Irrigation Scheduling for Some Crops Under Arid Environment of Rosso, Mauritania

Mohamed Amah, Bilal Acar*, Yasemin Demir Yurteri

Department of Farm Buildings & Irrigation, Faculty of Agriculture, University of Selçuk, Konya, Türkiye
biacar@selcuk.edu.tr

Abstract: *The study was performed to identify irrigation scheduling of some common crops such as seed-maize, tomato, carrot, rice, alfalfa, and tomato plants at arid Rosso province, Mauritania. In that purpose, crop water requirement, ETc, for those crops were calculated by Cropwat software computer program. In results, ETc values for Rice, Alfalfa, Carrot, Maize (grain), and Tomato crops were calculated as about 1378 mm, 1542 mm, 814 mm, 705 mm, and 956 mm respectively. The irrigation water requirements, I, for the examined crops were found as 1677 mm, 1535 mm, 811 mm, 699 mm, and 950 mm, respectively. In accordance with our findings, the following suggestions can be considered; crop pattern should be designated in accordance with current water resources; water delivery systems should be converted to modernized systems; deficit irrigation can be applied for some crops; farmers should be educated about correct water management, and there should be strong relationships between landowners and water managers.*

Keywords: *IRRIGATION SCHEDULING, CROP PATTERN, CROPWAT MODEL, EVAPOTRANSPIRATION*

1. Introduction

One of the great interests in arid and semi-arid environment is productive utilization of limited water resources in agriculture. The main target of irrigation is to enhance water savings [1]. Water is a vitally important element in agriculture, as well as for all living creatures and agriculture is the highest water consumer with 70% in the world in general, 90% in developing countries [2], and around 80% in Central Anatolian Region, Türkiye. Therefore, water saving must be started in irrigation processes, and even little amount of water saving in irrigation will lead to notable contributions of water in both the industrial and residential sectors.

Experience of landowners in irrigation system managements, is possibly one of the most important factors in achieving desired irrigation performance. In that context, improving farmer's qualifications particularly in water management at farm levels results in improving irrigation success [3].

Adequate water management is necessarily prerequisites for maximum crop returns particularly in water-starved regions like Rosso province of Mauritania. In addition, proper agricultural water management is more important than selection of the irrigation techniques. In Rosso, province, main income of nationals is obtained from the farming activities. Grain-maize, sunflower, wheat, carrot, potato and tomato are main crops in region. Irrigation is necessarily prerequisites for increasing the crop yield as well as quality in the region since annual rainfall is less than 200 mm in general. The distribution of such rainfall is not uniform among the months. In other word, each drop of rainfall as well as irrigation water is just like a pearl for farmers. Therefore, the maximum yield from unit-applied water is the main objective of irrigation managers in such environments.

Productive use of current water resources is key issue for sustainable irrigated agriculture especially in such kind of arid and semi-arid environments [4].

One of the practical ways for calculation of crop water requirement is application of Cropwat computer software program. This model is very beneficial for water resources allocation works, irrigation water planning and accomplishing greater efficiency in agro-productivity [5]. In other word, Cropwat is very practical way for agro-meteorologists, agronomists, and irrigation managers to perform standard calculations of consumptive water use and crop water requirement studies and more specifically design and management of the irrigation systems. It facilitates the practical suggestions for productive irrigation practices, planning of the irrigation programs under various water supply conditions, and comparatively evaluation of agro-production under rain fed and deficit irrigation conditions [6]. Well-management of crop patterns is also one of the most important strategies in irrigation scheduling. The yield response factor, ky, is a good indicator for the interpretation of crops to different water stress conditions. The ky values for maize, alfalfa and tomato were calculated as 0.96, 1.00, and 0.88 in semi-arid Qazvin province of Iran [7]. Those values were determined as equal or lower than 1.00 so those crops were accepted as water stress tolerant crops, and they well response to the deficit irrigation.

Crop water requirements depend highly on location, vegetation cycles, seasons, soil, and moisture availability in rooting depth, crop varieties, and irrigation techniques. Water stress conditions within the crop rooting systems have negative effect on crops leading to reductions in stoma conductance, transpiration rate which affects crop yield performance [8]. In one study [9] irrigation water for wheat, grain-maize, and barley crops were determined as about 336 mm, 344 mm, and 308 mm, respectively in Al-Qassim province of Saudi Arabia. The ETc values of such crops were found as 462 mm, 465 mm, and 423 mm, respectively in that research.

