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Designing Class A Pan Automation System (CAPAS) Based on Programmable Logic Control (PLC) And Testing

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Abstract: The objectives of this study are to design Class A Pan automation system (CAPAS) based on PLC and to test it using the water level (WLT) measured automatically using by pressure transmitter (PT) and water level (WLG) measured manually using by depth gauge (DG) in the Pan. The designed CAPAS measured automatically WLT through both delaying digital values readings and moving average method in Class A Pan, and switched on/off solenoid valve in filling/refilling of Pan, and saved WLT in a file on secure digital memory card (SD). WLT and WLG were evaluated using the Nash-Sutcliffe efficiency (NSE), the root mean square error (RMSE) and the root mean square error to observations' standard deviation ratio (RSR). Means ± standard error of the mean WLT and WLG were 172.4 ± 1.79 and 173.5 ± 1.66, respectively. The determination coefficient (R^2) and slope of the linear regression were found as 0.992 and 0.99. The results of the NSE and RSR showed that the performance of CAPAS was very good at measuring WLT, and also test's results determined that CAPAS conducted successfully the transactions of the automation under field conditions. As a result, it is recommended that the CAPAS be used in the irrigation automation.

Keywords: Filtration, PLC, sensor, Pressure Transmitter, CODESYS

Programlanabilir Lojik Kontrol (PLC) Tabanlı A Sınıfı Pan Otomasyon Sistemi (CAPAS)' nin Tasarımı ve Test Edilmesi

Öz: Bu çalışmanın amacı, PLC tabanlı A Sınıfı Pan otomasyon sistemi (CAPAS)'ni tasarlamak ve bu sistemi, basınç transmiteri (PT) aracılığı ile otomatik olarak ölçülen pandaki su seviyesini (WLT) ve derinlik ölçer (DG)'le ölçülen su seviyesini (WLG) kullanarak test etmektir. Tasarlanan CAPAS, A Sınıfı Pandan hem su seviyesini dijital değerleri geciktirerek hem de hareketli ortalama yöntemi ile WLT'yi otomatik olarak ölçmüş, bu değerleri kullanarak Panı, solenoid valfi açıp/kapa yöntemiyle belirlenen ölçütlere göre doldurmuş ve WLT'yi bellek kart (SD)'ındaki bir dosyaya kaydetmiştir. WLT ve WLG, Nash-Sutcliffe verimliliği (NSE), kök ortalama kare hatası (RMSE) ve kök ortalama kare hatası / gözlemlerin standart sapma oranı (RSR) kullanılarak değerlendirilmiştir. Ortalama WLT ve WLG'nin ortalama ± standart hatası sırasıyla 172.4 ± 1.79 ve 173.5 ± 1.66 olarak bulunmuştur. Regresyon belirleme katsayısı (R^2) ve eğim, 0.992 ve 0.99 olarak belirlenmiştir. NSE ve RSR'nin değerleri, CAPAS'ın performansının arazi koşullarında WLT'yi ölçmede çok iyi olduğunu göstermiştir. Aynı zaman test sonuçlarıyla, CAPAS'ın otomasyonda belirlenen görevleri başarıyla gerçekleştirdiği belirlenmiştir. Sonuç olarak CAPAS, sulama otomasyon sistemlerinde kullanılması önerilmektedir.

