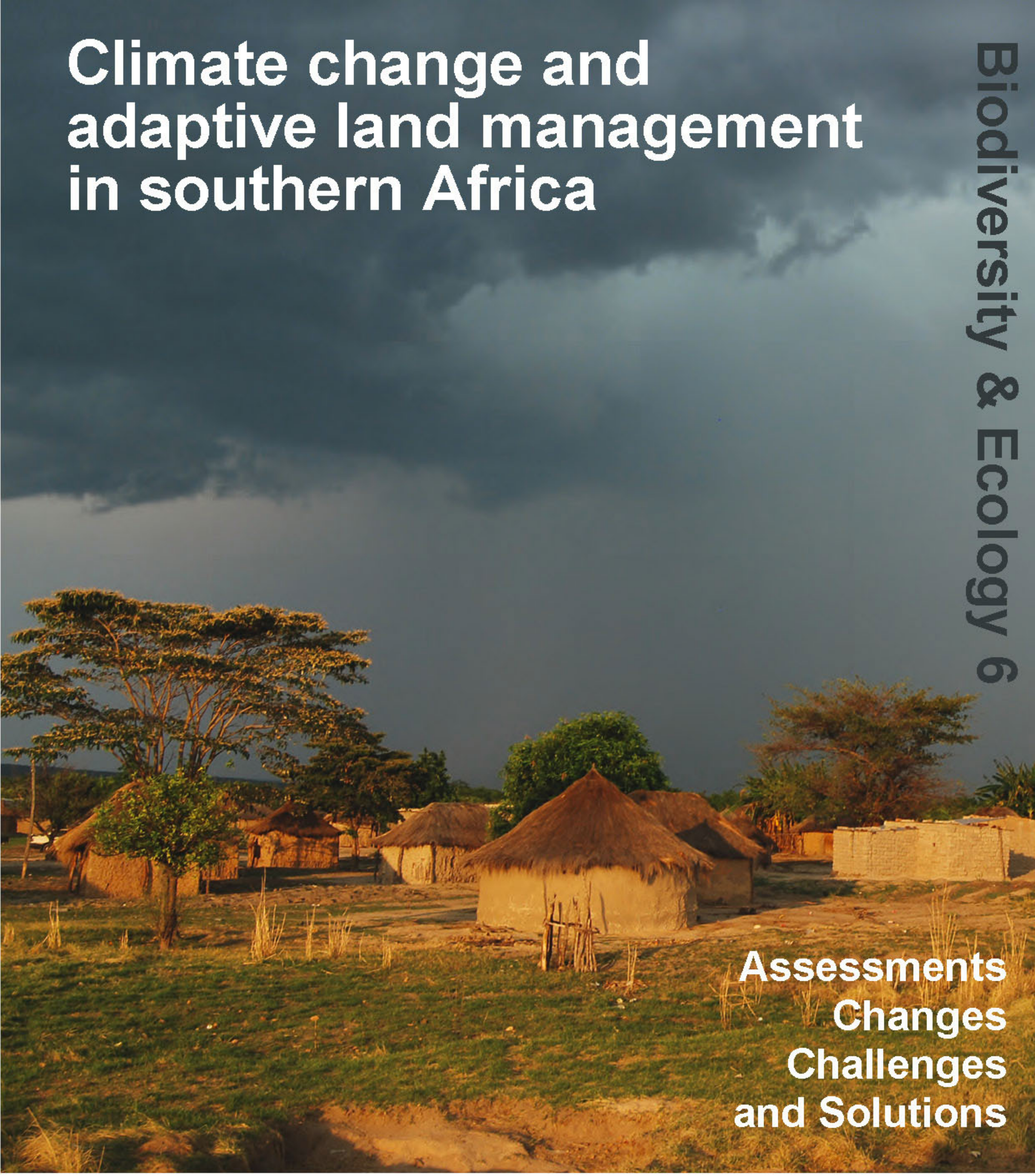
Climate change and adaptive land management in southern Africa

Biodiversity & Ecology 6



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Changes
Challenges
and Solutions

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Climate change and adaptive land management in southern Africa

Assessments, changes, challenges, and solutions

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Forest resources

Market analysis to assess timber products from dryland woodlots and farm forests in South Africa

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Abstract: The growing demand for renewable wood products and competition for land in South Africa will necessitate expansion of planted forests into moderately dry areas. Farm forestry and agroforestry options using species preselected for drought tolerance, water use efficiency, and pest/pathogen resistance may contribute to a sustainable timber supply. The feasibility of growing dryland farm forestry crops was tested as follows: current input costs and market prices of timber products were obtained in a market survey; growth data from existing dryland experiments were used together with four silvicultural regimes as forest growth model inputs; the yields per forest product class were modelled; and the land expectation values were calculated per regime over a range of site qualities. Projections indicate the best returns where pole markets are available, or where sawtimber plus small-scale poles are produced. With appropriate regime selection, attractive financial returns can be achieved on moderately low site qualities.

