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Variations in Soil and Groundwater Attributes in Ghaggar Basin of Rajasthan

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Abstract

This paper looks into the variations in soil and groundwater characteristics in Ghaggar river basin of Rajasthan. These variations have been dealt with in two ways- laterally and longitudinally. The lateral variations have been studied for both Hanumangarh and Ganganagar districts in regard to riparian or coastal, as well as non-riparian areas of Ghaggar river. The longitudinal variations have been studied for Hanumangarh district in the upstream area, and Ganganagar district in the downstream area, of the river. Results indicate significant variations in soil and groundwater characteristics between areas in the vicinity of the river and those situated away from it.

Keywords: Soil, Groundwater, Attributes, Variations, Ghaggar Basin, Hanumangarh, Ganganagar, Rajasthan.

Introduction

Rivers provide opportunities for human settlement, and for economic activities, by offering fertile soil and ample water for fulfilling his requirements. Coastal areas of the rivers, called as riparian zones, are especially gifted in this regard. Riparian zones are distinct from surrounding lands because of unique soil, water and vegetation characteristics. These areas consist of stratified sediments that may be replenished during intermittent floods, and provide fertile areas for agricultural production. Since riparian zones fall in the lowland areas, groundwater is generally higher and available for plants. Fine textured sediments in the flood plains are able to hold large amounts of water which increases plant fertility and diversity (NRCS, 2018).

Organic matter is found in greater proportion in the soils of these zones because of greater presence of vegetation and water. Riparian zones occur in a wide range of climatic, hydrological and ecological environments. The rivers in the arid and semi-arid zones are ephemeral or seasonal in nature. Characteristics of soil and groundwater in the riparian and non-riparian zones of such streams may not show much differentiation, compared to the streams of more humid regions. However, it may be argued that the effect of greater availability of water, and occasional depositions of fertile sediments, is seen in some differentiation in soil and groundwater attributes between riparian and non-riparian areas of such seasonal streams of the arid zones too.

The present study is concerned with the seasonal Ghaggar river of Himalayan origin, flowing through a Tropical Dry Region (BWhw, as per Koeppen), falling in Hanumangarh and Ganganagar (72 degree 3 minute to 75 degree 3 minute East, 28 degree 4 minute to 30 degree 12 minute North) districts of Rajasthan. The Ghaggar enters Rajasthan from Hanumangarh district in the east, crosses various parts of Hanumangarh as well as Ganganagar districts, before entering Pakistan in the west that too when it is in full spate. The paper looks into the soil and groundwater characteristics of riparian and non-riparian zones of Ghaggar river in both the districts. Both lateral (away from river) and longitudinal (along the river) variations in soil and groundwater characteristics of Ghaggar basin have been addressed here.

Review of Literature

Cox *et al*. (2018) found in their study of Rio Grande Valley in western Texas that due to flood irrigation from groundwater, as well as water of Rio, there was substantial increase in the salinity of root zone, in soil sodicity, as well as in leaching of nutrients downwards. Due to high evapotranspiration rates from fine textured soils, intensive irrigation with

water of high salinity, and limited infiltration, effects like obstruction to growth of crops, decrease in soil porosity and permeability, lesser aeration of soil and fast rate of salt accumulation are seen.

Liu *et al*. (2018) analysed the probable sources of salinization and salinity of groundwater in the internal drainage area of Manas river basin in China. Higher salinities were generally seen in areas of discharge, in groundwater irrigated areas, and in lowlands. The contribution of evaporation to salinity of groundwater was 5.87 percent only, while towards salinity of surface water it was 32.7 percent. Salinization of groundwater was observed to be mainly caused by solution of minerals, evapotranspiration and irrigation.

Krishan *et al*. (2017) assessed the concentrations of salinity and fluoride in the groundwater of semi-arid Bathinda area of Punjab. About 59 percent samples of groundwater had salinity above permissible limits, while 69 percent samples were having fluoride levels above permissible limit. The reason for increase in salinity was that rise in groundwater level leads to higher evaporation, which enhances the process of salt accumulation.

