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Effect of timber enumeration and cost accounting errors on forestry profitability and decision making

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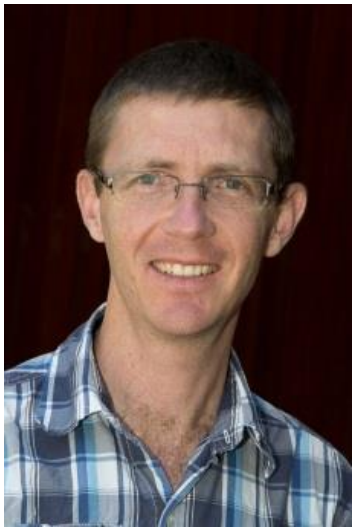


Introduction

- South Africa a growing focus on the establishment of new small scale enterprises in forestry
- Owners do not have formal forest management and operation training or access to inventory and costing systems
- Basic lack of skills in forest inventory, enumeration and cost accounting might prevent from assessing profitability

Introduction (2)

- Even worst - wrong assumptions about profitability due to errors in inventory and cost accounting
- Question of data accuracy
- What will be the effect of errors made in inventory and cost accounting on the decisions made by forest owners?
- Profitability = f(volume x price – costs)

Methodology

- Thought experiment
- Explores effect of enumeration errors and poor cost accounting on profitability of a single 10 ha stand of 15 year old *Pinus patula* pulpwood

Methodology (2)

Create simulated stand
Sample stand

↓

Full compartment volume
∑(individual tree volumes)

