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Investigation of quaternary deposits from the view point of direct evaporation from groundwater reservoir

Khadijeh Ebrahimi[1], Sadat feyznia[2], Mojtaba J. Rostami[1], Hadi Mohammadzadeh Khani[3*], Koorosh Shirvani[4]

[1]*Desert management, University of Tehran, Iran*

[2]*Department of Watershed Management Sciences and Engineering, University of Tehran, Iran*

[3]*Young Researchers and Elite Club, Karaj Branch, Islamic Azad University, Karaj, Iran*

[4]*Agriculture and Natural Resources Research Center, Esfahan, Iran*

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Key words: Evaporation, Quaternary deposits, Capillary rise, Segzi, GIS.

Abstract

The main objective of this research is calculation of evaporate rate and it's zonation in Quaternary deposits of Segzi plain. After preparation of basic maps, the location of wells and their water-table statistic in the region were determined. By calculating D10 and by entering the data in GIS software and their interpolation, isocapillary map is prepared and is subtract from water-table surface isodepth map. Other hand, with separation of photometric units on the band compound 7-4-1 and using collected samples texture, soil texture map and subsequently soil porosity map were drown. Then using existence maps in affected evaporate areas through capillary rise, with multiple areas in the water high obtained from abstraction of capillary rise and groundwater depth in each month, the monthly vaporizable water volume per year was calculated. The result have shown that evaporation in the region is highly related to the depth of water- table and the rate of capillary rise.

***Corresponding Author:** Hadi Mohammadzadeh Khani ✉ hmkhani@ut.ac.ir

Introduction

With soil moisture due to rainfall, irrigation or rising of water table, evaporation from soil surface begins. The amount of evaporated water depends on soil characteristics and climatic conditions of the area. In arid and semi-arid regions a considerable amount of rainfall is losses through evaporation. Even when the soil surface contains vegetation, between 10 to 80 percent of evatransporation is evaporation from soil surface depending on irrigation method, the stage of plant growth and the kind of plant (Campbell, 1985, batchelor, 1996, Warrick, 2002). Therefore, evaporation from surface soil constitutes a major portion of water budget in arid regions, especially in barren and dry-farming lands. Evaporation causes rising of groundwater to the surface and causes salinization of soils. In regions where water table is high, the effective measure for controlling evaporation from soil surface is understanding evaporation process in different status and for determining the suitable depth of water table, soil characteristics and the intensity of evaporation should be investigated(Gardner, 1958, Hillel, 1998).

Mirbagheri (1998) used field measurement for investigation and estimation of evaporation from groundwater surface in different soil conditions and water table depths, proposed a model and showed that this model is efficient for this purpose. Zarei (2003) used analytical solution and actual analysis for estimation of unsteady evaporation from soil surface without vegetation and founded acceptable match between actual and estimated measurements. Neshat (2006) using ZEP and water Budget models for determining evaporation from groundwater and concluded that the difference between evaporation amounts is low. Piri and Sepaskhah (2007) used a spurious water table physical method for determining the depth of evaporation front and evaporation intensity in non-uniform temperature and green-house effect from different water table levels and concluded that with increase inn the depth of water table, the depth of evaporation front also increases. WAGEN(2003) determined the effect of underground water depth on evaporation from soil and concluded that the effect of rising of water table level on evaporation increasing more rapidly in superficial level relation to lower levels. Rose *et al.* (1968) investigated the effect of water level on evaporation and accumulation of salt in saline underground water and suggested that the depth of evaporation front for determining salinization due to capillary from flow of water level in arid regions should be considered a critical limit. Young *et al* (2007) investigated the effect of surface water on evaporation amount of bare soil in one temporary irrigated land using mudflow underground water model and obtained a simple relationship for underground water discharge through capillary rising from surface water. Li (2008) in a study for underground water, investigated DEM for clarification of phreatic evaporation stages. The results showed that the accuracy of method depends on the resolution of maps and the method and the method and kind of evaporation equation which was used. The object of this study is calculation of the amount of evaporation from underground resources and its zonation in Segzi plain, Esfahan.

