Irrigation Rain Sensors Accuracy

B. Cardenas-Lailhacar[1], M. D. Dukes[2], P.E., and L. Meaks[3]

[1]Research Coordinator, Agricultural and Biological Engineering Dept., Univ. of Florida, Gainesville, FL 32611-0570. E-mail: bernardc@ufl.edu
[2]Corresponding author, Associate Professor, Agricultural and Biological Engineering Dept., Univ. of Florida, P.O. Box 110570, Gainesville, FL 32611-0570. E-mail: mddukes@ufl.edu , phone: 352-392-1864; fax: 352-392-4092.
[3]Graduate student, Agricultural and Biological Engineering Dept., Univ. of Florida, Gainesville, FL 32611-0570. E-mail: lmeeks@ufl.edu

ABSTRACT

In recent years, an increasing number of municipalities throughout the country have implemented mandates, rebates and/or cost-saving programs for the use of rain sensors (RSs). The objectives of this research were to evaluate two expanding disk RS types, Mini-Click (MC) and Wireless Rain-Click (WL), with respect to: a) the accuracy of their set point with respect to rainfall depth, b) the number of times in irrigation bypass mode, and c) the duration in irrigation bypass mode. For the MC treatments, rainfall set points of 3, 6, and 13 mm were established. Rain sensor models were monitored from 1 January 2006 to 31 July 2007, except for MC set at 6 mm which was monitored starting on 13 September 2006. The 576-day experimental period had rainfall frequency and cumulative amount below a historical year. The number of times that replicate units within a treatment switched to bypass mode tended to behave the same through time, for treatments WL and 3-MC, which ranged from 64 to 78 events and from 57 to 68 events, respectively. Treatment 6-MC was the most consistent between replicates, where three units switched to bypass mode on 39 occasions, and one unit did it on 34 times. Replicates from treatment 13-MC showed the most variable behavior, shutting off between 50 to 29 times. On average, treatment WL shut off after 2.8 mm of rain. Because this model does not have a specific set point, accuracy could not be calculated. Accuracies for the other treatments resulted in 73% for 3-MC, 30% for 6-MC, and 58% for 13-MC. Treatments WL, 3-MC, 6-MC, and 13-MC, remained in bypass mode 82, 80, 64, and 83% of the time, respectively, for less than 24 h.

INTRODUCTION

Rain sensors (RSs), are designed to interrupt a scheduled irrigation cycle on an automatic irrigation controller (i.e. time-clock or timer) when a specific amount of rainfall has occurred (Dukes and Haman 2002). During recent years, an increasing number of municipalities in seven states throughout the country have implemented mandates, rebates and/or cost-saving programs for the use of RSs because they appear to be a useful tool for irrigation water conservation, at a relatively low cost (Dewey 2008). Since 1991 Florida has had an overall RS statute, which requires an automatic rain sensor shut-off device that is properly installed and functioning on all automatic irrigation systems (Florida Statutes, 2008).

The most common type of RSs employs hygroscopic disks to absorb water and expand proportionally to the rainfall amount. Then, a mechanical switch interrupts the system common wire, disabling the solenoid valves, until the sensor hygroscopic disks dry out. To adjust the drying rate of the disks, these sensors have an adjustable vent ring.

A version of these devices (also with hygroscopic disks inside) is a wireless RS, which has a sensor/transmitter installed in an area subject to rainfall and a receiver unit connected to the timer. According to the manufacturer, these RSs have a quick shut down of the irrigation system after it starts to rain (without preset adjustments for a certain precipitation amount). The wireless RSs can also be adjusted to keep the irrigation system off after the rain stops by setting the adjustable ventilation windows that control the dry-out time (Hunter Industries, Inc. 2006).

This research was based on the original work by Cardenas-Lailhacar and Dukes (2008), who studied the performance and reliability of some expanding disk RSs. The objectives of this experiment were to evaluate the reliability of two commercially available expanding disk RS-types with respect to: a) the accuracy of their set point with respect to rainfall depth, b) the number of times in irrigation bypass mode, and c) the duration in irrigation bypass mode.