↓

Sampling: DBH-HT regression
Constant DBH and SPHA

↓

Sampling: Plot estimates DBH and SPHA
Mean HT

↓

Sampling: Variation in area

↓

Cash flow table with variable volume
Impact of enumeration on IRR

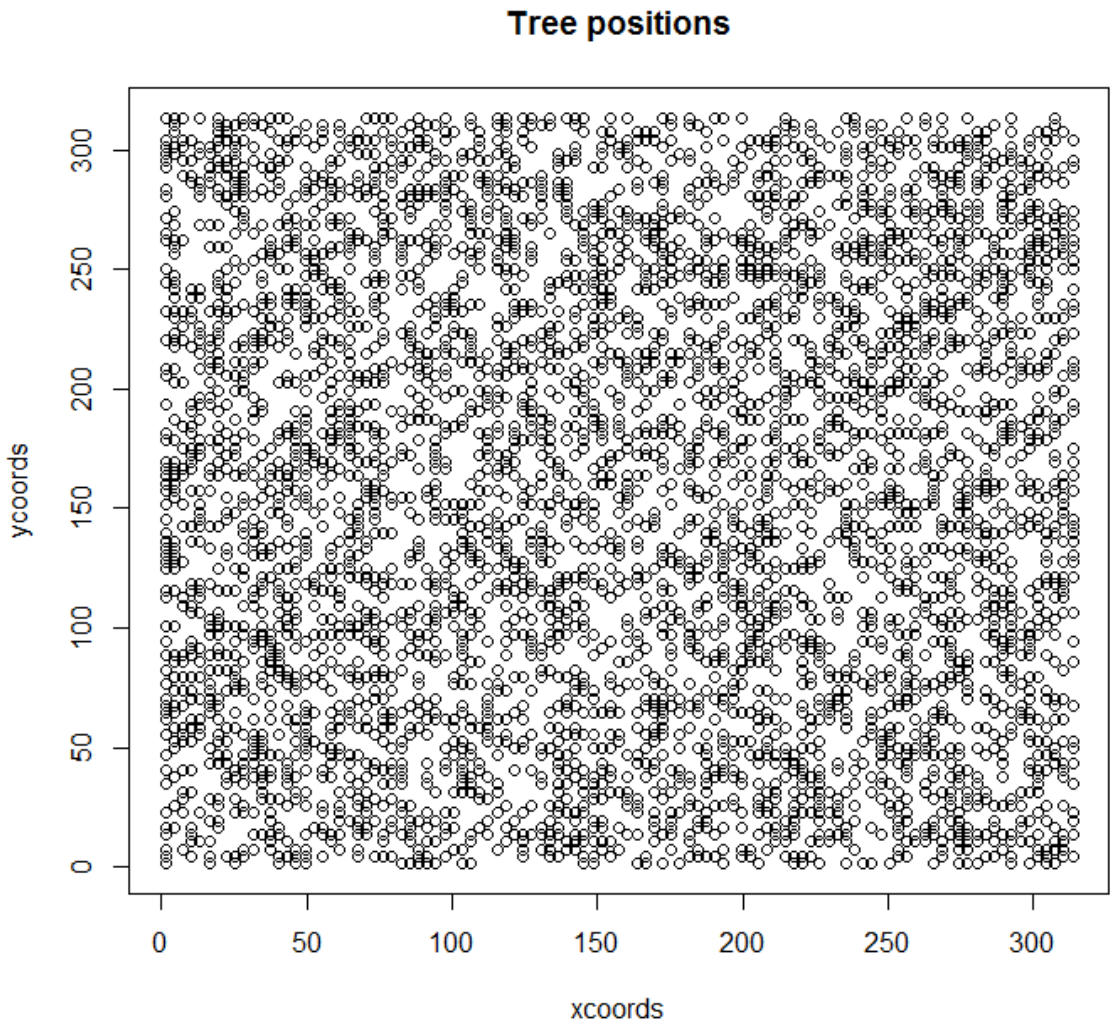
↓

Cash flow table with fixed volume
Inpact of cost accounting

Simulate stand

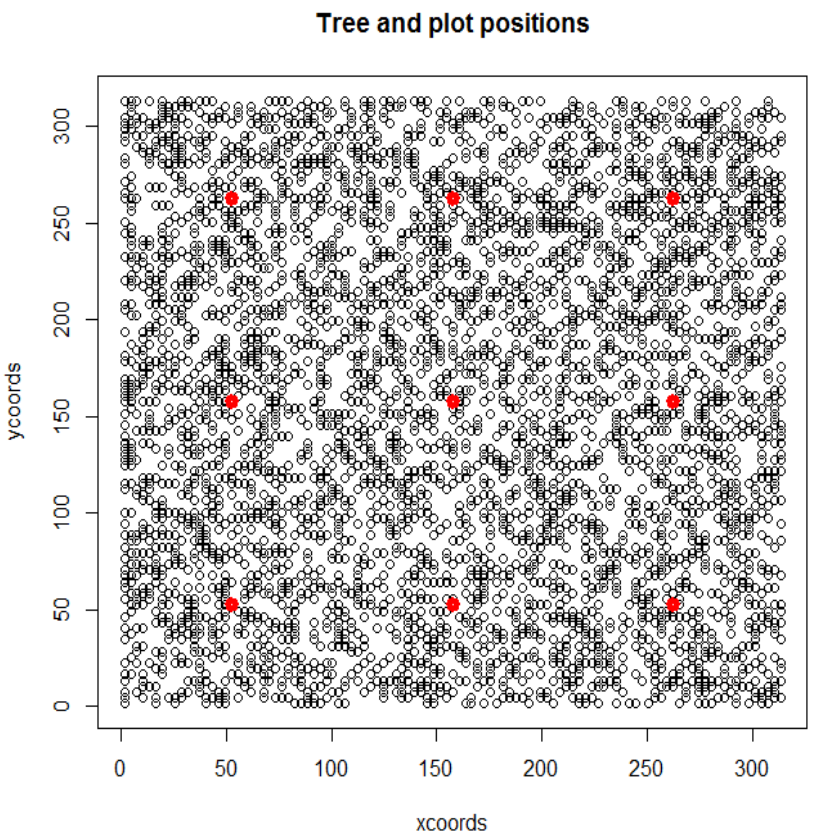
- 1111 SPHA - matrix of positions
- 38% survival rate to “kill” some positions - done randomly
  - SI – 20
  - Age – 15
  - SPHA – 418.9
- No trend in spatial variability as would be the case in a natural stand
- Results completely random and the error levels may be much more conservative than might be in a natural stand

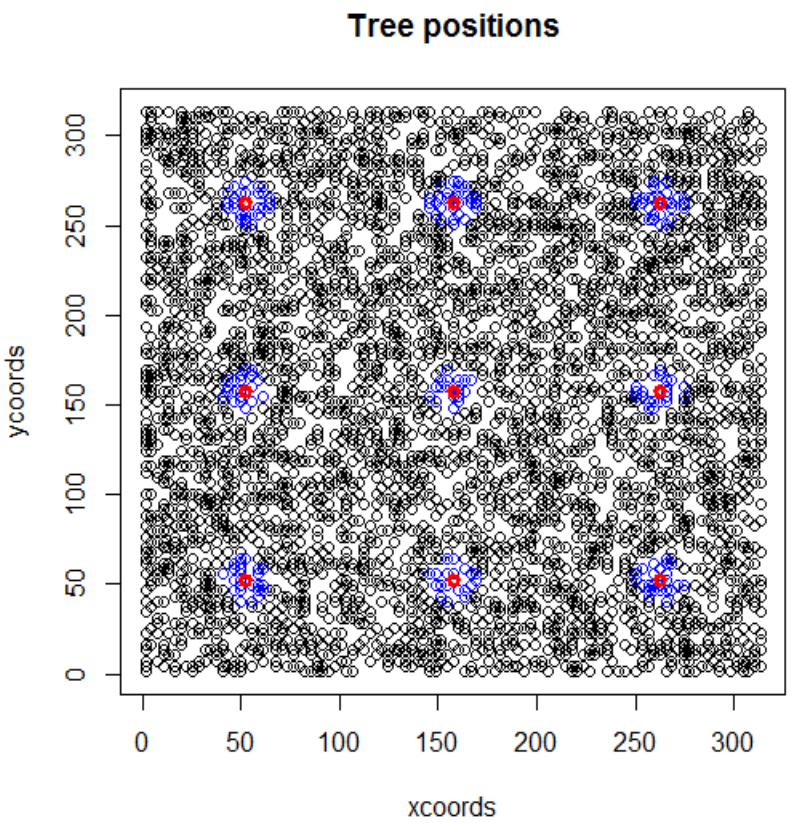
Simulated stand (2)



Sample stand

- 3 x 3 grid





Sample stand (3)

- DBH and stems from 9 plots
- Sample 1, 2 and 3
  - Randomly select 30 DBH/HT pairs from sample plots (differ per sample)

Full compartment volume

- Individual volumes calculated by means of:
  - Derived Max and Burkhart taper volume function
  - Schumacher and Hall function
    - lnV = b0 + b1*ln(DBH + f) + b2*lnHT
    - For *P. patula*
    - Also *P. elliottii, P. taeda, P. radiata* and *P. pinaster*
- <u>Schumacher & Hall *P. patula* - benchmark volume</u>
  - Δ for other functions

	Coefficients			
Species	b_o	b_1	f	b_2
P. patula	-13.4694	2.4396	8	1.3254
P. elliottii	-10.6771	1.9306	0	1.1567
P. taeda	-11.2265	2.0373	0	1.1815
P. pinaster	-10.9285	2.0696	2	0.9963

