Achieving production and environmental benefits in a challenging landscape

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Abstract

Twenty-seven years ago, 'Talaheni' a 245-hectare property in Yass Valley suffered from severe dryland salinity, soil acidity and associated vegetation decline. An integrated twelve-point plan was implemented to overcome environmental issues as a precursor to achieving increased production benefits. With soil-moisture management critical to environmental and production objectives, a soil-water balance model has been used to assist in timing pasture establishment, tree planting, grazing and saline water table management. The rationale for selecting vegetation types and their management on the different landscape components is discussed. Implementation of the plan has seen a steady increase in stock carrying capacity and quality improvement of all commodities despite the removal of over 25 per cent of 'Talaheni' from conventional production. With all vegetation types currently under stress, and increasing climate variability and change expected, new climate data sets reflecting the change are required to explore future options.

Key words

Salinity, acidity, pasture management, farm plan, soil-water balance model.

Introduction

'Talaheni' is a 245-hectare property located in the Yass Valley (34.96°S, 149.17°E, 644 m elevation) that was heavily cleared in the late 1800s for grazing purposes, primarily sheep. Currently the main activity is the production of quality ultra-fine wool (MFD av.14.4µ) from a self-replacing Saxon Merino flock, feedlot cattle from a commercial Angus herd and timber from a small farm forestry activity. The Yass Valley is one of the most saline affected areas in New South Wales (Langtry 1999; Scown 2000) and, as a result, saline seeps which originally occupied 23 per cent by area and secondary sheet and gully erosion were common and increasing on our property twenty-seven years ago (Oliver 2006).

The complex Ordovician metasediments form a diverse rolling to hilly landscape of north-south aligned ridges with shallow skeletal soils, interspersed with flat valleys with deeper gradational soils, predominantly silty-clay loams with clay content increasing with depth. The surface soil (0-10cm) has relatively poor water holding characteristics (wilting point 10-12% by vol.; field capacity 29-32%), with plant available water being higher at points lower in the landscape, probably reflecting deeper weathering and higher clay content. The near-treeless ridges host shallow skeletal soils of light texture, high stone-fragment content and high infiltration rates (saturated hydraulic conductivity of 25-250 mm per hour [extremes up to 3000 mm per hour] compared to flats as low as 2 mm per hour (Nicoll and Scown 1993)). This provides high ridge-top recharge opportunities leading to dryland salinity on the potentially more productive adjacent flats with their deeper soils (Anon. 2002). Soil acidity (surface down to pH_{CaCl_2} 3.6, and 4.2 at 200 cm) further limits not only vegetation vigour and cover but remedial options.

Collectively, salinity and acidity posed severe threats to the remaining native vegetation (Anon. 1974) which consisted mainly of isolated and moribund Red stringybark (*Eucalyptus macrorhyncha*) and Red box (*E. polyanthemos*) but included some remnants which were also in decline. Native pastures, mainly *Austrodanthonia spp.* and *Microlaena stipoides,* which had been augmented previously with introduced subterranean clover (*Trifolium subterraneum*), were also in decline, and serrated tussock (*Nassella trichotoma*) had become well established.

Climatic data for 'Talaheni' are shown in Table 1. On average, rainfall is relatively evenly distributed throughout the year, from a monthly low of 46 mm in February to a high of 68 mm in October, although in any particular year rainfall is seasonal and episodic rather than evenly distributed. Evaporation exceeds rainfall for the period September to April, with extreme differences in June (low) and December (high). The ratio of evaporation for these months is greater than 6.5. Mean maximum temperature varies from 11.4°C (July) to 28.5°C (January), while mean minimum temperature varies from 0.8°C (July) to 13.8°C (February), and mean daily temperature is below the nominal pasture growth requirement of 10.0°C for June, July and August.

Accordingly, a number of soil-water management issues are central to our objectives, including:
• minimising deep drainage on poorly developed but porous ridge-top soils,
• utilising soil moisture whenever it is available,
• tapping soil moisture from greater profile depth and,
• increasing infiltration on deeper soils.

Table 1: Mean monthly weather statistics collated from 118 years of SILO-based weather data for 'Talaheni' (http://www.nrw.qld.gov.au/silo/datadrill/).

