Determining the efficiency of contractors in clearing invasive alien plant species: The case of the Mopani District, Limpopo province, South Africa

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Abstract

This study assesses the efficiency of contractors hired by the Natural Resource Management programme of the Department of Environmental Affairs (DEA:NRM) in clearing invasive alien plants. We analyse the efficiencies of 49 contractors in two catchments for three time periods, namely 2003 to 2006, 2007 to 2010 and 2011 to 2014. It was found that the size of the contract areas allocated for clearing decreased slightly from 2003 to 2014, while the unit costs (in real terms) have increased considerably. A reason for the increase in the costs can be attributed, among others, to the increase in the infestation densities of stands, because the more densely the infestation is, the more time is required to clear a hectare (Pd/ha) and hence the higher the costs of clearing (R/ha). This is an important observation, as it suggests that focusing on early restoration will further accelerate the clearing of invasive alien plants (IAPs) towards achieving the desired targets.

Key words: contractor; invasive alien plant species; hollow state; efficiency; densities

1. Introduction

The prevalence and spread of invasive alien plant species (IAPs) are often detrimental to the environment. Interventions to clear them, on the other hand, can contribute to reclaiming the areas formerly infested and improve related ecosystem processes, which are essential to support livelihoods. This study conducted an appraisal of the performance of private contractors hired by the state from 2003 to 2014 to clear IAPs to determine their efficiency levels. We do this by first examining some literature, followed by a discussion of the emergence of the state contractor model, and the concept of the hollow state as it relates to the institutional arrangement between the state and private contractors. Thereafter we conduct an in-depth analysis of the data.

1.1 IAPs and the emergence of various government contracting models to control the spread of IAPs in South Africa

The dominance of IAPs in a landscape threatens biodiversity, the production of ecosystem goods and services, human health and the economy (Drake *et al*. 1989; Mooney & Hobbs 2000). IAPs often reproduce more rapidly than indigenous plant species because of the absence of natural predators and other growth inhibitors (Elton 1958; Richardson *et al*. 2000; Sakai *et al*. 2001). As a result, IAPs have invaded an estimated 10 million uncondensed hectares in South Africa (Le Maitre *et al*. 2000, 2011). The control of IAPs has therefore become an important area of focus, despite the challenges that exist, because of their ability to propagate in different climates while overcoming both biotic and abiotic factors (Higgins *et al*. 1996; Richardson *et al*. 1996). In an effort to control IAPs, the South African government, through the Department of Environmental Affairs, launched the Natural Resource Management programme (DEA:NRM). The control methods used to clear IAPs are manual, mechanical, chemical and biological. Manual control refers to the use of hand tools, mechanical control refers to the use of mechanised tools, chemical control refers to the application of herbicides (e.g. on the cut stump), while biological control refers to the use of natural enemies of IAPs (e.g. insects and diseases) (Richardson *et al*. 1997; eThekwini Municipality n.d.). It is also possible to integrate either some or all of the control methods when managing the spread of IAPs. Van Wilgen *et al*. (1997) argue that, in the past, political and financial constraints have led to the disbandment of a programme controlling the spread of IAPs. However, a study conducted by Cowling (1992) convinced the then minister (Kader Asmal) of the Department of Water Affairs (as it was known at the time) to commission the Working for Water (WfW) programme, which became the DEA:NRM.[1] This programme was initiated in 1995 with the aim of controlling IAPs in the country. The programme's objective was to enhance water security for rural and urban areas (Binns *et al*. 2001; Dye & Versfeld 2007). At its inception, the programme benefited underprivileged communities through the promotion of entrepreneurship and small business development (Rogerson 2000; Magadlela & Mdzeke 2004; Coetzer & Louw 2012). In 2000, the WfW programme *proposed the use of contractors to manage and conduct work for its projects* (Coetzer & Louw 2012:793) and defined a contractor as an individual/small teams with his/her/their own business that conducts work for the DEA:NRM. The contractors received continuous support from the project managers (experienced government representatives) throughout all the stages of the project until they matured to where they independently developed quotations and complied with clearing requirements (so-called norms and standards), health and safety standards, equity and minimum conditions of employment for workers. In this study, the performance of these contractors was explored in the context of what has become known as the hollow state concept, as will be explained below.

1.2 The hollow state

Recently, governments across the world have opted to use contractors to perform basic activities (Guttman 2003). This phenomenon is referred to as a "hollow state", a metaphor used to describe countries' increased reliance upon third parties, either non-profit or for-profit organisations, to deliver taxpayer-funded social goods and services (Milward & Provan 2000). It should be noted that this term in no way makes a value judgement on either the state or the contractor, but merely describes the global phenomenon of out-sourcing. One concern regarding a hollow state is, however, the lack of knowledge on how to manage the contractual relationship between the government and the non-government sectors. Brown (2008) argues that governments can reduce contracting problems by examining the organisational characteristics of private firms (for-profit), non-profit organisations and other government entities in order to identify common governance structures and approaches to contracting relationships. The private firms strive to reduce costs and maximise revenue, whereas non-profit organisations may aim for monopoly relationships (seeking long-term contracts) with governments (Van Slyke 2003; Brown 2008). Milward and Provan (2000) argue that a bureaucratic control mechanism is the main distinguishing feature between the hollow state and direct government

[1] In 2011, the Natural Resource Management Programme, with the Working for Water (WfW) programme as a sub-programme, was moved from Department of Water Affairs (DWA) to the Department of Environmental Affairs (DEA) and became a key component of the Department of Environmental Affairs' Natural Resource Management Programme (DEA:NRM) (Department of Water Affairs and Forestry 1997; Coetzer & Louw 2012; Department of Environmental Affairs n.d.).

service delivery, with the hollow state being less predictable, but very flexible. Through the DEA:NRM programme, the spread of IAPs is controlled and poverty in rural areas is reduced through job creation (Buch & Dixon 2009). Outsourcing as an option contributes to the implementation of these initiatives. In the case of the DEA:NRM programme, the private contractors' performance is captured in the Working for Water Information Management System (WIMS) in terms of total area cleared (ha), person days per ha cleared (Pd/ha), Rand per ha cleared (R/ha), team size, IAPs' density, gender composition, training attended, attendance and absenteeism, and Rand per person day (R/pd). These performance indicators show how productive and cost-effective each contractor is in clearing IAPs. Hence, this study investigated whether the South African government, through DEA:NRM, awards contracts to contractors who clear IAPs efficiently. This is important for justifying the state's reliance on private organisations to render some of its services (i.e. the hollow state concept), as taxpayers' money is increasingly being spent. The study did not evaluate the environmental improvements associated with the clearing of invasive alien plant species, but rather the efficiency of contractors in clearing IAPs.

