Fog water harvesting five sites south of Mazar-Karak (1992-1994) Jordan

Sulieman Tarawneh
Civil Eng. Dept. Mu'tah University, Jardan

Fog harvesting, a promising water resource, has been known for a long time, but has not been thoroughly investigated until the recent decades. It is becoming also a practical source for drinking water in several remote sites in many regions in the world. This study used the Standard Fog Collectors (SFC) of (1x1 m^2) to find the duration length of the fog season and tomeasure the amounts of water harvested in the period between (1992-1994) in five sites south of Mazar – Karak. The selected sites are Taibih, Dhabab, Moab, Mahy, and Abiad. The results were promising for the high plateau sites such as (Dhabab Mount), less promising for the lower plateau sites, and not promising at all in the Badia sites.

حصاد الضباب مصدر واعد للمياه معروف منذ زمن بعيد، لكنه لم يحظَ بدراسات علمية حقيقية كافية إلا في العقود الماضية الأخيرة. عندها أصبح حصاد الضباب أيضاً مصدراً عملياً لمياه الشرب لعدد من الأماكن البعيدة في مناطق مختلفة من العالم. وقد استعملت هذه الدراسة الشاشة النموذجية لاعتراض الضباب بمساحة متر مربع لمعرفة طول فصول الضباب ولقياس كميات المياه التي يمكن جمعها من الضباب في الفترة ما بين (١٩٩٢-١٩٩٤). وقد جرت التجربة في خمسة مواقع هي الطيبة والضباب ومؤاب ومحي والابيض إلى الجنوب من المزار-الكرك. ولقد كانت النتائج واعدة في مناطق الهضبة المرتفعة كجبل الضباب، وأقل من ذلك في مناطق الهضبة الأقل ارتفاعاً، لكن النتائج غير واعدة أبداً في مناطق البادية الأردنية.

Keywords: Fog, Low clouds, Fog collection, Fog harvesting

1. Introduction

Fog harvesting could become in the near future one of the most environmentally appealing solutions for water requirements in several unattended places in the world, specially in the high hilly mountains such as the study area. Many feasibility studies using small fog collectors to assess the technical and economical feasibility in several sites, have shown very encouraging results. Many sites in the high plateau of Jordan have a good potentiality for fog harvesting. Dhabab is a typical foggy mountain in south of Jordan like Ras Munief in north of Jordan.

Fog harvesting has not been addressed deeply as an unconventional source of water, even though its application has been existing in many countries for many centuries. Fog harvesting as a real source of drinking water was known for a long time, and has been under continuous investigation for decades, but fog harvesting has become practical method for drinking water since 1987 [1]. In Ecuador, two small experimental projects were set in the high Andes at elevation of 2830 m. Two mountain sites have produced large amounts of water from the fog collectors. Results in Ecuador are very encouraging because of the extended periods of fog [1]. Table Mountain near Cape Town in South Africa yields about 3300 mm/y, of harvested fog water. The mountain's actual annual rainfall total is about 1940 mm/yr. In this peculiar site, the fog water harvested is more than the regular rainfall totals [2].

Fog harvesting is mostly appropriate for hilly areas with frequent fogs with visibility less than 100 m and with winds about 10 km/hr which could carry the fog gently through the polypropylene meshes in the erected collectors [1]. In certain hilly and coastal areas, fog harvesting has more reliability than ground water in its safety and some times in its availability [1].

Fog is cloud which composes of many millions of tiny liquid droplets that form in the air near the ground, but not on the ground surface like dew drops. It has been found for several region's of arid and semi-arid lands that they have more foggy days than rainy days. This is actually true in the studied area.

Fog harvesting is a method for isolated villages, clusters of remote homes, and for forestation of the uplands in many promising sites in the world especially the developing countries.

In Oman, the experimental results are very encouraging because of the extended periods of seventy days of fog with an average collection rates of 30 l/m^3 /day. When using forty eight square meters collectors the amount collected in a day for each collector is around 3.36 m^3. This result makes fog harvesting very attractive source of fresh water in certain remote sites in south of Oman [3]. Also, fog drip amounts for about 450 mm/yr at elevation above 1200 in northern New England-USA, which is about 20% of annual precipitation there [4]. Fog water is the sole source of water in cloud forests on the rainless coast of Peru [1]. Fog drip from mature Douglas-fir forests near Portland, Oregon, U.S.A has been observed to add nearly 880 mm of water each year [5]. Evaluation projects were initiated in the high Andes in Ecuador and in Peru. The mountainous sites produced large amounts of water. These results were very encouraging for other studies in different places in the world like Jordan. For a decade now the experimental and the applied results are attractive [6].

To explore new means of augmenting water resources in Karak region- south of Jordan, the fog harvesting in several sites has been considered here to evaluate the technical feasibility of such unconventional water resource. This study is an initial evaluation project in Mazar area south of Karak region. The study area is mostly hilly or elevated plateau. The selected sites in the area are tabulated in table 1 with elevation, latitude and longitude descriptions. The site near vertical slopes was avoided, because they produce major vertical wind components which decrease the fog collection processes.

