Seasonal variation in long term estimates of soil water balance predicted by the SGS Pasture Model for a native pasture in northern New South Wales

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Estimating components of the long term soil water balance [SWB, Rainfall (R)= Evapotranspiration (Et)+ Surface runoff (Ro) +sub-surface lateral flow (Lf) + Drainage (D)] is essential to understanding the factors limiting pasture production in an environment and highlighting potential problems of soil erosion (from excessive runoff) or dryland salinity (by excessive drainage leading to rising water tables). Hence, within the Sustainable Grazing Systems (SGS, Mason and Andrew 1998) Program a substantial effort has gone into understanding the SWB for different environments and pasture types, including trees through both pre-experimental modelling (Simpson *et al.* 1998) and the development of the SGS Pasture Model (Lodge *et al.* 2001). Long term modelling (1971-1993, Simpson *et al.* 1998) of a native pasture in the Quirindi district of northern New South Wales indicated that evapotranspiration was likely to be 93% of average annual rainfall with runoff and drainage averaging 25 and 21 mm, respectively per year. However, there were substantial seasonal and yearly variations in these predictions and these were further examined using the SGS Pasture Model.

METHODS

Daily climate data for Tamworth (rainfall, maximum and minimum temperature, relative humidity, solar radiation and pan evaporation) were extracted from a Silo data drill for the 31-year period from 1971 to 2001. These data were applied to the SGS Pasture Model parameterised from site data (herbage mass, species composition, soil water content, hydraulic conductivity, and animal liveweight). The site was a red grass (*Bothriochloa macra*) dominant native pasture on a red chromosol soil type set stocked at 4 sheep per ha from spring 1997 to spring 2001 on the North-West Slopes of NSW, with no fertiliser inputs. The model was then run for these stocking rate and fertiliser inputs for the 31 years of daily climate data (after an 5 year initialisation period) to obtain annual estimates of the SWB and predicted values for evapotranspiration (using the Priestley-Taylor equation), surface runoff, sub-surface lateral flow and drainage (below 210 cm) each year. Sub-surface lateral flow was always <1 mm/year and so no data have been presented for this term.

Long term monthly rainfall data for Tamworth (1889-2001, Clewett *et al.* 1999) were used to classify years and seasons (summer and autumn, winter and spring) relative to the average. Long term annual average rainfall was 677 mm and average rainfall from December to May inclusive (summer and autumn) was 362 mm, compared with 316 mm from June to November (winter and spring). Based on rainfall, the calendar years and season between 1971 and 2001 were then categorised as being either; above average (i.e actual rainfall higher than 677 mm), below average (between 677 and 677 x 0.9 mm), dry (between 677 x 0.9 and 677 x 0.75), very dry (between 677 x 0.75 and 677 x 0.67 mm), or, extremely dry (rainfall less than 677 x 0.67 mm). Calculated values therefore corresponded to the 10, 25 and 33 percentile levels.

RESULTS AND DISCUSSION

Average annual rainfall for the 31-year period was 663 mm compared with the long term (113-year) annual average of 677 mm. The predicted long term SWB (mm) was;

663 (R) = 589 (Et) + 17 (Ro) + 1 (Lf) + 56 (D),

with Et, Ro and D accounting for 88.8, 2.6 and 8.4 % of average annual rainfall. These values are in reasonable agreement with those of Simpson *et al.* (1998), with the higher drainage value in the current study being influenced by the above average rainfall years from 1996-1998, with these 3 years accounting for 22% of total drainage from 1971-2001.

Annual rainfall was above the long term average in 12 of the 31 years (Table 1). In 6 of these years (1971, 1976, 1983, 1996, 1997, 1998) the amount of both surface runoff and deep drainage was predicted to be above the annual average for these parameters. For surface runoff, the predicted annual average was 17 mm (range 0-66 mm), while for drainage the annual average was 56 mm (2-272). The large ranges in these predicted values highlight both the large between year variability in runoff and drainage and the need to adequately incorporate the differing underlying processes into a biophysical model.