2. Description of the study area

The research study sites are located in the Tzaneen and Letaba municipalities, which fall under the Mopani District Municipality in Limpopo province (see Figure 1). The Mopani District Municipality is located near the Kruger National Park, a choice tourism destination of international significance (Mopani District Municipality n.d.). Moreover, there also are other environmental conservation areas in the region, such as the Wolkberg Wilderness area – a biodiversity hotspot, Debengeni waterfalls, Modjadji, Manombe and the Merensky Nature Reserve, to name a few. The aesthetic ecological state of the Mopani District Municipality makes it an attractive eco-tourism destination, and agricultural activities found in this district municipality include game farming and horticulture (citrus, vegetables and subtropical fruit). The Mopani District Municipality is located in the summer rainfall region of South Africa, with temperatures ranging between 28°C and 38°C in the summer and between 5°C and 11°C in the winter (Brodrick *et al*. 2014). The annual rainfall is between 400 mm and 900 mm. According to Statistics South Africa (2012), the estimated size of the human population is 1 090 000; 5% of that population resides on farms, 14% in urban areas and 81% in rural areas.

3. Materials and methods

Contract data was obtained from the DEA:NRM's Water Information Management System (WIMS), describing the clearing activities of 49 contractors who had cleared IAPs in catchments B81C and B81E from 2003 to 2014. It emerged that, over this period, a total of 675 observations (or contracts) were signed and concluded with the 49 contractors in the two designated catchments. Table 1 provides summary statistics of these contracts in terms of:

- Rand per hectare (R/ha) – defined as actual total expenditure per contract divided by the number of hectares cleared per contract, which is a measure for the cost of clearing each hectare. All the monetary values have been adjusted for inflation to reflect constant 2014 values.
- Rand per person-day (R/pd) – defined as actual total expenditure per contract divided by total person-days (the all-inclusive total working days) per contract, which is a measure for the cost per person-day.
- Person-days per hectare (Pd/ha) – the ratio of total person-days per contract divided by hectares cleared per contract; this is a measure of the number of person-days per hectare cleared.

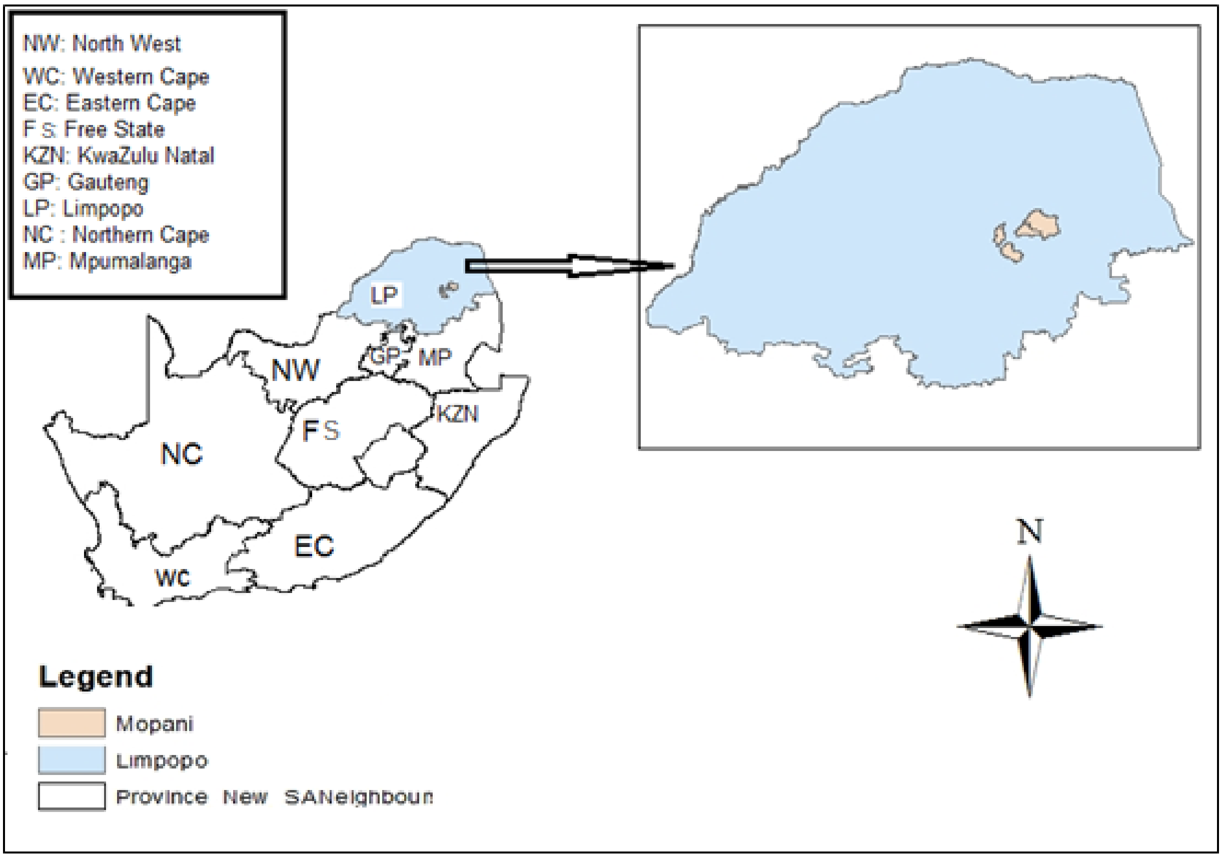

Figure 1: Research study site in the Mopani District Municipality, Greater Tzaneen, Limpopo province

Source: Department of Environmental Affairs (n.d.)

