SIMULATION OF IMPACTS OF INVASIVE ALIEN PLANTS ON WATER RESOURCES WITHIN THE LUVUVHU CATCHMENT

(ZF0150/R7937)

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1. INTRODUCTION

One of the requirements for the CAMP project was an investigation into the impacts of invasive alien plants (IAPs) on water resources within the Luvuvhu catchment, and how these impacts could vary under differing policy approaches. The policy of relevance in this regard is that defined by the Working for Water Programme (WfW). This is an initiative of the South African Department of Water Affairs and Forestry that aims to reduce the spread of IAPs through clearing operations, thereby providing employment and training within the poorer sectors of society. As part of a wider socio-economic analysis (Hope, 2003, in press) this report describes a modelling process that was undertaken to determine the hydrological impacts of various clearing and non-clearing scenarios.

2. SCENARIOS FOR INVASIVE ALIEN PLANT INFESTATIONS

Following discussions between project members it was decided that the first scenario requiring investigation was the potential hydrological gains following complete eradication of all woody IAPs (trees) within the Luvuvhu catchment as a whole. The alternative for investigation was agreed to be a non-clearing (“no action”) policy with associated impacts on streamflow after 10, 15 and 25 years. For the non-clearing policies it was hypothesised that the spread of the IAPs would take place at a rate of 10% per annum (based on a spread model from le Maitre, 1998). In addition to the general increase in extent of the IAPs, increases in density of the invasives over time were also taken into account. This was important as the variables required by the model to simulate the hydrological impacts of the IAPs differentiated between sparse, moderate and dense populations. In this regard it was assumed that IAPs of sparse density would become moderately dense after 10 years, and that moderately dense IAPs would become dense infestations after 10 years. These aspects were incorporated into algorithms within a spreadsheet model that predicted increases in both extent and density of the IAPs over time given the initial starting values within a particular catchment. Using this model, areas under sparse infestation reach a peak before declining because of the assumptions that although they increase in extent they also become moderately dense after 10 years. Likewise, the area under moderate infestation is converted to dense infestation after 10 years, until the catchment becomes totally infested with dense IAPs (Figure 1).

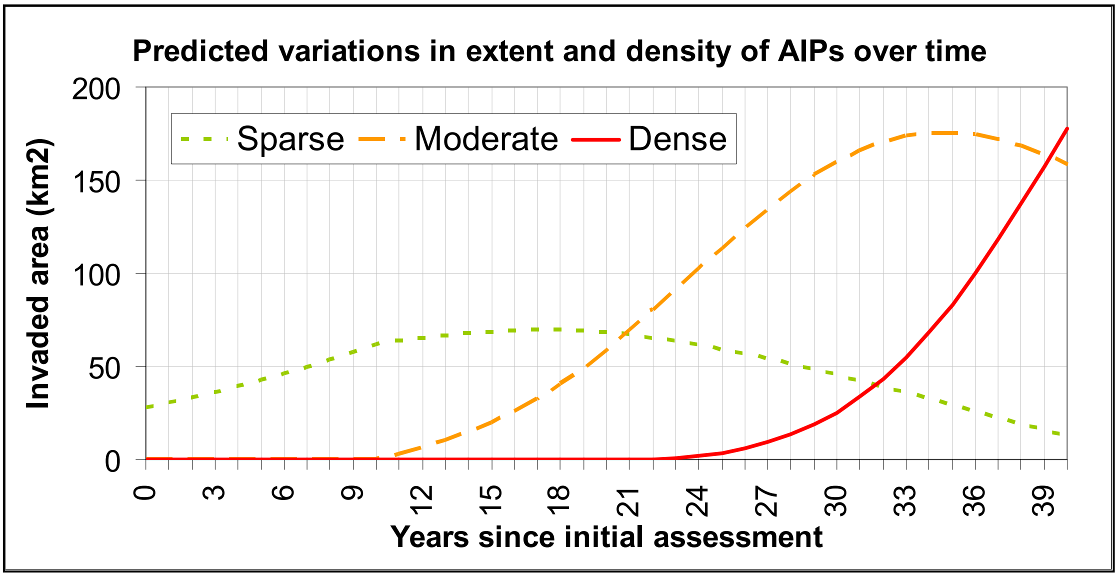

Figure 1. Example of variations in extent and density of IAPs over time.