Anahtar Kelimeler: Basınç Transmitteri, CODESYS, Filtrasyon, PLC, sensör,

1. Introduction

Evaporation rate from the pan to the atmosphere is valuable and has always played a key role in hydrologic and water resource studies. It is particularly important for water resource management (Chin and Zhao, 1995; Yahaya et al., 2018) and for climatic change studies (Burn and Hesch 2007). In agriculture, the evaporation from the pan has been used for irrigation scheduling (Phene and Campbell, 1975; Phene et al., 1992; Phene et al., 1996; Allen et al., 1998; Ertek et al., 2006; Gençoğlan et al., 2019) since it is a measurement of the integrated effect of radiation, wind, temperature and humidity on evaporation from the pan (Doorenbos and Pruitt, 1977; Ertek, 2011). In the evaporation measurements, there are different evaporation pans that have been used extensively for evapotranspiration studies in the past and nowadays (Chin and Zhao 1995; Irmak et al., 2002; Brutsaert 2006; Xing et al., 2008; Ünlü et al., 2014;). Among the evaporation pans, Class A pans are widely used and are the standard evaporation-measuring instrument (Burgess and Hanson, 1981). The ease of use, simplicity of data, and low cost have promoted the wide adaptation of them in many countries (Hatfiled, 1990). Class A pans were generally used by universities and research institutes in underdeveloped and developing countries. The advantage of using evaporation pans is that they are relatively simple and inexpensive in terms of equipment compared to other methods. According to Stanhill (2002), Class A pans continued use could be attributed to two reasons. The first reason is their simplicity, low cost, and the proven ease of application in determining crop water requirements for irrigation scheduling. The second reason is the important limitation to the alternative meteorological approach now widely recommended. Class A Pan evaporation method usually gives reliable results if its calibration is made for different climate regions (Jensen et al., 1990).

Since 1963, much efforts have been made to automate the measurement of water level using different sensors and techniques in several countries. Examples of these were given following. Summer (1963) described an evaporimeter consisting of a battery-operated long-period recorder coupled to a supply water tank. The tank is connected to a standard evaporimeter through an automatic control valve, which regulates the supply of water to replace that lost by evaporation, and disposes of excess water due to precipitation, so that evaporation in all weather conditions can be recorded. Phene and Campbell (1975) developed a class A pan evaporation measurement and control instrument to automatically measure pan evaporation with a linear variable differential transformer (LVDT). Burgess and Hanson (1981) developed a low-cost battery-operated integrated circuit system using assembly of probes to automatically fill Class-A evaporation pans from stored water. They stated that the system could be used in remote locations. Yıldırım (2016) used probes to in a mini-pan to activate drip irrigation system in a greenhouse. Yahaya et al. (2018) developed an automated Class A evaporation pan, which accurately measures evaporation depth using aluminum probe sensors. Asrar et al. (1982) weighed changes in the weight of an evaporation pan due to water loss using constant wire-resistance strain gauges and tested the system under field conditions. Van Haveren (1982) developed an automated recording system for evaporation pans to allow continuous analog type water level recording of pan evaporation. The system incorporates a water reservoir to supply water to the pan and can be left unattended for long periods of time. McKinion and Trent (1985) compared water levels in the pan as measured by pressure transducer and hook gauge. It was stated that the measurement system was accurate and simple to install and operate. Boughton and McPhee (1987) reported an automatic system for a standard Class A pan, measuring automatically evaporation loss and rainfall. Replenishment of evaporation loss and discharge of excess rainfall water was done through valves, and inlet and outlet water of the pan were also measured by tipping buckets. Thibault and Savoie (1989) automatically monitored water level with a floating-type water level gauge. In this system, a control module with inflow and outflow solenoid valves was designed and adapted to a Class A pan to correct the water level. Phene et al. (1992) developed an automatic Class A pan using an electronic strain gauge sensor to monitor water level in pan for scheduling real-time cotton irrigation. Mbajiorgu and Wilkie (1995) measured the level of water in the pan using a bidirectional linear actuator. Caissie (2011) designed refilling/measurement device to automate a Class A evaporation pan, consisting of an overflow apparatus which brought back the water in the pan to a predetermined level. The pan was studied using simulated evaporations in the laboratory and was also tested in the field under various meteorological conditions. Sezer et al. (2017) measured water level by ultrasonic sensor in class A pan and they found that relationship was well between water levels measured by ultrasonic sensor and hook gauge until distance of 35 cm between sensor and top of water and after that point worsen. Gençoğlan et al. (2013) monitored water level with the ultrasonic sensor in a pan in the laboratory and made comparison with values of hook gauge measurement. In addition, Gençoğlan and Gençoğlan (2016) measured the water level in the Class A pan by the pressure transducer in the workshop conditions and compared with the manually measured values. Hasanuddin (2019) evaluated a measurement system of water level in evaporation pan, which had an aluminum box (still well with sized 200x200x900 mm). The still well was mounted with the float-operated shaft encoder water level sensor.

