Irrigation Strategies to Mitigate Climate Change Impact on Water Resources

Hammami Moncef[1*], Ben Ali Hédi[2], Nagaz Kamel[2]

[1]*Higher School of Engineers, Medjez EL Bab. Tunisia*

[2]*Institute of Arid regions, Mednine. Tunisia*

1- INTRODUCTION

Because of world population growth, climatic changes and intensive agricultural activities, per capita arable land has decreased over the years, from a worldwide average of 0,38 ha in 1970 to 0,28 ha in 1990, and some analysts project a further decrease to 0,15 ha in 2050 (Ghassemi et al. 1995) .

Irrigation is the most used means of agricultural intensification and will stay a cornerstone in the domain of food security policies towards climatic variability. In fact, about 17% of agricultural land worldwide is irrigated, this 17% accounts for about 40% of the total global world food harvest (FAO, 2002) . Without increase in productivity, an additional 5000 Km^3 will be required for crop production to meet future food demands, while the land area used for crops and cattle will increase by 50-70% (Charlotte et al., 2010). However, irrigation water efficiency E_c is not yet sufficient (more than 35 % of supplied water volume is lost).

Tunisia is one of the most seriously concerned country by these trends because of water resources scarcity, insufficient water use efficiency ($E_c \leq 65$ %) and the more significant climate changes' impacts. In fact, by 2050, the average temperature increase reaches 1.6 °C (in the northeast) up to 2.7 °C (in the extreme south). Consequently, crops' water requirement are increasing. Whereas the average annual rainfall is to be reduced by 11% (in the northeast) up to 27% (in the southern vest) as compared to the reference (1961-1990) period (Timothy, 2003; Timothy and Philip, 2005) . Therefore, more rational agricultural water management became necessary. Such rational irrigation water management is to be insured at the academic, at the institutional and at the field level.

For a better water use efficiency, some irrigation strategies are recommended, essentially to mitigate climate change impacts on water resources. These strategies are to be implemented on irrigation system design and/or water supply practices.

2- IRRIGATION SYSTEM DESIGN

With the same equipment, changes on distributors' (or outlets) repartition and/or laterals' design could be used to improve irrigation efficiency, such as:

2.1- Alternate wetting and drying management (AWD)

The AWD practice consist on intermittent irrigation method for each crop row. Thus, it is suitable for trickle and sub-surface drip-irrigation systems. The positive effects of AWD was demonstrated with several numerical and experimental studies. Abdullah et al. (2018) and Chu et al. (2014) have showed that AWD strategy significantly improved water productivity by about 16% while decreasing evapotranspiration by about 32%.

2.2- Pulsed irrigation management

The pulsed water application was developed with localized irrigation spread worldwide. Which principal focuses on the control of the soil profile during the infiltration process.

The objective is to determine the required emitter flow rate.

The pulsed water application is an intermittent crop watering characterized by:

- emitter nominal rate (q)
- the pulse duration (T)

For any case, the proper combination (q, T) results on several in situ trials. Experimental results showed that continuous irrigation induce higher moisture content around the drip emitter position but reduce the soil moisture content in the horizontal spreading (especially in the deep soil layers) compared with pulse irrigation. Others researches demonstrate that the vertical component of the wetting front was greater for the pulse than for the continuous irrigation for a time equal to the irrigation duration (Elmaloglou and Diamantopoulos, 2007).

3- IRRIGATION PRACTICES

Minor changes on water amounts and/or on supply occurrence could be carried out such as:

3.1- By Night irrigation occurrence

This strategy is usually used to reduce soil and canopy evaporation. In fact, the atmosphere evaporative potential is so higher than during day time. By doing so, substantial water saving was recorded. Yacoubi et al. (2010) reported that by nighttime, water losses decreased from 24% to only 7% on sprinkler-irrigated tomato as compared with by daytime.