Resumo: A crescente procura de produtos de madeira renováveis e a concorrência por terras na África do Sul irão requerer a expansão das plantações florestais para zonas moderadamente secas. As opções de exploração florestal e agrofloresta que utilizam espécies pré-selecionadas para a tolerância à seca, eficiência do uso da água e resistência a pragas/patogénios, podem contribuir para um fornecimento sustentável de madeira. A viabilidade do crescimento de culturas de exploração florestal em terras áridas foi testada da seguinte forma: os custos dos insumos e os preços de mercado actuais foram obtidos num estudo de mercado; dados de crescimento de experiências já realizadas em terras áridas foram utilizados em conjunto com quatro regimes de silvicultura como insumos do modelo de crescimento florestal; os rendimentos por classe de produto florestal foram modelados; e os valores esperados da terra foram calculados por regime numa série de qualidades do local. As projecções indicam os melhores retornos onde os mercados madeireiros estão disponíveis, ou onde toras de madeira e postes de pequena escala são produzidos. Com a selecção do regime apropriado, retornos financeiros atractivos podem ser alcançados com qualidades de local moderamente baixas.

Introduction

South Africa relies heavily on its commercial plantation sector for timber and paper products. The forestry, timber, pulp, and paper (FTPP) sector currently plays a major role in South Africa with regards to contribution to the economy and employment: it contributed 10.2% to the agriculture GDP in South Africa during 2015 on 1% of the land base whilst supplying 158 000 direct employment opportunities (FSA, 2017). Commercial timber plantation forests cover approximately 1.224 million hectares of South Africa (FSA, 2017), with the main species planted comprising softwoods (pine species) and hardwoods (*Eucalyptus, Acacia,* and *Corymbia*). These plantations produced more than 18.7 million m³ of commercial roundwood worth an estimated R 8.34 billion (delivered at mill cost) between 2011 and 2012 (DAFF, 2014). However, a growing population and an emphasis on renewable, carbon-friendly commodities compel the sector to increase its output. South Africa is approaching the limits of increasing productivity from a limited resource base, and the expansion of the plantation area in South Africa in areas where it is economically, environmentally and socially appropriate to do so is considered a priority (DAFF, 2013). Areas that are both available and suitable for commercial forestry in South Africa are limited, and much of this limitation is driven by a competition for water, a scarce resource in what is essentially a semi-arid country (Dyer, 2007). The major plantation forestry areas in South Africa are located in the summer rainfall region (on the eastern and southern seaboard of South Africa) and cover a wide range of soils and biophysical environments. Changes

Figure 1: Eucalyptus woodlots (a) the Pampoenvlei experimental site for dryland eucalyptus (age 22 years and mean annual precipitation during the trial period of the experiment = 453 mm); (b) short rotation experimental planting of eucalypts for pole and/or biomass production picturing *Eucalyptus grandis* x *camaldulensis* hybrids at age 7 years (mean annual precipitation = 800 mm). (Photos A. Clarin and G.F. Malherbe)

in temperature and rainfall regimes are likely to affect the extent and location of land climatically suitable for specific genotypes (Warburton & Schulze, 2008; DEA, 2013), thereby increasing the risk that optimal forestry areas may become marginal as a result of climate change.

The FTPP sector plays a significant role in rural areas in regions where few economic alternatives exist and can contribute significantly to rural economic development through forestry activities as well as through innovation in nontimber fibre products, fibre waste utilisation, and downstream processing activities. Given the challenges experienced by the forest industry and the role forestry plays in supporting rural economic development, there is a need to explore options for expanding the production of timber outside the traditional forestry areas (in moderately dry environments) as well as selecting and breeding tree species that are resilient to climate change. Selection and future breeding should be undertaken in light of climate projections since tree species and provenances differ in their ability to adapt to climate change. Selection criteria for species, hybrids, and clones should focus on traits related to drought tolerance, water efficiency, and resistance to pests and pathogens. This approach will support the need for a sustainable supply of products from woodlots and tree farms from dry climates to specific markets (du Toit & Malherbe, 2017).

