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Performance of ISIAMOD and SWAP models in estimating Soil water balance components of a maize crop (Sammaz-28) under Rain-Fed condition

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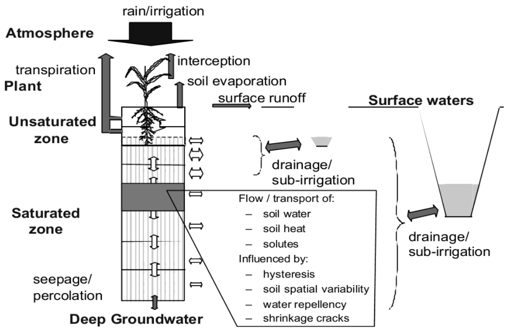
ABSTRACT

In this paper, the performance of Irrigation Scheduling Impact Assessment model (ISIAMOD) and Soil-Water-Atmosphere-Plant (SWAP) relationship model in estimating soil water balance of a cropped field under rainfall condition was studied under a sandy clayed loamy soil at the research field of the department of Agricultural Engineering, Ahmadu Bello University, Samaru, Zaria-Nigeria. Soil water balance data from the field study were used as reference values for the models performance evaluations. The statistical indicators used to compare the performance of the models were coefficient of residual mass (CRM), modelling efficiency (EF) and root mean square error (RMSE). The results showed that the two models satisfactorily simulated soil water balance components as their output compared closely to field measured data. CRM showed that ISIAMOD has the tendency of underestimating the ET, T, and E_{crop} *by a value which ranges from 2.5 to 6.0 % while SWAP has the tendency of overestimating the same components which ranges from 2.0 to 9 %. The modeling efficiencies of the two models range from 84 to 90 %, except for evaporation processes which ranges from 54 to 62 %. The RMSE of the two models ranges from 0.29 to 0.86. They both simulated the seasonal run-off and drainage well. The results show that the two models can be used for determination of soil water balance components of cropped soil and for analyzing a better water management option for agricultural production.*

Keywords: Simulation model; Soil Water Balance; Water management; ISIAMOD.

Graphical abstract



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1. Introduction

Most environmental degradation problems related to water are cause by changes in some or all the aspects of the hydrological cycle. The use of water management model (e.g. agro-hydrological model) couple with field experiment can provides a better understanding of the components of the hydrological cycle and its variability with time, from which an appropriate water management option can be sort for. The applications of computer-based Agro-hydrological simulation models as tools for providing soil water management options in agricultural research have being in practice for over four decades [1,2,3,4]. [5], used the Soil-Water-Atmosphere-Plant (SWAP) model and Decision Support System for Agro-technology Transfer (DSSAT) model to simulate crop growth and soil water balance in Thailand. [6, 7] developed and used ISIAMOD to study the impact of irrigation scheduling on yield and soil water balance of maize cropped field in Tanzania. [8], compared EPICphase and CROPWAT models to simulate maize yield under water stress condition (deficit irrigation) in Zaragoza, Spain at the experiment farm of the Agronomic Research Service (SIA).

These models (Agro-hydrological) play a very important role in studying and understanding the processes in soil-plant-atmosphere system. This is attributed to their increased computing capabilities. Mathematical models have the promising potential to explore solutions to both water and crop management problems. Models such as SWAT and SWAP have the best features for watershed modelling as they divide the watershed into smaller sub-watersheds with their unique attributes [9, 10]. They have significant potential for representing the natural hydrological system. These models simulate crop growth processes, soil water balance and soil water dynamic within crop rooting zone for both rain-fed and irrigation conditions

There are several models for estimating and predicting soil water balance, but comparing models results with field observation, or inter-comparison of models of differing nature will provide information on the performance of the models and reveal strong and weak points. The objective of this study is to compare the performance of SWAP and ISIAMOD in simulating the components of soil water balance of a maize crop (Sammaz-28). This comparison is envisaged to give an idea on which of the two models is more robust in handling water management scenarios and water balance. The data used in the simulation were from a field study of soil water balance of the maize crop (Sammaz-28) done at the experimental fields of the Department of Agricultural Engineering, Ahmadu Bello University Zaria, Nigeria. Soil-Water-Atmosphere-Plant (SWAP) by [11] and Irrigation Scheduling Impact Assessment Model (ISIAMOD) by [6] in simulating soil water balance of a maize crop field under rainfall condition. The two models are physically based and they simulate plant growth processes such as soil water balance, dry matter yield, and soil and crop other properties. There basic difference is on their soil water dynamic simulations. SWAP model is based on the analytical solution of Richard's equation while the ISAMOD is based on the "tipping-bucket" model, sometime called the reservoir cascade scheme.

1.1 ISIAMOD and SWAP Models

1.1.1 The ISIAMOD Model

The ISIAMOD [6], was built using empirical and semi-empirical functions which explain crop growth processes and water dynamic within the crop environment. ISIAMOD program was written in FORTRAN Power Station version 1.0F. The input data files are prepared as text and given names. The model runs on a daily time-step, from crop planting date to crop physiological maturity date. The water dynamic of ISIAMOD includes soil water balance and water management response indices (WMRI). The WMRI which are used to explain the impact of an irrigation scheduling decision are grouped into three: water accounting indices, crop water productivity indices and seasonal relative deficit/losses indices. The indices are generated within the model from the crop yield and soil water balance outputs.

