Soil Water Balance and a Water Satisfaction Index for Mustard Grown under Dryland Conditions.

L. C. Dharmasri*, and E. de Jong, Department of Soil Science, University of Saskatchewan.

Abstract

Mustard (*Brassica juncea* L. Coss) was grown under dryland condition in western Canada (near Saskatoon) and in southern Sri Lanka. Soil water balance for the cropping period was calculated , using data on climate, soil moisture, and root growth. Actual crop evapotranspiration was calculated and used to estimate water use efficiency for each location. A water Satisfaction Index was calculated based on cumulative deficit in water use during the crop growth. More rainfall but lower precipitation use efficiency was observed in tropical dryland conditions (rainfed uplands) in comparison to conditions at Saskatoon. The soil water balance indicated higher dependence of crop growth on seasonal rainfall in tropical conditions and more efficient use of precipitation and water stored in the soil profile under conditions at Saskatoon. Constraints to efficient use of precipitation under tropical conditions will also be discussed.

Introduction

Soil water balance estimations could be used to evaluate water availability for crop growth and could be approximated with data on precipitation, evapotranspiration, and soil moisture. A water satisfaction index (WSI) based on cumulative water deficit estimates during the crop growth could be used for yield prediction from climate data (FAO, 1986). In this study Soil water balance and WSI was calculated for Mustard (Brassica juncea L. Coss.) which was grown under dryland conditions in western Canada and southern Sri Lanka.

Materials and Methods

Description of experimental sites

- **Location 1** was near Saskatoon, Canada in summer, 92
- Soil was fine sandy loam in texture and classified as Orthic Haploborolls (Dark Brown Chernozemic)
- **Location 2** was at Weerawila (**6°12'N, 81°13'E**), Sri Lanka, in summer, 93
- Soil was sandy clay loam in texture and classified as an Alfisols (Reddish Brown Earth soils)
- A 40 m^2 plot was maintained entirely rainfed at upper slope position of the soil catena at each location
- Locally grown mustard varieties were seeded and local management practices were adopted

Data collected

Climatic data

- Rainfall
- Air temperature
- Relative humidity
- Pan evaporation

Soil data

- Soil moisture estimated to a depth of 120 cm
  - with a neutron probe at Saskatoon
  - gravimetrically at Sri Lanka

Plant data

- Plant water potential
- Growth and yield

Results and Discussion

Climatic Data

- Maximum potential evapotranspiration (PETm) was estimated using data on pan evaporation, pan coefficient (Doorenbos and Pruitt, 1984), and crop coefficients (Krogman and Hobbs, 1978)
- Soil water balance was estimated with data on rainfall, PETm, and change in soil moisture (for 120 cm)
- Water satisfaction index was calculated as cumulative percentage of water deficit during crop growth (FAO, 1986) (Tables 1 & 2)
- Water use efficiency (WUE) and precipitation use efficiency (PUE) were estimated based on actual evapotranspiration and total rainfall respectively
- Initially high soil moisture (data not shown) and continuous depletion occurred at saskatoon
- Soil moisture was completely dependent on seasonal rainfall at Weerawila and occurrence of dry spells limited crop growth
- Only 30% of the maximum potential yield (MPY) was obtained at Weerawila but the WSI was higher compared to Saskatoon. This may be due to onset of water deficit (moisture stress) at critical growth stages
- Weerawila received higher precipitation but high intensity and poor distribution of rainfall led to higher losses in comparison to Saskatoon

Grain yield and water use efficiency

Location	Yield (kg/ha)	%over MPY[1]	WSI	WUE[2]	PUE[3]
Saskatoon	905	50	48	82	133
Weerawila	200	30	75	12	14

1 ; Maximum Potential Yield, 2; Water use efficiency (kg. grain/ha.cm water)
3; Precipitation use efficiency (kg. grain/ha.cm water)

Conclusions

- **Moisture stored in the profile was used initially but continuous moisture depletion and low precipitation caused higher water deficit resulting low WSI for Saskatoon**
- **The higher precipitation at Weerawila was not effective in improving soil moisture conditions due to poor distribution and runoff.**
- **Crop growth was dependent on seasonal rainfall and occurrence of dry spells during critical growth stages caused poor crop growth and low yields at Weerawila**
- **WSI could be modified, considering critical growth stages and water deficit, to be a more satisfactory index to predict crop yield**

References

FAO. 1986. Early agrometeorological crop yield assessment, FAO Plant Production and Protection Paper No. 73, FAO, Rome, 11 - 37p.

Krogman, K. K., and E. H. Hobbs. 1978. Scheduling irrigation to meet crop demands, Canada Department of Agriculture, Ottawa, Canada.

Doorenbos, J., and W. O. Pruitt. 1984. Crop water requirements, FAO Irrigation and Drainage Paper No. 24, FAO, Rome, 1 - 65p.

Acknowledgments

The authors thank the International Development and Research Center, Canada for providing scholarship funding.