The aim of the research was to investigate the potential markets for products primarily from species in the genus *Eucalyptus* that can be grown as farm forests or woodlots, specifically in dryland situations (Fig. 1). The reasons for the focus on this genus are that it has some of the highest water use efficiencies of indigenous and exotic taxa tested in South Africa to date (Gush & Dye, 2009) and that there is a well-established market of timber products from this genus (FSA, 2017). Furthermore, the ability to grow eucalypts in a farm forestry or agroforestry setting (i.e., in a mosaic pattern in appropriate landscape positions, alongside other land uses) usually does not compromise but often enhances food production. Examples are farm forests, outgrower schemes, woodlots, windbreaks, shelterbelts and silvo-pastoral systems, rehabilitation projects that may yield both timber products (Evans & Turnbull, 2004; Gardner, 2007; Wessels et al., 2016; du Toit et al., 2017a) and other services such as honey bee forage, pollination services (De Lange et al., 2013), increased yield in associated animal production systems (Broom et al., 2013; Alemu, 2016), and carbon sequestration systems and rehabilitation of salt-affected lands (du Toit & Malherbe, 2017; Harper et al., 2017). There is some concern over two commercially important pure eucalyptus species that have become invasive in South Africa (*E. grandis* and *E. camaldulensis*), although the genus *Eucalyptus* has generally produced relatively few invasive species worldwide (Rejmánek & Richardson, 2011). A number of species that were introduced to South Africa more than a century ago are not invasive (Forsyth et al., 2004), and there is no published evidence in the scientific literature to demonstrate invasiveness by eucalypt hybrid clones in South Africa. It follows that eucalypt tree planting (if an afforestation licence has been obtained) is a legitimate land use option that can also contribute to the rendering of ecosystem services such as pollination services, carbon sequestration and animal shelter on farms (De Lange et al., 2013; Harper et al., 2017). This article focuses on the economic feasibility of growing farm forestry crops in dryland areas by calculating the internal rate of return (IRR) and land expectation value (LEV) that can be achieved on combinations of site quality and silvicultural regime. This information can enable potential growers to understand the financial feasibility of any new investment in relation with the interest rate that can be earned from a similar investment at any financial institution. The IRR is defined as the discount

Table 1: Input costs used in FORSAT for IRR and LEV calculations (adjusted from Meyer, 2015).

Forestry activity	Year	Cost (R ha^{-1}) 1667 S ha^{-1}	Cost (R ha^{-1}) 1111 S ha^{-1}
Land value	0	8864.00	8864.00
Land preparation and pitting	0	1687.58	1124.72
Planting including watering	0	2088.43	1391.87
Fertilizing	0	1076.33	717.34
Blanking	0	379.82	253.14
Weeding	1	359.65	239.81
Weeding	2	359.65	239.81
Pruning	3	448.40	298.84
Fire protection (25% of commercial forestry)	annually	83.00	83.00
Administration (25% of commercial forestry)	annually	251.00	251.00
Harvesting	15	90.65 with bark, 125.04 debarked	90.65 with bark, 125.04 debarked

Table 2: Product dimensions and prices from a market survey (after du Toit et al., 2017b) used in FORSAT economic calculations.

Product	Min. diameter (cm)	Max. diameter (cm)	Min. length (m)	Max. length (m)	Price (R m^{-1} delivered at roadside)
Sawlogs from high-wood-density species *	30	99	3.0	6.0	2000
Sawlogs	20	99	3.0	6.0	500
Small sawlogs	13	30	2.4	3.0	360
Pulp	6	99	1.8	3.0	177
Telephone and transmission poles	12	99	7.0	18	692
Building and fencing poles	7	15	1.2	7.0	350
Biomass	5	99	0.9	1.8	177

** The price is a weighted average where 30% of the sawn boards (by volume) are without sapwood and are suitable for outdoor decking grades while the remaining portion (70%) is sold as regular sawlog products.*

rate at which the net present value of a series of operational incomes minus costs over a tree crop rotation equals zero (Ham & Jacobson, 2012). The LEV is the present value (per hectare of plantation) of projected cash flows at rotation age (excluding the cost of land), as it is assumed that the rotation will repeat indefinitely (Ham & Jacobson, 2012). LEV is commonly used to evaluate financial feasibility of forestry projects (Ham & Jacobson, 2012) and is the preferred method of comparison between scenarios, especially when the rotation lengths between scenarios are different. The information described in this article is essentially a short summary of a more comprehensive report for SASSCAL Task 205 (du Toit et al., 2017b), and the reader is referred to this report for the finer details upon which results in this chapter are based. The detailed report includes an overview of the climatic, edaphic, regulatory and socio-economic realities in which dry-land "farm timber products" could potentially be grown, the status quo of emerging grower schemes in South Africa, site-species matching and silvicultural regimes required for specific site-species combinations, and an economic analysis of growing trees for a variety of identified markets.