As aforementioned, in some studies more advanced sensors were used such as ultrasonic and pressure sensors, and encoders, but in the others some simple devices and mechanisms were used such as floating-type water level gage and probes. The sensor technology is the important sign of the modern science and technology development level (Kovacs, 2003). The sensor technology is the key for information acquisition and modern measurement and industrial automation (Zhao and Wen, 2008). Benedict (1977) defines pressure as the force exerted perpendicularly by a fluid on a unit of area of any bounding surface. Pressure with a static fluid is independent of direction and is strongly influenced by position. Thus, as the height of a water column changes with respect to a reference position, the pressure within a static fluid at that position changes in direct proportion. Advantage of these principles was used in the pressure sensor and design of the automated evaporation measurement system. The current output of a pressure sensor changes in water level of an evaporation pan system. The pressure sensor provides a voltage or current output proportional to the water level (Hashemian and Jiang, 2009).

There are generally two methods to determine the rate of evaporation from Class A Pan. The first one is to measure the reduction in water level (Sezer et al., 2017) and the second one is to measure water level in Class A Pan (McKinion and Trent, 1985). In the CAPAS, the second method was selected due to pressure sensor measuring the water level from which evaporation rate is determined. Meanwhile, in water level measurement with PT in the still well, there are generally two methods available: installing the still well (1) inside (Eijkelkamp, 2020) and (2) outside (Akim, 2020) of Class A Pan. The water level measurement system used in present study is different from both them. So far, although many studies on automation of class A pan as aforementioned before have been conducted in many countries, and many sensors and technologies are available, its usage is still low in underdeveloped and less developing countries and also most of them is not compatible with the system used in the today's irrigation automation technology. Also, PLCs and pressure sensors were utilized in a few studies. Pan automation system should be made widespread in order to reduce the labor of technical personnel, make more reliable measurements under environmental signals called noise and windy conditions and provide data directly to the irrigation automation systems.

For this reason, aims of this study are to design CAPAS using a PLC on Class A pan and to test performance of CAPAS using WLG and WLT, which are measured in the Pan.

2. Materials and Methods

The study was conducted at Research Field, Faculty of Agriculture, Kahramanmaraş Sütcü İmam University (37°32'08" and 36°54'59" E and altitude 700 m above sea level). The measurements were done from 15th June to 15th October in 2017. Monthly average wind speed in the study period varied between 0.9 (light) and 2.0 m s^{-1}(moderate).

To measure automatically WLT with PT in Class A pan and to switch on/off solenoid valve in filling/refilling of pan, and to save WLT in a file on a secure digital (SD) memory card at 8:00 and 8:05 clock during the measurement period, a panel of CAPAS based on PLC-ETH was installed and a program was also written for it using CODESYS-ST language. Also since PLC has Ethernet, the save data into SD card was downloaded by the file transfer protocol (FTP) using a personal computer (PC) in every 15 days.

In water level measurement with sensor, generally two methods are available. Either the measurement device installs inside Class A pan (Eijkelkamp, 2020) or outside it (Akim, 2020). In the present study, a modified measurement system for CAPAS was designed using fittings and the pressure transmitter to measure water level in the Pan, which was called as "measurement arm". The measurement arm and line of the water source were mounted on a Class A Pan (1210 mm in diameter and 250 mm in depth and made of monel metal (0.8 mm)) (Doorenbos and Pruitt, 1977) (Figure 1a).