Table 1: Summary statistics of contractor dataset

Variables	Mean	Std. dev. Overall	Min	Max	Population and sample size
Rand per hectare cleared per contract (2014 prices)	1 645.71	1 090.48	12.50	7 871.11	N = 675 (contracts) N = 49 (contractors) $\underline{T}$ = 13.8
Person-day per hectare cleared per contract	8.86	7.02	0.04	64	
Rand per person-day per contract	217.07	132.96	18.39	2 008.36	
Actual expenditure per contract (constant prices)	33 300.40	21 766.3	427.40	148 878.50	
Size of clearing team per contract	10.44	1.98	1	24	
Total hectares cleared per contract	25.27	17.42	1.25	102.97	

Source: Own analysis based on WIMS database of the Department of Environmental Affairs

3.1 Performance of alien clearing contractors

If government is awarding contracts to contractors in such a way as to promote efficiency over time, we would expect to observe at least one of the following trends (or some combination thereof) from which overall efficiency gains are logically inferable:

1. Average contract expenditure (in constant prices) should decrease over time as a result of economies of scale;
2. Average area allocated for clearing under a contract should increase over time to allow for economies of scale;

3. Average person day per contract should decrease over time; and
4. Labour productivity (Pd/ha) should increase over time.

Upon generating time plots we noted that fewer contracts were observed in the latter half of the study period, but these had larger budgets (in Rand) (Figure 2) and smaller clearing targets (ha) (Figure 3), and required more labour to complete (pd/contract) (Figure 4). If all other things remain equal, smaller clearing targets should require less labour to clear. Due to the strong positive correlation (0.869) between average labour productivity and average unit costs per contractor (Figure 5), this should translate into smaller project expenditures. We observed the opposite, however, thus compelling us to investigate further by dropping the assumption that all things remain equal.

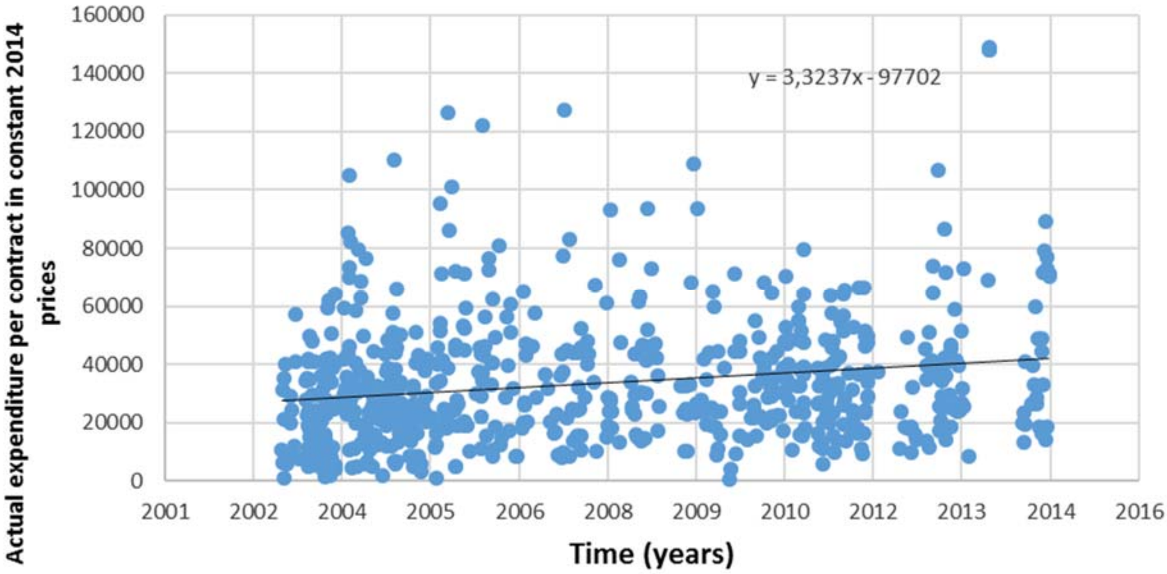

Figure 2: Real expenditure per contract and time for 675 contract observations for the period 2003 to 2014

Source: Own analysis based on WIMS database of the Department of Environmental Affairs