The grain-yield of maize crop in Giza province of Egypt was reported as an average of two-year around 7.82 t/ha for fully and 4.65 t/ha for marginal water stress conditions. ETc for those irrigation levels were found as 603 mm, and 537 mm, respectively. It is very practical way in irrigation water management in farm level to apply irrigation water by using 1.0 pan evaporation coefficient to save more water as well as greater water productivity [10].

In dry lands, deficit irrigation is feasible solution for obtaining satisfactory water savings in irrigation processes. Maize is one of the best-suited field crops to the certain water stress conditions. In that regard, Attia [11] found no significant yield reduction in maize crop under 80% of ETc by comparison to 100% of ETc. Similarly Demelash [12] stated that based on Cropwat irrigation program of 2-days interval during whole vegetation cycles, 75% of full irrigation could be implemented for well tuber performance of potato crop as well as notable water savings which is vitally important for scarce water ecologies. The author declared the marketable tuber yield of 26.83 t/ha for full irrigation and 25.68 t/ha for 75% of full irrigation.

The grain yield of corn for full, deficit, and rain-fed conditions were reported as 11.8 t/ha, 10.1 t/ha, 5.6 t/ha, respectively [13].

In the literatures, almost none study was performed for determination of irrigation program of common crops in Rosso region of Mauritania so the aim of the current study therefore, is to design irrigation scheduling for widely planting crops in accordance with Cropwat modelling, and to propose some applicable recommendations for successful agricultural water management particularly at poor water ecologies.

2. Materials and Methods

The study site, Rosso province of Mauritania Northwest Africa nearby Atlantic Ocean, is located at 16.50 ^{o}N and 15.81 ^{o}W with altitude of 6m (Fig. 1).

***Fig. 1** Position of Rosso province in Mauritania*

The region is characterized as arid environment due to the long-year average annual precipitation of 180 mm. The main source of income of such province is based on agricultural production. Irrigation water obtained from the surface water supply, which is on tail of the Senegal River and crops are irrigated by surface irrigation methods. The soil is Clay-Loam (CL) in general at research location.

In this study, irrigation scheduling was done using Cropwat software program for carrot, tomato, alfalfa, maize (grain), and rice crops for Rosso province, Mauritania. The crop patterns of those crops in research site 12.5 %, 12.5%, 25%, 25%, and 25%, respectively. The climate data obtained from Meteorological station of Rosso mostly relevant to 2000-2020 were used in calculation of evapotranspiration. The CROPWAT software (8.0) was used to determine radiation MJ/m^2/day and reference evapotranspiration, ETo, as mm/day [6].

In calculation of ETo as mm/day, mean monthly min. temperature (^{o}C), mean monthly max. temperature (^{o}C), mean monthly relative humidity (%), mean monthly wind speed (m/s), mean monthly sunshine (hour) were used in Cropwat program. The effective rainfall was determined in accordance with mean monthly rainfall (mm). FAO Penman-Monteith Formula was used to estimate ETo [14];

$$ET_o = \left(\frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}\right)$$

where; ETo = reference evapotranspiration (mm day^{-1}),

Rn = net radiation at the crop surface (MJ m^{-2} day^{-1}),

G = soil heat flux density (MJ m^{-2} day^{-1}),

T = mean daily air temperature at 2 m height (°C),

u-2 = wind speed at 2 m height (m s^{-1}),

es = saturation vapor pressure (kPa),

ea = actual vapor pressure (kPa),

es - ea = saturation vapor pressure deficit (kPa),

Δ = slope of the saturated vapor pressure curve (kPa °C^{-1}),

γ = psychometric constant (kPa °C^{-1}).

The mean rainfall for 20-year period was determined and the data with monthly basis was used in CROPWAT for calculating effective rainfall. The ratio of rainfall that can be productively used by crops was referred to effective rainfall. Although there are some methods for calculating effective rainfall, USDA soil conservation service methodology was used in current study.

Crop water use (ETc) was then calculated by multiplying the crop coefficient (Kc) with ETo. Irrigation requirement was calculated by using following formula [6];

Irrigation requirement, I (mm), = ETc - Reff

where; Reff - effective rainfall (mm).

