

Modeling wind drift and evaporation losses during sprinkler irrigation in arid areas (case of Touggourt - Algeria)

Sofiane Gheriani (✉ gherianisofiane@gmail.com)

National Institute of Agronomic Research: Institut National de la Recherche Agronomique

Noureddine MEZA

Universite Kasdi Merbah Ouargla

Djamel BOUTOUTAOU

université de ouargla

Short Report

Keywords: Evaporation, losses, sprinkler irrigation, wind drift

Posted Date: January 10th, 2022

DOI: <https://doi.org/10.21203/rs.3.rs-1017737/v1>

License:  This work is licensed under a Creative Commons Attribution 4.0 International License.

[Read Full License](#)

Abstract

In recent years, agriculture development in South-eastern Algeria progressed rapidly which increased the demand for agricultural products. Given that this region is characterized by hard agro-climatic conditions, irrigation seems to be a necessary factor for ensuring optimal development and high agricultural production. Like many irrigation technics widely used, sprinkler irrigation performance was considerably affected by these conditions, mainly evaporation, which causes water losses. This study aims to propose an adequate mathematical model predicting wind drift and evaporation losses under different weather conditions resume by the complex indicator of climatic intensity (ϕ). Results showed that complex indicators of climatic intensity, were significant factors affecting the wind drift and evaporation losses, puissance relationship between wind drift and evaporation losses, and complex indicators of climatic intensity, obtained model are adopted can be useful tools in the determination of the overall losses in terms of environmental conditions (air temperature, relative humidity, and wind speed). Totally 25 measure samples were used for training the model, and 15 measure samples for testing and validation of the model. The developed model for the WDEL modeling shows high good performance with a coefficient of determination (R^2) = 0.808, mean squared error (RMSE) = 3.39 %, and Mean Absolute Error MAE = 8.41%.

Keywords: Evaporation; losses; sprinkler irrigation; wind drift.

Introduction

In the spray irrigation practice, the wind drift and evaporation losses represent the most important form of water loss varies from 2 to 50 (Arshad et al., 1982; Hermsmeier., 1973). Whereas, precedent literature has assessed sprinkling water losses from water volumes of different irrigated area points using capture boxes (Kincaid et al., 1996; Kohl et al., 1987; Yazar., 1984). As well, others proved that the sum of the wind drift and evaporation losses (WDEL) during sprinkler irrigation, by using the catch–can method, depends on air temperature (T), wind speed (WS), and relative air humidity (RH) (Yazar, 1984; Sapunkov, 1991; Tarjuelo et al., 1999; Dechmi et al., 2003; Playan et al., 2005; Yacoubi et al., 2012).

Climatic conditions, in the region of Touggourt, are very hard in particular the period which extends between April and September. Temperature daily average can exceed 40° C, the relative humidity average of air is often less than 40% and the wind speed average oscillates between 2 and 4 m·s⁻¹., the most common irrigation method was gravity irrigation (board's lines), but new methods have been introduced in recent years such as sprinklers. requires studying water losses (Gheriani et al., 2020).

On the other hand, Sapunkov's relation involved a parameter called a complex indicator of climatic intensity (ϕ) which was defined by Khabarov (1982) and introduces climatic parameters:

$$WDEL(\%) = a \phi^b \quad (6)$$

WDEL=overall losses as a percentage of volume;

(a) And (b) = are coefficients according to geographical areas;

ϕ = complex indicator of climatic intensity; evaluated by the following formula:

$$\phi = T (WS + 1) (1 - 0.01.RH) \quad (7)$$

Unfortunately, these methods were not developed under the same geographical conditions as the study region. Therefore, this study aims to present a model that can estimate the overall WDEL specifically using the ϕ parameter.

The experiment was conducted from November 2017 to July 2019 at the National Institute of Agronomic Research of Algeria (INRAA), experimental station of Touggourt (33°.04.293' and 006°.05.788' E), located at 7 km from the South-eastern part of Touggourt, East of Wadi Righ.