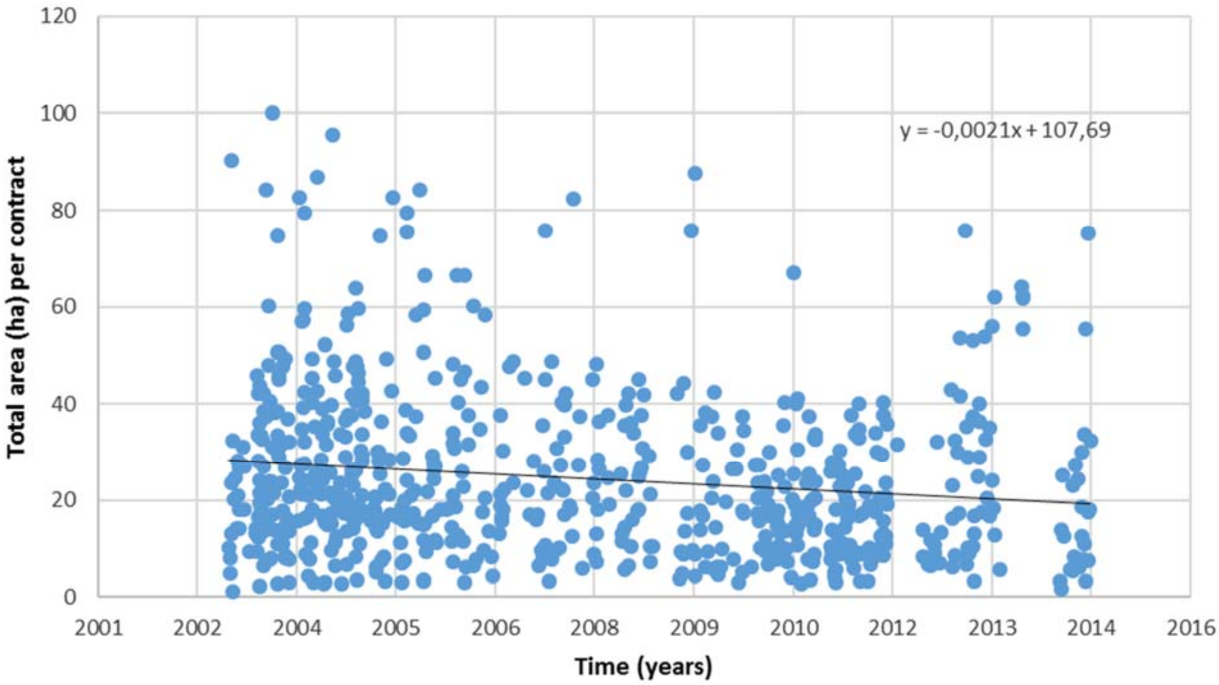

Figure 3: Total area (ha) cleared per contract and time for 675 contract observations for the period 2003 to 2014

Source: Own analysis based on WIMS database of the Department of Environmental Affairs

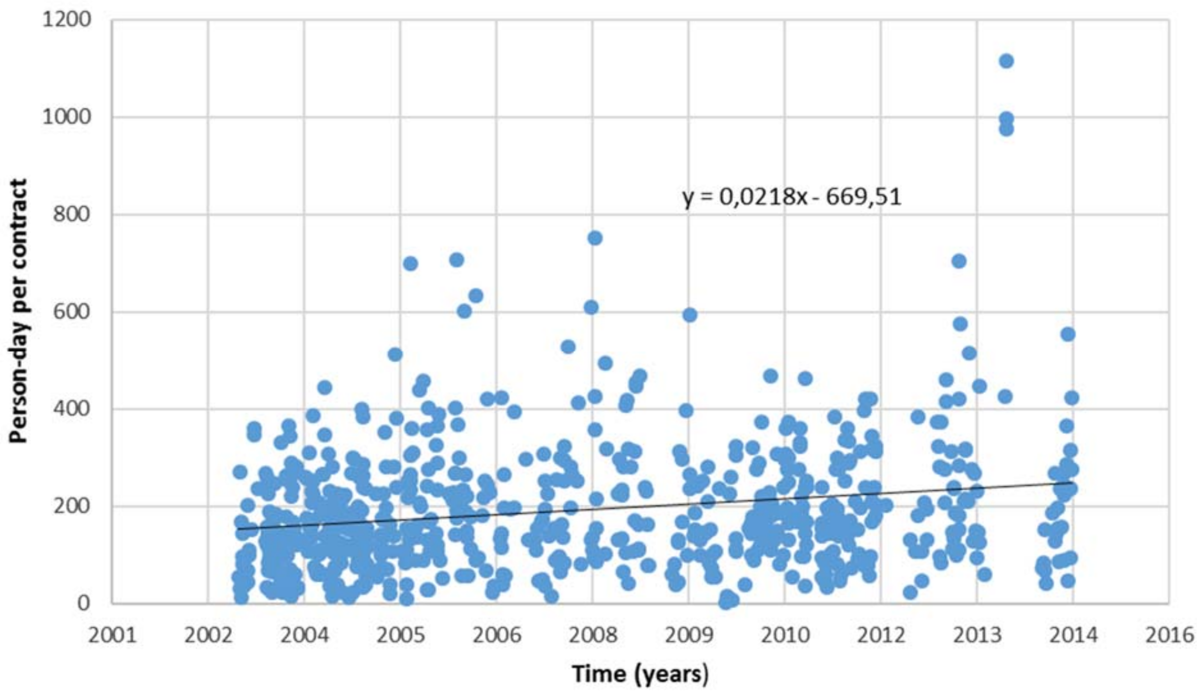

Figure 4: Total person-days per contract and time for 675 contract observations for the period 2003 to 2014

Source: Own analysis based on WIMS database of the Department of Environmental Affairs

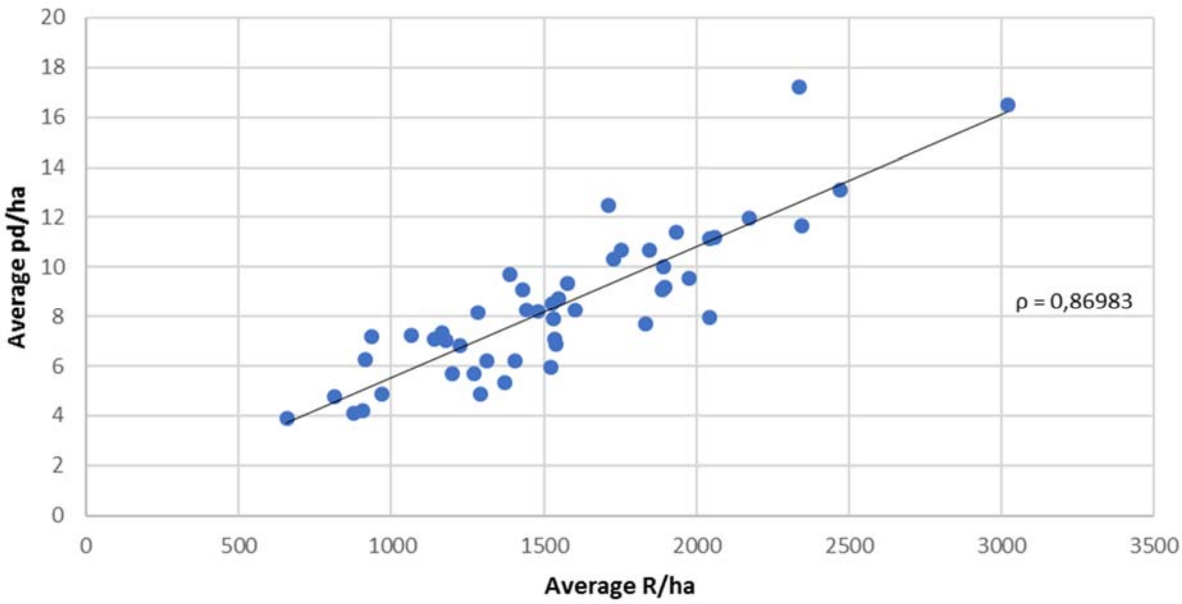

Figure 5: Plot of average Pd/ha and average R/ha for each of the 49 contractors (each data point represents a contractor)