To connect the measurement arm and line of the water source to the Pan, two holes were opened on the lower side edge of the pan and two stainless steel threaded sleeve fittings (muff) (Ø1/2") were welded these holes (w) (Figure 1b). The first one was used for the measurement arm and the second one for line of the water source. The measurement arm was assembled successively hex nipple, tee (used two opening and plugged the left one), elbow, hex nipple fitting, ball valve, reduction (Ø1/2" 3/8") and pressure sensor (3) (25 mBar, Ø3/8"). The line of the water source was assembled successively hex nipple, solenoid valve (2) (Ø1/2"), union fittings and water supply (1) (Fig. 1b). The solenoid valve is normally closed, operating voltage 10-32 VDC, pressure range 0.5-50 Bar, working ambient temperature -10 to +50 ºC and opening and closing time 500 ms. Surrounding by vegetation but no shadowing, Class A pan was located in a place at the research field.

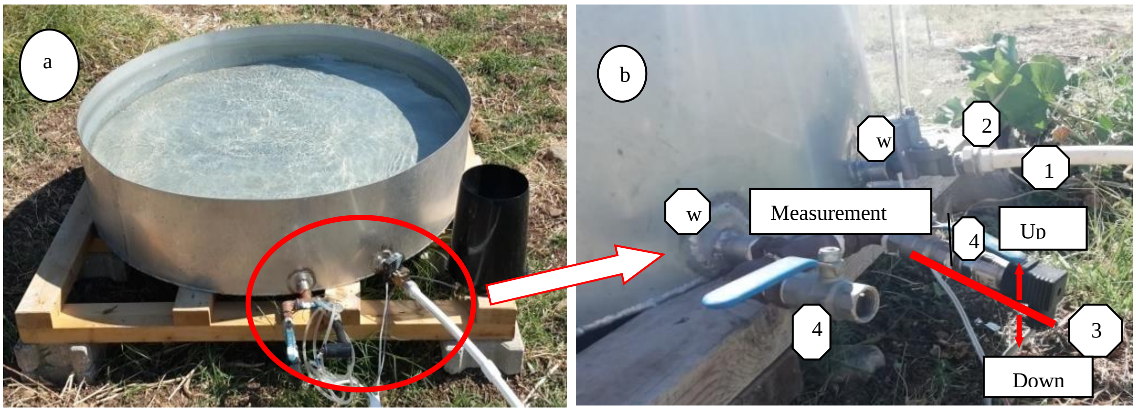

Figure 1. Connection of measurement arm and line of water source to Class A pan
Şekil 1. *Ölçüm kolunun ve su kaynağının A sınıfı buharlaşma kabına bağlantısı*

In the panel, there were switches, power supply, PLC-ETH [6 digital inputs ((DI) 24 VDC), 6 digital outputs((DO) 24 VDC, 0.5 A max. transistor outputs), 2 analog inputs ((AI), voltage 0...10 V), 1 analog output ((AO) voltage 0...10 V or current 0...20 mA/4...20 mA)], AI/AO module (4 configurable AI, 2 configurable AO, resolution 11 bits plus signal or 12 bits, measuring range from 0 to 27648 for 4-20 mA), relay plugged in socket and clemens. As explained above, the PLC has not current AI, so AI/AO module was used for the PT. Output of the PT was connected to %IW0 address on AI/AO module. A1-A2 coil terminals of the relay plugged socket were connected to PLC's DO0 canal, com contact was wired to the output contact of power supply, normally open (NO) contact was wired to solenoid valve. These devices were connected each other with the cable of Ø1 mm^2 (ABB, 2015). The panel was connected a power of 220 VAC. Since the input power of PLC is 24 VDC and which is between limits input power of the solenoid valve, the PT and relay (24 VDC), the selected power supply transformed power into output of 24 VDC and 10 A. To control the solenoid valve, it was connected to relay using shielded cable (about 10 m) and the output of the PT was also connected to analog input of PLC using shielded cable (about 10 m).