Mean HT from DBH-HT regression

- DBH_q and SPHA from full stand
- Mean HT for DBH_q with simple linear regression
  - $\text{Ln } H = b_0 + b_1 DBH_q^{-1}$
- Schumacher and Hall volume with DBH_q, mean HT and SPHA
- Different DBH-HT regression pairs to estimate mean HT

Mean HT from DBH-HT regression (2)

Model	Area (ha)	SPHA	DBH (cm)	HT (m)	Sample size	Remark
HT All Pat	10	418.9	27.26	16.588	4189	Used all tree data in DBH/ HT regression
HT Sys DBH138	10	418.9	27.26	16.687	30	Sorted all trees on DBH and selected every 138th trees for BDH/ HT regression
HT Sys HT 138	10	418.9	27.26	16.590	30	Sorted all trees on HT and selected every 138th trees for BDH/ HT regression
HT Sample 1	10	418.9	27.26	16.792	30	Randomly select 30 DBH/ HT pairs from plot sample
HT Sample 2	10	418.9	27.26	16.084	30	Randomly select 30 DBH/HT pairs from plot sample
HT Sample 3	10	418.9	27.26	15.719	30	Randomly select 30 DBH/ Ht pairs from plot sample
HT 2STDV HT	10	418.9	27.26	16.593	3990	Sorted all trees on HT, estimated mean HT and STD - exclude all trees outside 2 STD from mean in DBH/ HT regression
HT Median	10	418.9	27.26	16.979	32	Use all tree data and selected the median HT value for every DBH cm class for DBH/ HT regression
HT 3-tree	10	418.9	27.26	16.999	3	Use all tree data and selected the smallest and largest DBH trees as well as the tree closest to average from these two. Use avg HT for three trees

Plot estimates DBH and SPHA

- Mean HT from regression analysis
- DBH_q and SPHA from sample plot data

Plot estimates DBH and SPHA (2)

Model	Area (ha)	SPHA	DBH (cm)	HT (m)	Remark
HT All Pat Plots	10	451.1	27.27	16.588	Mean HT from All Pat regression with SPHA and DBHq from sample plots
HT All Pat Plots 10% slope	10	458.1	27.27	16.588	Mean HT from All Pat regression with SPHA and DBHq from sample plots, adjust for 10% slope
HT All Pat Plots 20% slope	10	480.1	27.27	16.588	Mean HT from All Pat regression with SPHA and DBHq from sample plots, adjust for 20% slope
HT Sample 1 Plots	10	451.1	27.27	16.793	DBHq, SPHA and mean HT from randomly selected 30 DBH/ HT pairs in sample plots
HT Sample 2 Plots	10	451.1	27.27	16.089	DBHq, SPHA and mean HT from randomly selected 30 DBH/ HT pairs in sample plots
HT Sample 3 Plots	10	451.1	27.27	15.720	DBHq, SPHA and mean HT from randomly selected 30 DBH/ HT pairs in sample plots

Variation in area

- Schumacher and Hall *P. patula* benchmark volume
  - Compartment size 9.5 ha
  - Compartment size 10.5 ha
  - Adjust per ha volume for comparison

Cash flow analysis

Age	Activity	Direct Costs	GAC	Total Cost	Gross Revenue	Net Cash Flow	Present Value
		R/ha					
0	Land	R 13 444					
0	Establishment	R 5 501		R 5 501		-R 18 945	-R 18 945.09
1	Tending	R 574	R 2 108	R 2 682		-R 2 682	-R 2 553.94
2	Tending	R 574	R 2 108	R 2 682		-R 2 682	-R 2 432.32
3	Tending	R 574	R 2 108	R 2 682		-R 2 682	-R 2 316.50
4			R 2 108	R 2 108		-R 2 108	-R 1 734.29
5			R 2 108	R 2 108		-R 2 108	-R 1 651.71
6			R 2 108	R 2 108		-R 2 108	-R 1 573.06
7			R 2 108	R 2 108		-R 2 108	-R 1 498.15
8			R 2 108	R 2 108		-R 2 108	-R 1 426.81
9			R 2 108	R 2 108		-R 2 108	-R 1 358.86
10			R 2 108	R 2 108		-R 2 108	-R 1 294.16
11			R 2 108	R 2 108		-R 2 108	-R 1 232.53
12			R 2 108	R 2 108		-R 2 108	-R 1 173.84
13			R 2 108	R 2 108		-R 2 108	-R 1 117.94
14			R 2 108	R 2 108		-R 2 108	-R 1 064.71
15	Clearfelling		R 2 108	R 2 108	R 78 212	R 89 548	R 43 074.27
	Land				R 13 444	**NPV**	R 1 700.38
						IRR	5.4%

US$1 = R14

Vol x (Mill price – H&T)

Results

Create simulated stand
Sample stand

Full compartment volume
∑(individual tree volumes)