The currently infested area within the Luvuvhu catchment was derived from GIS maps compiled from various sources. Some mapping exercises done under the auspices of the Working for Water Programme (WfW), which covered the upper part of the catchment, were used. A few additional GIS coverages were obtained, which were generated for the strategic planning of control operations in the portion of the catchment covered by the WFW management area (quaternary catchments A91A-G and A92A). These were supplemented with a data set obtained from the database on weeds being assembled by the staff of the Kruger National Park (quaternary catchments A91H-K and A92D). These maps illustrated invasive type (tall shrubs, wattle and eucalyptus) and density (rare, occasional, very scattered, scattered, medium, dense and closed), and also differentiated between riparian and dryland invasions. For the purposes of this exercise the rare, occasional, very scattered and scattered density classes were combined into a class named Sparse (<25% coverage), the medium and dense classes were combined to form a class named Moderate (25-75% coverage), and the closed class was renamed Dense (>75% coverage). Due to the limited extent of riparian invasions and the associated modelling complexities, no differentiation was made between dryland and riparian infestations.

It was decided to only model the woody IAPs (invasive wattle and eucalyptus) as these have the most significant impacts on water resources. This decision was prompted by the conclusions of Versfeld *et al*. (1998) who proposed that a wide range of tall shrub species were likely to use little more water than the indigenous species they replaced. The total area in the catchment invaded by woody tree species was calculated to be approximately 8843 ha, which is only 1.5% of the whole catchment. It is important to remember that substantial areas of the catchment apparently have not been mapped at all, nevertheless, it is probable that these areas are mostly infested with IAPs that fall into the shrub category, and are therefore unlikely to have significant hydrological impacts.

3. ACRU MODEL CONFIGURATION

The simulation of the various scenarios was performed using the ACRU agro-hydrological model (Schulze, 1995). The entire Luvuvhu basin was simulated after disaggregating the catchment into the various quaternary catchments (QCs) represented therein (A91A, A91B, A91C, A91D, A91E, A91F, A91G, A91H, A91J, A91K, A92A, A92B, A92C and A92D). Only quaternary catchments A91A, A91B, A91C, A91D and A91G had existing infestations of woody invasive alien plants, so these QCs were again subdivided into 4 subcatchments. These represented areas under 1) no infestation (i.e. existing National Land Ccover vegetation), 2) sparse AIP infestation, 3) moderate AIP infestation, and 4) dense AIP infestation. The allocation of these subcatchments to the various infestation states allowed their respective areas to be manipulated according to the results from the spread/density model described above. The only condition was that the overall quaternary catchment areas should remain the same. It was assumed that the densest infestations would be closest to the stream channels (riparian zones), consequently flow through the 4 subcatchments was routed in series from uninvaded (Current National Land Cover), through sparse and moderate infestations to the densely infested subcatchment. The final sub-catchment configuration and associated subcatchment numbers are represented in Figure 2.