The soil water balance unit in ISIAMOD is based on the principles of soil water budget, expressed as:

$$P + I_r = R_{off} + ET + I_{ntL} + D_p \pm \Delta S \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

Where Ir is irrigation depth; P is rainfall depth; ET is evapotranspiration (a combination of evaporation and transpiration); Roff is seasonal runoff; IntL is precipitation intercepted by the crop canopy; Dp is deep percolation depth, and ΔS is the difference between soil moisture on a daily time bases.

The water balance program of ISIAMOD starts with the quantification of the evaporative demand exerted upon the crop. The driving variables include weather, soil, rainfall and irrigation decision input data. Water is taken from the soil by the plant root to meet up with the crop water demand through the combined processes of evaporation and transpiration (evapotranspiration). The crop growth duration is divided into four phases. These consist of establishment, vegetative, flowering and maturity growth stage. The infiltration and distribution of applied water to the cropped field and deep percolation in the model is based on the “tipping bucket” method by [3]. By this method, it means that each compartment is assumed to be filled with water to “field capacity” after rainfall or irrigation before passing on any excess water to the next compartment below. In this way, any excess water beyond the bottom layer of the soil depth is term deep percolation. Upward movement of water by capillary rise is not simulated in ISIAMOD.

1.1.2 SWAP Model

The SWAP (Soil-Water-Atmosphere-Plant) model is physically based, detailed agro-hydrological model that simulates the relationship between soils, water, weather (atmosphere) and parameters. Figure 2.1 shows a schematic overview of SWAP modeled system. The main feature of the model is the Richards’ equation where the transport of soil water is modeled by combining Darcy’s law and the law of flow continuity. SWAP is a one dimensional model and it models the soil water movement by considering the spatial differences of the soil water potentials in the soil profile. The governing Richards’ equation is solved numerically where the implicit scheme used by [1] can be effectively applied in saturated and unsaturated condition. The important features of the Richards’ equation in SWAP are that it allows the use of soil hydraulic databases and the simulation of many kinds of soil, water and crop management scenarios. The soil hydraulic functions in SWAP are described by the analytical function of [12] and [13] for soil water retention and hydraulic conductivity. SWAP is a computer-based model that simulates transport of water, solute, and heat in variables saturated top soils. The program is an integrated modeling of the Soil-Atmosphere-Plant system.

The soil water balance is solved by considering two boundary conditions (that is, the upper and bottom boundary conditions). The boundaries can either be flux or head controlled. The penman-Moteith equation is used in estimating evapotranspiration. The model uses leaf area index (LAI) or soil cover fraction (SCF) to calculate potential transpiration and evaporation. The effect of salt, water and oxygen stress is considered multiplicative. The surface runoff is calculated by the ratio of the difference of ponding water and the maximum height of the sill or embankments, to the resistance of soil to runoff. Field drainage can be simulated using the Houghoudt and Ernst equation in homogenous and heterogeneous soil profiles. Figure 1, shows the schematic overview of SWAP model.

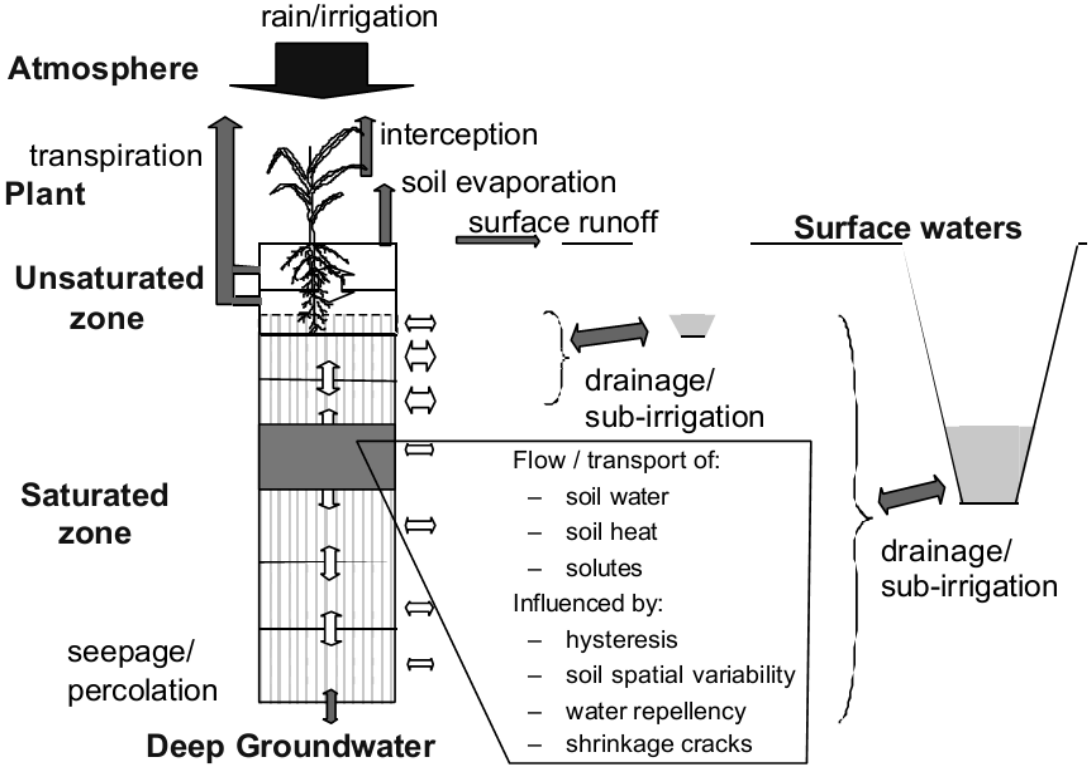

Fig 1. A schematic overview of SWAP modeled system [14].

