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ORIGINAL RESEARCH ARTICLE

EVALUATING THE EFFECTIVENESS OF FLOATING AND SUSPENDED MATERIALS FOR REDUCING EVAPORATION LOSSES IN SMALL WATER BODIES

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ABSTRACT

Evaporation is recognized as environmental process which can significantly reduce the quality and quantity of stored water available for industrial, agricultural and household purposes. However, this process is dependent on several meteorological factors such as water and air temperature, wind speed and atmospheric humidity. Thus, water savings especially in regions experiencing little rainfall resulting in low runoff events is crucial to enhanced optimum water usage by adopting the use of cover materials on ponds. Covering of water bodies could effectively help in reducing evaporation from open water bodies. This research aimed at investigating the effectiveness of two locally available materials, viz; plastic paint covers and weaved thatch grass. They are used as floating and suspended covers respectively for reducing evaporation. Three evaporation pans were used in this study. One pan was left uncovered as control (Pan C), another pan was covered with plastic paint covers (Pan A) while the last pan was shaded with weaved thatch grass (Pan B). Data were collected during dry season on weekly basis at 6:00 pm. This time-window was chosen because it is the hottest and driest months in Maiduguri. Sensitivity analysis was conducted between evaporation and climatic variables. The results show that evaporation is strongly correlated with temperature with R2 values of 0.8930, 0.9438 and 0.9566 for pans A, B and C respectively. It was also observed that the maximum monthly average percentage reduction (water savings) was found for Pan A to be 39.43%, 42.38%, 33.27%, and 45.14% compared to Pan B with 17.98%, 20.10%, 9.21%, and 32.55% for the months of March, April, May and June respectively. This comparison was relative to Pan C as baseline data. Additionally, plastic paint cover was found to be a good material for reducing evaporation from open water body compared to the suspended weaved thatch. Therefore, Plastic paint cover is recommended for use in reducing evaporation losses in small water bodies.

1.0 Introduction

Water is one of the nature's precious gifts, which sustains life on the planet earth. In arid and semi-arid regions, water is considered as a limited resource. It is now being realized that water, though replenishable, is not an unlimited resources and cannot be produced or added as and when required, by any known technological means. Availability of water over the years depends on the spatial and temporal variation of precipitation. Interestingly, water may be abundant during rainy season and scares in dry season, when it is mostly needed. Although water covers more than 70% of the earth, only 1% of the earth's water is available for drinking and other domestic purposes (Youssef and Khodzinskaya, 2019). It is noteworthy that intense agricultural practices, population growth, pollution and global warming are placing much pressure on the available water. Therefore, the cost of water supply in many countries of the world has increased significantly over the past ten years (Youssef and Khodzinskaya, 2019). The effect is more severe in the arid and semi-arid regions, especially during droughts when water scarcity is compounded by high evaporation losses from open water bodies (Dhirajlal, 2017, Singha, 2006).

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Additionally, changes in temperature and precipitation patterns can have remarkable impacts on water availability. Temperature is predicted to rise in most areas, especially in inland areas and at higher latitudes where it is expected to increase significantly. Higher temperatures will increase loss of water through evaporation (Benzahta and Mohamad, 2009; Beare and Heaney 2002). Igor (1999) observed that the trend of evaporation from reservoirs depends upon meteorological factors such as temperature of the air and water, wind velocity and atmospheric humidity. Additionally, in semi-arid regions, hot dry air moving from a land surface over a water body will result in higher evaporation rates (Larry et al., 2007). Evaporation is one of the most important environmental processes that can reduce the quantity and quality of stored water available for industrial, agricultural and household uses. In arid and semi-arid regions, evaporation can account for as much as 25 to 30% of the total consumptive use of surface water; therefore, control of evaporation from land based water bodies has remained one of the main planks of water conservation strategies (Khudair et al., 2013). This assumes greater significance in arid and semi-arid regions like northern Borno, Nigeria, where water scarcity is already a common challenge to farmers.