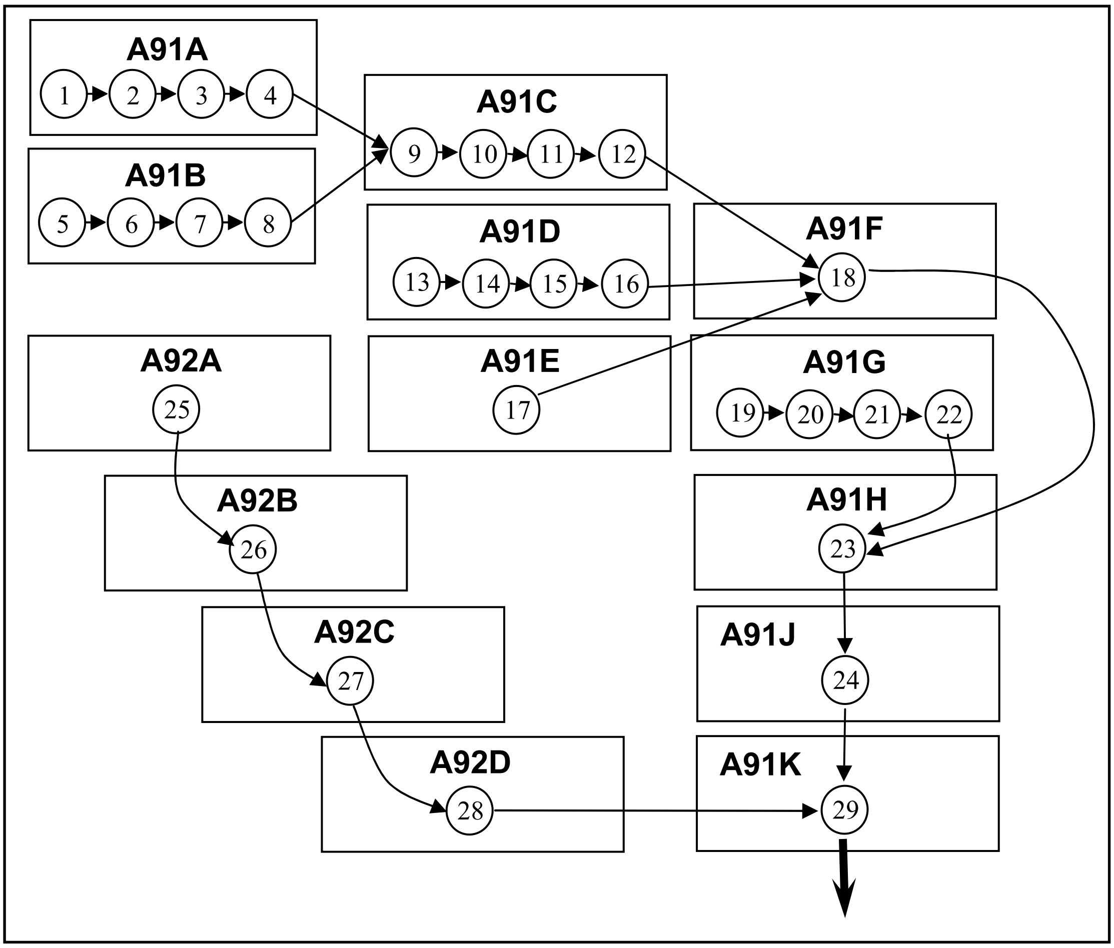

Figure 2. Schematic illustration of subcathment configuration and numbering for the purposes of the modelling exercise.

Table 1 lists the subcatchment areas applicable for each of the scenarios tested. The model required a minimum area of 0.01km² for each subcatchment, so this was the value assigned to the sparse, moderate or dense subcatchments where there was no infestation for that particular scenario.

Table 1. **A summary of subcatchment areas for the various scenarios that were modelled, as calculated from initial map data and using the spread/density model.**

