An assessment of the efficiency and effectiveness of the Working for Water NBAL mapping, contract teams and clearing of *Acacia mearnsii*

By

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ABSTRACT

Working for Water (WfW) works to fulfil their dual mandate of protecting ecosystem services and creating employment opportunities for poor communities. There have been many successes but evidence is increasing regarding the inefficiencies at project and site scales. The study was undertaken in the Eastern Cape, South Africa, at a farm called Ann's Villa situated in the Kommadagga valley, at the foot of the northern side of the Zuurberg pass. The study sought to assess the efficiency of the WfW mapping of natural biological aliens (NBAL), of contract teams and the effectiveness of the clearing methods employed to clear *Acacia mearnsii.* To achieve this, WfW mapping was analysed, contract team dynamics of the different task groups were observed and assessed and various *Acacia mearnsii* and indigenous plant variables were measured pre-and post-clearing of *A. mearnsii*. The first key finding was that overall the WfW NBAL mapping was inaccurate, with WfW *A. mearnsii* percentage cover (cover) estimations significantly over-estimated. *Acacia mearnsii* cover over-estimations resulted in fruitless expenditure as contracts were more expensive than necessary. Cover under-estimations also led to the inability to fulfill contractual obligations and the subsequent halting of the clearing of a large portion the study area. It was recommended that the NBAL mapping as well as the cover estimations of NBALs be conducted more rigorously, with expert assistance where skills are lacking, to avoid the associated fruitless expenditure. The second key finding was that WfW contract teams were largely inefficient, as a result of waiting, stemming from the lack of continuity in work. There was a strong positive relationship between subgroup chainsaw operator (CO) to stacker ratio and subgroup CO to stacker efficiency ratio. These inefficiencies meant that a mean of 58±67% of the total money spent per team resulted in fruitless expenditure. It was recommend that contract teams be organised to promote the continuity of work and that the current high stacker to CO ratios be reversed to increase efficiency and reduce fruitless expenditures. The third key finding was that overall the WfW methods of clearing *A. mearnsii* were 95% effective with a 90% removal success. The last key finding was that initial clearing operations had a largely insignificant impact on indigenous plant biodiversity. It was recommended that post-clearing inspection of quality control is conducted more rigorously and that penalties be implemented to deter contract teams from cutting indigenous species.

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LIST OF ACRONYMS

BCO	Brush Cutter Operator
CO	Chainsaw Operator
DAFF	Department of Agriculture, Forestry and Fisheries
DEA	Department of Environmental Affairs
EPWP	Extended Public Works Programme
GPS	Global Positioning System
ha	Hectares
HA	Herbicide Applicator
IAP	Invasive Alien Plant
IDs	Identities
MAR	Mean annual rainfall
NBAL	Natural Biological Alien
p.a.	per annum
SANParks	South African National Parks
WfW	Working for Water

CHAPTER 1

INTRODUCTION

Species, be they animals or plants, are generally restricted to a certain geographical distribution, but humans have, over the millennia, moved many different species around the globe for many different reasons, such as for agricultural, economic or horticultural purposes (Richardson and Rejmanek, 2011; Richardson *et al.,* 2000). This is one of the major reasons many countries are facing invasion problems today. Invasive alien plants (IAPs), in particular, are the most problematic because they threaten ecosystem services (Le Maitre *et al*., 2011). Richardson *et al*. (2000) define IAPs as naturalized plants that produce reproductive offspring, often in very large numbers, at considerable distances from the parent plants and thus have the potential to spread over a considerable area.

Morris *et al*. (2011) found that there is no single ecophysiological or morphological trait to which the success of IAPs can be attributed, but rather that the different traits that IAPs possess, compared to indigenous species, function holistically to give them high competitiveness. Most tree IAPs have common traits that allow them to be successful invaders. These traits include, firstly, the ability to procure crucial resources of light, water and nutrients (Morris *et al*., 2011). Secondly, their ability to procure these resources, more efficiently than indigenous species, enables them to be highly competitive and as a result grow at faster rates than and out-compete indigenous species (Werner *et al.,* 2008). Thirdly, they have high and early reproduction rates where they produce enormous and persistent seedbanks (Holmes, 1989). Fourthly, they have effective long distance dispersal mechanisms. Dispersal is effective as they produce many small, light and hard-coated seeds that can easily be carried or transported for long distances, even in water, without damage and can be deposited further downstream where they proliferate (Fourie, 2008; Holmes, 1989). Fifthly, they tend to have a high biomass of roots with a large surface area, as well as cast both deep and shallow roots compared to indigenous species, allowing for more efficient procurement of water both from deep and surface soil horizons (Calder and Dye, 2001). The ability to cast deep roots also allows IAPs to gain access to deep unexploited nutrients and water in times of scarcity at the upper soil horizons (Witkowski, 1991a). Sixthly, many species are efficient nitrogen fixers which enhances their own growth but hampers the growth of indigenous species (Yelenik *et al*., 2007; Witkowski, 1991b). Seventhly, they have no natural enemies in the areas they invade, i.e. no or few local animals or insects feed on them (Paterson *et al.,* 2011). The resources they would normally invest into dealing with the impacts of natural enemies they invest in other traits that contribute to their success, such as reproduction and growth (Paterson *et al.,* 2011). Lastly, IAPs have the ability to modify the fire regimes of the ecosystems they invade (van Wilgen and Richardson, 1985). Where fires are a normal and important part of the ecosystem, such as in the Fynbos, IAPs have been shown to prevent fires as the native vegetation typically prone to fire is significantly reduced with increasing invasion intensity. When fires do occur in the presence of increased IAP biomass these fires tend to be too intense damaging indigenous species as well as their propagules (Fourie, 2012; van Wilgen and Richardson, 1985). These traits give IAPs significant advantage over Fynbos, Savanna and Grassland indigenous species allowing them to increase both in biomass and density (Morris *et al*., 2011). Despite many studies on the characteristics of and impacts caused by IAPs, Jeschke *et al.* (2014) recently called for a tightening up of what is meant by the term impacts of IAPs.

Invasive alien plants are the second major cause of biodiversity loss across the globe (Kolar and Lodge, 2001). In South Africa, tree IAPs are a problem because of the threat they pose specifically to water resources, biodiversity and other important and valuable ecosystem services (Foxcroft, 2002). There are four types of ecosystem services namely: regulating, supporting, cultural and provisioning services (Millennium Ecosystem Assessment, 2005). Le Maitre *et al.* (2011) discuss how some IAPs such as Australian acacias have the ability to negatively affect factors that regulate ecosystem processes, such as resource supply and disturbance regimes, and their interactions which then impact on the supporting and, eventually, on the cultural and provisioning services. It was realized that the loss or diminishment of ecosystem services, due to tree IAPs, would ultimately lead to losses of economic, ecological and social benefits (van Wilgen *et al.,* 1998). It was estimated at the time that it would cost approximately US$100 million per year for an estimated 20 years to clear tree IAPs in South Africa (van Wilgen *et al*., 1998). It was these calculated losses further into the future, should IAP infestations be left uncontrolled, that motivated for the inception of South Africa's Working for Water (WfW) Programme in 1995 (van Wilgen *et al*., 1998).

Working for Water, as part of the Extended Public Works Programme (EPWP), aims to recover and protect the integrity of natural resources by reducing the density of IAPs in a labour intensive manner and in so doing also fulfill their social mandate of creating employment for poor marginalized communities (Department of Environmental Affairs (DEA), 2015; Marais *et al*., 2004). According to de Wit *et al.* (2001) South Africa has the lowest conversion of rainfall to runoff of any country in the world. South Africa receives a mean annual rainfall (MAR) of approximately 490 mm of which less than 10% becomes surface runoff (de Wit *et al*., 2001). Le Maitre *et al*. (2000) found that tree IAPs use approximately 6.7% of the country's runoff as well as reducing water yield from catchments by as much as 5%. The reduction in water yield has been shown to result from factors such as the high evapotranspiration rates of IAPs, with *A. mearnsii* stands found to cause evapotranspiration rates of 51% higher than indigenous Fynbos species (Le Maitre *et al*., 2000). This is a significant concern for a semi-arid country such as South Africa where the availability of water is important for development and economic growth (de Wit *et al*., 2001). It is therefore imperative that WfW is as effective and as efficient as possible in controlling IAPs because when drought situations arise IAPs will access and use ground water resources resulting in even more diminished reservoirs for the provision of water for human consumption and natural ecosystems and processes (Witkowski, 1991a).

Acacia mearnsii is a fast growing and an efficient nitrogen fixing species native to south-east Australia (de Wit *et al*., 2001). It produces copious numbers of small hard coated seeds that, in the presence of dispersal agents such as water, rodents and birds, can be dispersed long distances from the parent plants and where there is no active dispersal the seeds accumulate as they get buried in the soil and litter (de Wit *et al*., 2001; Duke, 1983). *Acacia mearnsii* also possess the ability to resprout or coppice from basal shoots after cutting or after a fire (Duke, 1983). It was introduced in South Africa in the 19th century (de Wit *et al*., 2001). According to Adair (2008) the spread of *A. mearnsii*, amongst other Australian acacias, was due to the boom of the trans-global trade of the species in the 1950s, initially, as a result of horticultural interests and later compounded by agricultural directed incentives. Plantations of *A. mearnsii* were estimated at 130 000 hectares (ha) in both the

Kwa-Zulu Natal and Mpumalanga provinces while plantations in the Eastern Cape were later largely deserted. *Acacia mearnsii* was an important commercial species, in South Africa, with incentives derived from it including tannins, charcoal, firewood, wood chips, timber and pulp amongst others (Adair, 2008; de Wit *et al*., 2001). Escaping from functioning and deserted plantations, *A. mearnsii* is now one of the most prolific IAPs in South Africa with R561.9 million, of the R2.1 billion clearing costs spent on the top 10 IAP taxa, spent on the clearing of *A. mearnsii* alone (van Wilgen *et al*., 2012b). The extent of *A. mearnsii* invasion has been found to increase regardless of the fact that most of the WfW budget is spent on the clearing of this species in comparison to other tree IAPs. This is largely because clearing operations, in many cases, only reach a small percentage of the overall invaded area infested with *A. mearnsii*, with only 8% and 4% cleared in the Grassland and Savanna biomes, respectively (van Wilgen *et al*., 2012b). The negative ecological and hydrological impacts posed by *A. mearnsii* will continue to increase should clearing operations remain inefficient and ineffective.

1.1. MAPPING

According to van Wilgen *et al*. (2012), in 2008, 1.8 million condensed hectares of South Africa were invaded by IAPs. Cobbing (2006) states that mapping of IAPs is an annual concern for WfW as insufficient mapping is conducted to satisfy the requirements of all South Africa's nine provinces. This is particularly a problem because WfW contracts cannot be generated without the spatial data of IAP infestations and also because the first operational phase in any WfW project is data capture (Cobbing, 2006). The data capture phase refers to the stage in the project where the spatial extent of IAPs is captured digitally (mapping). There are numerous methods of surveying vegetation which can also be used in the mapping of alien vegetation (Gibson and Low, 2003). These methods include satellite imagery, in flight reconnaissance, video/aerial photography as well as ground GPS. In the Eastern Cape province mapping methods such as remote sensing and spectral links have been found to have limitations because of the heterogeneity in both the nature of landscapes as well as of the vegetation in general (Gibson and Low, 2003). Limitations include an inability to distinguish indigenous vegetation from IAP vegetation where the two exhibit spectral patterns of similar nature (Cobbing, 2006; Gibson and Low, 2003). Another limitation includes the impracticality of these methods to map smaller growth forms such as that of herbaceous species. The methods have been shown to work more effectively in the Grassland biome which is generally lacking in tree species (Gibson and Low, 2003). In the Grassland biome IAP vegetation can often be detected as they stand out due to their tall stature as well as their tendencies to form dense clumps (Gibson and Low, 2003). From an assessment of methodologies available for use by WfW two methods are the most commonly used, which are digitizing of orthophotos and GPS field mapping (Smith *et al*., 1999).

The mapping of IAP vegetation can be done for different reasons such as for a catchment management plan or a treatment area (Cobbing, 2006). A management plan refers to the overall plan and area that a specific WfW project will cover, while a treatment area refers to an area of IAPs that has been delineated or demarcated as a contract (Cobbing, 2006). A management plan uses broad scale mapping conducted at a 1:50 000 scale and is defined by quaternary catchment boundaries to provide a catchment scale indication of the extent of IAPs (Cobbing, 2006). The WfW project operation standards (Working for Water, 2007) requires that the mapping of the IAP vegetation that is to be cleared should be done and recorded as natural biological alien units (NBAL). A management plan is then divided into NBALs, which refers to an area of IAPs of similar species type, age and density (Cobbing, 2006; Gibson and Low, 2003). From these NBALs, treatment areas or contracts are generated hence NBAL mapping needs to be accurate (Working for Water, 2007).

The mapping of NBALs can be done by digitizing of orthophotos or by GPS field mapping (Gibson and Low, 2003; Smith *et al*., 1999). These methods have both advantages and disadvantages. Digitizing of orthophotos can ensure that large areas are covered fairly quickly but the interpretational accuracy can be very low and the mapping can be obscure as not all things that are on the ground can be clearly seen from the orthophotos, such as seedlings or if the vegetation being viewed is actually IAPs. GPS field mapping, although time consuming and costly, can result in very high interpretational accuracy which can also result in complete classification of species and age classes. Data, such as the density, age class, species, etc., of IAPs, from these NBALs must be recorded. These data then further inform other activities such as the cost and number of person days estimated to clear a certain NBAL (Marais and Wannenburg, 2008). Once contracts have been generated, they are often tendered and interested contractors can prepare and submit quotation packages in response. According to the WfW (2003) a project evaluation committee made up of a WfW project manager and three other people, must evaluate the quotation packages received and recommend the most suitable to be awarded (Working for Water, 2007).

1.2. WORKING for WATER CLEARING METHODS

Working for Water typically employs contract teams to conduct the clearing of IAPs (Coetzer and Louw, 2012). The contract teams comprise a contractor and a group of workers. Criteria for the selection of contractors includes the individual being a South African citizen, having limited business opportunities or income, historically disadvantaged, not formally employed, not have taken a voluntary government severance package, not be financially involved with or be an immediate family member of any DEA or WfW staff member, have no criminal record, be of good character and show strong leadership qualities amongst others (Coetzer and Louw, 2012). Contractors are defined as individuals who have set up their own businesses and conduct clearing work for WfW and are therefore responsible for recruiting and managing their teams as well as their equipment (Coetzer and Louw, 2012). Contract teams usually comprise eleven members, contractor included, with different task groups namely: chainsaw operators (COs), stackers and herbicide applicators (HAs) (Coetzer and Louw, 2012). These members work together to implement clearing on the ground.

WfW employs five different types of IAPs control methods. Each method has both advantages and disadvantages. They include, firstly, mechanical control, which refers to the removal of IAPs by physical actions such as cutting. Although slow and labour intensive mechanical control can be target specific which means that with sufficient care there can be minimal, if any, damage to the surrounding indigenous species (Euston-Brown *et al*., 2007). Secondly, chemical control employs the use of herbicides. The use of chemicals tends to be time and labour efficient with high IAP kill efficacy. Their use is often implemented by means of spraying from nozzles connected to knapsacks, this can cause detrimental non-target impacts on indigenous species as well as soil residue impacts which may further impact indigenous species negatively (Euston-Brown *et al*., 2007). Thirdly, biological control employs the use of species-specific animals, insects and pathogens from the IAP’s place of origin. Research and development that goes into finding and testing suitable biological control agents can be lengthy and expensive but once found, released and established, biological control agents can be progressive, environmentally friendly and produce the most effective and successful control of IAPs (Paterson *et al*., 2011). Fourthly, the use of fire involves the control of IAPs by burning. Fire can form an essential part of management. Fire can assist control by causing mass germination of *Acacia* seeds as well as removing IAP seedlings and cut IAP trees and biomass (Fourie and Wilman, undated). Lastly, integrated control employs a combination of different methods to control IAPs. This method is important, especially for species where no single method on its own is sufficient to provide the necessary control (Paterson *et* al., 2011; Working for Water, 2008). The integration of different methods can ensure better results. For example, the integration of the mechanical and chemical methods can ensure that the target specific advantage of the mechanical method together with the high efficacy kill of chemical control result in minimal damage to indigenous species as applying chemicals to a stump of a cut IAP can be more target specific than spraying a whole plant. Integrating methods can therefore harness the benefits of the combined methods while simultaneously reducing non-target impacts on indigenous species.

Different methods are employed for clearing different size classes of trees, including hand pulling and foliar spraying for the clearing of seedlings, lopping or pruning for young trees, bark stripping, cut stump, ring-barking and frilling for adults. Equipment used to conduct clearing includes chainsaws, loppers and bow saws. Herbicide applicators employ the use of knapsacks with nozzles to both foliar spray seedlings and spray cut stumps (Working for Water, 2008).

1.3. CLEARING METHOD IMPLEMENTATION

Most methods are effective when carried out properly. There have, however, been cases where ineffectiveness has been attributed to the lack of knowledge or training in carrying out the clearing techniques properly. Witkowski and Garner (2008) found, for example, while working on the IAP *Solanum mauritianum* (bugweed), that cutting the species below 18 cm and applying herbicide soon after resulted in 100% kill while cutting above 50 cm resulted in 100% recovery by re-sprouting. Their results also showed that delays in applying herbicide after the plant had been cut led to the herbicide not being as effective as it would be when applied immediately after cutting.

This emphasizes the question of how much training goes into equipping the contract teams and how much knowledge is imparted to them to ensure a basic, but sufficient, understanding of IAPs, their hydrological, ecological impacts and basic plant physiology. Working for Water project managers interviewed by McConnachie (2012) cited challenges such as a lack of motivation stemming from inadequate performance incentives, lack of ethics related to work and environmental concerns and unskilled workers with little knowledge of IAP control. These cited challenges are, however, not surprising because one of the twin objectives of WfW is to create employment for the poorest and marginalized people who typically have low formal education levels. It is then the duty of the managers to ensure that these unskilled workers with little or no IAP knowledge are equipped with the necessary skills and knowledge they need to conduct effective clearing (Coetzer and Louw, 2012). While the level of training can be questioned, it is also true that in some cases contract teams have the knowledge they need to implement effective clearing but may be too demotivated, disorganized or unsupervised to carry out the methods properly. Cundill and Fabricius (2009), however, state that knowledge sharing is an essential first step in learning which can raise awareness, change attitudes and as a result lead to higher motivation and appropriate actions.

With regards to the methods employed for clearing IAPs, inefficiencies and ineffectiveness have been attributed to factors such as (i) lack of sufficient IAP knowledge amongst contract teams stemming from insufficient training and assessment of training and (ii) mostly the lack of monitoring (van Wilgen *et al*., 2012b). The thinking around methods of control employed and their implementation is important because only effective IAP control will result in functional native ecosystems (Le Maitre *et al.,* 2011). In a study on the management of yellow star thistle by diTomaso *et al.* (2006) at three sites in California, prescribed burning and herbicide application were effective in controlling the IAP but the repeated use of either method was found to be impractical and also presented other ecological problems. They found that integrating these two methods was more effective than either one on their own and resulted in fewer ecological problems. Sites where a year of prescribed summer burning was followed by a year of clopyralid herbicide application had 92-100% percentage cover reductions (cover) as compared to sites where the reverse order resulted in no cover reductions. Even more important than finding and understanding that integrating the two methods was more effective, was the specific sequence in which these two methods had to be integrated to achieve maximum effectiveness as well as the season in which the methods should be implemented as this is crucial to overall effectiveness.

All WfW contractors are supposed to receive a suite of training modules that include practical skills in clearing IAPs, theoretical and business knowledge and social development (Coetzer and Louw, 2012). Coetzer and Louw (2012), however, state that results of training outsourced from service providers are not assessed or evaluated and the contractors are also not assessed to evaluate whether they have acquired the necessary minimum requirements to start conducting actual clearing on the ground. It is therefore imperative that the information required with regards to methods should focus on appropriate and successful techniques that will enhance both efficiency and effectiveness from the planning to the mapping stages through to the implementation of clearing on the ground (Kettenring and Adams, 2011).