3.2- Roots water uptake modeling

Sustainable irrigation practices require better understanding of biophysical process of water uptake and crops' transpiration. Roots' water uptake term is generally included in Richards' equation as a sink term. Two approaches are proposed:

- **Microscopic formulation**: that describes the microscale physics of water flow from the soil to and through the plant roots. The most common form is:

$$S = K.C.\Delta H \quad (1)$$

$$S = K.C.(\frac{\partial H}{\partial x} + \frac{\partial H}{\partial y} + \frac{\partial H}{\partial z}) \quad (2)$$

Whith:

S = sink term (L^3T^{-1})

K = soil hydraulic conductivity (LT^{-1})

ΔH = water pressure head gradient (between soil and in root pressure head)

C = water flow geometry (L^2)

- **Macroscopic scale**: comprises empirical or semi-empirical functions that describes roots' uptake based on soil water potential. One of the suggested root extraction expression (Li et al., 2006; Todd et al., 2006) is:

$$S(h,z) = \alpha(h).S_m(h,z) \quad (3)$$

Where:

S(h,z) (L^3 L^{-3} T^{-1}) is the actual root water extraction rate.

$S_m(h,z)$ (L^3 L^{-3} T^{-1}) is the maximum possible root water extraction rate when soil water is not limiting.

α(h) is a dimensionless water stress response function that accounts for the pressure head *h* (L).

$$0 \leq \alpha(h) \leq 1, \quad (4)$$

$$\alpha(h) = \frac{1}{1+(\frac{h}{h50})^p} \quad (5)$$

h = the soil water pressure head [L]

h_{50} and p are adjustable parameters

p = dimensionless fitting parameter.

3.3- Deficit irrigation

Irrigation is to be scheduled to supply the minimum water amount that ascertain plant growth without noticeable yield decrease. Doing so, the crop water stress tolerance and the more sensible plant stages are to be carefully considered. Insignificant effect on some crops' yields (Cotton, Maize,…) were recorded under 75% crop evapotranspiration (ETc) compared with 100% ETc.

4- CONCLUSION

A brief description of some irrigation strategies is presented. These strategies are recommended to improve agricultural water productivity, to mitigate climate change impact and then to sustain water resources. Even though, rational irrigation water use is to be planned in three steps:

- Implement the suitable irrigation system with the proper equipment for in situ conditions.
- Design a special on farm layout
- Manage the optimal irrigation scheduling.

It is sur that to gain climate change challenge, more researches and field trials are needed on roots' water uptake, water redistribution within heterogeneous soil profiles, water transfer through the plant and to the atmosphere.

References

Abdullah Darzi-Naftshali, Fatemeh Karandish, Jiri Simunek. 2018. Numerical modeling of of water dynamics in subsurface drained paddies with midseason drainage or alternate wetting and drying management. AGWAT 197 (2018) 67-78.

Chu G., Chen T., Wang Z., Yang J., Zhang J., 2014. Morphological and physiological traits of roots and their relationships with water productivity in water-saving and drought-resistant rice. Field Crop Res. 162,108-119.

Charlotte de Fraiture, David Molden and Dennis Wichelns. 2010. Investing in water for food, ecosystems, and livelihoods: An overview of the comprehensive assessment of water management in agriculture. AGWAT 97, 4 (495-501).

FAO, 2002. The state of Food Insecurity in the World (the fourth edition). The Economic and Social Department. Rome. Italy.

Ghassemi, F.; Jakeman, A. J.; Nix, H. A. 1995. Salinisation of land and water resources: human causes, extent, management and case. ISBN: 0851989063. CAB International, Wallingford, UK

Elmaloglou S. and Diamantopoulos E. 2007. Wetting front advance patterns and water losses by deep percolation under the root zone as influenced by pulsed drip irrigation. AGWAT 90, 1-2 (160-163).

Li K. Y., De Jong R., Coe M. T. and Ramankutty N. 2006. Root-Water-Uptake Based upon a New Water Stress Reduction and an Asymptotic Root Distribution Function. Earth Interactions • Vol. 10 (2006) • Paper No. 14.

Timothy D. Mitchell, 2003. Pattern scaling: An examination of the Accuracy of the Technique for

Describing Future Climates. Climate Change. Vol. 60:217-242.

Timothy D. Mitchell and Philip D. Jones, 2005. An improved method of constructing a database of monthly climate observations and associated high-resolution grids. International Journal of Climatology. Volume 25, Issue 6.

Todd H., Skaggs Martinus, Th. Van Genuchten, Peter J. Shouse, James A. Poss. 2006. Macroscopic approaches to root water uptake as a function of water and salinity stress. AGWAT 86, 1-2 (140-149).

Yacoubi S., Zayani K., Zapata N., and Zairi A. 2010**. Day and night time sprinkler** irrigated tomato: Irrigation performance and crop yield. Biosystems Engineering 107 (1) : 25-35.