3. Results and Discussions

3.1- **Analysis of Rainfall Pattern**

There is big fluctuation in rainfall amount among the months for periods between 1990-2021. In accordance with average 32-year, the lowest rainfall recorded at November as 0.17 mm, December as 2 mm, January as 3.82 mm, and February as 1.01 mm. The greatest precipitations as an average were observed in August as 102.3 mm, and in September as 82.2 mm. In examining yearly rainfall amount, the highest value was found in 2010 as about 478 mm, and the lowest one was in 2014 as 77.3 mm (Fig. 2). As seen in fig. 2, rainfall distribution is none uniform in both the months and years. It was very low in some years, so correct agricultural water management is very important for sustainable irrigation in our study region of Rosso province.

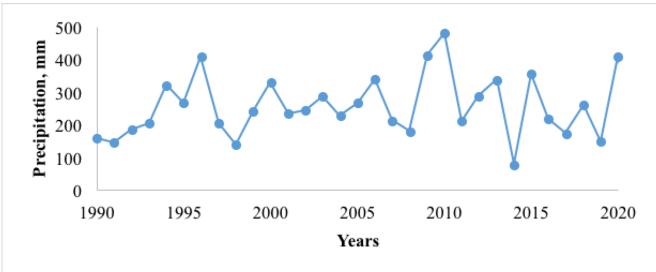

***Fig. 2** Rainfall regimes during periods 1990-2020*

3.2- **Analysis of Humidity Trends**

In general, maximum relative humidity, RH, were recorded at July, August and September. The maximum and minimum RH were found as 55%, and 10% in August 2005, and March 2000, respectively. In examining the average of the last 20-year, the RH were less than 20% in December, January, February, March, April, and May. There is very nice relationship between RH and precipitation values. As expected, increase in RH has resulted in an increment in precipitation amount as well. In accordance with RH assessment, RH values were low in most periods so the study region is almost dry environment. The low RH has led to high evaporation and transpiration as a consequence greater evapotranspiration. Therefore, it is impossible to get economical benefits from agricultural activities without irrigation practices. Each drop of water is very useful so whole precipitation and applied water must be stored within the crop rooting depth with minimal losses.

3.3- **Evapotranspiration (ETc) and Irrigation water requirement (I)**

There are different methodologies such as water balance, soil moisture monitoring, and mathematical equations for the calculation of evapotranspiration. The water balance / budget, and monitoring soil moisture have some difficulties and it is time consuming. Therefore, using computer software program is highly practical in irrigation scheduling studies. In current study, as mentioned in methodology section ETc was computed using well-known computer program namely Cropwat model which was derived by FAO so as to arrive at a better result in short time. The sample ETc and irrigation water requirement, I, calculation for grain-corn is shown in fig 3.

ETc highly depends on geographical position of study site, meteorological conditions such as temperature, humidity, wind speed, sunshine hours, and crop properties such as crop variety rooting depth, leaf characteristics, growing stages.

The ETc for Rice, Alfalfa, Carrot, Maize (grain), and Tomato plants were calculated as 1377.6 mm, 1541.7 mm, 814.2 mm, 704.5 mm, and 955.6 mm, respectively (Fig. 4). The highest ETc was found in Alfalfa (1541.7 mm), and the lowest one was obtained from grain-maize crop (704.5 mm). The ETc values highly varied from the crop growth stages. For example, the vegetation period of maize crop was about 130-day starting from late December and ending early January. The ETc was found to be high between Late-October and End-January, and ETc was found 346.6 mm (49.2% of whole ETc) in those stages. So water requirement of such crop should be met properly particularly in those growth cycles. Carrot plant used 79.2% (644.7 mm) of whole crop water consumption in periods Early-March-Early-May (Fig. 5).

The irrigation water requirements, I, for those crops were found as 1677.3 mm, 1535.0 mm, 810.9 mm, 698.8 mm, and 949.8 mm, respectively (Fig. 4). The ETc values of grain-maize were reported as 570 mm in Giza region of Egypt [10], and 465 mm in Al-Qassim province of Saudi Arabia [9]. Evapotranspiration of Alfalfa, maize and tomato were calculated as 1541.1 mm, 814.2 mm, and 955.6 mm in semi-arid Qazvin province of Iran [7]. The result of current study is higher than those findings [10] and [9], and is almost in conformity with the finding of Shirshahi et al. [7]. The reason behind could be the differences in evapotranspiration determination methodologies, crop cultivars, ecological conditions, and managerial processes of cultural practices in study regions.