Sampling: DBH-HT regression
Constant DBH and SPHA

Sampling: Plot estimates DBH and SPHA
Mean HT

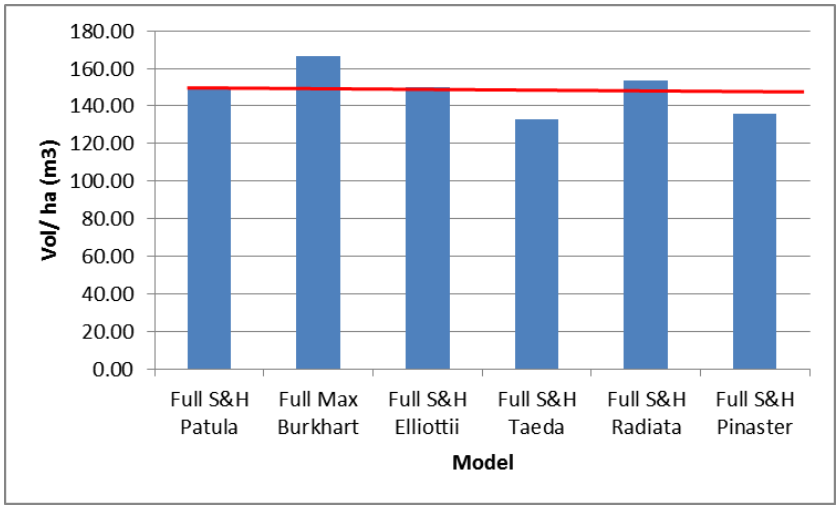
Sampling: Variation in area

Cash flow table with variable volume
Impact of enumeration on IRR

Cash flow table with fixed volume
Inpact of cost accounting

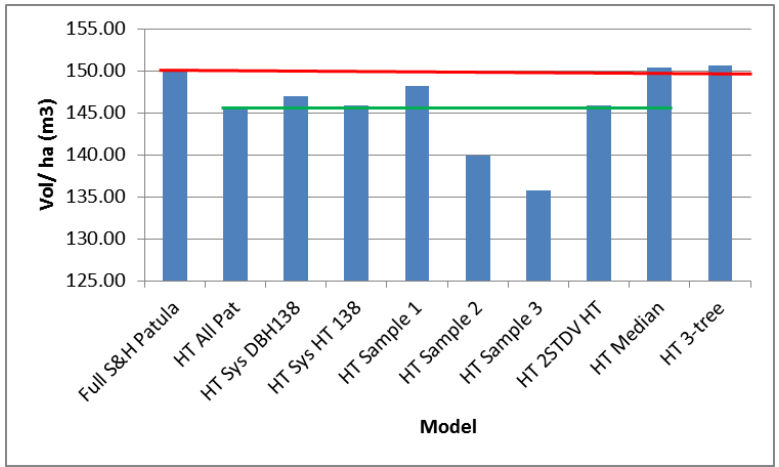
Full compartment volume

Model	Area (ha)	SPHA	DBH (cm)	HT (m)	Vol/ tree (m^3)	Vol/ha (m^3)	Vol/compt (m^3)	Vol var/compt (m^3)	% difference
Full S&H Patula	10	418.9	27.26	16.62	0.36	150.12	1501.19	0.00	0.00
Full Max Burkhart	10	418.9	27.26	16.62	0.40	168.02	1680.19	179.00	11.92
Full S&H Elliottii	10	418.9	27.26	16.62	0.36	150.07	1500.72	-0.47	-0.03
Full S&H Taeda	10	418.9	27.26	16.62	0.32	132.64	1326.43	-174.75	-11.64
Full S&H Radiata	10	418.9	27.26	16.62	0.37	153.53	1535.32	34.14	2.27
Full S&H Pinaster	10	418.9	27.26	16.62	0.32	135.80	1358.04	-143.15	-9.54



DBH-HT regression

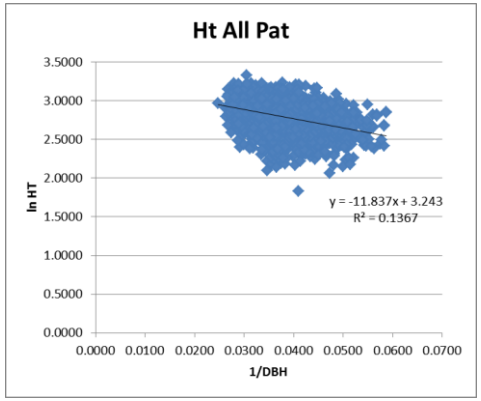
Model	Area (ha)	SPHA	DBH (cm)	HT (m)	Sample size	Vol/ tree (m³)	Vol/ha (m³)	Vol/ compt (m³)	Vol var/ compt (m³)	% difference
Full S&H Patula	10	418.9					150.12	1501.19		
HT All Pat	10	418.9	27.26	16.588	4189	0.35	145.81	1458.11	-43.08	-2.87
HT Sys DBH138	10	418.9	27.26	16.687	30	0.35	146.96	1469.60	-31.59	-2.10
HT Sys HT 138	10	418.9	27.26	16.590	30	0.35	145.83	1458.28	-42.91	-2.86
HT Sample 1	10	418.9	27.26	16.792	30	0.35	148.19	1481.86	-19.33	-1.29
HT Sample 2	10	418.9	27.26	16.084	30	0.33	139.96	1399.65	-101.54	-6.76
HT Sample 3	10	418.9	27.26	15.719	30	0.32	135.77	1357.73	-143.46	-9.56
HT 2STDV HT	10	418.9	27.26	16.593	3990	0.35	145.86	1458.61	-42.57	-2.84
HT Median	10	418.9	27.26	16.979	32	0.36	150.38	1503.78	2.59	0.17
HT 3-tree	10	418.9	27.26	16.999	3	0.36	150.62	1506.18	4.99	0.33

