A Developed Criterion for Rationalizing On-Farm Irrigation Water Uses Under Arid Conditions

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Abstract

Exploitation of irrigation water under arid ecosystem conditions becomes the pedagogical problem; therefore, rationalizing irrigation and maximizing water use efficiency based on appropriate developed technologies are the most important aspects in the water and agricultural policies. Therefore, the objectives of this study were to: 1) develop out a criterion to identify irrigation system effectiveness by using a dimensionless analysis; and 2) validate the suggested criterion.

Dimensional analysis outputs revealed that the irrigation efficiency, may be better if it replaced by new developed terminology noted as irrigation effectiveness for calculating the seasonal crop water requirements (SCWR) that represent a ratio of irrigation system performance and irrigated soil characteristics. The developed criterion may be expressed as follows:

\[
E_{ide} = \frac{S_{pi}}{I_{pi}} = \left[ \sum_{i} \frac{(q_{f} - q_{a})^2}{7 \times n \times p} \right] \times \left[ \frac{M_{Cafter} - M_{Cbefore}}{P. C - P.W.T} \right] \times \frac{d}{T_{i}} \times \ln(k) \times [f \times n] \times \text{conversion}
\]

Moreover, results analysis of the validation process of the application of the developed criterion indicated that SCWR had been improved by applying the developed criterion with about 10.55 – 21.56% comparing with the conventional method that had been recommended by FAO.

Keywords: Micro-Irrigation; Soils; Dimensional analysis; Irrigation Efficiency; Irrigation; Water use efficiency

Introduction

Arid ecosystems conditions could be characterized with dwindling water resources and growing competition for water will reduce water availability for agricultural development processing, while the need to meet growing food demands will require that more food is grown with less water. A more effective water and greater water-unit productivity will be a primary challenge for future development [1,2]. Due to excess or deficient levels of water or nutrients could result in yield reductions, meanwhile, proper design and management processes of micro-irrigation system are essential for successful production. Systems must integrate soil-hydro-physical properties, crop root distribution characteristics, water requirements related to crop growth stage and environmental demand [3-7].

There is no doubt that the average crop yield is a function of the irrigation water application factors (application uniformity; depth of application and the amount of daily evapotranspiration supplied by rainfall), the hydraulic variation of distributors as well as the crop sensitivity to the moisture stress. Application uniformity depends on the manufacture’s uniformity of the selected distributors, the hydraulic design and the systems maintenance program [8]. Following early research into the amount of water required for crop production, water use efficiency becomes a widely used agronomic term to express the efficiency of production per unit of water required [9-11]. Supply of water through irrigation involves the capture of water from the source, the transport through the irrigation system (i.e.), the distribution on the farm (i.e.) and the application to the field and to the crop. Enciso and Al-Jamal mentioned that water management will become an important practice used. Irrigation efficiency (IE) is an important factor into improving water management but so is economic return [12,13].

Patel and Rajput hypothesized that improved yields from subsurface drip systems are most likely due to more water being available to the plants, as compared to surface drip because of less evaporation in subsurface drip system. Burt, Slavil and Zavadil noted that crop evapotranspiration (ET) would be less for a well-watered crop with dry soil and plant surfaces (that is possible with subsurface drip system) than if the crops were to be irrigated with a method that wets the soil and plant surfaces [14,15]. On the other hand, El-Raie and Abdel-Wahab stated that the appropriate selection of the CWU method under diverse micro-climatic regions had to be considered for improving water uses under arid and semi-arid conditions [16]. Kumar, Alazba developed functions that can be used as a guide to yield potential allocation decision related to limited irrigation water [17,18]. However, the transport of on-farm irrigation water to cope the crop-water requirements’ is overcoming three levels of management: 1) the on-farm irrigation system managed by an irrigation agency; 2) the farm system managed by a group of farmers and/or an individual farmer and 3) the field system managed by the individual farmers.

Hereby, the objectives of this study were to: 1) develop out a criterion to identify irrigation system effectiveness based on a dimensionless analysis; and 2) validate the suggested criterion under field conditions.