Materials and methods

The studied area

The studied area is located in $51^{\circ} 45' 02''$ to $52^{\circ} 28' 58''$ east longitude and $32^{\circ} 22' 56''$ to $32^{\circ} 47' 59''$ north latitude. Having an area of 160172 hectares, 25 kilometers east of Esfahan with mean rainfall of 116.8 millimeters (Fig. 1).

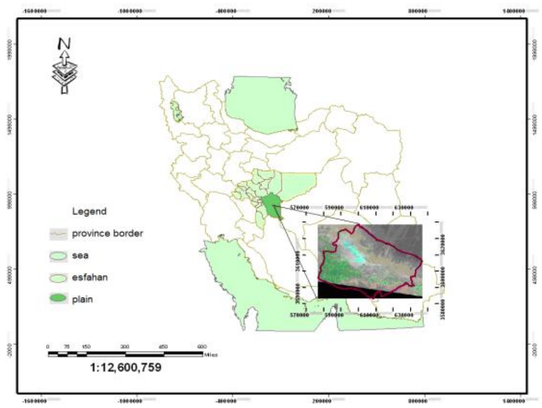


Fig. 1. The location of the study area.

Research method

In this study, the base maps of topography, hydrography and geology were prepared. The statistics, such as water depth in wells, were collected. By using base maps, Dem and Isopies maps were prepared and by subtracing these two maps. The map of isopdepth of water was prepared in GIS environment. Due to the fact that the area has constant K in depth, for estimation of capillary rise, soil samples were taken from the surface of the area. For determining D_{10} wet sieve and hydrometric analysis were performed and garnolometric carves were prepared. The capillary rise for each soil sample was calculated using Hazen formula (Alizadeh, 2004).

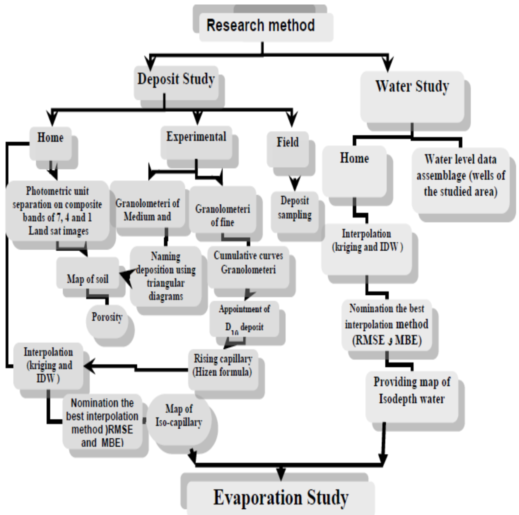


Fig. 2. Diagram of evaporation study.

Then by entering capillary rise data into GIS software and choosing the best interpolation methods the map of iso-capillary was prepared and subtracted from iso-depth map of surface water. By considering capillary rise and underground water depth, the area was divided into evaporable and non-evaporable areas according to capillary rise, in evaporable area; the volume of accessible water for evaporation was obtained by using texture and porosity of sediments. In the other hand, by considering evaporation potential of the area, the amount of annually evaporation from quaternary aquifer due to capillary rise was calculated (Fig. 2, 3).

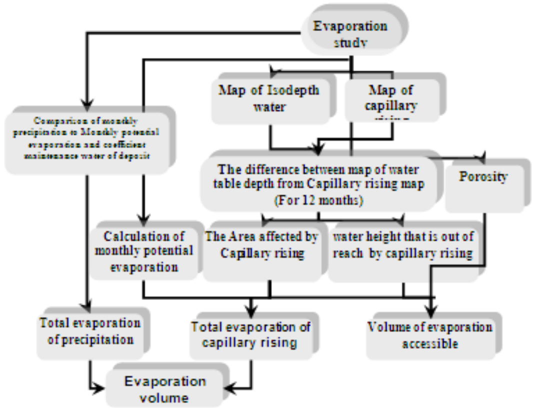


Fig. 3. Diagram of evaporation volume study.

Results

Results of mapping water depth and Capillary rise Fig. 3 shows quaternary deposits of the studied area which indicated that most part of the area is composed of these deposits.