1.4. WORKING for WATER SUCCESSES AND CHALLENGES

Lack of monitoring has also been identified as one of the key limitations of the efficiency of the WfW Programme as a whole (van Wilgen *et al*., 2012a). This is a major challenge that needs to be addressed. There is a need for proper planning to be done to identify goals and appropriate methodologies by which those goals should be achieved (van Wilgen *et al*., 2012a). Performance indicators should be formulated to conduct monitoring which will help the programme to move towards outcomes-based monitoring rather than the monitoring of inputs or activities only, as is currently done (van Wilgen *et al*., 2012a). Evaluating these outcomes should then identify the problems and implement the necessary changes to achieve the desired outcomes (Levendal *et al.,* 2008). Le Maitre *et al.* (2011) state that the WfW Programme, like many programmes, tends to adopt a passive approach to restoring systems that have been invaded by IAPs, i.e. they simply aim to remove the existing IAPs and limit or prevent their regeneration. Research has shown that more often than not this approach fails to achieve the desired outcome of a functional ecosystem dominated by indigenous species (Reinecke *et al.,* 2008).

This is perhaps the single most important reason why the spatial extent of IAPs has not decreased nationally despite the labour intensive efforts and the substantial amounts of money that go into WfW (Van Wilgen *et al*., 2012b). This is because by assuming a passive approach to restoration after clearing, attention is not paid to the practical problems that may follow post-clearing. Such practical problems include factors such as re-invasion (from seedbanks), possible secondary invasions (by other opportunistic IAPs) as well as legacy effects (such as resource alterations caused by the removed IAPs) (Le Maitre *et al.,* 2011). These problems often accompany and undermine the efforts of IAP clearing and restoring ecological integrity (Le Maitre *et al.,* 2011). According to Beater *et al*. (2008) the degradation (intensity and duration of invasion) of a system is indirectly proportional to the passive restoration potential, i.e. the greater the degradation the lesser the success of passive restoration (Beater *et al.,* 2008, Le Maitre *et al.,* 2011). It is for the above reasons that monitoring before, during and after clearing becomes almost imperative for the success of WfW operations (Levendal *et al*., 2008

Monitoring can, however, be challenging in the long term, especially in cases where infestations occur on private lands. Landowners enter into contracts with a WfW implementing agent such as South African National Parks (SANParks) as they seek assistance with IAP control on their lands. SANParks helps landowners clear IAPs for a minimum number of three years (Pers. comm. Henn, 2013). This involves initial clearing and a series of follow-up clearing, after which SANParks then hands responsibility back to the landowner for further follow-up treatments (Pers. comm. Henn, 2013). Many landowners do not, however, conduct follow-up clearing for various reasons, ranging from a lack of incentives, financial and human resources and lack of enforcement to unwillingness or lack of environmental concern, amongst others (McConnachie, 2012). This means that areas that have been cleared by WfW can regress to the state that they were in before WfW implemented clearing, and the resources spent on these areas have been wasted.

The contract that is signed between landowners and the implementing agent states that once the land has been handed back to the owner, the owner is responsible for conducting follow-up treatments, failing which they will be held liable for all the resources that have been spent on clearing the IAPs on their land (McConnachie, 2012). Despite landowners' non-compliance, they do not get taken to task because the contract itself is ambiguous (Pers. comm. Henn, 2013). This presents many challenges for implementing agents dealing with these landowners and they have to get officials from the Department of Agriculture, Forestry and Fisheries (DAFF) to come and effect enforcements. These officials are however rarely available to come and fulfill such duties (McConnachie, 2012).

Working for Water has been in operation for 21 years to date. According to the DEA (2015) WfW has more than 300 clearing projects currently operating across South Africa's nine provinces. Working for Water has cleared more than 1 000 000 ha of IAPs, creating employment and training to approximately 20 000, previously disadvantaged, people per annum (p.a.) (DEA, 2015; van Wilgen *et al*. 2012a). Marais and Wannenburg (2008) found that nearly 290 000 ha, equivalent to 41 653 condensed hectares, were cleared from riparian areas since the inception of WfW in 1995 to 2008. They also found that of the hectares cleared 19 600 condensed hectares occupied by species with high water consumption rates were cleared resulting in approximately 46 million m^3 p.a. increase in stream flow as well as 34.4 million m^3 p.a. increase in water yield. It is clear that there have been many successes that have come out of the programme with respect to the number of hectares cleared, number of people employed, training and skills transfer (DEA, 2015). However, WfW has not been plain sailing and evidence is increasing regarding the inefficiencies at local project scales and the limited impact of clearing strategies on the spatial extent of IAPs nationally (McConnachie, 2012). For example, it was found that in two catchments of the Eastern Cape (Kouga and Krom) the WfW projects were largely not cost-effective and that ecosystem services were largely not being protected or re-instated as a result of IAP clearing (McConnachie *et al.,* 2012). This was due to many factors including insufficient budget as well as ineffective clearing approaches (McConnachie *et al.,* 2012). These findings echoed those of van Wilgen *et al.* (2012a). In assessing the effectiveness of WfW, van Wilgen *et al*. (2012a) found that the extent of clearing operations has had diminutive impact on the overall extent of IAP invasions. Le Maitre *et al*. (2000) estimated the 1996 extent of IAP invasions at 1.7 million condensed hectares; in 2008 the extent of IAPs was found to have increased to 1.8 million condensed hectares (van Wilgen *et al*., 2012b). This was due to the fact that clearing operations were only reaching a comparatively lesser percentage of the total invaded area.

Notwithstanding the substantial progress made by WfW in suppressing several IAP species, such as *A. saligna* and *A. longifolia* in the Fynbos biome, it is evident that most biomes continue to remain under threat from several other prolific IAP species, such as *A. mearnsii* and *Pinus* species. This, therefore, means that the main objective of WfW to reduce the density of established IAPs in South Africa is not consistently met at a national scale. It also means that the overall negative ecological and hydrological impacts of IAPs are likely to continue increasing.

1.5. EFFICIENCY AND EFFECTIVENESS

An assessment of efficiency and effectiveness of the different aspects of the programme will help the programme to progress towards achieving both its social and ecological mandate. This then requires an assessment and introspection of what WfW does, how they do it as well as an understanding of where improvements and savings can be made by improving both efficiency and effectiveness. In this study efficiency was defined as the relationship between means (i.e. money, time and labour) and outcomes (i.e. reduced IAP cover), with a higher ratio being regarded as more efficient. Effectiveness was defined as the extent to which those particular outcomes are met (Heyne, 2008). The study will explore three key aspects of the WfW Programme namely the NBAL mapping, the contract teams and the methods employed to clear *A. mearnsii*. The efficiency and effectiveness of these three aspects is currently not known, despite how fundamental they are to the overall efficiency of the WfW Programme. Kettenring and Adams (2011) state that for informed decisions about efficient and effective IAP control to be made, information on how to improve current methods and approaches employed is required. A significant purpose of IAP control research is to provide information to guide practitioners in decision making. It is for this reason that this study sought to understand, by asking the following key questions, if, and where inefficiencies in the Working for Water Programme stem from.

1.6. OBJECTIVE and KEY QUESTIONS

The main objective of this study was to assess the efficiency and effectiveness of the methods currently employed by WfW to control *A. mearnsii.* The specific key questions that this study sought to answer and the sub-objectives by which they were answered were as follows:

Key question 1: What is the efficiency of the WfW NBAL mapping?

Sub-objective 1: In Chapter 2, the study assessed the mapping and studied the signed contracts between contractors and WfW as well as the associated estimations conducted by WfW.

Key question 2: What is the efficiency of the WfW contract teams?

Sub-objective 2: In Chapter 3, the study assessed the efficiency of the WfW contract teams by establishing the total amount of time members of the different task groups spent conducting clearing work in the field.

Key question 3: How effective are the WfW's methods of initial clearing in controlling *A. mearnsii*?

Sub-objective 3: In Chapter 4, the study assessed the *A. mearnsii* invasion intensities, density counts and basal area both pre- and post-clearing while seedbanks were assessed pre-clearing only and the presence of coppicing was assessed post-clearing only.

Key question 4: Do WfW initial clearing operations negatively impact indigenous plant biodiversity?

Sub-objective 4: In Chapter 4, the study assessed the aerial percentage covers, density counts and basal area of indigenous plant biodiversity pre-and post-clearing of *A. mearnsii*.

1.7. STUDY AREA

The study was undertaken in the Eastern Cape Province, South Arica. The farm, in which the study was conducted, is called Ann's villa, situated in the Kommadagga valley at the bottom of the northern side of the Zuurberg Pass at latitude and longitude coordinates of -33.253734 and 25.772734 respectively (Figure 1.1). The study area covers an area of 165 ha, is invaded by *A. mearnsii* and is currently used for grazing. According to Climate-Data.org (2015) the study area experiences rainfall throughout the year at a MAR of 489 mm, with the most rainfall experienced in March at 59 mm and the least in June at 23 mm. The average annual temperature is 16.9^{0}C with February being the hottest month at an average of 21.5^{0}C and July being the coldest month at an average of 12.0^{0}C (Climate-Data.org, 2015).

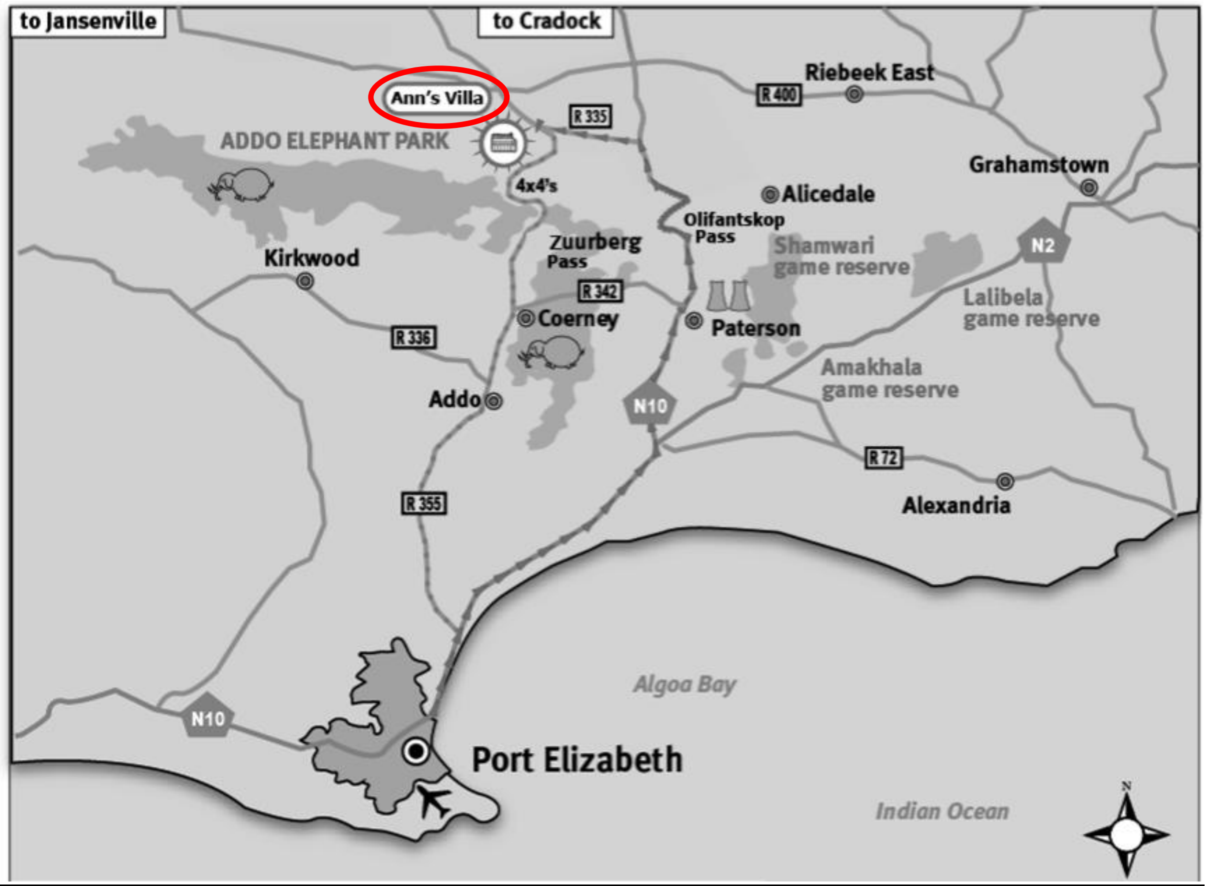

FIGURE 1.1: Study area.

Occurring at an altitude ranging from 250-970 m above sea level, the geology of the study area forms part of the Kommadagga Subgroup of the Witteberg Group, Cape Supergroup (Almond, 2013). The Kommadagga Subgroup consists of shallow marine originated sandstones and shales (Gess, 2014). Derived from sandstones and shales, the soils are sandy, and nutrient poor, as well as clay, and leached (Rebelo *et al*., 2006). The farm occurs in the Fynbos biome. It is characterized by the Suurberg Quartzite Fynbos and the Suurberg Shale Fynbos. The Suurberg Quartzite Fynbos is dominated by Grassy Fynbos with localized patches of proteoid and ericaceous fynbos (Rebelo *et al*., 2006). The Suurberg Shale Fynbos is dominated by graminoid fynbos with localized patches of proteoid fynbos (Rebelo *et al*., 2006).

The study area occurs on private land. The study area as well as the surrounding private lands have been used for grazing for many years and many still are. The Fynbos biome is known to be vulnerable to invasions by IAP trees, such as *A. mearnsii*, due to the lack of fynbos tree species (Mucina and Rutherford, 2006; Richardson and Cowling, 1992).

Landowners are said to have burned the fynbos frequently promoting the grass component of the fynbos vegetation, making these areas more vulnerable to invasion by tree IAPs (Pers. comm. Henn, 2013). Fire plays a major role in the cycle of removal and regeneration of fynbos species i.e. most fynbos plants that get removed in a fire either re-sprout or regenerate from stored seedbanks (Fourie, 2008). IAPs such as *A. mearnsii* increase the fuel load of these fynbos fires increasing their severity, damaging seedbanks of fynbos species thereby reducing their chance of regeneration (Fourie and Wilman, undated; Holmes, 2002).

CHAPTER 2

AN ASSESSMENT OF THE EFFICIENCY OF THE WORKING FOR WATER NBAL MAPPING

2.1. INTRODUCTION

Cobbing (2006) states that mapping of IAPs is an annual concern for WfW as insufficient mapping is conducted to satisfy the requirements of all South Africa's nine provinces. This is particularly a problem because WfW contracts cannot be generated without the spatial data of IAP infestations. A key phase in the WfW process is the digital capturing of IAPs (Cobbing, 2006). Once the extent of IAPs has been captured digitally for a management plan, the area can be divided into NBALs (Gibson and Low, 2007). Treatment areas or contracts are then generated from the NBALs (Working for Water, 2007).

The IAP cover estimations of the NBALs that are to be cleared can be conducted by private consultants or by the project manager themselves (Levendal *et al.*, 2008). The number of person days needed to clear a specified NBAL are calculated by entering data such as the size of the NBAL, the IAP growth form to be cleared, stage and method of clearing, underfoot conditions, obstructive vegetation height, obstructive vegetation density, walk time, slope of landscape and the actual drive time into a pre-determined Excel spreadsheet (Marais and Wannenburg, 2008; Working for Water, 2007). From these data as well as other factors such as transport, equipment and wages, the overall cost of a contract can be calculated. Limited time and financial resources have, however, often resulted in the mapping and estimations of IAPs not being conducted properly, particularly where infestations occur in patches rather than a continuous block (Pers. comm. Henn, 2013). These inaccurate estimations can further be compounded when the mapping is conducted on old imagery without conducting recent field verifications.

It is currently not known what the cost implications are of poor mapping or of erroneous estimations of key factors such as IAP cover of NBALs. The key question that this chapter sought to answer was therefore: What is the efficiency of the WfW mapping? This was answered by assessing the mapping, studying the signed contracts between contractors and WfW as well as the associated estimations conducted by WfW.

2.2. METHODS

Copies of contracts (quotation packages) signed between WfW and the contractors hired to clear the study area NBALs were obtained from WfW SANParks management. The contracts were read and scrutinised to better understand the agreement between WfW and the contractors. Relevant data such as NBAL number covered by contract, NBAL size, NBAL % cover (referred to as density in contracts), number of person days and overall contract costs were extracted from the acquired contracts. Relevant additional information regarding specific contracts and contract teams was obtained from WfW management by way of informal interviews with WfW SANParks management.

Natural biological alien units mapping data, in GIS, for the study area were also obtained from WfW SANParks management. The study area was covered by six NBALs as mapped by WfW (Figure 2.1). The NBAL mapping contained the NBAL identities (IDs), contract numbers as well as the sizes of the NBALs in hectares (Table 2.1). The NBAL IDs as well as contract numbers were allocated a representative number to avoid the use of the long WfW NBAL IDs and contract numbers as follows: 1- N40D401658 (Contract 1), 2- N40D401643, 3- N40D401637 (Contract 2), 4-N40D401634, 5- N40D401639 (Contract 3) and 6- N40D401646 (Contract 4) (Table 2.2).

Alterations (NBAL 1 was divided into two NBALs) to the acquired WfW NBAL mapping were done in ArcMap 10 to assess if there were any differences in the overall number of person days and costs between how an NBAL was mapped and how it could have been mapped. The WfW norms and standards used were the same as in the contracts except for the actual drive time which was reduced from 60 to 30 minutes, after determining the drive time from the camping site to the clearing areas. The cover estimates used in the calculations were determined as explained below. To calculate what the cost of contracts would have been if the NBAL mapping and cover estimates were conducted differently, the contract details were input into a person day calculating spreadsheet, and the calculated person days were multiplied by the standard WfW cost per person day of R250 (Pers. comm. Andrew Knipe, 2015).

Acacia mearnsii infestations were mapped on ortho-rectified, digital aerial photographs in ArcMap 10. Field verifications of the extent of infestations were conducted by walking the boundaries of the *A. mearnsii* infestations in the study area and integrating the data with the mapping done on the ortho-rectified, digital aerial photographs. A grid of 10x10 m blocks, henceforth referred to as plots, was created and overlaid on the mapped areas and a total number of 115 plots were randomly selected in GIS. Using the coordinates of the plots from GIS, the random 10x10 m plots were then located in the field using a Trimble GPS. Within each 10x10 m plot the aerial percentage cover of *A. mearnsii* (henceforth referred to as invasion intensity) was measured, by visually estimating how much of the 10x10 m plot it occupied, and recorded. Unpaired t-test, in STATISTICA, was used to determine if there were significant differences between the WfW and study *A. mearnsii* cover estimations.