Methodology

Each level of the methodology development is subjected to the technical sophistication of the hydraulic pathway and management of

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the irrigation system, in order to determines to a large extent efficiency of the irrigation systems. However, the first and second levels play a crucial role in the effective management of on-farm irrigation water.

**Dimensional and data analysis**

Factors affecting the performance analyses of on-farm irrigation systems had been gathered, analyzed and evaluated, in order to observe the dimensionless group. Also, data that represents the soil characteristics for managing the irrigation water had been gathered and evaluated for the same purpose. After then, the observed dimensionless groups had been verified individually and interactional-dynamic; then all groups had been validated under field conditions.

**Irrigation performance analyses index (Ipi)**: Irrigation systems that apply more uniformly and in limited amounts to avoid water stress in plants and to prevent excessive drainage is a crucial objective under arid ecosystems conditions. Herby, it can be concluded that the irrigation efficiency of localized irrigation systems is a function of distribution uniformity with which water discharged from the distributor devices.

From a point of view towards pressurize irrigation systems in general and localized irrigation in particularity, wherever, the forced stream through pipelines is the main factors of flow, it can accordingly clarified that both conveyance efficiency and farm efficiency can be negligible, however, their values are approximately to be a comply the maximum values, and their losses can be neglected too. After then, the most important efficiency that affected the performance of those irrigation system is that the application efficiency. Hereby, the factors that may be affecting the optimizing of the localized irrigation systems efficiencies are analyzed below.

**Soils performance index (Spi)**: Application of predicting models for optimizing localized irrigation systems efficiency needs information about hydro-physical properties, especially hydraulic conductivity under saturated and unsaturated conditions. In addition, other parameters such as field capacity and permanent wilting point that indicate soil texture may need to confirm the logical relation between them.

**Soil hydraulic resistance**: The resistance to vertical flow (Ri) of the (i-th) soil layer with a saturated thickness di, and vertical hydraulic conductivity (Kvi) is:

\[ R_i = d_i / K_v_i \]

Expressing Kvi in m/day and di in m, the resistance (Ri) is expressed in days, the total resistance (Rt) of the soil profile is:

\[ R_t = \Sigma R_i = \Sigma d_i / K_v_i \]

where \( \Sigma \) signifies the summation over all layers: \( i = 1, 2, 3, \ldots, n \)

The resistance plays a role in soil profile where a sequence of layers occurs with varying horizontal permeability so that horizontal flow is found mainly in the layers with high horizontal permeability while the layers with low horizontal permeability transmit the water mainly in a vertical sense. When the horizontal and vertical hydraulic conductivity (Kh and Kvi) of the (i-th) soil layer differ considerably, the layer is said to be anisotropic with respect to hydraulic conductivity. When the apparent horizontal and vertical hydraulic conductivity (Kvh and Kvi) differ considerably, the soil profile is said to be anisotropic with respect to hydraulic conductivity. When calculating flow to drains though soil profile with the aim to control the water table, the anisotropy is to be taken into account; otherwise the result may be erroneous.

**Transmissivity**: The Transmissivity is a measure of how much water can be transmitted horizontally, such as to the tile drains. Soil profile may consist of n soil layers. The Transmissivity for horizontal flow \( T_i \) of the \( (i - th) \), soil layer with a saturated thickness \( d_i \) and horizontal hydraulic conductivity \( K_i \) is:

\[ T_i = k_v d_i \]

Transmissivity is directly proportional to horizontal hydraulic conductivity \( K_i \) and thickness \( d_i \). Expressing \( K_i \) in m/day and \( d_i \) in m, the Transmissivity \( T_i \) is found in units m²/day. The Total Transmissivity \( T_t \) of the soil profile is the signifies the summation over all layers \( i = 1, 2, 3, \ldots, n \). When the soil layer is entirely below the water table, its saturated thickness corresponds to the thickness of the soil layer itself. When the water table is inside a soil layer, the saturated thickness corresponds to the distance of the water table to the bottom of the layer. As the water table may behave dynamically, this thickness may change from place to place or from time to time, so that the Transmissivity may vary accordingly. However, the estimation of K from grain size could be gotten from Allen-Hazen derived an empirical formula for approximating hydraulic conductivity from grain size analyses:

\[ K_v = C(D_i)^{1.5} \]