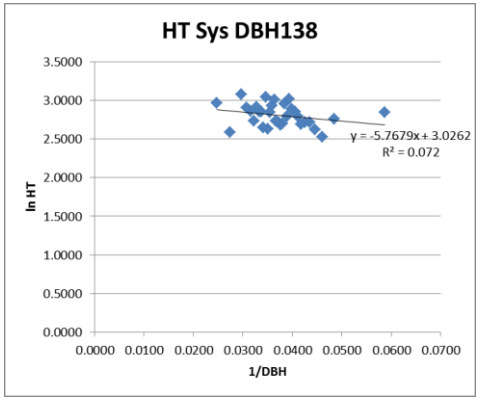


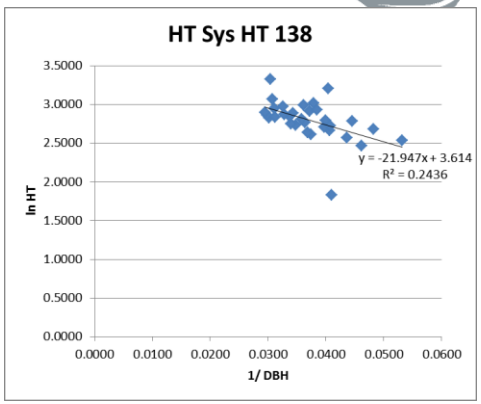
DBH-HT regression (2)

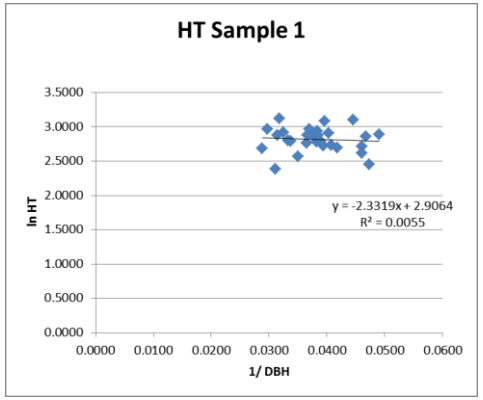
Model	R^2
Full S&H Patula	-
HT All Pat	0.137
HT Sys DBH138	0.072
HT Sys HT 138	0.244
HT Sample 1	0.005
HT Sample 2	0.312
HT Sample 3	0.009
HT 2STDV HT	0.127
HT Median	0.884
HT 3-tree	-

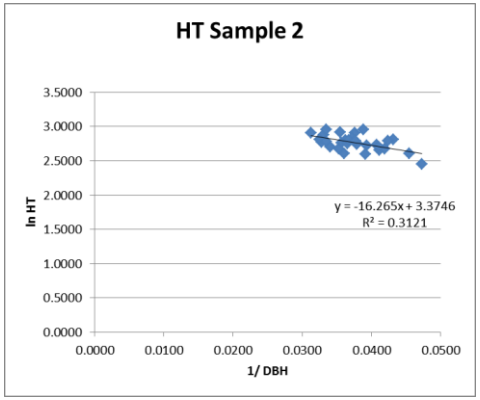
Model	% diff
Full S&H Patula	
HT All Pat	-2.87
HT Sys DBH138	-2.10
HT Sys HT 138	-2.86
HT Sample 1	-1.29
HT Sample 2	-6.76
HT Sample 3	-9.56
HT 2STDV HT	-2.84
HT Median	0.17
HT 3-tree	0.33