To measure automatically WLT at the bottom surface of Class A pan with CAPAS, PT was used. The PTs measures the physical quantity of the pressure and converts it into a standardized electrical measurement signal (Karabacak, 2003; Hashemian and Jiang, 2009). The PT (input power 10-32 DCV, output 4-20 mA) measured the water pressure applied by the water level inlet of the sensor, which was connected to the Pan and converted it into electrical signals, changing between 4 and 20 mA. The electrical signals were converted into normal range decimal value by the PLC and it changed between 0 and 27648. Its measurement capacity is 25 mBar, which is equal to water level of 250 mm H_2O. Its standard accuracy is ≤±0.5% full scale (FS) or of span (Atek, 2020). The reason for choosing the PT is that its measuring capacity (250 mm H_2O) is equal to the pan depth (250 mm).

To prepare the programs for CAPAS, flow charts were drawn as seen in Figure 2 and 3, and then from which the programs were written, namely, function block, 'Pan_Dpth_F_B', and main program, 'Evp_Pan'. Firstly, digital output of PT was transformed into water level (0-250 mm) using by 'trafo_1' function block (Figure 2). Secondly, since output of the PT is influenced by environmental signals called "noise" and wave due to wind under field conditions (Van Haveren, 1982; McKinion and Trent, 1985), water levels were filtered. To minimize these effects on them and to make them more stable, 'Filter_I' and 'Filter_MAV_DW' function block were used, respectively (Oscat, 2020; Tülücü, 2002). 'Filter_I' function block delayed 100 milliseconds water level readings to minimize noise. Ignoring water level greater than 250 mm or lesser than 0, moving average filter function block (Filter_MAV_DW) smoothed continuously water level, averaging out 32 successive water levels (Oscat, 2020). Finally, the filtered water levels were assigned a variable of function block called WH_M.

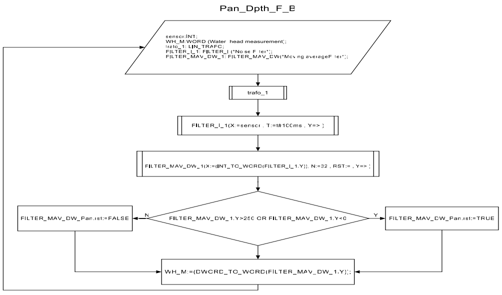

Figure 2. Function block flow chart of WLT
Şekil 2. *WLT'nın fonksiyon blok akış diyagramı*

In the flow chart of main program (Evp_Pan) for PLC, variables were described and some function blocks such as 'Pan_Dpth_F_B', 'R_Trig', 'TP' and 'Clock' were assigned (Figure 3). Function block 'The Pan_Dpth_F_B' was re-described as 'PS' in the 'Evp_Pan'. The clock was assigned due to real time based measurements such as valve on/off operations and data saving performed by PLC. In the water level measurements, two definitions were made, one of which was minimum water refill level (RL) and the second one was maximum water fill level (FL). RL was equal to 150 mm or lower than it (depending on daily evaporation) and FL was equal to 200 mm or greater than it (depending on wave in Pan). Water level in the Pan changed about between these two definitions (Güngör et al., 2004). A trigger (trg1), timer and real time clock (RTC) instructions were used to execute commands at the predetermined time. In program, case instruction was used to perform the operations in order. On the first day of the study (on 15^{th} June), CAPAS started and opened the solenoid valve (Figure 1-2) at 8 o'clock since the pan was empty (water level (PS.Water_H_M) was lesser than RL). Meanwhile CAPAS continuously controlled water level whether or not reached FL and closed valve as soon as FL was equal to or greater than 200 mm. At 8.00 o'clock before filling and at 8.05 o'clock after filling, CAPAS saved water level on SD card. Here the reason of the measurement at 8.05 o'clock was to minimize the effect of the wave formed during filling in the pan and to measure the water depth more accurately.