Where: \( C \) is the Hazen’s empirical coefficient, which takes a value between 0.4 and 10.0, with an average value of 1.0. \( pb / ps \leq 1 \) is packing system of soil particles which refers to soil porosity and therefore indicates the efficiency of soil tillage. Small this ratio indicates good aeration in soil and suitable tillage operation. While as this ratio increases this means soil tended to compacted or consolidated and characterized with bad aeration and high penetration resistance needs high power in plowing and through using other soil machines; \( n \) value in van Genuchten model affects the slope of the Soil Water Characteristics Curve for suction greater than the air entry suction \( (y_a) \). The slope becomes increasing negative as \( n \) value decreases. The value for \( n \) is always > 1 generally fluctuated between 1.1 to 1.3 for well-structured clay soil and from 1.4 to 1.8 for medium and light textured soil. The great value of \( n \) refers to raped and easily water depletion from the soil, so it can be closely related to the period between irrigations. As the soil slope is increases finger flow (Flow of water into macro pores in vertical direction) is decreased while lateral flow tended to increased may resulting in decreasing the efficiency of soil water distribution. However, different hydro-physical characteristics of the Egyptian soils had been gathered and analyzed, as shown in (Table 1).

- **Effect of “n” on hydraulic conductivity**: a value affects the slope of the hydraulic conductivity for suction greater than the air entry suction \( (y_a) \). The slope becomes shallower as \( n \) decreases.
- **Effect of “a” on Soil Water Content Curve**: a value (alpha) affects the breakdown in the curve, commonly referred to as the air entry suction \( (y_a) \). The air entry suction increases as \( a \) value (alpha) decreases.
- **Effect of “a” on hydraulic conductivity**: a value (alpha) affects the breakdown in the curve, commonly referred to as the air entry suction \( (y_a) \). The breakdown occurs at higher suction as a (alpha) value decreases.
as a function of both irrigation systems equivalent parameters, soils stored in the root zone and utilized effectively by plant in avoidance of water diverted to the irrigation system, which is ultimately effectively elaborated. Efficiency is generally associated with a developed criterion for optimizing localized irrigation efficiency.

Field experiments were carried out during two successive growing seasons in order to determine soil moisture distribution patterns under each treatments, the soil area had been gathered from Central Laboratory of Agricultural Climate (CLAC), Agriculture Research Center (ARC) for the cultivated growing season. After these, gathered data were analyzed and processed according to investigated level of treatments, as described later. Reference evapotranspiration (ET0) was computed using the FAO, modified Penman–Monteith method [19]. ET0 data were processed by using CropWat 8.1 model, for all calculation based on FAO method, or were processed to be used for calculation by using the developed criteria method.

\[ \text{CWU} = k_c \times \text{ET0} \]
\[ \text{SCWRFAO} = \text{CWU}/\text{Ea} \]
\[ \text{SCWREidc} = \text{CWU}/\text{Eidc} \]

Treatments:

Actual evapotranspiration treatments: FAO: determination of actual evapotranspiration based on traditional method that had been described by FAO.

\[ \text{E}_{\text{at}} = \text{determination of actual evapotranspiration based on the developed criterion.} \]

Irrigation systems treatments:

SD: surface drip irrigation system treatments.

SSD\(_{10}\): subsurface drip irrigation system with buried laterals at 10 cm depth treatments.

SSD\(_{20}\): subsurface drip irrigation system with buried laterals at 20 cm depth treatments.

Measurement and calculations:

Soil Water and Salts Distribution Pattern under Deficit Irrigation Treatments: Soil samples were taken periodically during each growing season in order to determine soil moisture distribution patterns under each treatment. Meanwhile, soil samples were taken twice (one before cultivation season and the second after harvesting) in order to determine salt distribution patterns under each treatments, the soil area had been gathered from Central Laboratory of Agricultural Climate (CLAC), Agriculture Research Center (ARC) for the cultivated growing seasons.