Month	Max temp (°C)	Min temp (°C)	Mean temp (°C)	Rain (mm)	Evap (mm)	Evap/Rain ratio
Jan	28.5	13.7	21.1	57.9	202.9	3.50
Feb	28.2	13.8	21.0	46.4	164.3	3.54
Mar	25.1	11.4	18.3	54.0	135.6	2.51
Apr	20.5	7.4	14.0	51.6	78.3	1.52
May	15.9	4.2	10.1	55.5	46.9	0.85
Jun	12.5	1.8	7.2	62.7	31.0	0.49
Jul	11.4	0.8	6.1	59.6	34.4	0.58
Aug	13.2	2.0	7.6	61.7	51.2	0.83
Sep	16.1	4.0	10.1	60.2	77.6	1.29
Oct	19.6	6.7	13.2	68.5	117.7	1.72
Nov	23.1	9.3	16.2	57.9	154.5	2.67
Dec	26.7	11.8	19.2	54.1	199.2	3.68
Mean/Total	**20.1**	**7.2**	**13.7**	**690**	**1294**	**1.87**

In terms of pasture performance, growth is temperature-limited in both summer and winter, particularly for introduced perennials and annuals, but native perennial pastures are summer-active, responding quickly whenever soil moisture is available. Overall, moisture can be excessive in winter (causing water-logging) and deficient in summer due to high evaporation demand. Pasture growth potential is further constrained by the relatively poor water holding capacity of the soils, making this a challenging region for pasture-reliant grazing enterprises and vulnerable to environmental decline. Even monthly mean values (Table 1) highlight significant intra-year climate variability, but this masks the wider variation experienced in any particular year, not to mention that of the extreme weather pattern currently being experienced.

Management under fluctuating rainfall is central to addressing the environmental and production challenges faced at 'Talaheni'. The consequences of landscape diversity are that soil-water relationships vary spatially across the property in response to variation in soil (e.g. type, profile depth, water holding capacity, infiltration rate) and landscape characteristics (e.g. slope, aspect, heat load, exposure).

A soil-water balance model (Ive 2006) is used routinely as a farm-decision making aid for tasks such as pasture seeding, tree planting, grazing and water table management. With growing evidence of increasing climate variability (Anon. 2006c) the role of the soil-water balance model has increased in exploring options and consequences of seasonal prospects. It was against this setting that a rolling integrated farm plan was developed and implemented to achieve both production and environmental benefits (Ive 2003). The latter are often a precursor to achieving further production goals.

Integrated farm plan

The plan has involved the following steps over a 27-year period:

1. Re-fencing the entire property in recognition of soil and landscape variation to assist with pasture selection and grazing management. Nine traditional 'square' paddocks have given way to 38 irregular, but resource-defined paddocks, often recognising sub-catchment boundaries. Each paddock is served by at least one dam with capacity to comfortably accommodate carrying capacity.
2. Constructing graded and contour banks to protect lower flats by intercepting overland flow from adjoining ridges; graded banks also intercept shallow

groundwater moving laterally down-slope before it reaches vulnerable flats. Collectively the banks slow the movement of surface water across flatter areas with low infiltration.

3. Contour ripping of mid-slopes to increase infiltration and slow down-slope water movement. To minimise and defray deep drainage, only mid-slopes with up-slope and down-slope tree cover are ripped.

4. Identifying high recharge areas with low production potential (by soil type and measurement of infiltration rate) and planting these areas to drought-tolerant native tree species.

5. Installing a network of piezometers and regularly monitoring movement and salinity levels of groundwater.

6. Measuring dam salinity (38 dams) as a means of establishing spatial variation in dryland salinity risk and monitoring the response of farm sub-catchments to amelioration, and the extent of on-going risk from salinity.

7. Developing and applying a daily soil-water balance model to assist in selection and management of various vegetation options, and provide greater insight into the range and effect of likely seasonal conditions using historical and current weather records.

8. Establishing perennial pastures (mainly phalaris, but including cocksfoot, fescue, chicory and plantain augmented with annual and perennial legumes) on areas reclaimed from dryland salinity, after applying sewage ash and/or lime to rectify soil acidity. To make best use of soil moisture, whenever it is available in the year, different perennial species have been selected.

