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Impact of Alluvial Deposits on Soil Fertility During the Floods of 2010 in Punjab, Pakistan

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Abstract

Flooding of the Indus River in Pakistan during July-August 2010 was the most intense in the area during the last 75 years. Flooding affected an area around 160,000 km^2, covering around 0.75 million hectares of cultivated land in Punjab province. On average, a layer of fine mud and silt, about 15 cm thick, was deposited on the soil surface, which is expected to have affected the soil fertility status of the affected areas.

In a bid to assess the impact of flooding on the soil fertility status, samples were taken from 146 selected sites across districts declared "flood affected" by the Government of the Punjab. Depth of deposited material was noted at each site as the soil samples were collected. These samples were then analyzed using the routine methods of the Engro Soil Testing Laboratory, Multan, and the Soil and Water Testing Laboratory, Lahore. The data obtained were subjected to descriptive statistical analysis to interpret the results.

It was noted that the depth of transported mud ranged from 2.5 cm to 30 cm, with higher values recorded for areas along the Indus River in comparison to areas affected by other rivers. It was observed that the combined effect of transported material and flooding resulted in a reduction in the risk of soil salinity and alkalinity in affected areas. The uppermost soil layer deposited after flooding was found to contain relatively lower values of organic matter and soil test P, while values of soil test K and saturation percentage were higher in comparison to the results obtained for the native soil lying beneath.

For early rehabilitation of such soils, it is recommended that they should be deep plowed and manured to improve their physical condition. In relation to fertilizer application, rationalization of resources in favor of N and P application at the cost of K addition is also recommended, at least in the short-term. A site specific approach should be adopted in assessing K requirements of high K demanding crops, such as sugarcane and orchard fruits, prevalent in these areas.

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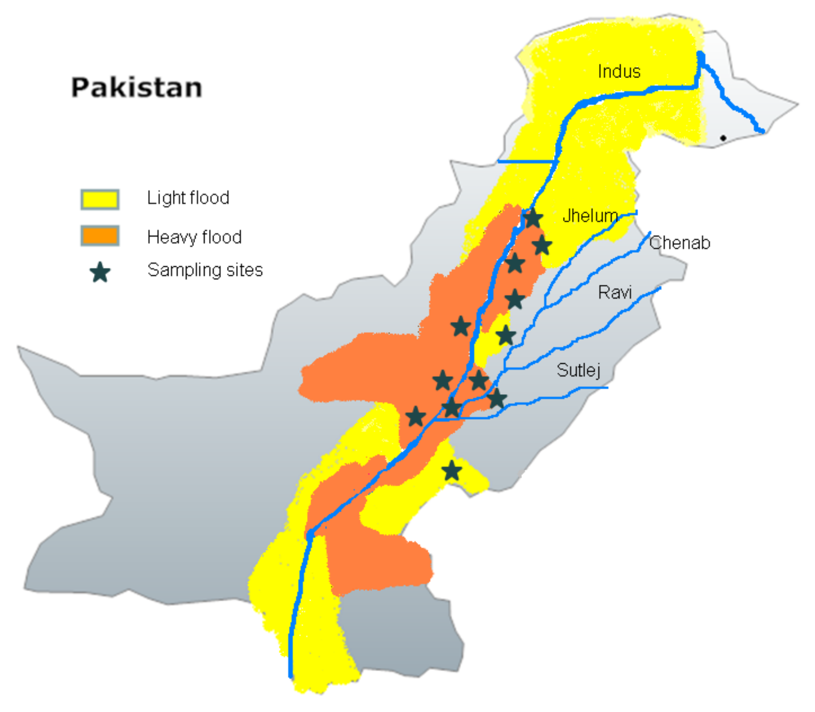

The IRS in Pakistan, flooding areas and sampling sites.

