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# Validation of SPAW model for soil moisture and evapotranspiration under wheat crop at Anand

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## ABSTRACT

Soil Plant Atmosphere Water (SPAW) model developed by Saxton was used to simulate the daily soil moisture content under irrigated wheat crop grown at Anand, Gujarat state during three seasons (2001-02 to 2003-04). Simulated soil moisture values were compared with gravimetrically observed data for three years for fourt soil layers 00-15, 15-30, 30-45 and 45-60 cm. The simulations were significantly correlated (r=0.79** to 0.86**) with the measured values for different layers. Pooled data over depth and year also gave highly significant correlations (r=.71**) with RMSE of 1.77'. The differences between measured and simulated actual evapotranspiration were found to be less than (9%) of the measured values.

*Key words:* SPAW model, simulation, wheat, soil moisture, evapotranspiration

The time distribution of soil water within the soil profile supplying plant roots is a complex interaction of many variables related to current and past occurrences of weather, crops and soils. While soil water principles have been studied for centuries only in recent years have we begun to develop a complex system approach to the understanding and prediction of soil water over time. There are many empirical methods (Thornthwaite and Mather, 1955; Philip, 1966; Baier *et al.*, 1972; Ritchie, 1972) to estimate soil water balance. The Soil Plant Air Water (SPAW) model (Saxton *et al.*, 1974) overcomes some of the limitations of the empirically based models. The SPAW model has been tested on agricultural crops such as corn and soybean (Sudar *et al.*, 1981). Pearl millet (Rao and Saxton, 1995) and wheat (Saxton *et al.*, 1992, Singh *et al.*, 1992).

In this study the SPAW model (Saxton, 1989) has been used to simulate the soil moisture profiles in the sandy loam soil of Anand under wheat crop grown over three years. The objective was to validate the SPAW model using data set generated at 10 m micrometeorological tower site of Anand.

### *The Model*

The Soil Plant Atmosphere Water (SPAW) model developed at USDA, ARS by Saxton (1989) is a predictive procedure

for daily accounting of moisture within the specified soil layers and is governed by the effect of weather, plant and soil. The SPAW model describes upright soil moisture budget on daily basis. The driving force in this model is daily potential evapotranspiration (ET). Intermediate computations using the percent ground shading, transpirability curve and rooting patterns divide the actual ET into principal components of interception evaporation, soil-water evaporation and plant transpiration. Saxton (1983) has described the model physics in detail with input and output requirements. Model application assumes horizontally homogeneous plant soil atmosphere conditions represented by model parameters and data. Daily infiltration is assumed to occur instantaneously. No diurnal patterns of soil water, heat or ET are considered even though they might occur. Parameterized water extraction patterns are not influenced by water stress.

## MATERIALS AND METHODS

The field experiment was conducted during three *rabi* seasons (2001-02, 2002-03 and 2003-04) at 10 m tower site existing at Anand (Latitude 22° 35'N Longitude 72° 55' E and Altitude 45.1m ) of Anand Agricultural University, Anand. The wheat crop cultivar GW-496 was sown on 30th November in each year. Agronomical package and practices were followed as per the recommendations for the cultivar. The crop was irrigated 6-7 times during the growth period with the fixed amount of 50 mm depth. Leaf area and root density were measured periodically. Soil moisture was measured in four soil layers (00-15, 15-30, 30-45 and 45-60cm) of wheat crop at regular interval using gravimetric method. Grain yield susceptibility value for wheat cultivar was taken from Singh *et al*. (1992). The soil physical parameters required by the model were taken from the reports (Anonymous, 2000). Daily rainfall and evaporation data were taken from the agro-meteorological observatory situated near the experimental site.

## RESULTS AND DISCUSSION

### *Soil moisture*

Daily soil moisture content in four different layers (00-15, 15-30, 30-45 and 45-60cm) for three seasons of wheat crop were simulated by SPAW model. Simulated soil moisture was compared with weekly measured data for respective soil layers Figs.(1-3).