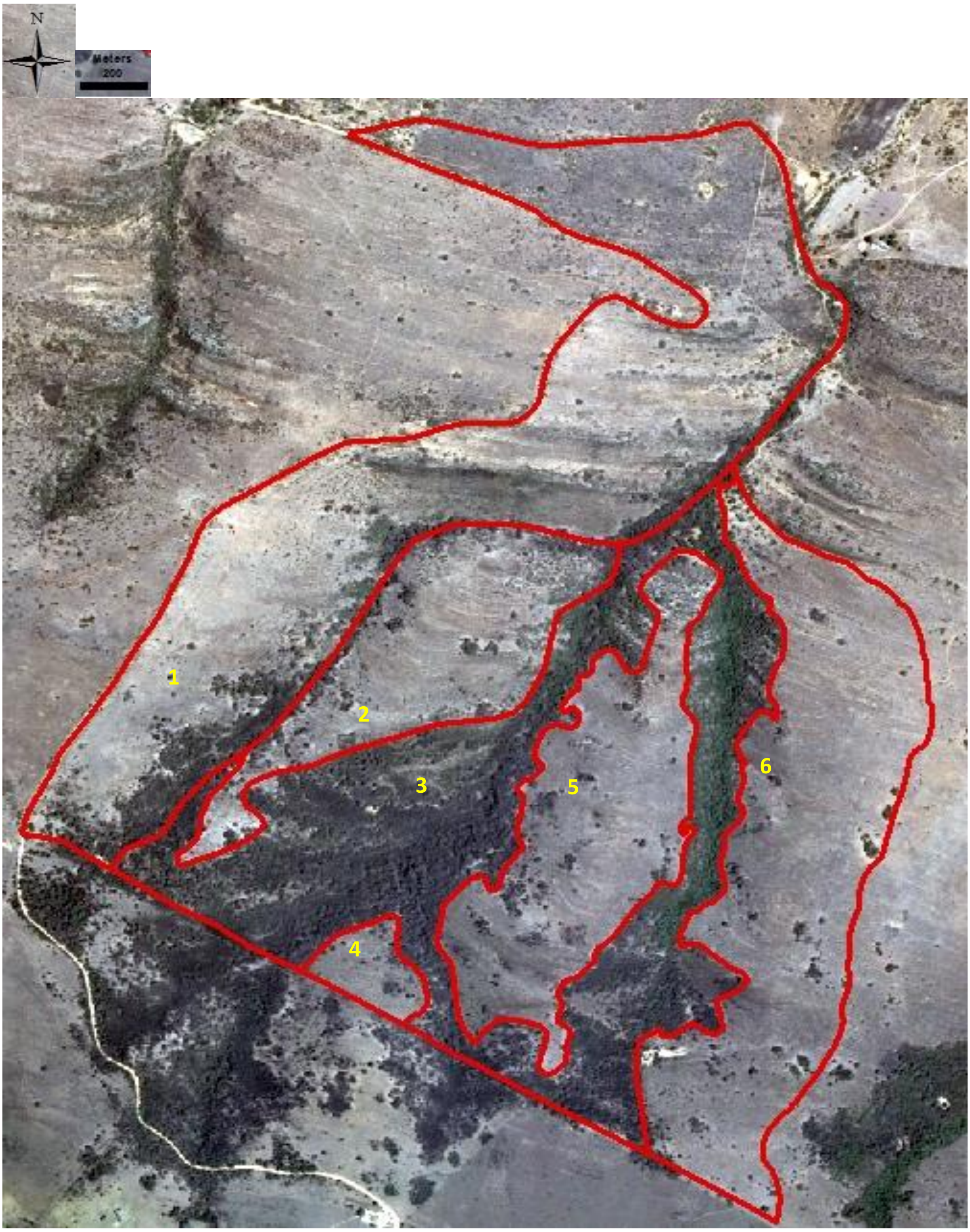

FIGURE 2.1: NBALs covering the study area as mapped by Working for Water.

2.3. RESULTS

In the study analysis, NBAL 1 was divided into two NBALs separating the sparse (NBAL 1a) infestation from the dense (NBAL 1b) infestation (Figure 2.2). Mapped as individual NBALs, NBAL 1a covered 46.08 ha with an estimated cover of 6%, while NBAL 1b covered an area of 10.60 ha, with an average cover of 65%.

The results showed that overall there were differences between WfW and the study in terms of *A. mearnsii* cover estimations. Table 2.1 illustrates that the WfW *A. mearnsii* cover was over-estimated from the NBALs except for NBAL 1b and 2. The *A. mearnsii* cover differences, of all the NBALs, between WfW and the study were not significant (t=-0.86, p=0.38). However, the results showed that all the observed differences were greater than 10%, with NBAL 1b and 2 being the only outliers. When NBAL 1b and 2, the only ones under-estimated by WfW, was excluded from the analysis the observed differences among the over-estimated *A. mearnsii* covers were significant (t=-3.58; p=0.02).

The observed over-estimations and under-estimation of *A. mearnsii* cover (Table 2.1) resulted in the over- and under-costing of contracts as seen in the number of person days and the associated costs in Table 2.2. The number of person days was over-estimated, for Contract 1, 3 and 4, by more than 90 days while under-estimated for Contract 2 by more than 690 days. Overall three contracts were over-costed by more than R25 000, while Contract 2 was under-costed by more than R150 000.

Table 2.1: The differences in *A. mearnsii* invasion intensity data between WfW and study.

Contract number	NBAL number	Size (Ha)	WfW Cover (%)	Measured Cover (%)	Difference Cover (%)
1	1a	46.08	43.0	6.0	37.0
1	1b	10.60	43.0	65.0	-22.0
2	2	15.97	13.5	43.0	-29.5
2	3	40.71	77.0	65.0	12.0
3	4	2.32	69.0	20.2	48.8
3	5	19.22	40.0	20.8	19.2
4	6	30.50	24.0	11.0	13.0
Mean (±SE)			44.4±10.1	27.7±9.1	16.8±10.9

Table 2.2: The differences between Working for Water and study person days and costs.

Contract no.	NBAL no.	WfW Person Days	Study Person Days	Difference Person Days	Contractor Cost (R)	Study Cost (R)	Difference Costs (R)
1	1	847	648	199	R227 643	R152 995	R74 648
2	2 & 3	880	1 576	-696	R230 452	R394 120	-R163 668
3	4 & 5	337	210	127	R88 432	R52 593	R35 839
4	6	263	167	96	R69 005	R41 825	R27 180
Mean (±SE)		581±164	650±327	-69±210	153 883±43 581	160 383±81 834	-6500±53 396

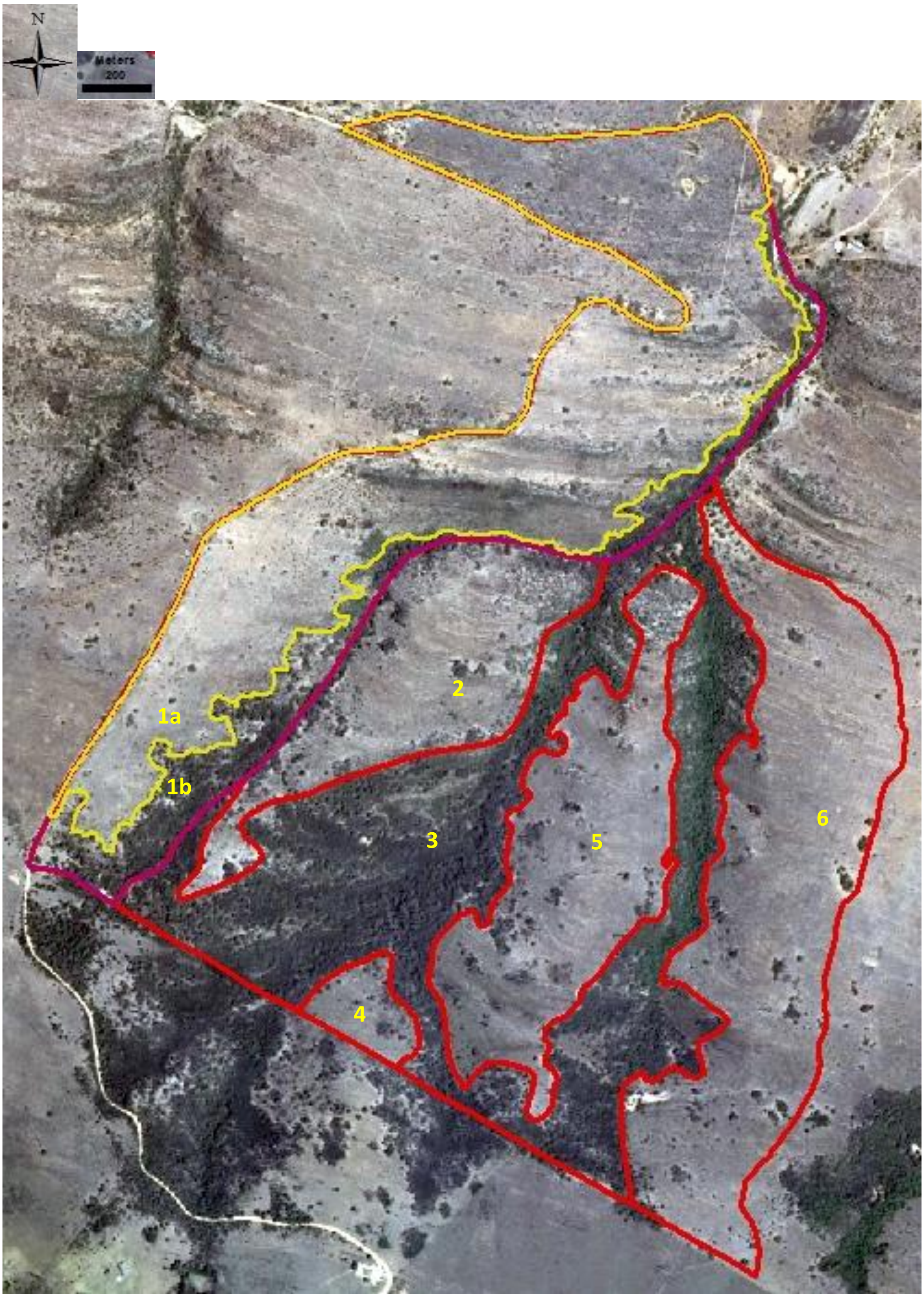

FIGURE 2.2: An illustration of the NBAL 1 sparse infestation (NBAL 1a, yellow boundary) and the dense infestation (NBAL 1b, purple boundary) mapped as separate NBALs.

2.4. DISCUSSION

According to Cobbing (2006) there are many determinants of how much a WfW clearing contract will cost. These include the size of the treatment area, cover of IAPs, type and the age of the IAP infestation, amongst others, in the treatment area. However, area and cover play key roles in determining the value of a contract. This presents a challenge, especially when the mapping is inaccurate, as in NBAL 1, because the area and the cover referred to the total area of the NBAL and not the area within the NBAL that was covered by IAPs of the same type, age and cover, as an NBAL is defined. NBAL 1, as seen in Figure 2.1, does not conform to this definition as it has two obviously different *A. mearnsii* covers in one NBAL. This makes it challenging to correctly determine cover, as was observed, which means that any cover that is estimated for such NBALs will not be uniform across the entire NBAL. This becomes problematic as other factors such as the number of person days and costs hinge on both the size of the area as well as the IAP cover within that area.

The cover of 43% for NBAL 1 was over-estimated for 46.08 ha of the larger 56.68 ha NBAL area, which the results have shown was closer to 6%. The 43% cover was at the same time under-estimated for the remaining 10.60 ha which had an estimated cover of 65%. This cover over-estimation over a large area resulted in Contract 1 being more expensive than it should have been. The results showed that had the mapping been done as shown in Figure 2.2, the clearing of NBAL 1 should have amounted to R152 995. This means that 199 person days were wasted on the clearing of NBAL 1 which resulted in R74 648 of fruitless expenditure. National Treasury (2014) defines fruitless expenditure as expenditure which was made in vain, i.e. expenditure made without value. The over-estimation of cover resulting in fruitless expenditure was also observed in Contract 3 and Contract 4. An over-estimation of cover by 48% and 19.2% in NBAL 4 and 5, respectively, resulted in a waste of 127 person days, representing fruitless expenditure of R35 840. A 13% cover over-estimation of NBAL 6 resulted in a waste of 96 person days, costing R27 180 fruitless expenditure. The fruitless expenditures from NBAL 1, 4, 5 and 6 amounted to a total of R137 669, equating to R1266/ha across the area of these NBALs.

The cover of NBAL 2 and 3 were divided into adult and young IAPs. Contract 2 showed that of the overall estimated 13.5% cover estimation for NBAL 2 only 4.5% was said to be adult cover and 9% was said to be young cover. The same goes for NBAL 3 where only 9% of the overall estimated 77% cover was said to be adult density while 68% was said to be the density of young IAPs. This allocation of a high cover to young IAPs compared to that of adult IAPs meant that the cost of clearing NBAL 2 and 3 would be lower because the method of clearing for young is different from that of adults IAPs. The method of clearing young *A. mearnsii* plants is by lopping/pruning while the clearing of adults requires a cut stump method which is more expensive, more time and energy consuming than lopping/pruning.

The results have clearly shown that an over-estimation of *A. mearnsii* cover results in fruitless expenditure. It is therefore logical that the reverse would also be true, i.e. an under-estimation of cover will result in the under-costing of a contract. The under- or over-estimation of *A. mearnsii* cover clearly poses financial consequences to the clearing of NBALs. These financial consequences come either in the form of fruitless expenditure resulting from *A. mearnsii* cover over-estimations or in the form of under-costing contracts which is bound to have financial repercussions of its own emanating from repeat contracts for incomplete or poorly cleared NBALs. The size of NBAL 1 (56.68 ha) was equal to the combined sizes of NBAL 2 and 3 (15.97 and 40.71, respectively). The *A. mearnsii* cover of NBAL 1 was over-estimated while the covers of both NBAL 2 and 3 were under-estimated. It is because of this that NBAL 1 cost almost the same amount of money (R227 643) as both NBAL 2 and 3 (R230 452) combined even though it was clear that NBAL 3 alone had a considerably higher *A. mearnsii* cover compared to NBAL 1. McConnachie *et al*. (2012) found that proportionately, the clearing of NBALs with lower IAP densities tended to be more expensive than NBALs with higher IAP densities. The difficulty in correctly estimating the cover of NBALs with low densities can serve as a plausible explanation for their finding, as the results showed that where *A. mearnsii* cover was low on the ground there was a tendency to over-estimate cover resulting in significantly costlier contracts (NBAL 1, 4, 5 and 6). The under-costing of a contract means that there is more work on the ground than there are resources allocated to effectively complete the work.

The team contracted to clear both NBAL 2 and NBAL 3 experienced challenges (WfW SANParks management, 2015). Firstly, because NBALs 2 and 3 were awarded as one contract (i.e. Contract 2), which was large and consequently the money could not be paid to the contractor all at once. The money was divided into four equal tranches of R57 613 which were meant to be paid as parts of the contract were completed. It was, however, found that after three of the four smaller payments were made, the team had not been able to start clearing NBAL 3 and decided that they could no longer continue with the contract. Secondly, the NBAL area of Contract 2 was not divided into four parts in line with the allocation of the money and it was not stipulated at the beginning of the contract how much clearing would suffice for a smaller payment.

A contractor is supposed to have a block plan of the area they are contracted to clear (Working for Water, 2007). A WfW project manager or their assistant is supposed to conduct ongoing inspections and quality checks of the areas cleared to check compliance with WfW clearing requirements (Levendal *et al*., 2008; Working for Water, 2007). The fact that three payments were made when the clearing was far from being completed illustrates the lack of monitoring on the part of WfW. Monitoring was very essential, especially in this case because the contract was large with a lot of work to be done on the ground. The team experienced challenges that led to their inability to finishing the contract (WfW SANParks management, 2015). This makes monitoring on part of WfW that much more important because had WfW been monitoring the team's performance and progress as well as conducting ongoing inspections as payments were made, they would have picked up these challenges early into the contract and made the necessary adjustments or interventions. It is also important to note that caution should probably have been exercised in awarding both NBAL 2 and 3 as one contract.

The team, employed to work on Contract 2, could not continue with the contract and WfW had to formally let them go (WfW SANParks management, 2015). This meant that new contractor (s) would have to be employed to clear NBAL 3. With only R57 613 of the R230 452 originally allocated for the clearing of NBAL 2 and 3 remaining, a further R273 295 would be needed to clear NBAL 3. At the end of the contract it would have cost WfW R446 133, equating to R7 871/ha, to clear NBAL 2 and 3 instead of the R330 908, equating to R5 838/ha, that the contract should have cost had the cover estimations been conducted accurately. This rendered the contract being R115 226 cost inefficient. The study could not ascertain exactly how much more WfW will spend on the clearing of NBAL 2 and 3 as, at the time of reporting, the clearing of NBALs 3 had still not been conducted. However the R172 839 already spent on the clearing of NBAL 2 (15.97 ha) alone at the WfW cover of

13.50% (equivalent to 2.16 condensed hectares), equates to R80 018/ condensed hectare, and at the study cover of 43% (6.87 condensed hectares) equates to R25 159/ condensed ha. Marais and Wannenburgh (2008) found that at the 1-5% *Acacia* cover the cost of clearing per condensed ha was approximately R9 000 and less than R4 000 at a cover of 75-100%. While it is generally accepted, in the Fynbos, that the lower the level of *Acacia* infestation the more expensive the clearing, at the WfW cover of 13.50%, the cost of clearing NBAL 2 was nine times higher, and at the study cover of 43% was three times higher than the estimated cost of 1-5% cover, further illustrating the extent of fruitless expenditure emanating from inefficiencies as well as the lack of monitoring.

That the team, tasked with clearing NBAL 2 and 3, were not able to finish clearing in the time that was allocated to them also brought to attention the nature of the contracts signed between WfW and the contractors they employ. The excerpt below, taken directly from a WfW contract, captures the agreement between WfW and its contractors.

"I declare that all the work will be done in accordance with Working for Water Operational Standards and Rules and Regulations that I've signed when registering with the Working for Water Programme. I also declare that the applicable contract boundaries have been shown to me infield by a WfW manager. I further agree to eradicate all alien species within the contract area boundaries. This quotation is based on my own estimations for the task, I was not influenced and/or forced by any WfW Management personnel, and therefore agree to complete the task, in full''

This illustrates the degree of the simplicity of the contract as it only indicates what a contractor will do. It does not outline the expectations of WfW, what consequences a contractor will face should they breach the contract or what legal action WfW will take in case of a breach. The Legal Information Institute (2015) defines a breach of contract as a violation of a contractual obligation. The contractor in this case was in breach of Contract 2 as they failed to clear NBAL 2 and 3 with the resources that they quoted for and was allocated to them. According to the contract, the contractor acknowledged conducting the estimations for the clearing tasks on their own and from that putting together a quotation package with an overall cost that is then broken down into different categories (total wage cost to clear site, unemployment insurance fund, capital build up, camping allowance, personal protective equipment, tools and equipment, transport, administration). The contractor also acknowledged that they were not influenced by any WfW management personnel in putting together the quotation package. This means that the contractor not only understood the extent of the work they were tasked with as well as the responsibility to finish the contract but also acknowledged that they would be able to complete the contract with the stated resources. However it might also be true that a contractor might have limited knowledge of what a realistic quotation package should entail for a particular extent of clearing, but accepts the conditions anyway because the perceived rewards are high and there is no risk on their behalf should they fail to complete the contract.

While the results have clearly shown that failure to complete Contract 2 was highly probable because the resources quoted for and allocated were not sufficient for the work on the ground, this has brought to light other issues. Firstly, that the contractors lack the necessary skills to conduct realistic cover estimations and to scrutinise estimations where these are conducted for them. Secondly, that WfW project and area managers do not conduct quality control checks of the raw data (person day/ha, Rands/ha and Rands/person day) before approving quotation packages as well as of cleared areas before approving payments to contractors. Thirdly, that there is a lack of the necessary skills to conduct realistic cover estimations among WfW personnel. Lastly, that two obviously different densities are mapped into one NBAL indicates both carelessness as well as a lack of understanding of the simple definition and purpose of NBAL mapping.

It is therefore recommended, firstly, that contractors and the relevant WfW personnel be equipped with sufficient knowledge and training such that they are able to either conduct realistic IAP cover estimations themselves or are able to scrutinise the accuracy, or representativeness, of cover estimations conducted for them. Secondly, that managers and area managers conduct the necessary quality control checks before, during and after contracts are awarded and that were it their responsibility to delegate tasks they cannot attend to that this is done.

CHAPTER 3

AN ASSESSMENT OF THE EFFICIENCY OF THE WORKING FOR WATER CONTRACT TEAMS

3.1. INTRODUCTION

The contract teams, employed by WfW to clear *A. mearnsii*, usually comprise eleven members with different task groups namely: chainsaw operators (COs), stackers and herbicide applicators (HAs). These members work together to implement clearing on the ground. They employ mechanical (physical actions and machinery) and chemical (herbicides) methods of controlling *A. mearnsii* (Euston-Brown *et al.,* 2008). Chainsaw operators use chainsaws to cut *A. mearnsii*, while herbicide applicators use knapsacks with nozzles to both foliar spray seedlings and cut stumps. Stackers are responsible for the strategic stacking of cut material into neat piles, which might be removed, burnt, chipped or left in-situ (DEA, 2015).

