and some recommendations for the activities applied to the Lower Witteklip Rehabilitation Site and for the experiments.

RESUMEN

El Black Wattle (*Acacia mearnsii*, Fabaceae) representa una de las más importantes especies exóticas invasoras que se han diseminado en grandes extensiones de las cuencas hidrográficas en Sudáfrica, con efectos bien documentados sobre la reducción de la producción de agua y en la alteración de la estructura de la vegetación autóctona. Diferentes medidas a nivel nacional se han aplicando para eliminar esta especie, y distintos protocolos están siendo evaluados para la restauración de las áreas altamente invadidas, como el sitio ubicado en la parte baja del rio Witteklip, Provincia del Cabo Oriental, la zona donde se realizó el presente estudio.

Como parte del Proyecto Piloto de Rehabilitación del río Kouga proyecto, este estudio describe cuatro temas: (a). el estado de degradación de la zona, de la cual se concluyó que estaba relacionado con la presencia de la *A. mearnsii*, (b) prácticas de revegetación que se establecieron como un experimento para evaluar los diferentes gremios de vegetación que podría ser utilizado para rehabilitar zonas similares, que define como una prioridad en la etapa temprana de la evaluación, que conviene usar una gran mezcla de distintas especies y densidades como tratamientos, (c) los efectos de quema de biomasa según su carga en la temperatura del suelo, experimento en el que se observó que los valores dependen de la carga de biomasa y no en el sitio de muestreo y (d) una evaluación de los efectos del fuego y la transformación de la madera a astillas, como métodos para eliminar la biomasa producto de la tala de la A. mearnsii a partir de la cual no hubo una conclusión definitiva sobre cuáles de los tratamientos influyeron en los resultados de germinación obtenidos, principalmente debido a la falta de tiempo para que el banco de semillas del suelo pudiera germinar plenamente. También pudo afectar en este resultado, un error en la metodología ya durante el conteo de especies, no se segregó por especie dentro del grupo de especies autóctonas. Este informe técnico incluye también una evaluación y algunas recomendaciones para las actividades aplicadas a la rehabilitación de la parte de baja del río Witteklip así como también algunas recomendaciones respecto de los experimentos realizados.

1. INTRODUCTION

South Africa's commercial forestry has around 1.52 million hectares of fast-growing species. (Louw and Scholes, 2002). Since there is a lack of commercial fast growing species native for the country, establishment of forest plantations was initiated in 1896 to meet fuelwood demand, props for mines and timber. Exotics from Australia, America and Europe were tried, as the growth rate of native species was too slow. The areas planted increased rapidly from 1920 onwards (FAO 2004).

However, the establishment of these plantations brought some negative impacts that include significant reductions in surface streamflow (Van Lill, et al, 1980) and loss of biodiversity (Ratsirarson et al, 2002). For South Africa, any reduction in its water resources represents severe problems, as the country's water requirements show a tendency of growing, with a 1.40% urbanization rate, a 3.8% industrial production growth rate and a population growth of 0.28 % (CIA 2009), and with more than half of the country's freshwater systems associated with rivers critically endangered.

South Africa's first large plantations were mainly *Acacia mearnsii* also known as Black Wattle (FAO 2004), grown for its vast amount of uses: tannin compounds, resins, timber, fuelwood, pulp and wood chips, used to produce paper (UNEP 2006). However, it's been classified as an Invasive Alien Plant (IAP) with the status of transformer. It can as dominate or replace any canopy or subcanopy layer of a natural or semi-natural ecosystem, altering its structure, integrity and functioning (Henderson 2001). It is considered amongst the 100 of the World's Worst Invasive Alien Species (Lowe et al, 2004).

As an option to clearing the alien invader species along watercourses and restoring the cleared areas, the Working for Water (WfW) program was initialized in October 1995 by Department of Water Affairs and Forestry. It also aims at the creation of jobs and the economical empowerment of unemployed people from historically disadvantaged communities (Marais and Wannenburg 2008).

The Working for Water program (WfW) includes two components. One has the task of removing riparian IAP's from their current distribution and repairing the ecosystem by promoting revegetation through planting, sowing or by managing the soil seedbank. The plants used, come from the second component, which includes the collection and reproduction of the indigenous species (Marais and Wannenburg 2008).

The following Final Report was made within the Kouga Riparian Rehabilitation Pilot Project, in South Africa's Eastern Cape Province. The catchment, has been affected Black Wattle (*Acacia mearnsii*) on a large scale. The project, aims on improving the ecological functions of the catchment, while developing protocols for Best Management Practices for use by the Working for Water Programme in similar conditions across the country.

Kouga Riparian Rehabilitation Pilot Project was developed by the World Wildlife Fund with the coordination of the Restoration Research Group (R3G) from Rhodes University, in partnership with Department of Water Affairs and Forestry's Working for Water Programme (DWAF/WfWater), the South African National Biodiversity Institute's (SANBI) Working for Wetlands Programme, Rhodes University and Gamtoos Irrigation Board. This research project was facilitated by LivingLands and R3G within the PRESENCE Network (Participatory Restoration of Ecosystem Services & Natural Capital, Eastern Cape), (http://www.livinglandscapes.co.za).

This Final Report was focused on the research activities being made at one of the restoration sites at the Witteklip River, a subsidiary from the Kouga River, especially on two methods available for the elimination of wood residues by using fire and transformation of wood to chips, and on the rehabilitation via revegetation of the study site. In an effort to evaluate the effects of biomass burning and temperature on the germination of the seeds from the seedbank, a nursery experiment was undertaken.

2. OBJECTIVES

2.1. Kouga Riparian Rehabilitation Project objectives

Defining the most efficient protocol to clear and restore areas invaded with Black Wattle (*Acacia mearnsii*) by stimulating riparian rehabilitation of invaded areas in the Kouga River's catchment.

It has the following specific objectives:

1. To demonstrate successful riparian rehabilitation in an upstream tributary of the Kouga at an operational scale.
2. To develop Best Management Practices for the rehabilitation of riparian zones after the clearing of alien invasive vegetation by Working for Water at an operational scale.
3. To develop and implement a defensible monitoring & evaluation protocol for the project.
4. To undertake a cost-benefit analysis of rehabilitation against the practice of standard follow-up practice (including the application of herbicides) of a site.
5. To communicate and build support for the outcomes of the pilot project.
6. To develop rehabilitation protocols to be applied and tested in other South African riparian systems

2.2. Master's Final Report objectives

The main objective of this Master's Final Report is to describe the results from the activities oriented towards repairing the functionality of a section of the Witteklip River and to evaluate the possibilities of using fire as a method for the disposal of the Black Wattle clearing residues.

3. IMPLEMENTED ACTIVITIES

The activities, were implemented during the practicum period of 5 months, and were oriented to the fulfillment of the following tasks.

a. A characterization of the current situation of the riparian area, including degradation factors and possibilities for restoration
b. A review of the activities implemented for the restoration the invaded area
c. A distribution of paired plots and planting sites in the area to be restored
d. Field data collection and basic statistic analysis of the soil temperature as an effect of depth, amount of dried wood and site location (floodbank, low slope hillside).
e. Description of the effect of two soil treatment methods on seedbank germination for two main groups: Black Wattle seedlings and indigenous species seedlings.

4. BACKGROUND INFORMATION

This section, will describe some of the basic concepts that will be referred to on the present Final Report. Although the available literature presents these concepts in a variety of contexts, this Report will focus mainly on its application to ecosystem restoration in riparian areas and on the focus area at the Witteklip River.

4.1. Riparian Restoration

Early definitions of the term Restoration, describe it as the reestablishment of predisturbance ecological functions and structure and dynamics (Brown & Lugo, 1987).

More recently and considering the difficulty encountered in reaching this goal, a more realistic approach to the term was developed by the Society of Ecosystem Restoration:

> Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed (SER, 2004).

River restoration embraces a great variety of measures that have in common, that they restore natural functions of rivers, which were lost or degraded by human intervention. Disposal of waste water into the river, for example, has negative effects upon many different functions, like drink water supply, irrigation water supply, maintenance of fisheries and maintenance of biodiversity. Dams for the generation of hydropower, as another example, interrupt the migration routes for migratory fish and by doing so, have a negative impact upon the income from fisheries. River restoration usually aims at restoring a multifunctional use of rivers, often by restoring more natural conditions in the river system. It is becoming increasingly clear that future river management should not focus upon adjusting the river system to human needs, but upon adjusting the human use to the natural river system. (Nijland & Cals, 2000)

Riparian zones around the World have been heavily degraded throughout the years, with alterations in the river dynamic through modifications on the stream, elimination of vegetation, extraction of sand as construction material and the introduction of IAP's amongst others. Riparian restoration initiatives, must consider the necessity of acting not only on the structure but on the function of the elements, allowing the interrelations between them (González del Tánago and García de Jalón, 2001).

The presence of IAP, has motivated restoration projects to improve ecosystem structure and functioning damaged by alien plant invasions. In South Africa, the primary motivation is to restore hydrological flows in rivers and deliver water benefits to humans, as the major invaders of riparian zones are trees which use more water than indigenous riparian plants and thus reduce water yields from catchments (Holmes, 2008; Vosse, 2008)

Restoration of riparian areas, where the presence if IAP has dominated the site for large periods of time, and with high densities, represents a challenge if it's only source for plant recruitment, is that of the seed bank (Pretorius, 2008; Holmes, 2008). In South Africa, the impact of alien species has resulted in both abiotic and biotic constraints to restoration at catchments scales. In highly-transformed catchments, interventions at the reach scale (i.e. along short river lengths) may fail if important constraints at the catchment scale are not addressed. Amongst the biotic constrains to restoration in heavily invaded catchments, include the lack of indigenous propagles and the modification of the microsite conditions needed for the establishment of them (Holmes, 2008).

The approach that most of the restoration projects in riparian zones in South Africa, are motivated by the necessity of restoring the hydrological flows of the rivers and the deliver benefits for the humans, especially in those areas which have been affected by invasive alien plants (Holmes et al, 2008).

4.2. Fynbos

Predominantly from the Cape Region, the Fynbos (fine bush in Afrikaans) is defined as an evergreen, hard-leafed shrubland occurring on nutrient-poor soils, especially those derived from heavily leached sandstones or limestones; dominated by small and leathery leafed shrubs associated with evergreen, grass-like perennials; and comprising essentially members of plant groups that are characteristics of the Cape Floristic Region. This definition includes both true Cape fynbos, recognized particularly by the presence of Restionaceae, as well as the outlying Afro-montane fynbos communities, which lack restios. (Manning & Patterson, 2007).

It occurs on acidic (pH 4.4 to 7.0) coarse-grained soils poor in nutrients, especially phosphorus and nitrogen. It rarely grows where rainfall is below 400 mm per annum or where droughts are common (Manning & Patterson, 2007).

Figure 1 Fynbos Ecoregion in Africa (UNEP/GRID-Arendal, 2007).

It's recognized globally as one of the world's richest floral regions it has the distinction of being by far the smallest of the world's six Floral Kingdoms, with some 9 000 species in only 90 000 km^2. With almost 70% of endemic species the Cape Floral Region, is considered as one of the richest areas for plants in the world and it has been catalogued as one of the worlds Hotspots. Fynbos vegetation is unique to the Cape Floral Region. The outstanding diversity, density and endemism of the flora are among the highest worldwide. It represents less than 0.5% of the area of Africa but is home to nearly 20% of the continent's flora (Government of South Africa, 2003).

Fire, is one of the most important drivers in fynbos ecology. Some species, such as the *Orothamnus zeyheri* are not able to complete their life cycle in the continued absence of fire. Therefore, fire should be considered as a management tool for this ecosystem (Kruger et al, 1979).

Riparian vegetation within the fynbos biome is fairly distinctive from the surrounding fynbos vegetation (Sieben & Reinecke, 2008). The composition of the riparian community varies according to the phytogeographic affinity towards either the fynbos or Afrotemperate Forest vegetation groups, which are, in turn, dependent on several environmental factors incrluding stream size and position in landscape, local topography and surrounding soils, vegetation or land use. The most recent description defines three broad community groups termed Fynbos Riparian Vegetation, Cape Lowlando Alluvian vegetation, and Cape Lowland freshwater wetlands running from upper catchments, through the floodplains and into the wetlands. Riparian communities with a fynbos affinity have been described as Close Scrub Fynbos. Such communities are usually found in the mountain stream or montane reaches of rivers where the extent of alluvium is limited as a result of the high levels of erosion.

Alien species pose a great threat for the conservation of fynbos shrublands. By 1985, over 20% of the region was estimated to be invaded. These alien species are able to invade fynbos in the absence of anthropogenic disturbance by exploiting the invasion window opened by fire, taking advantage of their copious seed production and their rapid seed bank accumulation and germination (Holmes & Cowling, 1997).

4.3. Invasive Alien Species

Invasive alien species (IAS) are non-indigenous plants, animals and microorganisms that have been deliberately or accidentally introduced to new areas beyond their native ranges, spreading beyond cultivation and human care to impact biodiversity. They can alter vital ecosystem processes such as fire, hydrology and nutrient cycling, kill, suppress, compete with or displace native species and communities, or alter gene pools through hybridization (Chornesky & Randall 2003).

IAS can occur in terrestrial, freshwater and marine habitats across the globe, altering the lands and waters that native plants, animals and communities need to survive, hurting economies and threatening human well-being, and can cause dramatic environmental changes that lead to significant declines in native populations. The most harmful invaders can transform diverse and productive ecosystems into nearly sterile lands and waters with completely different ecosystem processes (Lu, 2009).

Invasive alien species have affected native biodiversity in almost every ecosystem type on Earth and are one of the greatest threats to biodiversity. Since the 17th century, invasive alien species have contributed to nearly 40% of all animal extinctions for which the cause is known (CBD, 2006).

South Africa's commercial forestry has around 1.52 million hectares of fast-growing species (Louw and Scholes, 2002) with the introduction of exotic species from Australia, America and Europe, as the growth rate of native species was too slow (FAO 2004). Some of these plantations, have become mayor invaders, with an extension of close to 10 million ha (6.8% of South Africa's territory) has been invaded to some extent (Versfeld et al, 1998).

The main concerns on IAS for South Africa, is their aggressive use of water. Invasive Alien Plants, alter the hydrologic regimes by changing the rate or timing of evapotranspiration (ET) or runoff in a region. Such impacts are often explained by differences between invasive and native species in transpiration rates, phenology, biomass of photosynthetic tissue or rooting depth (Levine et al, 2003).

The extent and density of the invasions and thus the impact on water resources (currently accounting for 3,300 million m^3 of water per year) could increase significantly in the next 5 to 10 years, resulting in the loss of much, or possibly even all, of the available water in certain catchment areas, within . (Versfeld et al, 1998).

4.4. Black Wattle (*Acacia mearnsii*)

South Africa's first large plantations were mainly *Acacia mearnsii* also known as Black Wattle, a species native to Australia. It was introduced in 1864, and expanded in 1888, when it was grown mainly for the extraction of tannin compounds from the bark for the leather industry. Other uses are: resins, thinners and adhesives that can be made from bark extracts; the timber which is used for building materials; charcoal produced from wood is used for fuel; the pulp and wood chips that are used to produce paper (SAPPI, 2007 and UNEP, 2006).

The Black Wattle is fast growing leguminous tree from the Fabaceae family, which normally stands for 5-10 metres tall but can reach up to 15 metres. It occurs naturally in grasslands, riparian zones, disturbed, urban areas, water courses. It grows in disturbed, mesic habitats (at an altitude of between 600 - 1700m), within in a range of climates, including warm temperate dry climates and moist tropical climates (Marchante, 2006).

It removes large quantities of water daily, changing water table levels (Dye & Jarmain, 2004). It also disrupts vegetation dynamics by altering colonization ability, thereby affecting vegetation structure and indigenous plant establishment (Vosse et al, 2008). When planted along watercourses, the effects tend to disrupt the amount of water available as they can make a very effective use of the water (Pretorius et al, 2008; Dye &

Jarmain, 2004). It's leaves have been mentioned to have allelopathic components (Kumar et al, 2002).

The seeds from *Acacia mearnsii* show certain characteristics that are advantageous for outcompeting fynbos species, such as the water impermeability of testa, dormancy primarily broken by a heat pulse such as fire and adaptation for fire prone habitats. At the same time, the seedbank has a small proportion of seeds that will germinate or decay within the first three months, while the majority will persist thereafter, with little turnover and rapid accumulation (Richardson & Kluge, 2008).

The Black Wattle, has been considered an invasive alien plant (IAP) with the status of transformer, since it can as dominate or replace any canopy or subcanopy layer of a natural or semi-natural ecosystem, altering its structure, integrity and functioning, being the most serious environmental treat for indigenous vegetation (Henderson 2001). It has been catalogued amongst the 100 of the World's Worst Invasive Alien Species, a compendium endorsed by the World Conservation Union in 2004 (Lowe et al, 2004).

Biodiversity is loss in invaded areas affected with *Acacia*, given that they outcompete indigenous species and disrupt natural ecosystem functioning. The Cape Floristic Region is particularly vulnerable in this regard. The indigenous fynbos plants are adapted to nutrient-poor sandy soils, but acacias are nitrogen-fixing plants that increase nitrate levels in the soil. Many indigenous species cannot survive in the enriched soils surrounding acacias, allowing the alien invaders to form bland monocultures (Matthews & Brand, 2004).

Removal of Black Wattle is related to the increase of streamflow, especially in dense stands as explained by Dye and Jermain (2004). They also mention that evaporation from indigenous grasslands and fynbos shrublands is much less from that of Black Wattle stands, and in revegetated areas, a normal streamflow can be obtained.

4.5. Seed bank

The soil seed bank represents all the viable seeds present in the soil, either on the surface, buried, or in strata associated with the mulch. This bank could be transient, as all seeds germinate in the same year that production and dispersal took place, and persistent, where at least some of the seeds that remain in the ground last, longer than the phonologic cycle of the species (more than one year), (Thompson & Grime, 1979).

The majority of seeds in a seedbank, do not germinate in a particular year, but until the will find itself with the stimuli required for the breakage of dormancy, the conditions required for the germination processes to proceed and the appropriate amount of water and oxygen consumed during germination. (Whisenant, 1999).

Soil seed banks contribute significantly to the regeneration of plant cover following a disturbance under certain circumstances (Luzuriaga et al, 2005). However, little research has focused on riparian zones. The dynamics of seed banks within riparian ecosystems are very complex, and are likely to be influenced by flood water, animal activities and soil cracking. It can also be affected by human related disturbances, such as mechanical translocation of soil, and degradation of indigenous vegetation due to removal, overexploitation or intentional fires. Bare patches of soil are typically colonized by ruderals. However, longer-lived competitors (e.g. *Acacia mearnsii* in South Africa) may replace the ruderals (Vosse et al, 2008).

Organic materials on the soil surface are important modifiers of the seedbed environment (Whisenant, 1999). Such situation happens in South Africa's fynbos, where litter from IAP species such as *Acacia mearnsii* trees, affect indigenous fynbos, adapted to acid nutrient poor soils and Mediterranean climate, by altering the amount of nitrate levels on the soil, and thus, reducing the possibilities of a successful seedling establishment (Matthews & Brand, 2004).

It would appear that the recovery of indigenous vegetation can be reestablished after clearing, with the presence of a soil seed bank after alien clearing, with the sustainability of such vegetation with the complement of some missing guilds that could improve vegetation structure and composition (Fourie, 2008). However, it has been found that the older the alien stands, the less probability to find a viable seed bank (Holmes, 2001).

