HYDROLOGIC UTILITY OF PHASE FARMING BASED ON WINTER RAINFALL IN SOUTH EASTERN AUSTRALIA.

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Abstract

Landscape salinity derives from the hydrologic excess caused by the inability of winter annuals to utilise rainfall that exceeds evapotranspiration and soil storage of rainfall in winter in south eastern Australia. A simple model is used in a spatial risk framework to investigate hydrologic need for a short-term perennial pasture phase in existing winter annual grains production systems (phase farming). The model relies on a dual premise. Firstly, practical consequences of differences in species water use capability in SE Australia are evidenced by pre-winter soil water deficit. Secondly, the prerequisite for annual *in situ* rainfall consumption (hydrologic balance) is a pre-winter soil water deficit that allows the storage, by soil, of rainfall that exceeds evapo-transpiration (ET) in winter . Investigations for the southern Murray-Darling Basin relied solely on historic winter rainfall data. Results are discussed in terms of the aim to identify those areas where phase farming potentially redresses the hydrologic imbalance associated with winter annual species.

Key Words: Hydrology, phase farming, annuals, perennials, spatial risk

Introduction

Southern New South Wales and northern Victoria experience a uniform distribution of rainfall within years, and a large variation between years. Climate is 'pseudo' Mediterranean: 'wet' winters and 'dry' warm summers alternate in concert with solar radiation and evaporative demand. Rainfall commonly exceeds ET in winter.

Accordingly, soil water undergoes alternating cycles of repletion and depletion in winter and non-winter months, respectively. Climatic limitations on ET in winter are compounded by the minimal plant cover of regenerating annual crops and pastures. Conversely, the depletion phase is driven by the substantial evaporative demand that develops in spring, and the ultimate achievement of full plant cover. Winter annual farming systems are geared to the narrow window of climatic and soil water conditions favourable to plant growth in spring, and culminate in the terminal drying cycle that determines optimal flowering time (2).

By contrast, deep-rooted agronomic perennials, such as lucerne and phalaris, exploit subsoil water that is inaccessible to winter annuals. Their hydrologic value (and difficult agronomic management) derive from drought tolerance mechanisms that provide for survival through summer.

Increasing land and stream salinisation in SE Australia is attributed to the low annual ET of winter annual species by comparison with that of displaced native vegetation. By analogy, phase farming potentially redresses the hydrologic deficiencies of winter annual species.

This paper describes a simplified water balance model and its spatial application in a first-order appraisal of the ameliorative hydrologic benefit afforded by deep-rooted agronomic perennials in the southern Murray-Darling Basin.

Materials and methods

Simplified water balance model

Whitfield *et al.* (4,5) reported that differences in water use capability of winter annuals and deep-rooted perennials were expressed by pre-winter soil water deficits of 135 mm and 210 mm, respectively. According to the water balance equation, change in soil water content (Δ S) for rainfall, RF, in winter is:

$$\Delta S = RF - ET + (RO\&DD)$$

where (RO&DD) is excess rainfall dissipated as runoff (RO) and/or deep drainage (DD). Δ S is the upper bound to immediate rainfall storage, whereas (Δ S + ET) constitutes the ultimate limit to rainfall dissipation as ET where stored carryover winter rainfall contributes effectively to post-winter ET. Rainfall is dissipated as (RO&DD) when soil storage capacity is exceeded in winter. Pre-winter soil water deficits of 135 and 210 mm therefore provide respective upper bounds, ($135 + ET_W$) and ($210 + ET_W$), to the dissipation of winter rainfall, RF_W, as ET. Accordingly, ET_W was estimated by standard agrometeorological methods (1) based on Class A Pan evaporation, $E_{Class\ A}$:

$$ET_W = k_c\, k_p\, E_{Class\ A}$$

for the period, May - Aug, incl., using a value of 0.35 for the crop coefficient, k_c, and a value of 0.75 for the pan coefficient, k_p. $E_{Class\ A}$ was assumed to approximate 50 mm/ month in SE Australia. ET_W was therefore taken as 50 mm for the soil water repletion phase, May - Aug., yielding winter rainfall thresholds of 185 mm and 260 mm for winter annuals and deep-rooted agronomic perennials, respectively.

Annual *in situ* rainfall consumption, defined by $ET_W + ET_{SSA} = RF_W + RF_{SSA}$, where subscript, SSA (?spring + summer + autumn?), references the depletion phase, relies on minimal annual excess rainfall. That is, the condition:

$$(RO\&DD)_W = (RO\&DD)_{SSA} \Rightarrow 0,$$

requires $\Delta S_W + \Delta S_{SSA} \Rightarrow 0$.