On the second day at 8.00 o'clock, CAPAS saved water level on SD card. On the following days, same data savings were done. Finally, water level decreased to RL as water evaporated from Pan and it save water level on SD card at 8.00 o'clock and then refilled to FL at which it saved water level at 8.05 o'clock (Figure 3). The cycle, given above, was repeated to 15th October.

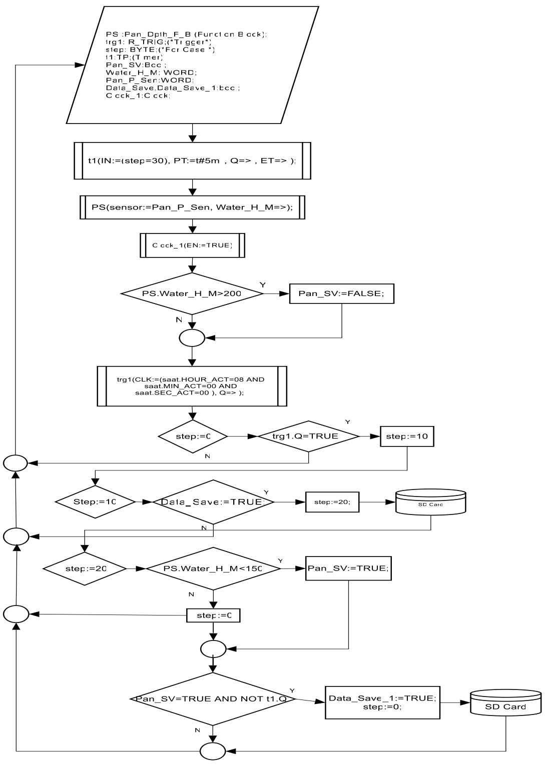

Figure 3. Flow chart of the main program for WLT

Şekil 3. *WLT'nin ana program akış diyagramı*

Apart from WLT, WLGs were done in still well using depth gauge during the study period and the still well was placed near the inlet of the measurement arm in the Pan. When water level was between RL and FL, WLG were performed at 7:55 o'clock. Also, on the re-filling days of the Pan, two WLG were done, before re-filling the Pan at 7:55 o'clock and after re-filling at 8:10.

By connecting the computer to the PLC online through interface of CODESYS, the program was loaded into PLC by a computer. The program run and then WLT was seen on screen of the computer. Before the WLG and WLT started, the WLG was compared with WLT, however, their values could be different because of PT position and friction through fittings between the pressure sensor and the Pan, calibration was made by moving up and down the measurement arm until WLT would be equal to WLG (Figure 1b).

WLG and WLT were compared to assess the performance of CAPAS. Agreement between WLG and WLT values were quantitatively evaluated using the NSE, RSR, RMSE, PBIAS and the standard regression (Moriasi et al., 2007). Details of the indices NSE, RSR, PBIAS and the standard regression are given by Moriasi et al. (2007). The NSE, RMSE, and RSR are given by the following equations, respectively.

$$RSR = \frac{\sqrt{\sum_{i=1}^{n}(\mathrm{WLG_i}-\mathrm{WLT_i})^2}}{\sqrt{\sum_{i=1}^{n}(\mathrm{WLG_i}-\mathrm{WLG_{mean}})^2}} \quad (1)$$

$$NSE = 1 - \frac{\sum_{i=1}^{n}(\mathrm{WLG_i}-\mathrm{WLT_i})^2}{\sum_{i=1}^{n}(\mathrm{WLG_i}-\mathrm{WLG_{mean}})^2} \quad (2)$$

$$RMSE = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(\mathrm{WLG_i}-\mathrm{WLT_i})^2} \quad (3)$$

$$PBIAS = \left[\frac{\sum_{i=1}^{n}(WLG_i-WLT_i)100}{\sum_{i=1}^{n}WLG_i}\right] \quad (4)$$

where WLG is the manually water level measurements (mm), WLT is automatically measured water level (mm), WLGmean is the average WLG (mm). PBIAS is the deviation of data being evaluated, expressed as a percentage.