Table 1 shows that thin plate spline is the best interpolation method for preparation of the map of water depth changes and kriging is the best one for preparation of capillary rise changes, because they have less error and fluctuations relative to the other methods (Hasani pak, 1988). The results show monthly iso-capillary map.

After drawing iso-depth map of water, if can be seen that the eastern parts of the area has shallower water table relative to the other parts.

Fig. 5 and 6 show the results of subtraction of iso-depth map from capillary rise map. In areas where the result of subtraction is lower than zero. Water depth is higher than capillary rise, then underground water in inaccessible for evaporation in these areas. In regions where the result of subtraction is above or equal zero, the probability that water of aquifer reaches the surface through capillary rise and is available for evaporation is high. Therefore, the area is divided into evaporable and non-evaporable through capillary rise. This figs have shown that the area with evaporation potential through capillary rise is limited; also its area dose not changes a lot in different months.

Table 1. The selection of the best interpolation method for drawing map of water depth and capillary change.

	Error	Thin Plate Spline	Inverse Multiquadric	Multiquadric	Spline with Tension	Completely regularized	Kriging	IDW(^4)	IDW(^3)	IDW(^2)	IDW(^1)
Groundwater depth	**RMSE**	8.77	9.49	9.1	8.82	9.43	10.97	10.14	10.9	10.47	11.19
	MBE	-0.34	-0.48	-0.37	-0.38	-0.6	-0.4	-0.98	-0.85	-0.86	-1.26
Capillary rise	**RMSE**	4.74	4.13	4.29	4.16	4.17	4.13	4.76	4.69	4.52	4.22
	MBE	-0.39	-0.07	-0.16	-0.06	-0.07	0.06	-0.05	-0.008	0.01	-0.04

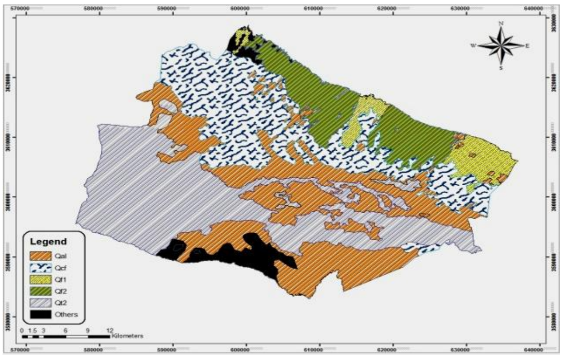
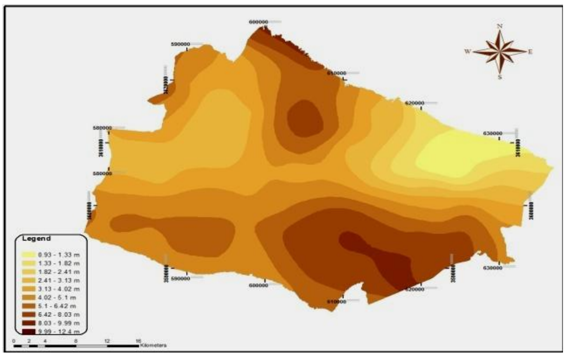
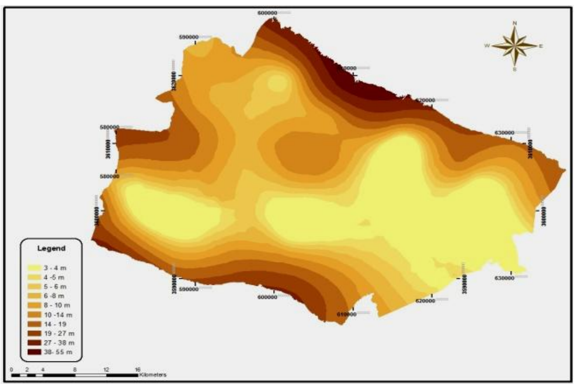


Fig. 4. The map of quaternary deposits of the area.



(a)



(b)

Fig. 5. Capillary rise changes (a) and Map of monthly water depth changes (b) for studied area.