4.6. Working for Water

The Working for Water Programme (WfW), was initiated in October 1995 and has been part of the Expanded Public Works Programme of the South African Government. It aims to sustainably manage natural resources, particularly water, by clearing IAP while creating jobs and economically empowering unemployed people from historically disadvantaged communities (Marais and Wannenburg, 2008).

Their initial assumption was that target ecosystems, mostly riparian, would "self-repair" once the main stressor (dense stands of invasive alien trees) had been removed (Eslera, et al, 2008). However, an evaluation of ten years of work, show that this approach hasn't been successful enough since many systems do not "self-repair". Thus, it becomes evident that there is a need for protocols that can combine clearing with restoration of the tall indigenous riparian canopy tree species in heavily invaded sites, as they might help to shade out many alien recruits (Beater et al, 2007).

Currently, the Working for Water teams have three main clearing treatments: Fell Only, Fell-Remove and Fell-Burn. Blanchard and Holmes (2008) compared these methods to a reference condition. It was possible to determine that the Fell & Remove treatment most closely approached the reference condition, while Fell Only and Fell-Burn plots had altered indigenous vegetation composition and structure. All clearing treatments had significantly lower vegetation cover than the reference and species composition was altered by invasion and clearance. Important growth forms, such as small (3–10 m) trees were suppressed by felled slash and burning.

During their research, Blanchard and Holmes (2008) also observed that there was a reduction of the woody alien species by burning, but secondary invasion by herbaceous species occurred where riparian vegetation did not re-establish. They concluded that in order to promote indigenous vegetation recovery and restore the main ecological processes, it's advisable to apply the Fell-Remove treatment together with continued alien follow-up control, as this could minimize alien re-invasion of riparian ecosystems. This might not be possible in all sites, due to the difficulties in removing the slash caused by the limitations imposed by the local topography and site inaccessibility.

A difficult management issue is the reduction of alien soil seedbanks as part of the overall control strategy of the Working for Water Programme. The effectiveness of follow up control could be seriously compromised by the unpredictable and sporadic, low density recruitment and reinvasion from seed banks over vast areas. If there were to be any reduction or interruption of the current clearing programme re-invasion from seed banks could jeopardize all the resources invested until now (Richarson & Kluge, 2008).

According to Boshoff (2005), around 180,000 ha of the Kouga River catchment had been cleared of IAP around 2005, and follow-up clearing completed; approximately 95% of this area was lightly invaded. Few lightly invaded areas remain and the challenge is now to clear the heavily invaded areas. It is estimated that some 80,000 ha remain to be cleared – a task that is estimated will take more than 20 years. The main species being removed are

Black Wattle (*Acacia mearnsii*) (95%), silky hakea (*Hakea sericea*) (2%), pines (*Pinus* species) (2%) and bluegum (*Eucalyptus* species), blackwood, rooikrans, Port Jackson (*Acacia* species) and grey poplar (*Populus* x *canescens*) (1%) (Boshoff, 2005)

5. METHODOLOGY OF IMPLEMENTED ACTIVITIES

5.1. Description of study site

5.1.1. General location

The study site is located in Witteklip River, an area of approximately 12.0 ha located in the Terra-Pi Conservation Area, under jurisdiction of the Kou-Kamma Municipality, Eastern Cape (Figure 2).

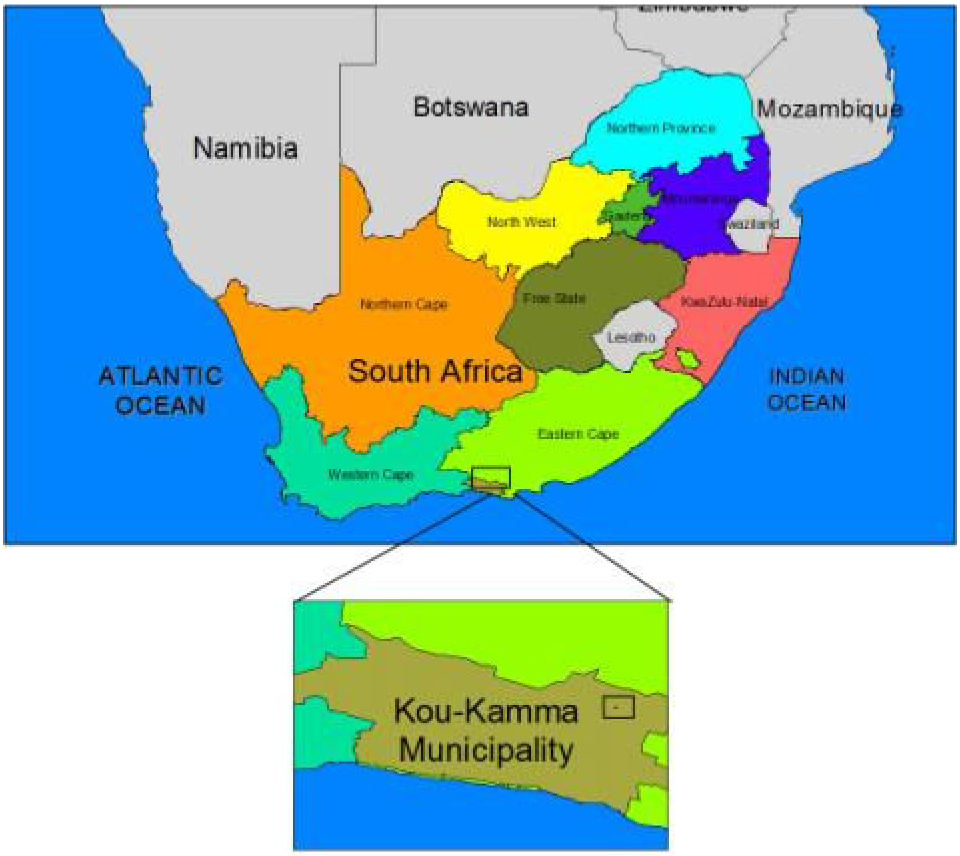

Figure 2 Approximate location of study area within South Africa.

The Kou-Kamma Municipality extends 3,575.17 km² and falls within the Cacadu District Municipality area, in the Eastern Cape Province. It is predominantly a rural Municipality with only 25.45% of the population being urbanized.

The closest town to the Terra-Pi Conservation Area, is Kareedouw, the capital of the Kou-Kamma Municipality. Together with Ravinia, Twee Revieren, Uitkyk, Kagiso and Mountain View, account for a population of 6,463. Kareedouw, is located about 120 km from Port Elizabeth, the largest city of the Eastern Cape.

The Lower Witteklip Restoration Area, is located The Witteklip River, which in turn is tributary of the Kouga river. The Kouga River Catchment, represents a key water source for the Nelson Mandela Bay Metropolitan Municipality, home to about 1,5 million people from the cities of Port Elizabeth, Uitenhage and Despatch, as well as hundreds of farmers throughout the Gamtoos Valley. The Kouga River: Catchment L 82 (figure 2) is located in Gamtoos River System: Catchment L, which is situated in the Water Management Area 15, Fish to Tsitsikamma (appendix 1)

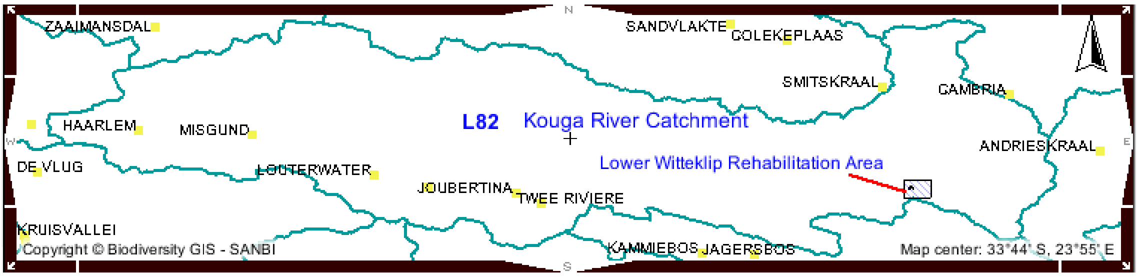

Figure 3 Kouga River: Catchment L82

The Gamtoos river system comprises three main rivers. These are from north to south, the Groot River, the Baviaanskloof River and the Kouga River, which join in the region of the present Kouga Dam to form the Gamtoos River. The Gamtoos drains into the sea northeast of Jeffrey's Bay after passing through a long and winding floodplain below the town of Hankey. The flow regime in this river system has been considerably altered due to extensive dam construction. The Beervlei dam (1957) and the Kouga Dam (1964) built at the confluence of the Kouga and the Baviaanskloof Rivers has altered the natural flow pattern, especially the flood regime. Only the Groot River delivers a freely flowing albeit reduced volume of water to it on a daily basis (Institute for Water Research 2004).

The Kouga River originates in the Tsitsikamma Mountains to the south and the Kouga Mountains in the north. Various tributaries congregate in the Middle Langkloof, in the vicinity of Haarlem to form the main channel. It then flows eastward through the Kouga Mountains before turning sharply north in the region of the Diep River catchment in the Suuranys Mountains to its confluence with the Baviaanskloof River. The river is located in a steep sided Table Mountain Sandstone gorge in rugged and harsh but spectacular mountainous terrain. This was a perennial river, which, in its natural state, seldom if ever ceased to flow despite the relatively low rainfall in the greater catchment (Institute for Water Research 2004).

5.1.2. Climate

The Köppen climate zone for this area according to the Agricultural Research Council (2009a), is described as Cfb: Marine West Coast Mild. Nine years of data collected at Onverwacht station, about 10 km southeast from the Witteklip Rehabilitation Area, have yielded the following climatic data:

- Annual average rainfall average: 540 mm
- Wettest months: March and November
- Driest month: June
- Maximum temperature: 23.7ºC (warmest month: March)
- Minimum temperature: 11.74ºC (coldest month: July)
- Relative Humidity: Maximum: 80%; Minimum: 55%

5.1.3. Geology and soil description

The Kouga river runs through Ecoregion 19, Southern Folded Mountains, (Kleynhans, et al, 2005). This system, formed Curvillineal belts of pressure which have led to folding, thrusting, compression and uplift of sedimentary rocks, and are associated with deep igneous intrusions and large scale deep metamorphism of sedimentary and igneous rocks. It's considered to be part of the older folded mountains, which appears to be related to the result of the uplift of crustal thickening by initial orogenic compressive forces (Chorley, R. 1985).

Table 1 Main attributes of the Southern Folded Mountains Ecoregion.

Main Attributes	Southern Folded Mountains
Terrain Morphology:	Plains; Low Relief (limited); Plains Moderate Relief (limited);
	Lowlands; Hills and Mountains; Moderate and High Relief;
	Open Hills; Lowlands; Mountains; Moderate to High Relief;
	Closed Hills; Mountains; Moderate and High Relief
Altitude (m a.m.s.l)	0-300 limited; 300-1,900, 1,900-2,100 (limited). **400-420**

The dominant lithology belongs to the Table Mountain Sandstone. Valley floors are lined with Bokkeveld shales. The sediment load of the river is small. Siltation due to erosion in the catchment does not appear to be significant at this stage, even taking the fragile nature of the soil cover into account.

The soils, have minimal development, usually shallow, on hard or weathering rock, with intermittent diverse soils Rock with limited soils (association of Leptosols, Regosols, Durisols and Calcisols). Lime is rare in the landscape. (Agricultural Research Council, 2009a).

Soil loss for the area, as predicted by the RUSLE model, describes it as Very Low to Low. However, the soil susceptibility to water related erosion might be low, on the smooth relief valleys, to high within the extremely steep slopes, so management of these must be considered (Agricultural Research Council, 2009b).

5.1.4. Fauna

The area, is characterized by the presence of different species of antelope, such as the common duiker (*Sylvicapra grimmia*), springbok (*Antidorcas marsupialis*), common eland (*Taurotragus oryx*), bushbuck (*Tragelaphus scriptus*), Hartebeest (*Alcelaphus buselaphus*), bontebok (*Damaliscus pygargus dorcas*). Also present, chacma baboons (*Papio ursinus*), Cape Mountain leopard (*Panthera pardus*), springhare (*Pedetes capensis*), African hare (*Lepus microtis*), warthog (*Phacochoerus africanus*), ostrich (*Struthio camelus*), black backed jackal (*Canis aureus*), bat-eared fox (*Otocyon megalotis*), rooikat or caracal (*Caracal caracal*), aardvark (*Orycteropus afer*), bushpig (*Potamochoerus larvatus*).

Snakes: Cape cobra (*Naja nivea*), Puff adder (*Bitis arietans*), Herald snake (*Crotaphopeltis hotamboeia*), brown house snake (*Lamprophis fuliginosus*), cape wolf snake (*Lycophidion capense*), slug eater (*Duberria lutrix*), boomslang (*Dispholidus typus typus*), Rhombic Skaapsteker (*Psammophylax rhombeatus rhombeatus*), Montane Grass Snake (*Psammophis crucifer*).

Different species of Swallow, Kingfisher, some raptors like the Black Eagle (*Aquila verreauxii*), and endangered species such as the Stanley Bustard (*Neotis denhami*), Blue Crane (*Anthropoides paradisea*) can be observed in the area.

Also present, some Tortoise, lizards, insects, amphibians.

The Kouga River, hosts the following fish: *Sandelia capensis*, whose population is decreasing, *Pseudobarbus asper* (V) and *P. afer*, considered endangered, the *Labeo unbratus*, and the *Barbus pallidus* least concern species.

5.1.5. Vegetation

The vegetation for this area, according to Pierce and Mader (2006), belongs to the Humansdorp Grassy Fynbos. In a recent survey for the area, Van der Waal (unpublished) reported the following species:

Forbs

Apiaceae	Anginon sp
Apiaceae	Centella glabrata
Asteraceae	Arctotheca calendula
Asteraceae	Aster bakeranus
Asteraceae	Berkheya decurrens
Asteraceae	Berkheya hetrophylla
Asteraceae	Conyza bonariensis
Asteraceae	Gazania krebsiana
Asteraceae	Gerbera piloselloides
Asteraceae	Haplocarpha lyrata
Asteraceae	Helichrysum nudifolium
Asteraceae	Hypochaeris radicata
Asteraceae	Lactuca capensis
Asteraceae	Vernonia capensis
Brassicaceae	Lepidium sp
Campanulaceae	Cyphia heterophylla
Caryophyllaceae	Pharnaceum sp
Chenopodiaceae	Rumex acetosellata
Clusiaceae	Hypericum sp
Dipsacaceae	Cephalaria attenuata
Dipsacaceae	Scabiosa columbaria
Euphorbiaceae	Phyllanthus incurvus
Malvaceae	Hibiscus aethiopicus
Malvaceae	Hibiscus pusillus
Polygalaceae	Polygala illepida
Ranunculaceae	Knowltonia cordata
Solanaceae	Solanum americanum

Geophytes

Anemiaceae	Mohria sp
Asparagaceae	Asparagus capensis
Asparagaceae	Asparagus densiflorus
Asparagaceae	Asparagus striatus
Commelinaceae	Commelina africana
Commelinaceae	Cyanotis speciosa
Euphorbiaceae	Euphorbia z silenefolia
Hyacinthaceae	Albuca sp
Hyacinthaceae	Hyacinthaceae sp
Hypoxidaceae	Hypoxis z small
Iridaceae	Aristea abyssinica
Iridaceae	Babiana sambucina
Iridaceae	Bobartia orientalis
Iridaceae	Gladiolus z magnif
Iridaceae	Moraea sp
Lanariaceae	Lanaria lanata
Oxalidaceae	Oxalis smithiana
Oxalidaceae	Oxalis stellata
Pteridacae	Cheilanthes hirta
Pteridacae	Cheilanthes viridis
Pteridacae	Pellaea calomelanos
Pteridacae	Pteridium aquilinum

Sedges

Cyperaceae	Cyperus sp
Cyperaceae	Ficinia spp.

Restios

Restionaceae	Elegia capensis
Restionaceae	Ischryolepis sp
Restionaceae	Ischryolepis z tall
Restionaceae	Restio whipstick

Grasses

Poaceae	Aristida congesta
Poaceae	Aristida junciformis
Poaceae	Brachiaria serrat
Poaceae	Cymbopogon pluridonis
Poaceae	Cynodon dactylon
Poaceae	Digitaria sp
Poaceae	Ehrharta calcynia
Poaceae	Ehrharta sp
Poaceae	Eragrostis capensis
Poaceae	Eragrostis curvula
Poaceae	Eragrostis acraea
Poaceae	Heteropogon contortus
Poaceae	Melinis nerviglumis
Poaceae	Merxmuelleria disticha
Poaceae	Panicum sp
Poaceae	Pennisetum clandestinum
Poaceae	Pentaschistis airoides
Poaceae	Pentaschistis diffusa
Poaceae	Setaria sp
Poaceae	Themeda triandra
Poaceae	Tristachya leucothrix
Pteridacae	Pteridium aquilinum

Trees

Anacardiaceae	*Loxostylis alata*
Anacardiaceae	*Rhus glauca*
Anacardiaceae	*Rhus incisa*
Anacardiaceae	*Rhus lucida*
Anacardiaceae	*Rhus tormentosa*
Apiaceae	*Heteromorpha trifoliata*
Asteraceae	*Tarchonanthus camphoratus*
Celastraceae	*Ptaerocelastrus tricuspidatus*
Ebenaceae	*Diospyros scabrida*
Mimosoideae	*Acacia longifolia* §
Mimosoideae	*Acacia mearnsii* §
Mimosoideae	*Acacia saligna* §
Papilionoideae	*Aspalathus z tall silver*
Proteaceae	*Protea nitida*
Rubiaceae	*Canthium inerme*
Rubiaceae	*Canthium sp*
Saliciaceae	*Populus canescens* §
Santalaceae	*Osyris compressa*
Sapindaceae	*Hippobromus pauciflorus*
Scrophulariaceae	*Halleria lucida*
Tiliaceae	*Grewia occidentalis*

Shrubs

Anacardiaceae	*Rhus dentata*
Anacardiaceae	*Rhus fastigiata*
Anacardiaceae	*Rhus pyroides*
Anacardiaceae	*Rhus sp*
Asteraceae	*Chrysanthemoides monilifera*
Asteraceae	*Dicerothamnus rhinocerotis*
Asteraceae	*Metalasia densa*
Asteraceae	*Metalasia z pink*
Asteraceae	*Metalasia wide lf sp*
Asteraceae	*Stoebe alopecuroides*
Asteraceae	*Stoebe plumosa*
Celastraceae	*Gymnosporia heterophylla*
Ebenaceae	*Diospyros dichrophylla*
Ebenaceae	*Diospyros polyandra*
Ebenaceae	*Euclea crispa*
Ebenaceae	*Euclea natalensis*
Ericaceae	*Erica curviflora*
Ericaceae	*Erica pectinifolia*
Myricaceae	*Myrica quercifolia*
Myricaceae	*Myrica sp*
Papilionoideae	*Aspalathus chortophila*
Papilionoideae	*Aspalathus sp*
Polygalaceae	*Polygala fruticosa*
Proteaceae	*Leucadendron salignum*
Proteaceae	*Leucospermum cuneiforme*
Rhamnaceae	*Phylica axillaris*
Rhamnaceae	*Phylica z buxifolia*
Rubiaceae	*Anthospermum sp.*
Rutaceae	*Agathosma venusta*
Rutaceae	*Agathosma sp*
Rosaceae	*Cliffortia illicifolia*
Sapindaceae	*Dodonaea angustifolia*
Thymeleaceae	*Passerina corymbosa*
Thymeleaceae	*Passerina falcifolia*
Vitaceae	*Rhoicissus tridentata*

