Agricultural Systems 120 (2013) 76–84

Contents lists available at SciVerse ScienceDirect

Agricultural Systems

journal homepage: www.elsevier.com/locate/agsy

# Opportunistic Mediterranean agriculture – Using ephemeral pasture legumes to utilize summer rainfall

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ARTICLE INFO

*Article history:*
Received 29 March 2012
Received in revised form 19 February 2013
Accepted 1 June 2013
Available online 2 July 2013

*Keywords:*
Low-rainfall environments
Climatic variability
*Cullen* species
Novel plants
Crop and pasture residues
Bio-economic modeling

ABSTRACT

The wet winters and summer droughts of dry Mediterranean-type climates create a highly seasonal supply of feed for livestock. Much of the forage value of winter-active annual pastures and crop residues is realized as dry feed during summer–autumn. Sporadic summer–autumn rainfall rapidly degrades the quality of dry plant residues. In low rainfall areas of the southern Australian wheatbelt, there are no well-adapted crops or pastures to convert summer rainfall into high-quality green feed and supplementary feeding is required to maintain livestock condition. We therefore investigated two undomesticated ephemeral legumes (*Cullen cinereum* and *Cullen graveolens*). In a field experiment, the ephemerals were dormant in winter–spring and responded strongly to summer rainfall, with 0.45–0.82 t ha$^{-1}$ of shoot dry weight produced over summer. Extrapolation of regional historic rainfall records showed similar or greater summer–autumn rainfall in 40% of years and also suggested that conditions will probably be too dry for perennial pastures such as *Medicago sativa* (lucerne) to persist in up to 60% of years. An analysis using MIDAS, a bio-economic model, suggested that ephemerals could increase total farm profit and stocking rates (10.3% and 7.7%, respectively), and decrease supplementary feeding of grain by >50% by providing high quality feed in years that summer–autumn rainfall occurs. We suggest there is considerable potential for ephemeral legumes to contribute to the sustainability of mixed agriculture in dry Mediterranean-type climates by utilizing sporadic summer rainfall whilst complementing existing annual pasture and cropping systems.



## 1. Introduction

Strongly seasonal environments present constraints to livestock systems due to peaks and troughs in feed quantity and quality. The present study focused on low-rainfall zones in dry Mediterranean-type climates which are characterized by hot, dry summers and mild, wet winters. Although characterized by a long, dry summer period, thunderstorms and degraded tropical cyclones can bring episodic summer–autumn rainfall to these regions, at least in Australia. Agricultural areas that receive infrequent summer–autumn rainfall events generally do not convert rainfall into additional forage due to a lack of profitable, commercial summer-forage options and poor persistence of summer-active perennial pastures.

Livestock in Mediterranean farming systems that are based on winter-active annual plants rely on dry plant residues during summer–autumn (Puckridge and French, 1983). When dry plant residues get wet, they rapidly degrade due to microbial activity and leaching of soluble nutrients. Rossiter et al. (1994) found single thunderstorms during summer can reduce the digestibility of high-quality dry pasture residues below those required for maintaining livestock condition. Brown (1977) reported different degradation rates among plant types, with high-feed-value legume residues degrading the most rapidly once wet. Thus, for livestock systems, supplementary feeding or alternate high-quality feed sources are required if summer–autumn rainfall occurs.

Although summer–autumn rainfall in dry Mediterranean-type environments such as south-western Australia is considered to provide little opportunity for plant growth due to high evaporation and temperatures, summer rainfall contributes to weed growth that can often be deleterious to stock (e.g. *Tribulus terrestris*, Aslani et al., 2003) or self-sown crop plants that increase the risk of disease carry-over to following crops (Roget et al., 1987). Summer-active weeds complete their entire life-cycles in dry Mediterranean-type environments in response to episodic rain events during summer–autumn. This demonstrates that at least some forage production is possible even with very infrequent rainfall, providing suitably–adapted plants possess adequate forage quality. Plants with such short growth seasons, and which may be absent most years, are often referred to as ephemerals.

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0308-521X/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.agsy.2013.06.001

We present the concept of using ephemeral summer-active plants as a means to offset the losses in feed quantity and quality that occur due to summer–autumn rainfall events. Our interest is focussed on environments where perennial pasture options are limited and/or winter-annual crops are dominant. We use the undomesticated native Australian legumes *Cullen cinereum* (Lindl.) J. W. Grimes and *Cullen graveolens* (Domin) J. W. Grimes (previously *Psoralea cinerea* and *P. graveolens*) as model ephemeral plants and the low rainfall, dry Mediterranean-type climate in the eastern wheatbelt of Western Australia as a case study. We present data from a field experiment and farming system modeling using the bio-economic model MIDAS (Model of an Integrated Dryland Agricultural System) (Kingwell and Pannell, 1987). Key opportunities for their potential role are then discussed.

