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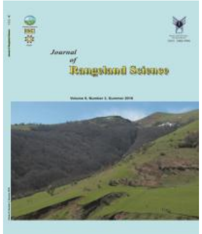

**Research and Full Length Article:**

# Infilterability Reduction of Artificial Recharge of Groundwater System in a Desert in the Absence of Sowbugs

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**Abstract.** Floodwater spreading for the artificial recharge of groundwater (ARG) is a logical alternative to build large dams for water resources management in dry environments so that it not only enhances water security, but also reclaims the degraded land due to the settlement of suspended load on the spreaders. However, translocation of very fine clay minerals existing in floodwater decreases the infiltration capacity of sedimentation basins (SB) and recharge ponds which eventually terminate their useful life. Although root channels facilitate infiltration and particularly percolation, crust formation substantially decreases the infiltration rate. As the role of a sowbug (Hemilepistus shirazi Schuttz) in enhancing the infiltrability has been previously reported, its absence had to be assessed too. Thus, the main objective of this research was to monitor the infiltration rate (IR) changes in the research plots devoid of the sowbug burrows in 3 SBs out of 6 ones in the Bisheh Zard1 ARG system in Gareh Bygone Plain (GBP) located in the southeast of Fars province applying the double ring method at constant hydraulic head during a 15 year operation. Each of those SBs was divided into three equal sections. One raised part in each section which had not been covered by floodwater was selected as the control. Results indicated that infiltrability after 15 years had decreased from 10.33 cm/h to 2.16, 2.49 and 7.47 cm/h in the first, second and third SBs, respectively. The largest decrease in infiltrability occurred in the upstream SB and the lowest one in the downstream SB. The volume of floodwater received by each SB and therefore, the volume of the settled suspended load depend on its location, the flow rate and duration of flooding. The ARG systems in the GBP are still functioning satisfactorily since 1983.

**Key words**: Desertification, Infiltration, Floodwater spreading, Gareh Bygone

## Introduction

Water is one of the scarcest natural resources in the Gareh Bygone Plain (GBP) in southern Iran. Therefore, it should be considered as a highly precious commodity. Deficiency of surface water in the Fasa Basin where the GBP is located and the accelerating rate of water table decline in that region which in some localities is followed by salinization of groundwater have prompted the water–related authorities to proclaim the Fasa Basin as a prohibited area implying that the required permits for digging or drilling new wells would not be issued, and deepening of the existing wells or extension of the qanats are allowed only under special circumstances (Kowsar, 1991).

Desertification control through floodwater spreading (FWS) for the artificial recharge of groundwater (ARG) is a logical action that not only replenishes the groundwater reservoirs, but also reclaims the degraded land due to the deposition of suspended load on them (Kowsar 1998, 2005). The ARG through FWS in the GBP has improved its environmental conditions as evidenced by the return of many flora and fauna to once a dilapidated desert (Mohammadnia *et al.*, 2015). As the desertification yearly removes some 20 million hectares (Mh) of arable land out of production, the Malthusian dilemma shall be realized in almost 100 years if the current trends of land degradation, conversion of prime farmlands to non-agricultural uses, and population growth continue unchanged. Therefore, desertification control through FWS on a very large scale, particularly for the ARG may delay this ultimate disaster. In the meantime, scientific breakthroughs in birth control and food production may hopefully reverse this predicament. Soil building in sedimentation basins (SB) as the integral part of the ARG systems has converted 2034 ha of moving sand into a fertile land in the GBP in southern Iran (Kowsar 1991, 2005). However, there is a dark side to many apparently suitable methods.