QC	Subcatch. No.	Landcover	Areas per scenario (km²)				
			Present	Cleared	10yr	15yr	25yr
A91A	1	Current NLC	223.14	233.77	207.74	193.84	142.06
	2	Sparse IAPs	10.29	0.01	25.08	30.98	36.96
	3	Moderate IAPs	0.37	0.01	0.97	8.71	51.35
	4	Dense IAPs	0.01	0.01	0.01	0.27	3.43
A91B	5	Current NLC	213.04	276.47	153.75	112.58	0.01
	6	Sparse IAPs	0.16	0.01	0.40	0.53	0.81
	7	Moderate IAPs	63.31	0.01	122.34	119.75	71.28
	8	Dense IAPs	0.01	0.01	0.01	43.63	204.39
A91C	9	Current NLC	237.26	251.37	216.82	198.36	130.91
	10	Sparse IAPs	12.03	0.01	29.17	35.81	41.93
	11	Moderate IAPs	2.11	0.01	5.40	15.69	65.51
	12	Dense IAPs	0.01	0.01	0.01	1.54	13.04
A91D	13	Current NLC	133.26	133.27	133.20	133.15	132.92
	14	Sparse IAPs	0.03	0.01	0.07	0.10	0.15
	15	Moderate IAPs	0.01	0.01	0.02	0.04	0.19
	16	Dense IAPs	0.01	0.01	0.01	0.01	0.04
A91E	17	Current NLC	224.80	224.80	224.80	224.80	224.80
A91F	18	Current NLC	584.40	584.40	584.40	584.40	584.40
A91G	19	Current NLC	408.87	408.97	408.65	408.45	407.60
	20	Sparse IAPs	0.13	0.01	0.33	0.44	0.68
	21	Moderate IAPs	0.01	0.01	0.01	0.09	0.70
	22	Dense IAPs	0.01	0.01	0.01	0.01	0.02
A91H	23	Current NLC	453.90	453.90	453.90	453.90	453.90
A91J	24	Current NLC	575.30	575.30	575.30	575.30	575.30
A92A	25	Current NLC	331.40	331.40	331.40	331.40	331.40
A92B	26	Current NLC	569.80	569.80	569.80	569.80	569.80
A92C	27	Current NLC	458.50	458.50	458.50	458.50	458.50
A92D	28	Current NLC	811.90	811.90	811.90	811.90	811.90
A91K	29	Current NLC	676.00	676.00	676.00	676.00	676.00

4. ACRU MODEL INPUT DATA

Each scenario was simulated using 44 years of rainfall data (1950-1993) to extract the range of variation caused by wet and dry years. All other catchment information required by the model (climatic and physical) was available from previous modelling exercises that had investigated the hydrological impacts of various afforestation scenarios. With regard to the input parameter values to be used in the model to represent the various scenarios, there was first a need to descide on how to represent the current landcover in the QCs. As is evident from Figure 3, a number of different landcover types are represented in each QC.

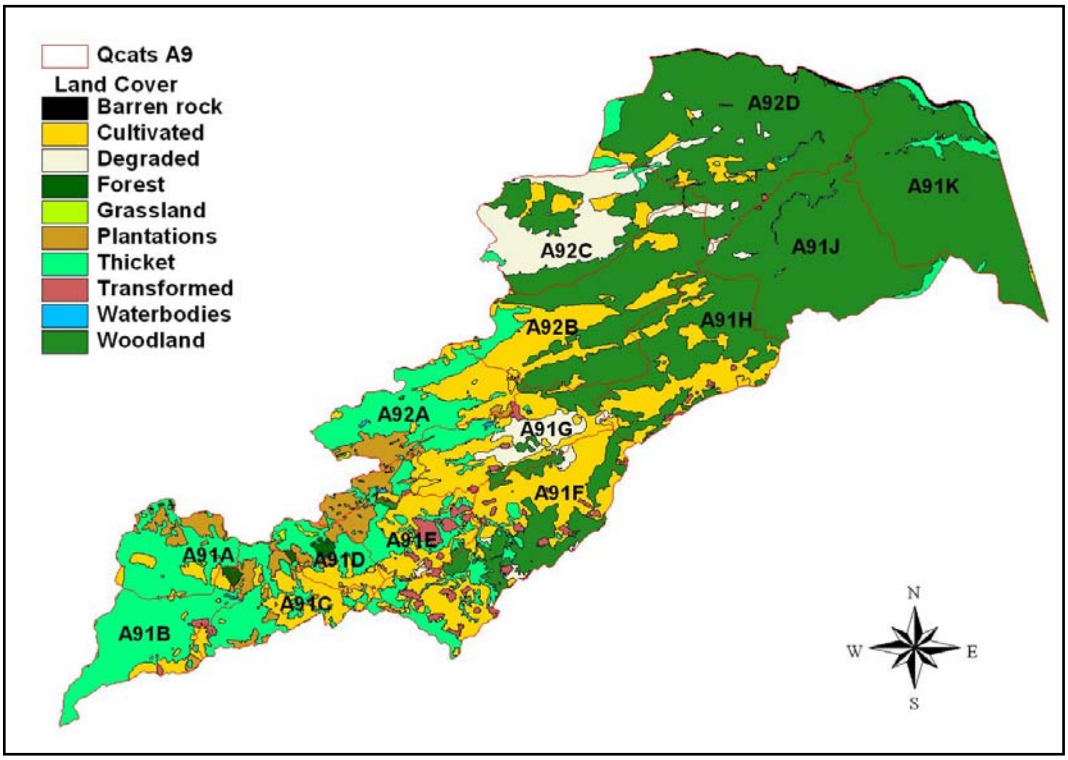

Figure 3. **Simplified landcover distribution per quaternary catchment within the entire Luvuvhu basin.**