9. Fertilising and managing native and introduced perennial pastures to increase pasture bulk and vigour, to assist in retaining and using rainfall where it falls and to increase farm production.

10. Undertaking a control program for noxious weeds, particularly serrated tussock, initially by spraying with flupropanate herbicide, and subsequently by timely chipping, with all vehicles and bikes carrying rabbit-trap setters to remove tussock on sight. Thistles have also been successfully controlled with the latter approach.

11. Confining grazing (with supplementary hand feeding) during dry periods to cleared ridges with shallow skeletal soils to encourage natural tree regeneration when the season breaks. The soil constraints (viz. high acidity and low water holding capacity) of these areas prevent establishment and persistence of pastures with sufficient vigour to avoid significant deep drainage. Trees eventually lower the recharge risk of these areas.

12. Fencing out native vegetation remnants and linking remnants with native mixed-genera corridor plantings, primarily along rocky ridge lines (recharge sites) and break-of-slope (immediately up-slope from potential saline discharge sites). Corridor plantings provide multiple benefits: linking remnants, contributing to recharge management, intercepting groundwater, providing for wildlife movement, and shelter for stock and pastures from inclement weather.

These twelve steps have resulted in the farm plan portrayed in Figure 1, which shows current vegetation types. A major goal in implementing the farm plan has been to address the major environmental issues, as a precursor to achieving further production goals (Anon. 2002; Anon. 2004).

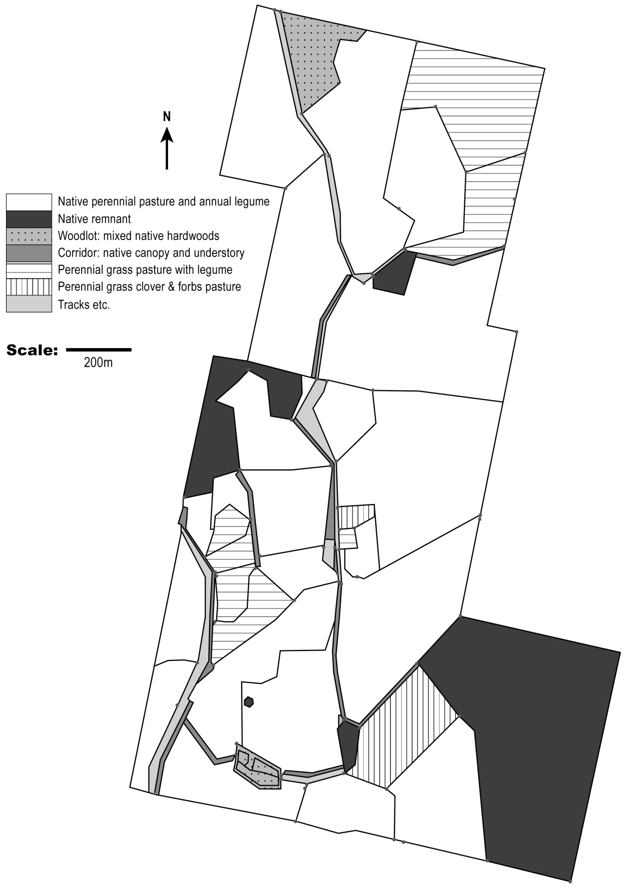

Figure 1: Farm plan developed on 'Talaheni' after implementing an integrated twelve step plan, and the vegetation types now established in each paddock.

Farm Vegetation Management

Ridges

Within the landscape, the ridges with their shallow poorly developed soils could never support the vigorous pastures necessary to avoid deep drainage which, with the elevated landscape head, leads to water table rise on the flats. Therefore, the objective has been to establish native trees on the rocky ridges to lower recharge potential and reduce the salinity risk to the lower flats. Trees have been established on these areas by planting tube stock of mixed native genera where no seed-trees remain. Given the targeting of inhospitable ridges and hilltops, the establishment of 25,000 trees over the past 25 years has been a labour-demanding task, often involving frequent watering during the establishment period.