2. Materials and Methods

2.1 Location of the Field Experimental study Area

The crop, soil and water data used in this study were collected from a field trial experiment carried out during the 2013 raining season at experimental fields of the Department of Agricultural Engineering, Ahmadu Bello University Zaria, Nigeria. It lies on latitude 11o11’N, longitude 7o38’E and altitude 686m above mean sea level. It is located within the Northern Guinea Savannah ecological zone of Nigeria. The climate of the area can describe as semi-arid, with three distinct seasons: the hot dry season from March to May; the warm rainy season, June to early October, and the cool dry season, which spans from late October to February. Table 1 presents the weather data of the study area for the period when the field experiment was carried out. The soils of the study area are predominantly heavy clay soils which when dry, cracked. The surfaces are covered with grasses, most of which survived the dry season. The soil has high proportion of organic matter, fine sand at or near the surface. The soils of the area are classified as Typic Haplustalf according to the United State Department of Agriculture (USDA) soil taxonomy [15] and Acrisols according to [16]. The physical soil properties of the site are given in table 2.

Table 1. shows the summary of the average monthly weather data during the experiment.

Months	**Tmax. (˚C)**	**Tmin. (˚C)**	**RHmax. (%)**	**RHmin. (%)**	**Wind speed (m/s)**	**Net radiation. (MJ/m^2)**	**Sunshine hour. (hr)**	**Precipitation (mm/day)**	**Pan Evaporation. (mm/day)**
July	30.6	22.4	80.0	67.6	1.8	22.2	5.3	10.2	4.7
Aug.	29.6	23.2	83.5	72.7	1.7	17.7	4.5	5.3	4.5
Sept.	31.4	22.1	77.3	65.6	1.2	20.4	6.2	7.8	4.6
Oct.	32.8	20.7	60.0	48.4	1.1	21.6	7.3	0.5	5.0

Table 2. Soil physical properties of the Experimental Field

Soil Depth (cm)	**Hydraulic Conductivity (cm/sec.)**	**Bulk Density (g/cm^3)**	**Moisture @ FC[a]**	**Moisture @ PWP[b]**	**Particle Size Distribution (%)**			
					Clay	silt	Sand	Texture Class
0-10	0.012	1.39	0.175	0.070	24	20	56	Sandy clay loam
10-30	0.080	1.30	0.173	0.077	20	20	60	Sandy loam
30-45	0.04	1.37	1.94	0.094	22	18	60	Sandy clay loam
45-60	1.697	1.34	1.97	0.115	24	20	56	Sandy clay loam
60-80	2.314	1.40	0.226	0.149	26	14	60	Sandy clay loam

a is the field capacity (@ -333cm suction head)
b is the permanent wilting point (@ -1500cm suction head)

2.2 Data Collection

The weather data were obtained from the meteorological station of the Institute of Agricultural Research (IAR), situated less than 1.0 Km from the research field (Table 1) to run the models. The rainfall amount were collected on daily bases. Daily soil water balance parameters of evaporations, transpirations, evapotranspiration, runoff and deepercolation were all collected from the weighing-type lysimetric set-up installed in the field. Separation of transpiration from evaporation was achieved using the weighing lysimetric set-up. The crop parameter of interest for the two models, such as Leaf Area Index (LAI), crop height and crop rooting depths were measured from the surrounding cropped field of the lysimetric set-up. They are measured on weekly bases to obtain a significant changes as demanded by models. Soil parameters from the field were obtain after laboratory testing (table 2).

2.3 Model Simulation

The SWAP 207d model in addition to the weather and crop's data above, allows the use of a soil hydraulic database parameters based on the field soil texture. The soil input data include number of layers and compartments, soil hydraulic function, soil texture, rooting depth limitation. The soil water content, soil water retention and soil hydraulic conductivity were related on the basis of [13], and are based on [12] parameters (Ks, Ɵs, Ɵr, α, n and l). In SWAP, soil surface with crop was taken to be the upper boundary condition and for the lower boundary condition, a Lysimeter with free-drained bottom was chosen. The files of weather, rainfall, irrigation, soil and crop in ISIAMOD were prepared as text file and used to run the model. Among the eight available options of weather parameter combination given by ISIAMOD, the third option was used in this research. In this option, the weather combinations are maximum and minimum temperature, wind speed, maximum and minimum relative humidity and sunshine hours. The crop input data are as shown in table 3.

