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The potential contribution of forage shrubs to economic returns and environmental management in Australian dryland agricultural systems

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ABSTRACT

In face of climate change and other environmental challenges, one strategy for incremental improvement within existing farming systems is the inclusion of perennial forage shrubs. In Australian agricultural systems, this has the potential to deliver multiple benefits: increased whole-farm profitability and improved natural resource management. The profitability of shrubs was investigated using Model of an Integrated Dryland Agricultural System (MIDAS), a bio-economic model of a mixed crop/livestock farming system. The modelling indicated that including forage shrubs had the potential to increase farm profitability by an average of 24% for an optimal 10% of farm area used for shrubs under standard assumptions. The impact of shrubs on whole-farm profit accrues primarily through the provision of a predictable supply of 'out-of-season' feed, thereby reducing supplementary feed costs, and through deferment of use of other feed sources on the farm, allowing a higher stocking rate and improved animal production. The benefits for natural resource management and the environment include improved water use through summer-active, deep-rooted plants, and carbon storage. Forage shrubs also allow for the productive use of marginal soils. Finally, we discuss other, less obvious, benefits of shrubs such as potential benefits on livestock health. The principles revealed by the MIDAS modelling have wide application beyond the region, although these need to be adapted on farm and widely disseminated before potential contribution to Australian agriculture can be realized.

1. Introduction

Projected changes in climate will affect many physical and biological systems across the globe (IPCC, 2007). The impacts of changes in temperature, precipitation and other climatic events can be expected to be particularly significant on agriculture due to its ties to a physical resource base and biological balance (World Bank, 2009). The fact that agriculture comprises a substantial proportion of the world's land cover while providing the main livelihood and/or food base for a growing population, will require a major effort of adaptation and mitigation for agriculture across the globe (World Bank, 2009).

In the Mediterranean bioclimates of Australia farmers already face a broad range of environmental challenges. Finding ways to cope with combinations of drought and unseasonable rainfall, rising water tables and soil salinity, soil erosion, soil acidification, herbicide resistance and reduced biodiversity will likely require adoption of novel technologies and modified farming systems. Inclusion of perennial species in farming systems seems like a feasible option to help mitigate the extensive impacts of some of these threats (e.g. Bathgate, 2006; O'Connell et al., 2006; Byrne et al., 2007; Norman et al., 2007). A change from traditional to sustainable farming systems is required at a time when soil salinity is estimated to affect up to 2.1 million hectares of arable land in Australia, with about half of this in Western Australia alone (Bennett and Price, 2007), while in South Australia 6 million hectares of arable land are highly susceptible to wind erosion, and a further 1.2 million hectares are at risk of water erosion (EPA, 2008). In addition, nearly 2 million hectares of agricultural land are affected by soil acidity in that state (EPA, 2008). Farmers will also need to continue to be responsive to economic pressures (e.g. decline in the terms of trade for agricultural commodities, increasing inputs costs), government policies (e.g. carbon trading scheme), social changes (e.g. decline of family farm, shortage of labour), as well as changing market trends and consumer demands.

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The *Enrich* project is intended to contribute to addressing these various challenges. It aims to help farmers develop profitable and sustainable farming systems in the low-medium rainfall zones (300–650 mm) of southern Australia, based around grazing of novel shrubs and shrub-based systems with potential to improve feed utilization and animal health (Revell et al., 2008b). In this target zone there are currently few perennial plant options available.

This project focuses on a range of mostly Australian native forage shrubs, which are especially well adapted to the environmental challenges of this land and, for many, appear to contain bioactive compounds that could be exploited in livestock production (Revell et al., 2008a). *Enrich* researchers are screening over 60 shrub species from genera such as *Atriplex, Rhagodia, Maireana*, *Acacia, Medicago, Drosophila* and *Kennedia* species, amongst others. They are being assessed for their ease of establishment, growth performance, nutritive value for livestock, anticipated impacts on the liveweight and the gut health of livestock, and overall effect on the profitability of farming systems. This information is supported by farmer experiences (Toovey and Revell, 2008) and by computer modelling through the use of Model of an Integrated Dryland Agricultural System (MIDAS), a bio-economic model of a mixed crop/livestock farming system (Kingwell and Pannell, 1987).

This analysis investigates the potential benefits of integrating forage shrubs in a farming system by evaluating shrub biological and management data in a whole-farm economic context using MIDAS. Even though many shrub species have been used successfully for hundreds of years in traditional grazing systems in North Africa (El Aich, 1991) and the Middle East (ICARDA, 2005) and in rangeland production systems elsewhere (Crisp, 1978; Bartolome and McCkran, 1992; Milton, 1994; Watson et al., 1997; Tiver et al., 2006), most previous attempts to use or develop forage shrubs in Australia in managed systems have fallen short of commercial viability. Exceptions include old man saltbush (*Atriplex nummularia*), and tagasaste (*Chamaecytisus proliferus*) that have found niche roles in agricultural landscapes (Dann and Trimmer, 1986; Snook, 1996; Lefroy et al., 1997; Stokes, 2000; Abadi et al., 2005; Bennett and Price, 2007; Liddicoat and McFarlane, 2007).