Where seed trees remain, an alternative and much less demanding approach, exploiting drought conditions, has been used to trigger extensive natural regeneration following drought-breaking rains (Ive 2007a). This has involved confining stock to the hills and ridges during drought periods where stock are hand fed until the drought breaks and pastures lower in the landscape recover sufficiently to carry stock. With high stone content and high infiltration rate, poor ground cover does not pose an erosion risk on these areas. This leaves competition-free conditions for mass germination and establishment from seeds produced by remaining ridge-resident native trees. If grazing is excluded for a number of months, trees quickly become well established. It is estimated that 200,000 local native trees have been established by this means following a series of drought periods over the past 27-years, involving very little labour.

With the trees 'turning off the ridge-top recharge tap' the saline water table has fallen (Ive 2003). Consequently, the area of saline seeps has declined from 23 to 2 per cent of 'Talaheni', with reclaimed areas becoming available for pasture development and significant improvement in the vigour of remaining pasture.

For the twelve month period July 2002 to June 2003, transpiration from one ridge-top woodlot planted to Red box (Eucalyptus polyanthemos) was 394 mm, or equivalent to 95 per cent of the period's rainfall of 414 mm (S. Roberts unpublished data). Although rainfall was only 60 per cent of the average 690 mm, it nevertheless still also had to meet the following:
a) interception (50 mm or 12 per cent [estimated]),
b) runoff (3 mm or 0.7 per cent [modelled]),
c) evaporation (184 mm or 44 per cent [modelled]).
With a total usage of 631 mm (*viz.* 394+50+3+184) compared to rainfall of 414 mm, there is little doubt that the woodlot trees continue to draw upon the water table resources, with no tree deaths even during the current severe drought (2006-07) despite a stand density of 1200 stems per hectare. Further evidence of the use of water table resources is that tree transpiration was more correlated with day length (R=0.647, n=378) and hence time available for transpiration, than either the demand indicator (potential evaporation [R=0.559]) and/or the supply indicator (available moisture in 60 cm soil profile above rock basement [R=0.340]). In contrast, many mature trees across 'Talaheni', even isolated individuals, have died in recent months after exhausting available soil moisture.

The 394 mm transpiration measured from the trees, compares to 257 mm (57 per cent of period's rainfall) modelled transpiration for the same period if the unproductive native pasture still occupied the area. The difference of 137 mm (33 per cent of rainfall) is due almost entirely to the trees accessing water table resources out of reach of the pasture. In contrast to the trees using previous deep drainage, the pasture contributed a further 7 mm (nearly 2 per cent of rainfall) to deep drainage even though rainfall conditions were below normal. Given the low water holding capacity and high infiltration rate of the ridge-top soil, deep drainage occurs despite an increase in runoff due to poor pasture with shallower rooting depth and lower interception.

Transpiration for the period of measurement common to the two years (25th April to 26th August - the winter period of low transpiration) was considerably different (*viz.* 2002- 113 mm, 2003- 62 mm) despite higher rainfall during the latter period (*viz.* 2002- 169 mm, 2003- 224 mm), indicating that not only are the native Red box trees capable of adapting transpiration to prevailing conditions, but also suggesting a run-down in water table resources. This is consistent with regular water table measurements, as weekly monitoring over the period recorded a fall of more than 2 metres in the water table to a depth approaching 7 metres (Ive 2003). Water table decline was well underway during the previous period (Ive 2003) of above average rainfall (*viz.* pre-December 2000), and has accelerated sharply during the drought. The salinity levels have also been lowered significantly, in some cases to less than 100 EC units. Measurements of dam salinities also confirm a whole-property reduction in salinity levels in runoff water to dams and beyond, although variation between dam catchments is still apparent.

With trees established on the ridges, attention then turned to improving the productivity of native pastures on the mid and lower slopes while the water table declined on the lower flats.

Mid and lower slopes

The slopes are the domain of native perennial pastures dominated by *Austrodanthonia* spp and *Microlaena stipoides* with an annual legume component. The production of these pastures has been increased by regular application of fertiliser, reduction in saline seeps and controlled rotational grazing that limits grazing during periods of seed set. Normal rainfall conditions combined with low pH provide recommended conditions for using sulphur-enriched reactive rock phosphate fertiliser, which was used for more than ten years before becoming difficult to source. Since that time superphosphate has been used every second year on average (with Mo added every fourth year for promoting legume production). Spreading rates are adjusted to reflect the previous year's stocking rate. Colwell soil P is now consistently above 35 mg/kg (October 2006), from a starting base of around Colwell 5.