Spatial risk analysis

Following general procedures outlined by Hutchinson (3), amount and probability of total rainfall for the months, May - August, were calculated for all rainfall stations in the region bound by the range of latitude, -33.20? S to -37.30? S, and longitude, 141.0? E to 148.8? E, subject to the availability of 20 years of complete monthly records for a station in the historic rainfall data (Bureau of Meteorology, Melb.).

Data for 700 stations were subjected to regression analysis, using Genstat 5.3. Analyses used elevation as an independent variate, and cubic splines for the variables, longitude and latitude. Regional response surfaces were generated from fitted functions, based on the variation of elevation with longitude and latitude as described by the digital elevation model, AUS40.DEM (CRES, ANU, Canberra).

Results

Fig.1 shows the probability that winter rainfall exceeds 185 mm. The data show an increasing incidence of 'wet' winters, ranging from $P(RF_W > 185) < 0.10$ in the north-west to $P(RF_W > 185) > 0.9$ in the south-east.

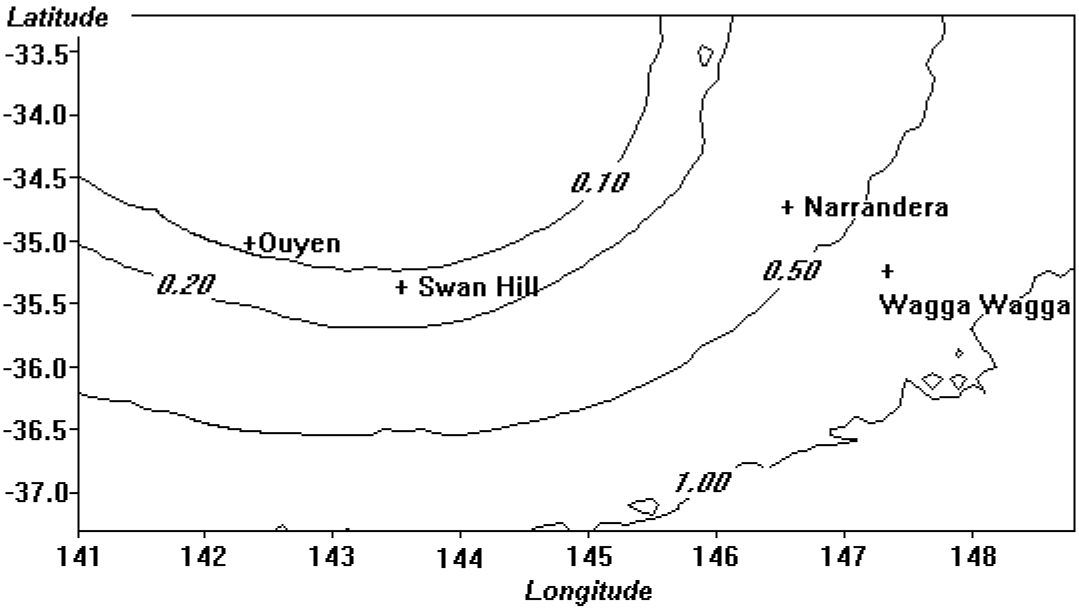

Figure 1. Spatial variation in $P(RF_W>185)$ with latitude and longitude. Contours are shown for P = 0.10, 0.20, 0.50 and 1.00.

The East West transect through Wagga Wagga (-35.25? , 147.34? E) includes the Victorian Mallee at longitudes < 144.0? E. Major variations in $P(RF_W>185)$ and $P(RF_W > 260$ mm) exist on the transect, as shown in Table 1. Maximum winter rainfall approximates 260 mm in the Mallee region, as shown by values, $P(RF_W>185) \leq 0.2$ and $P(RF_W>260) \approx 0.0$. The incidence of excess winter rainfall for both winter annuals and deep-rooted perennials increases rapidly to the east, culminating in $P(RF_W>185) \approx 0.90$ and $P(RF_W>260) > 0.70$, respectively, at longitude, 148? E.

Table 1. Changes in $P(RF_W>185)$ and $P(RF_W>260)$, and mean winter rainfall excess in years when May - Aug rainfall exceeds 185 ($RF_W > 185$) and 260 mm ($RF_W > 260$), with longitude at latitude, -35.2? .

Longitude:	141	142	143	144	145	146	147	148
$P(RF_W>185)$	0.15	0.15	0.15	0.18	0.21	0.31	0.72	0.90
$P(RF_W>260)$	0.02	0.02	0.02	0.03	0.04	0.07	0.28	0.74
$RF_W > 185$	3	5	5	6	7	11	42	207
$RF_W > 260$	0	1	1	1	1	2	15	140

Attendant changes in mean winter rainfall that exceeds thresholds of 185 mm and 260 mm (mean winter excess rainfall) indicate that winter annuals achieve *in situ* rainfall consumption in the arid zone at longitudes to 145? E, where values, $P(RF_W>185) \leq 0.2$, resulted in mean (RF_W - 185) < 10 mm.