Surface runoff was predicted to be above average in 9 of the 12 above average rainfall years (Table 1). For 7 of the 9 years that runoff was predicted to be above average, rainfall was also above average rom December to May, compared with above average rainfall in June to November in 4 of the 9 years (Table 1). However, in 3 of the years when runoff was predicted to be above average, annual rainfall was categorised as below average or dry, with rainfall from December to May being above average in 2 of these years (1974 and 1991, Table 1).

Runoff volume is markedly affected by rainfall intensity and in particular peak intensity and duration. These events occur at a time scale of minutes and so are not adequately represented by daily rainfall data. In the SGS Pasture Model, daily rainfall was distributed by a frequency distribution to reflect the likelihood of high intensity rainfall events. While this provides comparative long term predicted values, it should be noted that most of the volume

Table 1. Actual annual rainfall (mm) at Tamworth (1971-2001) and the classification of years, December to May (inclusive) and June to November into above average (Above), below average (Below), Dry, V. dry and E. dry rainfall categories, together with the predicted annual values (mm) for evapotranspiration, runoff and drainage.

Year	Annual rainfall (mm)	Compared with long term average Year	Dec-May	June-Nov.	ET	Runoff	Drainage
1971	820	Above	Above	Below	545	32	272
1972	599	Dry	Dry	Dry	598	1	9
1973	754	Above	Dry	Above	701	2	10
1974	577	Dry	Above	V. dry	552	66	44
1975	672	Below	Dry	Dry	599	15	8
1976	756	Above	Above	Dry	619	30	145
1977	698	Above	Above	E. dry	606	43	30
1978	904	Above	Above	Above	704	0	133
1979	581	Dry	Below	Dry	653	11	18
1980	420	E. dry	E. dry	E. dry	399	1	5
1981	546	Dry	V. dry	Above	479	0	3
1982	547	Dry	Below	E. dry	400	59	59
1983	876	Above	Above	Above	811	21	70
1984	805	Above	Above	Above	673	0	117
1985	613	Below	V. dry	Below	600	1	49
1986	487	V. dry	Dry	Below	468	0	14
1987	671	Below	Dry	Below	655	5	31
1988	749	Above	Above	Dry	629	19	38
1989	590	Dry	Above	Dry	544	11	81
1990	591	Dry	Above	V. dry	520	3	52
1991	658	Below	Above	E. dry	520	25	55
1992	538	Dry	Below	Dry	624	0	33
1993	650	Below	Dry	Above	606	7	6
1994	422	E. dry	Dry	E. dry	430	3	3
1995	683	Above	Dry	Above	586	44	2
1996	890	Above	Above	Above	716	47	79
1997	746	Above	Above	V. dry	585	32	147
1998	860	Above	Above	Above	627	26	158
1999	664	Below	E. dry	Above	633	2	27
2000	607	Dry	Dry	Above	556	6	6
2001	640	Below	Below	Below	621	17	29

of surface runoff occurs in a relatively few events.

Drainage was predicted to be above average in 8 of the 12 above average rainfall years (Table 1). For all of these years, rainfall was also above average for the period from December to May, compared with above average rainfall in June to November for 5 of the 8 years (Table 1). However, in 2 of the years when drainage was predicted to be above average (1982 and 1989), annual rainfall was categorised as dry, but rainfall from December to May was above average in 1989. Similar to runoff most of the drainage also occurred in relatively few years.

CONCLUSIONS

The highest proportion (around 89% of average annual rainfall) of water lost from the native pasture modelled was predicted to be from evapotranspiration. Since evapotranspiration is related to green leaf area and the amount of canopy, litter and ground cover then the manipulation of these components of the pasture system by graziers should affect the partitioning of water and its use for pasture production.

Clearly, from these data, both surface runoff and drainage of water were episodic events that tended to be associated with above average rainfall years and in particular above average rainfall in summer and autumn. However, their episodic nature makes them difficult to manage for and while high (>70%) ground cover will reduce surface run off, high rates of drainage (~ 150 mm/year) will occur in wet years.

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