One of the main theoretical constraints of this successful project was the inevitable impermeability of ARG systems due to the deposition of suspended load onto the SBs and recharge ponds, and the downward migration of fine clay particles, specifically those of chlorite, palygorskite and smectite through the soil profile (Mohammadnia and Kowsar, 2003). This process decreases both infiltration rate (IR) and hydraulic conductivity of spreaders. A study at the Kabudar Ahang Station, Hamadan indicated that the mean IR had decreased from 2.25 cm/h to 1.9 cm/h (Charkhabi and Amiri, 2003; Khalafi *et al.*, 2007). Boroomand Nasab *et al.* (2004) have reported the same results from Moosian. IR of a FWS system in Qusheh, Damghan has decreased by 9.6 fold (Shariati, 2001). The main reason for the reduced IR of the SBs in an ARG research station in Booshehr has been the formation of a thick layer of deposits consisting of fine clays and gypsum (Jafari and Tavakoli Rad, 2014). Zaremehrjardi*et al.* (2013) and Rajaie *et al.* (2013) have reported that the IR had decreased from 5.22 cm/h in the control plots to 2.32 cm/h in the SBs in the Sarchahan Aquifer Management Research Station in Hormozgan. They stated that the change in surface permeability reduction varied according to the flooding event conditions. Esfandiari and Rahbar (2004) have also reported the same outcome for the Dorz-Sayehban ARG systems.

Infiltration of water into a soil is an important factor affecting the efficiency of irrigation and drainage systems while optimizing the availability of water for plants, improving the yield of crops and minimizing the erosion. The double ring infiltrometer is a simple instrument used to determine the IR of water into a soil (Arriaga *et al.*, 2010). As vertically infiltrated water runs away to the sides, the outer ring of the infiltrometer serves as a device to mitigate this process. Measurements take place exclusively in the inner ring through which the water virtually runs vertical (Tricker, 1978). Many factors such as texture, structure, initial moisture content, water head, water temperature, amount and type of suspended load, concentration of soluble salt, distance to water table and presence of hard pans control IR (Bouwer, 1986).

Contemplating different rates of infiltrability reduction in various geological and climatological zones of Iran, a preliminary conclusion might be drawn: components of geological formations whose long term erosion has contributed to land formation on the plains decide the physico-chemical characteristic of soil used today to spread floodwater on. In this study, we have assessed the changes of infiltration rate in 3 SBs of a FWS system in the Gareh Bygone plain, Iran after a 28 year operation.

## Materials and Methods

### Study area

The research site is in GBP, a 6000 ha sandy desert in southern Iran, lies between 28º 35ˈ and 28º 41ˈ N latitude and 53º 55ˈ and 53º 57ˈ E longitude on a debris cone, and 1116 –1160 m above sea level. This plain is located 50 km to the southeast of Fasa, and 200 km from Shiraz. There are 4 villages in the plain including Ahmad Abad, Rahim Abad, Bisheh Zard and Tchah Dowlat (Fig. 1).

The mean annual precipitation and mean annual A-pan evaporation of the plain are 243 and 2860 mm, respectively (Kowsar and Pakparvar, 2004). The mean annual temperature is 19ºC and absolute minimum and maximum temperatures are –7 (Feb.) and 43ºC (July), respectively. Hot and dry winds which usually blow from the southwest during late spring and summer raise the temperature to around 50ºC in the shade (Kowsar 1998, 2005).