Materials and methods

Experimental database

The model has been developed using experiences Data from the published study by Gheriani et al. (2020) as presented in table 1 showing the statistical parameters of the inputs and outputs used for the training and test of the developed or XM, XA, XN, SD model designate the maximum, average, minimum and standard deviation respectively. The experimental site was equipped with a conventional sprinkler irrigation system (spaced by 18 m x 18 m). The total surface contained four lateral lines for every four sprinklers of RS130 type were installed, the operating pressure was maintained constant (about 200 kPa). The experiments were carried out based on ISO standard No 11545 and Merriam and Keller (1978). The test area was equal to 0.52 ha. The distribution of water under the sprinklers was assessed by collecting the amounts of water using the catch containers that were arranged in a grid at 4 to 4.5 of spacing. The catch containers were measured with 100 mm of diameter and 200 mm of height with a total of 273 containers. Furthermore, climatic parameters such as temperature, air humidity, and wind speed at the test area were measured with a conventional meteorological station installed near the field. Finally, the evaporation and wind drift losses were calculated using the following equation (Keller and Bliesner, 1990):

$$WDEL = \left(1 - \frac{h \cdot A}{V}\right) * 100 \quad (8)$$

where h (m) is the total depth of water in the catch containers, A(m²) the irrigated area around each container and V (m³) the volume of sprinkler discharge.

Statistical analysis

nonlinear regressions were performed, for a correct prediction of WDEL, in terms of climatic intensity complex indicator (ϕ), depending on the model indicated in equation (6). Analyses were performed using the SPSS version. 20 software.

Performance evaluation criteria

Mean absolute error (MAE), mean squared error (RMSE) determined by Maroufpoor et al. (2018), and coefficient of determination (R²) defined by Yasar et al. (2012) were used to see the convergence between the observed and the expected values:

$$R^2 = \frac{(\sum_{i=1}^n (O_i - \bar{O})(P_i - \bar{P}))^2}{\sum_{i=1}^n (O_i - \bar{O})^2 \cdot \sum_{i=1}^n (P_i - \bar{P})^2} \quad (9)$$

$$MAE = \frac{1}{n} \sum_{i=1}^n \left| \frac{P_i - O_i}{P_i} \right| \cdot 100 \quad (10)$$

$$RMSE = \sqrt{\frac{1}{N} \sum_{i=1}^N (O_i - P_i)^2} \quad (11)$$

Where:

O = observed value; P = expected value; n = number of observations

Results and discussions

Measurements of total losses, climatic parameters (air temperature, air humidity, and wind speed), and climatic intensity complex indicator parameter values (ϕ) were presented in Table 2.

The relationship between wind drift, evaporation losses (WDEL), and complex indicator of climatic intensity (ϕ), according to the equation (6), were shown in Fig 1:

The relationship between wind drift and evaporation losses and complex indicators of climatic intensity (training values) shown in Fig 1, is:

$$WDEL (\%) = 13.65 \cdot \phi^{0.255} \quad (12)$$

The development of the nonlinear regressions model

The development of the nonlinear model was based on the result indicated in Equation 12, where the initial value of $a = 13.65$ and $b = 0.255$. Otherwise, the non-linear multiple regression analysis of the data, after 7 iterations, the optimal solution was summarized in Table 3.

The model of relation was written as follows:

$$WDEL (\%) = 13.013 \cdot [T \cdot (W + 1) (1 - 0.01 \cdot H)]^{0.27} \quad (13)$$

Table 4 represents the statistical measures of the model in the different phases. The validation and test results clearly demonstrated satisfactory results for WDEL. The model performed better well in predicting the wind drift and evaporation losses in both training (with $R^2 = 0.808$, RMSE = 3.39 % and MAE = 8.41 %) and testing (with $R^2 = 0.804$, RMSE = 6.42 % and MAE = 12.04%) stages. Figure 2 a–b shows Scatter Plots of observed and calculated values of WDEL for the model. Moreover, Figure 2 a–b showed a fair convenience between the measured and expected WDEL. The regression line was practically identical to the first bisector.

Lack of research on this type of modelling on the irrigation unless Russian studies. In Stavropol, arid region ex USSR, Sapunkov (1991) has defined specific relations for each type of spraying technique including:

$$\text{Pivot 451-100} \quad WDEL(\%) = 0.206 \phi^{0.81} \quad (1)$$

$$\text{Pivot 454-70} \quad WDEL(\%) = 0.51 \phi^{0.65} \quad (2)$$

$$\text{Front-moving lateral 64} \quad WDEL(\%) = 2.26 \phi^{0.54} \quad (3)$$

$$\text{Trailed lateral 100 MA} \quad WDEL(\%) = 0.35 \phi^{0.82} \quad (4)$$

$$\text{Large-bore sprinkler} \quad WDEL(\%) = 8.75 \phi^{0.22} \quad (5)$$

Relationship between predicted and observed WDEL values

The present experiment allowed us to record the R^2 between predicted and observed WDEL values with 0.808 (Fig. 2a-b). This situation was also confirmed by the straight regression lines which express 80.8% of the overall variance. Also, a sample size of ($N = 25 < 50$) and data that follows the normal distribution at Sig. a value greater than 50 % (Kim, 2015; Gerald, 2018), Shapiro-Wilk significant values were equal to 0.02 and 0.086 for observed and predicted WDEL respectively. (Table 5).