It may be seen that the fluctuation in the observed as well as simulated soil moisture was maximum (6-18%) in the upper layer (00-15 cm) of soil profile, and minimum (9 to 15% ) in the lower layer (45-60cm). The trend was more or less similar in all the three years. The observed soil moisture values were closed to the simulated values. The correlation and regression analysis worked out between simulated and observed soil moisture for each layer revealed highly significant association (r=0.79** to 0.86**) between the two (Table 1). However, the model's performance in terms of $R^2$ was better in upper layers ($R^2$ = 0.74) than the lower

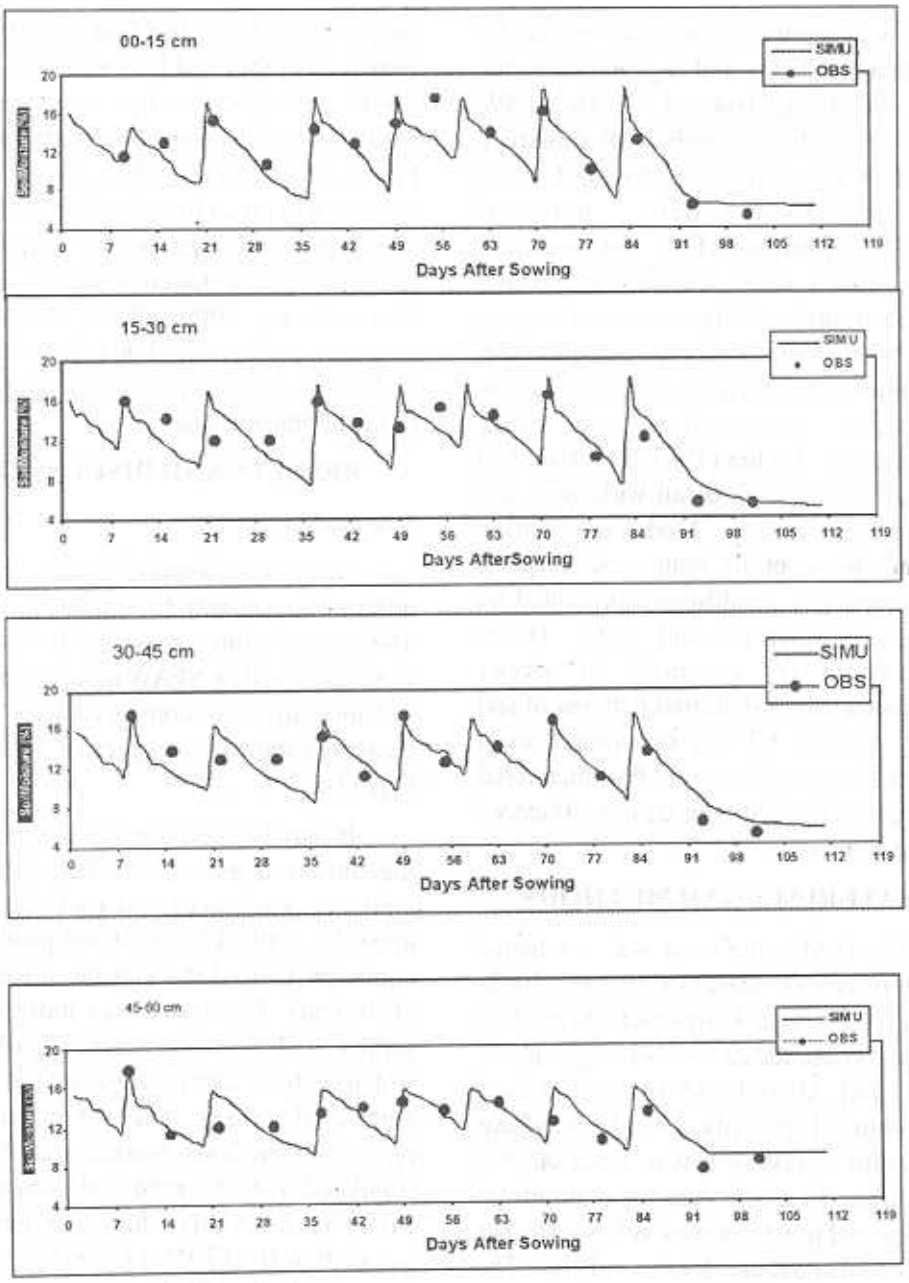


**Fig. 1:** Layer wise observed and simulated soil moisture under *rabi* wheat crop season 2001-02

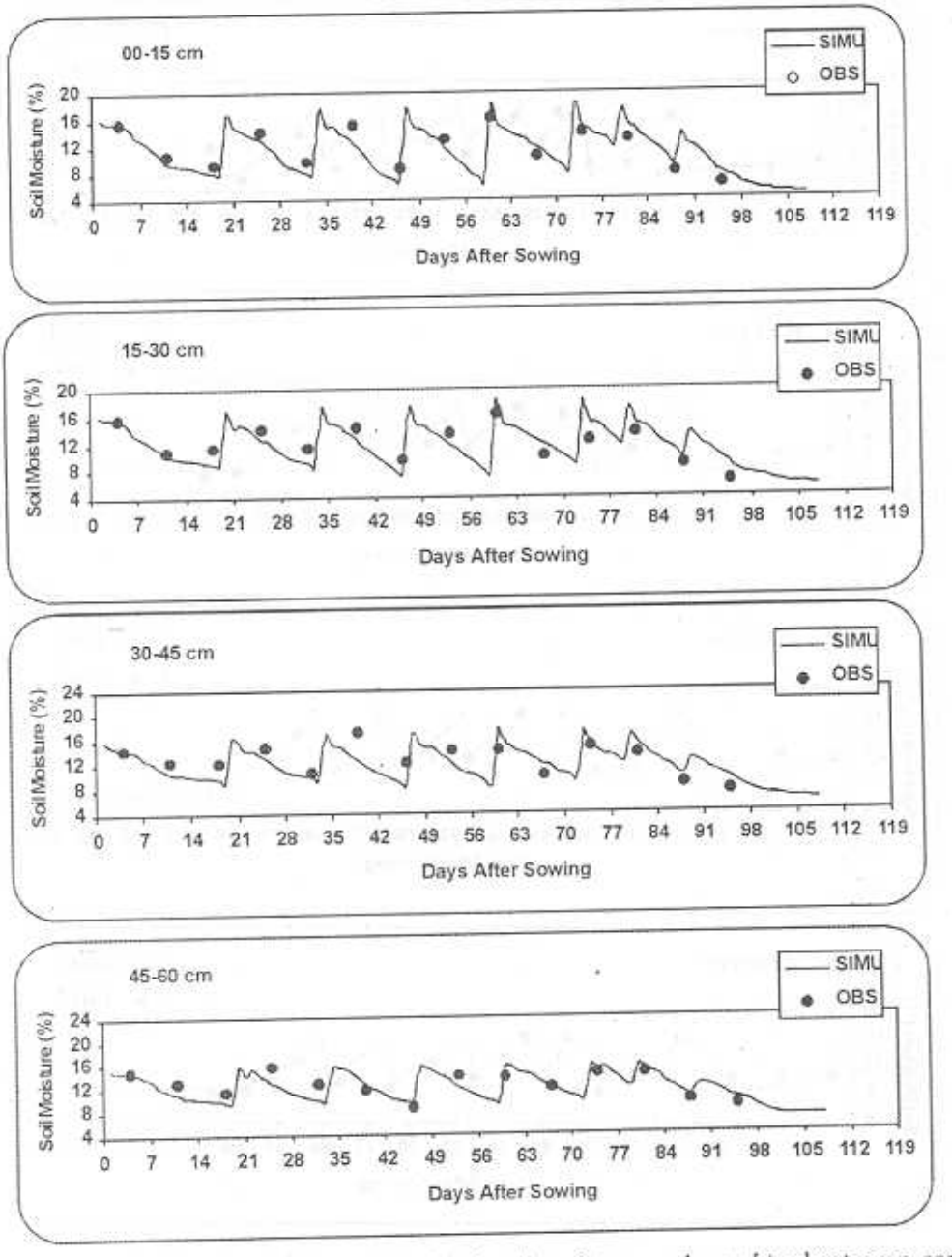


Fig. 2: Layer wise observed and simulated soil moisture under *rabi* wheat crop season 2002-03