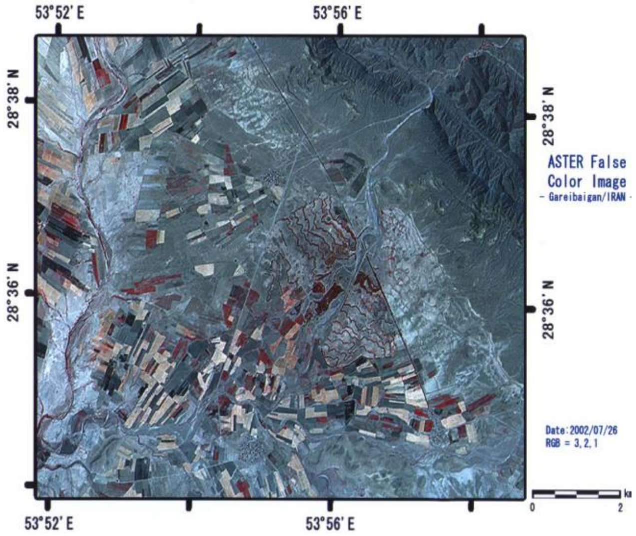


**Fig.1.** Satellite Imagery of study site in the Gareh Bygone Plain

The ARG system where this study was conducted was constructed in January and February, 1983 on a debris cone deposited by the Bisheh Zard River as an ephemeral stream that is a tributary of the Shur (salty) River of Jahrom and drains a sub basin of Mond River. The Bisheh Zard Basin which is 192 $Km^2$ in extent is a northwestern to southeastern syncline formed by the tectonic movement of Zagros Mountains during the Mio-Pliocene era in the Agha Jari Formation. This formation consists of rhythmically interceded brown to gray, calcareous, feature-forming sandstones and low weathering, gypsum-veined, red marls and gray to green siltstones. The Agha Jari formation lies conformably over the gray marls and lime stones of the Mishan Formation, which goes back to the early to middle Miocene age (James and Wynd, 1965). The soil of research site is loamy sand (coarse-loamy over loamy skeletal, carbonatic, (hyper) thermic, Typic Haplocalcids; Soil Survey Staff, 1998). More details on the physiography of site may be found elsewhere. This soil covers 6000 ha (Kowsar, 1991; Naderi et al., 2000; Mohammadnia and Kowsar, 2003).

The FWS system in the GBP was designed, laid out and constructed according to the procedure suggested by

Phillips (1957), Newman (1963) and Quilty (1972) with some modification (Kowsar, 2016).

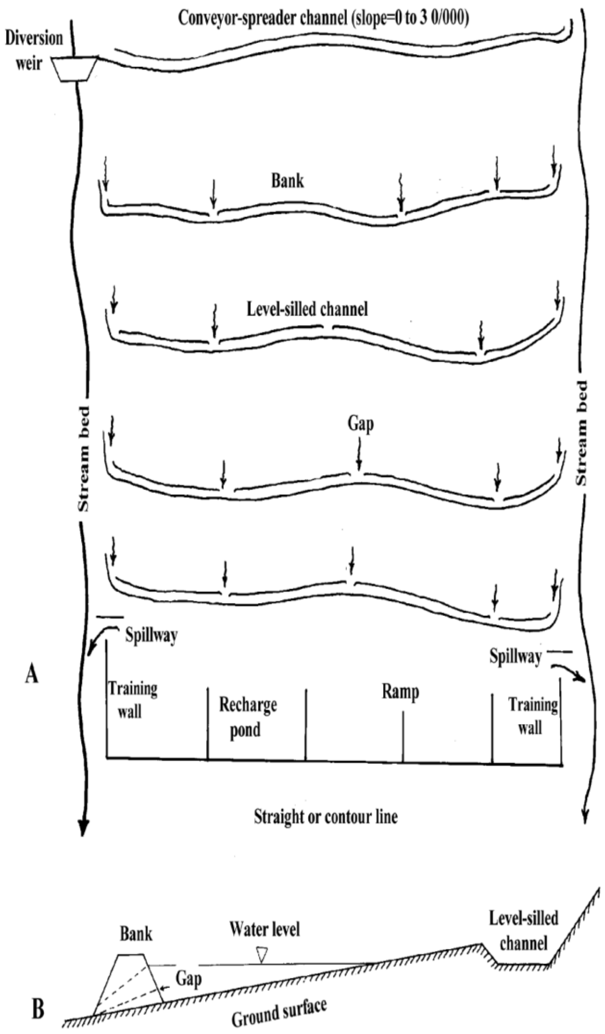


**Fig.2.** A. Plan of sedimentation basins with the embankments and a recharge pond. B. Longitudinal cross-section of a sedimentation basin. Level-silled channel is at the upstream end, and a gap (spillway) is at the downstream end.

A floodwater spreading system consists of a diversion channel including a conveyor–spreader channel, a few level-silled channels, and a tail drain (Fig. 2).