Source: Own analysis based on WIMS database of the Department of Environmental Affairs

The results above prompted us to investigate the possibility of a gradual change in contractor behaviour over time. We thus proceeded by investigating the differences in efficiencies between contractors, particularly the change in labour productivity over time. Figure 6 plots the Pd/ha for the three contractors who reported the highest average labour productivity, as well as the three contractors who reported the lowest average labour productivity. We observed that:

1. the most efficient contractors cleared only during the first few years of the study (no contractor cleared over the entire study period);
2. labour productivity was lower in subsequent years;
3. the variance in contractors' labour productivity increased with time; and
4. the nature and extent of labour productivity changes varied between contractors. Anomalies – such as that the contractor who improved labour productivity the most also had among the lowest labour productivity (contractor 29 in Figure 6) – were also possible.

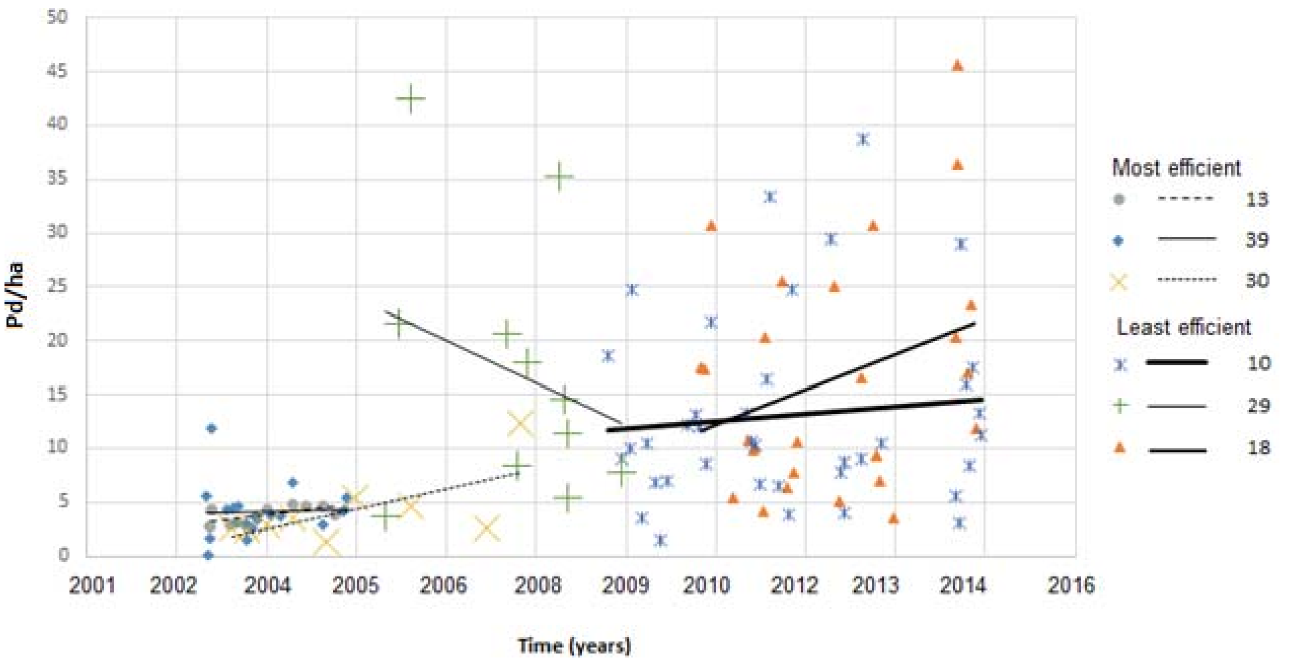

Figure 6: Plot of Pd/ha for the three contractors who had the lowest average Pd/ha and the three contractors who had the highest average Pd/ha
Source: Own analysis based on WIMS database of the Department of Environmental Affairs

As noted above, DEA:NRM allocated smaller plots of land for clearing in later years, which could have attribute to the diseconomies of scale. It is also possible that the contractors clearing in later years were generally less competent. It furthermore is true, however, that it is a DEA:NRM-stated operational protocol to clear areas with less invasion (lower densities) first, and thereafter progress to more dense stands. It therefore also is possible that the results we observed are as a result of changes to the biophysical characteristics of the clearing sites, and this could explain some, if not all, of the changes in contractor efficiencies. It is to this analysis that we now turn.

The archival records describing IAP clearing activities from 2003 to 2014 were statistically analysed and the contractors categorised according to the years in which they cleared IAPs. The early group operated from 2003 to 2006, the middle group from 2007 to 2010, and last group from 2011 to 2014. Furthermore, clearing operations involve two different processes, namely an initial clearing and then several follow-up clearing operations at the same site. We not only differentiate between contractors and time period, but also between catchments and whether the contract was issued for initial clearing or follow-up operations. Consequently, some of the cleared areas had a maximum of three follow-up clearings. Site-specific invasive alien plant species were identified, as well as their change in density over time. Where the density information was available, it was further analysed to determine how it influenced contractor performance.