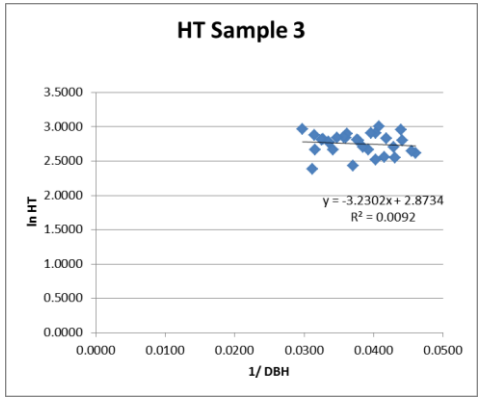


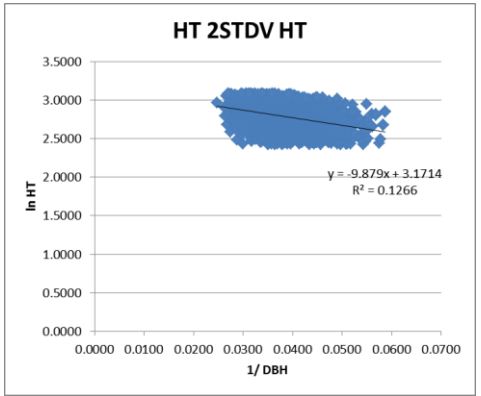


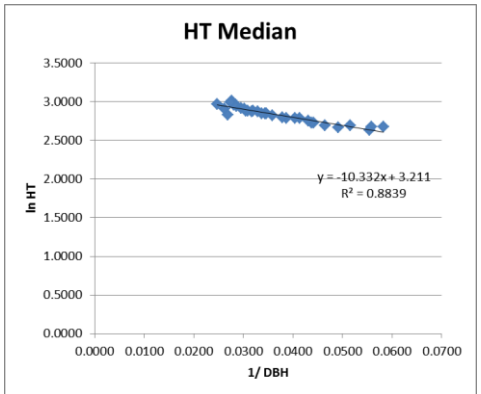






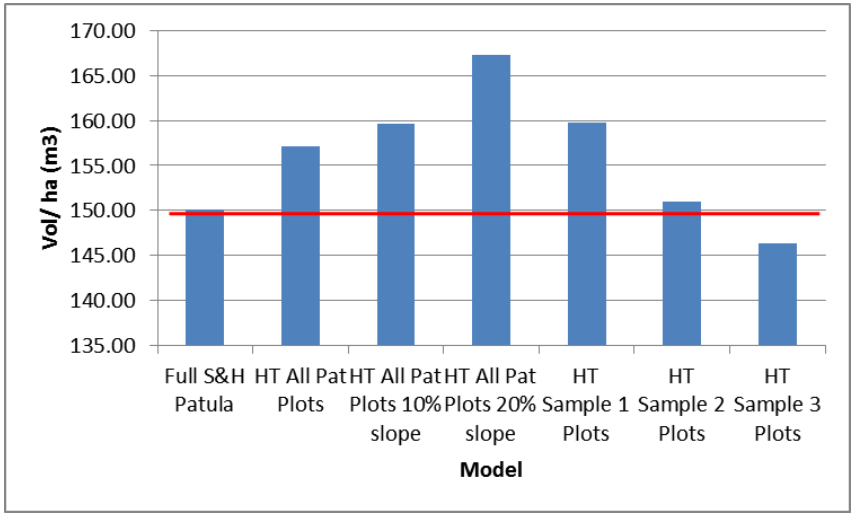






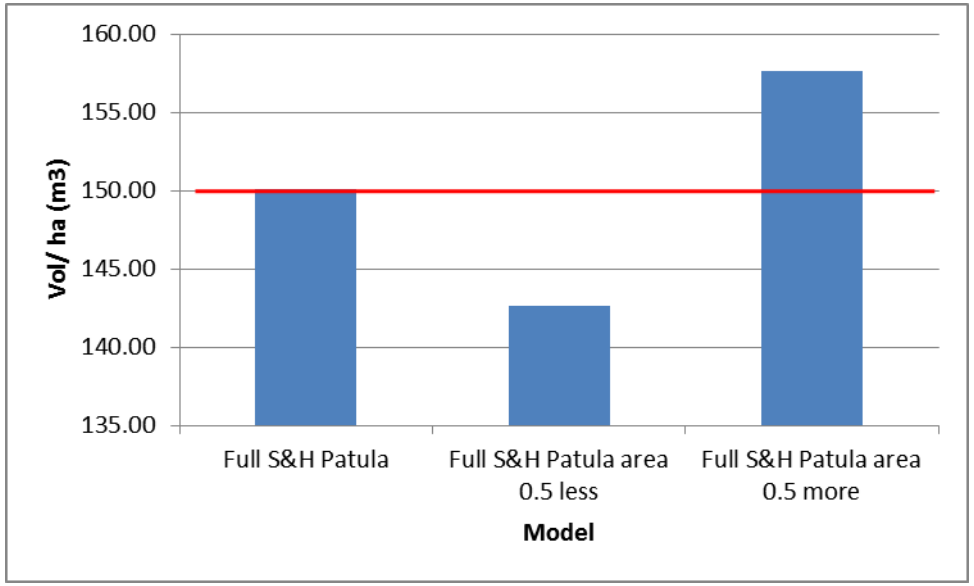
Plot estimates DBH and SPHA

Model	Area (ha)	SPHA	DBH (cm)	HT (m)	Vol/ tree (m^3)	Vol/ ha (m^3)	Vol/ compt (m^3)	Vol var/ compt (m^3)	% difference
Full S&H Patula	10	418.9				150.12	1501.19		
HT All Pat Plots	10	451.1	27.27	16.59	0.35	157.18	1571.84	70.66	4.71
HT All Pat Plots 10% slope	10	458.1	27.27	16.59	0.35	159.61	1596.09	94.91	6.04
HT All Pat Plots 20% slope	10	480.1	27.27	16.59	0.35	167.27	1672.72	171.53	10.75
HT Sample 1 Plots	10	451.1	27.27	16.79	0.35	159.75	1597.55	96.36	5.76
HT Sample 2 Plots	10	451.1	27.27	16.09	0.33	150.95	1509.47	8.29	0.52
HT Sample 3 Plots	10	451.1	27.27	15.72	0.32	146.38	1463.76	-37.42	-2.48



Variation in area

Model	Area (ha)	SPHA	DBH (cm)	HT (m)	Vol/ tree (m^3)	Vol/ ha (m^3)	Vol/ compt (m^3)	Vol var/ compt (m^3)	% difference
Full S&H Patula	10	418.9				150.12	1501.19		
Full S&H Patula area 0.5 less	9.5	418.9	27.26	16.62	0.34	142.61	1426.13	-75.06	-5
Full S&H Patula area 0.5 more	10.5	418.9	27.26	16.62	0.38	157.62	1576.25	75.06	5



Cash flow analysis

Age	Activity	Direct Costs	GAC	Total Cost	Gross Revenue	Net Cash Flow	Present Value
		R/ha					
0	Land	R 13 444					
0	Establishment	R 5 501		R 5 501		-R 18 945	-R 18 945.09
1	Tending	R 574	R 2 108	R 2 682		-R 2 682	-R 2 553.94
2	Tending	R 574	R 2 108	R 2 682		-R 2 682	-R 2 432.32
3	Tending	R 574	R 2 108	R 2 682		-R 2 682	-R 2 316.50
4			R 2 108	R 2 108		-R 2 108	-R 1 734.29
5			R 2 108	R 2 108		-R 2 108	-R 1 651.71
6			R 2 108	R 2 108		-R 2 108	-R 1 573.06
7			R 2 108	R 2 108		-R 2 108	-R 1 498.15
8			R 2 108	R 2 108		-R 2 108	-R 1 426.81
9			R 2 108	R 2 108		-R 2 108	-R 1 358.86
10			R 2 108	R 2 108		-R 2 108	-R 1 294.16
11			R 2 108	R 2 108		-R 2 108	-R 1 232.53
12			R 2 108	R 2 108		-R 2 108	-R 1 173.84
13			R 2 108	R 2 108		-R 2 108	-R 1 117.94
14			R 2 108	R 2 108		-R 2 108	-R 1 064.71
15	Clearfelling		R 2 108	R 2 108	R 78 212	R 89 548	R 43 074.27
	Land				R 13 444	**NPV**	R 1 700.38
						IRR	5.4%