This study which was implemented to assess some measurable changes in infiltration rate and had occurred during the 1983-98 period was conducted in the $BZ_1ARG$ system. This system, which covers 198 ha area, consists of 5 SBs and a recharge pond. The first 3 SBs which had received floodwater in most events were divided into three equal sections. One raised part in each section which had not been covered by floodwater was selected as the control. Some physico-chemical properties of surface in the sedimentation basins were determined (Table 1) in order to find some relationships between them and infiltrability results. Infiltrability of 3 paired plots was determined with3 replicates (three separate years) utilizing the double ring method (Anon, 1990; Teh and Talib, 2006). Data were analyzed using Statistical Analysis System Package (SAS). Data distribution was tested applying the Kolmogrov-Smirnov test. The significant difference between treatment means was examined using the Duncan test at $p< 0.01$.

## Results and Discussion

Infiltrability results are presented in Table 2 and Figs. 3 to 5. They indicated that infiltration rate (IR) in the first SB in 1998 (time1) had decreased from 10.31 cm/h to 2.16 cm/h; for the second and third SBs, they were 2.49 and 7.47 cm/h for the same year, respectively. The results indicated that IR of the SBs during these periods had decreased significantly as compared with the control ($p<0.01$). Figs. 3, 4 and 5 are the graphical presentation of the same results. There is also a significant difference between the 3SBs as well ($p<0.01$) (Table 2).

**Table 2.**Infiltration rate changes in the sedimentation basins in different years.

| event | SB 3 | SB 2 | SB 1 | Control |
|---|---|---|---|---|
| 1 | $7.44^{b} \pm 1.13$ | $2.49^{c} \pm 0.15$ | $2.16^{c} \pm 1.01$ | $10.31^{a} \pm 1.24$ |
| 2 | $3.27^{b} \pm 1.24$ | $1.57^{b} \pm 0.86$ | $1.91^{b} \pm 1.25$ | $5.65^{a} \pm 3.41$ |
| 3 | $3.85^{b} \pm 0.88$ | $2.67^{b} \pm 1.55$ | $1.50^{c} \pm 1.21$ | $6.59^{a} \pm 1.10$ |

Mean ±SD in row followed by common letters are not significantly different by Duncan test, $p\leq0.01$

Decreasing soil infiltration rate in Sedimentation Basins (SB) 1 and 2 is more than that of SB3 because the amount and thickness of layer sedimentation are more and infiltration decrease in Plot 3 is very low. The largest decrease in the IR occurred in the upstream basin (SB3) and the lowest in the downstream basin (SB1). The volume of floodwater received by each SB, and the volume of settled suspended load depend on its location, flow rate and duration of flooding. Physico-chemical properties of soil showed that the content of clay and silt increased in comparison with control which was significant at 99% level (Table 1).