Woody herbs

Acanthaceae	*Blepharis procumbens*
Acanthaceae	*Chaetacanthus setiger*
Aizoacaeae	*Aizoon rigidum*
Anacardiaceae	*Rhus rosmarinifolia*
Apiaceae	*Anginon difforme*
Asteraceae	*Athanasia dentata*
Asteraceae	*Athanasia quniquedentata*
Asteraceae	*Athanasia trifurcata*
Asteraceae	*Athrixia sp*
Asteraceae	*Berkheya angustifolia*
Asteraceae	*Chrysocoma ciliata*
Asteraceae	*Cineraria geifolia*
Asteraceae	*Disparago ericoides*
Asteraceae	*Eriocephalus africanus*
Asteraceae	*Euryops algoensis*

Woody herbs

Asteraceae	*Euryops munitus*
Asteraceae	*Helichrysum anomalum*
Asteraceae	*Helichrysum cymosum*
Asteraceae	*Helichrysum felinum*
Asteraceae	*Helichrysum herbaceum*
Asteraceae	*Helichrysum teretifolium*
Asteraceae	*Helichrysum umbraculigerum*
Asteraceae	*Helichrysum z white* lf
Asteraceae	*Pteronia teretifolia*
Asteraceae	*Pteronia sp*
Asteraceae	*Senecio crenatus*
Asteraceae	*Senecio deltoideus*
Asteraceae	*Senecio linifolius*
Asteraceae	*Senecio pterophorus*
Campanulaceae	*Wahlenbergia sp*
Crassulaceae	*Crassula canescens*
Crassulaceae	*Crassula ericoides*
Crassulaceae	*Crassula muscosa*
Crassulaceae	*Crassula tetragona*
Crassulaceae	*Crassula sp*
Euphorbiaceae	*Clutia small lf*
Euphorbiaceae	*Euphorbia z needle* lf
Gentianaceae	*Chironia tetragona*
Geraniaceae	*Monsonia emarginata*
Geraniaceae	*Pelargonium alchemilloides*
Geraniaceae	*Pelargonium capitatum*
Geraniaceae	*Pelargonium cucullatum*
Geraniaceae	*Pelargonium reniforme*
Geraniaceae	*Pelargonium trifidum*
Geraniaceae	*Pelargonium z succulent* lf
Lamiaceae	*Stachys aethiopica*
Lamiaceae	*Teucrium sp*
Lobeliaceae	*Lobelia tormentosa*
Mesembryanthemaceae	*Carpobrotus edulis*
Mesembryanthemaceae	*Lampranthus z blue* lf
Mesembryanthemaceae	*Lampranthus z rigid lf*
Mesembryanthemaceae	*Ruschia rigens*
Montiniaceae	*Montinia caryophyllacea*
Myrsinaceae	*Myrsine z africana*
Papilionoideae	*Argyriolobium z tall*
Papilionoideae	*Aspalathus sp*
Papilionoideae	*Aspalathus z silver lf smllr*
Papilionoideae	*Indigofera denudata*
Papilionoideae	*Indigofera glaucescens*
Papilionoideae	*Indigofera heterophylla*
Papilionoideae	*Otholobium caffrum*
Papilionoideae	*Rhynchosia capensis*
Papilionoideae	*Tephrosia capensis*
Polygalaceae	*Muraltia squarrosa*
Rosaceae	*Cliffortia z microphylla*
Rubiaceae	*Anthospermum sp*
Rutaceae	*Agathosma sp*
Rutaceae	*Diosma sp.*
Santalaceae	*Thesium strictum*
Santalaceae	*Thesium sp.*
Scrophulariaceae	*Graderia scabra*
Scrophulariaceae	*Jamesbrittenia phlogifera*
Scrophulariaceae	*Selago corymbosa*
Scrophulariaceae	*Selago sp*
Scrophulariaceae	*Sutera polyantha*
Solanaceae	*Solanum hermanii*
Solanaceae	*Solanum sp*
Sterculiaceae	*Hermannia althaefolia*
Sterculiaceae	*Hermannia saccifera*
Sterculiaceae	*Hermannia velutina*
Sterculiaceae	*Hermannia z square lf*
Thymeleaceae	*Gnidia styphelloides*
Thymeleaceae	*Struthiola sp*

§: Invasive alien species

5.1.6. Description of the socioeconomic environment

The Eastern Cape has been inhabited by humans for many thousands of years, with archaeological evidence of human occupation dating back some 120 000 years. Artefacts and rock paintings from rock shelters in the Baviaanskloof Mega Reserve, which borders the Terra Pi Conservancy Area to the South of the Reserve, indicate the presence of prehistoric humans from at least the Middle Stone Age (100 000 to 30 000 years ago).

The hunter-gatherer San, who occupied the region until the Khoikhoi arrived about 2000 years ago, are considered to be the direct descendants of these early dwellers. The Khoekhoen, who were herders, migrated southwards from what is now Botswana with their sheep and cattle and later mixed with the San, to form a group known to archaeologists as the Khoisan.

European settlement in the Baviaanskloof region, commenced in the mid to late 18th century. The European settlers impacted the land intensively by establishing livestock, and the arable parts were put to cultivation. Many of the remaining San had little option but to move permanently onto the farms as servants and labourers, intermarry outside their culture and so merge with the wider population of the region.

The Kouga River catchment is characterized mainly by two main types of farming: agrarian and pastoral. The main livestock are goats, sheep and cattle. The production of fruit is the main economic driver of the area and the production includes apples, pears, grapes, oranges, apricots and peaches. Most of the wetland areas on the valley floors of the Langkloof have been drained and put to orchards, and most of the streams are dammed.

Before the Terra-Pi Conservation Area was acquired by the present owners, it was dedicated mainly to sheep farming and to game hunting. Black Wattle was introduced to provide shade for animals and wood for fuel and construction, around late in the 18th century, which eventually spreaded in time (Bateman pers comm., 2009).

The Terra-Pi Conservation Area accounts for 13,000 ha and has a wide variety of activities that include: conservation tourism, local capacity building, permaculture, environmental education, volunteer hosting and two pilot projects: the Kouga Riparian Rehabilitation Project, and the Water Neutral Initiative, that seeks to clear and rehabilitate of the 172 ha of Black Wattle invaded area, in a project that involves the World Wide Fund for Nature, the South African Breweries Ltd and the landowner.

5.2. Lower Witteklip Rehabilitation Area description and mapping

5.2.1. Area description

A protocol for the Evaluation of the Ecological Status of Mediterranean rivers (RBP) has been adapted and used for the description of the general characteristics of the study site. This protocol provides the necessary methodology to determine the value of two indices: the QBR index (to evaluate riparian quality), and the IHF index (physical habitat). This protocol is described by Jáimez-Cuéllar (et al. 2002) and the most important considerations, summarized below.

The QBR index protocol includes four independent blocks, which are summarized in the table following, which describe:

Table 2 Block description of the evaluation of the riparian vegetation quality (QBR index)

1. Extent of riparian coverage:	It considers the coverage percentage of all vegetation, except annual plants. Considers both sides of the river together. It must also be taken into account, the connectivity between the riparian forest and the forest ecosystem adjacent to add or subtract points.
2. Cover Structure	The score is performed according to the percentage of tree cover and in their absence, shrubs on the entire study area. It considers both banks of the river margins. Elements such as linearity in the foothills of the trees (symptoms of plantations), or hedges not evenly distributed, forming patches are penalized in the index, while the presence of heliophytes in the bank and the interconnection between trees and shrubs on the riverbank, are enhanced.
3. Quality of coverage	To fill this section, the determination of the geomorphologic type of the riparian area will be obtained. It considers the presence of islands in the river, the presence of a hard, rocky soil and others. Forests in the form of a tunnel along the river reflecting an increase of the score, depending on the percentage of coverage over the section studied. Introduced species in the area are penalized in this part of the index.
4. Degree of naturalness of the river channel	Modification of terraces adjacent to the river reduces its channel, increasing the slope of margins and loss of sinuosity on the River. The fields near the river and extractive activities produce this effect.

Jaímez-Cuellar (et al., 2002) mentions the following conditions that must be considered for the application of the QBR index:

1. Selection of observation area: Choose a length of 100 m in length, water above the sample point, and considered all potential width of riparian forest to calculate the QBR. Visual delimitation of the floodplain, bank and riparian zone.
2. Independence of the blocks to analyze: The four blocks in which the QBR index is based on, are fully independent and the score of each of them cannot be negative or greater than 25.
3. Calculation block by block: In each block is chosen one of four options top, scoring 25, 10, 5 or 0. One can only choose an entry.
4. Final Rating: The final score resulted from the sum of the four blocks therefore vary between 0 and 100.

The IHF index, considers 7 independent blocks, described in

Table 3 Block description of the evaluation of the fluvial habitat for Meditarranean rivers (IHF index)

Inclusion of rapids, pond sedimentation	*Inclusion*: It counts the degree to which substrate particles are fixed (sunk) in the riverbed. *Sedimentation*: The deposition consists in fine material in the river lentic areas.
Rapid frequency	It makes an estimated average of the occurrence of rapids in respect to the presence backwaters. This section aims to assess the heterogeneity of the river course.
Substrate composition	To complete this section provides an estimate visual approximation of the average composition of substrate, following the categories of RIVPACS (River Invertebrate Prediction and Classification System). The particle diameter considered in the RIVPACS categories is as follows: Blocks and stones> 64 mm. Pebbles and gravel:> 64 mm> 2 mm. Arena: 0.6 - 2 mm. Silt and clay: <0.6 mm.
Speed/depth regime	The presence of a greater variety of schemes speed and depth provides greater diversity of habitat available to organisms.
Percentage of shade to the cannel	It visually estimates the shadow cast by adjacent vegetation cover, which determines the amount of light reaching the river channel and influence the development of primary producers.
Heterogeneous elements	Measures the presence of elements such as leaves, branches, trunks or roots in the riverbed. These provide the physical habitat

	can be colonized by organisms in water, while a source of food for them.
Percentage of aquatic vegetation	Coverage and diversity of aquatic vegetation. Measures the coverage of aquatic vegetation in the riverbed. The greater diversity of morphologies on primary producers increases availability of habitats and food sources for many organisms. As much as the dominance of one group over the total coverage should not exceed 50%.

The IHF index has the following conditions:

1. Selection of observation area: The stretch of river assessed shall have a length enough (about 100 m) to provide the observer the necessary information required to cover the seven blocks that comprise the index. The index will be applied during periods when the flow is low, so that the substrate and the characteristics of channel can be easily seen. Do not evaluate the habitat immediately after a flood.
2. Independence of the blocks to analyze: The seven blocks in which the IHF is based are independent and the score of each of them may be higher than indicated at the bottom of the page field
3. Final score: The final score resulted from the sum of the seven blocks and therefore can never be greater than 100.

The information obtained, was complimented by a series of questions to the project manager about the different activities applied to the area which began the last week of January, 2009, and to the landowner, who explained the previous actions that had been done in the area for the last 20 years.

In an effort to have a view of the area before the burning of the biomass left from clearing, a helicopter flight was successfully executed and various photographs taken. This will be part of the monitoring for the rehabilitation success further flights will be scheduled. The photographic archive can be seen in Appendix

The Lower Witteklip Rehabilitation Area was a subject to a series of activities, including clearing, stacking of wood, preparing of fire breaks, wood burning and planting. All of them were recorded in detail and are mentioned in the results.

5.2.2. Area mapping

5.2.2.1. General mapping

All mapping for the Lower Witteklip Rehabilitation Site was made using one a Trimble Juno SB® Handheld unit, equipped with a high-sensitivity GPS receiver with 5 meter position accuracy, and the data was processed using the Trimble GPS Pathfinder Office® software, which can improve accuracy down to 2 meters. The data process was done with two software suites: the in the Arc View® GIS version 3.2, and the Kosmo Open Geographical Information Systems version 1.2.1.

The features considered for the general mapping were:

- General polygon
- Main river channel and subsidiaries
- Distribution of intervened areas

A longitudinal profile was drawn for the area, based on the information from the slopes layer.

5.2.2.2. Invasion mapping

R3G team undertook the mapping of the invaded areas, before the start of the clearing. In this mapping, the following aspects were described.

- Density of invasion
- Average stem diameter

Both were obtained in order to describe: the characteristics of the invasion of the *Acacia mearnsii* in the study site; possible differences within the stand and to define the clearing planning. This information was clipped with the general polygon to generate a description of the invasion in the study area by using the GeoProcessing Wizard extension from Arc View GIS 3.2.

5.3. Experimental design

One of the objectives of the Kouga Riparian Rehabilitation Project is to develop rehabilitation protocols (for clearing and planting) that can be applied and tested on a large scale, and long term monitoring is determinant in achieving this goal. Three assessments were undertaken as part of this study to assist in developing protocols:

- An assessment of the effect of the burning of biomass on the soil
- Active revegetation
- A soil seed bank study

5.3.1. Burning of biomass

Soil-stored seed banks in fynbos tend to be concentrated in the upper 3–5 cm of the soil and it is therefore important to know what temperatures are reached in this zone under different conditions of biomass loads, especially as many small seeds cannot germinate from lower in the soil profile because of their limited resources. (Behenna et al, 2008).

An experiment was undertaken to evaluate the temperature reached in the first 5 centimeters of soil, by using metal labels marked with Tempilaq ºG, a temperature sensitive paint. It has an irreversible color change when exposed to the temperature indicated for more than ten minutes. It's reported to have a ±1% error margin. (B.J. Wolfe Enterprises, 2009). The scale and colors used were:

Table 4 Thermal indicating paints: Range and colors of one set

Paint name	Color	Color change temperature
TL0175	Blue	79
TL0225	Green	107
TL0300	Dark Pink	149
TL0575	Brown	302
TL0950	Turquoise	510
TL1300	Light Pink	704
TL1700	White	927

A total of 70 sites were selected, marked and established prior to burning. Two aspects were considered in the site selection: amount of biomass and zonal distribution (floodplain and low slope; high slope was excluded). Each site was referenced with a GPS reading and its location was marked with a metal peg.

The final distribution of sites was as follows:

Table 5 Distribution of plots for the soil temperature experiment

Location	Amount of wood	Total sites
Floodplain	Low fuel	10
	Medium fuel	10
	High fuel	13
	Extra large fuel	10

Low slope	Low fuel	10
	Medium fuel	10
	High fuel	7
	TOTAL	70

Three label sets were placed under the wood stacks as these were lifted. One on the soil surface; a second one buried at 2 cm and a last one at 5 cm depht (Figure 4). After being exposed to fire, the labels were retrieved and checked for changes in color (Figure 5). During burning, some of the wood stacks were moved. As a result, several sets were left unintentionally left as controls for a no-burn treatment. The labels were stored for future revisions.

Figure 4 Burying the painted labels

(a) (b)

Figure 5 (a).Removal of painted labels. (b). Revision of labels

5.3.2. Revegetation

Revegetation was carried out in the study site starting in late July. The objective is to identify those species or guilds and densities which would effectively restore the ecological functions. Under this premise, a total of 98 planting plots were in the process of being established. Distribution was made in the different zones selected, Floodplain, Low Slope Hillside, and High Slope Hillside (Appendix C).

After clearing, and burning of the *Acacia mearnsii* invasion, the study site was planted with a mixture of native species which were selected by the R3G researchers under several considerations:

a. Species from surrounding, uninvaded reference sites: One of the approaches to planting, was to consider native species as they have proven long-term climatic adaptations and their coexistence with other native species suggests compatibility. Native species are less likely to cause new problems unless other problems exist, such as poor management (Whisenant, 1999)
b. Species whose seeds could be collected, propagated and established well with relative ease: It is very difficult and time consuming to collect the seeds of certain species (because of their size or reproductive mechanism), so these were avoided. Since one of the objectives of the project is to establish protocols which can be replicated on a large scale, it was considered an important aspect to consider that selected species should be able to be propagated and established easily, so that large areas can be restored.
c. Species that would grow quickly: this would potentially suppress alien recruitment (Holmes et al, 2008).
d. Species that will provide good ground cover: This selection criteria considers the risk having bare ground exposed to erosion.

Each planting plot was divided into two subplots (Burned, Not-Burned) ranging from 6 m^2 to 10 m^2. Sampling site selection was made in adjoining areas which had Black Wattle stacks and a cleared area. Before burning, metal pegs and numbered metal labels were placed to indicate the location of each site. The Burned plots (D) were marked the inside of the burned area, while the Not-Burned plots (N) were just next to it (Figure 4).

Figure 4 Sample of paired plots site after burning

Holmes (et al, 2008) suggests certain measures that should be considered for planting in the revegetation of invaded areas in fynbos:

Table 6 Fynbos ecosystem repair suggestion for revegetation

Measure suggested	Measure applied to the study site
1. If some indigenous vegetation is present prior to alien clearance soil seed (and propagule) banks supplying indigenous herbaceous and shrub understory species are likely to be present. If there was little evidence of indigenous vegetation pre-clearance seed banks may still be present	The study site has suffered a long term and dense invasion from the Black Wattle. Seedbank is assumed to be poor.
2. If a severe fire has gone through the area (with evidence of burnt soil organic matter or subsequent soil erosion) seed banks will have been severely depleted. Therefore the site requires active revegetation. To restore ecosystem functioning the minimum requirement is bank stability and soil surface erosion control. Thus a mix of local pioneer understorey (herb and shrub) species should be sown or planted.	Evidence of previous fires is seen in the study site. Erosion is not evident. Active restoration is considered the main strategy for intervention.

Measure suggested	Measure applied to the study site
3. In terms of restoring structure if pockets of indigenous scrub persist along the river – within 200 m or upstream of the site – then these species will recolonize over time.	There are no pockets of remaining scrub in the catchment, and active planting will be applied.
4. Riparian scrub species may be established from rooted cuttings or seedlings transplanted in the field.	-
5. Sowing should be done directly onto bare ground with the seed lightly raked into the soil or covered by light wood chip mulch. If done after initial clearance the establishing vegetation has potential to partially suppress alien recruitment and reduce follow-up costs. Seed should be sown in autumn in the Western Cape and either early autumn or early spring in the Eastern Cape.	Planting and sowing were done without wood chip mulch during early spring.
6. Planting is best done under similar conditions to the sowing treatment although some scrub species may establish better in the presence of sheltering herbaceous species. In the Eastern Cape grasses are better planted in spring.	

The distributions of the planting treatments were as following:

Table 7 Treatments distribution for paired-plots experiment

Location	Control	High density planting (9/m^2)	Low density planting (4/m^2)	Seeding and planting	E. Tef sowing	TOTAL
Floodplain	8	8	8	8	8	40
High slope hillside	2	2	1	1	1	7
Low slope hillside	10	10	10	10	11	51
TOTALS	20	20	19	19	20	98

Each treatment consisted in:

Control: Control plots were left without any intervention

High density planting: This plots where planted with a 9 plants per m^2 density of in a mixture of species that will depend on the area (floodplain or slopes).

Low density planting: Planting will be established in a 4 plants per m^2 with the same conditions as the high density planting.

Seeding and planting: Seeding using grasses, and planting with the same design as the low density planting, will be performed. Seeding species will mainly be composed by grasses.