**Table 1:** Egyptian soil hydro-physical properties under arid conditions.

**Table 2:** Soil physical properties of the experimental site.

**Theoretical therapy:** The concepts of water use efficiency are introduced for the purpose of optimizing localized irrigation efficiency and the technical and agricultural options to increase production with less water elaborated. Efficiency is generally associated with a transformation process in which an input is transformed into an output. Therefore, the overall irrigation efficiency is defined as the fraction of water diverted to the irrigation system, which is ultimately effectively stored in the root zone and utilized effectively by plant in avoidance of plant-water stresses. The effective irrigation efficiency is characterized as a function of both irrigation systems equivalent parameters, soils equivalent parameters and application time.

**Validation process:** Field experiments were carried out during two successive growing at a farm located at Longitude 30° 13' 0 E, latitude 30° 25' 0 N and 25.5 m above MSL, which represents sandy soils conditions of the newly reclaimed soil of the Egypt. The analyzes to determine physical and hydro-physical characteristics of the soil site had been conducted according to standard methods and presented in (Table 2). Surface and subsurface drip irrigation systems networks were installed at the experimental site. A split-split plot design was used in this experiment. However, the area was divided into two main, every plot was divided into three sub-plots each (90 × 30 m) for drip irrigation treatments (SD, SSD\(_{10}\) and SSD\(_{20}\)).

**Cultivated crop:** Onion crop (Allium Cepa L.), Giza 20 for two successive growing seasons (2011-2012) and (2012-2013), the cultivated area was prepared into leveled basins of (30 × 30 m) for each treatment, and transplanted of onion seeds on Dec. 2011 in the first season and on Dec. 2012 in the second season, meanwhile, harvesting had been taken place on April of each growing season. The sawing was done in row at plant spacing of 14.3 cm between plants and the spacing between plant’s rows was varied according to the number of cultivated plant’s rows around laters. All agronomic practices and the rate of applications were applied as recommended by Vegetable Research Institute, ARC, MALR, Egypt. The crop began to show signs of maturity (over 70% dropping of leave head) at 12 and 14 weeks after germination. Harvesting was carried out about one week after, particularly 10th April 2012 and 13th April 2013. The area of 3 m in long and 1 m in wide in each plot were lifted (without discards), properly labeled and taken to be to laboratory to curve for about two weeks. Therefore, the onion bulbs were separated from the dry matter and weighed.

**Calculation methods of the applied amounts of irrigation water:** Onion plant-water requirements were calculated and scheduled. However, Reference evapotranspiration of the studied