Jia & Xue (2017) worked on the sources of groundwater salinity in western Hetao basin of Internal Mongolia in China. They found relatively lesser contribution of direct evaporation to groundwater salinity, whereas indirect evaporation (capillary evaporation, evapotranspiration) and solution of minerals/evaporites contributed to more than 60% of the salinity. Chemical weathering of minerals like calcium, magnesium, and of evaporites (Sodium sulphate and Calcium sulphate) also contributes salts to the groundwater.

Qian *et al*. (2017) analysed spatial variation in soil salinity, and its factors, in Minqin oasis of China. The major factors affecting soil salinity in this region were ground water salinity and vegetative cover, whereas the least important factor was distance from the nearest irrigation canal. In case of croplands, most important factor was distance from irrigation canals and other hydrological factors.

Goldstein & Reynolds (2017) studied a wet playa in Mojave desert of United States. They reported that in areas where groundwater was less than 3 metres deep, salts and trace elements were found to accumulate near the surface. In such areas, composition of surface crust was found to be similar to the local groundwater. On the other hand, in areas where groundwater was more than 3 metres deep, salts and trace elements were found to occur in the vadose zone.

Verma *et al*. (2005) showed in their study on distribution of soil fertility in Rajasthan that quantity of available nitrogen, available phosphorus and available potash in the soils of Ganganagar district are low, low to medium, and high respectively. In Hanumangarh district, these values were low, medium, and medium, respectively. The authors have also quoted that quantity of available nitrogen, phosphorus, potassium, mangenese, calcium etc in saline-alkaline soils is low. In conditions of high soil pH (alkalinity), the availability of iron, zinc, manganese and copper also gets highly decreased.

Kolarkar *et al*. (1980) found that salt affected soils are found to be distributed in small pockets all over Rajasthan, but these are particularly dominant in southeastern parts of Luni basin and Ghaggar flood plains.

Gupta & Abichandani (1973) noticed the effect of irrigation with saline water on several soils of Western Rajasthan and reported 3 to 7 time increase in soil salinity after irrigation. It was also seen that level of soil salinity after irrigation was lower than that of irrigation water. The reason for this was the presence of light and medium textured soils with good drainage conditions.

Objectives of The Study

1. To study the lateral (away from river) and longitudinal (along the river) variations in soil characteristics in the Ghaggar river basin of Hanumangarh and Ganganagar districts of Rajasthan
2. To study the lateral and longitudinal variations in groundwater attributes of Ghaggar basin of Rajasthan

Methodology & Sources of Information

This inductive study is based on the analysis of soil and groundwater samples, collected from the riparian and non-riparian zones of the Ghaggar river, draining the districts of Hanumangarh and Ganganagar in Rajasthan state. The soil samples were analysed for their pH level, salinity, percent organic carbon, available phosphorus and available potash. The groundwater samples were analysed for their salinity and pH levels.

A total of nine soil and groundwater samples each were collected from the riparian areas of Ghaggar river in Hanumangarh district. These samples were collected from the villages of Peer Kamariya, Budh Singh Wala, Dhaliya, Satipura, Rampura, Amarpura Rathan and Kalibangan. Fourteen soil and groundwater samples each were collected from non-riparian zone of Ghaggar river in Hanumangarh district. These samples belonged to the sites of Rorawali, Jorkiyan, Makkasar, 14 PBN, 16 PBN, 45 NDR, Pilibangan, Chak 4 NSW and Chak Daulatwala. Eleven soil samples were obtained from the riparian areas of Ghaggar River in Ganganagar district. These samples belonged to the villages of 1 PPM, Amarpura Jatan, Sadak Wali Dhani, 11 SD, Silwani and 8GB. Similarly, eight soil samples were obtained from non-riparian areas of Ganganagar district. The sample sites included 3 PPM (A), 2 PPM, Amarpura Jatan, 11 SD, Rang Mahal and 7 GB. Again, seven groundwater samples in all were collected from the riparian zone sites of 1 PPM, Amarpura Jatan, Sadak Wali Dhani and 11 SD in Ganganagar district. Besides, five ground water samples from non-riparian area of Ghaggar river in Ganganagar district were collected from 3 PPM (A), 2 PPM, 11SD and 7GB.