Fog harvesting techniques are not adequate for all areas in Jordan because of certain limitation, like very strong winds in some steep sites facing the west, not enough winds in the east of the hills, Inaccessible sites in some foggy valleys, and insufficient fog density in most of the Badia and the desert of Jordan. These limitations are not in all sites in Jordan since many hilly areas are very attractive for further studies and practice. Sophisticated programs using Standard Fog Collectors (SFC) of 1x1m^2 were conducted to measure production rate and to define the length of the fog season, in several regions of the world from Chile to Oman [7].

2. Methods

The fog collection process improves with larger fog droplets with moderate wind speeds besides narrower collection fibers [1]. These constraints are considered when designing the fog harvesting collectors for this study (tables 1,2).

The actual fog harvesting process depends on the fact that, as fog water tiny droplets pass through the man-made mesh, the water droplets are forced to become larger through collisions and droplet unions. These larger droplets do not pass the collector mesh, instead they flow down the mesh into attached gutters. The collected harvested water is allowed to flow into pipes which feed a reservoir of the experiment [8].

Table 1
Fog harvesting stations description

Station	Elevation	Latitude *N*	Longitude *E*
Taibih	1100	30° 57`	35° 30`
Dabab	1304	30° 58`	35° 33`
Moab	1120	30° 56`	35° 46`
Mahy	910	30° 52`	35° 56`
Abiad	810	30° 54`	36° 08`

Table 2
Fog harvesting related parameters

No.	Complete title	Code
1.	No. Of Days with Fog	NDF
2.	No. Of Cloudy Days	NCD
3.	No. Of Days with Mist	NDM
4.	No. Of Days with Dew	NDD
5.	No. Of Days with mean daily Relative Humidity more than 80%	NDRH
6.	Mean Monthly Relative Humidity	MMRH
7.	Total Monthly Precipitation (mm)	TMP
8.	Lowest Minimum Temperature (C°)	LMT
9.	Mean Monthly Temperature (C°)	MMT
10.	Total Water Harvested (mm)	TWH
11.	Fog Water Harvested (mm)	FWH

Fog droplets vary in diameter from about 0.001mm to 0.04mm; while drizzle droplets vary in diameter from 0.04mm to 0.5mm. On the other hand regular rain drops vary from

0.5mm to 5mm [2]. Because fog droplets are very small compared to rain drops, the droplets have very slow falling velocities. Due to these slow velocities, fog droplets usually do not condense as fog fall through direct condensation on the intercepting objects.

Improving the efficiency of fog collection could be achieved with larger fog droplets, appropriate wind speeds, and with narrower man-made collection fiber. Only the last variable here could be controlled and tested to evaluate efficiency. This evaluation ,however, is not considered here. It is estimated depending on previous experiences in several countries that the collectors have around ten years of life time. Also they have very low price which makes them economically very feasible, specially in selective sites in the hilly regions of Jordan.

Fog collectors were manufactured locally for this study in a standardized fashion to be comparable with the international standards. Comparing the amounts of fog harvesting in the studied sites was conducted to explore the effects of the elevation and west-east location in Mazar region south of Karak.

The used fog collector in this study consists of ultraviolet-resistant polypropylene mesh. This mesh is positioned in a stretched form between two upright poles. The collectors were set at right angles to the regular prevailing winds. These knitted polypropylene meshes are appropriate technology because they are inexpensive, durable, and available every where.

Fog collector's area in this study like most collection projects is 1.0m x 1.0m of a rigid metal frame to hold the double layered mesh. The area covered by the double polypropylene fiber is 50% with the fiber diameter 0.5 mm. This allows for a fog collecting space of 50% of $1m^2$ collector.

A one meter long, 0.15 meter wide, and 0.10 meter deep trough is attached to the frame for the conveyance of collected fog water, where the collected amounts are recorded at 8:00 o'clock each morning. Local materials were used for the posts and trough with a double layered standard mesh. The vertical posts were mounted in 0.5X0.5X0.5 m^3 holes packed with cemented stones. They were anchored with galvanized steel cables. Fig . 1.

The main limiting factors of these fog harvesting experiments are the very strong winds which blow the fog away, the winds with very low speeds which are not able to force fog into the meshes, and the insufficient dense fog most of the year. Fortunately, costs of the mesh, posts, and other necessary equipments are not limiting factors in this study and in the used methodology (Appendix A, tables A.1-A.5).

3. Discussion

Both fog and clouds are signs of the atmospheric cooling. They usually form due to cooling with vertical ascent of air. Clouds and fog form regularly when the air temperature reaches the dew point temperature by that lifting.