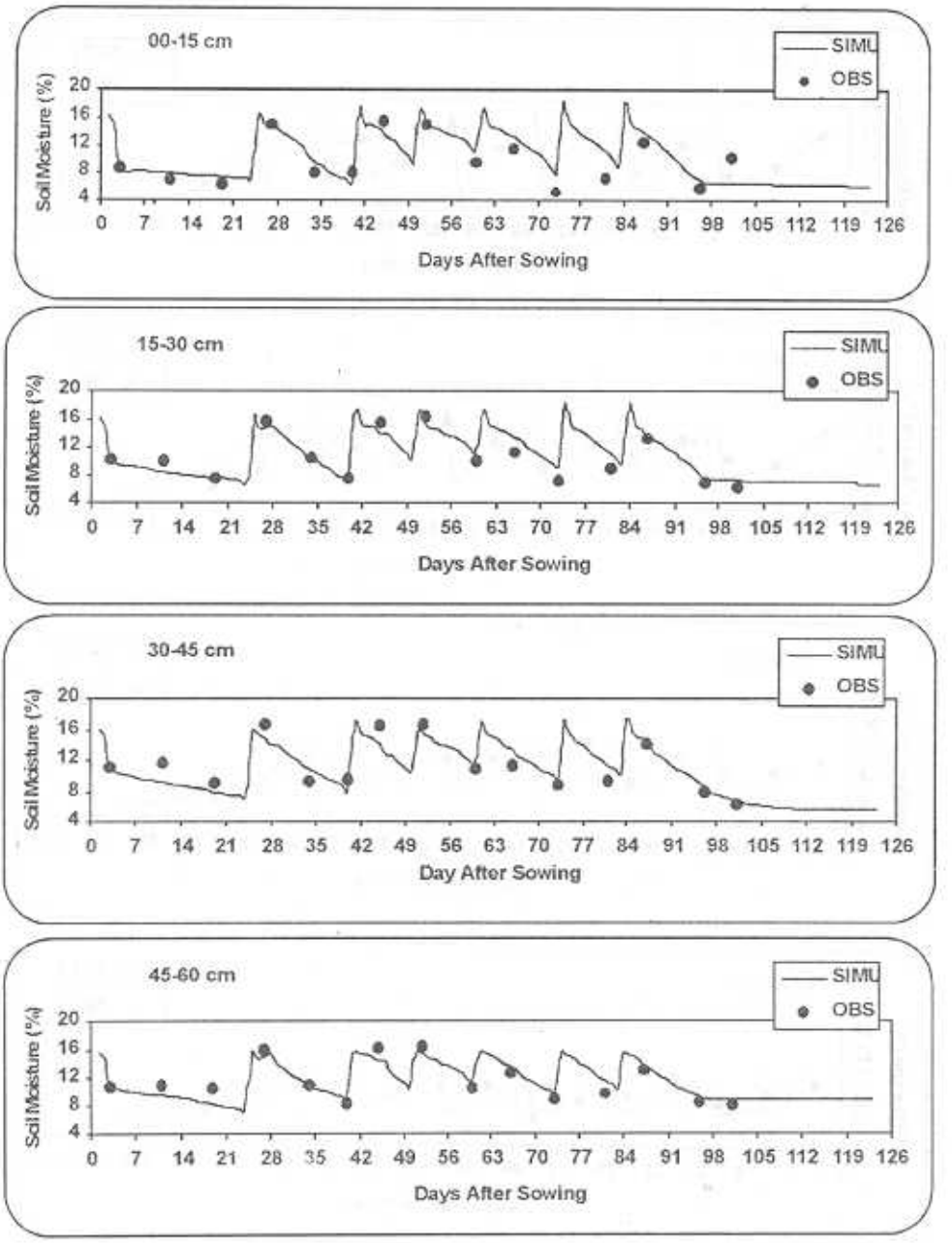


Fig. 3: Layer wise observed and simulated soil moisture under *rabi* wheat crop season 2003-04

