Igbadun and Salim, Irrigat Drainage Sys Eng 2014, 3:1
DOI: 10.4172/2168-9768.1000119

Irrigation & Drainage Systems Engineering

Research Article Open Access

Simulation Study of Yield and Soil Water Balance Responses of a Maize Crop to Farmers' Irrigation Scheduling Practices in Tanzania

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Abstract

Maize (*Zea mays.L*) farmers in the traditional irrigation schemes in middle Mkoji sub-catchment, Tanzania observes three irrigation scheduling practices. This paper presents a simulation study of the impacts of these scheduling practices on yield and soil water balance of the maize crop. The three scheduling practices include irrigating at 5 days and 7 days intervals throughout the crop growing season, respectively; and irrigating at 7 days interval from planting to vegetative growth stage and 5 days interval from flowering to crop maturity stages. ISIAMOD, a crop growth cum irrigation simulation model, was used to simulate grain yield, soil water balance components and crop water productivity responses for the three scheduling practices over a range of water application depths. Simulated grain yield varied from 1338 to 4023 kg/ha. Seasonal water applied and deep percolation varied from 425 to 1800 mm, and 50 to 113 mm, respectively. The crop water productivity in terms of water applied varied from 0.22 to 0.57 kg/m3. These values closely agree with field measured values reported by some researchers for the study area. Irrigating maize fields at 5 days interval throughout the crop growing season or at flowering to crop maturity gave higher water productivity output only when application depths per irrigation did not exceed 30 mm. Water application beyond this depth only led to very high deep percolation losses without appreciable difference in crop yield compared to irrigating at 7 days interval throughout the crop growing season. Moreover, the productivity of water applied dropped by about 30 and 50 %. This implies that farmers who irrigate at 5 days interval because of they have access to water do not have any advantage (in terms of yield and water productivity) over those who irrigate at 7 days interval except they minimize water applied to their fields. Water application depth for higher productivity under the 7 days irrigation interval for the maize crop in the study area was 40 to 45 mm depth. Beyond this depth, there was no appreciable increase in grain yield but a fall in productivity of applied water and a buildup of deep percolation. To avoid over irrigation and the consequences associated with it, maize farmers at any sector of the irrigation scheme in the study area are advised to observe 7-day irrigation interval and keep water application depth within 40-45 mm per irrigation.

Keywords: Irrigation practice; Maize crop; Simulation model; Crop water productivity

Introduction

Traditional and smallholders irrigation schemes are very common in Tanzania. These schemes usually cover relatively small areas of 5 to 50 ha, and are managed by the groups of farmers in the communities via Water Users Association. These schemes are common around the mountainous eastern regions of Tanga, Kilimanjaro, and Arusha and also in south western regions of Morogoro, Iringa, and Mbeya. There source of water are the perennial/semi-perennial streams and rivers that originate from the mountains and hill tops around the schemes. Crop cultivated in these schemes include paddy, maize and vegetables. The numbers of these schemes are on the increase in those regions and are contributing meaningful to the rapid growth of irrigated agriculture in the country largely because of government, foreign and local organizations are assisting many of the schemes to develop the intake structures to abstract water from the streams and rivers.

One of the very active traditional irrigation schemes in the South-western region of the country is the Igurusi ya Zamani Irrigation Scheme (IZIS) located in Igurusi village of Mbeya Region. IZIS is community-managed, and water abstraction from the networks of perennial streams flowing through the scheme follows a 7-day rotational arrangement so that farmers at the middle- and down-stream of the scheme can have access to water. However, some farmers at the upstream irrigate their maize fields every five days as against weekly. Some others observe weekly irrigation until the maize begins to tassel, and thereafter turn to 5 days interval until the crop matures. They take advantage of the fact that their fields are located at the upstream of the water source to irrigation more frequently. However, their activities sometimes deprive those downstream ample accesses to water. A field survey on water application regimes by farmers in the study area showed that farmers upstream apply water as much as 60 to 70 mm per irrigation while those with limited access downstream irrigate as low as 25 mm, as they minimize water application depth to ensure that the available water spread over their command area. A knowledge gap has remained on the implications of these different irrigation schedules practiced by the farmers on yield, soil water balance components and crop water productivity in the study area.

The effect of irrigation regimes on crop yield, soil water balance and water use efficiency varies with crops, soils and water application depths. Crop yield and water use response to irrigation is known to be climate specific; hence the continuous study of the subject by different researchers. Singh et al. [1], Al-Jamal et al. [2], Imtiyaz et al. [3], Camposeo and Robino [4], Mermoud et al.[5], Sun et al.[6], Nazeer [7], Ayana [8], Quanqi et al. [9] are few examples of such studies. According to Kang et al. [10], the responses of grain yields and water use efficiency to irrigation varied considerably due to differences in soil water content and irrigation schedule. Mermoud et al. [5] has also reported that the

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Received November 14, 2013; **Accepted** February 17, 2014; **Published** February 24, 2014

Citation: Igbadun HE, Salim BA (2014) Simulation Study of Yield and Soil Water Balance Responses of a Maize Crop to Farmers' Irrigation Scheduling Practices in Tanzania. Irrigat Drainage Sys Eng 3: 119. doi:10.4172/2168-9768.1000119

impact of irrigation regimes on yield and water use vary with climate. They reported that in Camboiné, Burkina Faso, West Africa, irrigating onion twice a week instead of once, leads to increase in root zone water storage, a better crop water availability throughout the whole root zone and higher yield. They also argued that changing irrigation frequency have a strong influence on the components of the water balance. A decrease in the irrigation frequency causes a decrease in the water stored in the root zone, an augmentation of the crop transpiration, and a decrease of the water content in the immediate vicinity of the soil surface leading to reduced evaporation. Jin et al. [11] also reported that excessive irrigation leads to decrease in crop water use efficiency (WUE) and that effective deficit irrigation may result in higher production and WUE. Sun et al. [6] supported this view when he noted that excessive irrigation might not produce greater yield or optimal economic benefit, and advised that suitable irrigation be established for crops, soil types and specific climates.