Multiple task groups (COs, stackers and HAs) in a team means that ratios and coordination are crucial to ensure an even and continuous workflow from felling to stacking to herbicide application. Yet it is not known how the current task group ratios impact on team efficiency. This research has the potential to provide WfW management with a better understanding of the different activities carried out by contract teams on the ground, exactly how these activities are conducted as well as determine how this impacts on the efficiency of the contract teams.

The key question that this chapter sought to answer was: What is the efficiency of the WfW contract teams? The objective was to assess the efficiency of WfW contract teams by establishing the total amount of time members of the different task groups spent conducting clearing work in the field.

3.2. METHODS

The three WfW contract teams conducting the clearing of *A. mearnsii* on the Ann's Villa farm were assessed. Members of the three teams, namely Team S, Team C and Team S2, were assessed, unknown to them, while conducting clearing work. Field visits were made to the different sites with the different contract teams. Diaries were kept into which field observations were noted. Notes included the number of people present (count), clearing methods employed, number and type of equipment used.

An observation key to determining a teams' efficiency was used to establish how much time team members spent doing actual work tasks. Additionally it was determined how much potential work time was, or not, lost in a day. Eleven members from Team S, 10 from Team C and 11 from Team S2 were assessed. In total eight COs, 17 stackers and seven HAs were assessed across the three teams. Different COs, stackers and HAs from each team were assessed on different days from the time they arrived in the field to the time they went home. Assessments were done per subgroup and where subgroups contained more than 3 people, only 3 were assessed and the rest assessed on a different day. Due to time and financial constraints each member was only observed for a day and the need to do repeat observations per member would be determined by the degree of variation in the data across the three teams. Using a stopwatch, time was recorded whenever a member started to work (start time) and time was stopped whenever the member stopped working (stop time).

Time lost was defined as the time within normal working hours a member spent not doing work tasks. By virtue of this definition the time a CO spent re-oiling or sharpening a chainsaw or the time a HA spent walking to and from the designated herbicide mixing area, to mix more herbicide or the time spent walking from one tree to another, was not considered time lost. The start times were subtracted from the stop times to get the total time a member spent working. The totals were added together to get the total time a member spent working the whole day. The total time a member spent working was converted into mean percentage efficiency. The mean percentage efficiencies were examined in relation to the wages of each member to determine how much of the money

WfW spent on a team and the different task groups resulted in fruitful or fruitless expenditure.

Descriptive statistics, using MS Excel, were used to calculate mean efficiencies and standard deviations of COs, stackers, HAs as well as of whole teams. A one-way ANOVA, in STATISTICA, was used to determine if there were any significant differences in efficiency within the different task groups, COs, stackers and HAs, across the different teams. A paired t-test was used to determine if there were significant differences in the fruitful and fruitless expenditure of teams. A simple linear regression, in STATISTICA, was used to see if there was a relationship between the subgroup CO to stacker ratio and the subgroup CO to stacker efficiency ratio.

3.3. RESULTS

Team S divided themselves into three subgroups; one of three members (a CO, stacker and a HA), and two subgroups of four members (a CO, two stackers and a HA). They employed the use of one chainsaw per subgroup to implement the cut stump method of clearing and ring-barking. The three COs operated at an average efficiency of 66.6±5.0%, while the five stackers ran at 34.7±6.9% and the three HAs at 24.3±20%. Chainsaw operators were the most efficient, the only task group higher than the team average of 40.6±20.4% (Figure 3.1).

Team C divided themselves into two subgroups; one of five members (two COs, two stackers and one HA) and the other of five members (one CO, three stackers and a HA). Team C employed the use of two chainsaws, loppers as well as bow-saws to implement the cut stump and ring-barking methods. The three COs operated at an average efficiency of 38.9±4.5%, while the five stackers averaged an efficiency of 32.5±16.9% and the two HAs at 32.0±25.8%. Chainsaw operators were again the most efficient, and were the only one task group higher than the team average of 34.3±13.9% (Figure 3.1).

Team S2 also divided themselves into two smaller subgroups; one of six members (CO, four stackers and one HA) the other of one five members (CO, three stackers and one HA). The team employed the use of two chainsaws, loppers as well as bow saws to implement the cut stump and ring-barking methods. The two COs operated at an average efficiency of

84.0±8.0%, while the seven stackers ran at 38.5±21.5% and HAs at 33.3±4.0%. As with the two previous teams, COs were the most efficient, and were higher than the team average of 45.8±25.5% (Figure 3.1).

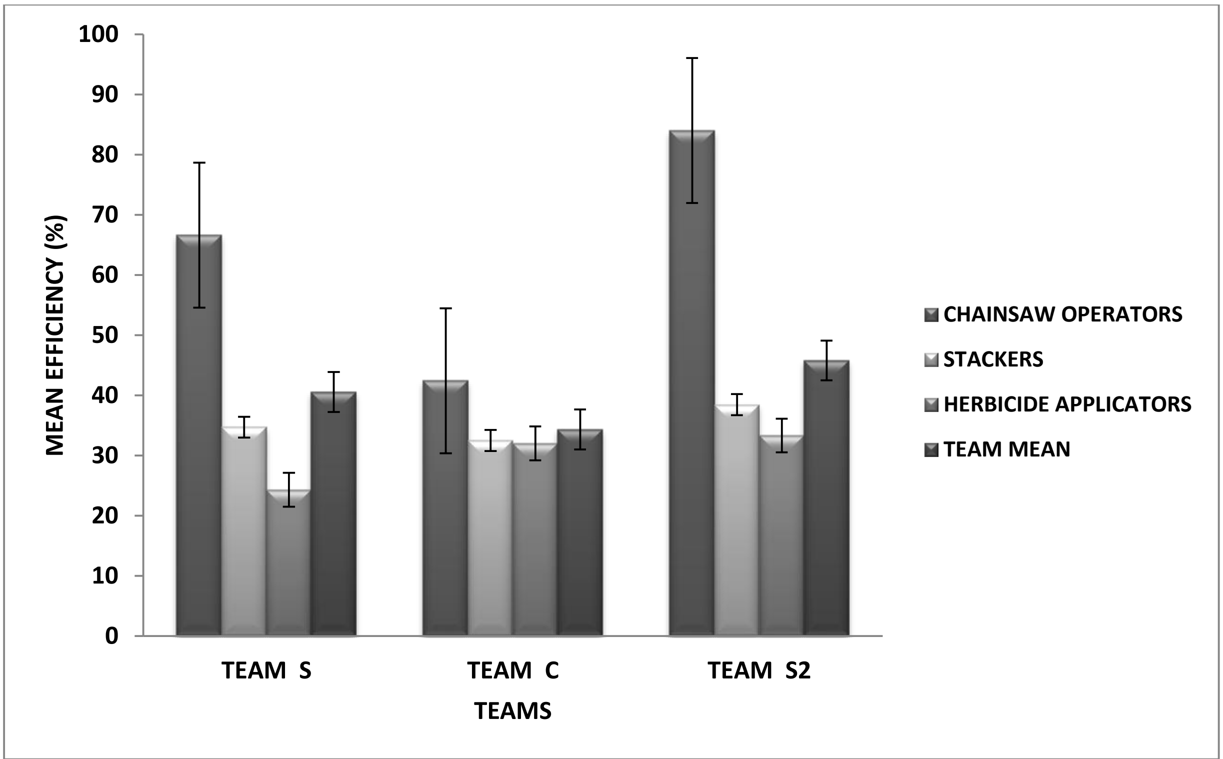

FIGURE 3.1: Efficiency (% mean ± SE) of the different task groups of the three contract teams.

When comparing mean efficiency of the task groups across all the teams, the differences observed between the stackers and HAs were not significant (F=0.19, p= 0.83 and F=0.16, p=0.85 respectively). Significant differences were observed between the COs across the teams (F= 41.93, p<0001). The significant differences were observed between Team S and Team C COs (p<0.01) and between Team S2 and Team C COs (p<0.01) with Team C COs being significantly less efficient than the other two (Figure 3.2).

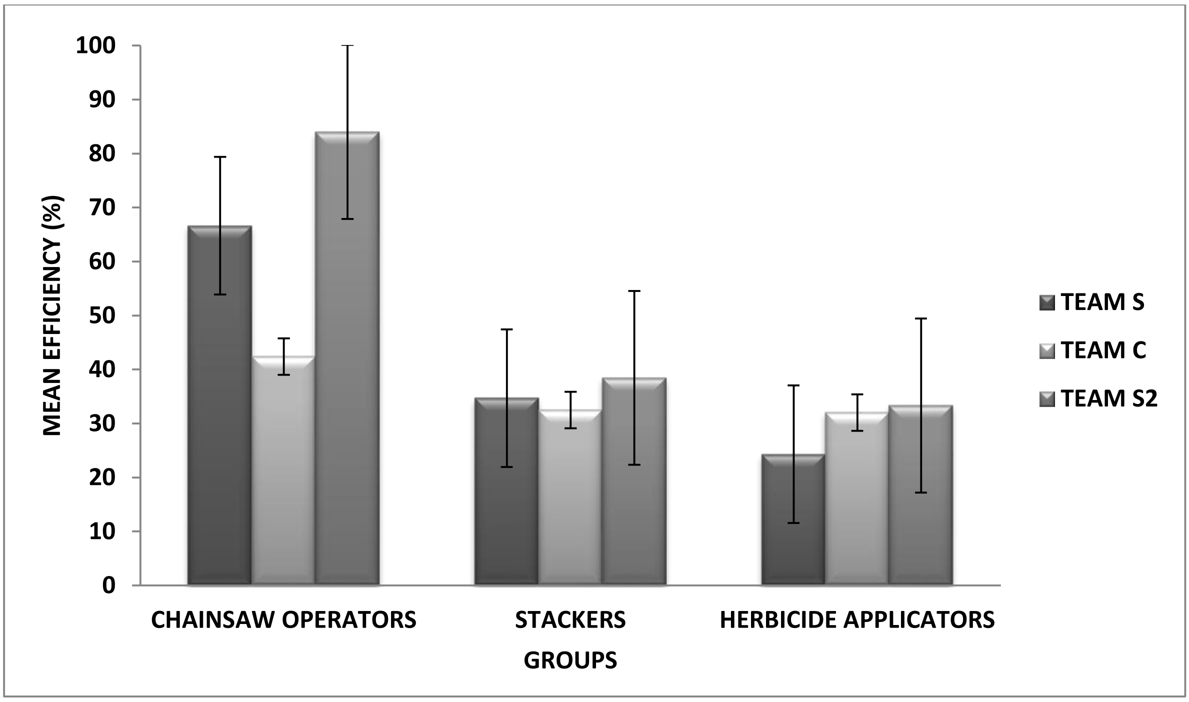

FIGURE 3.2: Efficiency (% mean ± SE) of different task groups from the different teams.

Based on the ratios and efficiencies of the subgroups from all the teams Figure 3.3 illustrates that there was a strong positive relationship between the subgroup CO to stacker ratio and the subgroup CO to stacker efficiency ratio (r^2=0.81; p<0.01). The CO to stacker ratios explained 81% of the variation in the CO to stacker efficiency ratios.

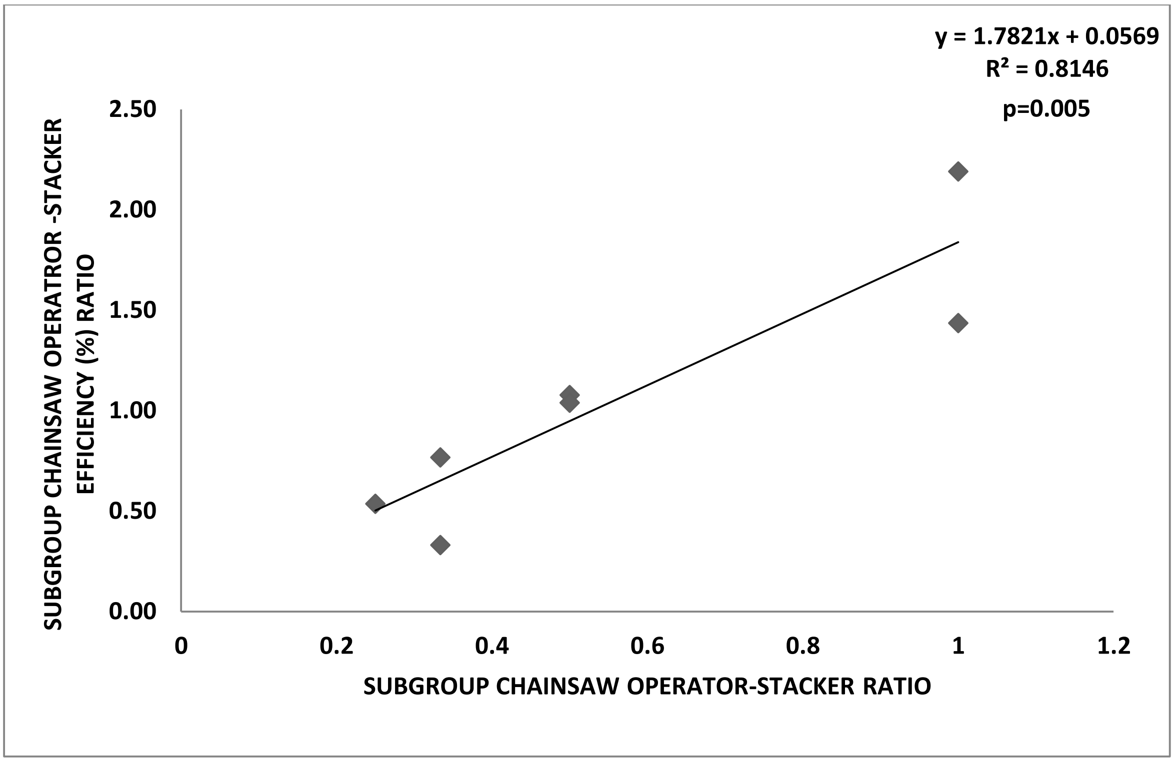

FIGURE 3.3: The relationship between chainsaw operator-stacker ratio and their efficiency ratio.

The amount of fruitless expenditure was found to be higher than the amount of fruitful expenditure in every team, but only significantly higher in Team C (t=-4.89; p=0.01) (Figure 3.4). On average, 58±67% of the total money spent per team was in fruitless expenditure. Of all the groups the stackers were responsible for 56±12% of the fruitless expenditure compared to the 27±8% and 17±13% for HAs and COs, respectively (Figure 3.5).

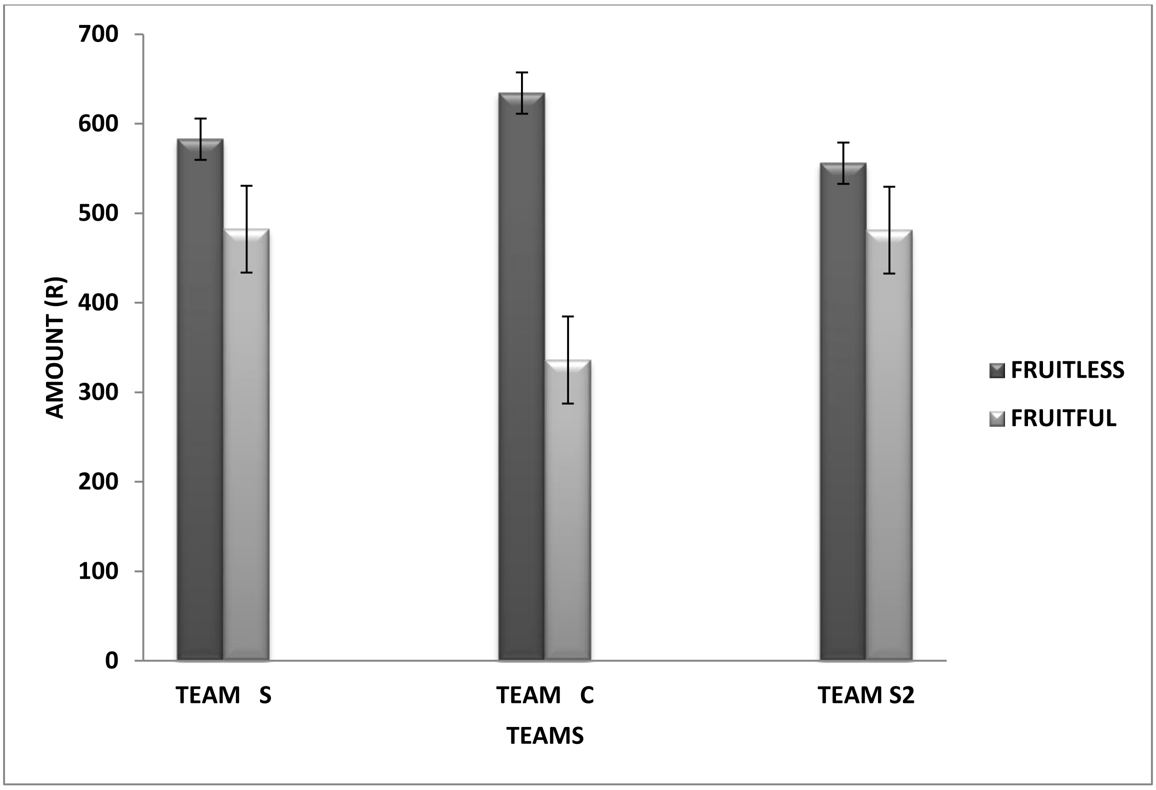

FIGURE 3.4: Total 'fruitless' and 'fruitful' expenditure (±SE) expressed in rands (R) per team per day.

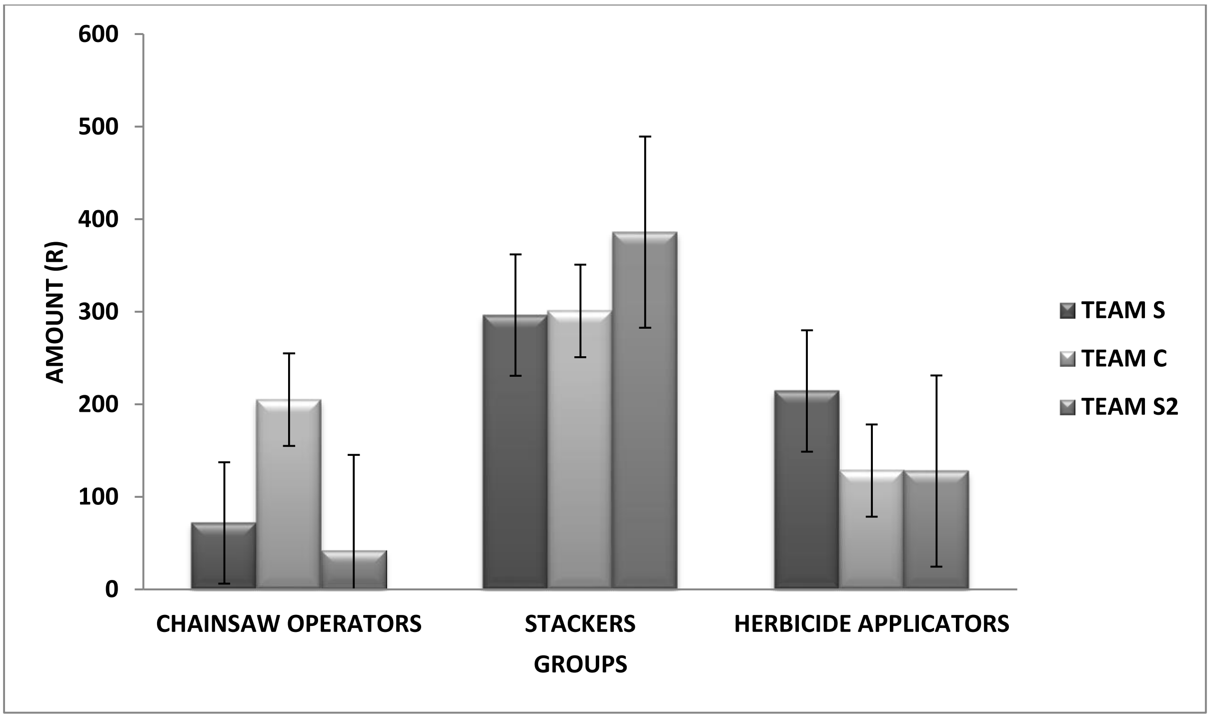

FIGURE 3.5: Total amount (R) of 'fruitless' expenditure (±SE) of the different task groups per day.