It is important that any development of water resources should ensure efficient control, conservation, and use of available water (christtansen. and Worlton, 1998; Benzahta and Mohamad, 2009). Whereas seepage loss in water courses and fields returns to streams and aquifers for reuse, evaporation loss signifies water that is totally lost from the available supply. Covering the water bodies could help in reducing evaporation and improve water security, leading to increased irrigation production (Prime et al., 2012). Hence, greater attention should be given on reducing, if not preventing, the losses due to evaporation (Shaw, 1988). There are many materials; chemical and physical covers which can effectively and efficiently reduce the evaporation from open water bodies. These materials are used to suit the local climatic conditions and availability as well (Anonymous, 2003, Shamshad et al., 2012, Simon et al 2014, Panjabi et al., 2016). Jat et al. (2010) observed that different evaporation retardants reduce evaporation from water surfaces. Evaporation reductions were determined directly by measuring the volume of water evaporated from the test recipients after a certain period of time. Tests have shown that floating sheets such as E-VapCaps can reduce over 95% evaporation from open water reservoirs (Craig, 2005). Also, Craig et al. (2007) observed that physical covers was able to reduce substantial evaporation from open water bodies. The study suggested that these types of covers would be more effective for small reservoirs (less than 10 ha in size). Thus, in this study, two local cover materials viz; suspended (weaved thatch) and floating (plastic paint cover) were considered for reducing evaporation using pan evaporimeter. The aim of the research is to evaluate the effectiveness of floating and suspended materials for reducing evaporation losses in small water bodies.

2.0 Materials and Methods

2.1 The Study Area

The study was conducted at Pompamari in Maiduguri Borno State, Nigeria, Figures 1 (a and b) with its coordinates given in Table 1. It is situated at an elevation of 325m above mean sea level (World atlas, 2020). The estimated population of Maiduguri is approximately 1,112,449, making it the biggest city in Borno State (National Population Commission, 2010).

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Figure 1a. Location of Pompamari (the study area)

Table 1. Coordinates of the study area

Coordinates	Latitudes	Longitudes
Upper right	11° 51’ 55.30”	13° 07’ 17.04”
Lower right	11° 50’ 37.54”	13° 07’ 16.57”
Upper left	15° 51’ 55.39”	13° 05’ 20.09”
Lower left	11° 50’ 37.64”	13° 05’ 20.28”