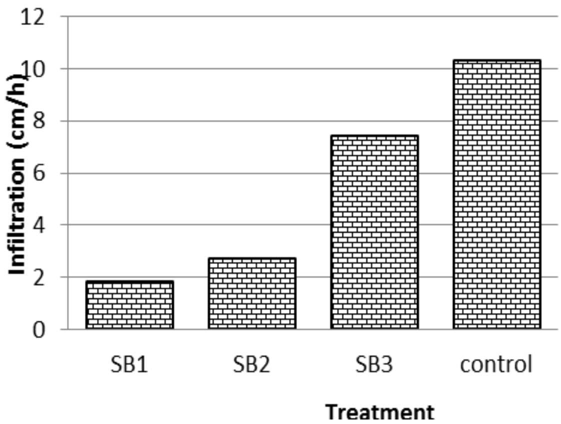


**Fig. 3.** Mean infiltration rate for different SBs in Bisheh Zard 1of floodwater spreading system (1)

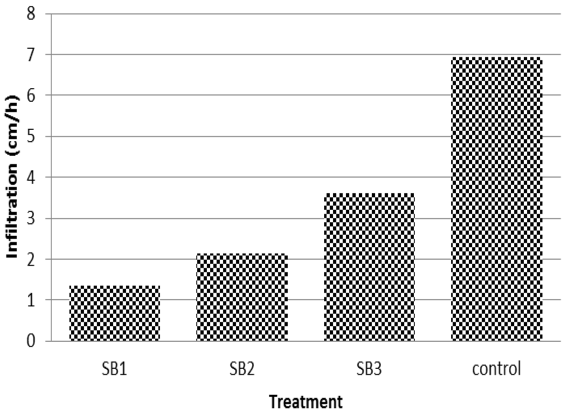


**Fig. 4.** Mean infiltration rate for different SBs in Bisheh Zard 1 of floodwater spreading system (2)

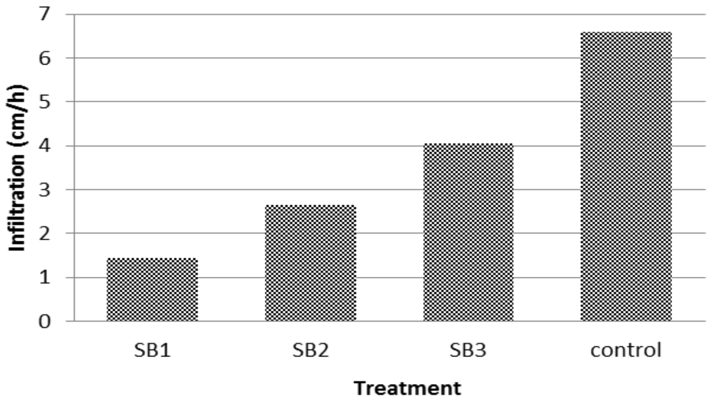


**Fig. 5.** Mean infiltration rate for different SBsn Bisheh Zard 1 of floodwater spreading system (3)

Eroding geological formations in Fars, Iran have formed the runoff producing watersheds that yield extraordinary volumes of suspended load. Deposition of very fine clay minerals such as chlorite, palygorskite and smectite in the suspended load in the SBs and recharge ponds decreases their permeability to the point that ends their useful life. Although the root channels increase percolation in the subsoil, crust formation decreases the infiltration rate substantially.

Extending the economic life of artificial recharge of groundwater systems is a challenge to the planners and implementers of these facilities. The nature has fortunately come to the help of ARG system in the GBP. Appearance of a sowbug (*Hemilepistus shirazi* Schuttz) by 1993 has extended the useful life of those systems. Apparently, those systems will function indefinitely. We foresee the need for raising the head of water in the Bisheh Zard River every 19 to 20 years.

**Table 1**.Some f the mean physico-chemical properties of surface soil in the sedimentation basins

| Soil properties | Sedimentation basin 1 | Sedimentation basin 2 | Sedimentation basin 3 | Control |
|---|---|---|---|---|
| Sand (%) | 51.16 [c] | 53.16 [c] | 70.00 [b] | 89.65 [a] |
| Silt (%) | 32.44 [a] | 32.44 [a] | 16.61 [b] | 7.51 [c] |
| Clay (%) | 16.40 [ab] | 14.38 [a] | 13.38 [a] | 2.83 [b] |
| SP (%) | 45.10 [a] | 51.42 [a] | 45.95 [a] | 23.83 [b] |
| pH | 7.65 [b] | 7.56 [bc] | 7.41 [c] | 8.12 [a] |
| EC (ds/m) | 0.71 [ab] | 1.01 [a] | 0.095 [a] | 0.37 [b] |
| $CaCO_3$ | 42.75 [ab] | 39.17 [b] | 33.93 [c] | 44.86 [a] |
| O.C. (%) | 0.71 [a] | 0.55 [b] | 0.45 [b] | 0.26 [b] |
| CEC (meq/100 g) | 6.40 [a] | 5.60 [b] | 4.30 [c] | 3.96 [d] |

Mean in rows followed by common letters are not significantly different by the Duncan test, $p \leq 0.01$.