3.4. DISCUSSION

3.4.1. Efficiency

The results clearly show that there was a lot of potential work time spent not doing work tasks (Figure 3.2). Three different scenarios were observed in the field that may help explain or account for the lost time. These scenarios relate mainly to the differences in the *A. mearnsii* density and age class. The scenarios were as follows:

Scenario 1

Areas considered for Scenario 1 were areas dominated by sparse large trees with basal diameters of greater than 20 centimetres (cm). In this scenario a CO spent roughly 30 to 45 minutes felling a large tree and cutting it into smaller pieces so that the stackers would be able to stack the logs into neat piles as required. This meant that for those 30 to 45 minutes that the CO was busy, the stackers and HAs were waiting for the CO to finish or was at a point where it was safe to start stacking while the CO finished up. Once the tree had fallen and the cut stump was completely exposed the HA could spray that stump in a matter of seconds. Until the CO felled another tree, by virtue of his or her job description, the HA had to wait for another cut stump to spray.

Scenario 2

In this scenario the areas considered were those dominated by dense but smaller trees with diameters ranging from 2-20 cm. The trunks of these trees were smaller in diameter but tall, such that once done felling a reasonably big enough area the CO had to cut the stems into stackable sizes. After the CO was done, only then could the stackers neatly stack these and ensure that all the cut stumps were exposed so that the HAs could have access and spray all of them. While the stackers and HA spent quite a bit of time waiting they also spent more time working, compared to scenario 1, because the denser the area the more cut material there was to stack and the more stumps there were to spray.

Scenario 3

Areas considered for Scenario 3 were areas dominated by a high density of plants with stems having basal diameters of less than two centimetres. While the majority of the plants in this scenario were emerging seedlings, those with stems that could be measured were small in both basal diameter and height and because of this the CO could fell many of them in a short space of time and the stacker could also stack them quickly because they were not heavy. The HA applicator however had a lot more work because the stumps were numerous and also very difficult to easily target for spraying compared to big stems.

These three scenarios highlight areas dominated by the different age and size classes of IAPs but are not mutually exclusive. The scenarios show that a lot of the time lost was as a result of members waiting and this resulted because of the lack of continuity in work, i.e. there was no way for all members in the subgroups to be working concurrently. While these scenarios may explain some of the time lost, they are however not to be used as excuses to legitimising the wasting of time. Gillikin (2014) states that while some companies or organisations have basic efficiency benchmarks and targets established most companies do not and must have these performance targets established for the different kinds of work in the company or organisation. Working for Water does not currently have specific efficiency benchmarks and targets established for the contract teams or the different task groups within the teams, so this study defined a general minimum of 80% as an acceptable daily efficiency target. An 80% efficiency target means that members would be allowed a 12 minute break in every working hour. This efficiency target therefore makes provisions for members, especially COs whose work tends to be very labour intensive, to take breaks as needed. These breaks will also come in handy in different conditions that members have to work in, for example, they can be used as bathroom breaks or as water breaks in hot weather and as rest breaks at sites with steep landscapes. This is important because such conditions can result in fatigue which further impact on efficiency and these breaks can help to minimise this. There is, however a need for WfW to define efficiency targets specific for the different task groups because of the differences in the intensity of labour amongst them.

McQuerry (2014) states that a team becomes more efficient when every member understands their own roles in the team but also has an understanding of their teammates' roles. The differences in combined efficiency observed between the teams stems from the differences in the number of COs in relation to the number of chainsaws in the teams. Team S had an equal number of COs (3) to chainsaws (3) and hence achieved the most combined efficiency. Team S2 also had an equal number of COs (2) to chainsaws (2) and achieved the second highest combined efficiency because of the fewer COs and chainsaws compared to Team S. Chainsaw operators from Team C were the least efficient of all the COs, and this was because there were three COs but only two chainsaws with one subgroup having two COs who took turns in felling. While the one CO was busy felling the other was waiting for his turn, it was this waiting that rendered them significantly less efficient compared to COs from Team S and Team S2 (Table 1).

Some stackers from Team S2 were observed using loppers as well as bow-saws to cut smaller trees whenever COs were busy felling large trees. The ability of these stackers to recognise the need to do this is important because Team S2 had seven stackers compared to the five stackers in each of Team S and Team C. This is also important because Figure 3.3 illustrated that the more stackers there are to one CO, in a subgroup the less efficient those stackers become. These efforts are also illustrated in their combined and mean efficiencies being higher than those of both Team S and Team C stackers. Team S stackers had a higher efficiency than Team C stackers and this was because the stackers from Team S would be more efficient based on the efficiency of the COs in their team compared to the COs in Team C. This was also because Team C stackers were helped with the stacking by the HAs in their team who then increased the number of people stacking per CO, hence reducing the efficiency of the stackers (Figure 3.2). This is also evident in the mean efficiency of Team C stackers and HAs being almost equal, a result not observed with the other teams (Figure 3.2). Some HAs from Team C and Team S2 were also observed taking off their knapsacks and helping with the stacking, especially in areas resembling scenario 1. This is evident in their mean efficiency being higher than that of HAs from Team S, who did nothing else besides spraying.

Instead of waiting to stack or spray, stackers and HAs could perform other tasks such as felling smaller trees using loppers or bow-saws, as some were observed doing. However, one could also argue that such tasks do not form part of their job description. The stackers and HAs constantly recorded the lowest efficiencies (Figure 3.2). While the study cannot attribute a percentage of the inefficiencies to factors such as laziness, the high standard deviations observed amongst stackers and HAs indicate that some members were much more efficient than others. This could also be due to other factors such as differences in diets resulting in differences in the blood sugar and energy levels of different members. It is also important that the benchmark targets established do not discriminate against disabled members. However, the fact that there were no significant differences in efficiency between all the stackers and HAs across all the three teams illustrates where the efficiency loopholes are. It is evident that if teams were better organised and workflow was not hindered in any way stackers and HAs would not find it necessary to deviate from their core tasks in order to increase efficiency but their ability and willingness to do also illustrates their adaptive capacity. To achieve this there is a need to increase the number of COs with chainsaws in teams. It also means that COs have to operate at optimum efficiencies in order to increase the efficiencies of the stackers and HAs.

Increasing the number of COs and reducing the number of stackers per team in the right proportions will increase the efficiency of the contract teams. This might however increase the operating costs of teams and also increase the number of male members per team, whereas WfW seeks to move towards teams that are dominated by female members (Coetzer and Louw, 2012; DEA, 2015). While it is realised that having more COs may have other cost benefits such as reducing the lengths of contracts which will, in the long run, mean that more IAPs are cleared annually, it is also realised that this will be in conflict with the mandate WfW is aiming to achieve (DEA, 2015). The scenarios, as discussed earlier, mirror the high variations in both size and age classes of *A. mearnsii* and the contract teams should also be organised to mirror these variations. Therefore, in addition to COs, some of the current female stackers could be trained in brush cutter operations. This will mean that contract teams can comprise of COs, brush cutter operators (BCOs), stackers and HAs in numbers that promote the continuity of work and consequently efficiency. For example, a team of three COs, three BCOs, three stackers and three HAs will mean that a team can divide itself into three subgroups of a CO, BCO, stacker and HA each and would prove more efficient because one stacker would be stacking for both a CO and BCO, and one HA will also be spraying for the two who are felling concurrently, instead of three stackers stacking for one CO and one HA spraying for one CO as is currently done.

Including BCOs in the contract teams will help teams become adaptable and promote the continuity of work by bridging the gaps observed in the different scenarios as, COs can focus on felling the bigger trees while BCOs can focus on felling smaller trees. This will also mean that more IAPs are felled daily per subgroup compared to when felling is by COs only. This, however, may be challenging to achieve unless baseline assessments of the areas to be contracted out for clearing, are conducted before contracts are given out to contract teams. Conducting baselines will allow WfW management to know to advise contractors as to how they should organise their contract teams in order for them to carry out clearing as efficiently as possible. It is recognised that for safety, from falling IAPs, stackers and HAs are required to stand at a safe distance, defined as twice the height of the tree being cut, while COs cut trees. In promoting work continuity teams will have to be strategic in how they organise themselves, for example, COs and BCOs can get a head start in clearing, where BCOs go ahead with some stackers and HAs and clear the path for the COs to gain easy access to the large trees, and cut a sizeable area then move to another area distant enough to ensure the safety of the stackers and HAs. When the stackers and HA are done in that area they can move to the area that was being cut as they were stacking and the COs and BCOs can go back to continue in the area where the stackers and HAs were and vice versa. It is key that teams are organised in such a way that promotes efficiency because the low efficiencies currently observed mean that the contract teams are operating at a high cost-benefit ratio.

3.4.2. Cost efficiency of contract teams

Members of a team are paid according to the skills they have acquired and are certified for, i.e. COs get paid a daily rate of R111.88, HAs get paid R94.40 while stackers get paid the general worker rate of R89.16 (quotation package, SANParks, 2015). These rates are paid for an 8 hour working day. Based on the daily rates and number of members, Team S was paid R1 064.64, Team C R970.24 and Team S2 R1 036.68 daily. However, the number of hours worked in the field did not correspond to the amount of money paid daily per team, i.e. members do not work the eight hours for which they are individually paid, therefore resulting in fruitless expenditure.

Stackers currently make up the bulk of the teams and hence their inefficiencies result in the highest percentage of fruitless expenditure. This is evident in the fact that, Team S2 stackers had the highest efficiency of all the stackers but their fruitless expenditure was also the highest. This illustrates where the causes are in terms of fruitless costs. It also emphasises the need to promote a higher CO to stacker ratio, as the results show that it is more costly to have many inefficient stackers compared to a few.

These fruitless costs may seem minor at a team level but they become profound when assessed over a long period and at project and national scales. If these three teams work for 150 days in a year, at a daily fruitless cost average of R590±39, it means that fruitless costs emanating from lost work time, per team amount to R88 500 per annum (p.a.). If WfW Addo Central has fifteen of these teams working in a year then fruitless costs amount to R1 327 500 p.a. This is money that could be used to fund more projects, clear more IAPs and create more jobs for impoverished people. It is clear that to curb these high fruitless costs, there is a need to improve the efficiency of teams. It is important to note that only member wages were included in the above calculations because other operating costs such as transport costs are not directly affected by efficiency.

3.4.3. Monitoring

Levendal *et al.* (2008) states that WfW tends to focus on the monitoring of the inputs, money spent, associated with projects as well as on outcomes such as effectiveness, trees properly cut, logs properly stacked, stumps all sprayed, etc., for obvious reasons. However, for more comprehensive information to improve the contract teams as well as WfW, there is a need to focus on performance indicators such as efficiency, there is a need to bridge the gap between inputs and outcomes (Levendal *et al.,* 2008; van Wilgen *et al*., 2012a). This was illustrated in the low efficiencies which translate into high fruitless expenditures. This study has already identified one way (time spent doing work) in which to measure the efficiency of contract teams. This efficiency measure requires a monitor independent of the contract team to be present in the field to do the assessments. However, it might be a worthwhile investment for WfW in the long run to employ a couple of capable people specifically for this job. These efficiency monitors can move randomly between teams and can be responsible for educating contract teams about the need and importance of efficiency as well as be able to report back to WfW as to what challenges teams face and what challenges they observe that hinder efficiency in the field and how these challenges can be overcome.

van Wilgen *et al*. (2012a) attribute some of the inefficiencies observed in the WfW Programme to the lack of monitoring. The lack of monitoring was also observed in this study. There was no monitoring as to when teams arrived at the clearing site and when they left. As a result of this teams came and went as they pleased. On several occasions teams never showed up for work or were observed arriving at site midday on a Tuesday, with reasons ranging from rainy weather, meetings at the park and refresher training, this however means that the team has already lost a day and half in which they could have conducted some clearing work. WfW therefore currently has no way of estimating how much time teams spend working in the field, i.e. they have no idea how much of the allocated days are actually used by teams. They could as a simple way of monitoring, require that a team must sign in with the landowner, when arriving at the beginning of the week, and, sign out when leaving at the end of the week. They would then be able to estimate how much of the allocated days teams used at the end of a contract. This could also give them information about the performance of specific teams. For example if a team was allocated 19 days and that team only used 12 days but still managed to complete the contract on time and pass quality inspection. Or if a team was given the 19 days but were only in the field for 12 days and do not manage to meet their deadline. While WfW can attribute this to the function of the contractor system and that they are not mandated to monitor how teams use their allocated days, this is information that could prove valuable to them in future when creating contracts and allocating days to those contracts.

Working for Water management often conducts in-field assessments. These assessments cover a wide range of topics from health and safety, individual responsibilities, absenteeism, to the knowledge of IAPs in the area, herbicide measurements, contract boundaries as well as the number of hectares and days in which a contract is to be completed. A ranger arrives at site, and goes through the in-field assessment with the team asking questions and grading their answers. At most the in-field assessments inform WfW about just how knowledgeable a team is about all the different things that they are supposed to know. While these assessments are important it is necessary to note that without performance indicators and proper monitoring it is not possible to know how teams are really doing. Common Ground (2003) outlines monitoring requirements and guidelines to help the program establish a clear basis for knowing how it is progressing. However WfW has not adopted the recommendations and monitoring continues to remain one of its main challenges. Equipping teams with knowledge is an essential first step in learning which can raise awareness and change attitudes but translation of that learning into appropriate actions requires regular monitoring (Cundill and Fabricius, 2009).

CHAPTER 4

AN ASSESSMENT OF THE EFFECTIVENESS OF THE WORKING FOR WATER CLEARING METHODS

4.1. INTRODUCTION

Acacia mearnsii was introduced in South Africa for commercial reasons and has from those commercial areas spread into adjacent areas (de Wit et al., 2001). Where commercial areas growing *A. mearnsii* occurred near riparian systems the spread, into surrounding areas, has been profound. One of the most invasive Australian acacias, *A. mearnsii,* plagues South Africa's riparian zones in most catchments, with 52.8% of the infestations found in the Grassland and Fynbos biomes (McConnachie, 2012). Riparian zones are especially susceptible to invasions by *A. mearnsii* due to the frequency of disturbances they experience as well as the availability of water (Le Maitre, 1998). Invasions of riparian zones by efficient water-using species such as *A. mearnsii* results in reductions in catchment yield (Le Maitre *et al*., 2002).

Acacia mearnsii also causes major biodiversity declines in the areas it has invaded. By creating dense stands, it is able to displace indigenous species as it out-competes them for resources (Gaertner *et al.,* 2009). The Grassland and Fynbos biomes generally lack tree species able to compete with tree IAPs such as *A. mearnsii,* and this is the reason why invasions are high in these biomes (Richardson and Cowling, 1992). The impacts caused by *A. mearnsii* both on water resources and biodiversity have resulted in the species being named as one of the most prolific invasive species in South Africa with most of the WfW budget spent on its clearing (van Wilgen *et al*., 2012b).

It is therefore important to understand why the impact of clearing has been minimal, despite the fact that *A. mearnsii* is the species most targeted by WfW (McConnachie *et al*., 2012; van Wilgen *et al*., 2012b). This chapter therefore sought to answer the question of how effective are the WfW methods employed to clear *A. mearnsii,* to establish whether the clearing operations have negative impacts on indigenous plant biodiversity as well as to establish the size and viability of *A. mearnsii* and indigenous seedbanks.

4.2. METHODS

Acacia mearnsii infestations, at Ann's Villa farm, were mapped on ortho-rectified digital aerial photographs using ArcMap10. Field verifications of the mapped infestations were conducted. A grid of 10x10 m blocks, henceforth referred to as plots, was created and overlaid on the mapped areas and a total number of 115 plots were randomly selected in GIS. Using the coordinates of the plots from GIS, the random 10x10 m plots were then located in the field using a Trimble GPS. The south west corners of each 10x10 m plot were demarcated using steel pegs which were hammered into the ground leaving up to 2 cm sticking out.

4.2.1. Pre-clearing assessments

Baseline (pre-clearing) assessments of each of the 115 10x10 m plots were conducted, in August 2014, as described below. A nested sampling design, Figure 4.1, was used due to the high density as well as the high variation in *A. mearnsii* tree size. Three sample scales, namely 10x10 m, 3x3 m and 1x1 m were used i.e. 115 replicates of 10x10 m plots, 230 replicates of 3x3 m plots and 460 replicates of 1x1 m plots were sampled (Figure 4.1). Within each 10x10 m plot the aerial invasion intensity of *A. mearnsii* and indigenous trees and shrubs (T&S) and the ground cover of combined forbs and of combined grasses were, measured by visually estimating how much of the 10x10 m plot was occupied by each, and recorded.

Stem density counts and the basal diameters, at 30 cm height, of all *A. mearnsii* trees with basal diameters greater than 20 cm and of all indigenous T&S were measured and recorded in the 10x10 m plots. Indigenous seedling density counts were also recorded from the 10x10 m plots. Basal diameters were measured using digital callipers. Within the 3x3 m plots, stem density counts as well as the basal diameters, at 30 cm height, of *A. mearnsii* trees with basal diameters between 2-20 cm were measured and recorded. Density counts of *A. mearnsii* seedlings were recorded from the four 1x1 m plots. Samples of all unknown indigenous T&S species encountered were collected, pressed and identified at the Selmar Schonland Herbarium in Grahamstown.

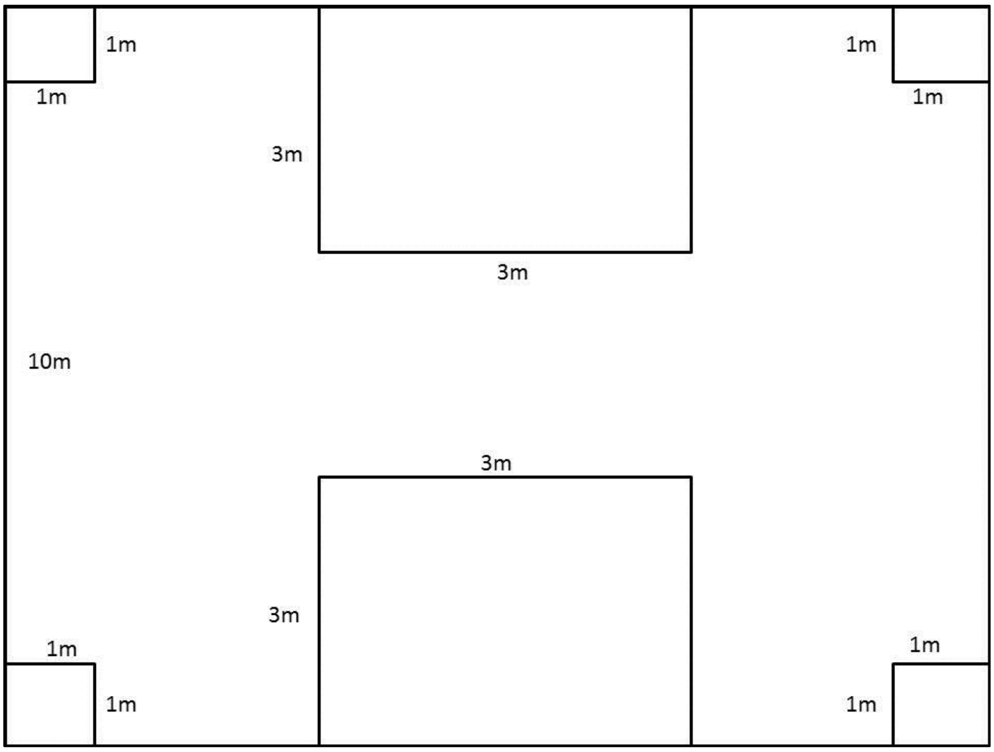

FIGURE 4.1: The nested sample design used.

4.2.2. Soil sample collection

At the centre of each 3x3 m plot, a 10 cm (depth) by 8 cm (length) metal frame was hammered 10 cm into the ground. A total sample of 126 leaf litter (hereafter litter) and soil samples were collected. The litter was removed and collected by hand into labelled paper bags while the soil from within the metal frame was removed using a hand trowel and collected into separate labelled paper bags. For the litter sample, seeds were sorted from the litter by hand. For the soil samples, the finer soil was sieve out leaving the coarser material together with the seeds. These were then sorted out by hand removing any seeds present in the remaining material. *Acacia mearnsii* seeds from each litter and soil sample were counted (Fourie, 2008).