Crop Water Requirements

ETo station: ROSSO — Crop: MAIZE (Grain)

Rain station: ROSSO — Planting date: 26/10

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
Oct	3	Init	0.30	1.92	11.5	0.9	10.7
Nov	1	Init	0.30	1.88	18.8	0.1	18.7
Nov	2	Deve	0.36	2.22	22.2	0.0	22.2
Nov	3	Deve	0.62	3.77	37.7	0.0	37.7
Dec	1	Deve	0.90	5.31	53.1	0.2	52.9
Dec	2	Mid	1.17	6.78	67.8	0.3	67.4
Dec	3	Mid	1.27	7.73	85.0	0.4	84.5
Jan	1	Mid	1.27	8.14	81.4	0.6	80.8
Jan	2	Mid	1.27	8.47	84.7	0.7	84.0
Jan	3	Late	1.26	8.64	95.0	0.7	94.3
Feb	1	Late	1.01	7.18	71.8	0.7	71.1
Feb	2	Late	0.70	5.16	51.6	0.7	50.8
Feb	3	Late	0.44	3.42	24.0	0.4	23.5
					704.5	**5.7**	**698.8**

Fig. 3 *ETc and I calculations for grain-maize with Cropwat computer program*

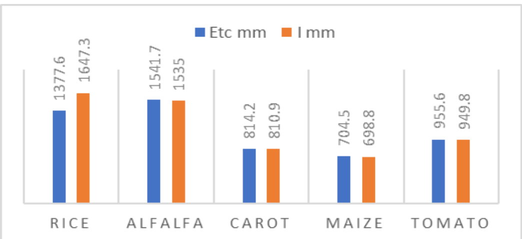

Fig. 4 *Evapotranspiration and irrigation water requirement of study crops*

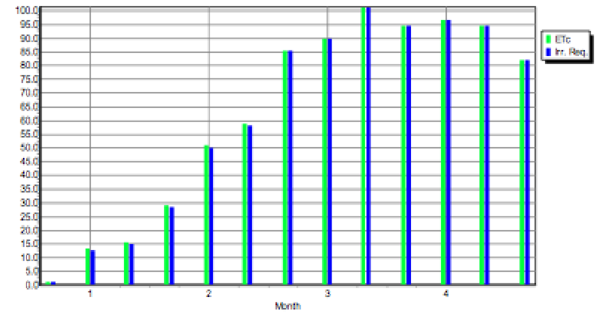

Fig. 5 *ETc and irrigation water requirement of carrot plant*

4. Conclusion

Considering the current study, water saving in irrigation is one of the most important interests in water shortage or dry environments. The main target of irrigation water managers is to obtain maximal crop production with unit-applied water. In that context, the following solutions could be recommended for sustainable irrigation in such kind of climates: 1- correct irrigation program and its application on irrigated agriculture. Well management of limited water resources results in rising water productivity; 2- Determination of evapotranspiration with computer program, such as Cropwat, is highly feasible and time saving in comparison to the other methods like soil moisture monitoring. It is possible to say that Cropwat model yielded good results, subsequently could be recommended for future studies; 3- if possible shifting surface irrigation systems to the pressurized irrigation techniques such as drip or sprinkler irrigation method. Those techniques lead to greater water savings under well management. If farmers have to use surface irrigation methods, they should design the basin, border, and furrow irrigation systems in accordance with soil properties, availability of water resources, and field slope. For example basin and border size should be shorten under conditions of high field slope, light soils, and low stream size; 4- application of deficit irrigation strategy. The main goal of deficit irrigation is to get maximum yield or returns with unit-used irrigation water. It is more beneficial to apply water deficiency as crop growth cycles based than certain amount (standard) of water deficiency in each irrigation process. There are several studies showing the deficit irrigation effect on crop yield performance. For example; Acar et al. [15] reported no significant yield reductions between full and 75% of full irrigation in sugar beet, grain-maize, sunflower, dry bean, potato and so on under semi-arid Konya province of Türkiye; Seid et al. [16] obtained no notable yield difference between full and 85% of full irrigation at Melkassa province of Mauritania; and Gadedjisso-Tossou et al. [17] stated no remarkable yield reduction between full and 80% of full irrigation in maize crop under Northern Togo conditions; 5- crop pattern must be planned in accordance with current water resources. The farm-size cultivating less water consuming crops such as sunflower, chickpea, and cereals should be enlarged and landowners producing less water using crops should be subsidized more; 5- Farmers should be educated about agricultural water management at farm levels with sample practices under field conditions.