**Table 1:** Egyptian soil hydro-physical properties under arid conditions.

<table>
<thead>
<tr>
<th>Texture Class</th>
<th>N</th>
<th>-θr- cm/cm³</th>
<th>-θs- cm/cm³</th>
<th>-log(α) log1/cm/cm</th>
<th>-log(n) log10</th>
<th>-Ks log(cm/day)</th>
<th>-Ko log(cm/day)</th>
<th>-L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Clay loam</td>
<td>84</td>
<td>0.098 (0.107)</td>
<td>0.459 (0.079)</td>
<td>-1.825 (0.68)</td>
<td>0.098 (0.07)</td>
<td>1.169 (0.92)</td>
<td>0.472 (0.26)</td>
<td>-1.561 (1.39)</td>
</tr>
<tr>
<td>Loam</td>
<td>140</td>
<td>0.079 (0.076)</td>
<td>0.442 (0.079)</td>
<td>-1.801 (0.69)</td>
<td>0.151 (0.12)</td>
<td>0.913 (1.09)</td>
<td>0.699 (0.23)</td>
<td>-0.763 (0.90)</td>
</tr>
<tr>
<td>Loamy Sand</td>
<td>242</td>
<td>0.061 (0.073)</td>
<td>0.389 (0.098)</td>
<td>-1.954 (0.73)</td>
<td>0.168 (0.13)</td>
<td>1.081 (0.92)</td>
<td>0.568 (0.21)</td>
<td>-0.371 (0.84)</td>
</tr>
<tr>
<td>Sand</td>
<td>201</td>
<td>0.049 (0.042)</td>
<td>0.390 (0.070)</td>
<td>-1.459 (0.47)</td>
<td>0.242 (0.16)</td>
<td>2.022 (0.64)</td>
<td>1.386 (0.24)</td>
<td>-0.874 (0.59)</td>
</tr>
<tr>
<td>Sandy Clay</td>
<td>308</td>
<td>0.053 (0.029)</td>
<td>0.375 (0.055)</td>
<td>-1.453 (0.25)</td>
<td>0.502 (0.18)</td>
<td>2.008 (0.59)</td>
<td>1.389 (0.24)</td>
<td>-0.930 (0.49)</td>
</tr>
<tr>
<td>S C L</td>
<td>11</td>
<td>0.117 (0.114)</td>
<td>0.385 (0.046)</td>
<td>-1.476 (0.57)</td>
<td>0.082 (0.06)</td>
<td>1.055 (0.89)</td>
<td>0.637 (0.34)</td>
<td>-3.665 (1.80)</td>
</tr>
<tr>
<td>S loam</td>
<td>87</td>
<td>0.063 (0.078)</td>
<td>0.384 (0.061)</td>
<td>-1.676 (0.71)</td>
<td>0.124 (0.12)</td>
<td>1.120 (0.85)</td>
<td>0.841 (0.24)</td>
<td>-1.280 (0.99)</td>
</tr>
<tr>
<td>Si loam</td>
<td>476</td>
<td>0.039 (0.054)</td>
<td>0.387 (0.085)</td>
<td>-1.574 (0.56)</td>
<td>0.161 (0.11)</td>
<td>1.583 (0.66)</td>
<td>1.190 (0.21)</td>
<td>-0.861 (0.73)</td>
</tr>
<tr>
<td>Silt</td>
<td>6</td>
<td>0.050 (0.041)</td>
<td>0.489 (0.078)</td>
<td>-2.182 (0.30)</td>
<td>0.225 (0.13)</td>
<td>1.641 (0.27)</td>
<td>0.524 (0.32)</td>
<td>0.624 (1.57)</td>
</tr>
<tr>
<td>Si Clay</td>
<td>28</td>
<td>0.111 (0.119)</td>
<td>0.481 (0.080)</td>
<td>-1.790 (0.64)</td>
<td>0.121 (0.10)</td>
<td>0.983 (0.57)</td>
<td>0.501 (0.27)</td>
<td>-1.287 (1.23)</td>
</tr>
<tr>
<td>Si C L</td>
<td>172</td>
<td>0.090 (0.082)</td>
<td>0.482 (0.086)</td>
<td>-2.076 (0.59)</td>
<td>0.182 (0.13)</td>
<td>1.046 (0.76)</td>
<td>0.349 (0.26)</td>
<td>-0.156 (1.23)</td>
</tr>
<tr>
<td>Si Loam</td>
<td>330</td>
<td>0.065 (0.073)</td>
<td>0.439 (0.093)</td>
<td>-2.296 (0.57)</td>
<td>0.221 (0.14)</td>
<td>1.261 (0.74)</td>
<td>0.243 (0.26)</td>
<td>0.365 (1.42)</td>
</tr>
</tbody>
</table>

**Table 2:** Soil physical properties of the experimental site.

Soil layer, cm

<table>
<thead>
<tr>
<th>Particle size distribution, %</th>
<th>Texture class</th>
<th>B. D (gm/cm³)</th>
<th>Moisture content by weight (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td>94.5 3.5 2</td>
<td>Sandy</td>
<td>1.65 8.03 3.3 4.7</td>
</tr>
<tr>
<td>Silt</td>
<td>95 3.3 1.7</td>
<td>Sandy</td>
<td>1.56 9.13 3.14 5.99</td>
</tr>
<tr>
<td>Clay</td>
<td>95.7 3 1.3</td>
<td>Sandy</td>
<td>1.44 10.07 2.99 7.08</td>
</tr>
</tbody>
</table>

F. C = Field capacity, P. W.P =Permanant wilting point, A.W= Available water B.D= Bulk density
samples were taken around the emitter, at 10 cm depth and 20 cm. Data were exposed to SURFER 7.