MATERIALS AND METHODS

Twelve Mini-Click (MC) and four Wireless Rain-Click (WL) rain sensor models (Hunter Industries, Inc., San Marcos, CA) were placed at the University of Florida Agricultural and Biological Engineering Department turfgrass research facility in Gainesville. This experiment took place from 1 January 2006 to 31 July 2007. Four treatments with four replications each were established. For the MCs, three set points were established: 3, 6, and 13 mm thresholds (treatment codes 3-MC, 6-MC, and 13-MC, respectively). The dry-out ventilation windows of the MCs and WLs were kept completely open. All RSs in this study were 9 months old having been set up originally for the study reported by Cardenas-Lailhacar and Dukes (2008).

Each time an RS unit changed status (from allowing irrigation, to bypass mode, or vice versa), the date and time were automatically recorded, at a one-second sampling interval, by means of two AM16/32 multiplexers connected to a CR 10X model datalogger (Campbell Scientific, Logan, UT). Weather conditions were recorded by an automated weather station containing a CR 10X model data logger, located within 15 m of the experimental site. Rainfall was measured by means of a tipping bucket rain gauge, which was routinely checked against a manual rain gauge located nearby. Rainfall data were recorded at intervals of 0.25 mm (day of year, hour, minute, and second were logged). Until 13 September 2006, treatment 6-MC was not connected to the datalogger, so it was not considered for the calculations previous to that date. The total time that each RS remained in the irrigation bypass mode after the rain has stopped was computed (dry out period). Total rainfall before each RS switched to bypass mode was calculated, in order to evaluate the accuracy of the rainfall thresholds. According to Figliola and Beasley (2000), the accuracy of an instrument refers to its ability to indicate a true value exactly. Accuracy is related to absolute error, ε, which is defined as the difference between the true value of a measurement and the indicated value of the instrument:

$$\varepsilon = \text{true value} - \text{indicated value} \qquad [1]$$

from which the percent accuracy, A, is found by:

$$A = \left(1 - \frac{|\varepsilon|}{\mathit{true\ value}}\right) \times 100 \qquad [2]$$

RESULTS AND DISCUSSION

Weather Conditions

Overall, the experimental period was drier than normal. During the 576-day experiment, 138 days exhibited rainfall (24%), including 28 days with more than 15 mm (3% of the days). These numbers could be considered below a historical year (1970 to 2000), which for the same period had 31% rainy days and 5% of rainfall events above 15 mm. The cumulative precipitation was 1,723 mm compared to a historical of 2,094 mm, or an 18% of deficit for the study period. Over the entire monitoring period, the tipping bucket rain gauge was very accurate (R^2= 0.99) compared to the manual rain gauge across a range of rainfall events from less than 1 mm up to 60 mm.

Number of Times in Bypass Mode

Figures 1 to 4 show the cumulative number of times in bypass mode of the replicates within treatments. It can be seen that this parameter was variable between the different replicates, with 13-MC the most variable treatment. Replicates at a particular set point sometimes responded properly according to their settings, sometimes did not detect rainfall events five or more times their set points, and sometimes they even shut off several hours after the rain had stopped (data not shown). This explains the range of variation in the number of times that individual RS units switched to bypass mode.

The four replications of the WL treatment (Figure 1) followed a similar pattern, with 64 to 78 events in bypass mode. However, these units were much more consistent when they were newer, varying between 78 and 83 bypassed events over a 282 day experimental period (Cardenas-Lailhacar and Dukes, 2008). Analogous to the WL units, all four 3-MC sensors (Figure 2) behaved similarly, with 57 to 68 times in bypass mode. In the case of the 6-MC treatment (Figure 3), the units were not set up until 13 September 2006. Therefore, the number of times in bypass mode were smaller than the other treatments. However, these replicates were very consistent, where three of them switched to bypass mode on 39 occasions, and one unit did it on 34 times. The different replicates of treatment 13-MC showed an irregular performance (Figure 4). All replicates tended to behave similarly until 23 July 2006. After that date, one replicate switched to bypass mode more times (50) than the other units. Two other replicates operated similarly until 13 May 2007 (with 34 and 33 time in bypass mode), but afterwards they followed a different pattern and ended the testing period with 42 and 36 times in bypass mode. Finally, the last replication of treatment 13-MC shut off a fewer number of times than the other units after 23 July 2006, and ended with a total of only 29 times on bypass mode. No recorded weather data or physical evidence was found to explain the different performances between the 13-MC units after 23 July 2006.