Methods

The Forestry Scenario Analysis Tool (FORSAT) has been designed by Kotze (2009) to estimate the stand growth rate and the production of specific round-wood products from plantations (as well as the economic gains) of the forest management scenarios being investigated. The tool essentially models stand growth based on site index and stand density information, taking into account the interaction between competition effects and site quality as measured in empirical experiments. Additional model out-

Table 3: Scenarios modelled for four regimes over five site indices indicating the potential product mix that could be grown (SI_5 = site index at base age 5 yrs; DBH = diameter at breast height).

Scenario number, regime and products	SI_5	S ha^{-1} planted	Internal Rate of Return (IRR)		Land Expectation Value (LEV)		Dimensions and Volume at Peak LEV age (m^3 ha^{-1})											
			Peak IRR (%)	Age at Peak IRR (yr)	Peak LEV (R)	Age at Peak LEV (yr)	DBH quadratic (cm)	HGT (m)	Stems ha^{-1}	Util Vol (m^3)	Saw: decking	Saw: saw	Saw: small saw	Poles: tel	Poles: build& fencing	Pulp: biomass	Thinning	Total
1. Pole production, planted 1667 S ha^{-1} with no thinning	9	1667	3.71	25	2049	24	14.5	17.3	1066	102				53	49			102
	11	1667	6.43	21	17906	21	15.2	20.6	1133	142				89	53			142
	13	1667	9.34	15	37401	18	15.5	23.1	1203	178				112	66			178
	15	1667	12.35	12	61729	16	15.8	25.4	1251	215				138	77			215
	17	1667	15.58	10	90333	15	16.4	28.1	1275	263				173	90			263
	19	1667	19.01	9	124209	15	17.3	31.7	1275	335				232	103			335
2. Sawlog production, planted 1111 S ha^{-1} with no thinning	9	1111	1.99	25	-314	25	16.8	18.5	801	109		19	46			44		109
	11	1111	4.01	25	4316	21	17.4	21.5	844	146		25	65			56		146
	13	1111	6.24	20	15437	20	18.6	25.2	855	200		45	93			62		200
	15	1111	8.57	16	28935	19	19.5	28.6	866	258		67	120			71		258
	17	1111	10.96	13	46291	19	20.7	32.7	866	339		117	144			78		339
	19	1111	13.4	11	66876	17	21.1	34.7	887	381		129	168			84		381
3. Sawlogs and poles, planted 1667 S ha^{-1} with thinning *	9	1667	2.57	25	-2331	23	15.8	18.7	800	96		5	15		51		10	81
	11	1667	4.63	22	6881	22	17.1	22.5	800	143		13	62		68		18	161
	13	1667	6.95	18	20726	24	19.1	28.2	800	224	2	43	106		72		22	245
	15	1667	9.25	16	40267	25	20.7	33.3	800	322	8	89	139		85		29	350
	17	1667	11.94	15	66546	23	22.9	36.9	700	378	14	127	164		74		38	417
	19	1667	15.07	13	110831	25	26.5	43.2	600	514	52	222	181		59		39	553
4. Pulp and Biomass production, planted 1667 S ha^{-1}	9	1667	-1.52	25	-12433	25	14.7	17.7	1044	103						103		103
	11	1667	-0.22	25	-10218	25	16.2	22.5	1044	164						164		164
	13	1667	0.98	25	-7542	25	17.6	27.2	1044	238						238		238
	15	1667	2.1	22	-3534	20	17.2	28.6	1156	265						265		265
	17	1667	3.28	19	1087	17	17.2	30.1	1227	293						293		293
	19	1667	4.49	16	6454	16	17.9	32.8	1251	349						349		349

