The role of groundwater depth on the hydrological benefits of lucerne and the subsequent recharge values

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Abstract

Large areas of cleared agricultural land in Western Australia are affected by dryland salinity. The cause of this salinity is excessive recharge under traditional agriculture, leading to rising groundwater levels. To effectively reduce land and water salinity a deep-rooted perennial, such as lucerne, is needed to reduce recharge and lower groundwater levels.

The data presented in this paper show that lucerne becomes more effective as groundwater levels drop and >3 m to groundwater level is required for realising the full benefits of lucerne. It demonstrates that the beneficial impact of lucerne extend beyond its life span.

Introduction

An increasing area of cleared land in Western Australia is becoming salt-affected. The cause of this salinity is excessive recharge under traditional agriculture, leading to rising levels of naturally saline groundwater. Lucerne (*Medicago sativa*), which has deep roots, is promoted to reduce recharge and contain salinity. This deep-rooted perennial can dry the soil profile and create storage for excess rainfall within its own phase and in subsequent cropping phase.

This paper explores the recharge processes operating during 15 years of crop-lucerne-crop-lucerne periods in a phase farming system. It quantifies groundwater level decline in various stages of lucerne growth and shows that as groundwater levels drop, lucerne becomes more effective in reducing or preventing recharge. Finally, the paper attempts to quantify and separate the effects of rainfall from the effects of lucerne using the HARTT method of hydrograph analysis (Ferdowsian *et al.* 2001).

Methods

The selected site is in the Jerramungup District (Fig. 1; 119?11′ E, 33?36′ S) on the south coast of Western Australia. The area has hot summers (December - February) and cold winters (May - September). The average annual rainfall is 400 mm. Sixty percent of the annual precipitation falls during the cereal growing season (May to October). A 70 ha paddock was selected in 1990. It includes the whole toposequence, which is 1200 m long. Groundwater has a local-scale flow system and the hydraulic head surfaces conform to local topography. The paddock was cleared in 1964 and cropped continuously until 1992 when it was sown to lucerne. Lucerne grew together with annual pastures in winter and on its own in summer between 1992 and 1998. A cereal crop was grown in 1998 and grew together with some surviving lucerne plants. Between 1999 and 2001 lupins and after that cereals, replaced both plant types. Lucerne was replanted in June 2002.

Two observation bores were drilled in 1988. Bore GB1 was drilled in the mid-slope, approximately 300 m upslope of a saline seep. The second bore (GB2) was located in the lower-slope in the same paddock. Bore GB2 was approximately 30 m upslope of an expanding saline seep. The depth to groundwater was measured once every 3 months (62 records over 15 years).

Evaluation method and statistical analysis

The HARTT (Hydrograph Analysis Rainfall and Time Trends) method (Ferdowsian *et al.* 2001) was used to supplement the standard empirical analysis of hydrographs. This model is appropriate for cases where there is no major change in land use during the period of analysis. To include the impacts of changes in land use, we define two types of dummy variables. The use of dummy variables is explained by Ferdowsian and Pannell (2001).

Results and discussion

Table 1 shows the statistical regression results, including all the terms, which had significant impact on groundwater levels. The selected models fitted the data extremely well, explaining >95?% of variation in groundwater levels. All selected variables were statistically significant (Table 1). The fitted graphs followed the actual data very well (Figure 1 for GB1 and GB2).

The time lag (in months) between rainfall and its impact on groundwater

At the mid-slope position, the lengths of the time lags increased from one month to 3 months, as lucerne became effective and groundwater levels dropped (Table 1). The increased time lag implies there will be longer period for lucerne roots and soil profile to absorb moisture and reduce recharge. In the lower-slope (GB2), the lengths of the time lag between rainfall and its impact on groundwater remain the same (one month). This was despite groundwater levels dropping to 3 m.