Table 3. Crop and other input parameters for the ISIAMOD model

S/N	**Parameters**	**Value**
1	Maximum rooting depth	0.76 m
2	Maximum harvest index	0.34*
3	Harvest index adjustment factor for the flowering stage	0.55**
4	Harvest index adjustment factor for the maturity stage	0.55**
5	Radiation extinction coefficient	0.55**
6	Maximum leaf area index	0.46m^2/m^2
7	RUE (establishment and vegetative stages)	0.23 g/MJ**
8	RUE (flowering and maturity stages)	0.23 g/MJ**
9	Base temperature	8^oC
10	Optimal temperature	30^oC
11	Fraction of the growth duration at which leaf area index starts to decline	1.0*
12	Days after planting at which establishment growth stage starts	0*
13	Days after planting at which vegetative growth stage starts	18*
14	Days after planting at which flowering growth stage starts	41*
15	Days after planting at which maturity growth stage starts	63*
16	Peak crop water use (k_c) coefficient	1.3
17	soil transpiration coefficient	0.018 m/day**
18	bare soil evaporation coefficient	1.05
19	Growth shape factor GSF	1120
20	b = exponent in the LAI equation	17.2
21	curve number	75

*= data obtained from field experimental data;

** = final values obtained through model calibration.

2.4 Model Evaluation

The Performance of the models were assessed quantitatively by comparison of the models' simulated results and measured data using the following statistical indicators, as given by [17]:

Average error of Bias (AE):

$$AE = \frac{\sum_{i=1}^{n}(P_i - O_i)}{n} \quad (5)$$

Coefficient of variation $$(CV) = 100 * \frac{\left[\frac{1}{n}\sum_{i=1}^{n}(P_i - O_i)^2\right]^{0.5}}{O_m} \quad (6)$$

Root Mean Square Error $$(RMAE) = \left[\frac{1}{n}\sum_{i=1}^{n}(P_i - O_i)^2\right]^{0.5} \quad (7)$$

Modeling efficiency $$EF = \frac{\left[\sum_{i=1}^{n}(O_i - O_m)^2 - \sum_{i=1}^{n}(P_i - O_i)^2\right]}{\sum_{i=1}^{n}(O_i - O_m)^2} \quad (8)$$

Coefficient of Residual Mass $$(CRM) = \frac{\sum_{i=1}^{n}O_i - \sum_{i=1}^{n}P_i}{\sum_{i=1}^{n}O_i} \quad (9)$$

Where: Pi is simulated values; Oi is measured values Om is mean of measured values, and is number of observations. The AE is measured of bias between simulated and measured data. The CV is a measure of variability while the RMSE is a measure of precision. The EF is the modelling efficiency. It gives the degree of fit between simulated and measured data. CRM is an indicator of the model to over or under predict measured values.

3. Results

The results of the field's experiment and models' simulations are presented in figures while the statistical analysis of variance (ANOVA) of the results are presented in tables. Figure 2, 3, 4, 5 and 6, show the field and models' simulated Evapotranspiration (ET), transpiration (T), Evaporation, Runoff (R), and drainage (D) respectively. Table 4, 5 and 6, presents the statistical analysis of the mean ET, T, and E for the field and models' simulated results respectively. Table 7 and 8, give the summary and overall comparison of the performance of SWAP and ISIAMOD simulated results.

3.1.1 Comparison of Models Simulated and Field-measured Evapotranspiration

Figure 2 presents the daily field-measured and models-simulated evapotranspiration by the two models under study. Table 4 shows the statistical indices of the comparison between the measured and simulated data.

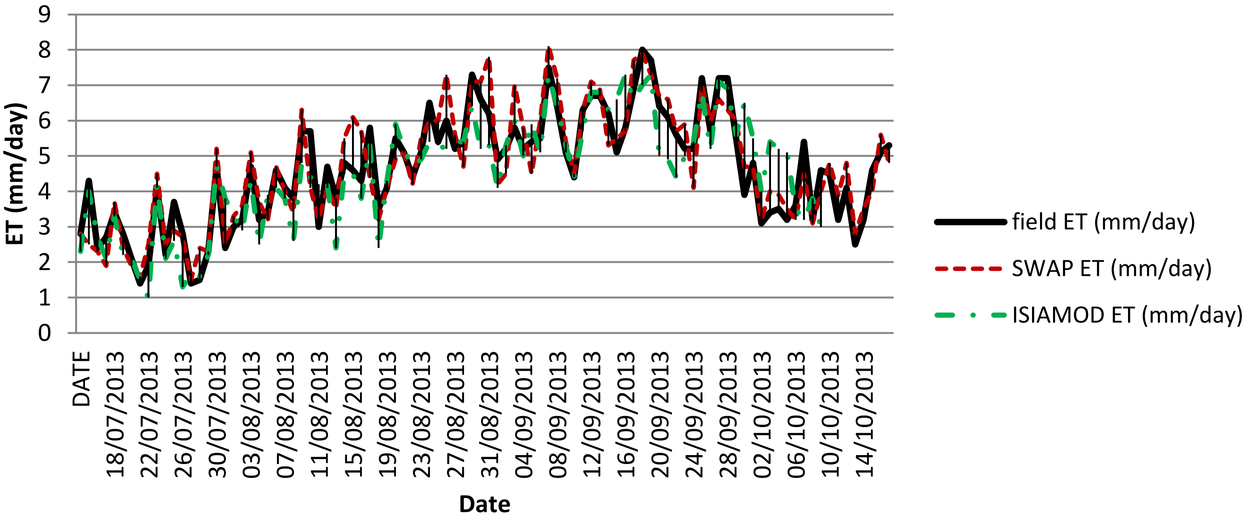

Fig 2. daily evapotranspiration measured and simulated by SWAP and ISIAMOD

Table 4: Statistics of the comparison between simulated and measured evapotranspiration (ET)

Statistical performance indices	**SWAP model**	**ISIAMOD**
	Evapotranspiration (ET)	Evapotranspiration (ET)
AE	-0.0958	-0.1136
RMSE	0.62	0.31
CV (%)	8.3	11.8
EF	0.84	0.88
CRM	-0.020	0.025

3.1.2 Comparison of Models-Simulated and Field-measured Transpiration

Figure 3 shows the daily field-measured and models-simulated transpiration by SWAP and ISIAMOD models. Table 4 shows the statistics of the comparison between measured and simulated transpiration (T) models.