A total of 20 litter and soil samples were then randomly selected using MS Excel and used for viability testing by way of germination. Seeds were placed in labelled plastic containers, according to their leaf and soil sample numbers, to which boiling water was added. The containers were closed, placed on top of a blanket, covered with another blanket to retain the heat and imbibed for 48 hours. Polyester trays and germination compost were used for the germination. The germination trays were labelled according to the litter and soil sample numbers. Germination compost was placed into the germination trays. Each tray accommodated 10 litter and 10 soil samples, each sample allocated 10 holes into which two seeds were placed. These were then replicated five times. A control was also set up where the seeds were not imbibed in hot water. The seeds were watered with 5 ml every day and germination was recorded whenever a clear and unobstructed emergence of the radicle was observed.

4.2.3. Post-clearing assessments

Unfulfilled promises and consequent delays in the clearing *of A. mearnsii* by WfW contract teams at the study area resulted in a large portion of the study area not being cleared as originally planned and agreed, a finding in itself of the efficiency and effectiveness of WfW in the region. Consequently from the parts of the study area that were cleared only 39 of the 115 baseline plots could be reassessed post-clearing. The methods of clearing included the cut-stump, lopping and the use of hand saws. Post-clearing assessments were conducted to assess how effective the clearing conducted was, as well as to ascertain if any negative impacts were imposed on the indigenous T&S during clearing. *Acacia mearnsii* invasion intensity, tree and seedling density counts, the presence of coppice, cover of indigenous T&S, cover of combined grasses, cover of combined forbs and density counts of indigenous T&S and seedlings were assessed post-clearing. The presence of coppice was determined by any new shoots occurring on *A. mearnsii* cut stumps. The mean percentage coppicing was therefore determined based on the total density of *A. mearnsii* recorded in a plot pre-clearing as well as the number of *A. mearnsii* trees coppicing post-clearing.

Data were captured into MS Excel spreadsheets and analysed as follows. Simple linear regressions, using MS Excel and STATISTICA, were used to establish relationships between *A. mearnsii* invasion intensity and (i) indigenous T&S cover, (ii) forbs cover, (iii) grass cover, (iv) total grass and forbs cover, (v) indigenous T&S density. Simple linear regressions were also used to establish relationships between *A. mearnsii* adult density and indigenous adult density as well as between indigenous T&S density and indigenous T&S abundance. A paired t-test, in STATISTICA, was used to determine if there were any significant differences pre- and post-clearing in the variables measured in the field. An unpaired t-test was used to determine if there were significant differences in litter and soil seed density.

4.3. RESULTS

Figure 4.2 illustrates the relationship between invasion intensity and indigenous T&S cover (Figure 4.2A), forbs cover (Figure 4.2B), grass cover (Figure 4.2C) and total forbs and grass cover (Figure 4.2D). The relationships were all highly significantly negative, indicating the suppression of indigenous flora with increasing *A. mearnsii* invasion.

Figure 4.2B illustrated that 22% of the variation in total forbs and grass cover could be explained by invasion intensity. Individually 13% and 19% of the variation observed in forbs cover and grass cover could be explained by invasion intensity compared to only 6% of the variation in indigenous T&S cover indicating an even weaker relationship. Invasion intensity also showed a significantly negative relationship ($p<0.0001$) with indigenous T&S density explaining 17% of the indigenous T&S density variation (Figure 4.3). *Acacia mearnsii* tree density illustrated a significant negative relationship ($p<0.0001$) with indigenous T&S density where 14% of the variation in indigenous T&S cover could be explained by *A. mearnsii* tree density (Figure 4.4).

Comparisons between pre- and post-clearing assessments showed differences in the different variables assessed. Variables that showed reductions from pre- to post-clearing included mean *A. mearnsii* basal area, mean indigenous T&S basal area, mean indigenous T&S cover, mean grass cover, mean invasion intensity, mean indigenous T&S density and mean IAP tree density (Table 4.1). Of all the variables that showed reductions pre- and post-clearing only mean IAP basal area ($p=0.004$), invasion intensity ($p<0.0001$) and mean IAP tree density ($p<0.0001$) were significantly reduced (Table 4.1).

Variables that showed increases from pre to post-clearing included mean forbs cover, mean indigenous seedling density/ha, mean IAP seedling density/ha as well as mean Shannon-Wiener diversity index (Table 4.1). Of the four variables that showed increases pre- and post-clearing only mean forbs cover ($p=0.02$) and mean IAP seedling density ($p<0.0001$) were significant (Table 4.1). Coppicing was evident on 5% of all the cut *A. mearnsii* trees.

Forty three indigenous T&S species, from 22 different families, were recorded at various densities and abundances (Table 4.2). The study area had a mean richness (number of different species) of seven indigenous T&S species per 100 m^2 with some having a higher density and being more abundant than others. Of the 43 indigenous T&S species, 27 were in the one to 10% abundance class, 14 species were in the 11 to 20% abundance class, one species was in the 21 to 30% abundance class and another one species in the 31 to 40% abundance class. In addition to *A. mearnsii* other IAP species recorded were *Acacia cyclops* and *Opuntia aurantiaca*. Figure 4.5 illustrates the significant positive relationship ($p<0.0001$) between indigenous plant species density/ha and their abundance, where 63% of the variation in species abundance could be explained by species density.

Table 4.3 illustrates that, from the 39 plots assessed post-clearing, 26 indigenous T&S species were recorded (Table 4.3). Comparisons between pre- and post-clearing indigenous T&S species mean density/ha, showed both increases and decreases. The density/ha of 14 indigenous T&S species increased and 12 decreased. Of the species that increased in density, only *Canthium inerme* increased significantly while *Rapanea melanophloes* was the only one that decreased significantly post-clearing.

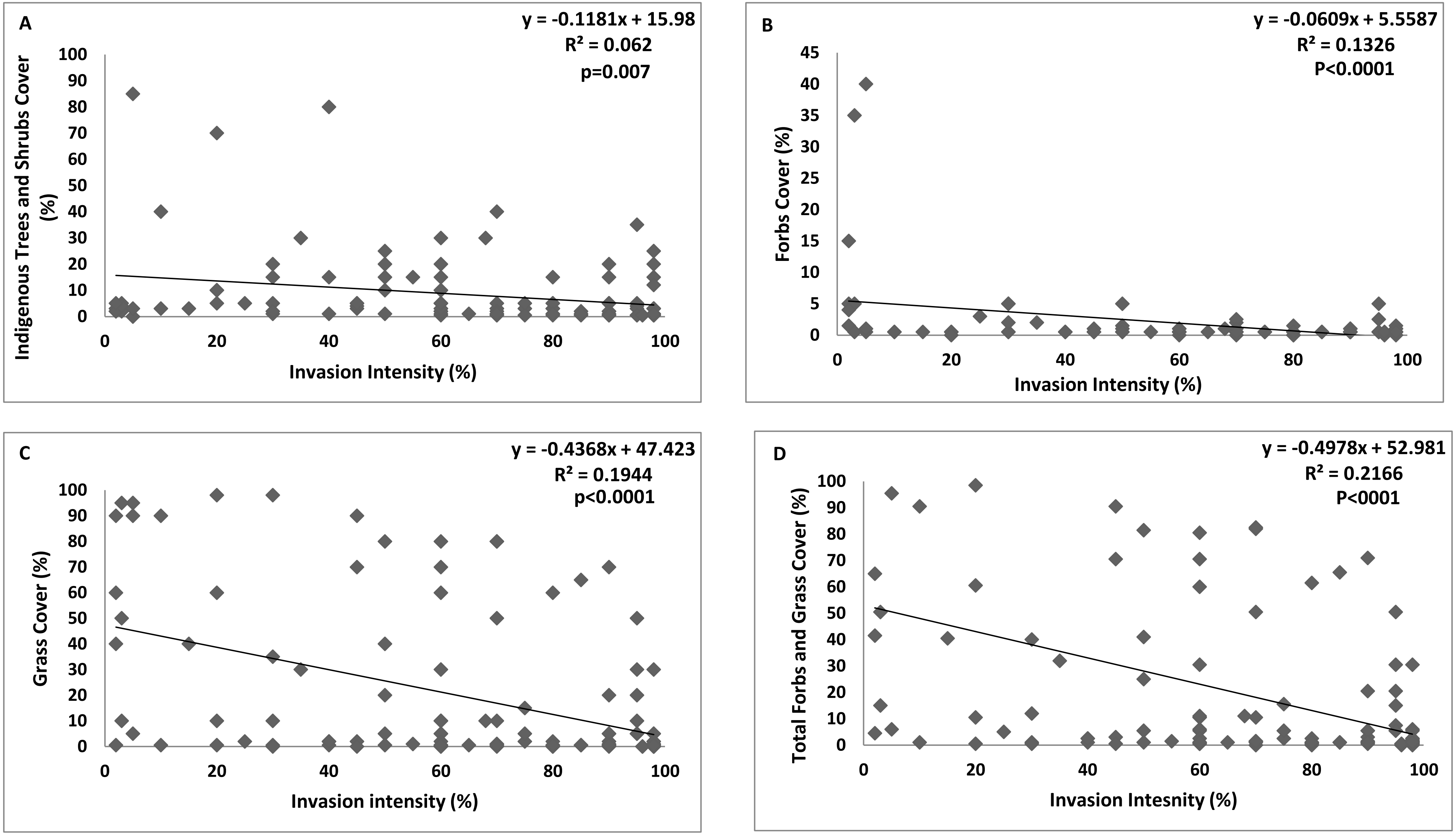

FIGURE 4.2: Pre-clearing relationship between invasion intensity and indigenous T&S cover (A), forbs cover (B), grass cover (C) and total forbs and grass cover (D).

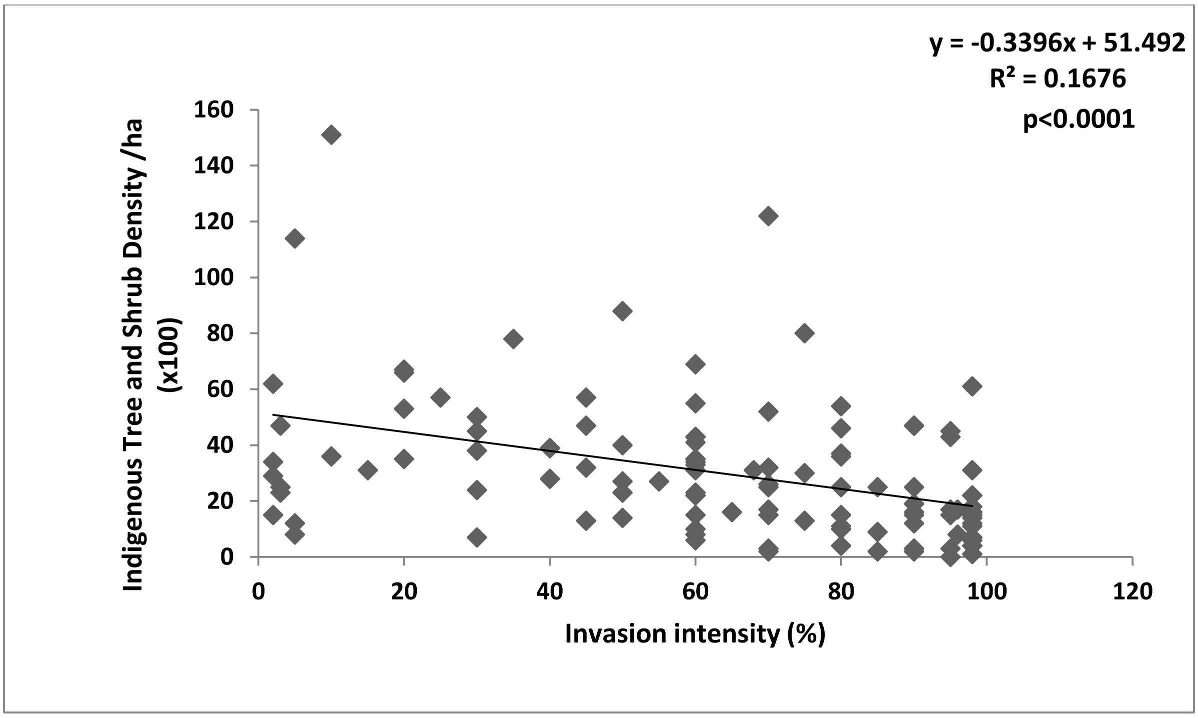

FIGURE 4.3: Pre-clearing relationship between invasion intensity and indigenous T&S density/ha.

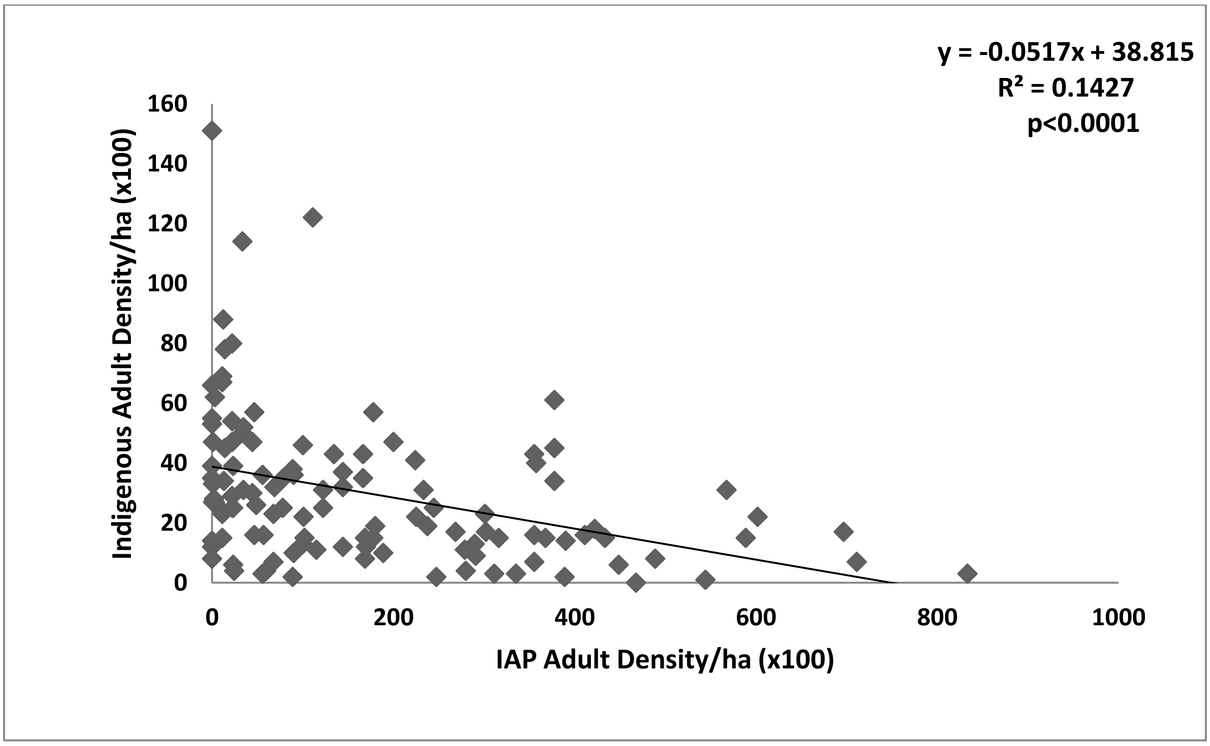

FIGURE 4.4: Pre-clearing relationship between mean IAP tree density and indigenous T&S density (B).

Table 4.1: The pre and post-clearing differences in measured variables.

Measured variable	Pre-clearing	Post-clearing	t-value	p-value
Mean *A. mearnsii* basal area (cm^2)	16	5	3.17	<0.0001
Mean indigenous T&S basal area (cm^2)	0.4	0.3	0.72	0.42
Mean indigenous T&S cover (%)	11	9	1.12	0.26
Mean grass cover (%)	21	16	1.2	0.21
Mean invasion intensity (%)	60	6	10.3	<0.0001
Mean indigenous T&S density/ha	3 323	3 238	1.13	0.26
Mean *A. mearnsii* tree density/ha	17 552	1 860	4.85	<0.0001
Mean forbs cover (%)	1	12	-2.53	0.02
Mean indigenous seedling density/ha	3 241	4 049	-1.4	0.16
Mean *A. mearnsii* seedling density/ha	39 551	318 526	-4.98	<0.0001
Mean Shannon-Wiener diversity index	1.54	1.61	-1.2	0.21

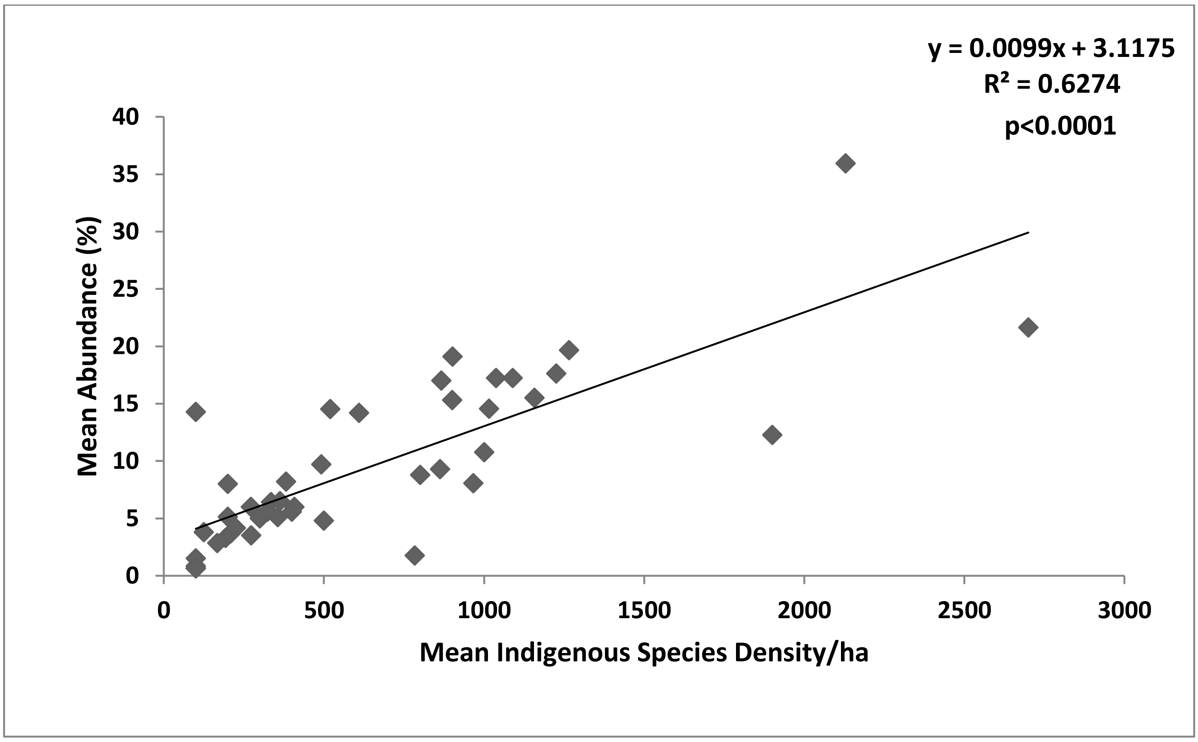

FIGURE 4.5: Relationship between mean indigenous species density/ha and mean indigenous species abundance.

Table 4.2: Indigenous T&S recorded pre- and post-clearing at study area.