The general objective of this study was to provide quantitative information on yield and soil water balance responses to the different irrigation scheduling practiced by farmers in the IZIS, Tanzania. The specific objectives were to use a computer-based simulation model to simulate grain yield, soil water balance (seasonal water applied, evapotranspiration and deep percolation) and crop water productivity of a maize crop cultivated based on the aforementioned irrigation scheduling practiced by farmers in the area, and to analyze the effect of the scheduling protocols on the simulated variables. The study is aimed at providing insight to the effect of the irrigation scheduling practiced by the farmers and to see if there is a window of opportunity for farmers to regulate water utilization at field level, and release excess of what they actually need to other water users in the downstream sector of the scheme.

Materials and Methods

The study location

The Igurusi ya Zamani irrigation scheme (IZIS) in the middle Mkoji sub-catchment (MSC) of the Great Ruaha River Basin, Mbeya Region of Tanzania. The River Basin itself is also a sub-catchment of the Rufiji River Basin which empties its water into the India Ocean. Figure 1a shows the map of the Mkoji sub-Catchment and Igurusi village located. Inserted is the map of Tanzania, showing the location of MSC. The IZIS lies on latitude 8.33°S, and longitude 33.53°E, and an altitude of 1100–1120 m above mean sea level. The Mkoji sub-catchment covers an area of about 3400 km^2 [12]. The study area has

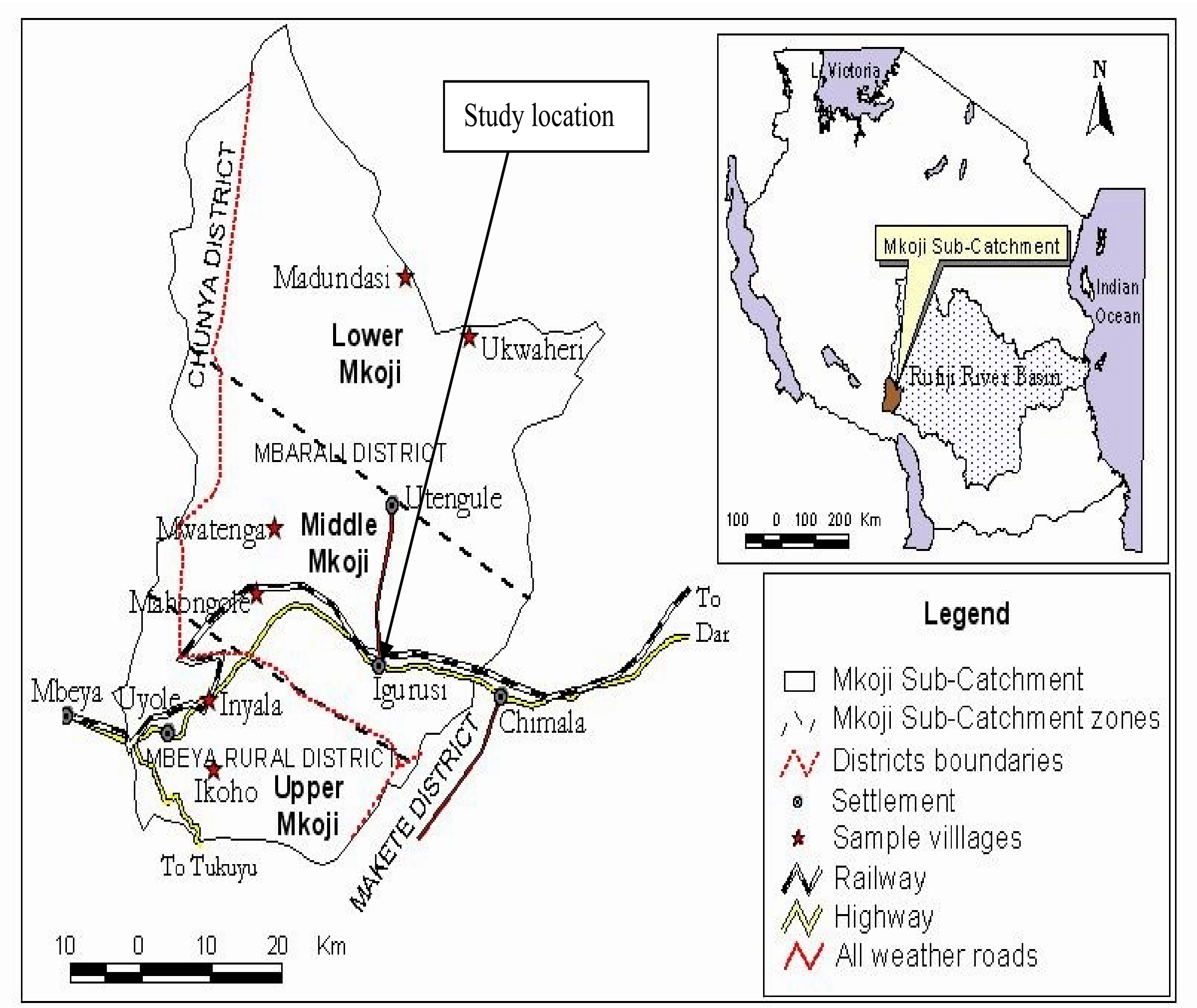

Figure 1a: Map of Mkoji Sub-Catchment (Inserted is the map of Tanzania).

a unimodal rainfall pattern which occurs between October and April with mean annual rainfall of 800 mm. The months of May to October are usually dry, but the weather favors the cultivation of arable crops like maize, cowpea, vegetables and fruits under irrigation. The mean daily maximum temperatures range from 28°C to 32°C, while the mean daily minimum temperatures range from 9.5°C to 19.5°C, respectively. The highest temperature values are recorded in October and November while the lowest values are experienced in June and July. The mean daily net solar radiation varies from 7.5 MJ/m^2/day to 12.3 MJ/m^2/day. The average annual open pan evaporation is about 2430 mm and the total open pan evaporation from June to October when dry season irrigation takes place is about 1080 mm [13]. The soils of the scheme vary from sandy clay to clay loam. The water holding capacity of a typical soil profile is about 97 mm/m with an average bulk density of 1.42 g/cm^3.