A process of averaging was undertaken in order to derive a single set of current landcover parameter values per QC. This was done by first investigating what landcover types were represented in each QC, and what fraction of the QC each one took up. Relevant monthly ACRU parameter values describing landcover, namely crop coefficients (CAY), rainfall interception rates (VEGINT), percentage of roots in the A-horizon (ROOTA), and coefficents of initial abstraction (COIAM), are known for the various landcover types represented. It was therefore possible to area-weight these for each QC according to the fractions shown in Table 2. In this way a single representative set of landcover parameters was derived for each QC to describe the portions of the catchment uninvaded by alien plants.

Table 2. **Landcover types and area-weighting fractions, used to calculate representative parameter sets for uninvaded portions of each QC.**

Landcover Description	A91A	A91B	A91C	A91D	A91E	A91F	A91G	A91H	A91J	A92A	A92B	A92C	A92D	A91K
Cultivated: permanent – commercial dryland			20	30										
Cultivated: temporary – semi-comm./subsistence dryland		10	15		40	50	40	40		30	40		10	
Degraded: forest and woodland												60		
Forest and Woodland						30	40	60	100		60	40	90	90
Forest plantations	20		15	20						10				
Thicket & bushland (etc)	80	90	50	50	40	20	20			60				10
Urban / built-up land: residential					20									
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100

This process produced the following current land cover input parameter set (Table 3).

Table 3. ACRU input parameter values used to represent the current land cover (uninvaded) within each of the quaternary catchments in the Luvuvhu basin.