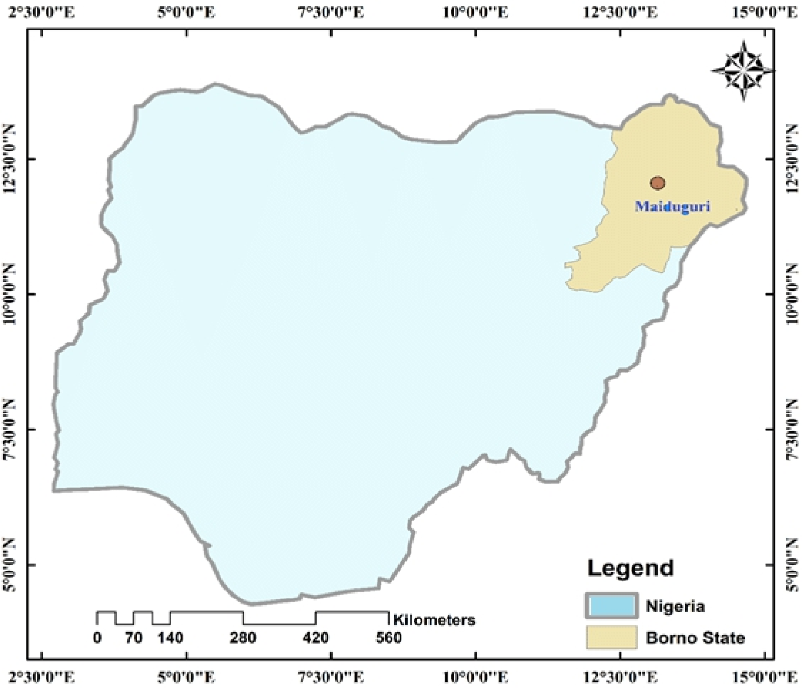

Figure1b. Map of Nigeria showing Borno State and the capital, Maiduguri

2.2 Agro-climatic Condition of the Study Area

Maiduguri is located in the semi-arid region of North-east of Nigeria. During the year, the wettest month (with the highest rainfall) is August (193.2 mm). Driest months (with the lowest rainfall), February - June (0 mm). It receives an annual rainfall of 613 mm. The maximum temperature could be as high as between 32- 43oC during summer and as minimum as between 6 - 15oc during winter. May is the hottest and December is the coldest month of the year. On average, August is the most humid while February is the least humid, and the average annual percentage of humidity is 30.0% (World Weather and Information, 2010 to 2020).

2.3 Experimental Tests

The experimental tests were conducted using three evaporation pans. One pan was covered with plastic paint covers and labeled as "Pan A", while another pan was shaded with weaved thatch grass and labeled as "Pan B" as in Figure 2. Additionally, the last pan was uncovered as control and labeled as "Pan C". The Floating covers of 30 cm in diameter were used on the water surface and supported by the water itself. However, the covers are fixed on the water surface using some form of anchoring mechanism when use on large water surfaces.

Weaved thatch of 3 m x 3 m made of yellow thatch grass was suspended at a height of 2m over "class A" evaporation pan which was externally supported by galvanized pipe. These pans were protected with open wire mesh to prevent insects, birds and animals drinking from the water.

Figure 2. Experimental set up of the evaporation pans.

2.4 Experimental Set Up

Pan evaporimeters were used in the study. One remarkable advantage of the evaporation pan is that it incorporates all possible physical effects (Shamshad et al., 2012). A US "class A" pan is a circular tub of 1210 mm internal diameter; 254 mm deep and was constructed of one-millimeter thick galvanized steel sheet. The evaporation pans were installed on wooden supports of 50mm, leveled on the ground. It was filled with water at a distance away from any obstacles which might affect natural air flow around the pan, thus, representing open pond water nearby. The evaporation pans provided measurements of combined effects of temperature, humidity, wind speed, and other ambient conditions as shown in Figure 2.

2.5 Measurement of Evaporation Rates

Evaporation rate was obtained by measuring changes in water levels in the pans. This was done manually using a point gauge. Data were collected during dry season on weekly basis at 6:00 pm. This window period was chosen because it is the hottest and driest in Maiduguri. Monthly evaporation is useful which can be applied to the drier months of the year when reservoir drawdown is maximum due to high water usage (Benzahta and Mohamad, 2009, Yu and Knapp,

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1985). Water was added into the pans to substitute the evaporated water when the level in the pans was dropped to 50 mm. Water depths were measured before and after the water was added. Also, water was taken out of the pans when the water levels raised much due to rain and the water depths before and after were recorded. In order to relate the evaporation and ambient conditions, data of ambient temperature, wind speed and relative humidity were recorded from nearby weather station (Weather Station of Maiduguri International Airport).

2.6 Measurement of Evaporation Losses Using US "Class A" Pans

There are several methods available for measuring or estimating evaporative losses from free water surfaces. Evaporation pan is one of the simplest, inexpensive, and most widely used methods of estimating evaporative losses (Jones, 1992). Pan evaporation is considered an indication of atmospheric evaporative power. Evaporation from free water surface is related to pan evaporation by a coefficient applied to the pan readings. According to Mayer (1982), Kpan (pan coefficient) = 0.75 for US "class A" pan.

$$\text{PER (mm)} = \text{Kpan} \times \text{Epan (mm)} \qquad (1)$$

Where: PER is pan evaporation rate in millimeters,
Epan = pan readings (mm)

$$\text{PEL} = \text{PER} \times \text{SAP} \qquad (2)$$

Where PEL is pan evaporation loss in meters, SAP is Surface area of the pan in square meters Correlation coefficient was conducted between evaporation to ambient air temperature, relative humidity and wind speed.