The computer simulation model used for the study

The computer simulation model used for this study was the Irrigation Scheduling Impact Assessment Model [14, 15]. ISIAMod consist of eleven modules which were integrated in hierarchical manner to simulate crop growth process, soil water balance of a cropped field, and water management response indices (WMRI) which are used to explain the impact of an irrigation scheduling decision. The input data required in the model include weather, soil, crop, rainfall, and irrigation scheduling decisions. The minimum weather data required are daily maximum and minimum ambient temperatures for the duration of crop growth. Other weather parameters may include wind speed, maximum and minimum relative humidity, sunshine hour or solar radiation. The model uses the weather data to simulate reference evapotranspiration either by Penman-Monteith or Hargreaves Methods [6], depending on available data. The soil input data include volumetric soil moisture content at field capacity and at wilting point, initial soil moisture contents, bulk density, and the percentage of sand in the soil texture. The crop input data include maximum rooting depth, maximum leaf area index, potential (non-water limited) harvest index, radiation use efficiency (RUE), radiation extinction coefficient, and peak crop water use coefficient (K_c). Others include crop base and optimum temperatures; leaf area index shape factors; water-limited harvest index adjustment factors; crop planting, emergence, and physiological maturity dates; days from planting for the start of each of the four crop growth stages, and fraction of the crop growth duration at which leaf area index started to decline. The four crop growth stages to be used in the model are crop establishment, vegetative, flowering and maturity (which include seed formation through to maturity). A unique feature of the model which makes it an improvement on existing model is the WMRI modules which generate the waters accounting indices, crop productivity indices and the seasonal relative deficit/losses indices used to define the level of impact of an irrigation scheduling decision on the crop and the environment.

ISIAMOD runs on daily time step from planting to maturity dates which are entered as part of the crop input data. The output simulated by the model include crop growth response like leaf area index, crop rooting depth, crop biomass, final harvest index and grain yield; soil water balance components such as daily soil moisture content, evaporation, transpiration, runoff, deep percolation, and rainfall interception. The crop yields and water balance components outputs are further processed by the model to generate the water management response indices. The detailed of model development, calibration and validation for a maize crop in the study area has been reported [14, 15].

Simulation procedure

The three irrigation scheduling practices that were simulated include 5-day irrigation interval labeled E5V5F5G5 (E stands for establishment, V for vegetative, F for flowering, and G for grain filling growth stages, and the numbers stands for the irrigation intervals); 7-day irrigation interval labeled (E7V7F7G7), and 7-day intervals at establishment and vegetative growth stage and a switch to 5 days interval at flowering and grain filling labeled E7V7F5G5. The weather data inputted into the model were daily maximum and minimum air temperature, relative humidity, wind speed and sunshine hour obtained from Igurusi Weather Station located about 4 km away from the irrigation scheme. The average weather data for 10 years (1985-1994) covering the crop growing season is presented as Table 1. The soil input data (Table 2) were those obtained from the research fields of the

Month of the year	Max. Temp (°C)	Min. Temp (°C)	Max. Rel. humidity (%)	Wind speed (m/sec)	Sun Shine (hr)
Jun	27.6	12.1	68.5	1.0	9.4
Jul	26.8	10.7	61.1	1.1	9.3
Aug	28.3	12.2	60.0	1.3	9.0
Sep	30.0	13.3	59.6	1.4	8.5
Oct	31.2	15.6	57.6	1.4	7.1

Table 1: Weather data from Igurusi Weather Station used to run the model (average of 10-year: 1985-1994).

Soil profile depth (mm)	MC @ field capacity (m^3/m^3)	MC @ wilting point (m^3/m^3)	Bulk density (dry) (g/cm^3)	Clay %	Silt %	Sand %	Soil Textural Class
0-150	0.262	0.127	1.44	19	18	64	Sand loam
150-400	0.295	0.163	1.39	31	17	52	Sand clay loam
400-700	0.305	0.226	1.45	33	22	45	Sand clay loam
700-1000	0.278	0.212	1.38	36	19	45	Sandy clay

Table 2: Soil physical properties of the research fields of MATI.

Parameters	Value
Maximum rooting depth	1.2 m
Maximum harvest index	0.34
Harvest index adjustment factor for the flowering stage	0.45
Harvest index adjustment factor for the maturity stage	0.5
Radiation extinction coefficient	0.55
Maximum leaf area index	0.35m^2/m^2
RUE (establishment and vegetative stages)	0.25 g/MJ
RUE (flowering and maturity stages)	0.23 g/MJ
Base temperature	8°C
Optimal temperature	24°C
Fraction of the growth duration at which leaf area index starts to decline	0.75
Days after planting at which establishment growth stage starts	0
Days after planting at which vegetative growth stage starts	23
Days after planting at which flowering growth stage starts	64
Days after planting at which maturity growth stage starts	93
Peak crop water use (kc) coefficient	1.2
Soil dependent transpiration constant	0.018 mm/day
Evaporation coefficient for bare soil	1.05

Source: [14]

Table 3: Crop and other input parameters used for running the model.