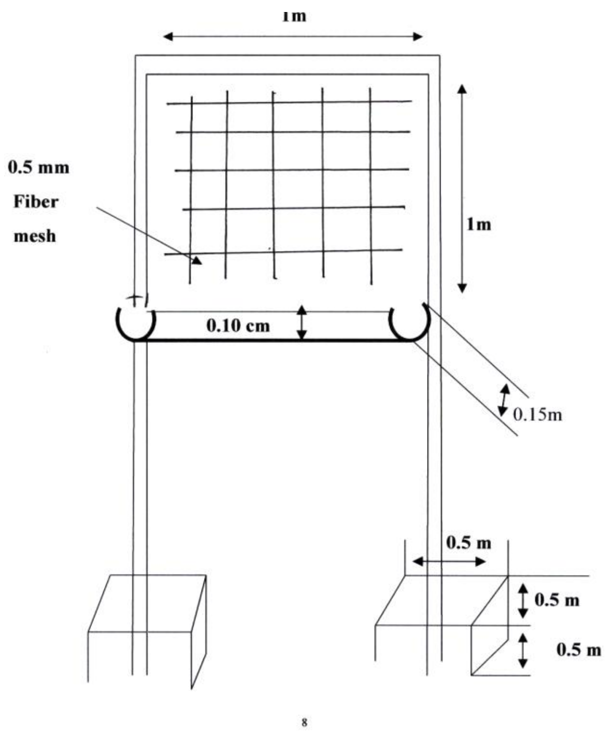

Fig. 1. Fog Collector sketch.

Dhabab mount fog is actually upslope fog, which is fog that forms as moist air flow up along an elevated plain, hill or mountain.

Typically, upslope fog forms during the winter and spring on the western side of the mount where the westward sloping has more than one kilometer elevation difference. Occasionally, cold moist air moves from the lower western hills eastward. The air gradually rises, expands and becomes cooler, therefore fog forms. This fog formation is similar to fog formation of the Rokies mountains where upslope fogs that form over an extensive area may last for many days [8].

Most of the fog around this mount is produced through advection of low clouds over the westward inclined terrain, also most fog formation is due to orographic lifting to the higher points of the mount.

There should be a deep analysis of the macro and micro geographical and topographical features before the site selection. Since fog is moved by wind, wind pattern should be taken into consideration to specify the best orientation of the collectors, to be approximately perpendicular to the direction of the wind carrying the fog.

The annual number of days with fog varies from site to in the world and in Jordan. The northern hemisphere has more foggy days than the southern hemisphere. While Europe has in the average up to 150 foggy days per year, America up to 125 foggy days per year, and Asia has up to 75 foggy days per year in the average. The number of the foggy days and the fog duration and intensity are actually site-specific.

Many sites in the high plateau of Jordan have acceptable potential for fog harvesting. On the other hand, most sites in the Badia and the desert of Jordan are not adequate for such techniques because of the low frequency, low duration, and low intensity of the foggy hours of the foggy days.

Most frontal storms have thick fogs and low clouds. During the initial thickening of clouds. Lower clouds tend to be suppressed from the continuous thickening due to the reduction in the warming of the ground surface by the sun. The distribution of liquid water in warm layer clouds and in fogs is relatively uniform over large horizontal areas [6].

The geographical and climatological aspects of the western Jordan plateau, specially certain hilly locations, were considered here for the intended experimentation. It is very well-Known that for Jordan plateau and the hilly sites, the humid winds are mostly western, south-western, and sometimes north-western, which are associated with fog, low level clouds and mist. Therefore, the fog collectors were erected vertically perpendicular to the western winds.

In the studied region, fog forms during late weeks of fall, the winter, and the early weeks of spring especially before, during, and after storms. Cooling is happening due to vertical up-lifting, where clouds specially low clouds or fog form on the windward slopes of hilly regions like the studied area. Once a fog bank has formed, the active radiating surface is not the ground surface anymore, but the fog top where the water droplets are almost becoming full radiators for long-wave radiation. Therefore fog dissipation does not usually result from solar heating of the droplets but by convection generated at the surface, or by increased wind speed [9].

4. Correlation between parameters of fog harvesting stations

Regarding Number of Days with Fog (NDF) it is positively correlated with Total Water Harvesting (TWH), Fog Water Harvesting FWH, and Total Monthly Precipitation TMP, but negatively correlated with the ratio of FWH over TWH. This type of correlation is consistent in all fog harvesting experimental stations. The same is the case with TWH, FWH and TMP. The highest correlation in all stations is between TMP and TWH which is logical physically, because most of TWH is due to TMP.

The lowest correlation in most station is between TMP and FWH. The reason for such low correlation might be because many foggy days in the area are not rainy days [12].

5. Correlations analysis of study stations

Regarding FWH, it has a variable correlation with TWH, which ranges from 0.548 in Abiad to 0.885 in Dhabab. This variation is expected because Dhabab is mostly more humid than Abiad which is in the Badia region (tables 3,4). As expected FWH has a high correlation with NDF number of days with fog. This correlation ranges from 0.643 in Dhabab to 0.84 in Mahay. The reasons would be the effects of the intensity and duration of fog in Dhabab are more influential than fog frequency in Mahay.