Depth of Rainfall before Shut Off

The average depth of rainfall before the rain sensors switched to bypass mode, accuracy, and standard deviation for the different treatments is shown in Table 1. Treatment WL shut off after 2.8 mm of rain on average, with a standard deviation of 1.1. Because this model does not have a specific set point, accuracy could not be calculated. However, when these replicates were new they triggered the switch at an average of 1.4 mm of rainfall (Cardenas-Lailhacar and Dukes, 2008). Treatment 3-MC switched to bypass mode after an average of 2.2 mm of rainfall, resulting in an accuracy of 73%, with a standard deviation of 1.9. Unexpectedly, treatment 6-MC shut off on average after 1.8 mm of rainfall (even less rainfall than 3-MC), with a standard deviation of 1.2, and a resultant accuracy of just 30%. It should be noted that the different units were very consistent in their behavior (Figure 3). These sensors were previously set at 25 mm for almost two years, but no physical evidence was observed of any alteration on their expanding disks neither on their mechanism that could be related to this behavior. Treatment 13-MC switched to bypass mode after an average of 7.5 mm of rain, which corresponds to an accuracy of 58%, and resulted in the highest standard deviation (2.7). These average accuracies show that only 3-MC responded close to its set point and that all MC sensors became more sensitive to rainfall; whereas, WL sensors became less sensitive to rainfall compared to previous results (Cardenas-Lailhacar and Dukes, 2008).

Duration in Irrigation Bypass Mode (Dry-Out Period)

The time that it takes the RSs to reset for normal sprinkler operation after the rain has stopped is determined by weather conditions (temperature, wind, sunlight, relative humidity, etc.), which will determine how fast the hygroscopic disks dry out.

Figures 5 to 8 show histograms and frequency distribution for 6 h intervals in bypass mode for treatments WL, 3-MC, 6-MC, and 13-MC, respectively. Results showed that WL sensors remained in bypass mode 82% of the time for less than 24 h, and 23% of the time for less than 12 h (Figure 5). This result does not agree with manufacturer claims that the WL sensors will remain on that status shortly after the rain stops (Hunter Industries, Inc. 2006). In previous work, WL sensors dried out 50% of the time before 12 hours (Cardenas-Lailhacar and Dukes, 2008). Similar to WL, the dry out period of treatment 3-MC (Figure 6) was 80% of the time less than 24 h, a higher frequency than the 51% found previously (Cardenas-Lailhacar and Dukes, 2008). Treatment 6-MC (Figure 7) also remained most of the time (64%) in bypass mode for less than 24 h, and 86% of the time for less than 36 h. Similar to the other treatments, the dry out period for 13-MC (Figure 8) was most of the time less than 24 h (83%). It is remarkable that the dry out period for all treatments occurred almost always in less than 48 h. Thus, it appears the MC sensors dried out faster with age, but the WL sensors dried out slower.

SUMMARY AND CONCLUSIONS

A study to evaluate and quantify the performance of RSs was carried out from 1 January 2006 to 31 July 2007. This testing period recorded a lower frequency and a lower amount of cumulative rainfall compared to historical records. Accuracy tests results suggested that the 3-MC responded close to its set point (73%), but 6-MC and 13-MC resulted in lower accuracies (30 and 58%). Replicates at a particular set point were variable, sometimes responding properly according to their settings, sometimes not detecting rainfall events five or more times their set points, and sometimes even shutting off several hours after the rain had stopped. This explains the accuracies and the range of variation in the number of times that individual RS units switched to bypass mode. Most of the time, treatments remained in bypass mode for less than 24 h, and almost all treatments dried out in less than 48 h during this testing period. Generally, MC sensors became more sensitive to rainfall and dried out quicker than when they were new; whereas, the WL sensors became less sensitive and dried out slower. In any case, after more than two years of continuous operation these devices still have the ability to bypass irrigation cycles during rainy weather; however, their accuracy appears to be degrading with time.

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Table 1. Average depth of rainfall before rain sensors switched to bypass mode.