Therefore, the parametric tests for the observed and the predicted values follow the abnormal distribution at a 95% confidence interval. In this case, the nonparametric test of Mann-Whitney was used in this comparison (Conover, 1999). The last test indicated that Sig Asymp's significance level value of 0.764 was less than 0.05, which means that there was no difference between the observed and predicted values of the WDEL, which confirmed that the model was precise. These results are confirmed by Sapoukov's results, which determine the wind drift and evaporation losses (WDEL) models to different spray devices depends on complex indicator of climatic intensity (ϕ).

Conclusion

Because of the climatic and agrolological conditions, the region of Touggourt (arid climate) saw a quick development of sprinkler irrigation technic that exposed enormous losses evaporation and entrainment.

In this study, an adequate mathematical model predicting wind drift and evaporation losses under different weather conditions was resumed by the complex indicator of climatic intensity (ϕ), in sprinkler irrigation, allowing their use by considering them in the correction of watering doses.

The experimentation showed that overall water losses were affected by weather factors i.e., air temperature, wind speed, and air humidity respectively. Formula 13, shows high good performance, with $R^2 = 0.808$, RMSE = 3.39 % and MAE = 8.41%, were the adopted model that seems to fit the conditions of the study region. We circulate this approach to study on various sprayers in future studies so that we can optimize water resources.

Ethical approval: This article does not contain any studies with human participants or animals performed by any of the authors.

Declaration on conflict of interest: No conflict of interest was declared.

References

- Arshad Ali S M, Barefoot A D (1982) "Low trajectory sprinkler patterns and evaporation". ASAE paper, n°81-2085, p. 189-196.
- Conover W J (1999) Practical Nonparametric Statistics. John Wiley.
- Dechmi F, Playan E, Cavero J, Faci JM, Martinez-cob A (2003) Wind effects on solid set sprinkler irrigation depth and yield of maize (*Zea mays*). *Irrig Sci* 22: 67–77.
- Gerald B (2018) A Brief Review of Independent, Dependent and One-Sample t-test. *International Journal of Applied Mathematics and Theoretical Physics* 4(2): 50-54. [https://doi: 10.11648/j.ijamtp.20180402.13](https://doi.org/10.11648/j.ijamtp.20180402.13)
- Gheriani S, Meza N, Boutoutaou D (2020) Overall water losses using sprinkler irrigation in the arid area (case of Touggourt - Algeria). *QJAS* 10 (2): 394-406.
- Hermesmeier LF (1973) Evaporation during sprinkler application in a dessert climate. ASAE Paper No. 73–216. ASAE, St. Joseph, MI, USA.
- Khabarov V E (1982) Studies of the influence of meteorological factors on The zone of formation of artificial rain under irrigation: author. dish. ... *Cand.tehn Science / Khabarov Vasily Evgenievich. - Novochoerkassk, 1982.*
- Keller J, Bliesner RD (1990) Sprinkle and Trickle Irrigation. AVI Book. Van Nostrand Reinhold: New York, USA.
- Kim TK (2015) T test as a parametric statistic. *Korean J Anesthesiol* 68(6): 540-546. [http://dx.doi.org/10.4097/kjae.2015.68.6.540.](http://dx.doi.org/10.4097/kjae.2015.68.6.540)
- Maroufpoor E, Sanikhani H, Emamgholizadeh S, Kişi Ö (2018) Estimation of wind drift and evaporation losses from sprinkler irrigation systems by different data-driven methods. *Irrig. and Drain* 67: 222–232.
- Merriam J L, Keller J (1978) "Farm Irrigation System Evaluation: A Guide for Management," Utah State University, Logan.
- Playan E, Salvador R, Faci JM, Zapatan, Martinez-COB A, Sanchez I (2005) Day and night wind drift and evaporation losses in sprinkler solid-sets and moving laterals. *Agricultural Water Management* 76: 139-159.
- Sapunkov AP (1991) Sprinkler application: current trends. *Agropromizdat*. p126.