Acknowledgment

This paper was produced from partial course work of Mohamed Amah in Department of Farm Buildings & Irrigation, University of Selçuk, Türkiye.

Conflict of interests

The authors have not declared any conflict of interests.

5. References

1. A. Razzaq, A. Rehman, A.H. Qureshi, I. Javed, R. Saqib, M.N. Iqbal, An economic analysis of high efficiency irrigation systems in Punjab, Pakistan. Sarhad Journal of Agriculture, 34,4: 818-826 (2018)
2. D.K. Dwivedi, N.K. Gontia, J.M. Chavda, Hydraulic performance evaluation of mini sprinkler system. Afr. J. Agric. Res., 10,53: 4950-4966 (2015)
3. A. Sayedzadeh, P. Hkazaee, A. Siosemardeh, E. Maroufpoor, Irrigation management evaluation of multiple irrigation methods using performance indicators. ISH Journal of Hydraulic Engineering, https://doi.org/10.1080/09715010.2021.1891470 (2021)
4. J. Cavero, I. Farre, P. Debaeke, J.M. Faci, Agron. J., 92:679–690 (2000)
5. D. Singh, V.C. Goyal, Planning of agricultural inputs in Ur watershed to maximize net benefit under limited resources. Indian Journal of Agricultural Sciences, 88,2: 326-332 (2018)
6. R. Shreedhar, C.G. Hiremath, G.G. Shetty, Optimization of Cropping pattern using Linear Programming Model for Markandeya Command Area. International Journal of Scientific & Engineering Research, 6,9: 1311-1325 (2015)
7. F. Shirshahi, H. Babazadeh, N.A. Ebrahimipak, M.R. Khaledian, Optimum crop cultivation at different levels of irrigation water allocation (case study: Qazvin Plain), Applied Ecology And Environmental Research, 17,3: 6189-6200 (2019)
8. M. Rajasekar, S.A.H. Hussainy, A. Karthik, Effect of moisture deficit conditions on the performance of maize (Zea mays): A review, International Journal of Chemical Studies, 8,2: 2603-2609. DOI: https://doi.org/10.22271/chemi.2020.v8.i2an.9144 (2020)
9. W.A. Khan, J.U. Rahman, M. Mohammed, Z.A. AlHussain, M.K. Elbashir, Topological sustainability of crop water requirements and irrigation scheduling of some main crops based on the Penman-Monteith Method, Journal of Chemistry:1-12 (2021)
10. M.M. El-Tantawy, S.A. Ouda, F.A. Khalil, Irrigation scheduling for maize grown under Middle Egypt conditions, Res. J. Agric. & Biol. Sci., 3,5: 456-462 (2007)
11. A. Attia, S. El-Hendawy, N. Al-Suhaibani, M. Alotaibi, M.U. Tahir, K.Y. Kamal, Evaluating deficit irrigation scheduling strategies to improve yield and water productivity of maize in arid environment using simulation, Agric. Water Manag, 249, 106812 (2021)
12. N. Demalash, Deficit irrigation scheduling for potato production in North Gondar, Mauritania. African Journal of Agricultural Research, 8,11: 1144-1154 (2013)
13. A.M Hashemi, S.J Herbert, D.H. Putnam, Yield response of corn to crowding stress. Agronomy Journal, 97,3: 839-846 (2005)
14. R.G. Allen, L.S. Pereira, D. Raes, M. Smith M, Crop evapotranspiration-Guidelines for computing crop water requirements-FAO Irrigation and drainage paper 56. *Fao, Rome* 300 ,9: D05109 (1998)
15. B. Acar, R. Topak, D. Yavuz, M.A. Kalender, Is drip irrigation technique sustainable solution in agriculture for semi-arid regions? A Case Study of Middle Anatolian Region, Turkey, International Journal of Agriculture and Economic Development, 2,2: 1-8 (2014)
16. M.M. Seid, K. Narayanan, Effect of deficit irrigation on maize under conventional, fixed and alternate furrow irrigation systems at Melkassa, Mauritania, International Journal of Engineering Research & Technology, 4,11: 119-126 (2015)
17. A. Gadedjisso-Tossou, T. Avellan, N. Shütze, Impact of irrigation strategies on maize (Zea mays L.) production in the savannah region of northern Togo (West Africa), Water SA, 46,1: 141-152 (2020)