Treatment	Set point (mm)	Rainfall depth (mm)	Accuracy (%)	Standard Deviation (mm)
3-MC	3	2.2	73	1.9
6-MC	6	1.8	30	1.2
13-MC	13	7.5	58	2.7
WL	--	2.8	--[z]	1.1

[z] Because these instruments do not declare a specific set point, accuracy could not be calculated

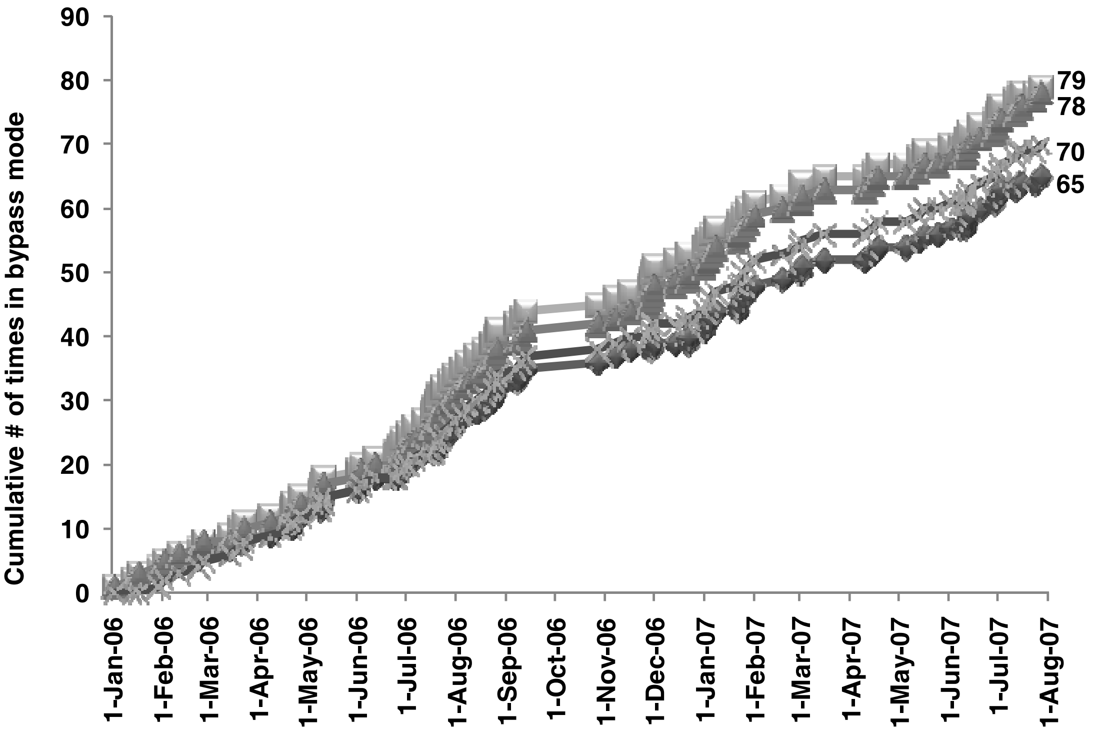

Figure 1. Cumulative number of times that replicates from wireless rain sensors (WL) switched to bypass mode.