***Eragrostis tef* sowing:** This species will be tested for ground cover to prevent possible erosion.

Planting will be done with the following species:

Table 8 Species selected for paired-plots experiment

Species	Growth form	Location	Propagation	Important characteristics
Anthospermum	Shrub	Floodplain	Plugs and bags	
Athanasia trifurcata	Shrub	Slopes	Plugs and bags	Very resistant
Cliffortia sp	Shrub	Slopes	Bags	Fast growing herbaceus. Ground cover
Conyza sp.	Herb-forb	Floodplain	Plugs and bags	
Cyperus textilis	Sedge	Floodplain	Plugs and bags	
Dodonaea sp.	Shrub	Slopes	Bags	
Helichrysum cymossum	Shrub	Floodplain	Bags	
Helichrysum papposum	Forbs	Floodplain	Plugs and bags	
Juncus sp.	Herb	Floodplain	Bags	Reseeder soil seedbank
Mariscus sp.	Sedge	Floodplain	Bags	
Metalasia sp.	Dwarf Shrub	Slopes	Bags	Good for erosion
Miscanthus capensis	Grass	Floodplain	Plugs and bags, seed	
Monopsis sp.	Woody herb	Floodplain-slopes	Bags	
Osyris compressa	Shrub	Slopes	Bags	Vast reproductive ability
Passerina sp.	Shrub	Floodplain	Plugs and bags	
Pelargonium sp.	Shrub	Floodplain	Plugs and bags	Seed, cutting other forms of propagation
Pittosporum viridiflorum	Shrub	Slopes	Bags	
Plectranthus sp.	Forbs	Slopes	Bags	
Protea repens	Tree	Slopes	Bags	Propagated from seeds and from cuttings
Restio sp.	Restio	Floodplain	Bags	Reseeder soil seedbank
Rhus longispina	Shrub/Tree	Floodplain-slopes	Bags	
Salix mucronata	Shrub/Tree	Floodplain	Bags	Resprouter
Schoenoplectus	Sedge	Floodplain	Bags	Emergent hydrophyte
Scirpus prolifer	Sedge	Floodplain-slopes	Plugs and bags	

Species	Growth form	Location	Propagation	Important characteristics
Senecio sp.	Woody herb	Floodplain	Bags	Seed
Themeda triandra	Grass	Floodplain	Plugs and bags	Seed
Tristachya leucothrix	Grass	Floodplain	Bags	Seed
Widdringtonia sp.	Tree	Slopes	Bags	

5.3.3. Effect of soil preparation methods on seedbank

Currently, the Working for Water teams has three main clearing treatments, differing from each other in the methods for removing material. Those methods are: Fell Only, Fell-Remove and Fell-Burn (Blanchard & Holmes, 2008)

This experiment was designed to compare two methods that can be used on a landscape level to eliminate unwanted biomass left on the ground after invasive species clearing: burning, or transformation to wood chips, considering that effectiveness of restoration could be seriously compromised by the unpredictable and sporadic, low density recruitment and reinvasion from IAP seedbanks over vast areas (Richarson & Kluge, 2008).

After clearing, Black Wattle residues are usually left on the field due to the difficulty for transporting them out. However, this might result in uncontrolled wildfires representing potential risk to safeguarding large areas. Using a wood-chipper or burning the dried wood, are both options for having these residues removed from the soil, so both were evaluated in this experiment.

Samples were collected randomly at the sites previously selected for evaluation of soil temperature. Most of the sites were visited twice. The first time was done before burning took place (pre-burn), whiles the second visit, was after burning (post-burn).

Soil samples were collected from the top 5 cm by taking an average of 5 scoops within an area of 1 m^2 for a total volume of 1 000cm^3 per sample and later placed in plastic reclosable bags. For the pre-burn, two samples were taken per site, on each side of the wood stacks and for the post-burn a single sample was collected where the wood stacks had been. Each post-burn site was described and photographed (Appendix E). The soil collected, was later left to dry in a shed at the Kouga Dam Nursery for a total of 2 weeks.

The soil from the pre-burn samples was mixed and homogenized and then spread in a tray containing bark at the bottom and washed river sand at the top. The same procedure was used for the post-burn samples.

The trays were placed in the Kouga Dam Nursery and watered daily. Seedling counting was done once a week for a total of 3 weeks, separating them in two categories: Black Wattle and indigenous species, which were not identified to species. Each seedlings counted, was removed from the tray. This method can present some inconveniences such as the absence of seeds on the soil fraction extracted and dormancy (Piudo & Cavero 2005, Ferrandis et al, 1999).

(a) (b)

Figure 7 (a). Soil collection pre-burn. (b). Soil collection post-burn

(a) (b)

Figure 8 (a) and (b) Preparation of trays for seed bank germination

5.4. Data analysis

Soil temperature data was analyzed by using basic descriptive statistics. The Student's t-test was used to compare the effect of different amounts of fuel over the two evaluated locations (Floodplain and Low Slope). ANOVA tests were applied to examine the effects of the 6 different soil treatment methods, on Black Wattle and on indigenous species germination. A Games-Howell post-hoc test was applied to test for pair-wise differences between the 6 treatments combinations. The analyses were performed using the Compare Means module of SPSS Statistics 17.0. Descriptive statistics were also analyzed for these experiments.

6. RESULTS

6.1. Characterization of a section of the Witteklip River

The study site was characterized during the austral autumn (April 2009). During this season, the river showed no water in its bed, which is probably related to the drought that affected the Eastern Cape in South Africa during the early part of the year, recalled as the worst in the last 40 years (Hayward, 2009).

The valley has a U-shaped morphology characterized with a minimal channel width of the section of 1.5 m and a maximum width of 3.0 m. The water flow during the sampling made in autumn was very scarce, and together with the drought, it's possible that the presence of IAP could have contributed to this situation.

The section of the Witteklip River subject to this study has the following longitudinal profile:

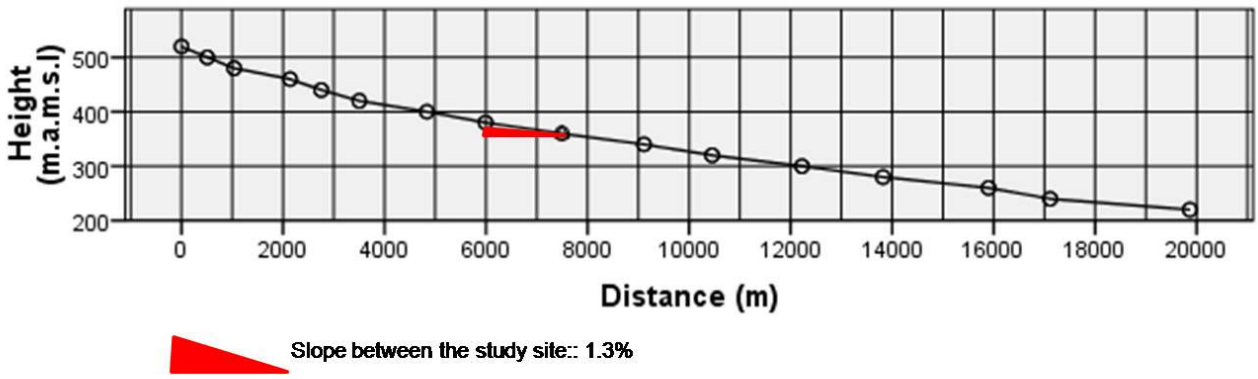

Figure 9 Longitudinal profile of the Witteklip River, and of the section of study.

The uses and impacts on the study area and the basic characteristics of the flow are described in the following tables:

Table 9 Uses of the study area

Description	Previous	Current
Predominant use of fluvial terrace (left)	Area completely invaded with Black Wattle	Cleared area in process of revegetation
Secondary use of fluvial terrace (left)		
Predominant use of fluvial terrace (right)		
Secondary use of fluvial terrace (right)		
Nature of the flow	Flow is minimal to the natural optimal. Almost no water was found.	
Possible causes	Alien invasive species	

Table 10 Flow characteristics

Characteristic	Description
Nature of the flow	Flow is minimal to the natural optimal. Almost no water was found.
Possible causes	Alien invasive species
Other impacts over the flow nature:	Weir upstream. Alien invasive species throughout the watercourse

The results riparian vegetation quality index of the study site, describe the area as an extremely degraded site with a very low quality (Table 11).

Table 11 Results from the evaluation of the riparian vegetation quality index (QBR)

Feature	Chacateristic	Punctuation
Percentage of riparian zone cover	< 10% of vegetation cover of the riparian zone	0
Cover structure	Less than 10% of cover composed of trees or shrubs	0
Quality of the cover	No indigenous trees	0
Nature of the fluvial channel	The river channel has not been modified	25
	TOTAL	25
	Rating	extremely degraded site very low quality

The site has been rated as a Type 2 Riparian Area (

Table 12) by using the rating method in Appendix A.2. According to the Jáimez-Cuellar (2002), this type of area, has an intermediate capacity to support vegetation with the current conditions.

Table 12 Geomorphologic type of the riparian area

Description		Punctuation		
Types of slope change in the riparian area		**Left**	**Right**	**Total**
Slope between 20 to 45^{o}		2	2	4
Presence of one or more islands in the middle of the watercourse		0	0	0
Percentage of hard substrate with incapacity to have permanent vegetation 20-30%		-	-	2
TOTAL		**-**	**-**	**6**

Results shows that the Lower Witteklip Rehabilitation Area can only have a partial success in holding aquatic biota, considering that at the time of visit, the aquatic vegetation was scarce or absent in most of the river's channel.

Table 13 Evaluation of the fluvial habitat for Meditarranean rivers

Blocks		Punctuation
Inclusion of rapids and ponds		
Ponds: Sedimentation 0-30%		10
Rapids frequency		
Constant laminar flow or shallow rapids		4
Substrate composition		
% of blocks and stones	1 - 10%	2
% of gravel	> 10%	5
% of sand	> 10%	5
% of stilt and clay	1 - 10%	2
Speed/depth regimes	No water found	0
Percentage of shade to the channel	Exposed	3
Heterogeneous elements		
Litter	>10% or <75%	4
Presence of logs or stems		2
Exposed roots		2
Percentage of aquatic vegetation		

% of Phanerogams and Charales	< 10% or > 50%	5
	Total Punctuation	44

6.2. Review of the clearing and rehabilitation activities in the study site

Part of the study site in the Lower Witteklip River, was treated in 2001 for Black Wattle invasion (Appendix B). The strategy at the time was only to fell and burn and the area was neither revegetated nor did it receive any follow-up treatments. In seven year, the area was covered with *Acacia mearnsii*, with trees with diameters ranging from 13.22 to 21.71 cm in the previously cleared area, and in the rest of the area, from 73.4 to 119.37 cm (Figure 10).

During the beginning of January 2009 and until late March, two Working for Water teams started clearing an area comprising 12 ha within a section of the Witteklip River. The clearing of IAP as performed by WfW, included the following procedures:

- Cutting all present trees (young and adult) near the base
- Application of herbicides herbicides (triclopyr, glyphosate, dicamba and picloram) to suppress resprouting
- Wood stacks piling

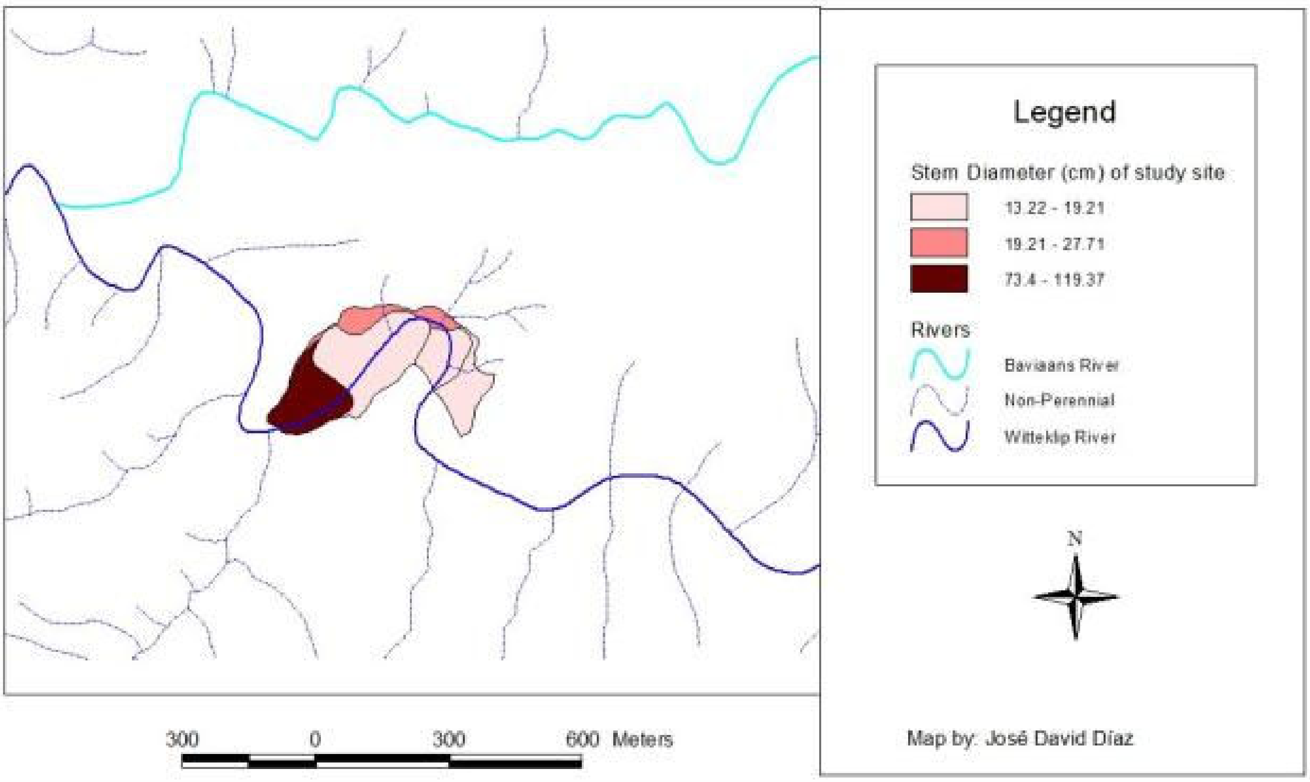

Figure 10 Stem diameter (cm) of Black Wattle in the invaded area at the study site

After the stacks were piled, wood was left to dry for a period of 4 months (Figure 11), and the experiments performed in the area, established. The follow-up treatment for the area was to burn all the woody biomass left on the ground and Working for Fire, a government institution with a similar scheme as WfW, was contacted to execute it. They recommended setting up firebreaks to prevent the fire from spreading to neighboring areas and turn into wild fire, so most of the wood located in the borders of the cleared polygon, had to be moved into the inside.

The burning was scheduled for the second week of April, but inappropriate weather conditions and administrative issues, forced the burning to be held back until early June, with two Working for Fire teams completing the task in 7 days. Planting was made following the plot distribution defined during the Paired Plots experiment and depending in the site.

Figure 11 Cleared area

6.3. Burning of biomass

Most of the label sets were collected and analyzed to record the changes in coloration that could indicate temperature increases. However, not all of the sets were found, and others were not exposed to heat since dry wood was moved during burning execution as some stacks were too small to be ignited properly and had to be placed together. The cases described, exclusively mention those sets which were exposed to heat.

For both sites, it was observed that temperature decreased as the depth of the labels increased, which is obvious when considering that the transmission of heat is greater as is the nearest object. This is described in Figure 12 and the complete descriptive statistics can be consulted in Appendix A.

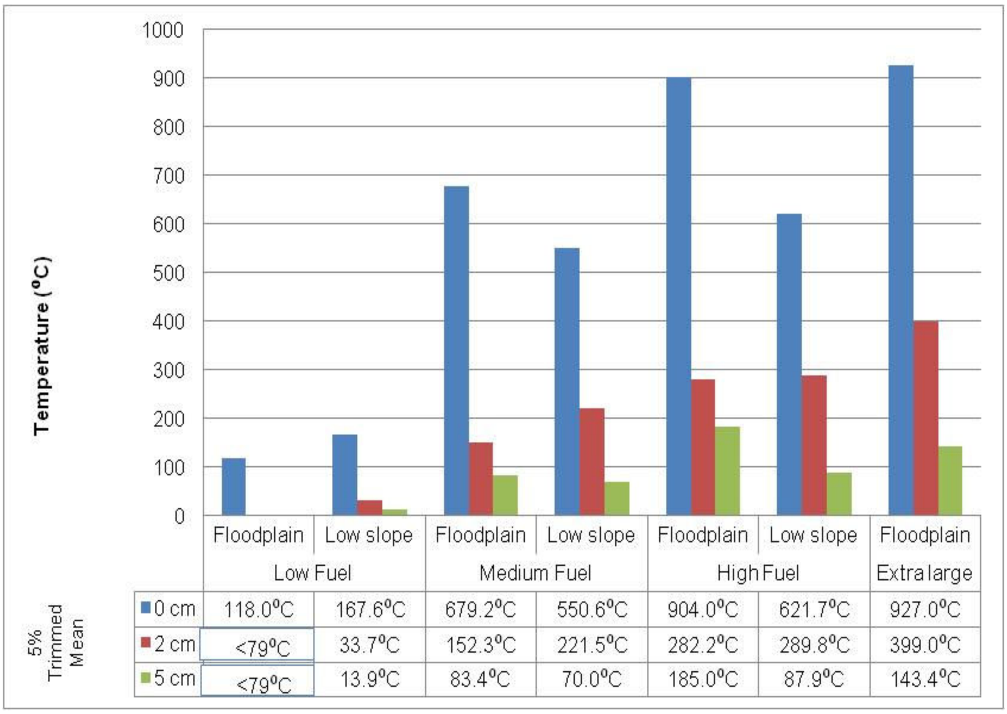

Figure 12 Mean (5% trimmed) of the soil temperature as measured in the floodplain and low slope sites for the different amounts of wood fuel.

Peak temperatures (927ºC) were reached at various samples located over the surface of all sites except those with low fuel, in the floodplain and low slope sites. At 2 cm, this temperature was reached in the medium, high and extra large fuel sites in the floodplain, while at 5 cm it was only registered in the medium and high sites located in the floodplain.

At 2 cm, the mean did not exceed 400ºC, having the highest registry at the extra large floodplain sites with 399ºC. For the 5 cm sets, temperature had the highest mean at 185ºC from the high fuel floodplain site. This data was later analyzed with the seedbank experiment.

6.4. Effect of soil preparation methods on seedbank

The experiment was set up July 17, but prior to this date, some of the reclosable plastic bags containing the sample collected from the burned treatment, showed some Black Wattle seedlings germinating. These seedlings were counted, separated from the soil samples and considered as the first measure for the burned treatment. Checkup was done for the control soil taken, but no seedlings were present.

The analyzed results showed certain tendencies, such as germination of Black Wattle in burned sites, which had a higher mean compared to that from the other treatments, except for the "low fuel-low slope" site, as can be seen in **¡Error! No se encuentra el origen de la referencia.** and in Table 14. It is also possible to observe that germination of Black Wattle for the wood chip treatment for both locations was less than those of the control.