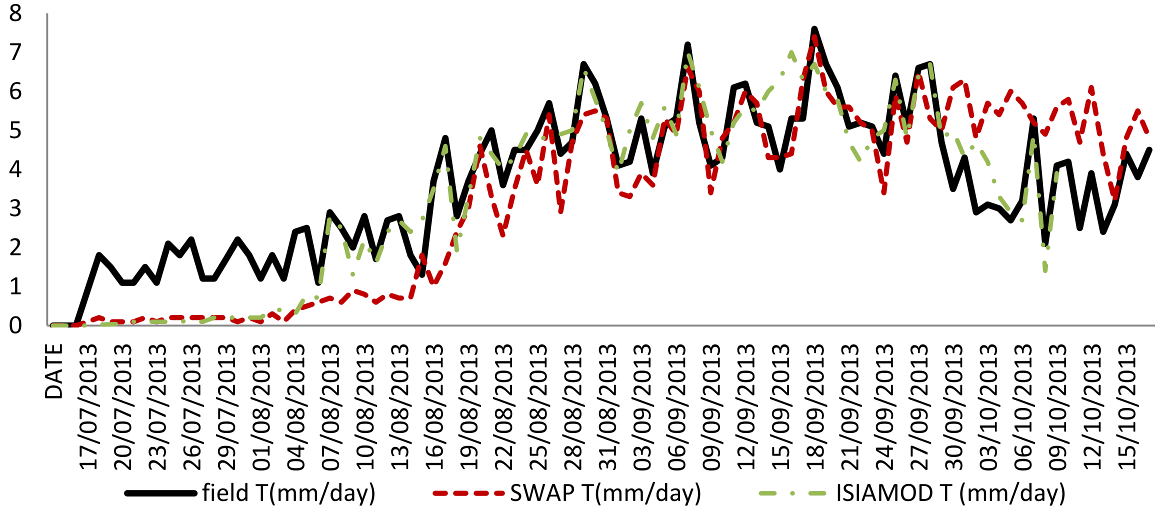

Fig 3. daily measured and simulated transpiration by SWAP and ISIAMOD models

Table 5. Statistics of the comparison between simulated and measured transpiration (T)

Statistical performance indices	**SWAP model**	**ISIAMOD model**
	Transpiration (T)	Transpiration (T)
AE	-0.34	-0.245
RMSE	0.583	0.86
CV (%)	17	24
EF	0.90	0.80
CRM	-0.097	0.0625

3.1.3 Comparison of Models-Simulated and Field-measured Evaporation

Figure 4 shows daily field measured evaporation (that is, ET-T) and simulated evaporation by SWAP and ISIAMOD models. Table 6 presents Statistics of the comparison between simulated and measured crop evaporation (E).

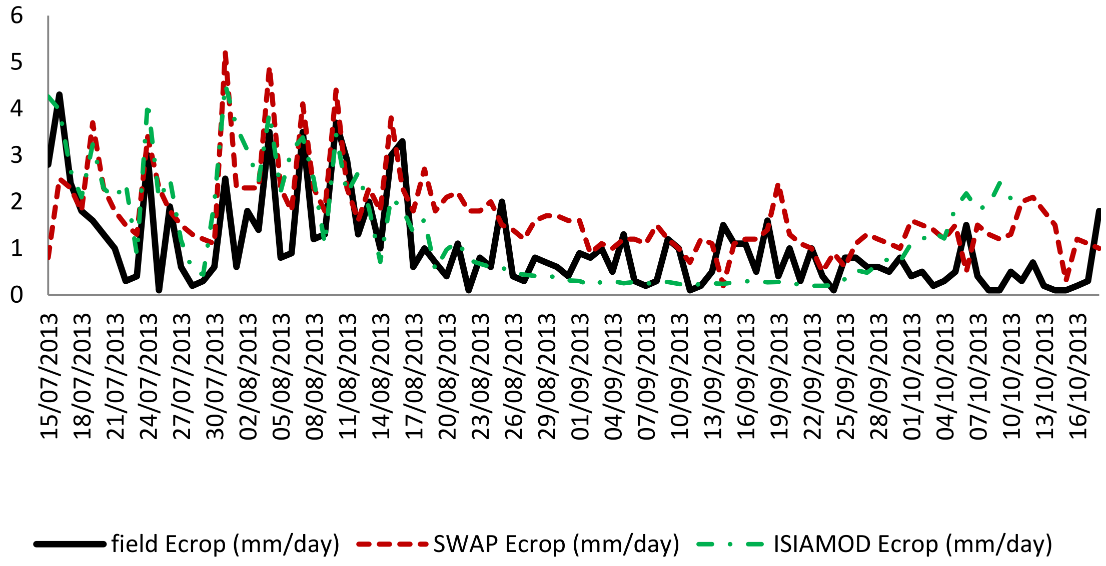

Fig 4. daily measured and simulated evaporation by SWAP and ISIAMOD models

Table 6: Statistics of the comparison between simulated and measured crop evaporation (E)

Statistical performance indices	SWAP model	ISIAMOD model
	Evaporation (E)	Evaporation (E)
AE	0.27	0.07
RMSE	0.29	0.33
CV (%)	41	29
EF	0.54	0.62
CRM	-0.21	-0.11

3.1.4 Comparison of Measured and Simulated Surface Runoff and Deep Percolation

Figure 5 and 6; show the daily measured and simulated surface runoff and drainage by SWAP and ISIAMOD models.