Grain yield and water use efficiency

Location	Yield (kg/ha)	%over MPY[1]	WSI	WUE[2]	PUE[3]
Saskatoon	905	50	48	82	133
Weerawila	200	30	75	12	14

1 ; Maximum Potential Yield, 2; Water use efficiency (kg. grain/ha.cm water)
3; Precipitation use efficiency (kg. grain/ha.cm water)

Conclusions

- **Moisture stored in the profile was used initially but continuous moisture depletion and low precipitation caused higher water deficit resulting low WSI for Saskatoon**
- **The higher precipitation at Weerawila was not effective in improving soil moisture conditions due to poor distribution and runoff.**
- **Crop growth was dependent on seasonal rainfall and occurrence of dry spells during critical growth stages caused poor crop growth and low yields at Weerawila**
- **WSI could be modified, considering critical growth stages and water deficit, to be a more satisfactory index to predict crop yield**

References

FAO. 1986. Early agrometeorological crop yield assessment, FAO Plant Production and Protection Paper No. 73, FAO, Rome, 11 - 37p.

Krogman, K. K., and E. H. Hobbs. 1978. Scheduling irrigation to meet crop demands, Canada Department of Agriculture, Ottawa, Canada.

Doorenbos, J., and W. O. Pruitt. 1984. Crop water requirements, FAO Irrigation and Drainage Paper No. 24, FAO, Rome, 1 - 65p.

Acknowledgments

The authors thank the International Development and Research Center, Canada for providing scholarship funding.

Figure 1. Cumulative rainfall and potential evapotranspiration at experimental sites.

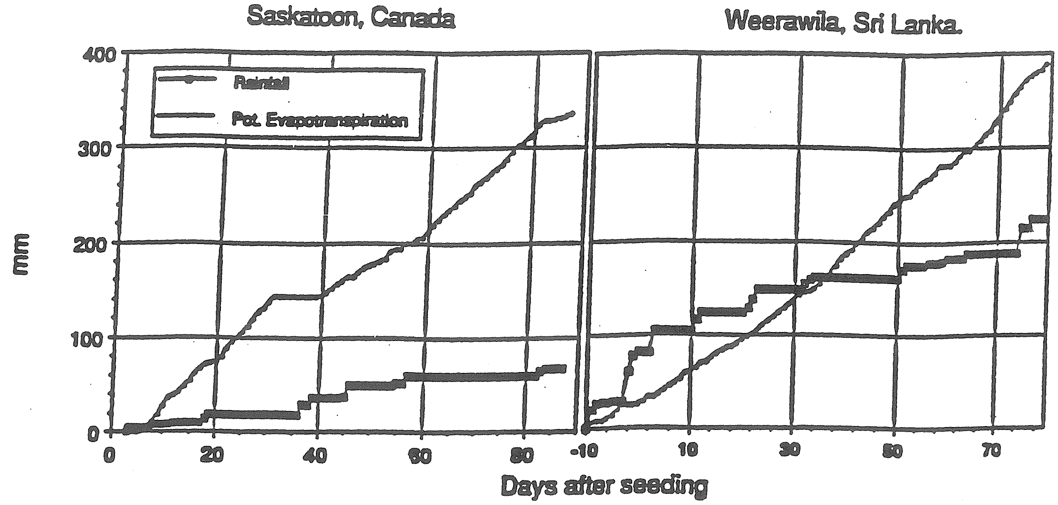

Figure 2. Daily maximum and minimum air temperatures at experimental sites.

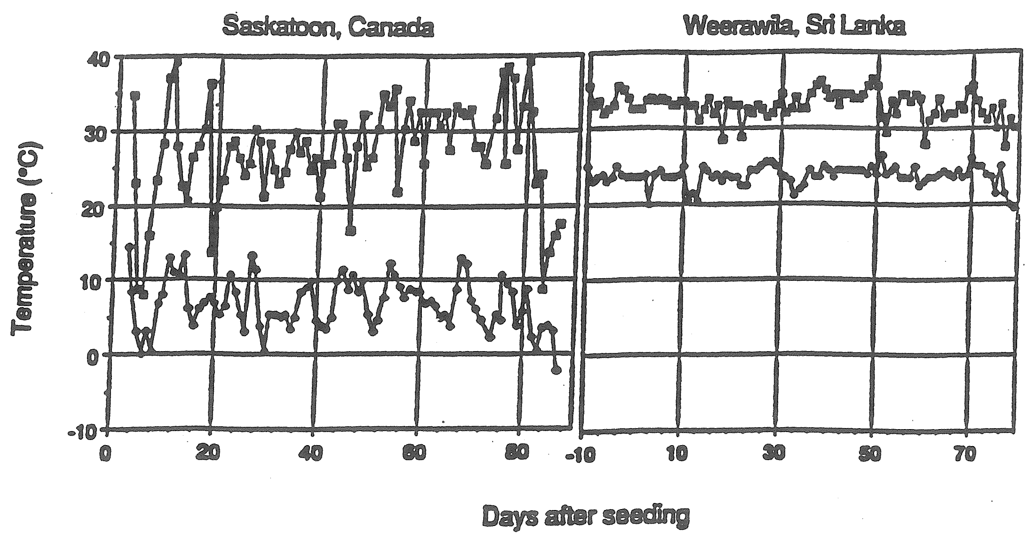

Figure 3. Daily Relative Humidity at experimental sites.