6. Variability of FWH

As expected the minimum for all stations is zero. On the other hand, the maximum is variable from station to station. Dhabab with 60 mm/month, was the first because it is the highest, facing west in all the studied sites. Then comes Moab with 45 mm/month, which is higher than Taibih 40 mm/month, even though Taibih is 12 Km to west, but the elevation difference was the reason. Abiad had the lowest maximum with 20.5 mm/month, which indicates that fog harvesting is not a promising water resource even for limited purposes in the Badia of Jordan.

The averages of fog water harvested in the study stations are not as encouraging as the maximums. The highest as expected in Dhabab was 21.07 mm/month and the lowest in Abiad was 0.42 mm/month. These discouraging numbers are not a good representation of the fog harvesting situation.

In all stations the months with zero or minimal fog were numerous which distort the average substantially. Actually any fog harvesting project concentrates on foggy days which are variable percentage of the year, but could be a supplement water resource for certain sites such as Dhabab for certain months of the year.

This study disagrees with Al- Jayyousi [10] in his conclusions that fog harvesting could be a partial solution for water problems in the Badia of Jordan. He made such assertion even though the average foggy days there are 7 days per year which is very low percentage. The fog duration is not more than 2 hrs per day at the mornings, and it is not thick enough to allow for feasible harvesting. Actually the results of AL- Jayyousi are from an experiment in Sweilih with different elevation and climate from the Badia.

7. Trend analysis

The study period is three years which is not enough period to draw substantiated trend Conclusions. Apparently, there is a decreasing trend in all experimental stations except Abiad which is some what increasing (Appendix B, Figs. B.1-B.5). But Abiad is essentially a dry site with occasional low intensity fog, which makes it not representative for the other wetter sites like Dhabab. Actually the dry period in Jordan continued to reach its lowest in decades in 1998. Also the years 1999 and 2000 were relatively dry years. But we do not have enough data to conclude whether it is a continuous dry period or part of a cycle [11].

8. Conclusions

The study sites in this experiment were selected to investigate the influence of elevation factor and west-east factor on the fog water harvested amounts. The results proved that the elevation has the highest influence on the amounts collected and the fog season length comes next to the west-east factor.

The Dhabab Mount, as expected had the highest amounts of fog water collected, then comes Moab which is lower in elevation and east of the Mount. So the hilly locations of western Jordan plateau have a real promising potential for fog water harvesting.

This promising source of water deserves comprehensive investigations in the Jordan plateau, especially in the hilly sites with western up-slopes. The collected water could be used as a drinking water for remote villages and as a supplement for afforestation of these hilly sites. Such fog harvesting project could have a real impact on the water demand in remote sites in Jordan plateau. and could contribute in restoring the green cover of the hills facing west where fog has high or moderate intensity, duration, and frequency.

Table 3
Correlation between variables of fog harvesting stations

Taibih	NDF	TWH	FWH	TMP	FWH/TWH
NDF	1	0.69	0.712	0.651	-0.467
TWH	0.69	1	0.853	0.991	-0.803
FWH	0.712	0.853	1	0.774	-0.652
TMP	0.651	0.991	0.774	1	-0.804
FWH/TWH	-0.467	-0.803	-0.652	-0.804	1
Dhabab	NDF	TWH	FWH	TMP	FWH/TWH
NDF	1	0.712	0.643	0.682	-0.375
TWH	0.712	1	0.885	0.977	-0.765
FWH	0.643	0.885	1	0.801	-0.617
TMP	0.682	0.977	0.801	1	-0.771
FWH/TWH	-0.375	-0.765	-0.617	-0.771	1
Moab	NDF	TWH	FWH	TMP	FWH/TWH
NDF	1	0.823	0.846	0.76	-0.594
TWH	0.823	1	0.811	0.986	-0.757
FWH	0.846	0.811	1	0.704	-0.522
TMP	0.76	0.986	0.704	1	-0.772
FWH/TWH	-0.594	-0.757	-0.522	-0.772	1
Mahay	NDF	TWH	FWH	TMP	FWH/TWH
NDF	1	0.801	0.884	0.75	-0.612
TWH	0.801	1	0.784	0.994	-0.676
FWH	0.884	0.784	1	0.71	-0.53
TMP	0.75	0.994	0.71	1	-0.671
FWH/TWH	-0.612	-0.676	-0.53	-0.671	1
Abiad	NDF	TWH	FWH	TMP	FWH/TWH
NDF	1	0.701	0.58	0.685	-0.519
TWH	0.701	1	0.548	1	-0.601
FWH	0.58	0.548	1	0.535	-0.427
TMP	0.685	1	0.535	1	-0.596
FWH/TWH	-0.519	-0.601	-0.427	-0.596	1