Infiltration on the slopes is low relative to the ridges, due primarily to the high runoff rates and consequent low retention time of surface water. Where such slopes have tree-protected ridges and remnant trees lower in the landscape, contour ripping with triple hydraulic tynes to 60 cm at 5 metre intervals has been undertaken, preferably under dry conditions for maximum soil shattering, to slow overland flow and increase infiltration. Even at depth these slope soils are non-dispersible and, therefore, tunnel erosion is not a concern. The success of this technique still can be seen after many years, with the ripped areas supporting a much higher clover component than the inter-ripped areas, with native perennial grasses occupying both ripped and inter-ripped areas. There is no sign down-slope that the increased infiltration has increased deep drainage consequences.

The north-west components of the mid slopes with the shallower soils frequently hosted *Austrostipa scabra* dominant pastures that troubled grazing sheep once seed heads appeared. Over the years, management has almost eliminated *Austrostipa scabra* from these areas. Once these areas were fenced, management was able to target these areas. Spray-topping was used prior to appearance of seed heads during two springs before stocking heavily for short periods, initially with cattle, followed by sheep. In later years, with a decline in *Austrostipa scabra* dominance, grazing alone has been used to tackle remaining *Austrostipa scabra* prior to seed head emergence.

An interesting advantage of fencing the slopes surrounding a near-conical hill on aspect has been the extended grazing of quality pasture achieved by controlling stock movement. The north-west slope (largest paddock) is used in winter, with stock being progressively moved around the hill; westerly in mid-spring, easterly in late spring, southerly in early summer. In normal seasons it is estimated about six weeks extra grazing on green pasture is gained by this process, as stock are prevented from abandoning the north-westerly aspect at the first sign of pasture haying-off, and now have to utilise this pasture before quality declines significantly. Stock are moved progressively and finally to the southerly aspect pasture, which has had the opportunity to develop good bulk and remain green rather than taking the brunt of grazing over an extended period, as was the case before undertaking 'aspect' fencing. A farm forestry woodlot was established on the top of the hill.

The slopes, although not the most productive areas, are the easiest areas to manage and appear the most resilient part of the landscape.

Flats

The flats were the main beneficiaries as the water table was progressively lowered. The reclaimed areas were colonised predominantly by sorrel (a traditional indicator of high acidity and low fertility) and couch grass (which is relatively tolerant of salinity). However, there was little evidence of re-establishment of native species, suggesting that the seed bank of original native perennial pasture species had been exhausted by the prolonged effects of salinity, acidity and erosion. To further the opportunities the reclaimed salinity areas offered, productive perennial pastures were established for the following reasons:

a) to capture the significant production potential that the deeper more developed soils on the flats offered, and

b) to continue to make use of any additional soil moisture available in the reclaimed areas.

A reclaimed site became the focus of an Acid Soil Action study (Ive *et al.* 2004) which evaluated different liming options to enhance the establishment (Ive and Ive 2003) and persistence of perennial pastures, as soil testing confirmed not only high acidity but also plant-threatening aluminium levels (10.7 and 26.0 per cent CEC at 0-10 and 10-20 cm respectively, and even higher at greater depth).

During the four years since establishment, the area has been rotationally grazed with high stocking rates for short periods; total grazing time has been equivalent to about three months in any year in four grazing events, predominantly in the August to December period, with cattle followed by sheep. For the period July 2005 to June 2006, the stocking rate was equivalent to 17.5 DSE per ha per annum across the trial site. This is in stark contrast to a carrying capacity of approx one DSE per ha per annum for the area before the water table was lowered and perennial pasture established.