Computation of Crop-Water Use (CWU), Seasonal Crop Water Requirements (SCWR): The crop water use, seasonal crop water use and seasonal crop water requirements at each onion plants growing stage were calculated, determined based on the calculation method base.

Results and Discussion

Dimensional analysis outputs of the developed criterion

Irrigation performance parameters index: The observed irrigation performance parameters that affecting the optimizing localized irrigation systems efficiency can be formed as follows:

\[ I_{ppi} = \sum_{i} \left( \frac{q_i - q_n}{q} \right)^2 \ast \frac{t \ast w}{DU} \]

Where:

- \( q_i \): is the actual discharge of the distributor devices, m³/h.
- \( q_n \): is the nominal discharge of the distributor devices, m³/h.
- \( \eta \): is the mean discharge rate of the distributor devices, m³/h.
- \( N \): is a fraction of the clogging risks, fraction.
- \( P \): is a fraction of pressure variation sensitivity (pressure drop fraction).
- \( DU \): is the distribution uniformity, %.
- \( T \): is the operating time of irrigation event, h.
- \( W \): is the effective coverage width of the irrigated soils.

Soils performance parameters index: The observed index comply the following relationships between the soil hydro-physical parameters based on a mathematical and logic analyses. The developed formula may be summarized as follows:

\[ S_{ppi} = \frac{M.C_{after} - M.C_{before}}{(F.C - P.W.P)} \ast \frac{d}{T} \ast \ln K \ast [f \ast n] \ast \text{conversion} \]

Where:

- \( M.C_{before} \): is the soil moisture content before irrigation in equivalent volumetric units, %.
- \( M.C_{after} \): is the soil moisture content after irrigation in equivalent volumetric units, %.
- \( EC \): is the soil field capacity, %.
- \( P.W.P \): is the permanent wilting point, %.
- \( K \): is the soil hydraulic conductivity, cm/h.
- \( T \): is the soil Transmissivity, mm²/day
- \( D \): is the applied irrigation water depth at each irrigation event, mm
- \( F \): is the soil porosity, fraction.
- \( N \): is an indices depend on the soil layer texture, which ranged from 1 – 1.6, fraction.

Developed criterion "E_{ad}"

\[ E_{ad} = \frac{S_{ppi}}{I_{ppi}} \]

Where:

- \( E_{ad} \): is the effective irrigation developed criterion.
- \( S_{ppi} \): is the soil performance parameter.
- \( I_{ppi} \): is the irrigation performance parameter.

Validation process outputs of the developed criterion

Soil-moisture and salts distribution patterns: Regarding soil moisture distribution patterns, data illustrated in (Figures 1 and 2) revealed that irrigation water was speeded on a large volume of soil in the treatment of 20 cm subsurface drip irrigation system followed with 10 cm subsurface drip irrigation one. Water distribution pattern under the treatment of 20 cm subsurface drip irrigation system could be represented with a deficit cone. While under surface drip irrigation one a complete cone was formed with a less volume of soil having readily available water (18% of soil water = 55% of Available water) of onion. Generally, subsurface drip irrigation system give a perfect water distribution in the soil based on the high percent of available water and a great amount of stored water localized at active root zone of onion plant. This finding may be due to upward movement of irrigation water from subsurface emitter plus downward one under the effect of gravitational potential. The obtained results indicated also that, using subsurface emitter buried at 20 cm below soil surface could improve water use efficiency of onion by minimizing the evaporative loss and delivering irrigation water directly to the root zone.