3. Results and Discussion

The recorded evaporation data were summarized as monthly average and presented in Figure 3. The results indicated some significant differences in evaporation from pan C compared to evaporations from the covered pans (A and B). Maximum evaporations were observed in pan C, followed by pan B and pan A throughout the entire period of the study. The maximum evaporation recorded was 273.65 mm, 230.60 mm and 169.48 mm for pan C, B and A respectively for the month of May. Similarly, minimum evaporation was observed for pan A (134.13 mm), followed by pan B (171.31 mm) and pan C (211.72 mm) for the month of June. This could be explained by the fact that the month of June is humid as rainy season is approaching. This confirms the feasibility of using floating plastic paint or suspended thatch in evaporation reduction because they provide a barrier between the water and atmosphere as reported by Craig (2005) and Craig et al. (2007), who used floating covers to achieve substantial reduction in evaporation.

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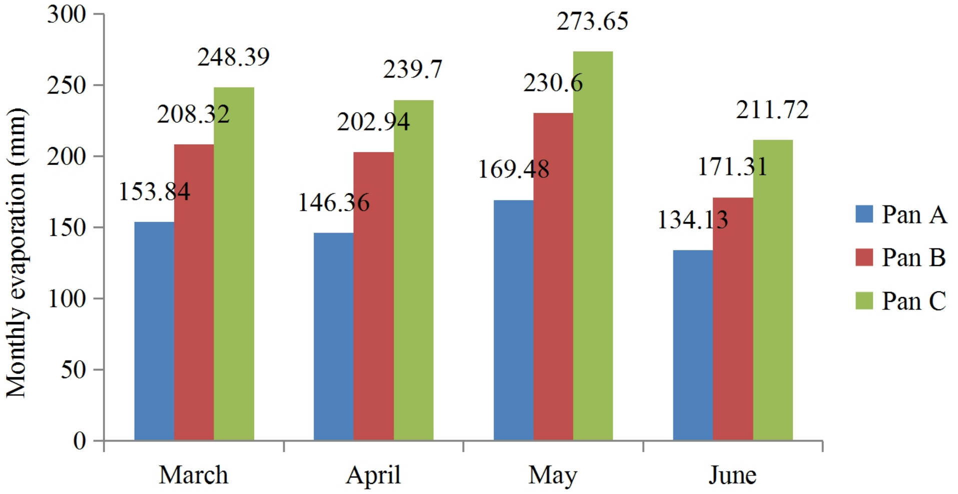

Figure 3. Comparision between monthly evaporation rates from evaporation pans

Figure 4 presents the overall percentage water savings for Pans A and B in evaporation over Pan C. The maximum water savings was found in pan A to be 45.14% compared to Pan B at 32.55% for the month of June. Pan A saves more water because it covers the water surface area of the pan completely and reduces climate effects. This agrees with Craig (2005) who observed that floating sheet can reduce evaporation by approximately 95% from open water reservoirs.

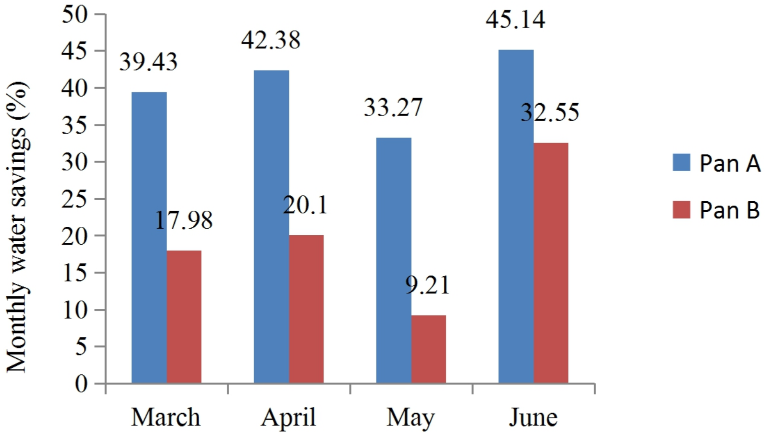

Figure 4. Comparison between monthly water savings from pan A and pan B over pan C

Figures 5 (a, b and c) show the relationship between the measured evaporations from the three evaporation pans and ambient air temperature, relative humidity and wind speed. It can be seen from the figures that evaporation from the pans have direct relationship to the ambient air temperature, relative humidity and wind speed. During the experiment; it was observed that period in weeks when higher ambient air temperatures and wind speeds were recorded, higher evaporation losses were obtained while for weeks with higher relative humidity, evaporation losses were minimal due to moist condition.