Species name	Family	Mean Density/ha	Abundance class (%)
			1 to 10
Vachellia karroo	Fabaceae	100	1
Canthium inerme	Rubiaceae	335	6
Carissa bispinosa	Apocynaceae	363	7
Cassine aethiopica	Celastraceae	408	6
Chrysanthamoides monilifera	Asteraceae	300	5
Cussonia spicata	Araliaceae	100	2
Euclea crispa	Ebenaceae	800	9
Hermannia salviifolia	Malvaceae	100	1
Hippobromus pauciflorus	Sapindaceae	863	9
Kiggelaria africana	Achariaceae	200	8
Loxostylis alata	Anacardiaceae	967	8
Maytenus undata	Celastraceae	382	8
Metalasia densa	Asteraceae	125	4
Olea europea subsp. *africana*	Oleaceae	192	3
Osyris wightiana	Santalaceae	167	3
Pavetta natalensis	Rubiaceae	273	4
Pterocelastrus tricuspidatus	Celastraceae	492	10
Rapanea melanophloes	Primulaceae	208	4
Searsia incisa	Anacardiaceae	500	5
Searsia tomentosa	Anacardiaceae	400	6
Rubus sp.	Rosaceae	100	1
Scolopia mundii	Salicaceae	324	6
Scutia myrtina	Rhamnaceae	200	5
Senecio linifolius	Asteraceae	783	2
Senecio pterophorus	Asteraceae	271	6
Trimeria trinervis	Salicaceae	225	4
Zanthoxylum capense	Rutaceae	355	5
			11 to 20
Aloe ferox	Xanthorrhoeaceae	100	14
Athrixia phylicoides	Asteraceae	519	15
Coddia rudis	Rubiaceae	1 900	12
Diospyros dichrophylla	Ebenaceae	901	19
Diospyros whyteana	Ebenaceae	1 038	17
Ehretia rigida	Boraginaceae	1 000	11
Elytroppas rhinocerotis	Asteraceae	610	14
Erica copiosa	Ericaceae	1 157	15
Euclea natalensis subsp natalensis	Ebenaceae	1 090	17
Grewia occidentalis	Malvaceae	1 015	15
Passerina corymbosa	Thymelaeaceae	1 265	20
Putterlickia pyracantha	Celastraceae	900	15
Searsia dentata	Anacardiaceae	1 225	18
Tarchonanthus camphoratus	Asteraceae	867	17
			21 to 22
Myrsine africana	Myrsinaceae	2 700	22
			31 to 40
Searsia rhemanniana	Anacardiaceae	2 129	36

Table 4.3: The pre and post-clearing differences in indigenous T&S species density/ha.

Species name	Pre-Mean Density/ha	Post-Mean Density/ha	t-value	p-value
Athrixia phylicoides	282	372	-1.14	0.28
Canthium inerme	353	753	-2.51	0.02
Carissa bispinosa	356	500	-1.29	0.23
Cassine aethiopica	364	236	1.74	0.10
Cussonia spicata	50	100	-1.19	0.32
Diospyros dichrophylla	1 131	1 403	-1.79	0.08
Diospyros whyteana	1 400	1 342	0.21	0.84
Elytroppas rhinocerotis	133	422	-1.23	0.25
Euclea natalensis subsp natalensis	635	482	1.97	0.07
Grewia occidentalis	661	756	-0.48	0.64
Hippobromus pauciflorus	1 375	1 025	0.31	0.77
Loxostylis alata	767	200	0.92	0.46
Maytenus undata	250	360	-0.94	0.36
Metalasia densa	150	100	1.00	0.50
Olea europea subsp. africana	156	144	0.19	0.85
Passerina corymbosa	622	1 133	-1.62	0.14
Pavetta natalensis	263	300	-0.27	0.79
Pterocelastrus tricuspidatus	511	383	1.20	0.24
Putterlickia pyracantha	500	300	2.19	0.12
Rapanea melanophloes	200	124	2.19	0.04
Scolopia mundii	244	356	-1.51	0.15
Scutia myrtina	233	217	0.24	0.82
Searsia rhemanniana	1 309	1 861	-1.42	0.16
Tarchonanthus camphoratus	557	500	0.23	0.83
Trimeria trinervis	118	509	-2.07	0.06
Zanthoxylum capense	439	500	-0.80	0.43

From the soil sample assessments, no indigenous seeds were found while *A. mearnsii* mean seed density in the litter and soil samples were 14 892 seeds/m^2 and 20 718 seeds/m^2, respectively, with a total of 35 610 seeds/m^2 and 356 100 000 seeds/ha (Figure 4.6). There was a significant difference in the density of seeds found in the leaf litter and those found in the soil (p=0.004), with the soil containing more seeds than the litter. A mean of 95% of the seeds found in the litter were viable while 97% of the seeds in the soil were viable. Only 5% of the seeds from the control germinated.

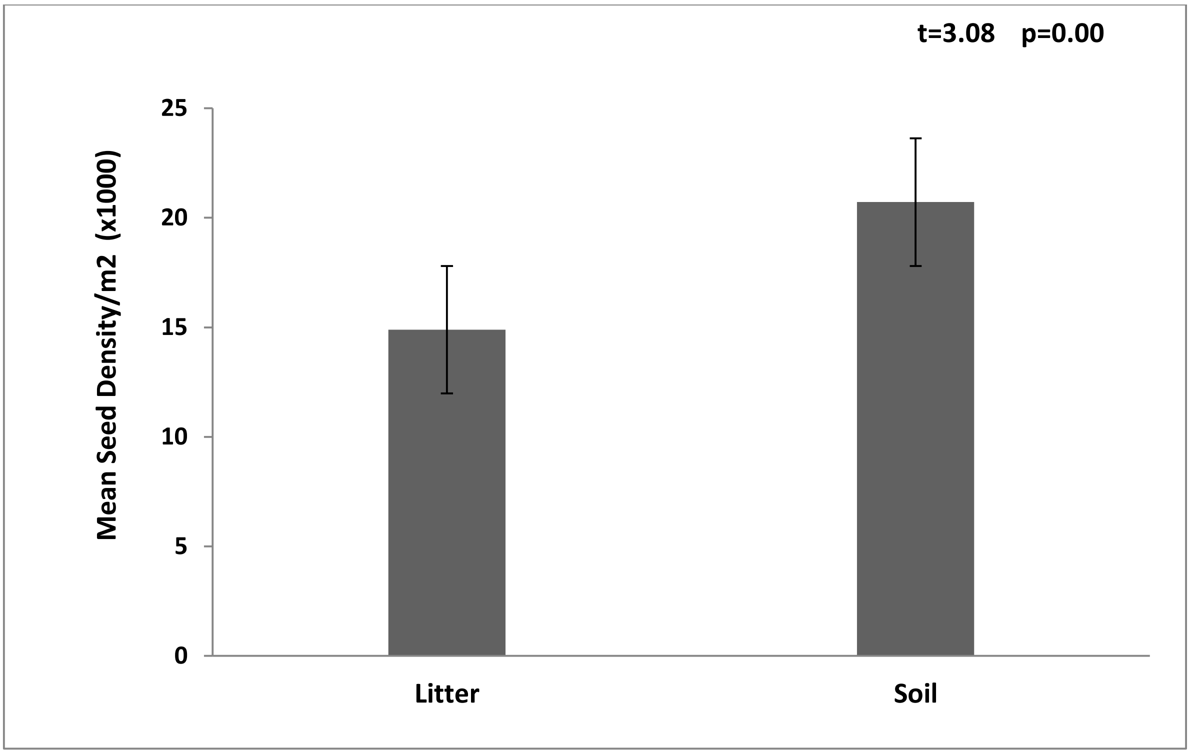

FIGURE 4.6: Acacia mearnsii seed density (mean, ± SE) in litter and soil.

4.4. DISCUSSION

In the presence of IAPs such as *A. mearnsii* it is typical for the indigenous T&S cover to decline as the invasion intensity increases (Gaertner *et al.*, 2009). Galatowitsch and Richardson (2005) found that invasion intensity affects the composition of riparian species with plots of high invasion intensity having lower species richness compared to low invasion intensity ones. Beater *et al*. (2008) found strong negative relationships between indigenous vegetation cover and invasion intensity where 58% and 70% of the variation in indigenous vegetation cover was explained by invasion intensity in Grassland and Savanna, respectively. Standish *et al*. (2001) also found a strong negative relationship between indigenous forest species richness and increasing IAP biomass and the decline in light at the forest floor, as did Jevon and Shackleton (2015). This was however not the case in this study as although the relationship between invasion intensity and indigenous T&S cover was significantly negative, invasion intensity explained only 6% of the variation observed. The high standard deviation of mean indigenous T&S cover suggests that although cover was generally low indigenous T&S cover varied greatly and did not decline uniformly with increasing invasion intensity.

The relationship could also be low because of the high variability in the invasion intensity, which according to Versfeld *et al*. (1998), falls in the dense IAP density class of 25-75% and was not a closed canopy stand (dense density class) of IAPs which is defined at a cover of >75% (Versfeld *et al*., 1998).

Ground cover (forbs and grasses) significantly declined with increasing invasion intensity as is typically observed in landscapes invaded by tree IAPs (Beater *et al*., 2008). Indigenous T&S density also declined with invasion intensity and increasing IAP tree density (Standish *et al*., 2001). The results also showed that the indigenous T&S to *A. mearnsii* tree density ratio was one to 22. This is concerning especially because the abundance of indigenous T&S significantly increases with increasing indigenous T&S density (Figure 4.5). It is therefore important that the clearing conducted is effective and reduces the invasion intensity and density of *A. mearnsii*.

4.4.1. Effectiveness of clearing

The significant declines in the mean *A. mearnsii* invasion intensity, basal area and density were the expected results after clearing. Based on the results WfW was successful in clearing 90% of the initial assessed *A. mearnsii* density and the clearing can be considered 95% effective with 5% of the cut *A. mearnsii* plants coppicing. Coppicing of *A. mearnsii* occurred as a result of one, or a combination, of the following reasons, firstly, cutting above ankle height, secondly, delayed herbicide application to the cut stump, thirdly, improper herbicide application that does not cover the edges of the cut stump fully, lastly, not applying herbicide to the cut stump at all (Witkowski and Garner, 2008). The results also showed that a mean of 1 860 *A. mearnsii* trees were still standing, some ring-barked and some not. Ring-barking can be defined as the removal of tissue containing the cork, cork cambium, phloem tissues and the cambium by creating a circumferential cut around the stem of a tree (Moore, 2013). It was observed that it was not only large *A. mearnsii* trees that were ring-barked but also smaller ones that could easily have been cut. It was also observed that all of the ring-barked trees were still alive as well as flowering. Moore (2013) states that high rates of fruiting and flowering have been shown to be one of the responses of trees to ring-barking resulting from the high amounts of accumulated carbohydrates in tree canopies that can no longer be transported to the roots. Priestley (2004) found that unless 100% of their girth was removed young trees, such as those of *Acacia melanoxylon,* survived ring-barking. The ring-barking of trees does not always translate to death as this can be highly dependent on both the species and the environmental conditions in which they grow. In forestry irrigation is used as one of the treatments to aid the recovery of trees after the bark has been damaged or removed, for vigorous species such as *A. mearnsii* occurring in riparian landscapes the availability of water might serve to limit the success of ring-barking (Moore, 2013). It is therefore important that the ring-barking of *A. mearnsii* trees in riparian landscapes is limited to only big trees and only when absolutely necessary.

While the results show success and effectiveness, it has however been found that WfW clearing operations tend to achieve this initial success and effectiveness where significant reductions in the IAP trees are achieved as well as the accompanying benefits of increased catchment yield, but that this success is not long lived (Beater *et al*., 2008; Le Maitre *et al*., 2000; Morris *et al*., 2008). In the case of a coppicing species such as *A. mearnsii,* the longevity of this achieved success is almost entirely dependent on monitoring and follow-up clearings.

Working for Water has been criticised for failure to conduct timely and regular follow-up clearings to deal with both the plants that have coppiced after the initial clearing as well as new plants from seedbanks (Beater *et al*., 2008; Holmes *et al*., 2008; Morris *et al*., 2008; Witkowski and Garner, 2008). According to Morris *et al*. (2008), cleared sites are often not monitored and as a result follow-up treatments are not conducted on time, if at all. This is particularly a problem when even the initial clearing was ineffective resulting in a lot of coppicing. The coppicing of a plant results in the plant becoming more of a shrub with multiple stems emerging from the cut stump (McConnachie, 2012). *Acacia mearnsii* plants are fast growing and this makes follow-up clearings more challenging as, when left to grow taller than 1.8 m, foliar herbicide application is ineffective and the sprayed plants do not die, this means that the IAP regrowth has to be cut which is costlier than if follow-up clearing had been conducted on time (Holmes *et al*., 2008).

Monitoring sites that have been cleared will determine and support the need for follow-up treatments and ensure that they are conducted on time. Monitoring will also inform managers as to whether cleared sites are recovering well on their own or whether active restoration is needed to assist the recovery (Levendal *et al*., 2008). Failure to monitor cleared areas has been found to result in the cleared areas regressing to being dominated by IAP trees (Morris *et al*., 2008). McConnachie (2012) also found that invasion intensity increased on 36.2% of the cleared sites in the Kouga catchment. This can only occur when after clearing sites are left to themselves and no follow-up clearing is conducted. Invasion intensities of cleared areas indeed have the potential to not only regress to their initial densities but to also surpass those densities as a result of post-clearing IAP seedling emergence, which according to Holmes and Cowling (1997), and as also observed in this study, can be high enough to form dense stands of IAPs.

This is a shortcoming that has long been realised and one that WfW has to start dealing with especially with the dramatic increase in IAP seedling densities that follow the clearing of IAP adults as well the potential for secondary invasions by other IAP species that might proliferate after the removal of the dominant IAP. To effectively do this WfW has to enforce strict post-clearing monitoring protocols specific for areas that have been cleared of adult IAPs otherwise the clearing of IAPs will remain cost-ineffective and counterproductive (Common Ground, 2003).

4.4.2. Impacts of clearing on biodiversity

The impacts of IAPs on indigenous plant biodiversity are well documented (Gaertner *et al*., 2009; Le Maitre *et al*., 2011; Levine *et al*., 2003). It is however also believed that it is no longer just IAPs that have negative impacts on plant biodiversity but that some methods of IAP management can also have negative impacts (Pereira *et al*., 2013). The observed reductions in variables pre and post-clearing can be attributed to a number of clearing operations (Pereira *et al*., 2013). It was observed while conducting post-clearing assessments that some indigenous T&S were, along with the *A. mearnsii* trees, also cut. While the overall reductions in density/ha of indigenous T&S from pre- to post-clearing were insignificant, the results showed that when assessed on a species level some of the differences were significant. The study found that the density/ha of 12 of the 26 indigenous T&S species was reduced but only one was reduced significantly. The overall objective of IAP clearing is to promote the recovery of indigenous vegetation. That a species was significantly reduced from pre- to post-clearing is of great concern as this defeats the purpose of IAP clearing. This could have occurred as a result of a number of reasons, firstly, mistaken identities where a chainsaw operator erroneously cuts the indigenous T&S because their stems looked similar to those of *A. mearnsii* stems. Secondly, the indigenous T&S were too compact to allow for easy access to *A. mearnsii* trees and a chainsaw operator had to then cut the indigenous T&S to be able to gain access to the *A. mearnsii* trees that were obstructed. Lastly, it could also be due to the simple lack of vigilance or the lack of awareness in terms of the impact of cutting indigenous T&S.

The reductions in indigenous T&S could also have resulted from the impact of falling IAPs (Blanchard and Holmes, 2008). A chainsaw operator can ensure that a tree is cut in such a way that it falls in a specific direction, it is not always possible to avoid the falling impacts on indigenous plants. While the indigenous species will coppice after being cut (and not foliar sprayed) or broken, this should still be considered as negative impacts because the damaged plants will have to allocate more resources into dealing with the damage instead of growth and reproduction. Another possible reason for some of the observed reductions could have resulted from human error in laying out the plot boundaries both pre- and post-clearing. When plot boundaries were laid pre-clearing, navigation was challenging because of the then high density of *A. mearnsii* trees, which was not the case when post-clearing assessments were conducted which possibly meant that what was considered straight pre-clearing might not have been so post-clearing. A slight shift in the plot boundaries post-clearing could therefore have resulted in the inclusion and/or exclusion of some indigenous T&S post-clearing. These declines in the density of indigenous T&S would also have resulted in the decline of cover and the basal area of the indigenous T&S, albeit not significantly. The reductions in grass cover can be attributed to seasonality, where the leaves die but the plants remain alive but dormant.

Acacia mearnsii trees stand at heights between five and 10 m when mature, and are efficient sunlight competitors resulting in shading impacts on forbs and other ground growth forms (Holmes and Cowling, 1997; McConnachie *et al*., 2012; Standish *et al*., 2001). The observed increases in mean forb cover, mean indigenous T&S species density/ha, indigenous and *A. mearnsii* seedling density can therefore be attributed to the sudden increase in the availability of resources. Resources, which would not have been readily available in the presence of adult *A. mearnsii* trees such as nutrients, water and perhaps most importantly sunlight, resulting from the clearing of the adult IAPs, would give forbs and seedlings an opportunity to thrive post-clearing (Beater *et al*., 2008). The observed increases in the density/ha of 14 species were attributed to the increase in their number of seedlings, with one species increasing significantly. Areas invaded by *A. mearnsii* have been shown to often lack indigenous propagules hence the increase in indigenous seedling density was surprising because all the collected soil samples contained no indigenous seeds (Beater *et al*., 2008; Ruwanza *et al.,* 2013). Holmes and Cowling (1997) found that some vertebrate dispersed thicket species were almost always present in *Acacia* stands and they presumed that these could have been introduced by frugivorous birds dwelling in the *Acacia* thickets. This could also serve as a plausible explanation for the observed increase in indigenous seedling density in the absence of seed propagules in the collected soil samples. It is believed that it was this increase in indigenous seedling density that increased the density of some indigenous T&S species as well as the slight increase in the Shannon-Wiener diversity index. The increase in indigenous seedling density in this study area indicates that there is some potential for recovery post-clearing. This recovery will, however, once again depend on the control of the *A. mearnsii* plant regeneration from both stored seedbanks as well as from coppicing, i.e. if regeneration is not timeously controlled then *A. mearnsii* seedlings and coppiced stumps will grow to outcompete and shade indigenous seedlings, further impeding recovery post-clearing (Holmes and Cowling, 1997; Morris *et al*., 2011).

By creating dense stands, *A. mearnsii* trees are able to displace indigenous species, while this does not necessarily mean reducing species richness, IAPs can cause declines in the abundance of indigenous species (Gaertner *et al*., 2009; Galatowitsch and Richardson, 2005). In this study species richness was found to be high but the abundances of the species were found to be very low, with the highest mean abundance recorded only at 36% from one species and the majority (63%) of the species encountered having abundances of 10% and below. While the low abundances may be due to the growing presence of *A. mearnsii* plants, it is also true that the Fynbos, although very diverse, is not known to host high abundances of tree and shrub species. It is therefore important that wherever there is potential for recovery post-clearing it should be harnessed and not be impeded by the lack of monitoring or the lack of timely and effective follow-up clearing. It therefore becomes imperative that, in combination to conducting timely and effective follow-up clearing, which they have been shown to mostly fail at achieving, WfW has to start moving towards finding ways to deal with the problem of stored seedbanks from which a massive number of *A. mearnsii* seedlings emerge post-clearing.

4.4.3. *Acacia mearnsii* seedbanks

Richardson and Kluge (2008) state that because WfW's main focus is on the chemical and mechanical removal of aboveground IAPs, there has been inadequate effort focussed towards reducing seedbanks as part of the overall control strategy. It is, however, clear that the removal of aboveground IAPs is as good as dealing with the symptoms instead of the causes and in many cases not successfully so. Working for Water has to indeed move towards finding ways of reducing and depleting stored seedbanks of *A. mearnsii* as an integral part of IAP management. *Acacia* species are known to produce enormous numbers of seeds which accumulate in the soil and litter, such that *Acacia cyclops* and *Acacia saligna* are estimated at 2 000 seeds/m^2 and 48 000 seeds/m^2, respectively (Holmes, 1989). This study found an *Acacia mearnsii* mean seed density of 356 100 000 seeds/ha, with the litter and soil containing mean seed densities of 14 892/m^2 and 20 718/m^2, respectively with a mean viability of 96%. *Acacia mearnsii* seeds are hard coated and water resistant and can, as a result, be transported long distances in water without being damaged and can be deposited in areas downstream where they proliferate. The seeds have been shown to have a dormancy that can persist for more than 50 years (Holmes, 1989). This study showed that in the absence of a dormancy breaking factor germination can be as low as 5%. This means that unless these seedbanks are significantly reduced or depleted the control of hard coated seed species such as *A. mearnsii* is highly improbable (Richardson and Kluge, 2008).