Table 4
Correlation between stations of fog water harvested

FWH	NDF	TWH	FWH	TMP	FWH/TWH
Taibih	0.712	0.853	1	0.774	-0.652
Dhabab	0.643	0.885	1	0.801	-0.617
Moab	0.846	0.811	1	0.704	-0.522
Mahay	0.884	0.784	1	0.71	-0.53
Abiad	0.58	0.548	1	0.535	-0.427

Appendix A

Table A.1
Fog water harvested in Taibih

Year	Month	M_No	NDF	TWH	TMP	FWH	FWH/TWH
1992	Jan	1	10.0	140.3	110.3	30.0	0.214
	Feb	2	12.0	196.0	160.0	36.0	0.184
	Mar	3	6.0	56.0	26.0	30.0	0.536
	April	4	8.0	24.5	0.5	24.0	0.98
	May	5	3.0	8.5	2.5	6.0	0.706
	June	6	2.0	6.0	2.0	4.0	0.667
	July	7	0.001	0.001	0.001	0.001	1.0
	Aug	8	7.0	3.5	0.001	3.5	1.0
	Sept	9	3.0	3.0	0.001	3.0	1.0
	Oct	10	4.0	6.0	0.001	6.0	1.0
	Nov	11	7.0	103.6	86.1	17.5	0.169
	Dec	12	8.0	122.4	90.4	32.0	0.261
1993	Jan	13	7.0	61.8	40.8	21.0	0.34
	Feb	14	8.0	73.3	53.3	20.0	0.273
	Mar	15	7.0	30.9	13.4	17.5	0.566
	April	16	4.0	8.0	0.001	8.0	1.0
	May	17	5.0	15.9	8.4	7.5	0.472
	June	18	2.0	4.5	1.5	3.0	0.667
	July	19	0.001	0.001	0.001	0.001	1.0
	Aug	20	5.0	2.5	0.001	2.5	1.0
	Sept	21	2.0	2.0	0.001	2.0	1.0
	Oct	22	3.0	4.5	0.001	4.5	1.0
	Nov	23	5.0	72.8	65.3	7.5	0.103
	Dec	24	6.0	94.5	76.5	18.0	0.19
1994	Jan	25	12.0	170.2	134.2	36.0	0.212
	Feb	26	10.0	92.4	72.4	20.0	0.216
	Mar	27	9.0	61.1	44.1	17.0	0.278
	April	28	6.0	29.4	22.4	7.0	0.238
	May	29	4.0	9.0	1.0	8.0	0.889
	June	30	9.0	9.0	0.001	9.0	1.0
	July	31	8.0	0.001	0.001	0.001	1.0
	Aug	32	10.0	0.001	0.001	0.001	1.0
	Sept	33	6.0	6.0	0.001	6.0	1.0
	Oct	34	3.0	15.4	12.4	3.0	0.195
	Nov	35	7.0	126.4	112.4	14.0	0.111
	Dec	36	10.0	110.2	70.2	40.0	0.111

Table A.2
Fog water harvested in Dhabab Mount

Year	Month	M_No	NDF	TWH	TMP	FWH	FWH/TWH
1992	Jan	1	12.0	190.1	130.1	60.0	0.316
	Feb	2	18.0	246.0	192.0	54.0	0.22
	Mar	3	10.0	91.1	31.1	60.0	0.659
	April	4	11.0	33.8	0.8	33.0	0.976
	May	5	4.0	15.2	3.2	12.0	0.789
	June	6	3.0	8.2	2.2	6.0	0.732
	July	7	13.0	0.001	0.001	0.001	1.0
	Aug	8	10.0	5.0	0.001	5.0	1.0
	Sept	9	5.0	0.001	0.001	0.001	1.0
	Oct	10	5.0	7.5	0.001	7.5	1.0
	Nov	11	11.0	139.1	106.1	33.0	0.237
	Dec	12	12.0	168.3	168.3	60.0	0.357
1993	Jan	13	11.0	96.3	52.3	44.0	0.457
	Feb	14	12.0	98.5	62.5	36.0	0.365
	Mar	15	9.0	39.6	17.1	22.5	0.568
	April	16	6.0	12.0	0.001	12.0	1.0
	May	17	5.0	15.2	10.2	5.0	0.329
	June	18	4.0	6.5	2.1	4.4	0.677
	July	19	7.0	3.5	0.001	3.5	1.0
	Aug	20	6.0	0.001	0.001	0.001	1.0
	Sept	21	5.0	0.001	0.001	0.001	1.0
	Oct	22	2.0	8.4	2.4	6.0	0.714
	Nov	23	10.0	24.6	4.6	20.0	0.813
	Dec	24	8.0	82.5	42.5	40.0	0.485
1994	Jan	25	15.0	197.6	152.1	45.5	0.23
	Feb	26	14.0	118.9	90.9	28.0	0.235
	Mar	27	13.0	78.1	52.1	26.0	0.333
	April	28	6.0	39.1	30.1	9.0	0.23
	May	29	5.0	11.0	1.0	10.0	0.909
	June	30	11.0	11.0	0.001	11.0	1.0
	July	31	10.0	0.001	0.001	0.001	1.0
	Aug	32	11.0	0.001	0.001	0.001	1.0
	Sept	33	8.0	8.0	0.001	8.0	1.0
	Oct	34	3.0	18.1	15.1	3.0	0.166
	Nov	35	11.0	172.0	138.0	34.0	0.198
	Dec	36	12.0	160.1	100.1	60.0	0.198