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Ministry of Agriculture Igurusi (MATI). The crop input data (Table 3) were those used to calibrate the ISIAMOD [16].

The three irrigation schedules were simulated over water application depths ranging from 25 to 70 mm at an increment of 5 mm; thus making a total of 10 simulation runs per schedule and 30 simulation runs per cropping season. The simulation was done for 10 cropping seasons covering the period of available weather data (1985-1994). The total simulation runs in the study were 3 scheduling practices x 10 water application depths x 10 seasons = 300. It was assumed in each run that soil moisture content at planting was at field capacity. Planting was in the third week of June and crop attained physiological maturity was at 120 days after planting. The maize variety was TMV1-ST.

Data analysis

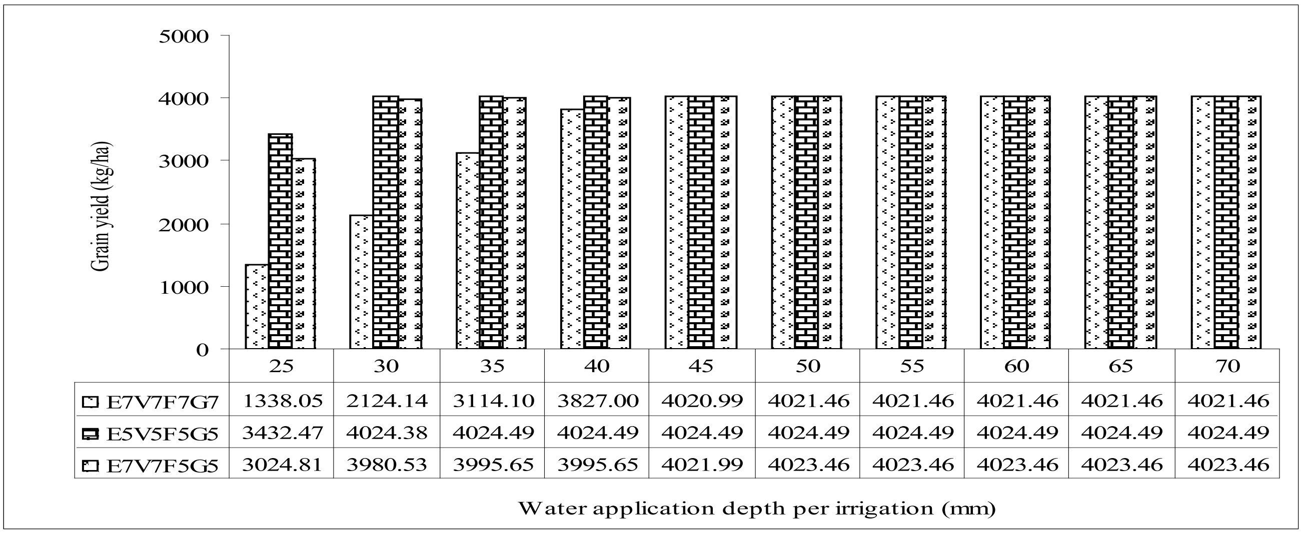
The model output variables that were analyzed in this study were grain yield, seasonal water applied, evapotranspiration, deep percolation and crop water productivity. Two-way Analysis of Variance tests were carried out for each of the output variables to study the effect of the water application depths and the scheduling practices on the output variables. The ten years simulation runs were regarded as replications in the analyses. The pooled data (averages of the 10 years simulation runs) for each of the output variables are presented graphically in the result and discussion section.

Results and Discussion

Simulated grain yield

Figure 1b shows the averages of the simulated grain yields for the three irrigation scheduling practices for the range of water application depths (WAD). The simulated grain yields ranged from 1338.08 to 4023.46 kg/ha. The lowest yield was obtained from the E7V7F7G7 schedule irrigated with 25 mm depth of water per irrigation event, while the highest yield was obtained when the maize crop was irrigated with 45 mm depth of water and above per irrigation event at 5 days interval throughout the crop growing season (E5V5F5G5). The simulated grain yields are found to relatively compared with the ranges of yield reported for irrigated maize by the National Irrigation Master Plan [17] and the Soil Water management Research Group (SWMRG-FAO, 2003) for the study area, which were 1800-2000 kg/ha and 1778 to 3703 kg/ha, respectively. More so, in a series of field experiments conducted in the study area, Igbadun et al. [18] reported grain yields ranging from 1580 to 3780 kg/ha for seasonal water application depths ranging from 400 to 700 mm.

Analysis of variance test indicated that there was a significant difference ($P < 0.05$) among the mean grain yields of the three scheduling practices. Moreover, while there was also significant difference ($P< 0.05$) among the mean grain yields of the water application depths, there was no significant difference in the interaction of water application depths and scheduling practices. This implies that the grain yields are largely affected either by water application or scheduling practices. Further analyses revealed that the differences among the mean grain yields happened when water application depths were below 40 mm. It may be observed from Figure 1 that there is no visible difference between the grain yields for E7V7F7G7 and the other two irrigation schedules (E5V5F5G5 and E7V7F5G5) except when the water application depths per irrigation were below 40 mm. When water was applied at 25 to 35 mm depth, the grain yield for E5V5F5G5 and E7V7F5G5 were higher than E7V7F7G7 by between 22 and 60 %. There was also no appreciable difference between the grain yield of E5V5F5G5 and E7V7F5G5 except at WAD of 25 mm where the grain yield for E5V5F5G5 was found to be higher than the E7V7F5G5 by about 13 %. The reason for these trends of result may not be far fetch. If the readily available moisture (RAM) of the effective root zone depth of the maize crop has been consumed by the crop before the next irrigation, water application depths below 40 mm may not raise soil moisture content to field capacity. Therefore, the crop will suffer moisture deficit and the resultant consequent is low yield. But when the interval of irrigation is at 5 days or it is shifted to 5 days at flowering and grain filling stages of the crop growth, the impact of moisture deficit on yield will be reduced and the grain yields will improve. This agrees with Yazar et al. [19] and Pandey et al. [20] who reported that maize grain yield increased significantly with irrigation, and Hsiao [21] and Jamieson et al. [22] who reported that the reduction in crop yield and its degree depend upon the timing, severity and duration of water stress.