Evaporation potential volume in different month of year is calculated by calculation of evaporable area through capillary rise and monthly evaporation potential using Torenwite formula (Mahdavi, 1999). Fig. 7 show the results which indicates the increase of evaporation intensity from early spring to early autumn, the reason being suitable climatic conditions for evaporation in these months. Evaporation and the volume accessible water for evaporations.

Soil map was prepared using photometric units from ETM+ land sat images (Gharechelo, 2009) and each unit was sampled and analyzed. Fig. 8 and table 2 shows the result of photometric units separation on composite bands of 7, 4 and 1 land sat images.

Fig. 9 shows soil texture map that provided using results of Photometric unit separation on composite bands of 7, 4 and 1 landsat images.

The texture of soil included Sandy mud, clayey sand, Gravelly mud, gravelly mud sand, gravelly sand, gravelly sandy mud, muddy sand, sandy clay.

Porosity of different samples was calculated using soil texture map and relationship between soil texture and porosity. Using porosity of soil, area and mean depth of soil in the region which is under evaporation through capillary rise, water volumes available for evaporation in different month were calculated (Fig.10). Due to the fact that in the area the volume of water accessible for evaporation is more than the potential of evaporation, it can be concluded that due to the fact that underground resources are near the surface in this region, evaporation potential approximately equals actual.

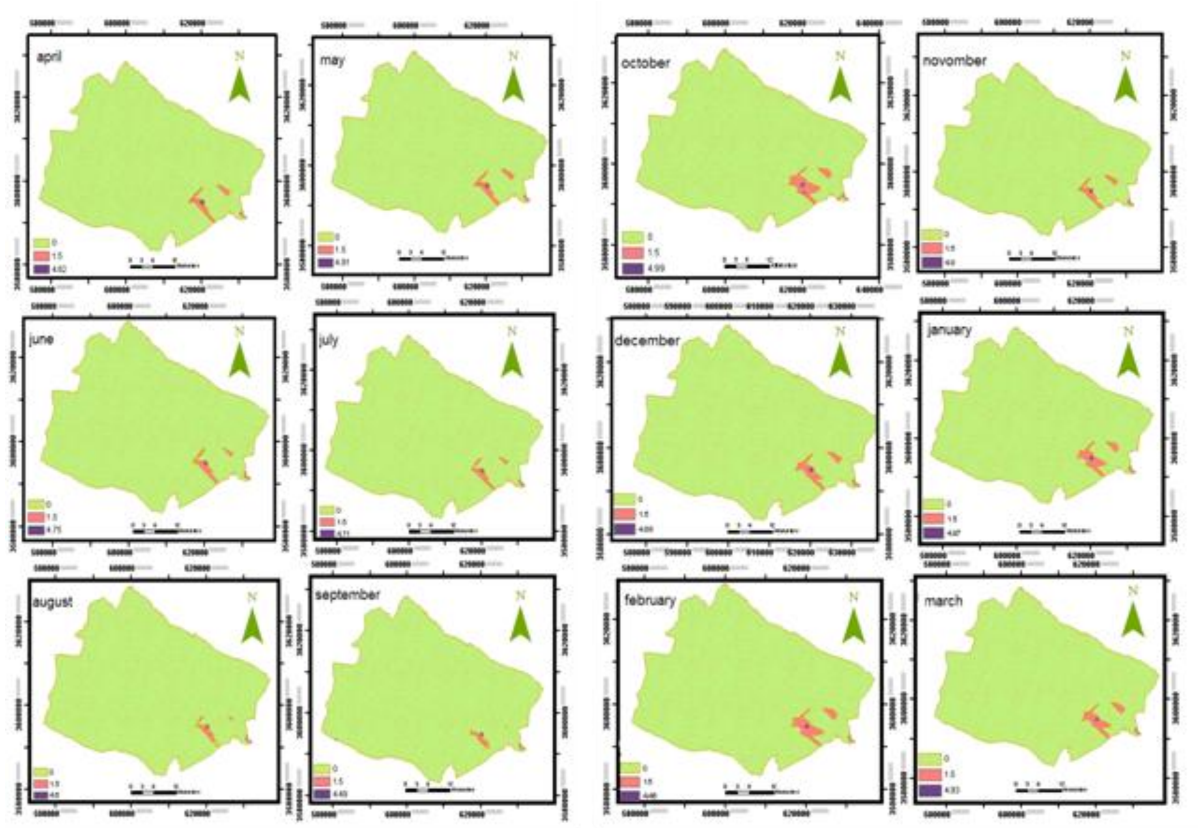


Fig. 6. Area zonation by view of rising capillary in evaporation.