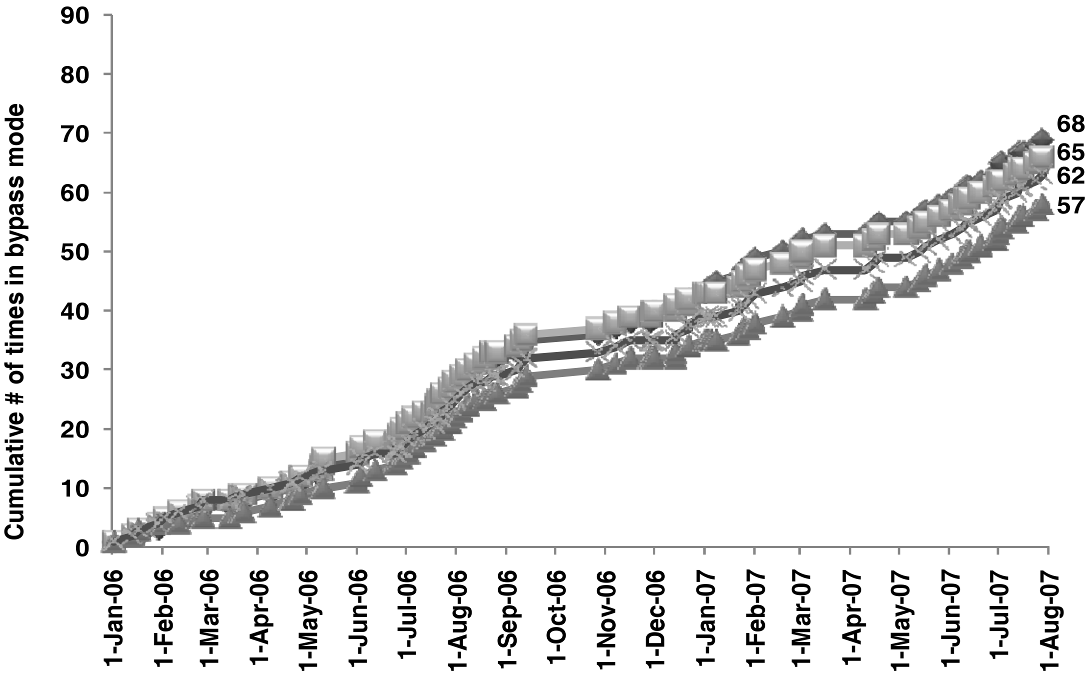

Figure 2. Cumulative number of times that replicates from Mini-Click rain sensors set at 3 mm (3-MC) switched to bypass mode.

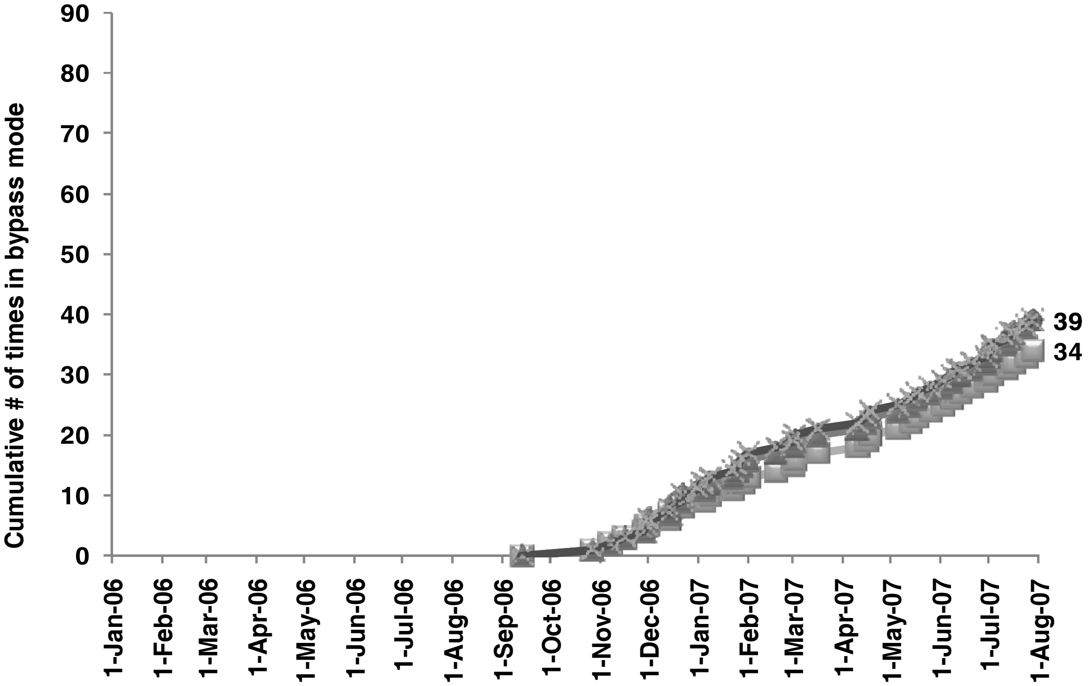

Figure 3. Cumulative number of times that replicates from Mini-Click rain sensors set at 6 mm (6-MC) switched to bypass mode.