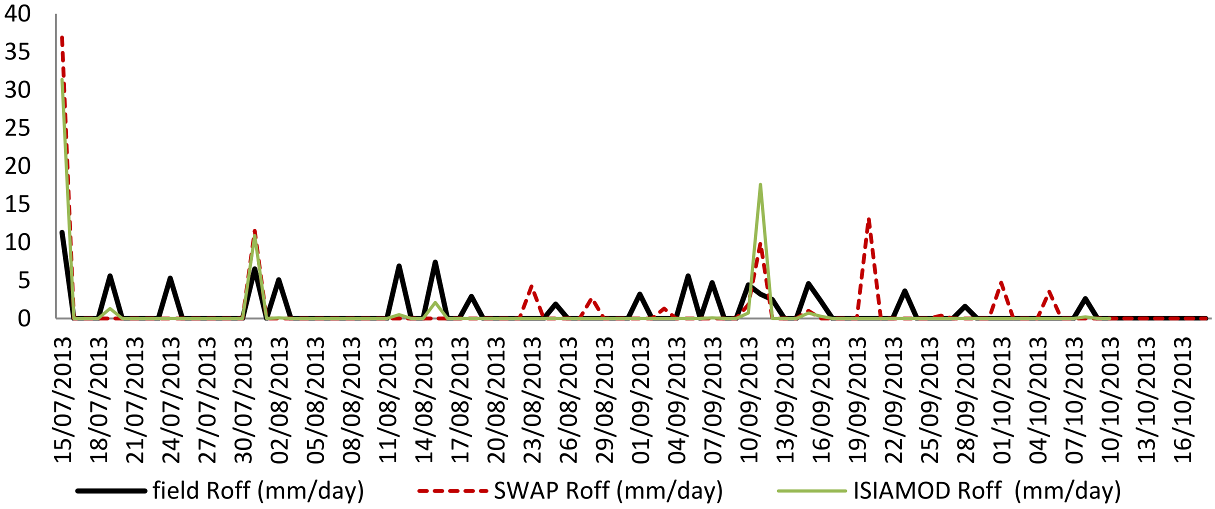

Fig 5. daily measured and simulated surface runoff by SWAP and ISIAMOD models

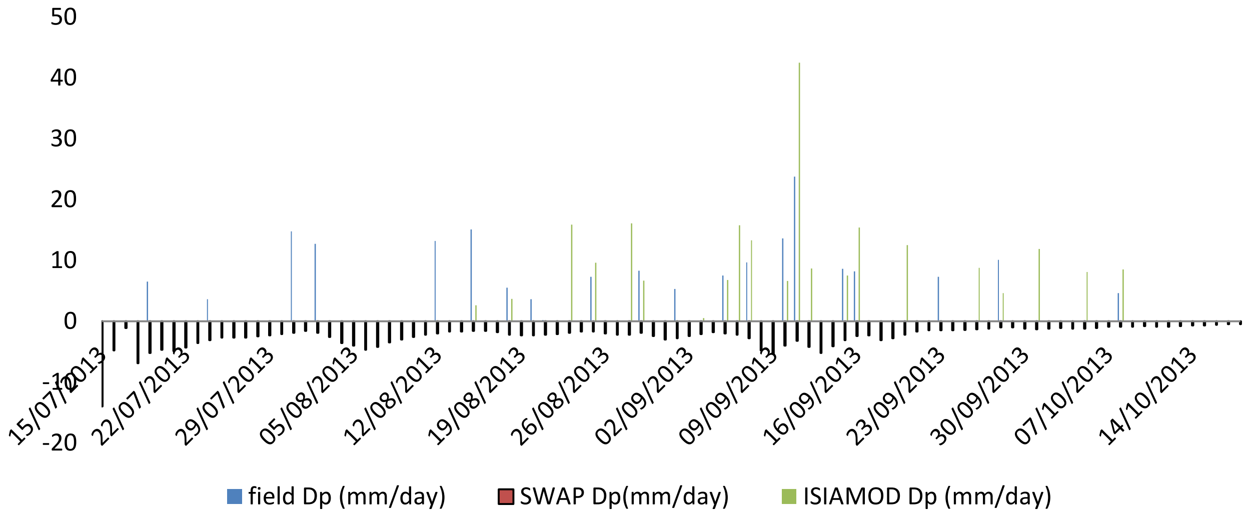

Fig 6. daily measured and simulated drainage by SWAP and ISIAMOD models

3.3 Summary and Comparison of the Performance of SWAP and ISIAMOD

Table 7. Summary of Measured and Simulated seasonal soil water balance from planting to maturity

Soil Water Balance components	Lysimeter	ISIAMOD model	SWAP model
Potential evapotranspiration (mm)		408.9	430.9
Actual evapotranspiration (mm)	395.6	385.1	386.3
Potential transpiration (mm)		288.6	321.0
Actual transpiration (mm)	304.0	272.7	270.0
Deep percolation (mm)	200.1	217.6	226.1
Surface runoff (mm)	88.6	65.96	91.2
Precipitation (mm)	511.5	511.5	511.5
Irrigation (mm)	205	205	205

Table 8 presents summary of comparison of the two models in terms of their ability to simulate soil water balance components. The note at the base of the table explained the performance rating. By satisfactory (++), it shows that the simulation of the components of soil water balance is ≥ 80%, while by good (+), it means the simulation is ≤ 60.