3.2 Analysis of density data of invasive alien plant species

The WIMS dataset either reports only initial clearing and no follow-up clearing, or follow-up clearing only. This is due to fact that areas that were initially cleared have been re-invaded due to the lack of post-clearing land-use plans. With these peculiarities in mind, Table 2 indicates the state of infestation density of IAPs with reference to catchments B81C and B81E. A distinction is made between all IAPs and the most dominant species (*Lantana camara* and *Chromolaena odorata*) occurring throughout the three time periods under investigation. This indicates that the densities are decreasing where operations are active. The WIMS dataset of 675 contracts described in Table 1 did not specify the IAP density for each contract. It therefore is not possible to state that there is a definitive difference in infestation densities over time. Additional data on reported densities cleared per contract therefore was requested from DEA:NRM to inform the analysis. In consolidating the two datasets, only 219 density entries corresponded to the initial contract dataset. This enabled a comparison between the cost of clearing and the density of invasion for the 49 contractors in the study area.

Table 2: Change in densities of IAPs (% cover) over time with reference to catchments B81C and B81E

			Dominant specie density % total cover				Number of observations			
Catchment	**Species**	**Years of operation**	IC*	FU1**	FU2	FU3	IC	FU1	FU2	FU3
B81C	*Chromolaena odorata* is dominant specie	2003-2006	15	15.13	8	5	3	4	5	1
		2007-2010	11.66	11.88	7.23	7	9	8	13	8
		2011-2014	31.66	26.2	17.5	14.38	3	5	8	8
	Lantana camara is dominant specie	2003-2006	15.33	5.8	6.86	10	9	5	7	2
		2007-2010	12.27	8.86	10.4	10.33	11	11	5	6
		2011-2014	13.63	13.6	12.57	19.88	8	5	7	16
	All species	2003-2006	35.82	40.62	44.04	42.25	17	17	12	4
		2007-2010	62.39	48.58	41.04	37.57	21	21	19	17
		2011-2014	89.45	68.39	60.00	52.07	11	11	18	28
B81E	*Chromolaena odorata*	2003-2006	16	15	-	-	2	2	0	0
		2007-2010	33.13	10	16.8	10	8	4	5	2
		2011-2014	10	7.33	11.83	5	2	3	6	10
	Lantana camara	2003-2006	3	-	-	-	1	0	0	0
		2007-2010	-	16.25	10	9.5	0	3	2	2
		2011-2014	3	-	-	10	1	0	0	3
	All species	2003-2006	75.25	24.5	-	-	2	2	0	0
		2007-2010	60.88	40.34	38.46	44.38	8	8	7	4
		2011-2014	36.23	31.03	40.4	34.46	3	3	6	9

Source: Own analysis based on WIMS database of the Department of Environmental Affairs
* Initial control (IC): drastic reduction of existing population
** Follow-up control (FU): control of seedlings, root suckers and coppice growth

4. Results

The outcome of analysing the efficiency of the different contractors who cleared invasive alien plants during the period from 2003 to 2013 in catchments B81C and B81E is presented in this section, along with the impact of the density of the invasive alien plant species on contractor performance.

4.1 Contractor analysis

The area (ha) allocated to contractors for initial clearing was gradually decreased from 2003 to 2014 in both catchments (B81C and B81E) (Tables 3 and 4, and Figure 8). This implies that substantially more hectares were cleared in the early years than during the later period. In contrast to the area allocated, the initial cost of clearing (R/ha) increased over time (2003 to 2014) in both catchment B81C and catchment B81E. In addition, the productivity (Pd/ha) also declined over time (2003 to 2014). As an example, in 2003 it took a minimum of 1.3 person-days to clear a hectare, but in 2014 it took a minimum of 11.7 person-days. Likewise, the average unit cost for initial clearing in catchment B81C increased by 78% when comparing the clearing period 2003 to 2006 with that from 2011 to 2014 in real terms (R3 204/ha compared to R1 798/ha). The average Pd/ha for this catchment increased by 188% (26.8 Pd/ha compared with 9.3 Pd/ha). The average unit cost for follow-up clearing in catchment B81E increased by 123% over the same reporting periods (R1 830/ha compared with R820/ha), with the average Pd/ha increasing by 100% (9 Pd/ha compared with 4.5 Pd/ha). This can be seen in the comparison of the individual contractors in Figure 7, and a summary thereof in Figure 8.

Table 3: Contractor performance with reference to key indicators in catchment B81C and B81E

Years (study period)	Performance indicators	Catchment B81C			Catchment B81E		
		Initial	Follow-up	Average total	Initial	Follow-up	Average total
2003-2006	Average of pd/ha	7	9	8	8	4	6
	Average of R/ha (real)	1 798	1 292	1 424	1 323	820	9 32
	Sum of total area	1 588	4 371	5959	579	2 509	3 088
2007-2010	Average of pd/ha	20	9	11	9	9	9
	Average of R/ha (real)	3 331	1 694	1 921	1 788	1 772	1 777
	Sum of total area	127	2 194	2 321	464	1 130	1 594
2011-2014	Average of pd/ha	27	10	12	13	9	10
	Average of R/ha (real)	3 204	2 090	2 173	2 197	1 830	1 952
	Sum of total area	1 790	8 593	2 103	560	970	1 530

Source: Own analysis based on WIMS database of the Department of Environmental Affairs

Table 4: Alien invasive plant clearing and contractor efficiency over time

		Total area	R/ha			Person day/ha		
Catchment	Years	ha	Minimum	Average	Maximum	Minimum	Average	Maximum
Initial: B81C	2003-2006	1 588.3	196.3	1 797.5	5 264	1.3	9.3	42.6
	2007-2010	127.2	1 835.8	3 330.9	5 976	2.0	19.8	48.9
	2011-2014	74.3	1 856.7	3 203.9	6 054	11.7	26.8	42.3
FU: B81C	**2003-2006**	**4 371.1**	**12.5**	**1 291.6**	**6 403.5**	**0.1**	**7.2**	**64.0**
	2007-2010	**2 193.8**	**16.0**	**1 693.6**	**7 518.7**	**0.0**	**9.1**	**35.2**
	2011-2014	**2 028.2**	**542.2**	**2 089.9**	**7 871.1**	**2.6**	**10.4**	**45.6**
Initial: B81E	2003-2006	579.2	256.1	1 322.9	3 373.0	1.8	8.1	22.4
	2007-2010	464.0	734.1	1 788.3	3 482.4	1.8	9.1	28.0
	2011-2014	560.0	1 054.6	2 196.8	2 869.8	6.8	13.1	18.3
FU: B81E	**2003-2006**	**2 509.3**	**175.8**	**820.3**	**2 151.0**	**1.3**	**4.5**	**14.7**
	2007-2010	**1 130.5**	**253.1**	**1 772.0**	**6 336.3**	**1.3**	**9.0**	**37.0**
	2011-2014	**970.0**	**1 051.6**	**1 829.9**	**7 378.6**	**3.7**	**9.0**	**13.6**