Similarly, mean winter rainfall exceeding 260 mm was < 10 mm at longitudes to 146.5? E (approximating Narrandera; -34.75? , 146.55? E). Thereafter, mean winter rainfall exceeding thresholds of both 185 mm and 260 mm increased rapidly.

Discussion

The data elucidate three major features of the hydrological response function applying to winter annual farming systems in the region. These include the ?arid? zone, where soil water deficits of ca. 135 mm suffice for hydrologic control, an intermediate zone where the larger soil water deficits of deep-rooted perennials provide for annual *in situ* rainfall consumption, and an extensive 'high-rainfall' zone where both deep-rooted agronomic perennials and winter annuals shed a significant proportion of winter rainfall as either runoff or deep drainage. The spatial delineation of these zones is an important first step towards an objective coupling of hydrologic and agronomic management in the region.

Several features of the model impact on the interpretation of outcomes. Firstly, the assumption was made that winter annuals and deep-rooted perennials provide for soil water deficits of 135 mm and 210 mm, respectively, throughout the region. These assumptions are tenable if soils are physically and chemically capable of supporting soil water deficits of the respective magnitude. Additionally, crop agronomy must provide for a ground cover conducive to the consumption of spring rainfall and carryover soil-stored water. Sub-optimal ground cover compromises soil water depletion and maximal pre-winter soil water deficits (4, 5), as exemplified by fallows.

Impacts of the soil and agronomic assumptions appear to apply differentially within the region. For example, mean rainfall exceeding 185 mm in ?wet? years averaged < 10 mm in the ?arid? zone, suggesting a minimal requirement for hydrologic intervention. The actual hydrologic balance within the zone varies with the incidence of shallow or light soils of modest water holding capacity and, also, fallowing. The ?arid? zone may therefore benefit from hydrologic control imparted by deep-rooted perennials, subject to soil factors and the local adaptation of species.

Deep-rooted perennials provided for annual *in situ* rainfall consumption on the transect at longitudes < 146.5? E. Lucerne, the most likely deep-rooted perennial for inclusion in phase farming systems, was estimated to confer hydrologic balance (winter rainfall excess ≤ 10 mm), whereas winter rainfall excess of winter annuals ranged to ca. 30 mm ($P(RF_W>185) \approx 0.45$; $P(RF_W>260) \approx 0.20$). Average annual excess rainfall was 13.5 mm under winter annuals and ~ 2 mm under lucerne, suggesting that 30% of the landscape in lucerne would provide for effective hydrologic control at 146.5? E, the easterly limit of the non-arid phase-farming zone. The landscape value represents one year of lucerne in three, the absolute maximum frequency for inclusion of lucerne in cropping systems using current technology applied at a paddock scale. Subject to earlier considerations, landscape proportions and paddock frequencies decline towards the arid zone.

Conversely, the ability to contain average annual excess rainfall by substituting deep-rooted perennials for winter annuals decreased rapidly beyond 146.5? E on the transect. East of Wagga Wagga at 148? E, for example, average annual excess rainfall was ca. 140 mm in a lucerne-dominated landscape, compared to a mean of ca. 200 mm for winter annuals. These data indicate an hydrologic demand for trees and/or shrubs in the 'high rainfall' zone .

Conclusion

Phase farming practices apply in a restricted zone of the southern Murray-Darling Basin. Subject to model assumptions, the apparent minor justification for deep-rooted perennials in the north-west contrasts with a progressive demand for hydrologic control in winter annual enterprises to the south-east that rapidly extends beyond the water use capabilities of deep-rooted agronomic perennials.

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References

1. Doorenbos, J., and Pruitt, W. O., 1975. In: Crop Water Requirements. (FAO Irrigation and Drainage Paper 24) pp. 30 - 40.

2. Fischer, R. A., 1979. *J. Aust. Inst. Agr. Sc.* **45**: 83-89.

3. Hutchinson, M. F., 1989. *CSIRO Div. Water Resources Tech. Memo.* 89/5: 95 - 104.

4. Whitfield, D.M., Newton, P.J., and Mantell, A., 1992. *Proc. 6th Aust. Agron. Conf.*, Armidale. p. 263.

5. Whitfield, D.M., Newton, P.J., and Feehan, T.K., 1993. Proc., 'Land Management for Dryland Salinity Control', La Trobe University, Bendigo, Vic. p. 54.