Introduction

Soils of the Indus Basin, which constitute about 70 percent of the total cultivated area (~27 million ha) of Pakistan, have developed predominantly over the centuries by the deposition of alluvial material transported through water carried by the River Indus and its tributaries. The "Indus Rivers System" (IRS) is the collective name given to the River Indus and its five tributaries in Punjab i.e. Jhelum, Chenab, Ravi, Sutlej and Beas, and Kabul in Khyber Pakhtunkhawah province (NDMA-UNDP, 2010 (see map above). This system originates from vast areas of the Himalayan, as well as the Karakoram and the Hindu Kush, mountain systems, where water flows at high speed until these streams enter the plains (Rehman and Kamal, 2005). The water flowing in these streams originates from a variable mix of sources, including subsurface fountains, melting ice, and rainfall in catchment areas etc.

There are two basic reasons which make the water flowing in these streams a source of enriching plant nutrients for the cultivable lands of the Indus Basin: i) The geologically active and structurally unstable nature of the Himalayas gives rise to large quantities of loose material that is transportable as suspensions in flowing water, and ii) The transport of these waters across the vast spread of plains at negligible gravitational levels which allows the suspensions to settle.

In addition to normal water flow in the

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IRS, and its controlled distribution on cultivable lands of the Indus basin, floods are a frequent seasonal phenomenon that provides occasional impetus to the process of soil formation described above. Floods occur mostly during summer, when the combined effect of monsoon rainfall in catchment areas and increased snowmelt due to elevated temperatures result in increased water flows, which are far beyond the capacity of these streams. The consequence of this is water overflow from streams, which spreads to adjacent areas. Here it is finally leached, or evaporated over time, leading to an impact on the productivity of these soils by the deposition of suspended material. In the short-term, floods are generally destructive in nature for standing crops, water distribution and other agricultural infrastructure, as well as for livestock and humans dwelling in affected areas. In the long-term, however, floods are considered as an important factor in the process of soil formation and a source of enhancing soil productivity due to deposition of fresh alluvium, which is free of excessive soluble salts and rich in minerals, especially potassium (K).

A historical review of floods in Pakistan reveals that traditionally floods mostly occurred due to high monsoon in catchment areas of IRS tributaries rather than the Indus River itself, which is mostly considered to contain water originating from snowmelt and which remains largely unaffected by monsoon flashes. During 2010, however, the tributaries were mostly docile while the Indus itself became vibrant due to high rainfall in its direct catchment areas during the second fortnight of July. It may be noted that more than half of the total monsoon rainfall in the Indus and Kabul catchment areas occurred in just one week (the 28th July to the 4th of August 2010) while the total monsoon span is generally three months. It was impossible for the Indus River to cope with this amount of water in such a short period, which was about eight to ten times higher than the normal amount expected at this time of year. The result was also unprecedented. The area flooded is estimated to be the most extensive in the known history of floods in the IRS during the last 75 years: A total area of 160,000 km^2 is estimated to have been affected by these floods, in comparison to about 90,000 km^2 during 1976, which is considered to be the highest area of flooding prior to the 2010 flood.