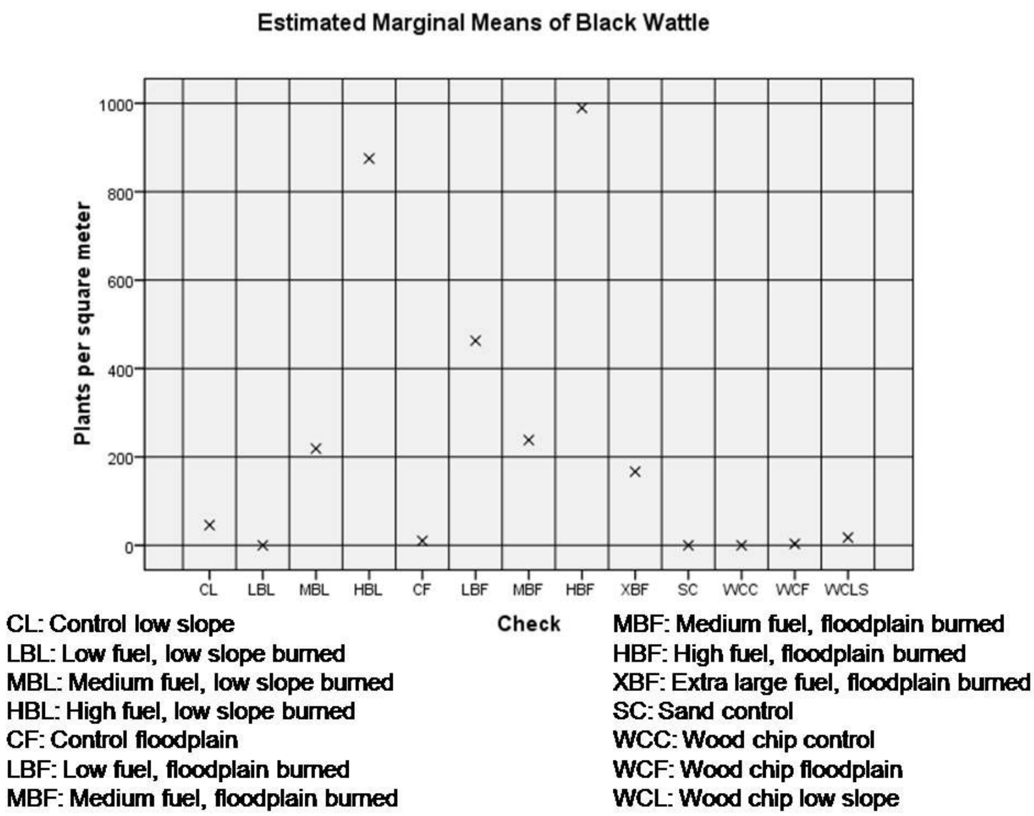

Figure 13 Estimated marginal means of Black Wattle germination with the different treatments applied

Table 14 Estimated marginal means, standard error and the 95% confidence interval for the Black Wattle germination under different residue removal methods

Estimated marginal means

Descriptive statistics for Black Wattle

Location	Description	Mean	Std. Error	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Low slope	Control	45.834	85.057	-122.161	213.828
Low slope	Low fuel	0.000	170.113	-335.989	335.989
Low slope	Medium fuel	218.749	134.486	-46.874	484.372
Low slope	High fuel	875.000	268.973	343.754	1406.246
Floodplain	Control	10.000	76.077	-140.259	160.259
Floodplain	Low fuel	462.962	126.795	212.531	713.394
Floodplain	Medium fuel	238.096	143.772	-45.867	522.058
Floodplain	High fuel	989.583	134.486	723.960	1255.205
Floodplain	XBF	166.667	120.288	-70.913	404.247
-	Sand control	0.000	79.316	-156.656	156.656
-	Wood chips control	0.000	120.288	-237.580	237.580
Floodplain	Wood chips	3.333	76.077	-146.926	153.592
Low slope	Wood chips	17.544	87.266	-154.815	189.903

Significant differences were observed for the "high fuel-floodplain" for the Black Wattle germination compared to all of the other treatments. Only the "high fuel-low slope" and the "low fuel-floodplain" sites did not show differences, as it can be observed in Table 15.

Table 15 Results from the Games-Howell post-hoc test for the 'high fuel-floodplain' treatment to test for pair-wise differences between the 12 treatments combinations

(I) Check	(J) Check Treatment	(J) Check Location	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
High fuel, Floodplain	Control	Low slope	943.7490*	159.12631	.000	408.4131	1479.0849
	Low fuel	Low slope	989.5825*	216.85260	.001	260.0427	1719.1223
	Medium fuel	Low slope	770.8338*	190.19232	.005	130.9850	1410.6825
	High fuel	Low slope	114.5825	300.72045	1.000	-897.1072	1126.2722
	Control	Floodplain	979.5829*	154.51297	.000	459.7673	1499.3985
	Low fuel	Floodplain	526.6203	184.83371	.191	-95.2009	1148.4415
	Medium fuel	Floodplain	751.4868*	196.86775	.012	89.1804	1413.7931
	Extra large fuel	Floodplain	822.9155*	180.43227	.001	215.9017	1429.9293
	Sand control	-	989.5825*	156.13307	.000	464.3166	1514.8484
	Wood chips control	-	989.5825*	180.43227	.000	382.5687	1596.5963
	Wood chips	Floodplain	986.2493*	154.51297	.000	466.4337	1506.0649
	Wood chips	Low slope	972.0388*	160.31828	.000	432.6929	1511.3847

For the other species group, it was possible to observe that there was not a clear tendency related to the treatments based on the estimated marginal means for germination (Figure 14, Table 16). However, it is important to notice that there were seedlings present in the sand control as well as for the wood chip control. Since there was no separation between the other group species, it was not possible to segregate the species from source. Thus, it is possible that the germination data available might be flawed.

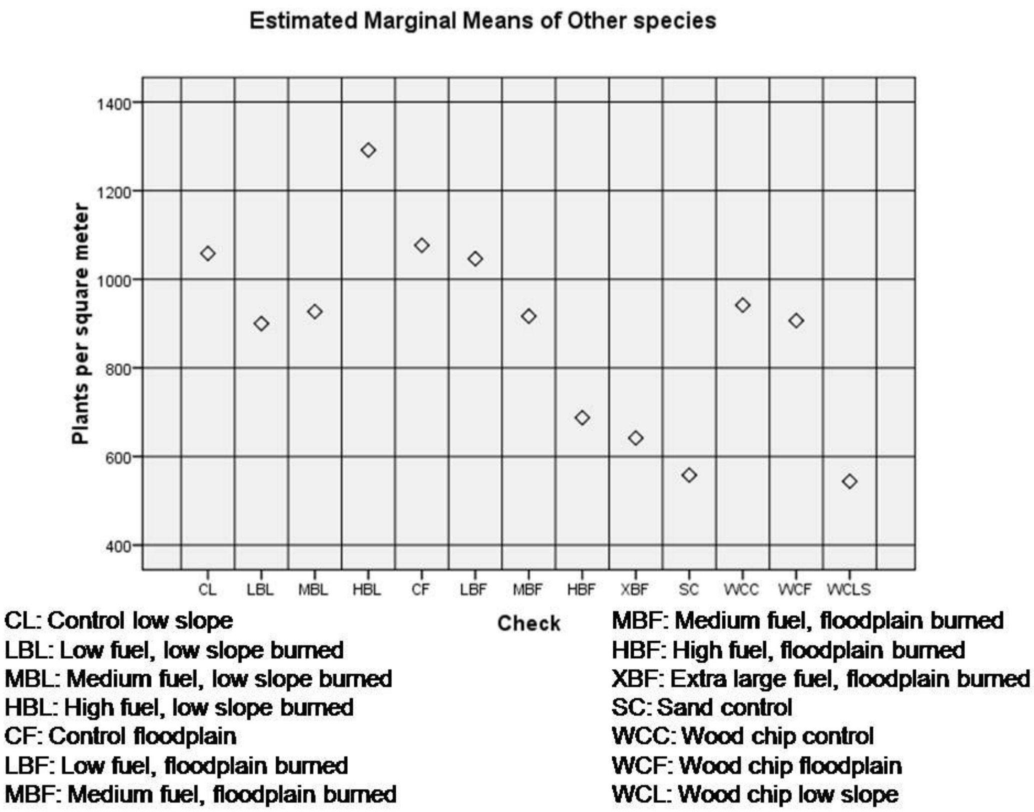

Figure 14 Estimated marginal means of the other species germination with the different treatments applied

Table 16 Estimated marginal means, standard error and the 95% confidence interval for the Black Wattle germination under different residue removal methods

Estimated marginal means

Descriptive statistics for Other species

Location	Description	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
Low slope	Control	1058.334	146.006	769.959	1346.708
Low slope	Low fuel	900.000	292.011	323.251	1476.749
Low slope	Medium fuel	927.083	230.855	471.122	1383.043
Low slope	High fuel	1291.665	461.710	379.745	2203.585
Floodplain	Control	1076.665	130.591	818.735	1334.595
Floodplain	Low fuel	1046.297	217.652	616.413	1476.180
Floodplain	Medium fuel	916.669	246.794	429.227	1404.110
Floodplain	High fuel	687.500	230.855	231.540	1143.460
Floodplain	XBF	641.667	206.483	233.844	1049.490
-	Sand control	557.970	136.151	289.060	826.881
-	Wood chips control	941.667	206.483	533.844	1349.490
Floodplain	Wood chips	906.667	130.591	648.737	1164.597
Low slope	Wood chips	543.859	149.799	247.993	839.725

No significant differences were obtained for the other species germination.

By grouping seedbank soil samples by peak temperature at intervals of 150 °C (Figure 15), it was possible to observe that for the temperature range of 600 °C to 750 °C, the highest mean germination for the Black Wattle was obtained, whereas in the case of the other species group, the range of 300 º C to 450 º C was the most representative. This figure however does not segregate between growth forms nor between species.

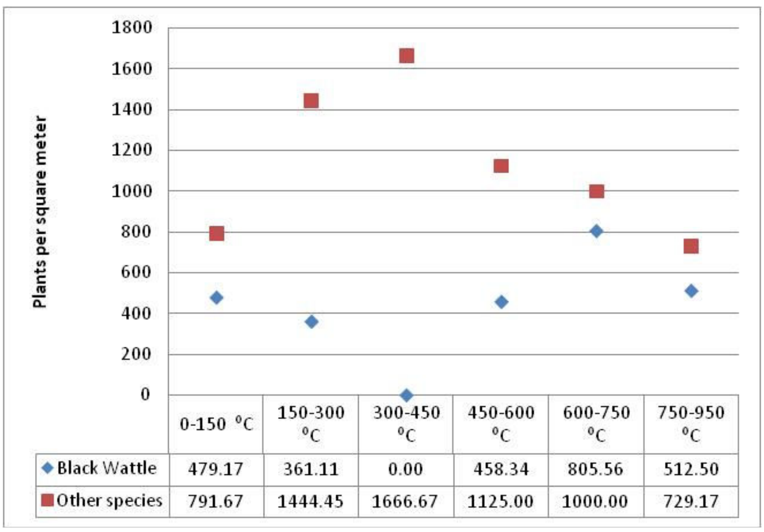

Figure 15 Estimated germination means for Black Wattle and the other species group, separated by temperature range.

7. DISCUSSION

7.1. Characterization of the Witteklip River:

The study site at the Lower Witteklip River has been classified as an extremely degraded site with very low riparian vegetation quality as stated in Table 11, and the influence of Black Wattle in this results, is evident. Black Wattle established itself in this degraded area previously used to graze sheep. Its high competitive ability and its efficient use of water were key elements for damaging the hydrological cycle and suppressing the indigenous vegetation in the area (Pretorius et al, 2008; Dye & Jarmain, 2004).

Thus, complete clearing of the Acacia mearnsii (trees, shrubs and seedlings) was essential to improve the ecological conditions of the area (Holmes et al, 2008). Considering that the study site was previously cleared with no success, and that the presence of indigenous trees that might serve as propagules is marginal, the Project's approach aims towards active restoration, complemented by an active seedbank.

The study site is a Type 2 Riparian Area (Table 11) which specifies that it has an intermediate potentiality to endure vegetation (Jáimez-Cuéllar et al., 2002). This could predict that with the area does not require interventions that would modify the substrate conditions in order to have successful vegetation.

The current degradation situation of the Lower Witteklip Rehabilitation Area, presents difficulties for the establishment of aquatic fauna, according to the Evaluation of the fluvial habitat for the Mediterranean rivers (Table 13). Considering that immediately after clearing the area did not have any aquatic fauna present, the evaluation of aquatic biota could be used one of the indicators of success (Ffoillott & DeBano, 2007)

7.2. Distribution of paired plots and planting sites

The success of Black Wattle clearing executed in 2001 was very limited. Natural regeneration of indigenous species did not succeed in dominating the environment, succumbing to the very competitive *Acacia mearnsii*. Active restoration may be decisive in obtaining success in riparian environments such as the Lower Witteklip Restoration Site.

Holmes (et al, 2008) mentions that riparian ecosystems in Fynbos, regularly present a relatively high ecological resilience to invasions by alien species. Although recovery of natural revegetation post-alien clearance is desirable, it might not always be possible in sites with heavily invaded stands with densities above 75% of aerial cover, in areas with a long term invasion and in those areas were closed alien acacia stands have received the 'Fell and Burn' alien-clearing treatment. The three conditions were seen in the study site at the Lower Witteklip Restoration Site.

The elaboration of a restoration protocol that can be used in the areas invaded with Black Wattle in South Africa, estimated that the best option was to apply active restoration. Efforts for the Kouga River Rehabilitation Project are oriented towards identifying the species or species groups that can be considered key in restoring processes (reducing light availability for IAP, providing a habitat for wildlife species associated with the ecosystem) and avoiding further degradation, such as erosion, (Holmes et al, 2008).

Since the reach of the Working for Water Program is of national importance, aspects such as seed collection and plant nursery management are important issues as they are part of a national interest to improve environmental conditions for riparian areas, and using the 'paired plots' technique, will complement the information generated by including the effects of burning on the survival of the planted and sown species in the different zones (floodplain, low slope, high slope).

7.3. Biomass burning

Measuring soil temperature using the painted labels method, allowed a large sample distribution, whilst having the same amount of samples using thermocouples, would have been more difficult to establish and more expensive.

As expected, the temperature at which the soil was exposed became higher as the fuel load increased. This temperature increase did not depended on the location of the sampling site (Floodplain or low slope), but on the depth at which the labels were buried. Results from the surface, showed substantial differences from those located at 2 cm. At 5 cm, differences were even larger. Samples reaching the highest temperature peak (927 º C) were observed at all depths at least once. However, at 5 cm only one in 77 sites reached this temperature. These data confirms that the highest temperatures are more likely to happen in the surface.

Some of the sites were established about three weeks before the burning treatment took place. During this period, it is possible that soil humidity could have damaged the labels, especially those marked with the 704ºC and 927ºC paints, which were very sensitive to being scratched or damped. Label digging was performed very carefully to prevent any damage for being caused to the paint that could alter the reading.

The presence of different diametrical classes in the cleared area might have been one of the factors that affected the fuel load. This data was not measured during the experiment, but previous data show that most of the large trees located in the area left standing in 2001, ranged from 73.4 to 119.37 cm. Most of these areas were included in the extra large treatment.

When burning was executed, the large logs present burned very slowly before the fire would extinguish, exposing the top soil to high heat for extended periods which lasted for at least 24 hours in some cases. Some of those sites presented loose-yellowish soil, presumably due to the damaging of the soil's physical properties, such as soil structure, soil porosity, water retention and water repellency (Neary et al, 1998). Effects of fire on the soil physical systems are complex and result from changes in organic matter during soil heating (Neary et al, 1998).

Soil analysis for the content of these materials is scheduled as a follow up for this experiment. Further information should be gathered in order to determine the indigenous species' tolerance to temperature, considering the temperatures reached in the experiment.

7.4. Effect of soil preparation methods on seedbank

The effect of fire on seed germination of Black Wattle was a determining factor for the experiment, as most of the germinated *Acacia mearnsii* seedlings came from the burned sites, with the highest frequency in the "high fuel-floodplain" site, which had the following mean temperatures: surface, 895.14 ºC ±31.86; 2 cm, 305.71ºC ±116.03; 5 cm, 212.86 ºC ±120.57. It was followed by the "high fuel-low slope" site, with mean temperatures in the surface of 613.29 ºC ±133.21; at 2 cm, 291.71 ºC ±77.45 and at 5 cm, of 86.57 ºC ±25.32. Soil exposed to higher temperatures in the "extra high fuel-floodplain" site, resulted in less germination, which implies that as temperature rises to a certain threshold, germination will decrease for the *Acacia mearnsii* seeds. This data can be observed graphically in Figure 15.

For the other species group, the highest mean germination values were observed in the temperature range of 300 ºC to 450 ºC, followed by the 150 ºC to 300 ºC. As the temperature suffered an increment at the 750 ºC to 950 ºC group, the mean germination decreased.

The use of fire for removing the Black Wattle biomass represented an efficient way for eliminating unwanted material from the soil. However, it was possible to observe that germination of Black Wattle increased with the burned treatment compared to the control and to the wood chips treatment.

Although this is possible to observe in figures, it is statistically significant when comparing the "high fuel-floodplain" site to the all but the "high fuel-low slope" and the "low fuel floodplain" burning treatments using the Games-Howell post-hoc test. Further management must be applied to control the outbreak in order of *A. mearnsii* seedlings responding with a follow-up clearance treatment of blanket herbicide spraying. However, this would indiscriminately kill all dicotyledonous species, indigenous and aliens alike (Holmes et al, 2008) and should be evaluated before selecting it as the main follow-up treatment.

The results for the control and for the wood chips treatment resulted in almost no germination for Black Wattle in both the floodplain and the low slope sites, whilst for the other species group, germination was observed but low.

It was not possible to define if germination for the other species group in the controls section (sand control, wood chips control) was a result of the presence of seeds in the sand control or in the wood chips, as there was no separation between species for the other species group.

Some of the fynbos species are fire dependant, but so is the *Acacia mearnsii* and as it was described by Holmes (2002), areas with high densities of invasive alien species present, show a significantly lower fynbos seed density.

It is possible that some of the results yielded for both the Black Wattle and the other species group seedbank were low as an effect of the treatments, a low seed rain, depletion of surface seedbank, or simply because seeds did not germinate during the length of the experiment. Similar experiments have yielded their final results in a period of 12 months (Fourie, 2008) and time consumed for this experiment probably was not enough.

8. CONCLUSIONS

1. The Lower Witteklip Rehabilitation Site is a degraded area which has had a long history of Black Wattle invasion. This situation has probably depleted the local seedbank, and it has established a long lasting *Acacia mearnsii* seedbank.

2. Although it was not measured in this study, the most important environmental issue affected by this IAP was the alteration of the hydrological cycle.

3. Presence of Black Wattle in the area reduced the occurrence of indigenous species in the study site, decreasing the quality of the riparian vegetation which was almost absent, such as the aquatic fauna.

4. After applying the Fell and Burn method, it's likely to expect that the seedbank will be dominated mostly by Black Wattle with few indigenous species present. Holmes (et al, 2002) describes this scenario as ideal for Black Wattle recolonization, unless follow-up treatments are applied. Therefore, the immediate revegetation with native species is expected to suppress Black Wattle population within the area for each specific zone (low slope, high slope and floodplain).

5. For the revegetation of the floodplain, the selected species are resistant to inundation and to floods while for the other zones, the selected species contribute with other attributes such as erosion control. It will be then important to monitor the survival from these species in order to determine the most successful species to be included in a protocol for restoration at a large scale within the WfW format.

6. For the biomass burning, it was observed that temperatures from the surface reached the highest values and as depth became higher, values decreased. This values, did not depend on the sampling site (floodplain or low slope) but on the amount of burning material that was placed.

7. Having large wood stacks on the ground, might cause soil to be exposed to high temperatures for a long period, resulting in damage to the soil structure, soil porosity, water retention, and water repellency. All this factors should be checked for later analysis.