puts include the calculation of IRR and LEV, using methodology similar to that described by Ham & Jacobson (2012). The major model input values required are listed in Tables 1 and 2, and the following explanatory notes are given: Site quality is assessed by site index at base age 5 (SI_5), which is defined as the height (in metres) of the 20% largest diameter trees in a forest population at age 5 years. The site indices used in this comparison range from 9 to 19 m. The growth rates of best-performing species and hybrids in dryland eucalypt trials of southern Africa (Verryn et al., 1996; Gardner, 2001, 2007; Swain & Gardner, 2004; du Toit et al., 2017a) were comparable per aridity index class (du Toit et al., 2017b). We therefore chose to base site qualities in this report on the results from a series of trials in the Dryland Industrial and Rural Afforestation Programme (DIRAP). This series is situated on a transect from subhumid to semi-arid regions in the Western Cape, with mean annual precipitation (MAP) ranging from 319 to 800 mm and aridity indices from 0.2 to 0.6 (du Toit et al., 2017a). [Aridity index is defined as mean annual precipitation / mean annual potential evapotranspiration]. These scenarios are thus presented for very low to medium site qualities that widely occur in southern Africa (compared to the generally higher site indices found in commercial plantation forestry) (Kotze et al., 2012). The industry averages of forestry activity costs for 2014 from Forestry Economic Services (Meyer, 2015) were used as a basis for calculating IRR and increased with the inflation rate to predict the costs for 2016 (Tab. 1). The 2016 product prices listed in Table 2 were derived from a South African industry market survey (du Toit et al., 2017b). Four scenarios were selected for the IRR calculations using FORSAT: The first scenario simulates areas close to pole treatment plants and no eucalypt sawlog markets. The primary products are telephone and transmission poles as well as building and fencing poles, with pulp or biomass as secondary products. The second scenario simulates conditions where a sawlog market is available and no pole market. The primary products are sawlogs and small sawlogs, with pulp or biomass as secondary products. The third scenario is a combination of poles from one mid-rotation thinning and the utilisation of poles and sawlogs at clear-fell age. A potential higher-value wood for decking is included in the third scenario to get an indication of the financial returns if a grower wants to extend the clear-fell age to 25 years. The fourth scenario simulates areas where no pole or sawlog markets exist and pulpwood or biomass, including firewood, is the only market. All management regimes consider a woodlot or plantation established at a density of 1 111 to 1 667 stems ha^{-1} (Tab.3). Thinnings (where applicable), were included in the model on a sliding scale as a function of site index: from thinning at 6 years (SI_5 = 19) to thinning at age 13 years (SI_5 = 9). The rotation length is strongly influenced by site quality and stocking: all models were run to 25 years of age, but the output graphs in Figures 2 to 5 were truncated at an age where the relative density exceeded a value of 8, indicating severe competition among trees (du Toit et al., 2017b). [The relative density is defined as stand basal area / ($Dq^{0.5}$), where basal area is measured in m^2 ha^{-1} and Dq = quadratic mean tree diameter (in cm)]. It will thus not be feasible to grow the stands in question on a longer rotation without thinning. The rotation length where LEV reached a peak is regarded as the optimum economic rotation length, and this rate (provided that it did not exceed the relative density criteria) was reported in Table 3 for each case study.

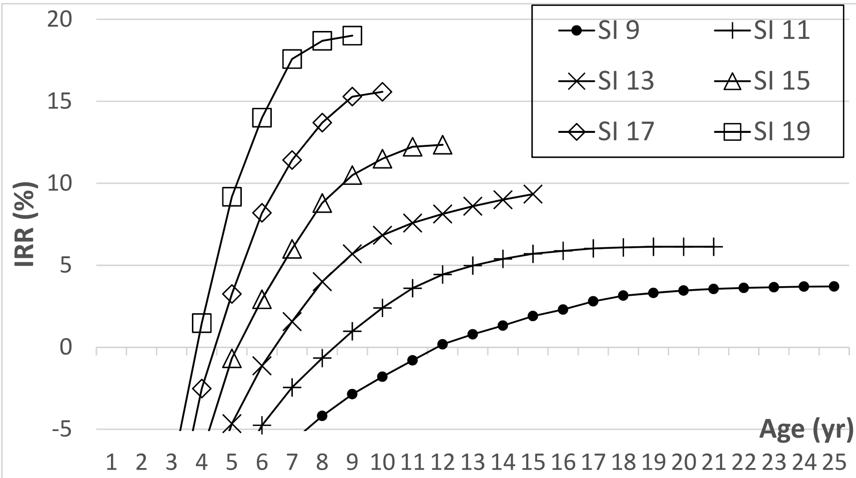

Figure 2: IRR for Scenario 1 (pole production) projected for five different site qualities.