Table 1: Correlation and regression analysis of simulated and observed soil moisture along with RMSE values

| Particulars | Regression Equations | Correlation Coefficients (r) | $R^2$ | RMSE (±) |
|---|---|---|---|---|
| **Year** | | | | |
| 2001-02 | Y = 1.5490 + 0.8686 X | 0.87** | 0.76** | 1.70 |
| 2002-03 | Y = 4.1365 + 0.6994 X | 0.75** | 0.66** | 2.10 |
| 2003-04 | Y = 1.8827 + 0.7669 X | 0.88** | 0.78** | 1.44 |
| **Soil Depth** | | | | |
| 00-15cm | Y = 1.7019 + 0.8317 X | 0.86** | 0.74** | 1.77 |
| 15-30cm | Y = 2.0045 + 0.8232 X | 0.86** | 0.74** | 1.75 |
| 30-45cm | Y = 1.8471 + 0.8533 X | 0.82** | 0.67** | 1.87 |
| 45-60cm | Y = 2.5973 + 0.7774 X | 0.79** | 0.62** | 1.64 |
| Pooled | Y = 2.0303 + 0.8213 X | 0.84** | 0.71** | 1.77 |

X = Simulated Soil moisture (%) ** Significant at P = 0.01
Y = Observed Soil moisture (%).

Table 2: Cumulated measured and computed (SPAW model) seasonal evapotranspiration and related parameters at Anand

| Parameters | 2001-02 | 2002-03 | 2003-04 |
|---|---|---|---|
| Rainfall | 0.0 | 23.3 | 0.0 |
| Irrigation | 400.0 | 350.0 | 350.0 |
| Pan Evaporation | 512.0 | 520.0 | 585.0 |
| Measured Evapotranspiration | 354.7 | 367.2 | 304.7 |
| **Computed Parameters** | | | |
| Actual Evapotranspiration | 322.7 | 339.5 | 277.7 |
| Soil Evaporation | 147.7 | 144.5 | 102.5 |
| Transpiration | 175.0 | 192.5 | 175.5 |

layers ($R^2$ = 0.62 to 0.67). The root mean square error (RMSE) value less than 1.87 signifies the reliability of the SPAW model in accurate prediction of soil moisture at various depths in the wheat crop at Anand.

The correlation coefficients worked out between simulated and observed soil moisture pooled over the depths were also highly significant (r=0.75** to 0.88**). The lower correlation coefficient during year 2002-03 (Table 1) may be due to un-seasonal rainfall during later stages of the crop which might not be detected well by the model in terms of soil moisture. Model generally over estimated the soil moisture under the wheat crop (Fig.2) in year 2002-03. The overall pooled analysis gave $R^2$ of 0.71** with RMSE values of ±1.77. The