	25	30	35	40	45	50	55	60	65	70
▢ E7V7F7G7	1338.05	2124.14	3114.10	3827.00	4020.99	4021.46	4021.46	4021.46	4021.46	4021.46
▤ E5V5F5G5	3432.47	4024.38	4024.49	4024.49	4024.49	4024.49	4024.49	4024.49	4024.49	4024.49
▨ E7V7F5G5	3024.81	3980.53	3995.65	3995.65	4021.99	4023.46	4023.46	4023.46	4023.46	4023.46

Figure 1b: Simulated grain yield for the E7V7F7G7, E5V5F5G5 and E7V7F5G5 irrigation schedules.

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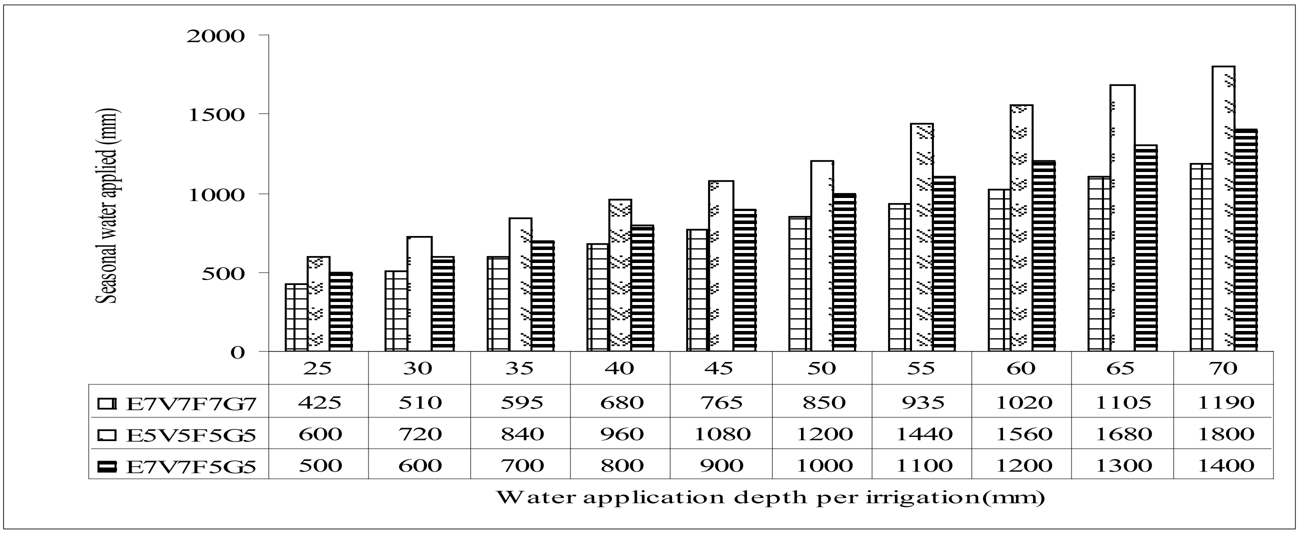


	25	30	35	40	45	50	55	60	65	70
▦ E7V7F7G7	425	510	595	680	765	850	935	1020	1105	1190
☐ E5V5F5G5	600	720	840	960	1080	1200	1440	1560	1680	1800
▤ E7V7F5G5	500	600	700	800	900	1000	1100	1200	1300	1400

Figure 2: Simulated seasonal water applied for the E7V7F7G7, E5V5F5G5 and E7V7F5G5 irrigation schedules.

Simulated soil water balance components

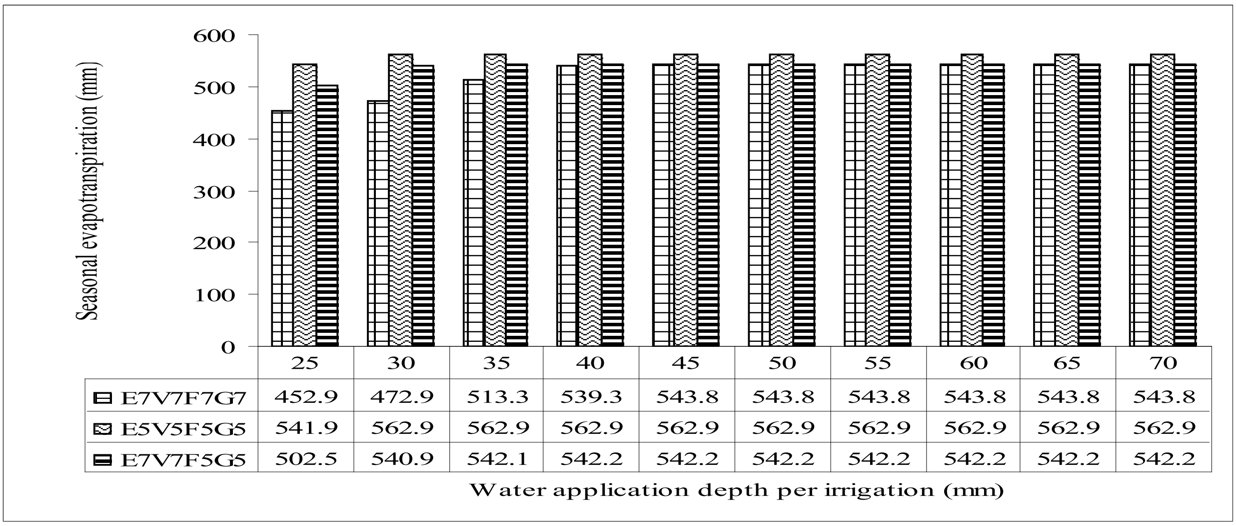
The soil water balance components considered in this study were seasonal water applied, evapotranspiration and deep percolation only. Figure 2 show the simulated seasonal water applied for the different water application depths per irrigation event. The seasonal water applied for E7V7F7G7 varied from 425 to 1190 mm, depending on water application depth. The seasonal water applied for E5V5F5G5 varied from 600 to 1800 mm, while the seasonal water applied for E7V7F5G5 varied from 500 to 1400 mm. These values are without the pre-planting irrigation since the model assumed that the soil moisture was at field capacity at planting. The highly significant differences ($P < 0.01$) in seasonal water applied among the three schedules were as a result of the frequencies of irrigation. The E5V5F5G5 schedule which was the most frequently irrigated recorded the highest seasonal water applied. Its range of water application far exceeds the crop water requirement of the maize crop given as 500 to 800 mm [23]. But the fact that some farmers used such amount of water in their fields is supported by Rajabu et al. [24] who reported that farmers in the study area abstracts water ranging from 825 to 1628 mm depth to irrigate their crops. Farmers who observe a weekly irrigation interval and apply water at 25 mm depth (E7V7F7G7) are irrigating fell below the seasonal crop water requirement, and this explains the reason for the poor grain yield recorded in that schedule.