Table A.3
Fog water harvested in Moab

Year	Month	M_No	NDF	TWH	TMP	FWH	FWH/TWH
1992	Jan	1	11.0	169.6	125.6	44.0	0.259
	Feb	2	16.0	224.3	184.3	40.0	0.178
	Mar	3	9.0	66.3	26.3	45.0	0.679
	April	4	9.0	27.5	0.5	27.0	0.982
	May	5	4.0	10.5	2.5	8.0	0.762
	June	6	2.0	4.0	2.0	2.0	0.5
	July	7	0.001	0.001	0.001	0.001	1.0
	Aug	8	0.001	0.001	0.001	0.001	1.0
	Sept	9	4.0	4.0	0.001	4.0	1.0
	Oct	10	4.0	6.0	0.001	6.0	1.0
	Nov	11	8.0	106.7	90.7	16.0	0.15
	Dec	12	6.0	118.8	86.8	32.0	0.269
1993	Jan	13	9.0	83.4	50.4	33.0	0.396
	Feb	14	10.0	78.3	58.3	20.0	0.255
	Mar	15	7.0	33.1	15.6	17.5	0.529
	April	16	5.0	10.0	0.001	10.0	1.0
	May	17	4.0	12.2	8.2	4.0	0.328
	June	18	0.001	0.001	0.001	0.001	1.0
	July	19	0.001	0.001	0.001	0.001	1.0
	Aug	20	0.001	0.001	0.001	0.001	1.0
	Sept	21	0.001	0.001	0.001	0.001	1.0
	Oct	22	2.0	7.0	2.0	5.0	0.714
	Nov	23	7.0	17.6	3.6	14.0	0.795
	Dec	24	9.0	76.6	40.6	36.0	0.47
1994	Jan	25	12.0	160.2	130.2	30.0	0.187
	Feb	26	10.0	109.0	89.0	20.0	0.183
	Mar	27	9.0	63.4	46.4	17.0	0.268
	April	28	4.0	30.4	26.4	4.0	0.132
	May	29	6.0	6.0	0.001	6.0	1.0
	June	30	0.001	0.001	0.001	0.001	1.0
	July	31	6.0	0.001	0.001	0.001	1.0
	Aug	32	5.0	0.001	0.001	0.001	1.0
	Sept	33	4.0	4.0	0.001	4.0	1.0
	Oct	34	3.0	15.2	12.2	3.0	0.197
	Nov	35	6.0	132.8	122.8	12.0	0.09
	Dec	36	10.0	125.5	95.5	30.0	0.09

Table A.4
Fog water harvested in Mahay

Year	Month	M_No	NDF	TWH	TMP	FWH	FWH/TWH
1992	Jan	1	3.0	67.3	61.3	6.0	0.089
	Feb	2	6.0	100.2	87.2	13.0	0.13
	Mar	3	5.0	24.6	14.6	10.0	0.407
	April	4	2.0	0.001	0.001	0.001	1.0
	May	5	1.0	1.2	1.2	0.001	0.001
	June	6	0.001	0.001	0.001	0.001	1.0
	July	7	0.001	0.001	0.001	0.001	1.0
	Aug	8	0.001	0.001	0.001	0.001	1.0
	Sept	9	2.0	0.001	0.001	0.001	1.0
	Oct	10	3.0	3.0	0.001	3.0	1.0
	Nov	11	4.0	46.3	42.3	4.0	0.086
	Dec	12	5.0	61.2	46.2	15.0	0.245
1993	Jan	13	2.0	31.5	26.5	5.0	0.159
	Feb	14	5.0	38.7	31.2	7.5	0.194
	Mar	15	4.0	14.4	8.4	6.0	0.417
	April	16	1.0	0.001	0.001	0.001	1.0
	May	17	0.001	4.5	4.5	0.001	0.0
	June	18	0.001	0.001	0.001	0.001	1.0
	July	19	0.001	0.001	0.001	0.001	1.0
	Aug	20	0.001	0.001	0.001	0.001	1.0
	Sept	21	1.0	0.001	0.001	0.001	1.0
	Oct	22	2.0	2.8	0.8	2.0	0.714
	Nov	23	3.0	5.1	2.1	3.0	0.588
	Dec	24	4.0	34.3	22.3	12.0	0.35
1994	Jan	25	5.0	75.7	68.2	7.5	0.099
	Feb	26	5.0	63.1	53.1	10.0	0.158
	Mar	27	4.0	35.3	27.3	8.0	0.227
	April	28	2.0	16.2	16.2	0.001	0.0
	May	29	0.001	0.001	0.001	0.001	1.0
	June	30	0.001	0.001	0.001	0.001	1.0
	July	31	0.001	0.001	0.001	0.001	1.0
	Aug	32	0.001	0.001	0.001	0.001	1.0
	Sept	33	1.0	2.0	2.0	0.001	0.001
	Oct	34	2.0	10.6	8.6	2.0	0.189
	Nov	35	3.0	72.8	70.8	2.0	0.027
	Dec	36	4.0	50.3	40.3	10.0	0.027