## Conclusions

It is obvious that the deposition of suspended load present in turbid floodwater in soil pores clogs them, and mitigates their function in infiltrability and hydraulic conductivity. However, many factors involving biopores and root channels enhance these properties. As it had been previously reported on the remarkable function of a sowbug (*Hemilepistus shirazi* Schuttz) in enhancing those properties, this study was performed to assess the performance of an ARG system devoid of them. This study revealed that although there had been a decreasing trend in infiltrability of the sedimentation basins, they were working properly commensurate with the flow rate of diverted floodwater. The largest decrease in infiltrability occurred in the upstream SB and the lowest one in the downstream SB. The volume of floodwater received by each SB, and therefore, the volume of the settled suspended load depend on its location, the flow rate and duration of flooding. The first SB receives the flow in every flooding event; however, the downstream SBs might not be inundated in low and short duration flows. The mean infiltration rate of the first 3 basins after 15 years of operation was 4.0 cm/h; for the 198 ha $BZ_1$ ARG system, the amount was $22m^3/s$. The original capacity of inundation canal had been designed at $5m^3/s$; however, some 20 $m^3/s$ entered the system in the deluge of 3rd December, 1986 proving that it could handle that flow rate. Although a decrease from the original infiltration rate of 10.33 cm/h to 2.13 cm/h in the first SB was substantial, it proved that the system could have performed satisfactorily after 28 years of floodwater spreading even in the absence of the sowbugs. It is important to realize that the ARG systems in the GBP are still functioning satisfactorily since 1983. However, flood also carries large amounts of fertile nutrients and can improve the productivity of soil and can also modify the physical properties of soil as reported by Rahbar (2008), Funseca (2003) and Hirst and Ibrahim (1996).

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# کاهش نفوذپذیری سامانه‌های تغذیه مصنوعی آب‌های زیرزمینی در یک منطقه بیابانی بدون حضور خرخاکی‌ها (مطالعه موردی: دشت گربایگان)

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**چکیده**. پخش سیلاب به منظور تغذیه مصنوعی آبخوان‌ها اقدامی منطقی است که نه تنها مخازن زیرزمینی، بلکه برخی زمین‌های به شدت تخریب شده به علت وجود مواد معلق در سیلاب، را نیز احیاء می‌کند. ذرات رس و مواد معلق موجود در سیلاب سبب کاهش ظرفیت نفوذپذیری خاک در استخرهای تغذیه شبکه‌های پخش سیلاب می‌شود. تشکیل سله و لایه‌ای سخت که به واسطه رسوبات و ذرات ریز همچون پالی‌گورسگایت عمر شبکه‌های پخش سیلاب را کوتاه می‌سازند. اگرچه ریشه راه‌های ایجاد شده اکالیپتوس به تراوایی رسوبگیرها و استخرهای تغذیه می‌افزاید، در عین حال تراوایی آنها به علت سله ایجاد شده، کاهش می‌یابد. هدف اصلی پژوهش حاضر بررسی تغییرات نفوذپذیری خاک در شبکه‌های پخش سیلاب گربایگان فسا در جنوب شرقی استان فارس می‌باشد. در یکی از شبکه‌های پخش سیل گربایگان فسا موسوم به بیشه زرد یک، با کاربرد روش استوانه‌های دوگانه (Double Ring) اقدام به آزمایش نفوذپذیری گردید. هر نوار پخش سیلاب به سه قسمت مساوی تقسیم شد و در هر قسمت (با و بدون پخش سیلاب) سه آزمایش نفوذپذیری و جمعا ۹ آزمایش در هر نوار انجام گرفت. نتایج نشان داد که میزان نفوذپذیری خاک در اولین نوار پخش سیلاب بیشه زرد شماره یک از ۱۰/۳۳ سانتی متر بر ساعت به ۲/۱۶ و در نوار دوم و سوم به ترتیب به ۲/۴۹ و ۷/۴۷ سانتی متر بر ساعت رسید. نتایج حاکی از آن است که بیشترین کاهش نفوذپذیری در استخرهای تغذیه بالا دست و کمترین کاهش در استخرهای تغذیه پایین دست به وقوع پیوسته است. حجم سیلاب دریافت شده و در نتیجه حجم بار معلق بستگی به محل و حجم سیلاب و مدت زمان آن دارد. با این وجود عملکرد سامانه‌های پخش سیلاب به منظور تغذیه مصنوعی آبخوان‌ها در دشت گربایگان فسا از سال ۱۹۸۳ کاملا رضایت بخش و کارآمد می‌باشد.

**واژگان کلیدی:** بیابان‌زایی، پخش سیلاب، نفوذپذیری،گربایگان فسا