Table 8. Performance of ISIAMOD and SWAP in this specific studies

Predicted	ISIAMOD	SWAP
Evapotranspiration (ET)	++	++
Transpiration (T)	++	++
Evaporation (E)	++	+
Drainage/deep percolation (D_p)	+	+
Runoff (R)	+	+

Note: ++ satisfactory, and + Good

3.2 Discussions

3.2.1 Models' Simulated and Field-measured Evapotranspiration

For the first 20 days after sowing, the simulation of evapotranspiration (ET) by the two models and that of the field measured values are closely related. When the crops grown from the vegetative stage to when it reaches its maximum leaf area index (LAI), SWAP model over-estimated the ET. ISIAMOD on the other hand, simulated the ET optimally well except for the later part of the crop maturity stage (30/09 to 06/10/2013) where its over-estimates the ET. Generally, the two models simulated the process of ET well as evidence by the statistical analysis.

The CRM shows that SWAP model has a tendency of over-predicts the ET by 2%, while ISIAMOD under-predicts the model by 3%. The modeling efficiency (EF) is 84% for SWAP and 88% for ISIAMOD. These values (of EF) show a close relationship between the measured and simulated data and hence the prediction capacity of both models is good. [4] used ISIAOMD to simulate the ET of an irrigated maize crop in Tanzania during 2004 and 2005 season and obtained the modelling efficiency (EF) to range from 0.56 to 0.95 with CRM of -0.01 to -0.04. This shows ISIAMOD could also be used here in the research area for water management both for rain-fed and irrigated agriculture.

3.2.2 Models'-Simulated and Field-measured Transpiration

SWAP underestimated the crop transpiration (T) when the crops are still small. It overestimated it during the latter part of the crop's maturity growth stage, that is, during the peak of the growth when the canopy covers most of the soil. This difference is attributed to the disadvantage of considering the aerodynamic factor as multiplicative over crop growth, as assume in Penman-Montheith equation for the estimation of both potential and actual ET, T and E in SWAP model. ISIAMOD, on the other hand, simulated the T fairly well except for the early growth stage where it also underestimated it, when the measured values are taken as the reference values. During the early crop growth stage when T is expected to be small, the weighing-lysimeter could overestimate the T. So, the real T could be taken as the average of the three especially during the early growth stage of the crop.

The statistical indices in Table 5 reveal that, SWAP model has a tendency of over-predicts the T by 9% (CRM= 0.097), while ISIAMOD has a tendency of under-predicting the T by 6% (CRM= 0.0625). The modeling efficiency (EF) is 90% for SWAP and 80% for ISIAMOD. These values (of EF) show a close relationship between the measured and simulated data and hence the prediction capacity of both models is good one.

3.2.3 Models'-Simulated and Field-measured Evaporation

Figure 4 shows that, the cropped actual evaporation simulated by SWAP ranged from 3.7mm at the early crop growth stage (19/07/2013) to 0.2 mm toward the crop maturity stage (13/09/2013) with a seasonal total of 146.4 mm. The actual evaporation simulated by ISIAMOD ranged from 4.3 mm at the beginning of the crop season (15/07/2013) to 0.2 mm at the full vegetative stage of the crop (13/09/2013) with a seasonal total of 110.6 mm. SWAP overestimated the crop actual evaporation almost for the entire crop growth season. This is attributed to the fact that SWAP model assumes that the energy available for evaporation is entirely used to evaporate the intercepted water independent of the soil cover fraction. This could be valid for high soil cover fraction, that is, when the crop has fully matured and shed the ground. At small soil cover fraction (that is, at the early crop growth stage), this assumption might overestimate the actual evaporation rate of the intercepted water. ISIAMOD on the other hand, simulated the actual evaporation well except for the early crop growth stage where it overestimated it slightly. The actual evaporation in ISIAMOD depends on the soil moisture content of the soil.

Table 6 also shows that SWAP model overestimated the actual evaporation by 21%, while ISIAMOD only overestimate it by 11%. The modeling efficiencies was about 55% for SWAP and 62% for ISIAMOD, their coefficients of variability are 41% and 29%, respectively. ISIAMOD gave a better simulation of the actual evaporation than SWAP. Generally the performances of the two models are averagely okay.

3.2.4 Field-Measured and Models'-Simulated Surface Runoff and Deep Percolation

SWAP determines if the soil water flux is directed upward (that is, capillary rise of water at the bottom of the soil profile) or downward (that is, flux of water out of the soil root zone). The downward flux in SWAP is given a negative value, as shown figure 6. ISIAMOD on the other hand only simulated a downward (which is positive) of water out of the root zone. Since the lower boundary condition chosen for SWAP model is a lysimeter with free drainage bottom, all the drainage depths depicted in figure 6 are downward flow of excess water out of the root zone. The runoff and drainage from no-mulch lysimeter set-ups were used only to compare with the simulated runoff and drainage from the models. This was because the set-ups are more closely related to the soil-water-plant environments the two models are trying to simulate.