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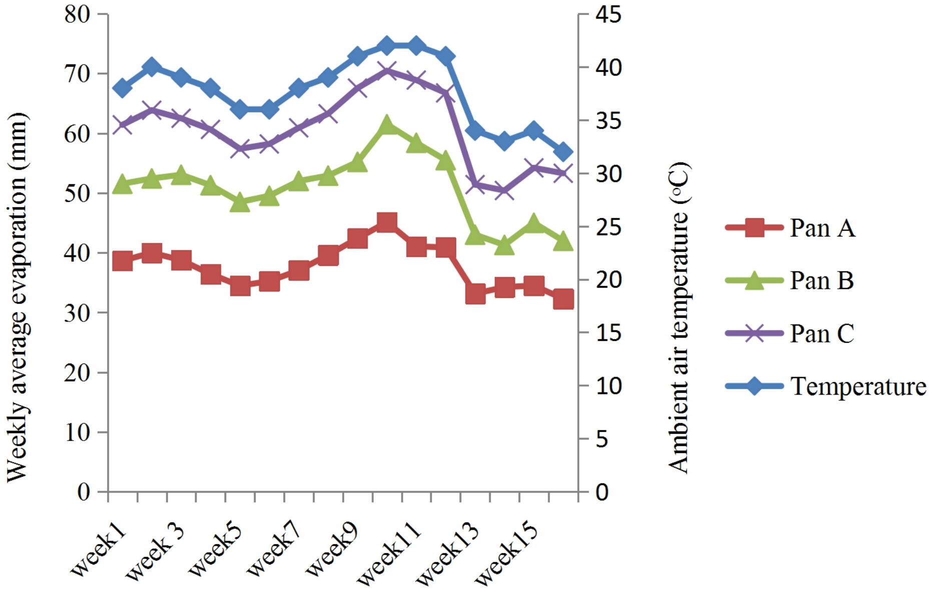