For salts distribution patterns, (Figures 3 and 4) indicated that an accumulation process of leached salts directly under emitter, which occupying from 10 up to 25 cm soil depth, while, it reached to 25 up to 35 soil depth horizontally far from emitter with about 10 cm in vertical direction. Due to leaching process which extended up to 10 cm horizontally far from the emitter from each side. Generally, the treatment of 20 cm emitter depth in subsurface irrigation, introduce best salt distribution and give the low value of soluble salt at active root depth of onion seedlings (0-25) beside emitter (10 cm horizontally far from emitter). From data analysis it could be concluded that soil salts are accumulated under emitters as a result of salt transported downward. In the case of 10 cm subsurface emitter, capillary action was more pronounced than in 20 cm case because the weakness of capillary action in this soil (coarse textured soil), which have dominance of macro pores.

Seasonal values of crop water requirements (SCWR): Data illustrated in (Table 3) showed that the general trend of increasing CWU and attributed SCWR from the beginning of cultivation up to the end of bulb formation stage (72 days after sowing seeds), then it decreasing within bulb enlargement and maturity stage. This is normally observation due to the crop water requirements and the change of micro-climate factors and attributed reference evapotranspiration, as well as, changes of either crop coefficient or crop water stress coefficient. In addition, from data analyses it could be noticed that, the highest values of CWU under developed criteria basis had been reduced compared with traditional way of calculation based on FAO under establishment, vegetative growth, bulb fermentation and bulb enlargement and maturity stages respectively. However, the increment percentage of SCWR had been ranged from 10.55 up to 21.21% under developed criterion comparing with the FAO base calculation method.

Conclusion

Rationalizing on-farm water uses has the majority of the agricultural development processes under arid conditions. Hereby, proper management of irrigation water unit by using monitoring and change-detection of dynamic behavior of soil-moisture are essential in this respect. Therefore, the developed criterion maybe consider as an effective index for maximizing water-unit productivity. Generally, observed-data analysis concluded that soil-moisture/or salt distribution...
Figure 1: Water distribution around surface (a) and subsurface (b, c) emitter at 10, 20 cm depth based on developed criteria.

Figure 2: Water distribution around surface (a) and subsurface (b, c) emitter at 10, 20 cm depth based on FAO.
Figure 3: Salt distribution around surface (a) and subsurface (b, c) emitter at 10, 20 cm depth based on a developed criterion.

Figure 4: Salt distribution around surface (a) and subsurface (b, c) emitter at 10, 20 cm based on traditional calculation methods of FAO.
patterns had improved under the developed criterion compared with conventional method of FAO. Therefore, plant-water stressed had been avoided. Also, CWU and SCWR had been reduced effectively. Therefore, it can be concluded that, the developed criterion has the integrity for using under arid conditions effectively.

References

Table 3: Seasonal Crop water requirements of onion under investigated parameters for the validation process.

<table>
<thead>
<tr>
<th>Growing season</th>
<th>Drip irrigation system</th>
<th>CWU calculation method</th>
<th>Growing stages / days after sowing seeds</th>
<th>Es(0-16)</th>
<th>Vegetative(17-44)</th>
<th>Bulb formation(45-72)</th>
<th>SCWR, m³/fed</th>
<th>Leaching requirements (10%), mm</th>
</tr>
</thead>
<tbody>
<tr>
<td>2011-2012</td>
<td>SD</td>
<td>ETₐₒ</td>
<td>29 12.6 10.06 14.84 18.34 19.04 28 30.66 26.32 23.94 21.28 17.76 24.08 324.64 32.46 1499.8 10.61</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SSD₁</td>
<td>ET₁ₐ</td>
<td>29 7.56 6.58 13.3 17.78 22.96 23.94 25.48 28.56 23.94 26.32 21.12 20.44 290.20 29.02 1340.7 11.20</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>SSD₂</td>
<td>ET₂ₐ</td>
<td>25 8.54 8.68 12.88 17.08 21.14 26.32 27.3 26.04 22.4 22.82 22.08 28 315.62 31.56 1458.2 21.21</td>
<td></td>
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