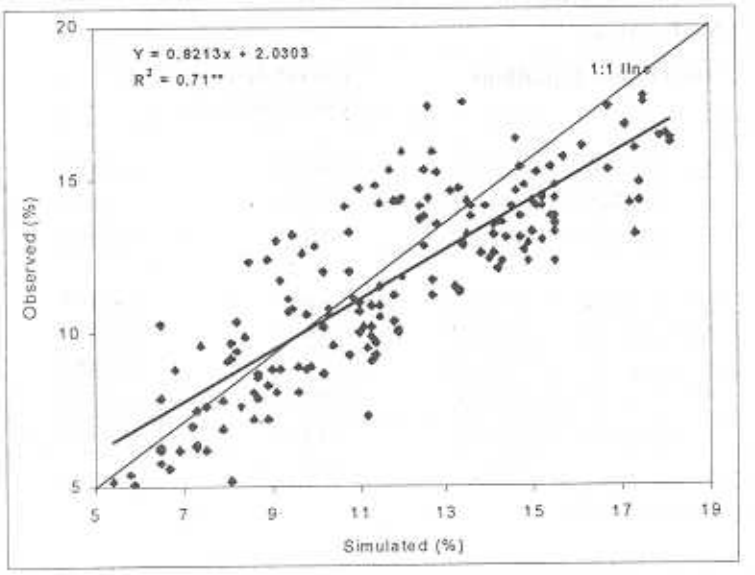


Fig. 4: Simulated and observed soil moisture (%) under wheat in three seasons

simulated versus observed soil moisture pooled over depth and year (Fig.4) revealed reasonable agreement between the two. Thus the results revealed that the model can be used to predict soil moisture under wheat crop.

*Evapotranspiration*

Various parameters related to soil water balance for three seasons of wheat crop are summarized in Table 2. It may be seen that un-seasonal rainfall (23.3mm) was received in year 2002-03 only. The amount of irrigation water applied varied between 350 to 400 mm. The pan evaporation was maximum (585.0mm) in year 2003-04, where as the actual evapotranspiration (AET) was maximum (367.2mm) in year 2002-03. Measured AET values were between 52 to 70.4 % of the pan evaporation. As per SPAW model output, the computed AET ranged between 277.7 to 339.5 mm over the years. The differences between measured and computed AET of wheat were less than 9% (Table 2). The transpiration component of AET of wheat crop accounted for 54 to 63 % of the actual evapotranspiration.

## CONCLUSION

The study found that the SPAW model can be used for predicting the moisture content of the soil profile under irrigated wheat crop at Anand. This can also be useful in deciding the irrigation scheduling.

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## REFERENCES

Anonymous, 2000. Annual Progress Report on AICRP, Department of Agricultural Meteorology, B. A. College of Agriculture, Anand Agricultural University, Anand.

Baier, W., Chaput, D. Z., Russelo, D. A. and Sharp, W. R. 1972. Soil moisture estimator program system. Technical Bulletin 78. Ottawa : Agrometeorological Section, *Agriculture Canada*. 55 pp.

Philip, J. R., 1966. Plant water relations : Some physical aspects. *Annual Review, Plant Physiology*. **17** : 245-268.

Rao, A. S. and Saxton, K. E. 1995. Analysis of soil water and water stress for pearl millet in an Indian arid region using the SPAW model. *Indian J. Arid Env.*, **29**:155-167.

Ritchie, J. T., 1972. Model for predicting evaporation from a row crop with incomplete cover. *Water Resour. Res.* **8** : 2104-2113.

Saxton, K. E., 1983. Soil water by Hydrology ; Simulation for water balance computations. New approaches in water balance computations. *Proc. Hamburg workshop*, August,1983.

Saxton, K. E., 1989. Users Manual for SPAW. A Soil-Plant-Atmosphere-Water Model. Pullman, Washington: United States, Department of Agriculture, *Agric. Res. Service*. 89 pp.

Saxton, K. E., Johnson, H. P. and Shaw, R. H., 1974. Modeling evapo-transpiration and soil moisture. *Trans. American Soc. Agric. Eng.*, **17** : 673-677.

Saxton, K. E., Porter, M. A., and McMahon, T. A., 1992. Climatic impacts on dry land winter wheat yields by daily soil water and crop stress simulations. *Agric. Forest Meteorol.*, **58** : 177-192.

Singh, K. K., Rathore, L. S. and Srinivasan, G. 1992. Simulating Soil Moisture Profiles under cropped condition using SPAW model. *Proceedigs of a National seminar* on Soil Moisture Processes and Modeling held at Agricultural Engineering Department IIT, Kharagpur, 141-147.

Sudar, R. A., Saxton, K. E. and Spomer, R. G. 1981. A predictive model of water stress in corn and soybeans. *Trans. American Soc. Agric. Eng.*, **24** : 97-102.

Thornthwaite, C. W. and Mather, J. R.,1955. The water balance. Publications in Climatology. Drexel Institute of Technology, New Jersey, **8**: 1-104.