These soil and groundwater samples were got analysed from the laboratory. The classificatory scheme, used by Dept of Agriculture, Government of Rajasthan has been used here to classify the analysis

results. Average values for different attributes of soil and groundwater were calculated, for riparian as well as non-riparian areas of Ghaggar river in Hanumangarh and Ganganagar districts. The calculated data have been presented through various tables and diagrams, and used for comparison and derivation of conclusions.

Results & Discussion

Soil characteristics in the riparian (riverside) and non-riparian (distant from river channel) areas of Ghaggar river of Hanumangarh district are exhibited in Table 1 and Fig. 1. The soil pH in both areas is normal or neutral, i.e., it is neither acidic nor alkaline in nature. Soil salinity in nearby areas of Ghaggar river is 0.839 deci Siemen/metre, while it is only 0.387 in far off areas. Organic carbon percentage too was on the lower side, while available phosphorus and potash were of medium level in both these zones.

Table 1 : Soil Characteristics in Ghaggar's Riparian and Non-Riparian Areas of Hanumangarh District

Soil Characteristics	Riparian (River Coastal) Areas	Non-Riparian (Away from Coast) Areas
Soil pH	8.23 (Normal)	7.96 (Normal)
Soil Salinity (deci siemen/meter)	0.839 (Normal)	0.387 (Normal)
Organic Carbon (%)	0.319 (Low)	0.223 (Low)
Available Phosphorus (Kg/Hect)	25.54 (Medium)	25.61 (Medium)
Available Potash (Kg/Hect)	300.05 (Medium)	308.33 (Medium)

Fig. 1: Soil Attributes in Ghaggar Basin of Hanumangarh District

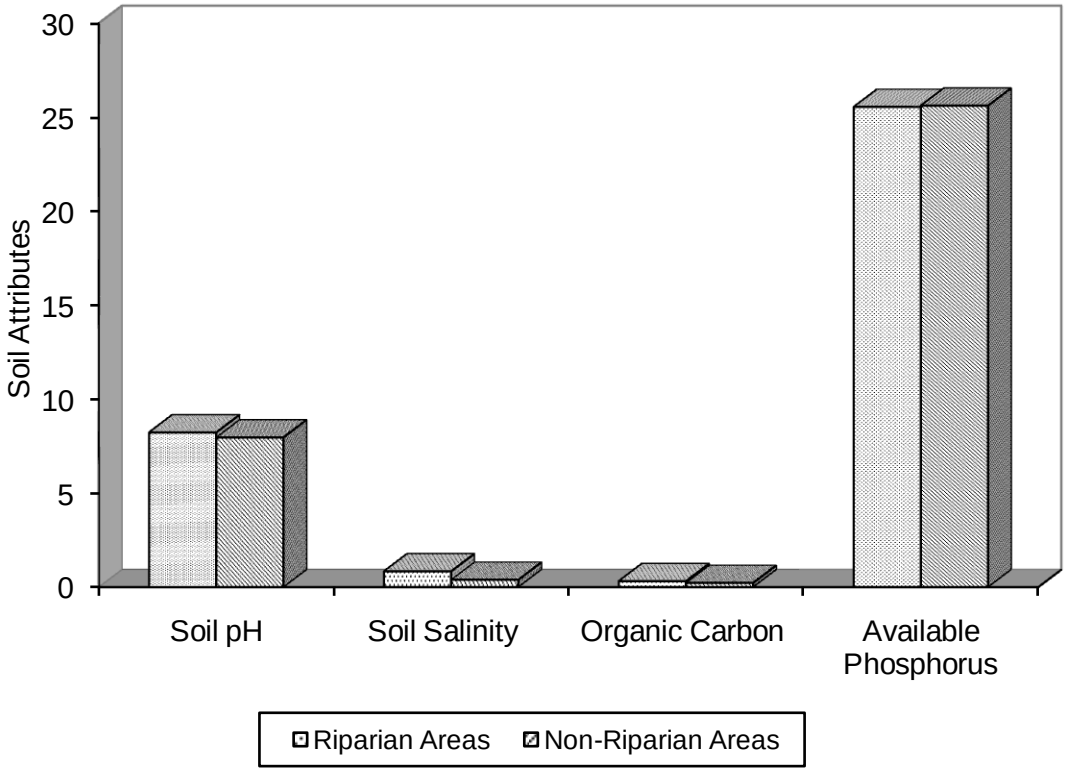
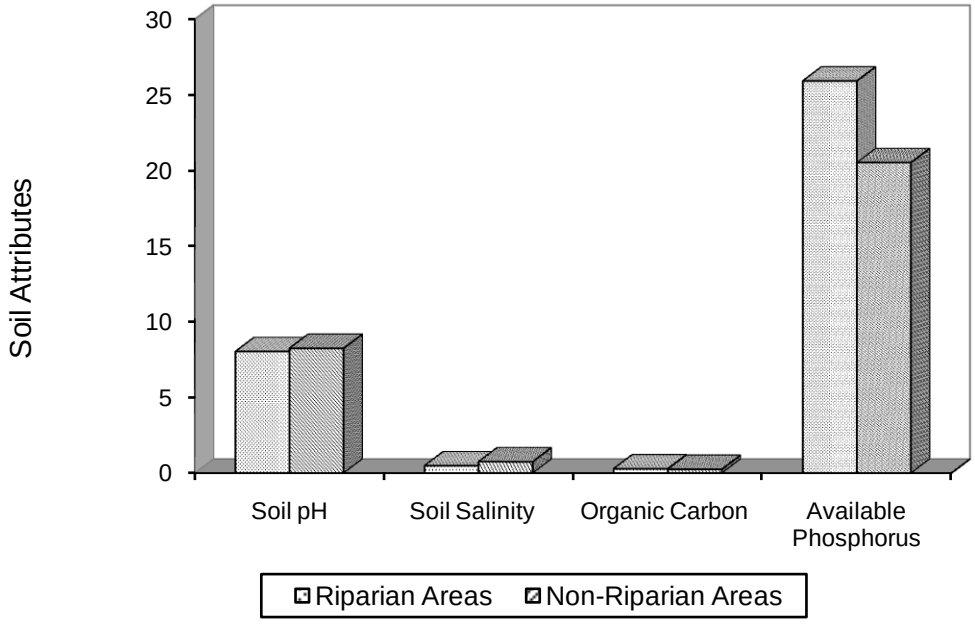