Phalaris plant density continues to increase under all treatments, including the no-lime control, with all five treatments now having a basal presence of over 40 per cent, and with a maximum over 60 per cent for the combined treatment of topdressing (3 t lime/ha) and drilled lime-super mix (300 kg/ha). On the other hand, fescue has declined steadily after the first year and cocksfoot since 2005, both species now having an average basal presence of less than 7 per cent across all treatments. Interestingly, differences in basal presence between liming treatments for all species are consistently and substantially less than the treatment differences between pasture species. Of most surprise is the overall excellent performance (albeit after a slow start) of the no-lime treatment (phalaris basal presence now 47 per cent), given the high aluminium levels (Al 26 per cent CEC at 10-20 cm), low pH (4.5, half to one unit lower surface (0-10 cm) pH than any of the lime treatments which persists to depth (pH 4.2 at 200 cm)), and consistently poor seasons when the effects of aluminium toxicity and low pH are most felt.

Following the success of the trial site, additional reclaimed areas have been seeded after liming, using direct drilling with Caldow boots, following spray-out with glyphosate. A phalaris-dominant mix was chosen including plantain and chicory to increase the deep-rooting perennial component and to assist further year-round management and use of the water table. Phalaris again established well and continues to persist strongly. Plantain and chicory have both succumbed under the recent harsh seasonal conditions, when soil moisture levels have been regularly below permanent wilting point (standard 15 bar). Fertiliser history and application strategy are similar to the mid and lower slopes, although using heavier application of fertiliser at pasture seeding, Colwell soil P values are around 45 mg/kg (October 2006). Currently, new acid-tolerant phalaris cultivars are being evaluated on 'Talaheni' (Culvenor unpublished) and, if successful, will provide additional pasture options without the need for lime treatment.

With saline water tables lowered, soil acidity addressed and productive pastures successfully established, the flats are now realising their production potential, thanks in large part to the ecosystem services the adjoining areas continue to provide.

Land use outcome

'Talaheni' is now a mosaic of vegetation types that offer complementary interactions between all the vegetation types and the landscape elements they occupy. Furthermore, re-fencing recognising landscape (e.g. slope, aspect) and soil conditions (e.g. soil depth, water holding capacity) made initial selection and subsequent management of each vegetation type easier. Implementing the twelve-point integrated farm plan has removed over 25 per cent of the property from traditional grazing. The area removed from grazing now provides ecosystem services contributing significant improvement to the adjoining grazed areas. The ecosystem services contributing directly to production include recharge reduction, interception of laterally moving groundwater, drying of the soil profile, lowering saline water table, providing shade and shelter protection to livestock and pastures, improving the quality of stock-dam water, arresting soil pH decline at depth, and reducing soil erosion and sediment movement. Further ecosystem services achieved, although not confirmed as providing production benefits, include biodiversity, particularly native birds (chiefly declining threatened insectivorous woodland species), native plants and carbon sequestration (Ive and Ive 2007). Public good benefits include improvement in quality (lower salinity level and sediment load) of runoff water leaving our property and entering the Yass River (Anon. 2006b), as well as contributing to biodiversity, soil health and salinity as encouraged in the Murrumbidgee Catchment Action Plan (2005).

Farm production outcomes

The realities of commercial agriculture are that more environmentally sensitive land use will only come about on the broad scale required if there are demonstrated production benefits or significant publicly supported stewardship payments. Major increases in production performance have been recorded since commencing to implement the integrated farm plan (Figure 2). Similar positive time trends have been recorded in quality of commodities (beef, wool and timber) produced.

Despite withdrawing more than 25 per cent of 'Talaheni' from grazing, production in terms of standardized carrying capacity has continued to increase. Thus, not only has there been a steady consistent increase in the stock units carried on a steadily declining portion of the property, but the quality of all products produced has improved, in large part due to addressing the environmental issues in this challenging landscape. However, the most recent 2006-07 drought, which is the second worst ever recorded in terms of soil moisture availability during the critical spring-growing period (Ive 2007b), has necessitated significant destocking (40 per cent reduction).