Vol x (Mill price – H&T)

Financial viability per enumeration model

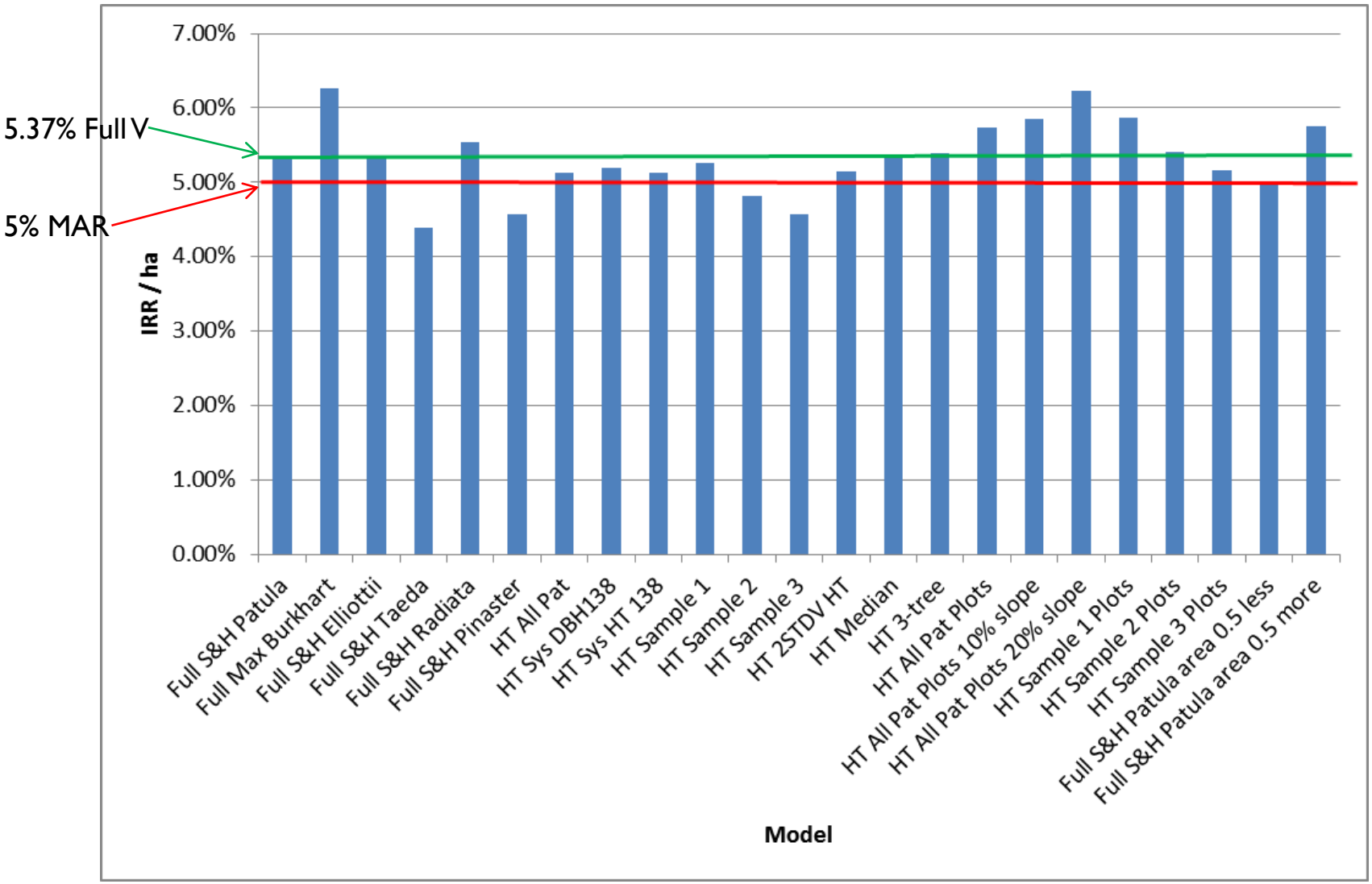
Model	Vol/ ha (m^3)	Value/ Ha	IRR	Var MAR	Reject project	Over predict
Full S&H Patula	150.12	R 78 212	5.37%	0.37%		
Full Max Burkhart	168.02	R 87 538	6.26%	1.26%		X
Full S&H Elliottii	150.07	R 78 187	5.36%	0.36%		
Full S&H Taeda	132.64	R 69 107	4.39%	-0.61%	X	
Full S&H Radiata	153.53	R 79 990	5.54%	0.54%		X
Full S&H Pinaster	135.80	R 70 754	4.57%	-0.43%	X	
HT All Pat	145.81	R 75 967	5.14%	0.14%		
HT Sys DBH138	146.96	R 76 566	5.20%	0.20%		
HT Sys HT 138	145.83	R 75 976	5.14%	0.14%		
HT Sample 1	148.19	R 77 205	5.26%	0.26%		
HT Sample 2	139.96	R 72 922	4.81%	-0.19%	X	
HT Sample 3	135.77	R 70 738	4.57%	-0.43%	X	
HT 2STDV HT	145.86	R 75 994	5.14%	0.14%		
HT Median	150.38	R 78 347	5.38%	0.38%		X
HT 3-tree	150.62	R 78 472	5.39%	0.39%		X
HT All Pat Plots	157.18	R 81 893	5.73%	0.73%		X
HT All Pat Plots 10% slope	159.61	R 83 156	5.85%	0.85%		X
HT All Pat Plots 20% slope	167.27	R 87 149	6.23%	1.23%		X
HT Sample 1 Plots	159.75	R 83 232	5.86%	0.86%		X
HT Sample 2 Plots	150.95	R 78 644	5.41%	0.41%		X
HT Sample 3 Plots	146.38	R 76 262	5.17%	0.17%		
Full S&H Patula area 0.5 less	142.61	R 74 295	4.96%	-0.04%	X	
Full S&H Patula area 0.5 more	157.62	R 82 110	5.75%	0.75%		X