QC	PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
A91A	**CAY**	0.81	0.81	0.81	0.73	0.65	0.57	0.45	0.45	0.61	0.69	0.81	0.81
	VEGINT	2.32	2.32	2.32	2.08	1.92	1.76	1.76	1.76	1.52	2.00	2.16	2.32
	ROOTA	0.76	0.76	0.76	0.84	0.84	0.84	0.84	0.84	0.84	0.76	0.76	0.76
	COIAM	0.27	0.23	0.23	0.23	0.23	0.31	0.31	0.31	0.31	0.31	0.31	0.27
A91B	**CAY**	0.80	0.79	0.75	0.66	0.57	0.48	0.35	0.35	0.53	0.62	0.76	0.78
	VEGINT	1.90	1.90	1.86	1.58	1.40	1.22	1.22	1.22	0.95	1.44	1.67	1.88
	ROOTA	0.79	0.80	0.81	0.91	0.91	0.91	0.91	0.91	0.91	0.82	0.81	0.80
	COIAM	0.25	0.20	0.20	0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.25
A91C	**CAY**	0.87	0.82	0.66	0.56	0.51	0.46	0.39	0.39	0.49	0.54	0.68	0.81
	VEGINT	1.99	1.97	1.89	1.71	1.47	1.37	1.37	1.37	1.22	1.34	1.62	1.84
	ROOTA	0.75	0.76	0.81	0.89	0.89	0.89	0.89	0.89	0.89	0.84	0.81	0.77
	COIAM	0.27	0.22	0.22	0.22	0.22	0.31	0.31	0.31	0.31	0.31	0.31	0.27
A91D	**CAY**	0.90	0.86	0.71	0.58	0.53	0.48	0.41	0.41	0.51	0.56	0.72	0.86
	VEGINT	2.17	2.14	2.11	1.93	1.62	1.52	1.52	1.52	1.37	1.52	1.77	1.99
	ROOTA	0.74	0.75	0.79	0.87	0.87	0.87	0.87	0.87	0.87	0.82	0.80	0.76
	COIAM	0.27	0.23	0.23	0.23	0.23	0.31	0.31	0.31	0.31	0.31	0.31	0.27
A91E	**CAY**	0.80	0.76	0.60	0.54	0.48	0.42	0.36	0.36	0.46	0.52	0.62	0.72
	VEGINT	1.48	1.48	1.30	1.12	1.02	0.92	0.92	0.92	0.82	0.88	1.18	1.40
	ROOTA	0.78	0.79	0.84	0.94	0.96	0.96	0.96	0.96	0.94	0.90	0.85	0.80
	COIAM	0.25	0.20	0.20	0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.25
A91F	**CAY**	0.79	0.74	0.54	0.49	0.44	0.37	0.34	0.37	0.46	0.51	0.56	0.69
	VEGINT	1.50	1.50	1.30	1.13	1.03	0.99	0.99	0.99	0.93	0.86	1.18	1.40
	ROOTA	0.77	0.79	0.86	0.94	0.95	0.95	0.95	0.95	0.95	0.92	0.86	0.80
	COIAM	0.25	0.20	0.20	0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.25
A91G	**CAY**	0.78	0.74	0.58	0.52	0.46	0.38	0.35	0.39	0.49	0.55	0.60	0.70
	VEGINT	1.60	1.60	1.44	1.26	1.14	1.10	1.10	1.10	1.04	1.04	1.32	1.52
	ROOTA	0.78	0.79	0.84	0.92	0.94	0.94	0.94	0.94	0.94	0.90	0.85	0.80
	COIAM	0.25	0.20	0.20	0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.25
A91H	**CAY**	0.77	0.73	0.57	0.51	0.45	0.36	0.36	0.42	0.51	0.57	0.59	0.69
	VEGINT	1.60	1.60	1.44	1.28	1.16	1.16	1.16	1.16	1.16	1.08	1.34	1.52
	ROOTA	0.78	0.79	0.84	0.91	0.94	0.94	0.94	0.94	0.94	0.91	0.85	0.80
	COIAM	0.25	0.20	0.20	0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.25
A91J	**CAY**	0.75	0.75	0.75	0.65	0.55	0.40	0.40	0.50	0.65	0.75	0.75	0.75
	VEGINT	2.00	2.00	2.00	1.80	1.60	1.60	1.60	1.60	1.60	1.80	1.90	2.00
	ROOTA	0.80	0.80	0.80	0.85	0.90	0.90	0.90	0.90	0.90	0.85	0.80	0.80
	COIAM	0.25	0.20	0.20	0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.25
A92A	**CAY**	0.81	0.78	0.66	0.60	0.54	0.48	0.39	0.39	0.51	0.57	0.67	0.75
	VEGINT	1.86	1.86	1.74	1.53	1.41	1.29	1.29	1.29	1.11	1.32	1.59	1.80
	ROOTA	0.76	0.77	0.81	0.90	0.90	0.90	0.90	0.90	0.90	0.84	0.82	0.78
	COIAM	0.26	0.22	0.22	0.22	0.22	0.31	0.31	0.31	0.31	0.31	0.31	0.26
A92B	**CAY**	0.77	0.73	0.57	0.51	0.45	0.36	0.36	0.42	0.51	0.57	0.59	0.69
	VEGINT	1.60	1.60	1.44	1.28	1.16	1.16	1.16	1.16	1.16	1.08	1.34	1.52
	ROOTA	0.78	0.79	0.84	0.91	0.94	0.94	0.94	0.94	0.94	0.91	0.85	0.80