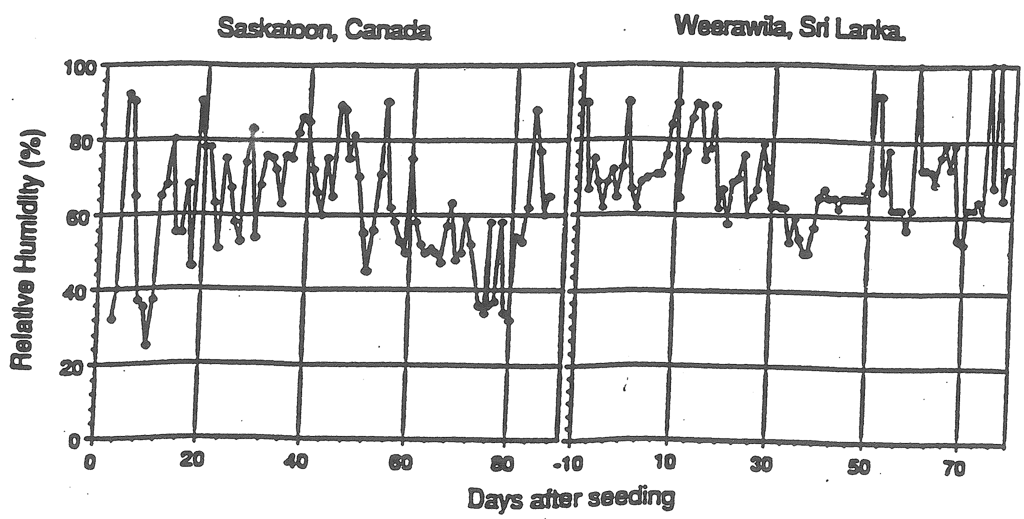

Table - 01. Calculation for Soil Water Balance and the Water Satisfaction Index for Saskatoon (all water measurements are in mm ; crop duration is from 26, May to 25 Aug. 1992).

Days After Seeding	Rainfall (RF) (days)	Maximum PET* (PETm)	RF - PETm	Change in Soil moisture	Water surplus or Deficit (SorD)	Water Satisfaction Index (WSI)
00 - 07	01.2 (1)	10.0	-08.8			100
08 - 14	08.1 (5)	04.7	03.5	07.0	-03.5	99
15 - 23	05.8 (2)	14.5	-08.7	02.6	-11.0	94
24 - 31	03.6 (2)	10.9	-07.3	-31.3	24.1	94
32 - 38	00.3 (1)	21.6	-21.3	-23.2	01.9	94
39 - 45	18.3 (3)	01.6	16.7	-14.7	31.4	94
46 - 52	12.7 (3)	23.0	-10.3	-05.6	-04.7	92
53 - 59	00.3 (1)	23.8	-23.5	-03.6	-20.0	83
60 - 70	10.4 (2)	46.0	-35.6	-15.1	-21.0	74
71 - 76	00.0 (0)	22.2	-22.2	-07.2	-15.0	67
77 - 84	00.0 (0)	32.1	-32.1	-04.6	-28.0	55
85 - 91	07.2 (3)	19.9	-12.7	03.9	-17.0	48

* ; PET = Potential Evapotranspiration

Total Rainfall = 68 mm. Total water requirement = 230 mm. Total water deficit = 120 mm.

Table - 02. Calculation for Soil Water Balance and the Water Satisfaction Index for Weerawila (all water measurements are in mm ; crop duration is from 04, May to 22 July, 1993).

Days After Seeding	Rainfall (RF) (days)	Maximum PET* (PETm)	RF - PETm	Change in Soil moisture	Water surplus or Deficit (S or D)	Water Satisfaction Index (WSI)
00 - 19	47.4 (5)	14.7	32.7	-02.0	34.7	100
20 - 30	24.4 (3)	10.8	13.6	21.5	-07.9	97
31 - 36	13.0 (3)	05.2	07.8	-02.0	09.8	97
37 - 48	00.0 (0)	61.2	-61.2	-58.7	-02.5	95
49 - 56	13.3 (3)	35.2	-21.9	07.5	-29.4	82
57 - 66	12.4 (4)	30.0	-17.6	-14.8	-02.8	81
67 - 70	00.5 (1)	25.7	-25.2	-17.0	-08.2	77
71 - 79	36.0 (2)	41.3	-05.3	00.0	-05.3	75

* ; PET = Potential Evapotranspiration

Total Rainfall = 147 mm. Total water requirement = 224 mm. Total water deficit = 56 mm.