Results

The results of the IRR calculations are summarised in Figures 2–5, and the product volumes produced at given rotation ages plus their associated LEVs at the specified rotation lengths are shown in Table 3. The LEVs are strongly dependent on site quality (as modelled by SI_5) and the silvicultural regime (Tab. 3). Generally speaking, the two management regimes that included pole production as a main or secondary product were the most lucrative options across a wide range of site indices.

Scenario 1 (pole production only) yielded the best LEV across all site indices that had been tested. The IRR on the lowest site quality tested (SI_5 = 9) starts to realise a positive return when the rotation length exceeds 12 years, and it reaches a peak IRR of 4% at age 25. The corresponding IRR on the highest site quality tested (SI_5 = 19) starts to realise a positive return when the rotation length exceeds 3.8 years, and it reaches a peak IRR of 19% at age 9. (Fig. 2). The peak LEVs for the range of site indices tested span from R2 049 (SI_5 = 9; age 24) to R124 209 (SI_5= 19, age 15) (Tab. 3).

For Scenario 2 (sawlog production), the initial stand densities were reduced to 1 111 stems ha^{-1} in an attempt to allow trees to accelerate individual tree diameter growth, as it is not realistic to achieve sawlog dimensions in a short rotation on a low site index whilst maintaining high levels of stand density. With this regime, only a modest volume of sawlogs

Forest resources

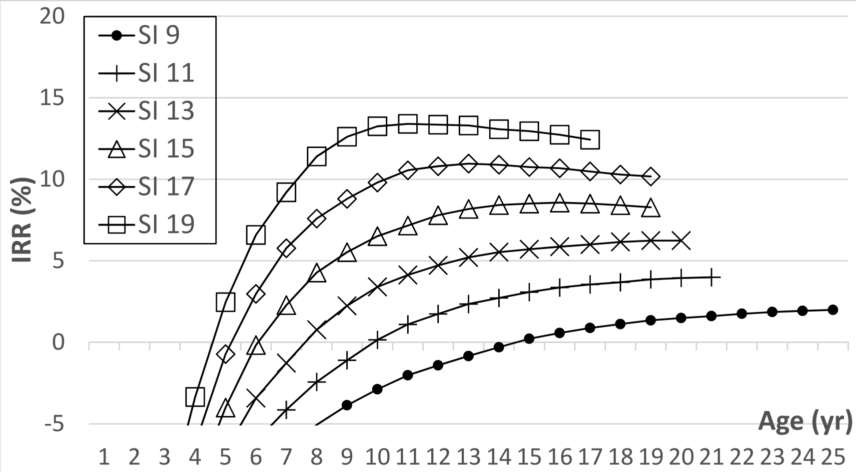

Figure 3: IRR for Scenario 2 (sawlog production), projected for five different site qualities.

(mostly in the small sawlog class) can be produced. The IRR on the lowest site quality tested (SI_5 = 9) starts to realise a positive return when the rotation length exceeds 14 years, and it reaches a peak IRR of 2.0% at age 25. The corresponding IRR on the highest site quality tested (SI_5 = 19) starts to realise a positive return when the rotation length exceeds 4.5 years, and it reaches a peak IRR of 13.4% at age 12. (Fig. 3). The peak LEVs for the range of site indices tested span from –R314 to R66 876 (Tab. 3), implying that a positive LEV can be achieved only with SI_5 = 10 or higher. As before, graph lines are truncated at the age when the relative density of the stand becomes risky (Fig. 3).

Scenario 3 (combination of poles from a mid-rotation thinning and sawlogs at clear-felling age) also turned out to be an economically attractive option for SI_5s greater than 10, provided that longer rotations are employed for the higher end of the reported site index range (Tab. 3). Note that no timber with decking dimensions is produced for the lower two site index classes (Tab. 3). In Scenario 3, the trajectories of the IRR plotted as a function of age are almost horizontal near the age of peak IRR, meaning that a near-optimum IRR can be obtained with a shorter or longer rotation. IRR on the lowest site quality tested (SI_5 = 9) starts to realise a positive return when the rotation length exceeds 12 years, and it reaches a peak IRR of 2.5% at age 23. The corresponding IRR on the highest site quality tested (SI_5 = 19) starts to realise a positive return when the rotation length exceeds 3.5 years, and it reaches a peak IRR of 15.1% at age 13. (Fig. 4). The peak LEVs for the range of site indices tested span from –R2 331 (SI_5 = 9; age 23) to R119 831 (SI_5= 19, age 25) (Tab. 3).