QC	PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
	COIAM	0.25	0.20	0.20	0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.25
A92C	**CAY**	0.69	0.69	0.69	0.56	0.52	0.37	0.37	0.44	0.59	0.69	0.69	0.69
	VEGINT	1.85	1.85	1.85	1.68	1.54	1.54	1.54	1.54	1.54	1.68	1.78	1.85
	ROOTA	0.83	0.83	0.83	0.88	0.93	0.93	0.93	0.93	0.93	0.88	0.83	0.83
	COIAM	0.25	0.20	0.20	0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.25
A92D	**CAY**	0.67	0.66	0.62	0.48	0.48	0.35	0.35	0.39	0.53	0.62	0.62	0.65
	VEGINT	1.68	1.68	1.64	1.49	1.40	1.40	1.40	1.40	1.40	1.44	1.58	1.66
	ROOTA	0.84	0.84	0.86	0.91	0.96	0.96	0.96	0.96	0.96	0.91	0.86	0.84
	COIAM	0.25	0.20	0.20	0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.25
A91K	**CAY**	0.67	0.67	0.67	0.52	0.51	0.37	0.35	0.40	0.55	0.65	0.67	0.67
	VEGINT	1.78	1.78	1.78	1.61	1.50	1.48	1.48	1.48	1.45	1.60	1.71	1.78
	ROOTA	0.85	0.85	0.85	0.90	0.95	0.95	0.95	0.95	0.95	0.89	0.85	0.85
	COIAM	0.25	0.20	0.20	0.20	0.20	0.30	0.30	0.30	0.30	0.30	0.30	0.25

Input parameter values required by the model to represent the three classes of woody invasive aliens were taken from the MSc. thesis of Ms. Louise Hayes (in preparation), and are represented in Table 4. These were derived from expert opinion following a workshop of hydrological modellers held at the School of Bioresources and Environmental Hydrology (BEEH) of the University of Natal, Pietermaritzburg, South Africa.

Table 4. ACRU input parameter values used to represent infestations by three density classes of woody invasive alien plants.

INFESTATION	PARAMETER	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
DENSE ALIEN TREES >75% (closed canopy / thicket)	**CAY**	0.80	0.80	0.80	0.78	0.68	0.66	0.66	0.66	0.68	0.79	0.79	0.80
	VEGINT	2.86	2.86	2.86	2.86	2.84	2.84	2.84	2.84	2.84	2.86	2.86	2.86
	ROOTA	0.76	0.76	0.76	0.77	0.77	0.78	0.78	0.78	0.77	0.76	0.76	0.76
	SMDDEP	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
	COIAM	0.34	0.34	0.34	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.34	0.34
MEDIUM ALIEN TREES 25-75% (intermediate cover)	**CAY**	0.78	0.78	0.78	0.70	0.60	0.48	0.48	0.48	0.60	0.75	0.75	0.78
	VEGINT	2.30	2.30	2.30	2.30	2.20	2.20	2.20	2.20	2.20	2.30	2.30	2.30
	ROOTA	0.80	0.80	0.80	0.83	0.83	0.88	0.88	0.88	0.83	0.80	0.80	0.80
	SMDDEP	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.33
	COIAM	0.28	0.28	0.30	0.33	0.33	0.33	0.33	0.33	0.33	0.33	0.30	0.28
SPARSE ALIEN TREES <25% (open scrub/thicket)	**CAY**	0.76	0.76	0.76	0.62	0.52	0.30	0.30	0.30	0.52	0.71	0.71	0.76
	VEGINT	1.74	1.74	1.74	1.74	1.56	1.56	1.56	1.56	1.56	1.74	1.74	1.74
	ROOTA	0.84	0.84	0.84	0.89	0.89	0.98	0.98	0.98	0.89	0.84	0.84	0.84
	SMDDEP	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.31
	COIAM	0.22	0.22	0.26	0.31	0.31	0.31	0.31	0.31	0.31	0.31	0.26	0.22

5. RESULTS

Outputs from the model for the given scenarios were aggregated into monthly totals for the period 1950-1993 and entered into a spreadsheet. Since the model was run in distributed mode it was possible to extract simulated streamflow from each of the QCs individually. Annual totals of streamflow were averaged to obtain the final results, which are shown in Table 5.

Table 5. Simulated streamflow (mm) per quaternary catchment for scenarios representing the current vegetation in the catchment, all IAPs cleared, 10-year, 15-year and 25-year unhindered infestation. The absolute (mm) and relative (%) increases (+) / decreases (-) in streamflow relative to the present-day situation are given for each scenario.