Table 2. Characteristics of photometric units of the studied area.

photometric unit	Facies	Color	Texture	Drainage network	Background	Lithological charact-eristics	Land use
1	Sd_4	blue with brown spots	medium	radial	spolted	Qcf	bare land
2	Drc_1	light brown with green spots	soft	flat	dark with colored spots	Qt	rangeland
3	Drc_2	dark brown with green spots	medium	irregular drainage	spolted	Qt	rangeland
4	Qt_{1-2}	light to dark grey	soft	banded	light to dark	Qt	rangeland
5	Qt_{1-1}	olive green	medium	little hilly,	light with dark spots	Qt	good rangeland
6	Qal	light grey with green spots	soft	banded	light	Qal	range with agricultur
7	Mic	light brown	medium	hilly with relatively deep valleries	light	K	bare
8	Hio_1	medium brown	medium	hilly with low elevation	spolted	K	bare
9	Hio_2	blue with brown spots	medium	ridges with low elevation	spolted	Mpm	bare
10	Qc	light brown with green spots	soft	parallel	spolted	Qcf	rangeland
11	Qf_1	dark violet with brown spots	medium	parallel	spolted	Qf	rangeland

photometric unit	Facies	Color	Texture	Drainage network	Background	Lithological charact-eristics	Land use
12	Qf_2	medium violet	medium	parallel	spolted	Qf	range with agricultur
13	Ht	light brown with medium spots	coarse		spolted	Variable (Quaternary)	residential

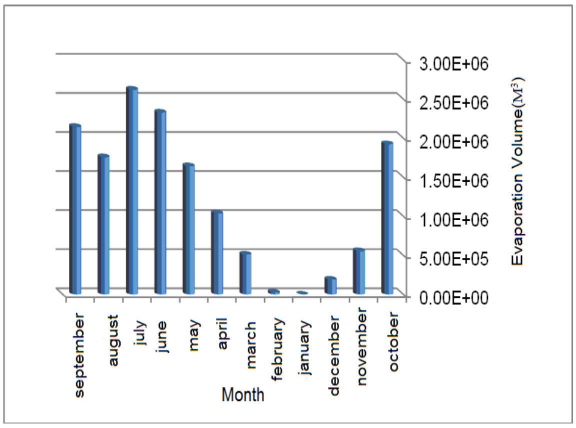


Fig. 7. Evaporation volume (m3).

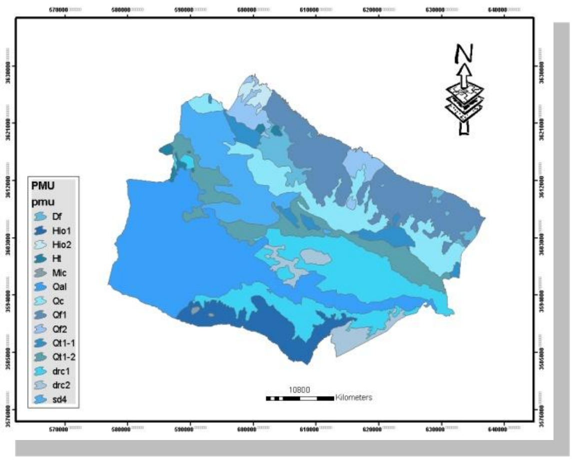


Fig. 8. Photometric unit separation on composite bands of 7, 4 and 1 landsat images.