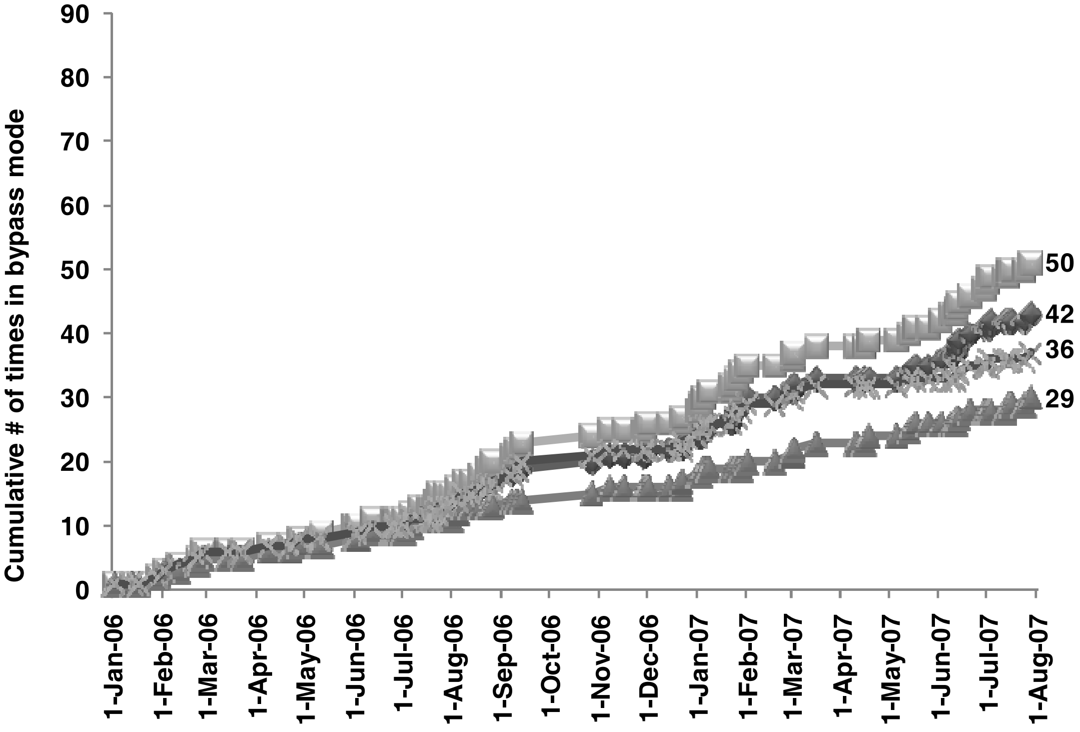

Figure 4. Cumulative number of times that replicates from Mini-Click rain sensors set at 13 mm (13-MC) switched to bypass mode.