Table 2 and Fig. 2 show the characteristics of soil in the downstream area of Ganganagar district of Ghaggar river basin. Here also soil pH value is normal in either regions. Soil salinity in riparian areas was found to be 0.482, while it was slightly greater at 0.748 deci siemen/metre in non-riparian areas of Ganganagar. Organic carbon was found to be low in both the zones. Available phosphorus was medium in the riparian areas, while it was towards lower side in the more distant non-riparian areas. In Ganganagar district, available potash tends to be much higher in both the zones, as compared to Hanumangarh district, and its availability increased as one moves away from riverside to the more distant areas of the Ghaggar belt.

Table 2 : Soil Characteristics in Riparian and Non-Riparian Areas of Ghaggar River in Ganganagar District

Soil Characteristics	Riparian (River Coastal) Areas	Non-Riparian (Away from Coast) Areas
Soil pH	8.03 (Normal)	8.24 (Normal)
Soil Salinity (deci siemen/meter)	0.482 (Normal)	0.748 (Normal)
Organic Carbon (%)	0.282 (Low)	0.247 (Low)
Available Phosphorus (Kg/Hect)	25.92 (Medium)	20.52 (Medium)
Available Potash (Kg/Hect)	464.04 (Medium)	485.28 (Medium)

Fig. 2: Soil Attributes in Ghaggar Basin of Ganganagar District



In regard to the attributes of groundwater in Ghaggar basin of Hanumangarh district, water salinity was 1.24 deci siemen per metre in nearby areas of Ghaggar river, but it increased substantially to 3.11 in non-riparian areas, making the waters there saline in nature. The pH of water was 7.07 in the former areas, but increased to 7.64 (normal values) in more distant areas (Table 3).