Figure 5a. Variation of weekly average evaporation with ambient air temperature

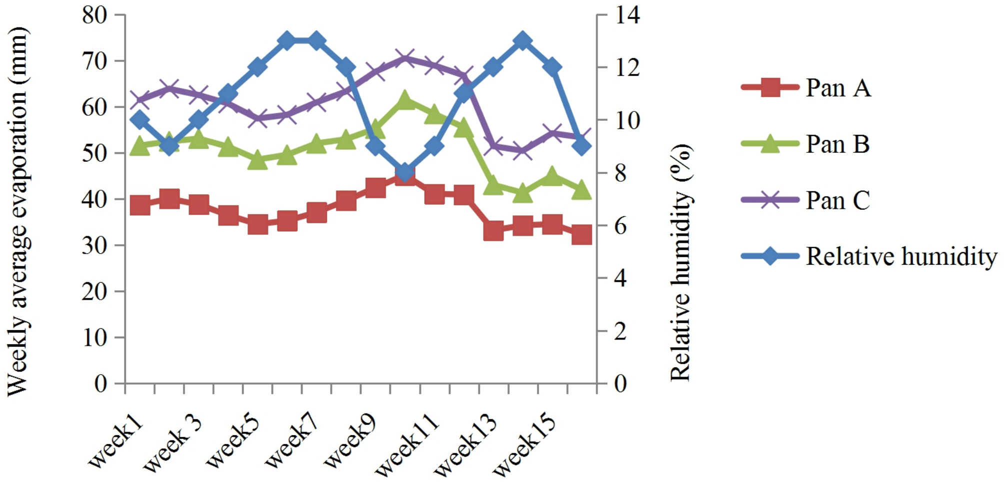

Figure 5b. Variation of weekly average evaporation with relative humidity

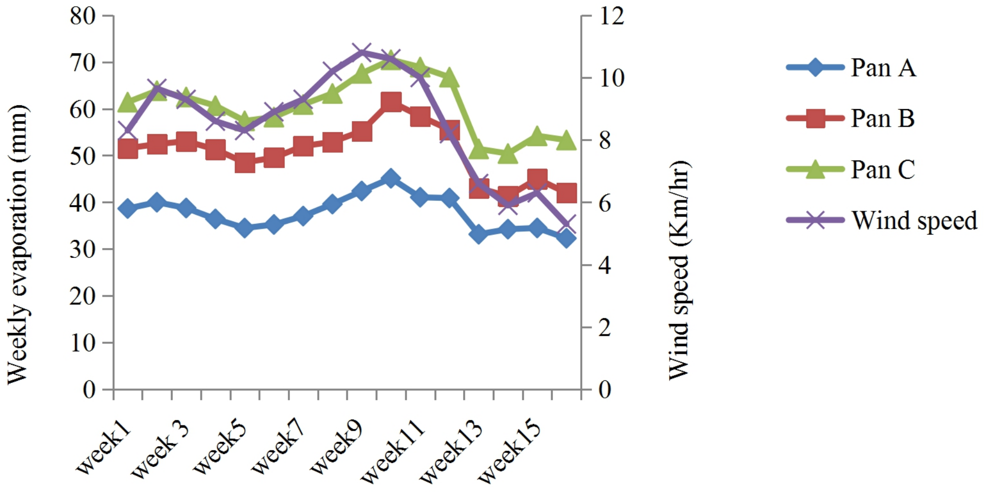

Figure 5c. Variation of weekly average evaporation with wind speed

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Figure 6a shows a linear relationship between evaporation and temperature. The results showed an R^2 value of 0.893 for pan A, 0.9438 for pan B and pan C was 0.9566. This is an indication of a strong and positive linear relationship between evaporations and ambient air temperature with most of the data points closely distributed.

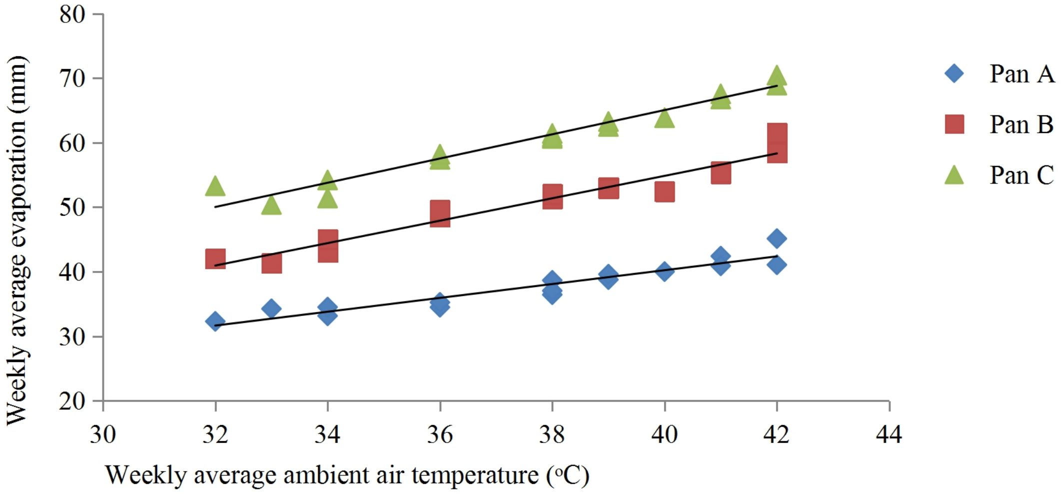

Figure 6a. Variation of weekly average evaporations with ambient air temperature

Interestingly, a moderate linear relationship was obtained between evaporations, relative humidity and wind speed as shown on Figures 6 (b and c). The R^2 values for pan A, pan B and pan C were 0.5218, 0.6386 and 0.5713 respectively. It can be observed from Figure 6b that the higher the relative humidity, the lower the evaporation, whereas lower relative humidity resulted in higher evaporation. The R^2 values for pan A was 0.7028, pan B was 0.7995 and pan C was 0.7717 (Figure 6c). It is clear from the Figure that, higher evaporations are obtained at higher wind speeds. This suggests that trees or shrubs should be planted around the open water bodies to serve as wind breakers in order to minimize evaporation losses.