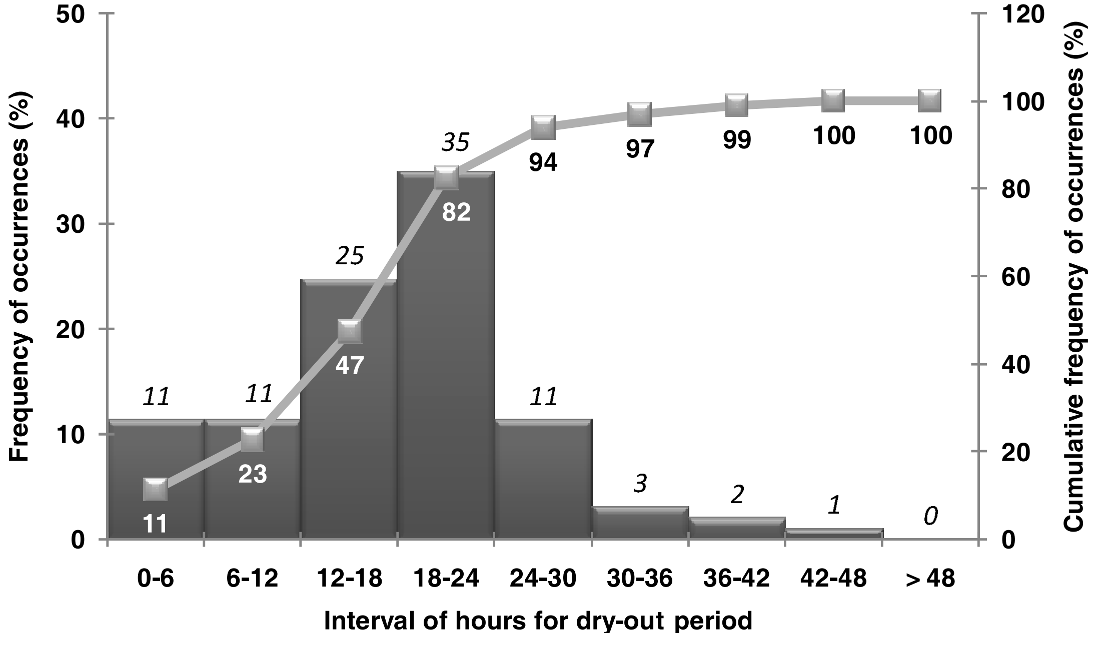

Figure 5. Average dry-out period of wireless rain sensors (WL); histogram and frequency distribution for 6-hour intervals.

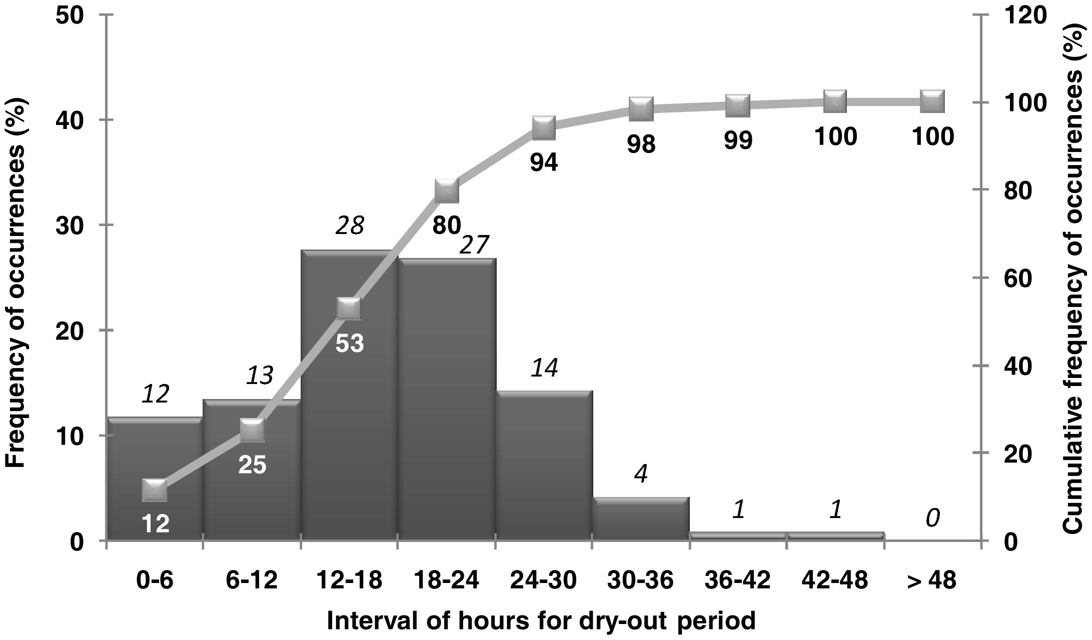

Figure 6. Average dry-out period of Mini-Click rain sensors set at 3 mm (3-MC); histogram and frequency distribution for 6-hour intervals.