Table 3 : Ground Water Characteristics in Riparian and Non-Riparian Areas of Ghaggar River in Hanumangarh District

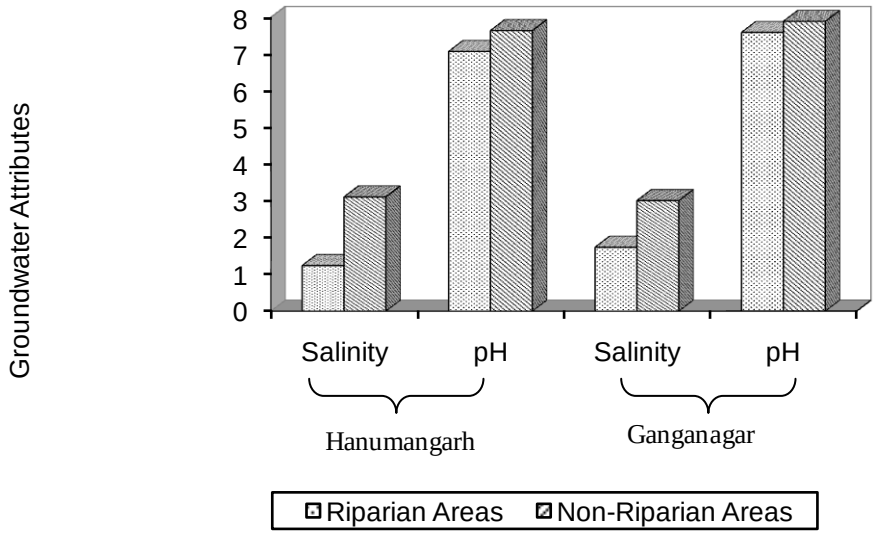
	Riparian Areas	Non-Riparian Areas
Water Salinity (deci siemen/meter)	1.24 (Slightly Saline)	3.11 (Saline)
Water pH	7.07 (Normal)	7.64 (Normal)

Analysis of the groundwater samples from Ganganagar district showed that average salinity of water in nearby areas of Ghaggar channel was 1.74 (Slightly Saline), but salinity increased to 3.01 in non-riparian areas making the waters there 'Saline'. Groundwater pH values were only slightly higher in both the areas of Ghaggar basin of Ganganagar district, as compared to Hanumangarh, but were still classified as normal (Table 4 & Fig. 3).

Table 4 : Ground Water Characteristics in Riparian and Non-Riparian Areas of Ghaggar River in Ganganagar District

	Riparian Areas	Non-Riparian Areas
Water Salinity (deci siemen/meter)	1.74 (Slightly Saline)	3.01 (Saline)
Water pH	7.59 (Normal)	7.89 (Normal)

Fig. 3 : Groundwater Characteristics in Ghaggar Basin of Hanumangarh and Ganganagar Districts



A more detailed analysis of changes in soil attributes, as we move away laterally from Ghaggar river basin in Hanumangarh and Ganganagar districts, has been made in Table 5. It shows that lateral changes in soil pH, organic carbon and available phosphorus in Hanumangarh district were nominal, availability of potash increased slightly, but salinity of soil showed a decrease of 53.90 percent away from the Ghaggar river. In case of Ganganagar district, percent changes in soil attributes were not much in case of soil pH, organic carbon and available potash. However, soil salinity showed increase of 55.19% in Ganganagar district, while available phosphorus decreased by around 20.8 percent. When we consider the overall situation for both the districts, we find that available potash increased slightly, available phosphorus decreased away from the river banks by a value of 10.34%, while soil salinity decreased by 13.94%. The decrease in soil salinity may be attributed to widespread use of canal waters in various parts of both the districts.

Table 5 : Quantitative Changes in Soil Attributes with Distance Away from Ghaggar River of Hanumangarh & Ganganagar District

(in percent)

District of Ghaggar Flow	Soil pH	Soil Salinity	Organic Carbon	Available Phosphorus	Available Potash
Hanumangarh	-3.3	-53.90	-0.096	+0.30	+2.80
Ganganagar	+2.62	+55.19	-0.035	-20.8	+4.60
Whole Drainage Area	-0.37	-13.94	-0.065	-10.34	+3.86