- Tarjuelo JM, Ortega JF, Montero J, Juan JA (1999) Modeling evaporation and drift losses in irrigation with medium-size impact sprinklers under semi-arid conditions. *Agricultural Water Management* 43: 263-284.
- Yacoubi S, Zayani K, Slatni A, Playan E (2012) Assessing Sprinkler Irrigation Performance Using Field Evaluations at the Medjerda Lower Valley of Tunisia. *Engineering* 4: 682-691.
- Yasar A, Bilgili M, Simsek E (2012) Water Demand Forecasting Based on Stepwise Multiple Nonlinear Regression Analysis. *Arab J Sci Eng* 37: 2333–2341.
- Yazar A (1984) Evaporation and drift losses from sprinkler irrigation systems under various operating conditions. *Agricultural Water Management* 8: 439-449.

Table 1. Summary of experimental data used in the model's development.

WDEL = wind drift and evaporation losses, T = air temperature, WS= wind speed and RH = relative humidity

| Statistical parameters | Variables | | | |
|------------------------|-----------|-------|------------------------|---------|
| | T(°C) | RH(%) | WS(m.s ⁻¹) | WDEL(%) |
| Training set | | | | |
| XM | 38.5 | 55.33 | 3.68 | 50.47 |
| XN | 9.8 | 28.17 | 0.7 | 24.09 |
| XA | 20.44 | 41.3 | 1.78 | 33.07 |
| SD | 8.78 | 7.92 | 0.91 | 7.89 |
| Testing set | | | | |
| XM | 41.2 | 48.6 | 3.61 | 40.78 |
| XN | 11.3 | 10.63 | 0.9 | 28.96 |
| XA | 28.19 | 28.29 | 2.1 | 34.26 |
| SD | 10.81 | 11.61 | 0.8 | 3.53 |

Table 2. Global total values, climatic parameters and ϕ parameters

| Day | T (°C) | RH (%) | WS (m·s ⁻¹) | ϕ | WDEL (%) |
|-----------------|--------|--------|-------------------------|--------|----------|
| Training values | | | | | |
| 09.11.2017 | 15.86 | 38.33 | 1.24 | 21.91 | 29.41 |
| 22.11.2017 | 12.53 | 53 | 0.9 | 11.19 | 27.5 |
| 27.11.2017 | 14.4 | 49 | 0.77 | 12.99 | 29.62 |
| 05.12.2017 | 9.8 | 53.66 | 0.81 | 8.22 | 24.13 |
| 12.12.2017 | 14.66 | 42.33 | 1 | 16.91 | 24.78 |
| 19.12.2017 | 9.86 | 52.66 | 0.72 | 8.03 | 25.09 |
| 24.12.2017 | 11.46 | 55.33 | 0.71 | 8.75 | 24.09 |
| 02.01.2018 | 16.33 | 37.33 | 0.74 | 17.81 | 30.92 |
| 18.01.2018 | 14.33 | 41.33 | 1.73 | 22.95 | 26.89 |
| 21.01.2018 | 15.33 | 49.33 | 0.7 | 13.20 | 26.52 |
| 28.01.2018 | 13 | 45.33 | 2.18 | 22.60 | 24.58 |
| 12.02.2018 | 11.66 | 45.66 | 1.77 | 17.55 | 28.08 |
| 08.03.2018 | 20.26 | 43.16 | 1.43 | 27.98 | 27.11 |
| 12.03.2018 | 19.8 | 37.33 | 1.07 | 25.68 | 28.29 |
| 20.03.2018 | 20.2 | 28.66 | 2.6 | 51.87 | 34.38 |
| 27.03.2018 | 16.2 | 42 | 2.14 | 29.50 | 36.35 |
| 17.04.2018 | 23 | 36.3 | 3.29 | 62.85 | 43.89 |
| 25.04.2018 | 31.4 | 28.17 | 3.68 | 105.55 | 50.46 |
| 30.04.2018 | 28.5 | 33.5 | 2.51 | 66.52 | 43.90 |
| 07.05.2018 | 28 | 38.33 | 2.5 | 60.43 | 38.46 |
| 14.05.2018 | 25.6 | 42 | 2.73 | 55.38 | 38.36 |