## 2. Materials and methods

### 2.1. Field experiment

The field experiment was located approximately 25 km north-east of Mukinbudin (−30.78°, 118.31°) in the low rainfall zone of the wheatbelt of Western Australia. Mukinbudin has a dry Mediterranean-type climate and a mean annual rainfall (MAR) of 286 mm (http://www.bom.gov.au/climate/data/). The field site soil was a duplex, red-brown colored, sandy clay loam over calcareous clay that had been cropped with wheat for the previous 3 years. The pH ($CaCl_2$) ranged from 6.5 near the surface (0–0.1 m) to 8.5 in the highly sodic and alkaline subsoil (>0.4 m). The soil contained 12 mg $kg^{-1}$ mineral nitrogen and 12 mg $kg^{-1}$ bicarbonate extractable (Colwell) phosphorus (0–0.2 m). The organic carbon content was 0.35% w/w (0–0.2 m). No fertilizer was applied. The experiment was a randomized block design, with 24 plots consisting of 4 replicates of 6 legume species and accessions/cultivars (Table 1). Seeds were scarified where required and inoculated with appropriate rhizobia in peat inoculum. The experiment was sown on 5 May 2008 by hand (5–15 mm depth), with 16 pre-germinated seeds $m^{-2}$ in each 4 × 4 m plot. Only the middle 3 × 3 m of each plot was sampled.

The plots were maintained as monocultures by hand weeding. Little rainfall was received after sowing, so 7.5 mm of irrigation was applied on 1 and 4 June 2008. On the 15th of each month, photographs were taken from a tripod on a permanent marker in each plot. These photographs were used to visually compare growth and estimate biomass from dry weights harvested on 15 October 2008 (*M. truncatula* (medic) only), 15 April 2009 (both *Cullen* spp. and *M. sativa* (lucerne)) and 15 October 2009 (lucerne only). Shoot dry weights (DW) were obtained by cutting all plants 30–50 mm above the base of the stems, followed by drying at 60 °C for 72 h.

### 2.2. Regional historic rainfall assessments

Historic monthly rainfall data were downloaded (http://bom.gov.au/climate/data) from 142 weather stations that are dispersed throughout the wheatbelt of Western Australia. These were then allocated to the agro-climatic zones of the wheatbelt of Western Australia described by the Department of Agriculture and Food, Western Australia, for summarizing crop variety suitability (Brown, 1994). These zones are defined in terms of MAR isohyets and wheatbelt boundaries to give L-low (<325 mm), M-medium (325–450 mm) and H-high (450–750 mm) rainfall zones. Superimposed on these are north–south divisions reflecting changes in solar radiation and temperature gradients giving zones 1–5. The M5 and H5 (southern-most high and medium rainfall) zones are divided further into west, central and eastern zones due to their wide distribution across the south coast.

The 142 sites were selected on the basis of how complete they were and to ensure an even spread of data across the zones. Small data sets (<30 complete years) were avoided wherever possible and as many sites as possible were used for each zone. The growing season for 'winter' annual crops and pastures is May–October and summer–autumn or 'out-of-season rainfall' was considered November–April. Years with >100 mm summer–autumn rainfall (similar to the rainfall in the first summer–autumn of the field experiment) were counted at each site. Seasons with any missing data were omitted from the analysis. The frequency of years with >100 mm summer–autumn rainfall was averaged for each agro-climatic zone and presented visually to give an overview of the distribution of summer–autumn rainfall across the wheatbelt.

### 2.3. Farming system modeling

The MIDAS Eastern Wheatbelt Model (EWM) is a whole-farm bio-economic model, which considers the biological, physical, technical and financial aspects of farming systems representative of farms in the low rainfall (∼300 mm MAR) eastern wheatbelt regions of Western Australia. The objective function of the model is profit maximization with farm enterprises being selected on the basis of assumed yields, system interactions, commodity prices and overheads (Kingwell and Pannell, 1987). When used in its normal configuration, MIDAS reflects an average farm in an average season. Assumptions relating to resource requirements and performance have been suggested by Department of Agriculture and Food, Western Australia, researchers and advisors based at the Merredin Dryland Research Institute. The major crops included in the model are bread wheat (*Triticum aestivum*), barley (*Hordeum vulgare*), oats (*Avena sativa*), triticale (× *Triticosecale*), canola (*Brassica napus*), lupin (*Lupinus angustifolius*), field pea (*Pisum sativum*), chickpea (*Cicer arietinum*) and faba bean (*Vicia faba*). Annual pastures are based on traditional *Trifolium subterraneum* and annual *Medicago* spp. ley pastures and livestock systems involve self-replacing flocks of merino sheep farmed for wool and meat.

### 2.4. Modifications of MIDAS to consider weather scenarios

Due to the high variability in summer conditions in the study environment, weather effects on crop and pasture production, changes in plant residue quality and quantity, and requirements

**Table 1**
The 6 legume species, accessions/cultivars, sources of seed and rhizobia used in the field experiment.

| Species | Accession/cultivar | Seed source | Rhizobia source |
|---|---|---|---|
| *Cullen cinereum* | Bill022CC | The University of Western Australia collection | Fortescue[a] |
| *C. cinereum* | Fortescue[a] | Mulga Research Centre | Fortescue[a] |
| *C. graveolens* | AusTRCF320184 (QLD origin) | Australian Tropical Crops and Forages GRC | Fortescue[a] |
| *C. graveolens* | Fortescue[a] | Mulga Research Centre | Fortescue[a] |
| *Medicago sativa* | cv. Sardi10 | Commercially available | AL type commercial |
| *M. truncatula* | cv. Caliph | Commercially available | AM type commercial |

[a] Seed and rhizobia of Fortescue accessions were collected from −22.85°, 120.21° by Mulga Research Centre, Curtin University of Technology, WA. Rhizobia were trapped from soil collected under host plants and sent to Rutherglen Department of Primary Industries, Victoria, Australia for development of peat inoculum.