8. Increased germination occurred to the *Acacia mearnsii* seeds contained in the seedbank due to the effect of fire stimulation. This was more evident for the "high fuel-floodplain" which was statistically significant when compared to all of the other treatments applied but the "high fuel-low slope" and the "low fuel floodplain" treatments.

9. The effect of not being burned might have caused the Black Wattle seeds to germinate in a lower rate than those exposed to the burned treatment. This might have also been the case for the wood chips treatment.

10. It is unconfirmed if the germination of the other species group from the different treatments, is a result of the presence of seed in the soil seedbank, in the sand or in the woodchips, since there was no segregation of species during separation of groups and in the samples for both the sand and the wood chips controls, presented seedlings.

11. It is not conclusive which one of the treatments influenced on the results for the germination of the seedbanks of both the Black Wattle and the other species group. Possible causes could have been an effect of the treatments, a low seed rain, depletion of surface seedbank, or because seeds did not germinate during the length of the experiment.

12. ASSESSMENT OF ACTIVITIES

8.1. On the rehabilitation of a section of the Lower Witteklip River

Concerning the rehabilitation activities for the section of the river Witteklip evaluated and the diagnosis of the area and following the Principles for River Restoration proposed by Garcia de Jalon and Gonzalez del Tánago (2001), the following is an analysis of the each principle, the observed situation during the study and the applied or proposed solution selected for each situation:

<table>
<tr><th>Principle</th><th>Observed situation</th><th>Applied solution/
Proposed solution</th></tr>
<tr><td>1. Connection between the river and the catchment area</td><td>Flow absent during most visits. Water was observed associated with a heavy rain event in late summer. The fact that constant flow was not seen, allows the interpretation that the connection of the basin with the banks, could be considered as very poor.</td><td rowspan="2">Proposed solution: On a catchment level, it is important to keep track of the river flow in the closest station downstream (at the Kouga Dam) in order to determine if the interventions had any influence on the water yield.</td></tr>
<tr><td>2. Flow regime</td><td>It is assumed that since there was no water running, the ecological regime to should be below the required level for this type of ecosystem. Although this information was not obtained, it can be implied that the presence of low riparian vegetation, this may be related with a low flow regime.</td></tr>
<tr><td>3. The morphology of channel in response to hydrological behavior of the catchment and the river processes of erosion and sedimentation:</td><td>The river has not been altered by factors that require some intervention. However, clearing of Black Wattle might increase the possibilities for soil erosion leaving a bare soil.</td><td>Applied solution: An adaptation of the 'Wischmeier erosion plots' was distributed in 5 sites at the low slope hillside to measure the water erosion and the effects of revegetation on this.</td></tr>
</table>

Principle	Observed situation	Applied solution/ Proposed solution
4. The biodiversity of the river is the product of a diversity of habitats and functional connectivity between them	The presence of Acacia mearnsii forming almost monospecific vegetation in the assessment area have failed to comply with the terms of habitat heterogeneity and thus, reduced functional connectivity between them. However, elements such as logs and litter on the channel, might enhance the diversity of habitats in the system.	Applied solution: Black Wattle clearing and revegetation with different guilds according to the different riparian zones, will present a heterogeneous habitat and hydraulic conditions for a wider number of species than from the previous situation.
5. Individuality of river systems	The reference area is in similar conditions to the study site but it has not been invaded with *Acacia mearnsii*.	Applied solution: Taking the reference of ecosystems not invaded, that the section sought to restore the river in reference to the composition from these reference sites.
6. Enhancement of natural response by their own means	Possible erosion scenarios might have been possible from the presence of Black Wattle in the river channel. Management of the seedbank might allow for this principle to be accomplished by exploiting the natural conditions of the site.	Applied: No mechanical methods will be applied for containment of floods, but revegetation with flood-resistant species.
7. River restoration requires space	There are no barriers established to block the connection of the channel to its floodbank.	No measures were considered necessary.
8. Prevention of degradation may be less expensive than restoration	The intervention at the time that was done, could help prevent the colonization of the Black Wattle in surrounding areas, and hence in reducing future restoration costs	-

Principle	Observed situation	Applied solution/ Proposed solution
9. The restoration of rivers required investment on studies and projects, specialized personnel and knowledge of riparian vegetation	The Kouga River Rehabilitation Project has included the work of 5 researchers each working on different subjects, and specialized personnel in charge of plant propagation.	-
10. The restoration of rivers should be included in each basin water planning	The rehabilitation of a section of the Lower Witteklip River, is included in the Kouga River Rehabilitation Project, which intends to work at a catchment level	-

8.2. On the experiments

- It should be possible to keep track of time in which the large logs consume themselves since the soil could be exposed to high temperatures that could destroy the soil structure, especially organic conglomerates formed by the influence of organic matter. This situation could reduce the possibilities of having a functional soil for a plant to complete its life cycle.

- Further information should be analyzed to determine the temperature and time in which soil for this area, lose the organic bonds that hold together soil particles.

- Water table level should be measured at different times of year to assess changes due to restoration activities.

- Black Wattle (*Acacia mearnsii*) invasion on the Lower Witteklip Rehabilitation Site, caused various forms of environmental degradation, but the most important, was the alteration of the hydrological cycle. It should be consider for future studies, to determine the water flow before clearing, in order to have a reference from the effect of Black Wattle clearing and rehabilitation.

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14. BIBLIOGRAPHY

Agricultural Research Concil, (2009a). Agricultural Geo-Referenced Information System: AGIS Comprehensive Atlas. Retieved 15:24, August 7, 2009, from http://www.agis.agric.za/agisweb/agis.html

Agricultural Research Concil, (2009b). Agricultural Geo-Referenced Information System: AGIS Natural Resource Area . Retieved 16:11, August 8, 2009, from http://www.agis.agric.za/agisweb/nr_atlas?rb=nr_atlas_predict_soil_loss

Adair, R. (2004). Black Wattle: South Africa Manages Conflict of Interest. CABI Biocontrol News, 23 (1), Retrieved 13:21, March 17, 2009, from http://www.pestscience.com/Bni23-1/Gennews.htm

Baskin, J. and Baskin, C. (1985). The Annual Dormancy Cycle in Buried Weed Seeds: A Continuum. BioScience, Vol. 35 (8), 492-498

B.J. Wolfe Enterprises, Inc., (2009). Tempilaq G Datasheet. Retrieved 10:05, August 1, 2009 from http://www.bjwe.com/zzpdf/tempil/laq6.pdf

Blanchard R. & Holmes, P.M.. (2008). Riparian vegetation recovery after invasive alien tree clearance in the Fynbos Biome. South African Journal of Botany, Vol. 74, 421-431.

Boshoff, A. F. (2005). The Baviaanskloof Mega-reserve: an environmentally, socially and economically sustainable conservation and development initiative Terrestrial Ecology Research Unit, Nelson Mandela Metropolitan University. Report 52. 47pp.

Brown, J.H. & Lugo, A.E. (1987). Rehabilitation of tropical lands: A key to sustainable development. Restoration Ecology 2, 97-111

Castro Díez, P., J. Guerrero Campo, and M. A. Muñoz Yanguas. (2001). Plan de restauración del bosque de ribera en la Reserva Natural de los Galachos (Zaragoza). Consejo de Protección de la Naturaleza de Aragón, Zaragoza

CBD, (2006). Global Biodiversity Outlook 2 Secretariat of the Convention on Biological Diversity, Montreal, 81 + vii pages

Central Intelligence Agency -CIA-, (2009). The World Factbook 2009 (Washington D.C.). Retrieved 18:39, August 04, 2009 from https://www.cia.gov/library/publications/the-world-factbook/index.html

Chornesky, E.A. and J.M. Randall (2003). The threat of invasive alien species to biological diversity: Setting a future course. Annals of the Missouri Botanic Garden 90: 67-76.

Chorley, R., Schumm, S.A. & Sugden, D.A. (1985). Geomorphology. London: Methuen. 605 pp

Dye, P. and Jarmain, C., (2004) Water use by Black Wattle (Acacia mearnsii): implications for the link between removal of invading trees and catchment streamflow response, South African Journal of Science 100, pp. 40–44.

Kleynhans, CJ, Thirion, C and Moolman, J (2005). A Level I River Ecoregion classification System for South Africa, Lesotho and Swaziland. Report No. N/0000/00/REQ0104. Resource Quality Services, Department of Water Affairs and Forestry, Pretoria, South Africa.

Eslera P.M., Holmes, P., Richardson, D.M. & Witkowski E. (2008). Riparian vegetation management in landscapes invaded by alien plants: Insights from South Africa. South African Journal of Botany, 74 (2008), 397-400.

FAO (2004). FAO Forestry country profile, South Africa. In Food and Agriculture Organization of the United Nations. Retrieved 11:13, February 26, 2009, from http://www.fao.org/forestry/18316/en/zaf/

Ferrandis, P., Martínez-Sanchez, J.J., Agudo, A., Cano, A. L., Gallar, J.J., Herranz, J. M., (1999). Presencia de especies del género Cistus L. (Cistaceae) en el banco de semillas del suelo en el pastizal de la raña del Parque Nacional de Cabañeros. Invest. Agr. Sist. Recur. For. Vol. 8(2): 361-376.

Ffoillott, P., DeBano, L. (2007). Riparian Areas of the Southwestern United States: Hydrology, Ecology, and Management. Arizona. Lewis Publishers, 432pp.

Fourie, S.. (2008). Composition of the soil seed bank in alien-invaded grassy fynbos: Potential for recovery after clearing. South African Journal of Botany, 74(4), 445-453.

Government of the Republic of South Africa (2003). Nomination of the Cape Floral Region of South Africa for inclusion on the World Heritage List. South African National Parks, South Africa. 684 pp.

González de Tánago, M., García de Jalón, D. (2001). Restauración de ríos y riberas. Fundación Conde del Valle de Salazar, Mundi-Prensa, Madrid, 319p.

Henderson, L.. (2001). Alien weeds and invasive plants. A complete guide to declared weeds and invaders in South Africa. ARC, Plant Protection Research Inst.Roodeplaat (South Africa).

Holmes, P.M. & Cowling, R. (1997). Diversity, composition and guild structure relationships between soil-stored seed banks and mature vegetation in alien plant-invaded South African fynbos shrublands. Plant Ecology, 133, 107-122.

Holmes, P. M.. (2002). Depth distribution and composition of seed-banks inalien-invaded and uninvaded fynbos vegetation. Austral Ecology, 27, 110-120.

Holmes, P.M. Esler K.J., Richardson, D.M. and Witkowski E.T.F.. (2008). Guidelines for improved management of riparian zones invaded by alien plants in South Africa. South African Journal of Botany, 74(3), 538-552.

Jáimez-Cuéllar P., Vivas S., Bonada N., Robles S., Mellado A., Álvarez M., Avilés J., Casas J., Ortega M., Pardo I., Prat N., Rieradevall M., Sáinz-Cantero C.E., Sánchez-Ortega A., Suárez L., Toro M., Vidal-Abarca M.R., Zamora-Muñoz C & Alba-Tercedor J. (2002). Protocolo GUADALMED (PRECE). Limnetica, 21(3-4), 187-204.

Kruger, F.J., Day, J., Siegfried, W., Louw, G. and Jarman, M. (1979). Fynbos Ecology: A preliminary synthesis. South African Nation Scientific Report No. 40. Cooperative Scientific Programmes, Pretoria. 166 pp.

Levine, J.M., Vilà, M., D'Antonio, C., Dukes, J.S., Grigulis, K., & Lavorel, S. (2003) Mechanisms underlying the impacts of exotic plant Invasions. *Review Paper* Proceedings of the Royal Society B., 270, 775–781

Louw, J. H and Scholes, M. (2002). Forest site classification and evaluation: a South African perspective. Forest Ecology and Management, 171(1-2), 153-168.

Lowe S., Browne M., Boudjelas S., De Poorter M. (2000) 100 of the World's Worst Invasive Alien Species: A selection from the Global Invasive Species Database. Published by The Invasive Species Specialist Group (ISSG) a specialist group of the Species Survival Commission (SSC) of the World Conservation Union (IUCN), 12pp.

Hayward, Brian. (2009). EC in grip of 'worst drought in 40 years'. Weekend Post [Port Elizabeth] 31 January, 2009: Retrieved 11:55, August 09, 2009, from http://www.weekendpost.co.za/main/2009/01/31/news/nl03_31012009.htm

Institute for Water Research (2004). Catchment L: The Gamtoos River System. PDF version of document retrieved 15:34, March 17, 2009, from http://www.ru.ac.za/static/institutes/iwr//wetland/data/GamtoosSYSTEM/GamtoosSystemReport.pdf

Kumar, R., Singh, H. & Batish, S. 2002. Allelopathy in Agroecosystems. Philadelphia, Taylor & Francis, Inc. 447p p.

Luzuriaga, A.L. Escudero, A., Olano, J.M., Loidi, J. (2005). Regenerative role of seed banks following an intense soil disturbance. Acta Oecologica, Vol 27(1), 165-174.

Manning, J., Paterson-Jones, C. (2007). Field guide to fynbos. South Africa. Struik Publishers. 508 pp.

Marais, C. Wannenburgh, A.M. (2008). Restoration of water resources (natural capital) through the clearing of invasive alien plants from riparian areas in South Africa Costs and water benefits. South African Journal of Botany, 74 (3), 526-537.

Marchante, H. (2006). Ecology of *Acacia mearnsii*. In IUCN/SSC Invasive Species Specialist Group (ISSG). Retrieved 12:24, March 17, 2009, from http://www.issg.org/database/species/ecology.asp?si=51&fr=1&sts=tss&lang=EN

Matthews, S. & Brand, K. (2004). Africa Invaded: The growing danger of invasive alien species. The Global Invasive Species Programme (GISP). South Africa, 80 pp.

Nel, J.I., Richardson, D.M., Rouget, M., Mgidi, T.N., Mdzeke, N., Le Maitre, D.C., Van Wilgen, B.W., Shonengevel, L., Henderson, L. and Neser, S. (2004). South African Journal of Science, 100 (1), 53-64.

Neary, D., DeBano, L., Ffolliott, P. (1998). Fire effects on ecosystems. San Francisco. John Wiley & Sons. 352pp.

Nelson Mandela Bay Municipality (2009). Nelson Mandela Bay – uniting Port Elizabeth, Uitenhage and Despatch. Retrieved 18:55, July 19, 2009, from http://www.mandelametro.gov.za/Content.aspx?objID=33

Nijland, H.J., Cals, M.J. editors. (2000) River Restoration in Europe. Practical Approaches. Memoires from the Conference on River Restoration, Wageningen 2000. European Centre for River Restoration/ECRR. 343 pp.

Pierce SM & Mader AD. (2006). The STEP Handbook. Integrating the natural environment into land use decisions at the municipal level: towards sustainable development. Centre for African Conservation Ecology (ACE). Report Number 47 (Second Edition). Nelson Mandela Metropolitan University, South Africa. 146 pp.

Piudo, M.J. & Cavero, R.Y. (2005). Banco de semillas: comparación de metodologías de extracción, de densidad y de profundidad de muestreo. Publicaciones de Biología de la Universidad de Navarra, Serie Botánica. Pamplona. No. 16, 71-85

Pretorius, M.R. Esler, K.J. Holmes, P.M. Prins, N. (2008). The effectiveness of active restoration following alien clearance in fynbos riparian zones and resilience of treatments to fire. South African Journal of Botany, 74(3), 517-525.

Richardson, D., Kluge, R. (2008). Seed banks of invasive Australian Acacia species in South Africa: Role in invasiveness and options for management. Evolution and Systematics, 10, 161-177.

Ratsirarson, H. Robertson, H.G., Picker, M.D., van Noort, S. (2002). Indigenous forests versus exotic eucalypt and pine plantations: a comparison ofleaf-litter invertebrate communities. African Entomology, 10(1), 93-99.

SAPPI (2007). Tree Farming Guidelines Chapter 1: Species Selection. SAPPI Technical document, 21pp.

Sieben, E.J.J., Reinecke, M.K. (2008). Description of reference conditions for restoration projects of riparian vegetation from the species-rich fynbos biome. South African Journal of Botany, 74, 401-411.

Society for Ecological Restoration International Science & Policy Working Group. (2004). The SER International Primer on Ecological Restoration. Retrieved 14:24, April 3, 2009, from http://www.ser.org

Thermal Paint Temperature Tecnology, (2009). Thermal paint, thermal indicating strips, temperature paint technology. Retrieved 19:55, August 1, 2009, from http://www.thermalpaint.com/main.html

Thompson, K. & Grime, J.P., (1979). Seasonal variation in the seed banks of herbaceous species in ten contrasting habitats. Journal of Ecology. 67(3), 893-921

Tu, M. (2009). Assessing and Managing Invasive Species within Protected Areas. Protected Area Quick Guide Series. Arlington, VA. The Nature Conservancy. 40 pp.

United Nations Environment Programme (2006). Africa Environment Outlook 2: Invasive Alien Species. Retrieved 14:24, August 3, 2009, from http://www.unep.org/dewa/Africa/publications/AEO-2/content/175.htm

UNEP/GRID-Arendal (2007). Fynbos Ecoregion in Africa, UNEP/GRID-Arendal Maps and Graphics Library, Retrieved 22:11, August 4, 2009 from http://maps.grida.no/go/graphic/fynbos-ecoregion-in-south-africa

Van Lill, W.S. Kruger, F.J. and Van Wyk, D.B. (1980). The effect of afforestation with Eucalyptus grandis Hill ex Maiden and Pinus patula Schlecht. et Cham. on streamflow from experimental catchments at Mokobulaan, Transvaal . Journal of Hydrology, 48(1-2), 107-118.

Versfeld, D.B., Le Maitre, D.C., Chapman, R.A., (1998). Alien Invading Plants and Water Resources in South Africa: A Preliminary Assessment. Report TT99/98, Water Research Commission, Pretoria.

Vosse, S., (2006). The restoration potential of fynbos riparian seed banks following alien clearing. MSc Thesis. Stellenbosch University. 201 pp.

Vosse, S. Esler, K.J. Richardson, D.M. Holmes, P.M. (2008). Can riparian seed banks initiate restoration after alien plant invasion? Evidence from the Western Cape, South Africa. South African Journal of Botany, 74(3), 432-444.

Whisenant, S. G.. (1999). Repairing Damaged Wildlands: a process-oriented, Landscape-Scale Approach. Cambridge: Cambridge University Press. 312pp.

Woodworth, P. (2006). Working for Water in South Africa: Saving the World on a Single Budget? World Policy Journal. Vol. 23, No. 2: 31–43

APPENDIX

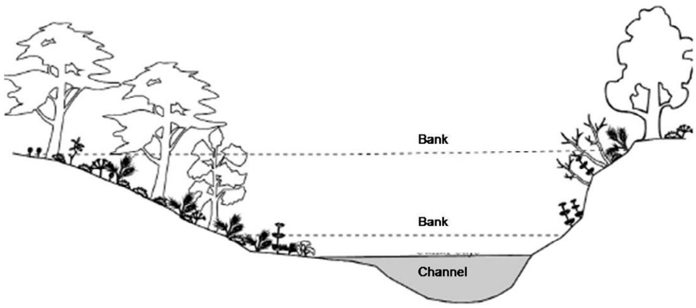
A. Log sheet sample

A.1. Evaluation of the quality of the riparian vegetation index (QBR)

QUALIFICATION AREA BANK OF RIVER ECOSYSTEM.
CONTENTS QBR

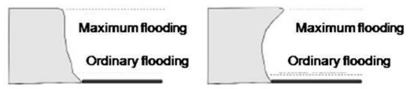
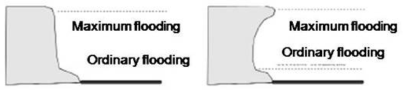
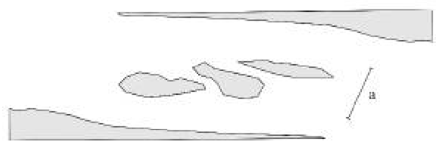
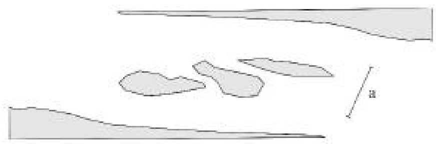
This rating should be applied throughout the riparian zone of rivers (and river bank itself). Periodically flooded areas along the ordinary avenues and the maximum.
The calculations are performed on the area has a potential to support a aquatic vetegation on the riverside. Areas not considered, are those covered with hard substrate where one cannot establish permanent vegetative cover.