| | | | | | |
|----------------|-------|-------|------|-------------|-------|
| 21.05.2018 | 27.83 | 43.5 | 2.73 | 58.65 | 38.71 |
| 25.07.2018 | 36 | 33.33 | 2.49 | 83.76 | 40.86 |
| 30.07.2018 | 38.5 | 31 | 1.48 | 65.88 | 46.75 |
| 01.08.2018 | 36.66 | 32 | 2.73 | 92.98 | 37.64 |
| Testing values | | | | | |
| 11/02/2019 | 16 | 33,43 | 1,29 | 24,391248 | 31,02 |
| 18/02/2019 | 12,9 | 48,6 | 1,91 | 19,295046 | 29,99 |
| 25/02/2019 | 11,3 | 42,73 | 2,03 | 19,6086753 | 28,96 |
| 04/03/2019 | 17,7 | 38,16 | 0,9 | 20,796792 | 29,90 |
| 11/03/2019 | 18,53 | 42,03 | 3,61 | 49,51988701 | 31,63 |
| 18/03/2019 | 22,73 | 22,4 | 1,64 | 46,5655872 | 30,89 |
| 17/04/2019 | 25,9 | 40,13 | 1,54 | 39,3860782 | 36,27 |
| 24/04/2019 | 30,33 | 19,06 | 1,7 | 66,2825754 | 36,67 |
| 19/06/2019 | 37 | 20,86 | 1,7 | 79,06086 | 36,20 |
| 24/06/2019 | 41,2 | 10,63 | 3,4 | 162,009936 | 40,78 |
| 01/07/2019 | 37,13 | 25,5 | 3,3 | 118,945955 | 36,21 |
| 03/07/2019 | 36 | 25,23 | 2,82 | 102,823704 | 35,95 |
| 04/07/2019 | 37 | 22,66 | 1,8 | 80,12424 | 34,99 |
| 08/07/2019 | 39,16 | 17 | 1,95 | 95,88326 | 37,58 |
| 09/07/2019 | 40 | 16 | 1,94 | 98,784 | 36,81 |

Table 3. Estimates of the parameters

| Parameter | Estimation | Standard error | R ² |
|-----------|------------|----------------|----------------|
| a | 13.013 | 1.373 | 0.808 |
| b | 0.27 | 0.028 | |

Table 4. Performances of the model in different phases

| performance criteria | R ² | MAE | RMSE |
|-------------------------|----------------|-------|------|
| Training process | 0.808 | 8.41 | 3.39 |
| Testing process | 0.804 | 12.04 | 6.42 |

Table 5. Normality test.

| Shapiro-Wilk | | | |
|----------------|-----------|-------------------|---------|
| | Statistic | Degree of freedom | p-value |
| WDEL observed | 0.902 | 25 | 0.02 |
| WDEL predicted | 0.93 | 25 | 0.086 |

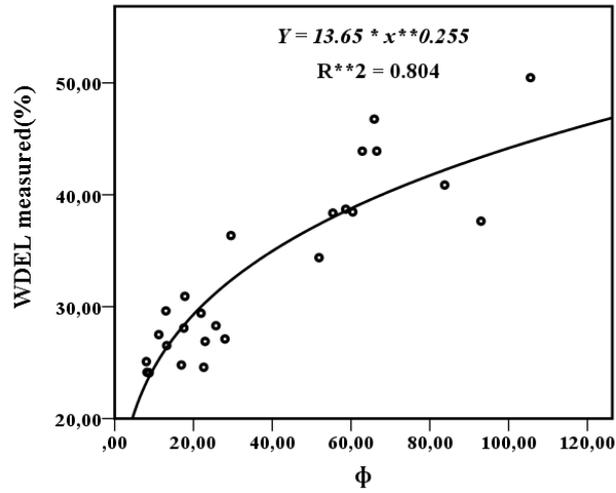


Figure 1. Relationship between wind drift and evaporation losses and complex indicator of climatic intensity.

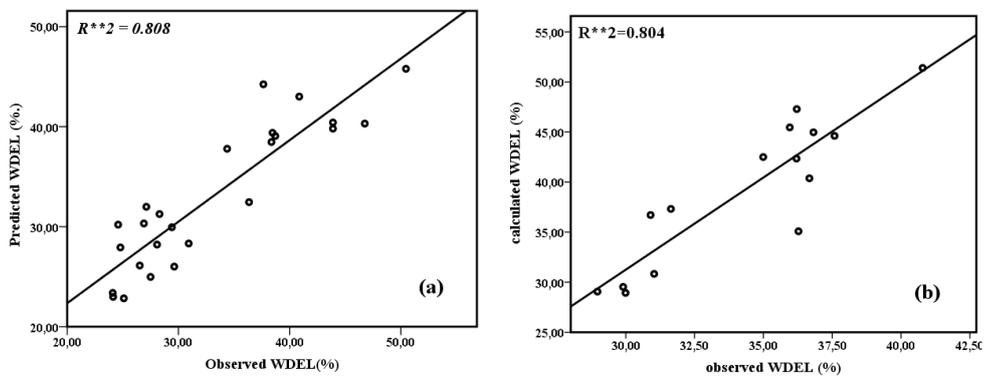


Figure 2. Measured values of WDEL compared with predicted values for, a training, and b testing.