Source: Own analysis based on WIMS database of the Department of Environmental Affairs

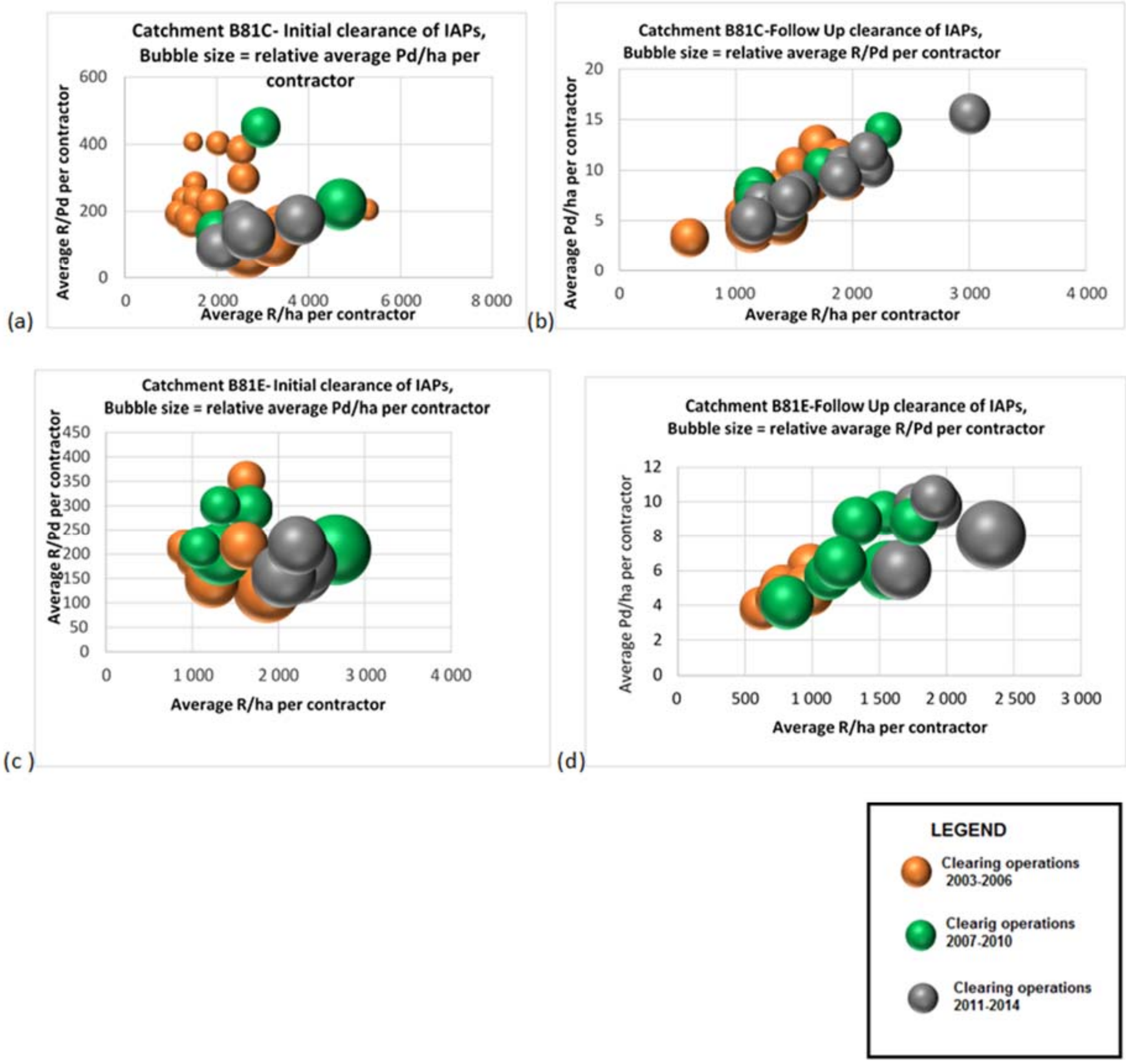

Figure 7: Distribution of individual contractor performance with reference to Pd/ha and R/ha in catchments B81C and B81E

Source: Own analysis based on WIMS database of the Department of Environmental Affairs

Figure 7a: In catchment B81C, the initial clearing operations in the early years (2003 to 2006) required, on average, a minimum number of working days per contractor per ha cleared (Pd/ha) at a low average cost per contractor per ha cleared (R/ha), but the labour cost, on average, was high per contractor. In the following years (2007 to 2010 and 2011 to 2014), the average Pd/ha per contractor increased, as well as the average R/ha and Pd/ha.

Figure 7b: In catchment B81C, the follow-up (FU) clearing cost per contractor per ha cleared (R/ha) increased on average over time, as well as the average Pd/ha, but labour cost was generally high per contractor. In the following years, the average Pd/ha increased, as well as the average R/ha and Pd/ha.

Figure 7c: In catchment B81E, the average working days per ha cleared (Pd/ha) increased gradually.

Figure 7d: In catchment B81E, the follow-up (FU) clearing cost per ha (R/ha) increased over time, as well as person days (Pd/ha) and R/pd.