While some seedbank management interventions, such as solarisation, soil inversion, microorganisms and containment, have been shown to have some potential to reduce seedbanks, their application or implementation are, however, impossible over large areas, keeping in mind the extent of the invasion intensity of *A. mearnsii* and other acacias in South Africa (Egley, 1983; Kremer, 1993, Richardson and Kluge, 2008; Wood and Morris, 2007). Fire is the only method that has been shown to have the potential to significantly reduce seedbanks of hard coated seeds as well as be applicable over large areas (Holmes, 1989; Pieterse and Cairns, 1986; Richardson and Kluge, 2008). While currently the most effective method known for reducing seeds in leaf litter and upper seedbanks fire is not without its own shortcomings. For seeds in the leaf litter the fire has to be moderately hot, i.e. just hot enough to burn the leaf litter, while for seeds in the upper seedbank the fire has to be slow and hot to break the dormancy of hard coated seeds while simultaneously stimulating the germination of stored seeds (Fourie, 2012; Fourie and Wilman, undated). The aftermath of which is dense infestations of seedlings, which, according to Viljoen and Stoltsz (2008) can be controlled using low Garlon-4 concentrations of 0.25% - 0.75% or an even lower concentration of 0.125% in knapsack sprayers, to achieve >95% control. If not implemented properly at the right temperatures fire can have devastating impacts on both the soil as well as on indigenous species and seedbanks, especially in the presence of cut and stacked IAP material on the ground (Blanchard and Holmes, 2008, Fourie, 2012; Holmes and Cowling 1997).

Besides fire, Richardson and Kluge (2008) suggest that the next best thing is the reduction of seed production. In South Africa, two biocontrol agents have been released for *A. mearnsii*, a seed-feeding weevil (*Melanterius maculatus*) and a gall forming fly (*Dasineura rubiformis*) (Impson *et al*., 2008). These two biocontrol agents have been shown to significantly reduce reproductive output in places where the agents have established and spread well (Impson *et al*., 2011). While this means that significantly fewer seeds are produced, the problem of seeds that have already accumulated underground remains. This, however, presents many opportunities for research, including further exploring seedbank management interventions such as the role of microorganisms for *A. mearnsii*.

CHAPTER 5

CONCLUSIONS AND RECOMMENDATIONS

This project has examined a number of aspects relating to the effectiveness and efficiency of South Africa's WfW project, the largest programme of its kind in the world. Given the magnitude of the WfW Programme and its multiple social and ecological objectives, it is inevitable that at times and in some sites, operations may not be as efficient as they could be. However, the sheer size of the WfW operations also means that any structural or common inefficiencies at local project level will represent significant fruitless expenditure when scaled across all sites and projects. Consequently, it is important that WfW undertake or commission regular assessments of their activities to ensure that fruitless expenditure is minimised (McConnachie *et al*. 2013). It is within this framing that the project examined WFW activities at the Ann's Villa site right from the original mapping through to the extent of IAP mortality resulting from clearing operations.

The first key finding was that there were significant difference between the NBAL mapping done by WfW and that done by myself. There was a greater than 10% difference for all of NBALs mapped, and in all but two instances, the WfW estimates of IAP cover were greater than those recorded during this project. In one instance WfW created a single NBAL across two areas with markedly different IAP covers, which could only lead to difficulties in making accurate costings. McConnachie *et al*. (2013) similarly reported inaccurate mapping and monitoring as amongst the key concerns of WfW managers. The systematic over-estimations of *A. mearnsii* cover resulted in most of the contracts being significantly more expensive than necessary, resulting in fruitless expenditure. Under-estimations of *A. mearnsii* covers led to contract teams being unable to fulfill their contractual obligations and the subsequent halting of the clearing of a large portion of the study area they were contracted to clear, impacting on both the progress of WfW as well as this research project. It was, however, found that three-quarters of the contract money had already been paid to the contractor regardless of the little progress made.

Some of these findings echo those of McConnachie *et al*. (2012), who assessed the cost effectiveness of WfW operations in the Krom and Kouga catchments. They found that sites with low IAP covers tended to be more expensive than sites with high IAP covers. While they attributed this to their inability to account for the spread that would have occurred had there not been any treatment, my study has illustrated that this has more to do with the challenge of accurately estimating the covers of sparsely invaded NBALs. This challenge resulted in significant cover over-estimates that led to high fruitless expenditure. That *A. mearnsii* covers were significantly over-estimated highlights the need to conduct realistic cover estimations at the start, because this influences all the subsequent steps and their financing. The under-estimation of *A. mearnsii* cover resulted in unfulfilled contractual obligations. This meant that the progress of WfW, in terms of clearing, has been hindered, it also meant that more funds would have to be secured to complete the contract that was left unfulfilled.

The unfulfilled contract brought to attention the training of contractors and the simplistic nature of the contract signed between WfW implementing agents and contractors tasked with IAP clearing. Whilst contractors do receive substantial training from WfW, Coetzer and Louw (2012) questioned the validity of criteria that WfW use in selecting contractors, and that more rigourous criteria are likely to result in improved efficiency and effectiveness. In terms of the actual contract, it did not outline the expectations of WfW, nor consequences contractors could face should they fail to fulfill their clearing obligations as per the contract. This echoes problems WfW has had around contracts with private landowners to take over maintenance operations once WfW has done the initial clearing and two follow-ups (Urgenson *et al*., 2013). Here too, the consequences of landowners not abiding by the contract are unclear. This study not only bore witness to the divide of an implementing agent-contractor contract, but also suffered the consequences resulting from this divide. While the results clearly showed that failure to complete the contract was inevitable, the fact remains that the chances of the implementing agent, from the signed contract, recovering the financial losses experienced from the contractor are small. A similar situation has been observed with the contracts signed between WfW implementing agents and private landowners, where landowners sign contracts to continue the clearing of IAPs on their lands once the responsibility of clearing has been handed back to them. It was found in both the Krom and Kouga catchments that none of the landowners assisted with clearing actually honoured their contract agreements with WfW implementing agents (McConnachie *et al*., 2012). This means that WfW bears high financial losses from both unfulfilled contracts as well as wasted resources emanating from landowners who do not continue the maintenance of IAPs resulting in the state of IAPs reverting back to pre-clearing covers. One of the reasons often cited for landowners taken to task with regard to bridging contracts is that officials, from the DAFF, tasked with enforcing the agreements are rarely available to conduct such enforcements.

That three-quarters of the contract money was paid out to the contractor regardless of the team not having completed half the contract is of concern. The total cost of the contract was divided into four equal tranches but the contract itself was not divided so as to indicate how much clearing would suffice for a part payment. This raises the question of clarity regarding the basis upon which the three tranches were paid to the contractor. This indicates the lack of monitoring and adherence to the WfW guidelines. According to Levendal *et al*. (2008) when clearing has been concluded and found to comply with the WfW specifications, an inspection sheet should be signed off by the project manager, the landowner as well as the contractor. The project manager is then supposed to make a recommendation to the area manager that payment can be made to the contractor.

The second key finding was that the contract teams observed were not as efficient as they could be. The efficiencies of the three contract teams were low with all task groups, apart from COs from two teams, achieving efficiencies well below 50%. These low efficiencies were attributed to the make-up of the teams which constrained the continuity of work, resulting in time being lost to waiting in different scenarios. The COs were the most efficient of all the task groups. The stackers and the HAs constantly recorded the lowest efficiencies, illustrating the efficiency loopholes of the teams. The stackers made up the bulk of the teams and their low efficiencies resulted in the highest fruitless costs. There was a significant positive relationship between subgroup CO-stacker ratio and subgroup CO-stacker efficiency ratio.

The combined efficiencies of COs from the different teams, indicated that the higher the number of COs with chainsaws the higher the overall CO efficiency. The mean efficiencies of the COs illustrated the importance of COs functioning at optimal efficiencies regardless of the number of COs, as the team with only two COs and two chainsaws achieved the highest mean efficiency compared to the COs from the team that achieved the highest combined CO efficiency. The need to re-organise teams more efficiently and for COs to operate at optimal efficiencies so as to increase the efficiency of the stackers and HAs, was demonstrated by some stackers and HAs who, instead of waiting for COs were observed cutting smaller trees with loppers and bow saws as well as stacking, respectively. It was also found that even at the highest recorded efficiencies of COs as well as with the efforts of stackers and HAs to keep busy, instead of waiting, the overall efficiencies of stackers and HAs were very low. This suggests there was an efficiency gradient in the subgroups and teams in general, where efficiency decreased going down the task groups i.e. from the CO to stackers to the HAs. This further indicates that it might be unrealistic to expect stackers and HAs to achieve the same level of efficiencies as those of the COs, especially if they are to stick to their core tasks. It is for this reason that further research must be conducted to establish more realistic efficiency targets for the different task groups. The significant positive relationship between subgroup CO-stacker ratio and the subgroup CO-stacker efficiency ratio emphasised that the more stackers there were to one CO, the less efficient the stackers became. This further emphasised the need to increase the number of COs, with chainsaws, and reducing the number of stackers per CO in ratios that will optimise the efficiency of the stackers. Another way in which the efficiency of the stackers can be optimised is by adding BCOs to teams such that subgroups have both COs and BCOs cutting concurrently. While COs focus on cutting large trees BCOs can focus on cutting the smaller ones. This will make teams more adaptable as well as bridge the waiting gaps in different scenarios. It will also increase the number of people cutting per team which should increase the area of IAPs cleared daily and reduce the duration of clearing contracts, which would be of benefit to WfW as a whole.

The third key findings was that the WfW methods of clearing *A. mearnsii* at Ann's Villa were 95% effective and with a 90% success of removal. The clearing methods also had a largely insignificant impact on indigenous plant biodiversity. Mean *A. mearnsii* seedbank density was 356 100 000 seeds/ha. With an effectiveness of 95%, only 5% of all the cut *A. mearnsii* trees were found to have coppiced. The coppicing of these plants was likely to be a consequence of one or more causes, including being cut too high (above ankle height), herbicide application to the cut stumps was delayed (max 0.5 hr post felling), herbicide application was applied such that the edges of the cut stumps were not fully covered or herbicide was not applied to the cut stumps at all (Witkowski and Garner, 2008). This presents a challenge for teams that are tasked with conducting follow-up clearing as by the time follow-up clearing is conducted these plants would have grown into multi-stemmed shrubs on which herbicide foliar spraying is ineffective (Holmes *et al.*, 2008; McConnachie *et al.*, 2012). The presence of coppicing is challenging, in terms of WfW and landowners assessing how effective the clearing conducted was. This is because coppicing is not a phenomenon that can be observed immediately after clearing when final quality control inspections are conducted, but only a few months later. This means that WfW is unable to hold contractors accountable for poor quality clearing because by the time the coppicing of these plants manifests contractors would long have completed their contracts, been paid, and moved on, leaving WfW to bear the increased costs of follow-up clearing. In light of this, it is clear that there needs to be more than one quality control inspection, i.e. there is a need for quality inspection as soon as clearing has been concluded as well as a month or two post-clearing. Landowners can be tasked with conducting the second quality inspection post-clearing and report to WfW if they are not satisfied with the extent of copping. This can also form part of the contracts they sign with WfW and it should also be made clear that doing this diligently is in their best interest because at the end of the contracts further clearing will be their responsibility. To do this the contract signed between WfW and contractors must be amended such that it stipulates that, should the need arise post-clearing, WfW can and will re-call contractors to remove all coppicing plants. This will not only ensure that WfW does not bear the unnecessary increased cost of compounded follow-up clearing, from poor initial clearing, but it will also motivate contract teams to implement highly effective clearing so as to avoid re-calls.

The same can also be applied for the 10% of *A. mearnsii* plants that were not cut but left standing, some ring-barked and some not. It was evident from the standing *A. mearnsii* trees that there did not seem to be a benchmark as to what size trees should be ring-barked. This was problematic as Moore (2013) states that the ring-barking of trees does not always result in death and also because most trees experience high rates of flowering and fruiting in response to ring-barking. For vigorous species such as *A. mearnsii*, occurring in riparian landscapes, the availability of water might serve as a hindrance to the success of ring barking. It is therefore important that only large trees are ring-barked and only when absolutely necessary. The areas covered by clearing contracts can sometimes be vast meaning that it may not always be possible for WfW managers and landowners to walk the extent of the clearing conducted and hence some of these issues might not be observed. However it would, again, be in the best interests of landowners to try and assess the cleared areas more rigorously so that they can be able to report to WfW should there be coppicing issues or trees that should have been removed but were left standing.

The high success of *A. mearnsii* removal and effectiveness are the typical achievements of clearing operations accompanied by significant reductions in the density of IAP trees, increased indigenous forbs cover and increased catchment yields but this success is often short-lived (Beater *et al*., 2008; Morris *et al*., 2008). The longevity of this achieved success is almost entirely dependent on follow-up clearings as well as the methods employed. According to Morris *et al*. (2008) cleared sites are often not monitored and as a result follow-up treatments are not conducted on time, if at all. Failure to monitor cleared areas has been found to result in cleared areas regressing to being dominated by IAP trees (Morris *et al*., 2008). McConnachie (2012) also found that invasion intensity increased on 36.2% of the cleared sites in the Kouga catchment despite the fact that the sites had been cleared. This can only occur when after clearing, sites are left to themselves and no follow-up clearing is conducted. Invasion intensities of cleared areas indeed have the potential to not only regress back to their initial densities but to also surpass those densities as a result of post-clearing IAP seedling emergence, which according to Holmes and Cowling (1997), and as also observed in this study, can be high enough to form dense stands of IAPs.

Working for Water has been criticised for the lack of monitoring (van Wilgen and Wannenburg, 2016), resulting in failure to conduct timely and regular follow-up clearings to deal with both the plants that have coppiced from the initial clearing as well as new plants from seedbanks (Beater *et al*., 2008; Holmes *et al*., 2008; Morris *et al*., 2008; Witkowski and Garner, 2008). WfW project managers interviewed by Levendal *et al*. (2008) cited time and financial constraints as well as clearing sites being far apart to allow for regular monitoring. This is perhaps another responsibility that can and should be vested with landowners. It is clear that WfW managers cannot, on their own, monitor all cleared sites at all times so as to determine when a cleared site should receive follow-up clearing. Landowners could be tasked with the responsibility of monitoring IAP seedling emergence as well as the responsibility to notify WfW whenever seedlings are at a stage where follow-up clearing should be conducted soon. Landowners are assisted with the clearing of IAPs on their lands by WfW, it is therefore reasonable that landowners could assist. The monitoring of IAP seedling emergence or coppicing post-clearing can be conducted by landowners at limited financial costs because they are visiting and observing their lands on a constant basis. To be able to do this effectively landowners should be equipped with knowledge of the different stages of IAPs so that they know at what stage to notify WfW. That being said, the IAP problem is large-scale and country wide and WfW must take the lead in monitoring progress in order to assess progress at scale (Common Ground, 2003). It would also be beneficial for WfW to study, understand and implement recommendations made by different researchers in the country regarding monitoring and progress (Common Ground, 2003).

The impacts of initial clearing at Ann's Villa on indigenous plant biodiversity were overall insignificant with only one species significantly reduced. Evidence of some cutting of indigenous plants was observed. This was attributed to a number of possible reasons, including mistaken identity, indigenous plants preventing access to IAPs, lack of vigilance during cutting and lack of environmental awareness in terms of the impacts of cutting indigenous plants. Where indigenous plants are too dense to allow for access to IAPs, COs should request stackers to use loppers to remove branches to make way instead of cutting whole plants. This is important because the density and abundance of indigenous tree and shrubs was very low, although this might be a normal feature of the study area. This is also important because the recovery of invaded areas, post-clearing, tend to be better where indigenous vegetation has persisted (Levendal *et al*., 2008). Working for Water contract teams are comprised of relatively inexperienced contractors and largely untrained workers with low levels of formal education. The lack of environmental concern has been stated as one of the disadvantages emanating from WfW's twin objective of creating jobs for impoverished people (van Wilgen *et al*., 2012b). It is also important to note that while the impacts of clearing were largely insignificant, that this was only for initial clearing and does not represent the overall impacts of a full cycle of WfW clearing. It is essential that the cumulative impacts of repeated WfW operations are measured and monitored i.e. the cutting of indigenous T&S during initial clearing, the spraying of indigenous forbs and T&S during follow-up clearing.

The mean *A. mearnsii* seedbank density was 356 100 000 seeds/ha with a mean viability of 96%, emphasising the enormity of the *A. mearnsii* problem that lies underground. Research has shown that options for depleting such seedbanks are limited, with many shown to have potential but not practical enough to implement over large areas (Egley, 1983; Kremer, 1993; Richardson and Kluge, 2008; Wood and Morris, 2007). Fire is the only method that has been shown to have the potential to significantly reduce seedbanks of hard coated seeds as well as be applicable over large areas (Holmes, 1989; Pieterse and Cairns, 1986; Richardson and Kluge, 2008). Fire is effective because it is able to break dormancy and stimulate seeds to germinate resulting in dense infestations of IAP seedlings, which can then be sprayed with herbicide (Viljoen and Stoltz, 2008). However, if not implemented properly at the right temperatures fire can have devastating impacts on both the soil as well as on indigenous species and seedbanks, especially in the presence of cut and stacked IAP material on the ground (Blanchard and Holmes, 2008; Fourie, 2012; Holmes and Cowling 1997). Richardson and Kluge (2008) state that besides fire, to control seedbanks, the next best option is to reduce the production of seeds. The biocontrol agents that have been released in South Africa for the control of *A. mearnsii* have been instrumental in significantly reducing reproductive output (Impson *et al*., 2008; 2011). There is however a more imperative need for methods that will reduce seedbanks at minimal impacts to indigenous flora.

In conclusion, the study has shown, firstly, that at the Ann's Villa site the WfW NBAL mapping was inaccurate, secondly, that the contract teams could be more efficient, thirdly, that the clearing methods were highly effective and. lastly, that the initial clearing methods had largely insignificant impacts on indigenous plant biodiversity. It can also be concluded, firstly, that the inefficiencies, resulting in high fruitless expenditure, observed at the mapping and cover estimation level, are filtered down and compounded at the contract team level. Secondly it can be concluded that, although largely inefficient the contract teams implemented efficient clearing emphasising the need to focus on efficiency as a performance indicator to bridge the gap between inputs and outcomes. Overall, the study demonstrated that there are areas where the efficiency and effectiveness of WfW could be improved.

It is, firstly, recommended that the NBAL mapping is conducted in a more rigorous manner to improve efficiency as well as avoid instances of different class covers mapped into one NBAL and the associated challenges. Secondly, that more rigorous cover estimations are conducted on maps then verified in the field by skilled and experienced personnel.

Thirdly, to protect the interests of WfW, that the contracts signed between WfW and contractors be amended to stipulate, a) the expectations of WfW in employing contractors, b) what the consequences will be should contractors fail to fulfill their contractual obligations and c) that WfW will re-call contractors to remove all coppicing or standing IAPs, should the need arise post-clearing.

Fourthly, that the contracts signed between WfW and landowners are amended to bind landowners into playing more active roles when being assisted with clearing on their land. The contracts should bind landowners to conduct quality control inspections of cut IAPs as well as the monitoring of IAP seedling emergence post-clearing in order to notify WfW of progress.

Fifthly, that there, a) be a reorganisation of the make-up of the contract teams in such a way that the loss of time in the form of waiting is limited and the continuity of work is promoted; b) that the current high stacker to CO ratio be reversed, such that teams have more COs as well as an addition of BCOs, in the right proportions, than stackers, and c) the appointment of trained efficiency monitors, who will be responsible for educating contract teams about efficiency as well as be able to report back to WfW as to what challenges teams face and what challenges they observe that hinder efficiency in the field and how these challenges can be overcome. Finally, d) that simple monitoring systems be put in place to monitor the time teams arrive at field and when they leave.

Lastly, that contract teams are educated about the consequences of unnecessary and careless cutting of indigenous species, and such measures be included in quality control inspections.

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