IRR – 5.37%

Accept

MAR – 5%

Financial viability per enumeration model (2)



Financial viability – volume decrease

% Vol decrease	Vol/ ha (m^3)	Value	IRR
0	150.12	R 78 212	5.37%
1	148.62	R 77 430	5.29%
2	147.12	R 76 648	5.21%
3	145.62	R 75 866	5.12%
4	144.11	R 75 083	5.04%
5	142.61	R 74 301	4.96%
6	141.11	R 73 519	4.88%
7	139.61	R 72 737	4.79%
8	138.11	R 71 955	4.71%
9	136.61	R 71 173	4.62%
10	135.11	R 70 391	4.53%
11	133.61	R 69 609	4.45%
12	132.10	R 68 827	4.36%
13	130.60	R 68 044	4.27%
14	129.10	R 67 262	4.18%
15	127.60	R 66 480	4.09%
16	126.10	R 65 698	3.99%
17	124.60	R 64 916	3.90%
18	123.10	R 64 134	3.81%
19	121.60	R 63 352	3.71%
20	120.09	R 62 570	3.61%

Pulp price	R/ m^3
Pulp at mill	R 750
Harvest roadside	R 102
Transport costs	R 127
Pulp standing	R 521

20% Vol decrease – 1.75 P% IRR decrease

Financial viability – H&T cost increase

% Cost increase	Pulp price (R/m³)	Value	IRR
0	R 521	R 78 212	5.37%
1	R 519	R 77 868	5.33%
2	R 516	R 77 524	5.30%
3	R 514	R 77 181	5.26%
4	R 512	R 76 837	5.23%
5	R 510	R 76 493	5.19%
6	R 507	R 76 149	5.15%
7	R 505	R 75 806	5.12%
8	R 503	R 75 462	5.08%
9	R 500	R 75 118	5.05%
10	R 498	R 74 774	5.01%
11	R 496	R 74 430	4.97%
12	R 494	R 74 087	4.94%
13	R 491	R 73 743	4.90%
14	R 489	R 73 399	4.86%
15	R 487	R 73 055	4.83%
16	R 484	R 72 712	4.79%
17	R 482	R 72 368	4.75%
18	R 480	R 72 024	4.71%
19	R 477	R 71 680	4.68%
20	R 475	R 71 337	4.64%

Pulp price	R/ m³
Pulp at mill	R 750
Harvest roadside	R 102
Transport costs	R 127
Pulp standing	R 521

20% Harvesting and Transport cost increase – 0.73 %P IRR decrease

Financial viability – Establishment cost increase

% Cost increase	Establishment costs (R/ha)	IRR
0	R 5 501	5.37%
1	R 5 556	5.35%
2	R 5 611	5.34%
3	R 5 666	5.33%
4	R 5 721	5.32%
5	R 5 776	5.31%
6	R 5 831	5.29%
7	R 5 886	5.28%
8	R 5 941	5.27%
9	R 5 996	5.26%
10	R 6 051	5.25%
11	R 6 106	5.23%
12	R 6 161	5.22%
13	R 6 216	5.21%
14	R 6 271	5.20%
15	R 6 326	5.19%
16	R 6 381	5.17%
17	R 6 436	5.16%
18	R 6 491	5.15%
19	R 6 546	5.14%
20	R 6 601	5.13%

Age	Activity	Direct Costs
		(R/ha)
0	Establishment	R 5 501

20% Establishment cost increase – 0.24 %P IRR decrease

Financial viability – General Annual Cost increase

% Cost increase	GAC (R/ha)	IRR
0	R 2 108	5.37%
1	R 2 129	5.32%
2	R 2 150	5.27%
3	R 2 171	5.22%
4	R 2 192	5.18%
5	R 2 213	5.13%
6	R 2 234	5.08%
7	R 2 256	5.04%
8	R 2 277	4.99%
9	R 2 298	4.94%
10	R 2 319	4.90%
11	R 2 340	4.85%
12	R 2 361	4.80%
13	R 2 382	4.76%
14	R 2 403	4.71%
15	R 2 424	4.66%
16	R 2 445	4.62%
17	R 2 466	4.57%
18	R 2 487	4.53%
19	R 2 509	4.48%
20	R 2 530	4.43%

Age	Activity	Direct Costs
		(R/ha)
	GAC	R 2 108

20% GAC increase – 0.93 %P IRR decrease

Conclusions

- Large difference in volume between Max & Burkhart and Schumacher & Hall
- Random sample DBH/ HT more variability than systematic samples
- Plot size and slope - effect on SPHA and Vol
- 15 of 23 models could lead to wrong decision making
- Change in volume had a bigger effect on IRR than changes in costs
- Critical importance of good inventory techniques

Thank you!