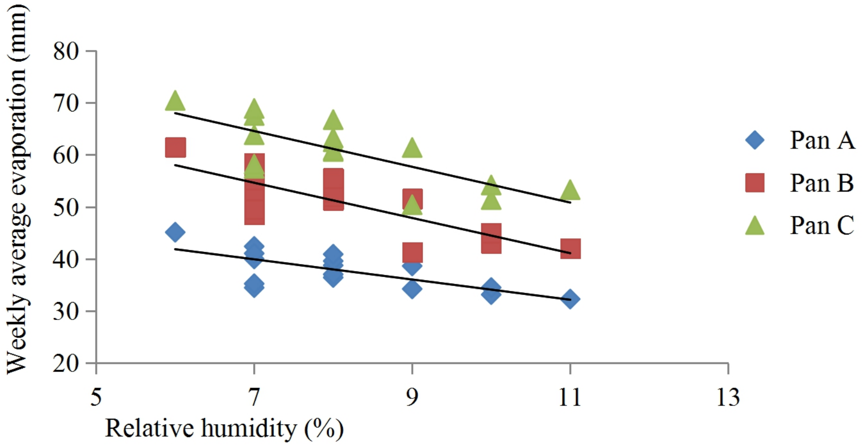

Figure 6b. Variation of weekly average evaporation with relative humidity

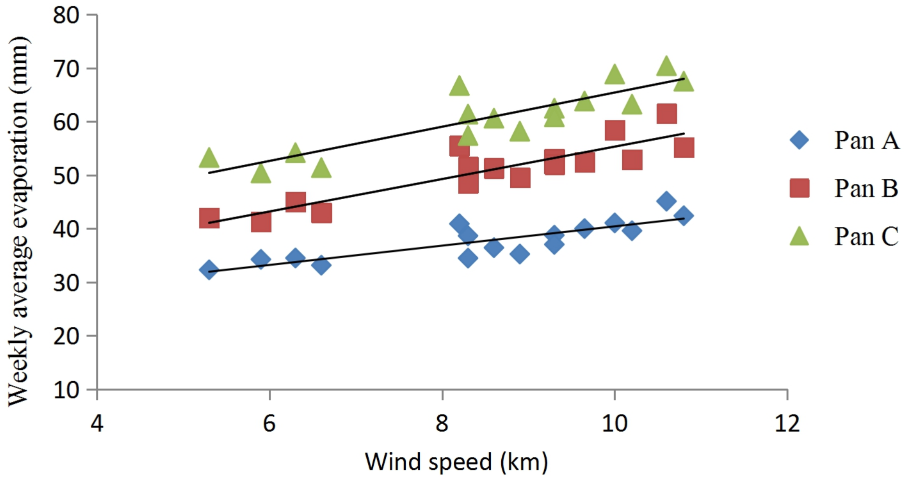

Figure 6c. Variation of weekly average evaporations with wind speed .

4. Conclusion

Floating and suspended materials (plastic paint covers and weaved thatch grass) have significant potentials for reducing evaporation from open pans. During the four months of this investigation, pan with plastic paint covers were able to reduce evaporation and saves water substantially compared with the shaded thatch cover. It is noteworthy that plastic paint cover could be a promising alternative material to reduce evaporation from open water body compared to the suspended weaved thatch grass. Interestingly, notable weeks with higher ambient air temperature and wind speed resulted in higher evaporation records. In addition, sensitivity analysis suggests that evaporation is strongly and positively correlated with the climatic variables. Thus, it is advisable to plant trees or shrubs around open water surfaces to reduce evaporation losses.

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