The score of each of the 4 sections cannot be negative nor exceed 25



Level of cover riparian area	Score between 0 and 25
Punctuation	
25	> 80% cover in the riparian zone (annual plants are not counted)
10	50-80% of vegetation cover in the riparian zone
5	10-50% of vegetation cover in the riparian zone
0	<10% cover in the riparian zone
+10	If the connectivity between the riparian forest and adjacent forest ecosystem is the total
+5	If the connectivity between the riparian forest and adjacent forest ecosystem is more than 50%
-5	If the connectivity between the riparian forest and adjacent forest ecosystem is between 25 and 50%
-10	If the connectivity between the riparian forest and adjacent forest ecosystem is less than 25%
Structure of the cover (is posted throughout the area of bank)	Score between 0 and 25
Punctuation	
25	tree cover over 75%
10	tree cover between 50 and 75% or tree cover between 25 and 50% and the rest of the cover shrubs exceed 25%.
5	tree cover less than 50% and the rest of the cover with shrubs between 10 and 25%.
0	without trees and shrubs below 10%.
+10	If Heliophytes or shrubs concentration in the bank is over 50%.
+5	If Heliophytes or shrubs concentration in the bank is between 25 and 50%.
+5	If the trees have an understory shrub.
-5	if there is a regular distribution (linear) feet of trees and undergrowth is> 50%.
-5	if trees and shrubs are distributed in patches, with no continuity.
-10	if there is a regular distribution (linear) feet of trees and undergrowth is <50%.
Degree of naturalness of the river channel.	Score between 0 and 25
Punctuation	
25	the river channel has not been modified.
10	Modifications of the terraces adjacent to the river bed with reduction of the channel.
5	signs of alteration and intermittent rigid structures that change the river channel.
0	river channel in the entire stretch.
-10	if there is a solid structure within the riverbed.
+10	if there is any dam or other infrastructure <o> cross the river bed.
Final score (sum of the previous ratings)	

A.2. Determination of the geomorphologic type of the riparian area

Types of gradient of the riparian zone		Punctuation Left	Punctuation Right
Vertical / concave (slope> 75 °), with a height not exceed the maximum flood		6	6
Same, but with a slight slope or periodically flooded banks (ordinary avenues)		5	5
Slope between 45 and 75 °, scaling or not. The slope with the angle between the horizontal and the line between the bank and the last point of the shore. Σ a> Σ b		3	3
Slope between 20 and 45 degrees, graded or not. Σ a <Σ b		2	2
Slope <20 °, uniform and flat bank.		1	1
Existence of an island or islands in the middle of the riverbed			
Joint width "a"> 5 m.		-2	
Joint width "to" between 1 and 5 m.		-1	
Percentage of hard substrate with a disability to permanent plant root mass			
	> 80%	Cannot be measured	
	60-80 %	+6	
	30-60%	+4	
	20-30%	+2	
	TOTAL PUNCTUATION		

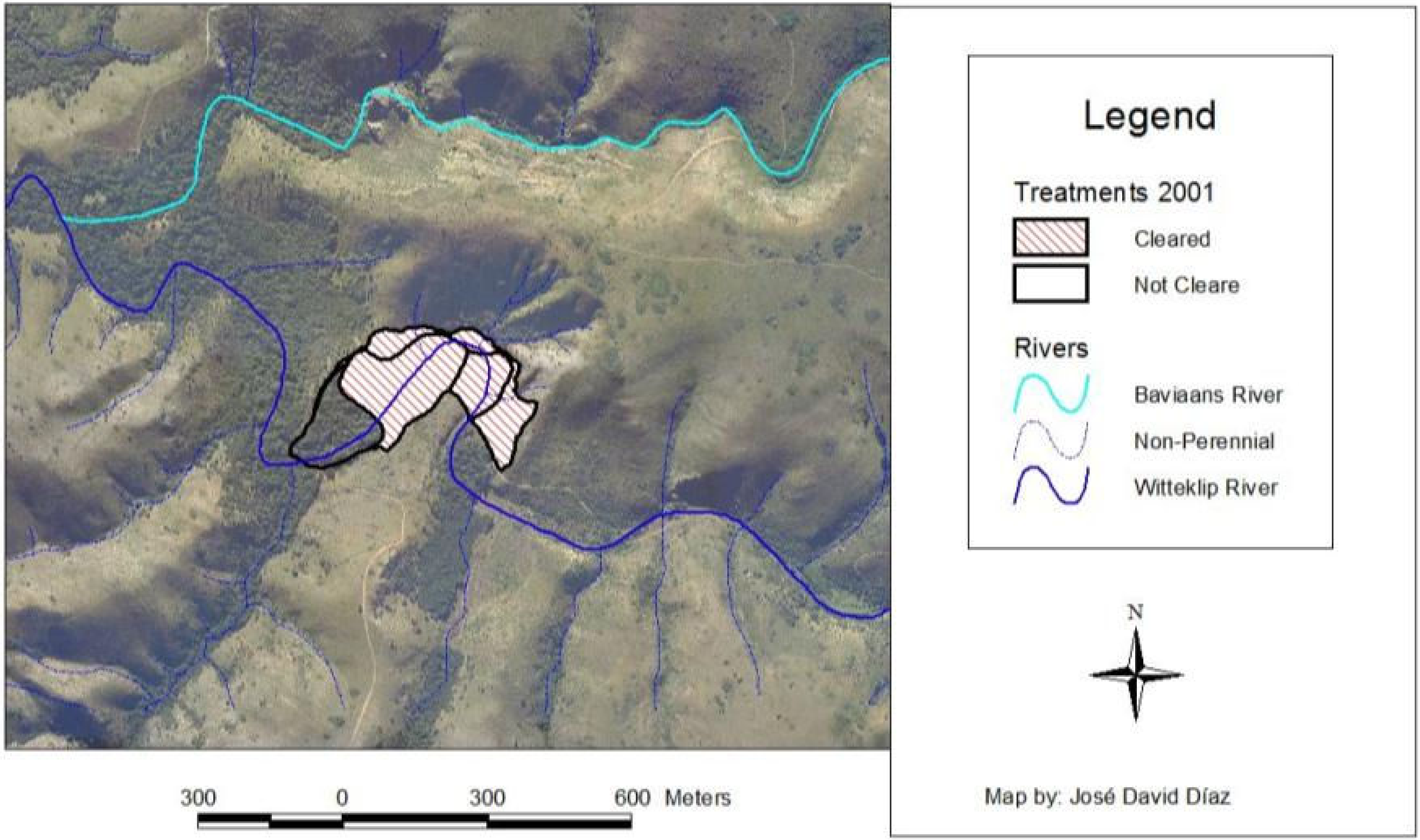
GEOMORPHOLOGICAL TYPE ACCORDING TO PUNCTUATION	
> 8	Type 1: Banks closed, usually general practitioners, with low potential for extensive riparian forest between 5 and 8.
Between 5 and 8	Type 2: Banks with a potential term to support a vegetated area, middle reaches of rivers
< 5	Type 3: Large banks, lower reaches of rivers with high potential to possess a vast forest

A.3. Evaluation of the Fluvial habitat for Meditarranean Rivers

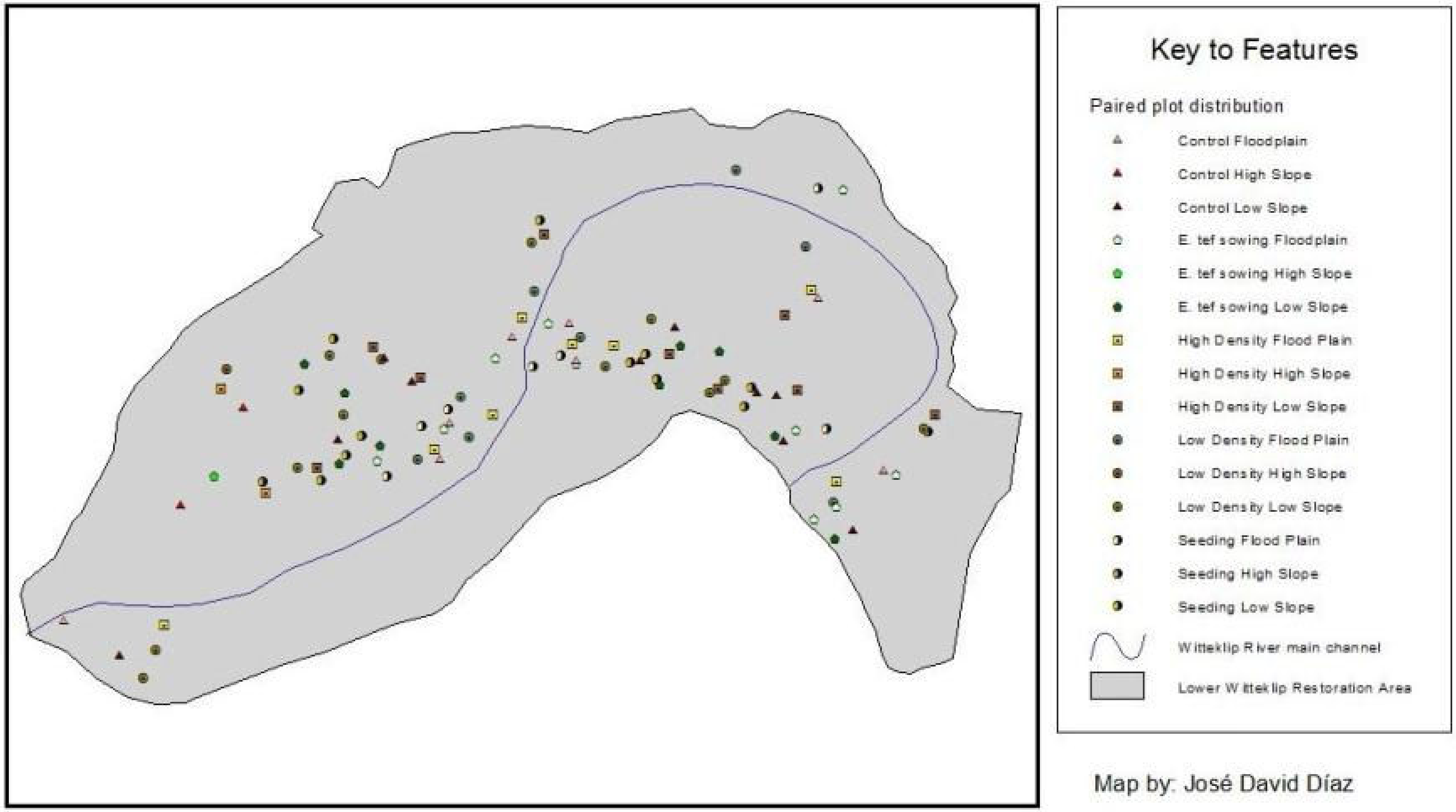
Evaluation of the riparian habitat for Mediterranean Rivers : IHF index			
Measure by:	Station		
	Date		
Blocks:			
1. Inclusion of rapids, pond sedimentation			Punctuation registered
Rapids	Rocks, pebbles and gravel by fine sediment unfixed. Inclusion 0-30%	10	
	Rocks, pebbles and gravel sediments slightly fixed. 30-60% Inclusion	5	
	Rocks, pebbles and gravels moderately fixated by fine sediments. Inclusion >60%	0	
Ponds	Sedimentation 0-30%	10	
	Sedimentation 30-60%	5	
	Sedimentation >60%	0	
TOTAL FOR CATEGORY			
2. Rapid frequency			Punctuation registered
High rapid frequency. Rapid distance/River width relation is < 7		10	
Scarce rapid frequency. Rapid distance/River width relation is 7-15		8	
Occasional occurrence of rapids. Rapid distance/River width relation is 15-25		6	
Constant laminar flow or shallow rapids Rapid distance/River width relation is > 25		4	
Ponds only		2	
TOTAL FOR CATEGORY			
3. Substrate composition			Punctuation registered
% of blocks and stones	1 - 10%	2	
	> 10%	5	
% of gravel	1 - 10%	2	
	> 10%	5	
% of sand	1 - 10%	2	
	> 10%	5	
% of stilt and clay	1 - 10%	2	
	> 10%	5	
TOTAL FOR CATEGORY			
4. Speed/depth regime			Punctuation registered
Shallow: < 0.5 m	4 categories: Shallow-deep, shallow-slow, fast-deep, fast-slow	10	
Slow: < 0.3 m/s	3 out of 4 categories	8	
	2 out of 4 categories	6	
	1 out of 4 categories	4	
TOTAL FOR CATEGORY			
5. Percentage of shade to the channel			Punctuation registered
Shaded with windows		10	
Completely shaded		7	
Large gaps		5	
Exposed		3	
TOTAL FOR CATEGORY			
6. Heterogeneous elements			Punctuation registered
Litter	> 10 or < 75%	4	
	< 10 or > 75%	2	
Presence of logs or stems		2	
Exposed roots		2	
Natural dikes or dams		2	
TOTAL FOR CATEGORY			
Blocks:			
7. Percentage of aquatic vegetation			Punctuation registered
% of plocon + bryophytes	10-50%	10	
	< 10% or > 50%	5	
% Pecton	10-50%	10	
	< 10% or > 50%	5	
% Phanerogams + charales	10-50%	10	
	< 10% or > 50%	5	
TOTAL FOR CATEGORY			
		FINAL PUNCTUATION	

MAXIMUM PUNCTUATION POSSIBLE PER BLOCK	
Inclusion of rapids, pond sedimentation	10
Rapid frequency	10
Substrate composition	20
Speed/depth regime	10
Percentage of shade to the channel	10
Heterogeneous elements	10
Percentage of aquatic vegetation	30

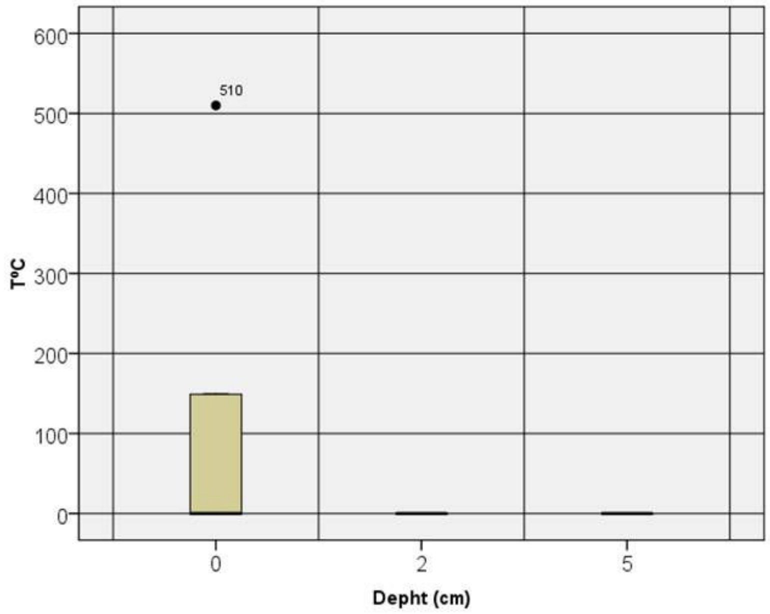
B. Treatments to Lower Witteklip area in 2001



C. Paired plots distribution



D. Descriptive statistics for soil temperature experiments



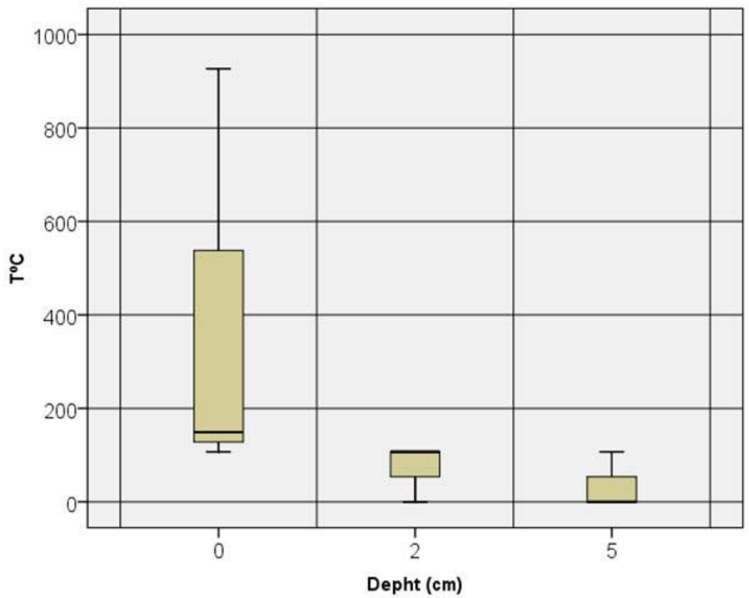
a. Low fuel, floodplain

Descriptives[a,b]

	Depht (cm)			Statistic	Std. Error
T°C	0	Mean		131.80	98.855
		95% Confidence Interval for Mean	Lower Bound	-142.66	
			Upper Bound	406.26	
		5% Trimmed Mean		118.11	
		Median		.00	
		Variance		48861.200	
		Std. Deviation		221.046	
		Minimum		0	
		Maximum		510	
		Range		510	
		Interquartile Range		330	
		Skewness		1.822	.913
		Kurtosis		3.186	2.000

a. T°C is constant when Depht (cm) = 2. It has been omitted.