The LEVs for Scenario 4 (pulpwood, biomass, or firewood as the only available markets) were negative for site indices from 9 to 15, and on the two best site index classes, small positive numbers were obtained (Tab. 3).

Discussion

The results presented show that short-rotation pole crops (and to a lesser degree, sawlogs plus building/fencing poles from early thinnings) can be economically feasible production options for farm forests and woodlots in dry regions. The reader is reminded that the scenarios were run with realistic product costs but with lowered administration and fire protection input costs (Tab. 1), as the calculations were done to simulate a farm forestry/woodlot setting where the income of the landowner/forest manager and fire protection costs are supported by other activities besides forestry (coupled to the fact that a landscape with mixed agriculture and forestry land use usually has a lower fire risk profile). It must also be emphasized that FORSAT predicts the maximum utilizable volume of products based on input dimensions, negating the effect of losses due to poor stem form (i.e., a pole will be downgraded to pulp or biomass if it does not comply with the specifications for straightness, splitting and knots). For this reason, the real utilization might be lower than the predicted value, but the error factor will be the same for all products and the results are still useful in comparative studies as in this article. The main reasons for the superior economic performance of the pole crop simulated as Scenario 1 are (a) better volume utilization because the smaller thin-end specifications for poles are 5 cm for building and fencing, 7 cm for telephone and transmission poles (versus 13 cm for small sawlogs), and 20 cm for regular sawlogs; and (b) the fact that the past and current prices of poles are higher than those of sawlogs (du Toit et al., 2017b). On moderate-quality site indices, a relatively short rotation can be implemented whilst still reaching maximum LEVs, and this makes the whole operation also more risk-averse and suited to smaller-scale farmers.

Sawlog production with Scenario 2 did not fully utilize the site, and this is the main reason for its poor economic performance. It does not provide interim income from thinnings and it also poses a moderate biological risk, as the relative density values remain at a high level for an extended period near rotation end. The combination of all these factors makes this an undesirable option.

Scenario 3 (sawlogs plus building/fencing poles from early thinnings) was quite competitive with the pole-only crop of Scenario 1 (with the exception of the lower site qualities – Table 3). The denser initial planting followed by thinning for small pole classes allows for better site and stand volume utilization. It also ensures that trees with only moderately good stem form grow straighter than when planted on wide espacements (du Toit et al., 2017a). The relatively flat peaks of the IRR graphs (Fig. 4) mean that the forester has greater flexibility to shorten or lengthen the rotation as market prices dictate, without incurring significant losses. It is important to note that this scenario relies strongly on the premium paid for decking timber, and that prices will only apply to high-wood-density, low-splitting species such as *E. diversicolor*, *E. cladocalyx* and *E. gomphocephala* (Wessels et al., 2016) and are not applicable to *E. grandis* and

E. grandis hybrids. The sawmilling sector creates a large number of jobs per unit volume of timber produced, and is therefore very important in supporting rural livelihoods.

Timber production in South Africa is currently sufficient, with a net positive balance of trade (i.e., exports minus imports of wood products) (FSA, 2017), but the country's rapid population growth makes it unlikely that the balance will remain positive in the future. A strong case can thus be made for additional timber production. However, most of the currently undeveloped land in South Africa in the high-rainfall zones is not likely to become available for forestry because of competition for land. Furthermore, the aspirations of landless people have to be taken into account. Expansion into moderately dry areas is thus needed, and this places constraints on the species that can be grown, the regimes under which they can be grown, and the types of roundwood that can be produced. For example, timber regimes are not economically viable on low-productivity sites, but pole crops may offer a viable alternative. In addition, there are market limitations in some areas (e.g., no pulp markets in the Southern and Western Cape). Diversification into niche product markets such as pole crops and decking timber may be the catalyst that allows small-scale tree growers in sub-humid and semi-arid areas to develop economically viable opportunities for growing tree crops. If some of the additional environmental benefits from tree growing can generate income (e.g., pollination services, rehabilitation and maintenance of salt-affected lands, or carbon sequestration services), the economic scenarios become even more positive, as demonstrated in Western Australian case studies (Harper et al., 2017). The stream flow reduction if a catchment is *fully afforested,* on sites where MAP ranges from 650 to 800 mm, is estimated to be between 4 and 6% in the summer rainfall area, and between 2.5 and 3.5% in the winter rainfall area (Gush et al., 2002). Mosaic plantings of farm forests will have a significantly smaller impact than the numbers quoted because only a fraction of catchments will eventually be planted to trees, as currently regulated by the national afforestation licence system. In this way, additional water use by farm forests can be limited to a level that is balanced with other water users in each catchment. Economically viable dryland forests could stimulate the economy and help to eradicate poverty in rural areas whilst being based on a renewable, carbon-sequestering growing stock and subject to regulation of the total area planted in individual catchments, as is the status quo in South Africa.