Figure 3 show the simulated seasonal evapotranspiration (SET) for the different water application depths per irrigation event. The SET ranged from 412 to 563 mm for the three irrigation schedules. Analysis of Variance test showed the mean SET values of the three scheduling practices were significant at $P<0.01$. The mean SET values associated with the water application depths were significantly different at $P<0.05$, but the interaction were not significantly also different, which implies that the variation was not as a result of the combine effect of the scheduling and water application depth. Further analyses indicated that only the E5V5F5G5 schedule that was significantly different from the other two. The mean SET values of the E7V7F5G5 and the E7V7F7G7 were not significantly different. The highly significant difference associated with the E5V5F5G5 scheduling may be due to high evaporation rate since the field is frequently irrigated. However, the simulated SET values for the three scheduling practices were found to be within the range of seasonal consumptive use of maize crop reported by Howell et al.[25] and Farré and Faci [26] being 465-802 mm and 234-578 mm, respectively. Figure 4 shows that simulated deep percolation losses for the three schedules for the ranges of WAD. It may be observed from the figure that deep percolation increased with increase in WAD per irrigation, and this was expected. The deep percolation losses for E7V7F7G7 varied between 50 and 675 mm, while that of E5V5F5G5 varied between 86 and 1133 mm. The E7V7F5G5 also recorded deep percolation of 50 to 874 mm depth of water. It may be noticed from the figure that applying water above 40 mm depth for any of the three irrigation schedules lead to high loss of water to deep percolation. The amount loss to deep percolation when water was applying water above 45 mm depth either at 5 days interval from flowering stage or throughout the crop growing season was found to be about 30 to 100 % of water loss to evapotranspiration.

The trend of results in this study imply that only at WAD of between 25 and 30 mm is the 5-day irrigation interval either throughout the crop growing season or at flowering and grain filling growth stages of any advantage over the 7-day irrigation interval. Water application beyond this 35 mm will only lead to high water losses without appreciable increase in grain yield. The consequences of high deep percolation losses as outlined in Michael [27] include rapid buildup of water table, soil salinity, water logging which leads to poor yield due to low soil temperatures and poor aeration of plant roots. It is not unlikely that in a practical field setup, the high percolation losses under the 5-day irrigation interval especially at WAD exceeding 50mm could lead to poor crop yield. However, this is not reflected by the model as the current version does not have the module to capture the effect of water logging on crop yield performance.