The runoff simulated by ISIAMOD varies from 1.29 to 36.9 mm with a seasonal total 65.9 mm; the runoff simulated by SWAP varies from 2.1 to 31.4 mm with a seasonal total of 91.2 mm. The drainage on the other hand, simulated by ISIAMOD varies from 2.6 to 42.5 mm with a season total of 217.6 mm; the drainage simulated by SWAP varies from 0.5

to 4.5 mm with a seasonal total of 226.1 mm.

The seasonal runoff from SWAP and ISIAMOD were about 12.7% and 9.2% of the total input water (rainfall + irrigation) respectively, while the seasonal deep percolation from SWAP and ISIAMOD was 31.5% and 30.4% of the total input water (rainfall + irrigation). Comparing with field measured values, SWAP overestimated the seasonal runoff by 0.3% while ISIAMOD under estimated the seasonal runoff by 3.2%.For the drainage, SWAP overestimated the seasonal drainage by 3.6% while ISIAMOD also overestimated the seasonal drainage by 2.5%. The differences between the models and the field measured data were partially insignificant, meaning that SWAP fairs well with ISIAMOD in estimating seasonal runoff and drainage. This result for seasonal runoff and drainage were similar to those in the literature. For example, [18] uses SWAP model and obtained similar result for seasonal water cycle under deficit irrigation in Beijing, China. [19], also obtained a modeling efficiency of 70% while comparing the seasonal deep percolation for various irrigation treatments of maize crop in a traditional irrigation scheme in Tanzania. [20], also used SWAP model in Sicilian vineyard on two soil profiles and results showed that SWAP provides reliable predictions soil water contents, electrical conductivity of saturated soil extract. They also predict the effect of climate change on soil water balance prediction under soil-crop and irrigation management condition. Several other studies on soil water balance simulation capability in different places around the world have being published under irrigation and rain-fed conditions using different crops [21, 22-23]. All these works' results had shown similar and promising results that SWAP mode is a good tool for soil and water management in agricultural field under varying soil and climatic conditions. With the results of this study, ISIAMOD can be considered also as good tool for simulation of soil water balance since it compared efficiently with SWAP model.

Both SWAP and ISIAMOD poorly simulate the daily trends of runoff and drainage process as depicted in Figure 5 and 6, respectively. Drainage water was recorded by SWAP right from the first day of sowing, while ISIAMOD did not record any drainage water till 32 days after the crop sowing. Though, effort was made to repack the soil dug out from the field into the lysimeter tank in stratified order as it occurred in the field, but the various cracks and fissures that may exist in the natural soil profile cannot be created in the lysimeter tank. More so, the presence of wire-mesh and gravel in the bottom of the lysimeter tank could have affected the flux of water out of the lysimeter tank. Therefore, the wide disparity between lysimeter measured and the models-simulated deep percolation/drainage daily trends can be attributed to that. Also for SWAP, the soil database was use to estimate the soil hydraulic function, using the soil textural class and per cent organic matter content obtained from the field soil. Measuring the hydraulic functions parameters directly could have improves the daily trends of the deep percolation. Table 7 shows the summary of measured and simulated seasonal balance.

4. Conclusion

The performance of the ISIAMOD and SWAP (2.0d) models in predicting the components of soil water balance was evaluated using the lysimeter/field experimental data. The two models satisfactorily predicted daily evapotranspiration (ET), transpiration (T) and evaporation (E) from the cropped field. The modeling efficiencies of the two models range from 84 to 90%, except for evaporation process of 54 to 62%. However, SWAP model overestimated ET, T and T components of the above soil water balance slightly during the vegetative to maturity growth stages of the crop, while ISIAMOD gave a better estimate during these growth stages except for early growth stage where it overestimated these components. On average, the statistical indicator used (CRM) shows that the tendency of ISIAMOD to underestimate ET, T and T falls in the range of 2.5 to 6.0% while the tendency of SWAP to overestimate ET, T and T falls in the range of 2.0 to 9%.The two models could only simulate the seasonal run-off and drainage, but could not simulate the daily trends of the run-off and drainage processes. For the SWAP model, on-field estimation of the soil hydraulic parameters than using the soil data-based (in-built in the model) could give a better prediction of the daily trend of deep percolation, and hence the surface runoff. The two models can be used for determination of soil water balance components of cropped soil and for analyzing a better water management option for agricultural production.

5. Recommendation

The results confirmed that SWAP and ISIAMOD models are good for estimation of soil water balance components and can be used for water management strategies for agricultural production. When considering detailed crop studies, SWAP model is preferred because ISIAMOD assumes water to be the only limiting factor for crop growth [6]. Research by [4] in

Italy, also confirmed that SWAP model can be reliably used for simulation of water content, electrical conductivity of soil extract and simulation of water and solute transport. In a situation where water management option is more pressing, then ISIAMOD can serve as a good tool.

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Ethical Statement

This study does not contain any studies with human or animal subjects performed by any of the authors.

Conflict of Interest

The authors declare that they have no conflict of interest.

Data Availability Statement

Not applicable.

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