3. Results and Discussions

CAPAS based on PLC was installed at Research Field and the written program in CODESYS-ST language was also downloaded into PLC. The modified recently water level measurement device for CAPAS is called as "measurement arm", which is easy assemble and calibration. The calibration was made by moving up and down the measurement arm until WLT would be equal to WLG. WLT values were smoothed by both delaying digital values readings and moving average method (Oscat, 2020). The CAPAS successfully executed all following operations according to the flow charts from 15th June to 15th October. Every in 15 days, the saved data into SD card was downloaded by FTP using the PC.

At the first day of the study, having opened the solenoid valve at 8:00 clock, CAPAS filled the empty Pan up to FL through the smoothing WLT and then closed the valve. The first filling of the Pan with water was taken about 2 minutes. Due to the wave occurred in the filling the Pan, which could affect negatively WLT, it was measured after 5 minutes (another saying at 8:05 clock) and then CAPAS saved the smoothed WLT in the file on the SD cart. In the subsequent days, since water from the Pan evaporated, water level decreased and CAPAS measured daily it at 8:00 clock and saved in the file on SD card. As it was equal to or lower than RL, having opened the solenoid valve at 8:00 clock, CAPAS again refilled up to FL and then closed the valve. CAPAS saved WLT 2 times in the refilling day. The first one was before pan was refilled at 8:00 o'clock and the second one was after pan was refilled at 8:05 o'clock. Refilling of the Pan was taken about 1-2 minutes depending on water source flow rate. In the subsequent refills, WLT measurement and savings, CAPAS followed same procedures.

In order to test CAPAS's performances on the smoothed WLT, statistical analyses were conducted on data of WLG and WLT, and their results were given in Table 1. As seen in Table 1, WLG and WLT were done 132 times, respectively, from 15th June to 15th October under field conditions in Class A Pan and 19 of them were at the FL. Dropping water level from 200 to 150 mm by evaporation in Class A Pan changed between 4-7 days depending on climatic conditions. In this study, both RF and FL are not the fixed water level thresholds because RF and FL defined as being equal to or lower and equal to or greater. Accordingly, function of the RF is to end the former water level measurement cycle and FL is to start the new cycle. Meanwhile CAPAS saved available water levels on SD card within both RF and FL limits.

Table 1. Results of statistical analyses on WLG and WLT
***Çizelge 1**. WLG ve WLT değerlerinde yapılan istatiksel analiz sonuçları*

Parameters	Results
Observation Number	132
Mean of WLG (mm)	173.5
Mean of WLT (mm)	172.4
RMSE (mm)	2.11
Correlation coefficient (r)	0.996
Determination Coefficient (r^2)	0.992
WLG STD Error (mm)	1.66
WLT STD Error (mm)	1.79
PBIAS (%)	0.598
RSR	0.11
NSE	0.99

In some water level measurements, WLT was greater (e.g. 202 mm) or lower (e.g. 198 mm) than FL due to the wave, and less (e.g. 142 mm) then RL because of the daily evaporation from the Pan. Means ± standard error of WLG and WLT were 173.5 ± 1.66 mm and 172.4 ± 1.79 mm, respectively. Although standard errors of WLG and WLT were close to each other, there was a difference of 1.1 mm in between means.

Linear regression between WLG and WLT was performed and shown in Fig. 4. For water level measurements, the determination coefficient (R^2) was well above 0.9. The slopes (0.99) of the linear regression line were close to 1:1 with minor intercept values (1.47 mm). This means that the smoothed water level measured by CAPAS with the PT are satisfactory when to be compared with WLT. The determined coefficient (R^2=0.9999) of linear regression between hook gauge and PT water level measurements by McKinion and Trent (1985) is similar to the result (R^2=0.99) of linear regression of the present study. According a study conducted in workshop conditions by Gençoğlan and Gençoğlan (2016), determination coefficient resulted as R^2 =0.999 between the PT and depth gauge measurements in the Class A pan.