Table A. 5
Fog water harvested in abiad

Year	Month	M_No	NDF	TWH	TMP	FWH	FWH/TWH
1992	Jan	1	1.0	32.6	30.6	1.0	0.031
	Feb	2	2.0	76.4	73.4	0.001	0.0
	Mar	3	0.001	9.6	9.6	0.001	0.0
	April	4	0.001	0.001	0.001	0.001	1.0
	May	5	0.001	0.001	0.001	0.001	1.0
	June	6	0.001	1.0	1.0	0.001	0.001
	July	7	0.001	0.001	0.001	0.001	1.0
	Aug	8	0.001	0.001	0.001	0.001	1.0
	Sept	9	1.0	0.001	0.001	0.001	1.0
	Oct	10	1.0	1.0	0.001	0.001	0.001
	Nov	11	1.0	27.1	25.6	1.0	0.037
	Dec	12	1.0	33.1	31.1	1.5	0.045
1993	Jan	13	1.0	19.6	18.6	1.0	0.051
	Feb	14	2.0	22.2	20.2	0.001	0.0
	Mar	15	0.001	6.2	6.2	0.001	0.0
	April	16	0.001	0.001	0.001	0.001	1.0
	May	17	0.001	2.5	2.5	0.001	0.0
	June	18	0.001	0.001	0.001	0.001	1.0
	July	19	0.001	0.001	0.001	0.001	1.0
	Aug	20	0.001	0.001	0.001	0.001	1.0
	Sept	21	0.001	0.001	0.001	0.001	1.0
	Oct	22	1.0	1.0	0.001	0.001	0.001
	Nov	23	1.0	2.5	1.5	1.0	0.4
	Dec	24	1.0	16.7	15.2	1.5	0.09
1994	Jan	25	1.0	42.2	40.2	2.0	0.047
	Feb	26	2.0	37.6	35.1	2.5	0.066
	Mar	27	0.001	15.9	15.9	0.001	0.0
	April	28	0.001	8.4	8.4	0.001	0.0
	May	29	0.001	0.001	0.001	0.001	1.0
	June	30	0.001	0.001	0.001	0.001	1.0
	July	31	0.001	0.001	0.001	0.001	1.0
	Aug	32	0.001	0.001	0.001	0.001	1.0
	Sept	33	1.0	0.001	0.001	0.001	1.0
	Oct	34	1.0	5.6	4.1	1.5	0.268
	Nov	35	1.0	43.1	42.1	1.0	0.023
	Dec	36	1.0	36.3	35.3	1.0	0.023