The *Enrich* project was built on the assumption that shrubs alone will not provide sufficient edible biomass to support productive livestock systems (Barrett-Lennard et al., 2003). This has directed our research towards the incorporation of shrubs into forage systems including a pasture understorey. In addition, the systems under development include a diverse assembly of plants (in space and time) that can collectively provide nutrients and beneficial bioactive compounds for grazing livestock, as well as flexibility in farming systems.

2. The MIDAS model

The circumstances under which novel forage shrubs are likely to be profitable and thus potentially adopted into the farming system are investigated here using Model of an Integrated Dryland Agricultural System (MIDAS). Detailed descriptions of earlier versions of the model are provided by Morrison et al. (1986), Kingwell and Pannell (1987), Pannell and Bathgate (1991) and Young (1995). MIDAS was chosen because its complex framework allows for the integration of biological, physical and financial information relevant to whole-farm economics. The model uses linear programming (LP) to select a farm strategy that maximizes equilibrium farm profit in the medium term (although other objectives may also be defined, such as environmental conservation). Its detailed representation of the farming system allows us to assess: the economic trade-offs of including a new farming option in the system; how the system should be altered to accommodate it; and the overall change in profit when it is included in an optimal way. We acknowledge the importance of applying farming systems models to participatory action learning (e.g. Llewellyn et al., 2004; Pannell et al., 2006), but the actual farmer decision-making process is beyond the scope of this study.

Here we use the Central Wheatbelt version of MIDAS (CWM) (Blennerhassett et al., 2002), which represents a typical crop/livestock farming system in a region of south-west Western Australia (Fig. 1). This region has average annual rainfall of 350 mm, of which less than 20% falls outside the relatively short growing season (May–October). The summer maximum daily temperature is over 30 °C on average. Farms are heterogeneous in terms of soil types, so the model describes eight main land management units (LMU) for the typical 2000 ha farm. Mixed crop-livestock farms make up the majority of farm businesses. Typically, farms in the region allocate 50–60% of their farm area to crops and the remainder to pasture production for livestock grazing, although this varies with the mix of soil types present and with farmer preference. Crops grown in the region include wheat (*Triticum aestivum*), barley *(Hordeum vulgare*), lupins (*Lupinus angustifolius*) and a range of other pulse crop options, triticale (×*Triticosecale*) and canola or rape seed (*Brassica napus*). Sheep are the dominant livestock and are grazed mainly on annual pasture, which vary widely in composition, some improved by planting of high-quality pasture species (e.g. yellow serradella (*Ornithopus compressus*)), some dominated by species that may have been planted for feed purposes decades ago (e.g. subterranean clover (*Trifolium subterraneum*) or annual ryegrass (*Lolium rigidum*)) and some consisting largely of volunteer weeds. There is also a relatively small area of improved perennial pasture (e.g. lucerne or alfalfa, *Medicago sativa*). Historically, wool production from Merino flocks made up the majority of the sheep enterprise, by value of production, but lamb production for meat has increased in recent years as a result of improved prices (ABARE, 2000–2008). The model also includes an option for oil mallee eucalypt trees, a novel enterprise that provides energy, oil and activated carbon, but is not yet firmly established as an economic enterprise in the region.

In addition, the CWM incorporates in its structure: over 60 crop-pasture rotations and their inter-year biological effects (e.g. plant nutrition and disease effects); ten pasture growing periods within the year; 10 major feeding periods within the year; a range of supplementary feeding options (pasture, grain, stubble, hay, forage shrubs); 86 categories of sheep with distinctive characteristics and management options (depending on breed, gender, age, bodyweight, reproductive status, feeding regimes, and lambing/shearing/sale times); different energy and dry matter intake requirements for each sheep category; several grain, stubble and wool quality classes; soil nitrogen balance and fertilization options; deferment of pasture grazing from one time period to the next, allowing for degeneration in terms of both quality and quantity of feed; groundwater recharge; machinery specifications (crop establishment method, machine type, fuel use, contracts, repairs and maintenance); chemical control of diseases, pests and weeds; labour (fixed, casual); and finance (credit, debt limit, interest rates, operation costs, depreciation costs, bi-monthly overhead costs, cash return, profit).

Model outputs include: rotations for each LMU; enterprise areas for each LMU; sheep stocking rates and flock structure; supplementary feed; fertilizer rates; volume of groundwater recharge; expected annual profit; and shadow prices and costs (which indicate the relative value of alternative activities).

Being an optimisation model, MIDAS is not amenable to the sort of validation processes advocated for, say, a biological simulation model. However, it has undergone an extensive process of verification, of expert assessment of input parameters, and of comparison with actual farming practice. A very wide range of issues have been analysed using MIDAS since its creation in 1982, including the