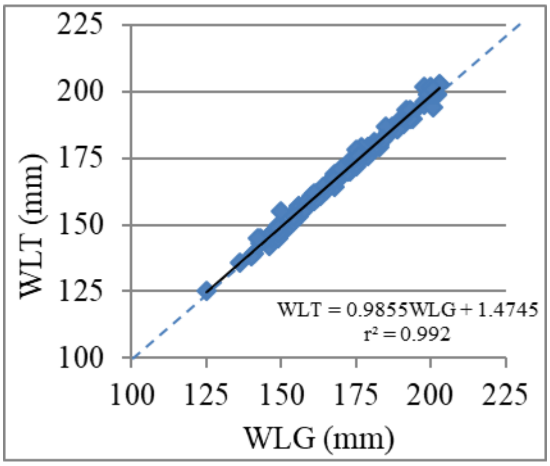

Figure 4. Linear regression analysis between WLG and WLT

Şekil 4. *WLG ve WLT arasında yapılan istatiksel analiz sonuçları*

In addition, PBIAS with 0.6% showed that the average tendency of the WLT data was smaller than their WLG counterparts. Since CAPAS measured WLT values closer to WLG values, it was found that PBIAS value (0.6%) was close to BIAS optimal values (0.0) (Table 1) (Gupta et al., 1999). Both average and PBIAS values showed that values of WLG were greater than WLT values. RMSE over the measurements period was calculated as 2.11 mm. The NSE and RSR values also indicated that the CAPAS performed 'Very Good' in WLT. The result show that the smoothed measurements of water level using the PT can be acceptable.

The PTs utilized in the present study has standard accuracy of ±0.5% FS (Atek, 2020). Accordingly, this means that error of 1 mm (0.005*200 WLG) will be occur in the measurement of the sensor. However, the standard error (1.79 mm) of WLT and RMSE (2.11 mm) resulted higher than error (1 mm) of the PT. On the other hands, results of the NSE and RSR indicated that very good agreement was found between the water level measured manually and automatically (Asrar et al., 1982). Similarly, the study conducted by McKinion and Tarent (1985) using low coast PT in the automatic pan evaporation gave satisfactory result. So far, many studies were done to measure water level using different sensors such as integrated circuit by Burgess and Hanson (1981), water level sensor by Van Haveren (1982), constant wire-resistance strain gauges by Asrar et al. (1982), tipping buckets by Boughton et al. (1987), floating-type water level gauge Thibault and Savoie (1989) and Hasanuddin (2019), overflow apparatus by Caissie (2011), ultrasonic sensor by Gençoğlan et al. (2013) and Sezer et al. (2017). Results of all these studies show that measurements are acceptable level.

As a result, the designed CAPAS measured automatically water level both delaying digital values readings and moving average method with PS in Class A Pan and switched on/off solenoid valve in filling/refilling of Pan, and saved daily water level in the file on the SD card at 8:00 and 8:05 clock during the measurement period. The results of test showed that the performance of CAPAS was very good under field conditions.

4. Conclusion

The designed CAPAS measured automatically WLT through both delaying digital values readings and moving average method in Class A Pan and switched on/off solenoid valve in filling/refilling of Pan, and saved WLT in a file on secure digital (SD) memory card at 8:00 and 8:05 clock from 15th June to 15th October in 2017. WLGs in the pan were also measured manually at 7:55 o'clock and at 8:10 o'clock. WLT and WLG were saved 132 times under field conditions and 19 of them were at FL. The results show that the performance of CAPAS is very good at measuring WLT and conducting other transactions related automation under field conditions.

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