Appendix B

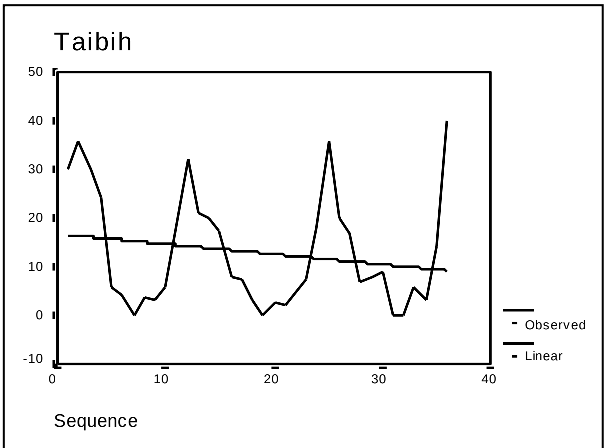

Fig. 1

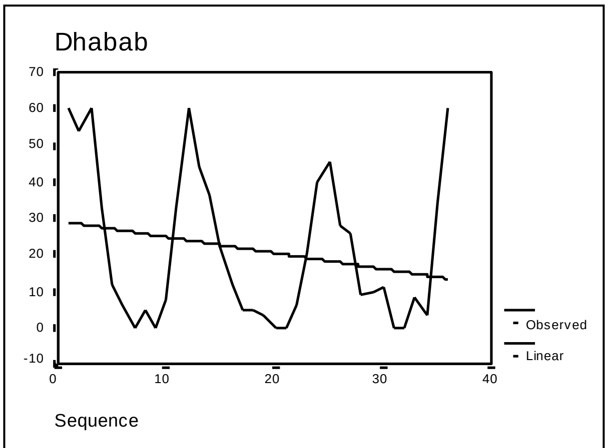

Fig. 2

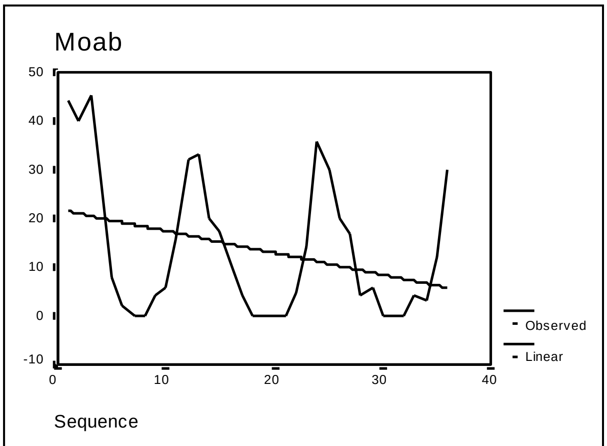

Fig. 3

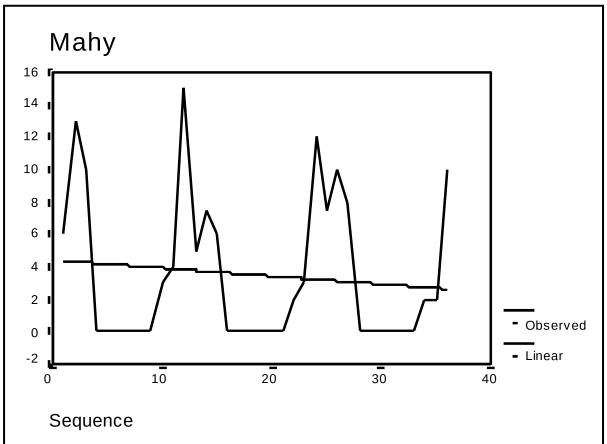

Fig. 4

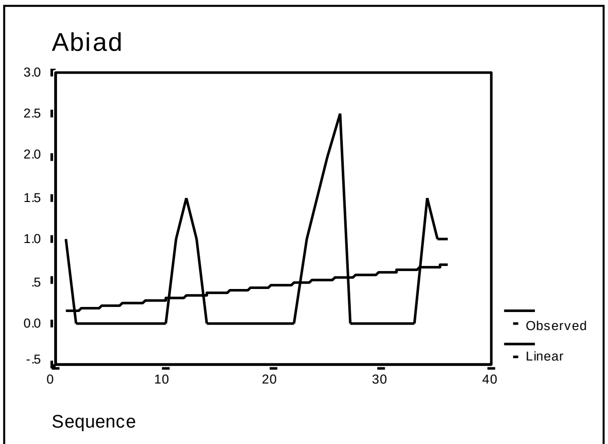

Fig. 5

References

[1] R.S. Schemenaur, and P Cereceda; Fog Colleetion's Role in Water Planning for Developing Countries, Natural Resource Forum, Vol. 18, pp. 91 – 100, UN. New Ypork (1994).
[2] G. Sumner, Precipitation Process and Analysis, John wiley & Sons, New York, (1988).
[3] H.A. Abdel – Rahman, and I.M. Abdel – Magid, Water Conservation in Oman, Water International, Vol. 18 (2) p. 95 (1993).
[4] G.M. Lovett, W.A. Rriner and R.K. Olson, "Cloud Droplet Deposition in Subalpine Balsam Fir Forests," ltydrology and chemical Inputs, Science, 218: 1303 – 1304 (1982).
[5] Harr, R.D., Fog drip in the Bull Run Municipal Watershed, Oregon, Water Resources Bulletin 18: 785-789.
[6] Beysens, H.g., I. Milimouk and V. Nikolayers, "Dew Recovery, Old Dreams and Actual Results, proceedings: First International conference on Fog and Fog Collection, Vacouver, Canada, July 19-24, pp. 269-272 (1998).
[7] Schemenaur, R.S., and P. Cereceda, "Water From Fog-Covered mountains, water lines," Vol. 10 (4), p. 10 (1992).
[8] Schemenaur, R.S., and P. Cereceda, "The Role of Wind in Rainfall Catchment and fog Collection," Water International 19, 70 (1994).
[9] Jacobs, A.F. B.G. Heusinkveld, and S.Berkowicz, "Differentiating Between Dew and Fog Deposition," Proceeding: Second International conference on fog and fog collection, St. john's New found land, Canada, July 15-20, (2001).
[10] O.R. Al-Jayyousi, and M.S.Mohsen, "Evaluation of Fog Collection in Jordan," J. CIWEM, Vol. 13, pp. 195-199 (1999).
[11] Meteorological Department, Jordan, Jordan Climatological Data Handbook, 1992-1994.

Received July 28, 2003
Accepted November 19, 2003