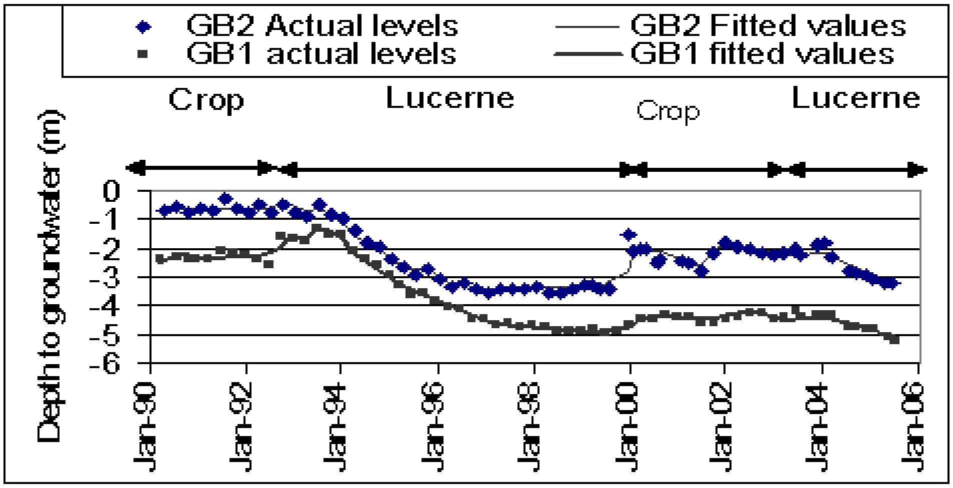

Figure 1. Groundwater level changes in relation to treatment in GB1 and GB2.

Effects of Rainfall on groundwater levels

Excessive rainfall had very little or no impact on groundwater level when it was very close to the soil surface (GB2; Table 1). This is because there was little or no storage capacity for water. In the absence of lucerne rainfall had significant impact on groundwater levels in GB1 (mid-slope; Table 1), where the levels were >1.6 m below the soil surface. After planting lucerne, the impact of rainfall on groundwater was reduced. Three incidences of >80?mm/month rainfall occurred during the last stages of lucerne in Phase-1. Despite these high rainfalls, no significant impacts on groundwater levels were observed (Table?1). This indicates that very little or no recharge occurred in these stages.

Underlying trend in groundwater levels and effects of treatments

Prior to the planting of lucerne (May 1990 - July 1992), there was no statistically significant time trend in groundwater levels in GB1. This is not surprising since with such a shallow watertable, there would be significant discharge at the site (or nearby areas) to offset any ongoing recharge. During the same period, groundwater levels under the mid-slope continued to rise (Table1).

Table 1: Statistical analysis results after excluding the non-significant terms.

Parameters	**GB1; Mid-slope**		**GB2; Lower-slope**	
	Coefficients	***P*-value**	**Coefficients**	***P*-value**
R^2	0.989		0.953	
Intercept	-2.539	0.0000	-0.662	0.0000
Pre-lucerne period (31 months)	**2.4 to 1.59 m***		**0.46 to 0.80 m***	
Effect of rainfall	0.0022	0.0083	N/S	
Pre-lucerne trend (m/month)	0.0096	0.0252	N/S	
First stage in lucerne (30 months)	**1.59 to 3.45 m***		**0.80 to 2.50 m***	
Effect of	0.0043	0.0000	0.0024	0.0001
Trend 32-61 Months (m/month)	-0.0345	0.0000	-0.0612	0.0000
Second stage in lucerne (23 month)	**3.45 to 4.58** m*		**2.50 to 3.43** m*	
Effect of rainfall	N/S		0.0029	0.0308
Trend 62-85 months (m/month)	-0.0572	0.00000	-0.0352	0.0000
Third stage in lucerne (25 months)	**4.58 to 4.98 m***		**3.43 to 3.44 m***	
Effect of rainfall	N/S		N/S	
Trend 86-111 months (m/month)	-0.0115	0.0043	N/S	
28 months cropping period after lucerne	**4.98 to 4.28 m***		**3.44 to 2.10 m***	
Effect of rainfall	0.0015	0.0022	0.0045	0.0000
Trend during second cropping period	0.0196	0.0000	0.0416	0.0000

33 months of lucerne after cropping	**4.28 to 5.11 m***		**2.10 to 3.21 m***	
Effect of rainfall	0.0019	0.0033	0.0035	0.0065
Trend Second lucerne (m/month)	-0.0266	0.0000	-0.0485	0.0000

N/S = Not significant; they were removed from the model.
* = Depth to water level during that period.

Lucerne was shown to reduce groundwater levels. The estimated net effect of lucerne during the first phase was up to 2.7 m reduction in groundwater levels over 80 months (Table 1). The impact during 34 months of the second phase was a drop of only 0.86 m in mid-slope and twice that in the lower-slope.

Conclusion

The two case studies and the data presented in this paper show that lucerne reduced recharge and lowered groundwater levels in the whole toposequence. Lucerne intercepted more of the rainfall as saline watertable dropped. This indicates that the exploration zone of lucerne’s roots extended into the depths previously occupied by saline groundwater. These positive effects occurred despite having very saline groundwater (between 25,000 mg/L and 26,000 mg/L) and high initial groundwater levels (0.5 m and 1.6 m below soil surface). Another important observation was that less recharge occurred during the cropping phase that followed the lucerne.

References

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