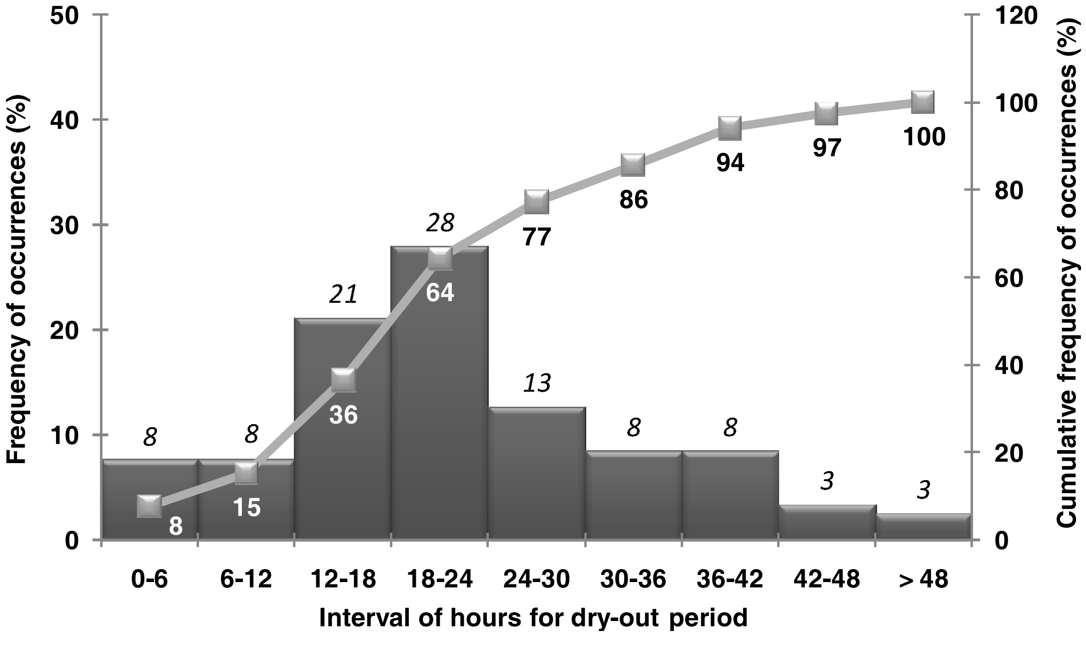

Figure 7. Average dry-out period of Mini-Click rain sensors set at 6 mm (6-MC); histogram and frequency distribution for 6-hour intervals.

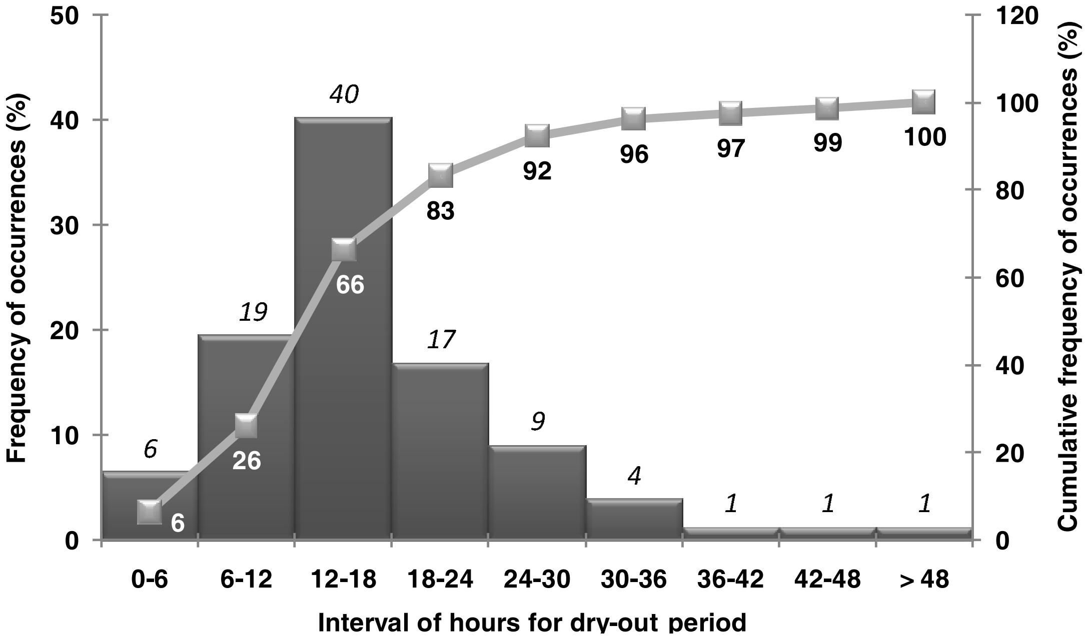

Figure 8. Average dry-out period of Mini-Click rain sensors set at 13 mm (13-MC); histogram and frequency distribution for 6-hour intervals.