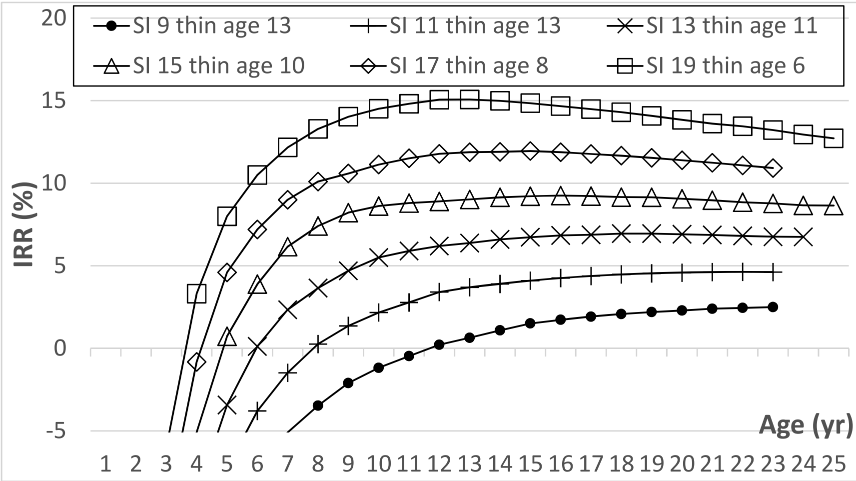

Figure 4: IRR for Scenario 3 (a combination of poles from a mid-rotation thinning and high-value sawlogs at clear-fell age), projected for five different site qualities.

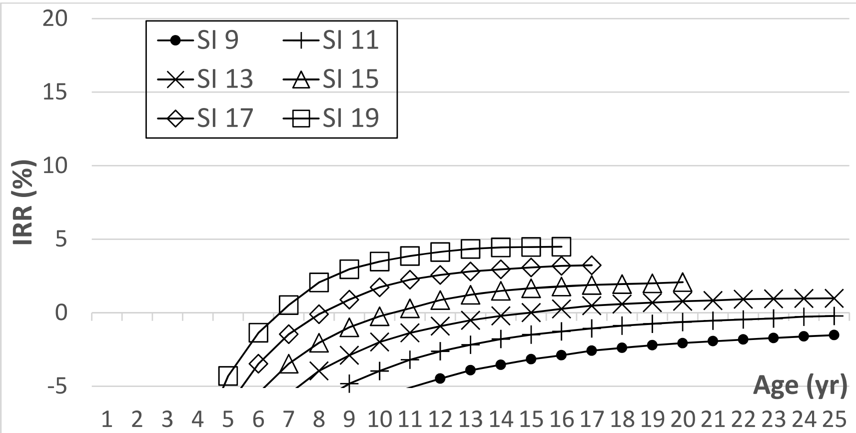

Figure 5: IRR for Scenario 4 (pulpwood and biomass production in the absence of poles or sawlogs markets), projected for five different site qualities.

Conclusions

The LEV projections for eucalypt farm forests and woodlots are strongly influenced by site quality and silvicultural regime, yielding the best returns where well-developed pole markets are available. The second best option is a combination of smaller classes of poles from a mid-rotation thinning and sawlogs at clear-felling age, using high-density species. The fact that the genus *Eucalyptus* has many species with rapid initial growth means that the maximum LEV is achieved in a time span that does not place it out of reach of small growers, even on moderately low-productivity sites in dry areas. The IRR results are a good indication that eucalypts can be grown profitably even on low-productivity sites (SI_5 around 10) and that financial returns in excess of 10% can be achieved on moderate site qualities (SI_5 of 15 to 20). At the same time, farm forestry projects could deliver several environmental benefits, some of which may also generate monetary income. Farm forestry in dryland areas should thus be viewed as an economically feasible land use that will also yield additional benefits such as job creation and various ecosystem services.

Forest resources

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