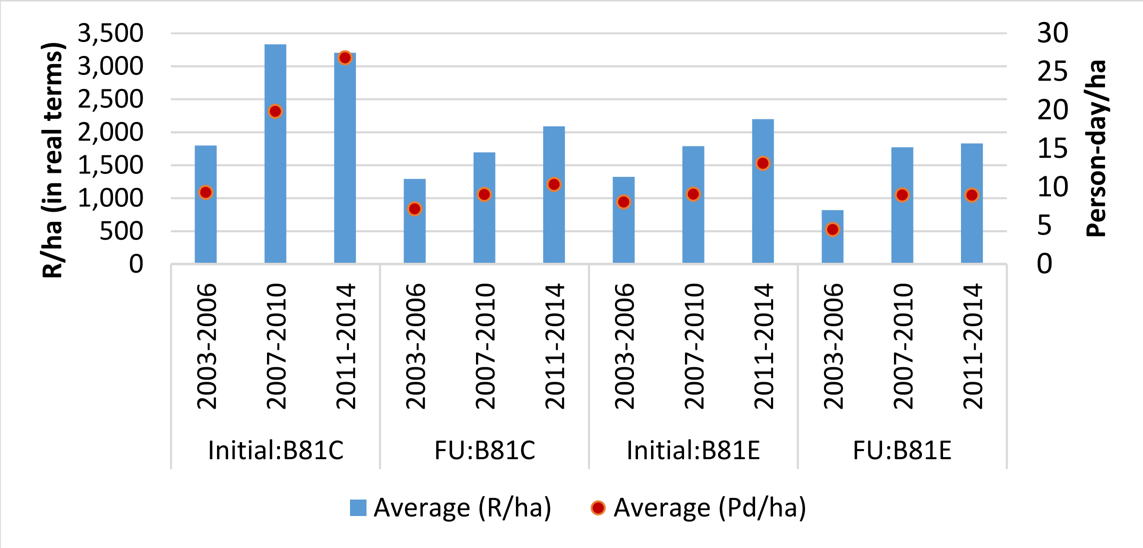

Figure 8: Efficiency of contractors in terms of R/ha and Pd/ha cleared, 2003 to 2014
Source: Own analysis based on WIMS database of the Department of Environmental Affairs

4.2 Impact of density of invasive alien plant species on Rand per hectare (R/ha)

Examining the ability of the DEA:NRM programme to remove invaders is a dynamic process, influenced by changes in species composition, density, land use and drought cycles over time, among others. The scale of clearing operations would change annually and one would expect the less densely invaded areas to be treated first, leaving the more densely invaded areas for clearing in later years. Figure 9 indicates that, with one exception, there is a positive correlation between R/ha cleared and density over the period 2003 to 2014. It is only with respect to catchment B81E between the latter two periods that the cost of clearing has remained about the same, although the density has declined marginally.

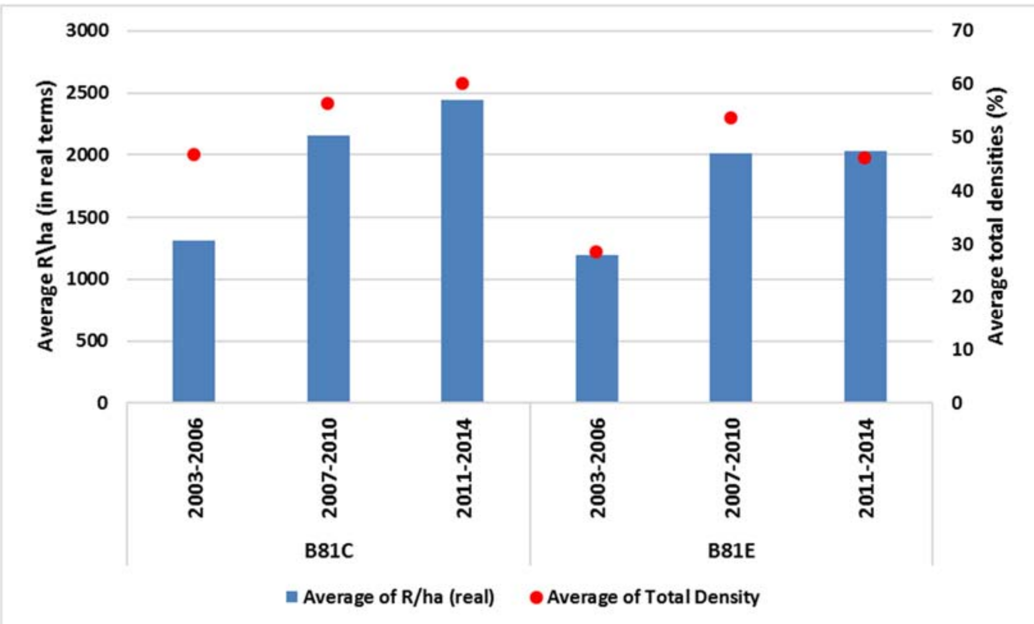

Figure 9: The relationship between R/ha cleared and density over time in catchments B81C and B81E
Source: Own analysis based on WIMS database of the Department of Environmental Affairs

5. Discussion and conclusion

A retrospective analysis of the empirical data describing the IAP clearing activities of 49 contractors for a 12-year period was conducted to investigate whether or not the so-called hollow state, a condition associated with increased outsourcing, led to efficiency gains in catchments B81C and B81E. With respect to catchments B81C and B81E, we considered IAP clearing trends from 2003 to 2014. This analysis indicated a decrease in areas allocated to contractors for clearing in both catchments, but the cost of clearing in real terms (R/ha) increased over time, as well as the person days per ha cleared (Pd/ha). In seeking a reason for this seeming deterioration in efficiencies, the data was compared with data describing the densities of the invasions. It was established that the land parcels cleared over time increased in invasion density. This indicated that i) areas with higher densities were cleared later, providing some substance to the stated DEA:NRM objective to clear land parcels with higher densities later, and ii) it is more expensive to clear higher density stands than low-density stands. This outcome suggests that it is not possible, given the data scrutinised, to make a conclusive statement with respect to the efficiencies of contractors under a hollow state scenario, but it does become evident that increasing degradation in the form of increasing densities of invasion costs more money. The earlier restoration is done, the better. Equally important is the need for proper and consistent data capturing and ongoing monitoring and evaluation of clearing activities to get rid of invasive alien plant species.

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