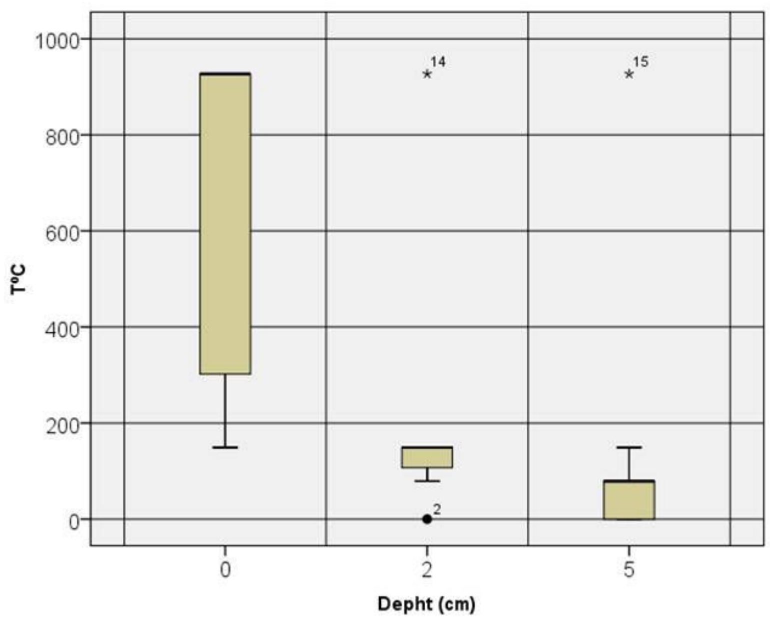
b. T°C is constant when Depht (cm) = 5. It has been omitted.



b. Low fuel, low slope

Descriptives

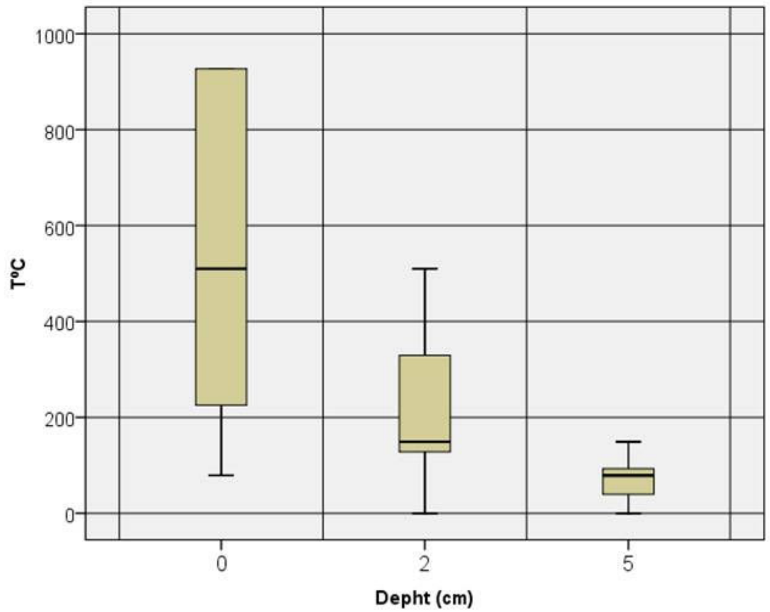
	Depht (cm)			Statistic	Std. Error
T°C	0	Mean		394.33	266.609
		95% Confidence Interval for Mean	Lower Bound	-752.79	
			Upper Bound	1541.46	
		5% Trimmed Mean		.	
		Median		149.00	
		Variance		213241.333	
		Std. Deviation		461.781	
		Minimum		107	
		Maximum		927	
		Range		820	
		Interquartile Range		.	
		Skewness		1.716	1.225
		Kurtosis		.	.
	2	Mean		71.33	35.667
		95% Confidence Interval for Mean	Lower Bound	-82.13	
			Upper Bound	224.79	
		5% Trimmed Mean		.	
		Median		107.00	
		Variance		3816.333	
		Std. Deviation		61.776	
		Minimum		0	
		Maximum		107	
		Range		107	
		Interquartile Range		.	
		Skewness		-1.732	1.225
		Kurtosis		.	.
	5	Mean		35.67	35.667
		95% Confidence Interval for Mean	Lower Bound	-117.79	
			Upper Bound	189.13	
		5% Trimmed Mean		.	
		Median		.00	
		Variance		3816.333	
		Std. Deviation		61.776	
		Minimum		0	
		Maximum		107	
		Range		107	
		Interquartile Range		.	
		Skewness		1.732	1.225
		Kurtosis		.	.



c. Medium fuel, floodplain

Descriptives

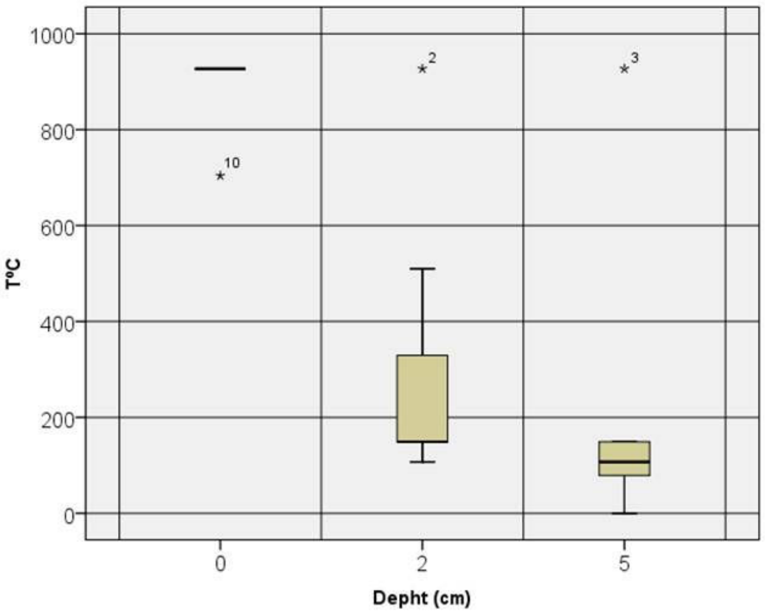
	Depht (cm)			Statistic	Std. Error
T°C	0	Mean		665.08	95.209
		95% Confidence Interval for Mean	Lower Bound	457.64	
			Upper Bound	872.52	
		5% Trimmed Mean		679.20	
		Median		927.00	
		Variance		117840.577	
		Std. Deviation		343.279	
		Minimum		149	
		Maximum		927	
		Range		778	
		Interquartile Range		702	
		Skewness		-.814	.616
		Kurtosis		-1.315	1.191
	2	Mean		183.46	63.226
		95% Confidence Interval for Mean	Lower Bound	45.70	
			Upper Bound	321.22	
		5% Trimmed Mean		152.35	
		Median		149.00	
		Variance		51967.603	
		Std. Deviation		227.964	
		Minimum		0	
		Maximum		927	
		Range		927	
		Interquartile Range		56	
		Skewness		3.341	.616
		Kurtosis		11.749	1.191
	5	Mean		121.38	68.530
		95% Confidence Interval for Mean	Lower Bound	-27.93	
			Upper Bound	270.70	
		5% Trimmed Mean		83.37	
		Median		79.00	
		Variance		61053.256	
		Std. Deviation		247.090	
		Minimum		0	
		Maximum		927	
		Range		927	
		Interquartile Range		93	
		Skewness		3.353	.616
		Kurtosis		11.694	1.191



Descriptives

	Depht (cm)			Statistic	Std. Error
T°C	0	Mean		545.86	144.091
		95% Confidence Interval for Mean	Lower Bound	193.28	
			Upper Bound	898.44	
		5% Trimmed Mean		550.62	
		Median		510.00	
		Variance		145335.476	
		Std. Deviation		381.229	
		Minimum		79	
		Maximum		927	
		Range		848	
		Interquartile Range		778	
		Skewness		-.053	.794
		Kurtosis		-2.326	1.587
	2	Mean		224.86	76.271
		95% Confidence Interval for Mean	Lower Bound	38.23	
			Upper Bound	411.49	
		5% Trimmed Mean		221.51	
		Median		149.00	
		Variance		40721.143	
		Std. Deviation		201.795	
		Minimum		0	
		Maximum		510	
		Range		510	
		Interquartile Range		403	
		Skewness		.910	.794
		Kurtosis		-.877	1.587
	5	Mean		70.43	20.501
		95% Confidence Interval for Mean	Lower Bound	20.27	
			Upper Bound	120.59	
		5% Trimmed Mean		69.98	
		Median		79.00	
		Variance		2941.952	
		Std. Deviation		54.240	
		Minimum		0	
		Maximum		149	
		Range		149	
		Interquartile Range		107	
		Skewness		-.238	.794
		Kurtosis		-.595	1.587

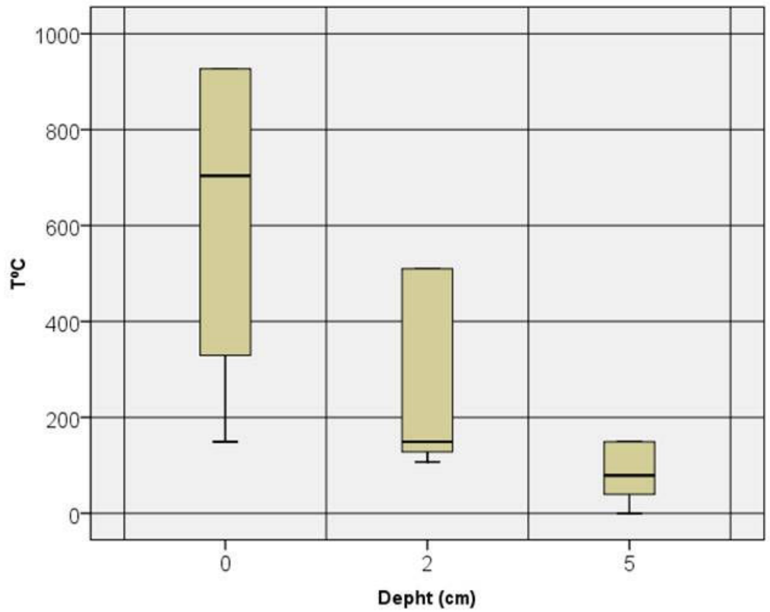
d. Medium fuel, low slope



e. High fuel, floodplain

Descriptives

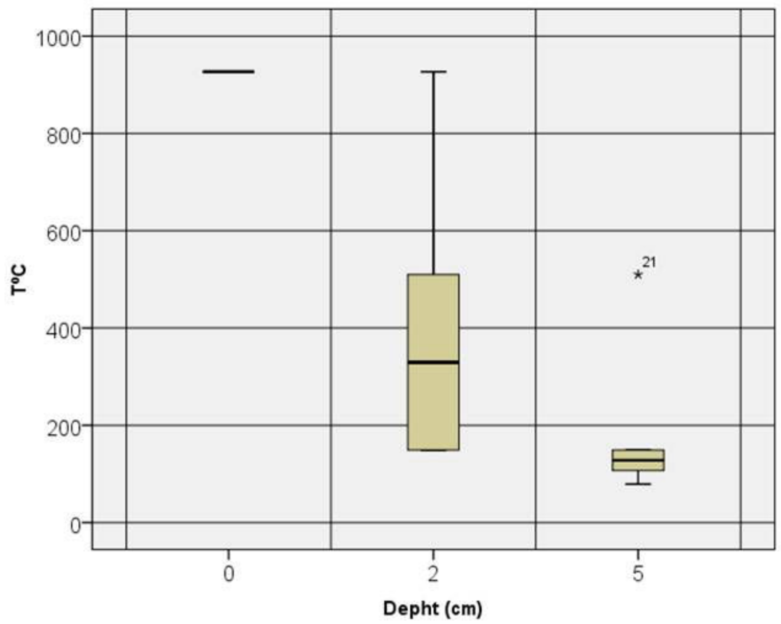
	Depht (cm)			Statistic	Std. Error
T°C	0	Mean		895.14	31.857
		95% Confidence Interval for Mean	Lower Bound	817.19	
			Upper Bound	973.09	
		5% Trimmed Mean		903.99	
		Median		927.00	
		Variance		7104.143	
		Std. Deviation		84.286	
		Minimum		704	
		Maximum		927	
		Range		223	
		Interquartile Range		0	
		Skewness		-2.646	.794
		Kurtosis		7.000	1.587
	2	Mean		305.71	116.031
		95% Confidence Interval for Mean	Lower Bound	21.80	
			Upper Bound	589.63	
		5% Trimmed Mean		282.24	
		Median		149.00	
		Variance		94242.238	
		Std. Deviation		306.989	
		Minimum		107	
		Maximum		927	
		Range		820	
		Interquartile Range		361	
		Skewness		1.815	.794
		Kurtosis		2.729	1.587
	5	Mean		212.86	120.565
		95% Confidence Interval for Mean	Lower Bound	-82.15	
			Upper Bound	507.87	
		5% Trimmed Mean		185.01	
		Median		107.00	
		Variance		101750.810	
		Std. Deviation		318.984	
		Minimum		0	
		Maximum		927	
		Range		927	
		Interquartile Range		70	
		Skewness		2.502	.794
		Kurtosis		6.453	1.587



f. High fuel, low slope

Descriptives

	Depht (cm)			Statistic	Std. Error
T°C	0	Mean		613.29	133.209
		95% Confidence Interval for Mean	Lower Bound	287.34	
			Upper Bound	939.24	
		5% Trimmed Mean		621.65	
		Median		704.00	
		Variance		124211.571	
		Std. Deviation		352.437	
		Minimum		149	
		Maximum		927	
		Range		778	
		Interquartile Range		778	
		Skewness		-.575	.794
		Kurtosis		-1.705	1.587
	2	Mean		291.71	77.447
		95% Confidence Interval for Mean	Lower Bound	102.21	
			Upper Bound	481.22	
		5% Trimmed Mean		289.85	
		Median		149.00	
		Variance		41986.571	
		Std. Deviation		204.906	
		Minimum		107	
		Maximum		510	
		Range		403	
		Interquartile Range		403	
		Skewness		.347	.794
		Kurtosis		-2.761	1.587
	5	Mean		86.57	25.318
		95% Confidence Interval for Mean	Lower Bound	24.62	
			Upper Bound	148.52	
		5% Trimmed Mean		87.86	
		Median		79.00	
		Variance		4486.952	
		Std. Deviation		66.985	
		Minimum		0	
		Maximum		150	
		Range		150	
		Interquartile Range		149	
		Skewness		-.432	.794
		Kurtosis		-1.717	1.587



Descriptives[a]

	Depht (cm)			Statistic	Std. Error
T°C	2	Mean		412.90	100.283
		95% Confidence Interval for Mean	Lower Bound	186.04	
			Upper Bound	639.76	
		5% Trimmed Mean		399.00	
		Median		329.50	
		Variance		100566.544	
		Std. Deviation		317.122	
		Minimum		149	
		Maximum		927	
		Range		778	
		Interquartile Range		465	
		Skewness		.795	.687
		Kurtosis		-.795	1.334
	5	Mean		158.50	40.071
		95% Confidence Interval for Mean	Lower Bound	67.85	
			Upper Bound	249.15	
		5% Trimmed Mean		143.39	
		Median		128.00	
		Variance		16056.722	
		Std. Deviation		126.715	
		Minimum		79	
		Maximum		510	
		Range		431	
		Interquartile Range		49	
		Skewness		2.868	.687
		Kurtosis		8.669	1.334

a. T°C is constant when Depht (cm) = 0. It has been omitted.

g. Extra large fuel, floodplain

E. Observations from burned sites

Code	Number	Observation	Photographic references
K	A	Just a slight ammount of ash in the ground	
K	B	Slash piles seemed moved, resulting on non-burned soil	
K	F	Superficial burn.	
K	G	Not burned	
K	H	Ashes observed on the surface of the soil	
K	I	No noticeable residues of ash on the place of extraction	
K	L	Slash piles seemed moved, resulting on slightly burned soil	
L	2	Superficial ash, white-gray	
L	8	Soil slightly burned.	

Code	Number	Observation	Photographic references
L	9	Superficially burned.	
L	12	Ash on surface. Very hard and stoney ground	
L	17	Slightly burned where soil was taken but inside, it seems much burned	
L	18	Medium burned soil, with some surface residues	
L	?	A large scar on the ground, with some light grey ash	
L	8?	Located on a low slope. White ash content, with some small coals	
L	16	Superficial ash observed, which presumably burned on top of soil	
M	B	Small patches of burned soil, with presence of orange-coloured soil	

Code	Number	Observation	Photographic references
M	C	Some white and some orange-coloured ashe next to site of sampling. Some black ash also present. It seems to have been exposed to extreme temperatures.	
M	D	Surface, with some white ashes. Middle grey and bellow, black coals and some sparse small not burned material	
M	E	Superficially burned. Very sandy and pebbles.	
M	F	Superficial burn of what seems to be leaves. Dark grey ashes	
M	G	Superficial burn of what seems to be leaves. Dark grey ashes	
M	H	Spots of yellow material. Sme grey ashes sparsed on the ground	
M	I	Ashes, but no half burned residues. Soil is loose. Next to yellowish soil, indicating possible extreme heat up	
M	J	Sandy soil. Some yellow spots, indicating burned soil	

Code	Number	Observation	Photographic references
P	2	Superficially burned, slightly	
P	3	Not burned. Soil taken as a control	
P	4	Very close to slash pile	
P	6	Not burned.	
P	8	Almost no burning of material where soil taken. No ash	
P	9	Not burned.	
P	10	Soil fairly hard. Superficial ashes.	
P	10	Possible number duplication. Close to L 10. Scar on the coals soil, with some greyish ash	
T	2	Superficial ashes. Some coals close by, or perhaps some round thin wood	
T	4	Superficially burned, slightly	
T	5	Soil slightly burned.	

Code	Number	Observation	Photographic references
T	6	Ashes with some spreaded coals	
T	7	White scar, with spreaded slightly burned leaves	
T	9	Medium intensity burn. Greyish ash	
T	10	More or less burned. Some light superficial slash on the soil	
X	1	Mostly, orange-coloured soil, with some ashes on top. It shows an extrem rise of temperature	
X	2	Similar to X1, but apparently with less temperature exposure.	
X	3	Similar to X2.	
X	4	Where collected, some slight-medium ashes can be seen.	
X	5	Some dark residues. Where main stack was located, a heavy load of light grey ash	
X	6	Similar to X5	

Code	Number	Observation	Photographic references
X	7	Reference point located close to a large log, pressumably burned for a long period. Some superficial ashes, but still a fair amount of black ashes on the top soil	
X	8	Site appears to have been exposed to fire for a long period. Superficial soil has a large amount of ash. Heat possibly damaged soil structure	
X	9	Medium burned site. Infront of an intensely burned stack, with lots of orange soil.	
X	10	Burned area, but not so intensely.	

F. Photographic archive

Picture 1. Low fuel site, floodplain and slope

This picture depicts a sample of the low burn sites in the floodplain and in the slope

Picture 2. Medium fuel site, floodplain

Picture 3. High fuel site sample, floodplain

Picture 4. Extra large fuel site, floodplain

Placement of the temperature sensitive painted labels

Picture 5. Study site as seen from a helicopter

Picture 6. Study site after clearing

Wood stacked is left for burning

Picture 8. Burning at night

(a) (b) (c)

Picture 9. Retrieval of temperature sensitive painted sets from the surface (a), 2 cm (b) and 5 cm (c)

Picture 10. Soil exposed to extreme heat

This soil, had several coals burning for long, and it shows yellowish patches.

Picture 11. Preparation of the trays for the soil seedbank assessment

Picture 12. Trays being prepared with the three main treatments

From top to bottom: wood chips, control and burned soil.

G. Other activities considered for the practicum

Research visit to the Baviaanskloof

Accompanying a 10 day field expedition to the Baviaanskloof, with a group of Honors Students from Rhodes University (Grahamstown) led by Prof. Fred Ellery from the Dept. Environmental Sciences. This expedition had the purpose of collecting important data to better understand the fluvial / catchment processes of the Baviaanskloof.

The projects are:

1. Determine the effects of current human activities on alluvial fans. The primary emphasis is in understanding the impact of roads, channels and other human-made constructions in how they alter the flows of the natural system.

2. Determine the current topographic view of the Baviaans River floodplains and channels to record any human-made constructions that during a period of approximately 50 years of historic photographic reconstruction could have influenced the state of the river as it is today;

3. Determine Baviaans River's behaviour on a local scale by using a more detailed surveying process, by mapping the sediment accumulation and erosion occurring on the river's sand banks.

This project, is feeding into the overarching Baviaanskloof integrated catchment restoration programme (PRESENCE in the Baviaanskloof).