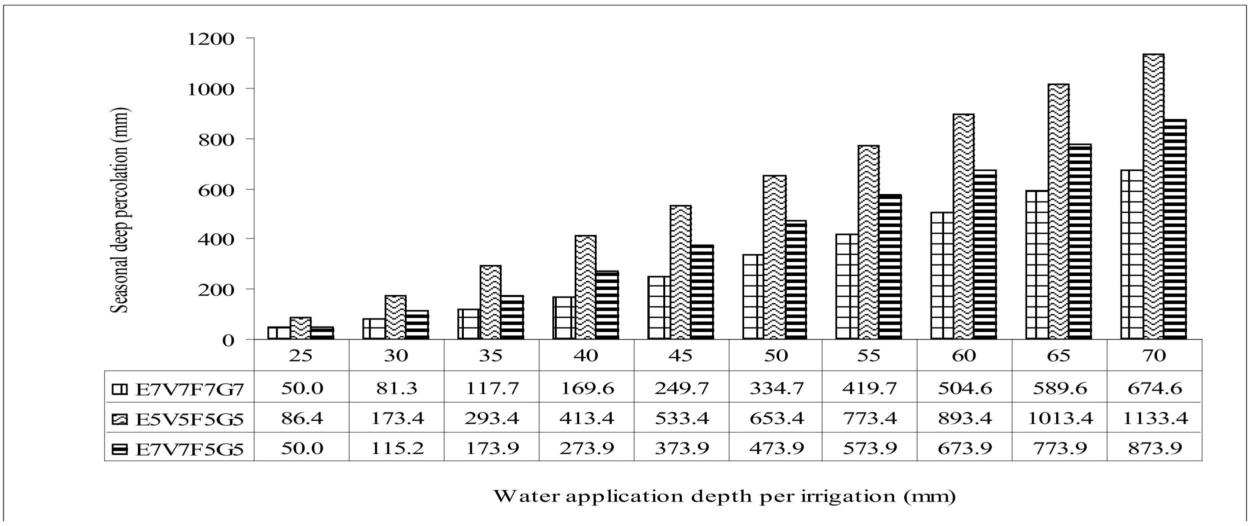
Crop water productivity

Table 4 shows the simulated crop water productivity expressed in term of yield per seasonal water applied ($CWP_{(wa)}$) and yield per seasonal evapotranspiration ($CWP_{(ET)}$) for the three irrigation schedules under study. The values of the $CWP_{(wa)}$ ranged from 0.31 to 0.53, 0.22 to 0.57 and 0.29 to 0.66 kg/m3 for E7V7F7G7, E5V5F5G5, and E7V7F5G5 schedules, respectively. The $CWP_{(ET)}$ were also found to range from 0.31 to 0.74, 0.63 to 0.71 and 0.60 to 0.74 kg/m^3, for E7V7F7G7, E5V5F5G5, and E7V7F5G5 schedules, respectively. These ranges of water



	25	30	35	40	45	50	55	60	65	70
▤ E7V7F7G7	452.9	472.9	513.3	539.3	543.8	543.8	543.8	543.8	543.8	543.8
▨ E5V5F5G5	541.9	562.9	562.9	562.9	562.9	562.9	562.9	562.9	562.9	562.9
☰ E7V7F5G5	502.5	540.9	542.1	542.2	542.2	542.2	542.2	542.2	542.2	542.2

Figure 3: Simulated seasonal evapotranspiration for the E7V7F7G7, E5V5F5G5 and E7V7F5G5 irrigation schedules.



	25	30	35	40	45	50	55	60	65	70
▤ E7V7F7G7	50.0	81.3	117.7	169.6	249.7	334.7	419.7	504.6	589.6	674.6
▨ E5V5F5G5	86.4	173.4	293.4	413.4	533.4	653.4	773.4	893.4	1013.4	1133.4
☰ E7V7F5G5	50.0	115.2	173.9	273.9	373.9	473.9	573.9	673.9	773.9	873.9

Figure 4: Simulated seasonal deep percolation for the E7V7F7G7, E5V5F5G5 and E7V7F5G5 irrigation scheduling scenarios.

Treatment	**Water application depth**									
	25	**30**	**35**	**40**	**45**	**50**	**55**	**60**	**65**	**70**
	Crop water productivity (water supply) CWP$_{(wa)}$									
E7V7F7G7	0.31	0.42	0.52	0.56	0.53	0.47	0.43	0.39	0.36	0.34
E5V5F5G5	0.57	0.56	0.48	0.42	0.37	0.34	0.28	0.26	0.24	0.22
E7V7F5G5	0.60	0.66	0.57	0.50	0.45	0.40	0.37	0.34	0.31	0.29
	Crop water productivity (evapotranspiration) CWP$_{(ET)}$									
E7V7F7G7	0.31	0.45	0.61	0.71	0.74	0.74	0.74	0.74	0.74	0.74
E5V5F5G5	0.63	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
E7V7F5G5	0.60	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74	0.74

Table 4: Crop water productivity in terms of water applied (CWP$_{(wa)}$) and evapotranspiration (CWP$_{(ETa)}$) for the irrigation scheduling intervals.

productivity were found to be within 0.25 to 1.80 kg/m^3 range obtained for irrigated maize in the Mediterranean environment by Farré and Faci [26]. Pandey et al. [20] also reported water productivity range for various deficit irrigation and nitrogen regimes in Niger Republic of 4.91 to 6.46 kg/ha-mm (0.49 to 0.65 kg/m^3).

It may be noticed from the Table that the productivity of water applied of E5V5F5G5 schedule was highest (0.57 kg/m^3) only at 25 mm WAD, and declined steadily with increase in water application depth. The productivity of water applied for E7V7F5G5 schedule peaked at 30 mm WAD, while that of E7V7F7G7 schedule peaked at 40 mm WAD and declined thereafter. The productivity of water in terms of seasonal evapotranspiration (CWP_{ET}) of E5V5F5G5 and E7V7F5G5 schedules were noticed to reach their peaked at 30 mm WAD while that of E7V7F7G7 was at peak at 45 mm WAD.

These results clearly show the water application regimes at which best water productivity level can be achieved. Among the three irrigation schedules, the best productivity of water may be obtained if water is applied 30 mm depth per irrigation event if the E7V7F5G5 schedule is followed. The $CWP_{(wa)}$ for E5V5F5G5 and E7V7F5G5 were found to be higher than E7V7F7G7 by between 25 and 48 % only at WAD of 25 and 30 mm. In other words, grain yield production per cubic meter of water applied will be 25 to 48 % higher if water is applied at 25-30 mm depth at 5 days irrigation interval throughout the crop growing season or at flowering to maturity stage. If water is applied at higher depths, water productivity of such schedules will drop lower that of weekly irrigation interval by about 30 to 50 %.

Conclusion

The implications of the irrigation schedules practiced by farmers in Igurusi ya Zamani irrigation scheme (IZIS) in the middle Mkoji sub-catchment of the Great Ruaha River Basin was studied using a simulation model. Irrigating maize fields at 5 days interval throughout the crop growing season or at flowering to crop maturity gave better water productivity output only when water application depths did not exceed 30 mm depth. Water application beyond this depth leads to very high deep percolation losses without significant difference in crop yield when compared to irrigating at 7 days interval throughout the crop growing season. Moreover, the productivity of applied irrigation water will drop by about 30 and 50%. The water application depth for best productivity under the 7 days irrigation interval for the maize crop in the study area was 40 to 45 mm depth. Beyond this depth, there was no appreciable increase in grain yield but a fall in productivity of applied water and a buildup of deep percolation. It is advised that farmers in the upstream of the irrigation scheme should maintain water application regime at 40 to 45 mm depth per irrigation while observing a weekly irrigation scheduling throughout the crop growing season. If they must observe a more frequent irrigation, the water application depths should not exceed 30 mm so as not to harm the soil and waste water and labor.