The future

After nearly seven years of well-below average rainfall, all vegetation types are showing increasing signs of stress. For instance, an estimated 100-plus mature trees, some no doubt spared decades ago during the original clearing, have died. Deaths have been particularly noticeable in the last six months, whether paddock isolates or members of remnants from which stock have been excluded for many years. After a long period of increasing *Microlaena stipoides* coverage, this species is now in decline, even in areas with negligible grazing pressure. The past poor seasons have seen an annual decline in the germination of subterranean clover, due to poor seed set and false or late autumn breaks. Phalaris-dominant pastures have so far persisted on more favourable flats, but have retreated on slopes to drainage lines and depressions where soil moisture is augmented by runoff from upslope areas. Finally, moisture-needy Yorkshire fog grass, once a common volunteer in drainage lines, has disappeared with the series of dry seasons.

These observations, although anecdotal, suggest vegetation types and management, despite having halted and reversed the detrimental and production-

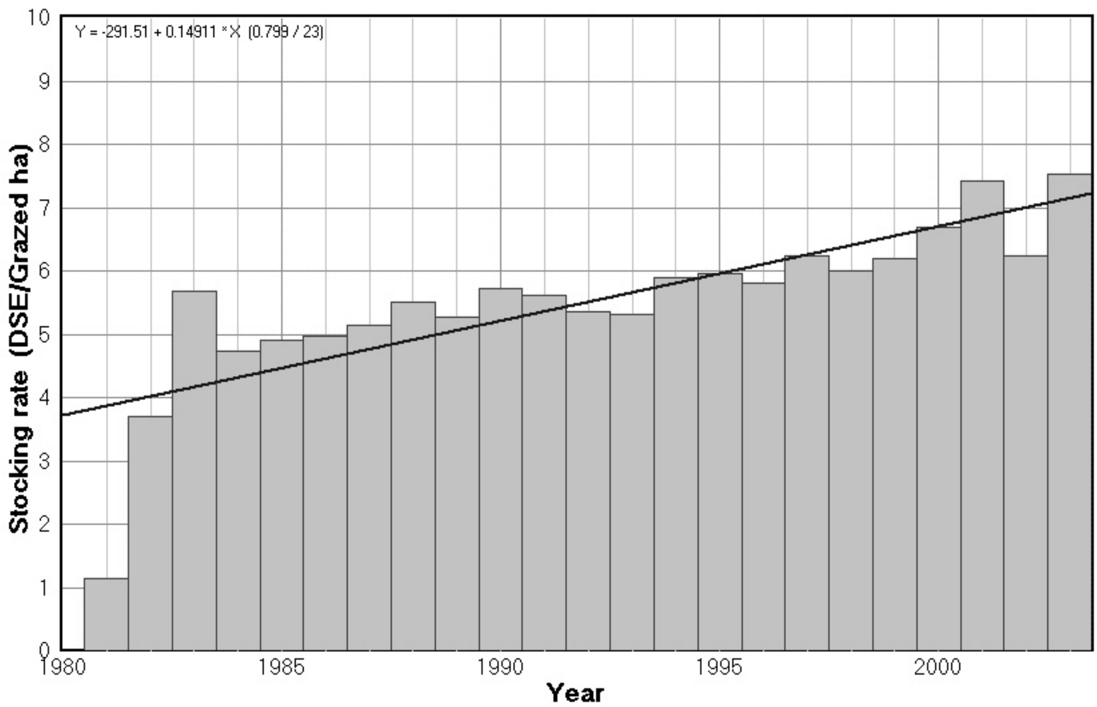

Figure 2: Trend in stock carrying capacity since starting to implement the twelve-point farm plan on 'Talaheni'. This has been achieved despite assigning 25 per cent to various native (re)vegetation management activities for provision of ecosystem services, and enhancing production opportunities on the remaining area. (Stocking rate is calculated on the base of grazed area; DSE= dry stock equivalents).

limiting effects of environmental decline, are at their limit under prevailing conditions for this challenging landscape. Increasing evidence of climate change, bringing higher mean temperatures, higher evaporation and more episodic although possibly increased rainfall (Anon. 2006c), suggests current management will have to be seriously re-evaluated (c.f. Tiffany 2005).

We recognise that we will need new and improved tools (Blackadder 2005) to cope with increasing climate variability. For example, there is an urgent need for regionally-relevant synthetic weather data sets that reflect expected increases in climate variability. The soil-water balance model, which provides a powerful tool for evaluating consequences for future vegetation and management options, can then be used to improve the reliability of predictions and evaluate further options.

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