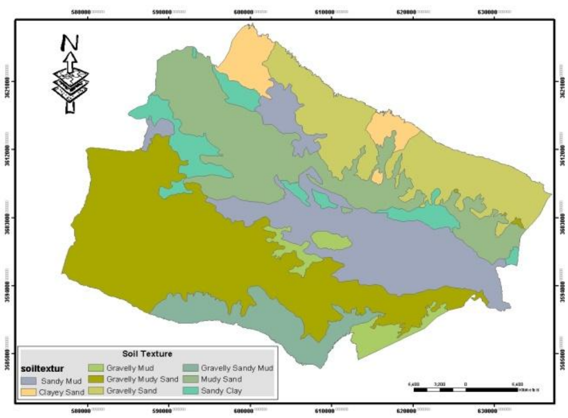


Fig. 9. Soil texture map.

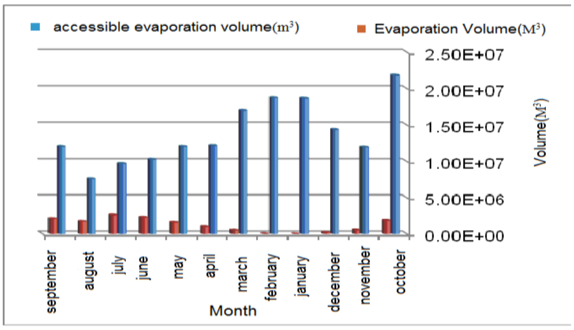


Fig. 10. Comparison between evaporation and the volume accessible water for evaporations.

Discussion and conclusion

Zonation of studied area according to evaporation capillary through capillary rise indicates that a limited area in the eastern part is under evaporation through capillary rise, the reason being the aridity of the area in the studied year. In arid years, underground water level is in deeper parts and may not be under capillary rise. therefore, studying evaporation volume through capillary rise is more important in humid years which indicates the importance of losing water in arid and semi-arid regions, the area of evaporation potential through capillary rise in different months shoe little variations, the cause being low precipitation, therefore, variations of underground water depth does not follow the pattern of monthly precipitation. In fact, underground water resources flows from adjacent areas(Gardner 1958).

This study corresponded with the results of Young and Wallender (2007) has endorsed that The map of variation of water depth shows that the water depth in the eastern part of the area is less and this area is more under evaporation through capillary rise because water flow direction to the area is from this direction and water level is closer to the surface here. The depth of water table decreases from west to east. Actually the evaporation volume in this area is highly corrected with under table level so that highest amount of evaporation volume is found in the eastern part in which water table is higher. This conclusion is in accordance with findings of Wagen (2003) and Steve (2005).

Due to little fluctuations of water table in different months of year, temperature has been an important factor in increasing evaporation potential of the area and maximum evaporation has occurred in summer seasons and minimum evaporation during January, in winter seasons.

The result of D_{10} showed that D_{10} of the sediment is very low which has caused higher porosity and increase of capillary rise. Therefore it can be concluded that quaternary deposits of the area play important role in having high evaporation volume, due to their high porosity. Capillary rise changes indicated that capillary rising is low in clay flat. This statement is in accordance with the results of Piri and Sepaskhah (2007).

The results of evaporation investigation indicated the total volume of evaporation is high (14.76 million m^3). The cause for this being: high temperature (yearly mean temperature of 15.5 °C), low relative humidity shown in amberothermic curve due to location of the area which is in arid conditions. These factors causing the increase in evaporation potential of the area. In other hand they affect on rising velocity of water due to capillary forces. Therefore Due to high evaporation potential in the area, a higher amount of water is evaporated through capillary rise and is lost. Evaporation from soil surface is an important part of water budget (especially in arid and dry-forming land) and it can actually be considered as the major element of water budget. Also the result showed that qualitative and quantitative status of groundwater in terms Direct Evaporation from Groundwater Reservoir easily can be studied using GIS and iso-capillary map Consistent with the results of Steve *et al*, (2005).

It can be concluded that evaporation in this region is highly related to water table depth and capillary rise. Also, the presence of quaternary deposits has had important effect on the volume of evaporation, because due to their textural characteristics; these deposits have high porosity. Therefore larger volume of water is moved into evaporation layer of soil through capillary rise.

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