References

1. Singh PK, Mishra AK, Imtiyaz ZM (1991) Moisture stress and the water use efficiency of mustard. Agr Water Manage 20: 245-253.
2. Al-Jamal MS, Sammis TW, Ball S, Smeal D (1999) Yield-based, irrigated onion crop coefficient. Appl Eng Agric 15: 659-668.
3. Imtiyaz ZM, Mgadla NP, Chepete B, Manase SK (2000) Response of six vegetable crop to irrigation scheduling. Agr Water Manage 45: 331-342.
4. Camposeo S, Rubino P (2003) Effect of irrigation frequency on root water uptake in sugar beet. Plant Soil 253: 301-309.
5. Mermoud A, Tanini TD, Yacouba Y (2005) Impact of different irrigation schedules in water balance components of an onion crop in a semi-arid zone. Agr Water Manage 77: 282-295.
6. Sun HY, Liu CM, Zhang XY, Shen YJ, Zhang YQ (2006) Effect of irrigation on water balance, yield and water use efficiency on winter wheat in the North China Plains. Agr Water Manage 85: 211-218.
7. Nazeer M (2009) Simulation of maize crop under irrigated and rainfed conditions with CROPWAT model. ARPN Journal of Agricultural and Biological Science 4: 68-73.
8. Ayana M (2011) Deficit irrigation practices as alternative means of improving water use efficiencies in irrigated agriculture: case study of maize crop at Arba Minch, Ethiopia. African Journal of Agricultural Research 6: 226-235.
9. Quanqi L, Xunbo Z, Yahai C, Songlie Y (2012) Water consumption characteristics of winter wheat grown under different planting patterns and deficit irrigation regime. Agr Water Manage 105: 8-12.
10. Kang S, Zhang L, Liang Y, Hu X, Cai H, et al. (2002) Effects of limited irrigation on yield and water use efficiency of winter wheat in the loess Plateau of China. Agr Water Manage 55: 203-216.
11. Jin MG, Zhang RQ, Gao YF (1999) Temporal and spatial soil water management: A case study in the Heiloonggang Region, PR China. Agricultural Water Management 42: 173-187.
12. SMUWC (2001) Irrigation water management and efficiency. Directorate of Water Resource, Ministry of Water and Livestock, Government of Tanzania, Dar es Salaam, Tanzania.
13. FAO (2003) Comprehensive Assessment of Water Resources of Mkoji sub catchment, its Current Uses and Productivity. FAO-Netherlands Partnership Programme, Water and Food Security.
14. Igbadun HE (2006) Evaluation of Irrigation Scheduling Strategies for Improving Water Productivity: Computer-Based Simulation Model Approach. Sokoine University of Agriculture, Morogoro, Tanzania.
15. Igbadun HE (2012) Irrigation scheduling impact assessment model (ISIAMOD): A decision tool for irrigation scheduling. Indian Journal of Science and Technology 5: 3090-3099.
16. Allen RG, Pereira LS, Raes D, Smith M (1998) Crop Evapotranspiration: Guideline for Computing Crop Water Requirements. FAO Irrigation and Drainage.
17. JICA/MAFS (2002) The study on the National Irrigation Master Plan in the United Republic of Tanzania. Ministry of Agriculture and Food Security 1: 240.
18. Igbadun HE, Mahoo HF, Tarimo AKPR, Salim BA (2006) Crop water productivity of an irrigated maize crop in Mkoji sub-catchment of the Great Ruaha River Basin, Tanzania. Agricultural Water Management 85: 141-150.
19. Yazar A, Howell TA, Dusek DA, Copeland KS (1999) Evaluation of crop water stress index for LEAP irrigated corn. Irrigation Science 18: 171-180.
20. Pandey RK, Maranville JW, Admou A (2000) Deficit irrigation and nitrogen effects on maize in a sahelian environment I. Grain yield and yield components. Agr Water Manage 46: 1-13.
21. Hsaio TC (1990) Measurement of plant water status, Annual Review. Plant Physiology 24: 519-570.
22. Jamieson PD, Martin RJ, Francis GS, Wilson DR (1995) Drought effects on biomass yield production and radiation use efficiency in barley. Field Crop Research 43: 77-86.
23. Doorenbos J, Kassam AH (1979) Yield Response to Water. FAO Irrigation and Drainage, Rome, Italy.
24. Rajabu KRM, Mahoo HF, Sally H, Mashauri DA (2005) Water abstraction and use patterns and their implications on downstream river flows: A case study of Mkoji Sub-catchment in Tanzania. Proceedings of the East Africa Integrated River Basin Management Conference, Morogoro, Tanzania.
25. Howell TA, Tolk JA, Arland DS, Evertt R (1998) Evapotranspiration, yield and water use efficiency of corn hybrid differing in maturity. Agronomy Journal 90: 3-9.
26. Farre I, Faci JM (2006) Comparative response of maize (Zea mays L.) and sorghum (Sorghum bicolor L. Moench) to deficit irrigation in a Mediterranean environment. Agr Water Manage 83: 135-143.
27. Michael AM (1999) Irrigation Theory and Practice. Vikas Publishing House Pvt Ltd, New Delhi.

Citation: Igbadun HE, Salim BA (2014) Simulation Study of Yield and Soil Water Balance Responses of a Maize Crop to Farmers' Irrigation Scheduling Practices in Tanzania. Irrigat Drainage Sys Eng 3: 119. doi:10.4172/2168-9768.1000119