Table 6 showcases the changes in soil attributes, for both riparian and non-riparian areas, as we move longitudinally along Ghaggar river, from upstream Hanumangarh to downstream Ganganagar district of the study area. Such longitudinal changes in riparian areas of the Ghaggar river indicate decline of 2.43 in the soil pH values, nominal changes in case of organic carbon and available phosphorus. However, soil salinity was observed to decline by 42.6% downstream along the river in the study area. Available potash increased by 54.6% from Hanumangarh to Ganganagar district in the riparian areas. In case of non-riparian areas, average soil pH values increased by 3.5 % from Hanumangarh to Ganganagar, organic carbon showed increase of around 11%, while available phosphorus decreased by around 20% downstream. In these non-riparian areas, available potash increased by 57.4% and soil salinity by 93% from Hanumangarh towards Ganganagar. When we look at the downstream changes combinedly for both riparian and non-riparian areas, we find soil pH increase of 0.5%, soil salinity increase of 0.33 percent, decline of 9.23 % in available phosphorus, and increase of 56% in case of available potash.

Table 6 : Changes in Soil Attributes Downstream Along Ghaggar River of Hanumangarh & Ganganagar District

(in percent)

Vicinity/Distance from Ghaggar	Soil pH	Soil Salinity	Organic Carbon	Available Phosphorus	Available Potash
Riparian Areas	-2.43	-42.6	-0.037	+1.50	+54.6
Non-Riparian Areas	+3.50	+93.3	+10.8	-19.9	+57.4
Whole Drainage Area	+0.50	+0.33	-0.006	-9.23	+56.04

Changes in groundwater quality, laterally from Ghaggar river in Hanumangarh and Ganganagar districts, as well as the whole drainage basin of Ghaggar has been shown in Table 7. In Hanumangarh, groundwater salinity showed lateral increase of around 150.8%, while this increase was 73% in Ganganagar district, making an average of 105.4 % increase for the Ghaggar drainage area. In Hanumangarh, water pH showed a little increase of 8.1%, for Ganganagar it was around 4%, making an average of around 6% for the whole drainage basin.

Table 7 : Changes in Groundwater Quality with Increase in Lateral Distance from Ghaggar in Hanumangarh & Ganganagar Districts

(in percent)

Groundwater Quality Indicator	Hanumangarh District	Ganganagar District	Whole Drainage Area
Water Salinity	+150.8	+73.0	+105.40
Water pH	+8.1	+3.95	+5.94

Groundwater quality longitudinally along Ghaggar river has also been analysed and shown in Table 8. Water salinity increased by 40.3% downstream along the Ghaggar riparian areas, but decreased by 3.2 % in case of non-riparian areas. For the whole river basin, downstream increase of 9.2 % was observed. Longitudinal changes in groundwater pH indicate downstream increase of 7.4% in riparian areas, but only 3.3% in non-riparian areas, making an overall average of 5.24 % increase from Hanumangarh downstream towards Ganganagar district.

Table 8 : Changes in Groundwater Quality Longitudinally Along Ghaggar in Its Riparian and Non-Riparian Areas from Hanumangarh to Ganganagar

(in percent)

Groundwater Quality Indicator	Hanumangarh District	Ganganagar District	Whole Drainage Area
Water Salinity	+40.3	-3.20	+9.2
Water pH	+7.40	+3.30	+5.24

Conclusion

1. Average soil salinity was normal in Hanumangarh district. It showed lateral decrease away from Ghaggar river in Hanumangarh district, but exhibited a reverse increasing trend in Ganganagar district. This decreasing trend in Hanumangarh may be due to high canal irrigation in non-riparian areas of the district.
2. Longitudinally along the river, soil salinity was observed to decrease downstream in the riparian areas of the Ghaggar. It had a markedly increasing trend in non-riparian areas from upstream Hanumangarh to downstream Ganganagar district.
3. Available potash showed a longitudinal increase downstream from Hanumangarh towards Ganganagar district, in both riparian as well as non-riparian zones of the stream. Available phosphorus was observed to increase downstream in the non-riparian zone of Ghaggar stream. It exhibited a decreasing trend, laterally away from Ghaggar, in Ganganagar district.
4. Groundwater salinity increased heavily as one moves laterally away from Ghaggar river in Hanumangarh as well as Ganganagar district.
5. Downstream along Ghaggar river from Hanumangarh to Ganganagar district, water salinity increased by around 40% in the riparian areas.

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