Average Annual Streamflow (mm) per Scenario - 1950-1993													
QC	Current	Cleared	Diff	%	10yr	Diff	%	15yr	Diff	%	25yr	Diff	%
A91A	112.4	112.4	0.0	0.0	112.5	0.1	0.1	112.3	-0.2	-0.2	110.2	-2.2	-2.0
A91B	98.9	102.8	3.8	3.9	95.4	-3.6	-3.6	92.0	-7.0	-7.1	81.8	-17.2	-17.4
A91C	134.8	136.1	1.4	1.0	133.5	-1.3	-0.9	132.0	-2.7	-2.0	126.8	-8.0	-5.9
A91D	397.7	397.7	0.0	0.0	397.7	0.0	0.0	397.7	0.0	0.0	397.7	0.0	0.0
A91E	286.1	286.1	0.0	0.0	286.1	0.0	0.0	286.1	0.0	0.0	286.1	0.0	0.0
A91F	160.3	160.9	0.6	0.4	159.7	-0.6	-0.3	159.0	-1.2	-0.8	156.7	-3.6	-2.2
A91G	195.8	195.8	0.0	0.0	195.8	0.0	0.0	195.8	0.0	0.0	195.8	0.0	0.0
A91H	165.8	166.2	0.4	0.2	165.4	-0.4	-0.2	165.0	-0.8	-0.5	163.4	-2.4	-1.4
A91J	148.4	148.8	0.3	0.2	148.1	-0.3	-0.2	147.8	-0.7	-0.4	146.5	-1.9	-1.3
A92A	326.6	326.6	0.0	0.0	326.6	0.0	0.0	326.6	0.0	0.0	326.6	0.0	0.0
A92B	249.9	249.9	0.0	0.0	249.9	0.0	0.0	249.9	0.0	0.0	249.9	0.0	0.0
A92C	184.7	184.7	0.0	0.0	184.7	0.0	0.0	184.7	0.0	0.0	184.7	0.0	0.0
A92D	124.1	124.1	0.0	0.0	124.1	0.0	0.0	124.1	0.0	0.0	124.1	0.0	0.0
A91K	129.6	129.7	0.2	0.1	129.4	-0.2	-0.1	129.2	-0.3	-0.3	128.6	-1.0	-0.8

From these results it appears that increases in streamflow associated with clearing woody invasive alien plants are unlikely to be significant for the Luvuvhu basin as a whole. The Quaternary Catchment at the outlet (A91K) showed only a 0.2mm (0.1%) increase. Nevertheless, useful increases in streamflow are probable under a clearing scenario for individual QCs that are currently infested. The greatest absolute and relative increase in streamflow was predicted for the most extensively invaded QC A91B, which showed a 3.8mm (3.9%) increase. With regard to the non-clearing scenarios, reductions in streamflow were exponential as the non-clearing period was prolonged. Decreases were again most noticeable in A91B, which showed a 17.2mm (17.4%) decrease in streamflow after a 25yr no-clearing policy, however streamflow at the outlet QC (A91K) was only reduced by 1mm (0.8%).

The surprisingly insignificant impacts on streamflow at the outlet of the Luvuvhu catchment as a whole may be attributed to the fact that localised impacts in individual QCs are diffused by un-invaded catchments before the basin outlet is reached. Evidence of this is seen if one traces impacts from a heavily infested QC (A91B) through a lightly infested QC (A91C), to the un-infested QCs of A91F, A91H and A91J, and the outlet A91K. Under a clearing scenario, increases in streamflow for these QCs converge from 3.8mm, to 1.4mm, to 0.6mm, to 0.4mm, to 0.3mm, to 0.2mm respectively. Similarly, following 25 years of no clearing decreases in streamflow for these QCs converge from -17.2mm, to -8.0mm, to -3.6mm, to -2.4mm, to -1.9mm, to -1.0mm respectively.

Possibly of greater significance is the time of year when these impacts are likely to be felt. Considering that the evergreen nature of the woody IAPs would contrast most noticeably with the senescent natural vegetation (sourveld grassland) in the critical dry winter months, it is this period that would be most affected (positively or negatively) by the application of the respective scenarios. For this reason a more thorough assessment of the impacts of IAPs on the low flow period would be a useful study.

6. REFERENCES

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