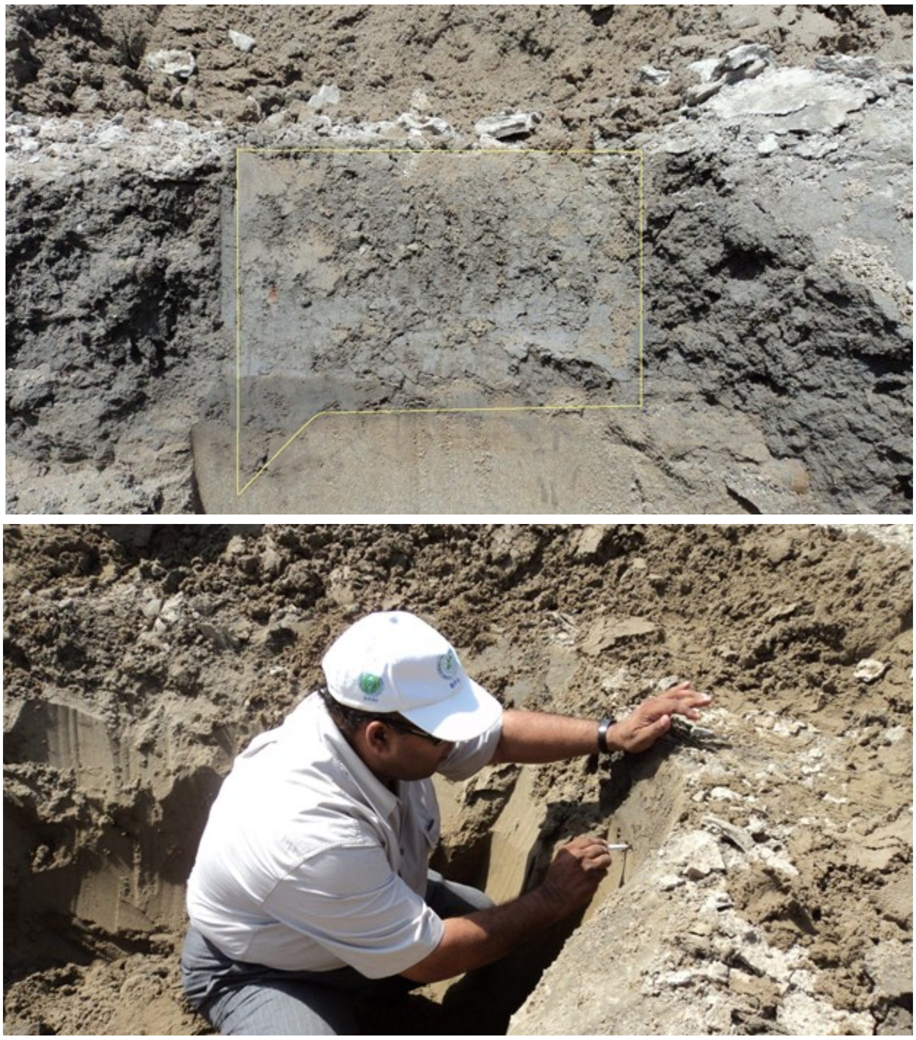

***Photo 1.** Distinction and measurement of deposited material in Muzaffargarh area (top) and in Dera Ghazi Khan area (bottom). Photo by Z. Ahmad.*

The objective of this report is to assess the impact of the 2010 floods on soil quality in affected areas in the Punjab, in terms of changes in nutrient status and other relevant soil properties such as pH, electrical conductivity (EC) and soil texture. With knowledge of this information, it is suggested that farmers in affected areas may be provided with a suitable soil management strategy for use in crop cultivation for future seasons.

Methodology

The objective of this study was to undertake a rapid assessment of the impact of flood deposited material, and the heavy flooding itself, on selected soil properties relevant to crop production. A limited number of soil samples were therefore collected from representative sites of selected districts out of the 25 districts declared as “flood affected” by the Government of the Punjab during the 2010 flood. Only

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those districts which were affected by riverine flood were selected for sampling, ignoring those affected by heavy monsoon only. From each selected site, two samples were drawn: i) the deposited mass of mud and silt and ii) underlying soil up to 15 cm.

Samples were taken during the third and fourth week of September, 2010. Prior to this, local Market Development Officers of Engro Fertilizers in areas to be sampled were trained by the Senior Market Development Officer (North) as to selection of sites, collection of soil samples, and color/visual observation to distinguish thickness of deposited material (Photo 1). By that time, the flood water had either receded or leached/evaporated from around 90 percent of the affected area and land was at an appropriate moisture level that sampling was possible from these areas. A geographical/area grid was not used for selecting sites. However, the distance between any two sites was kept at a minimum of 5 km. In any given Union Council (UC, a demographic unit consisting of a population of 10,000 people used for the purpose of civil administration), more than one sample was drawn if it was expected to be different in terms of thickness of deposited material and/or length of time for which water was reported to have stayed there.

The samples were then analyzed in the laboratory for pH, texture, organic matter, sodium bi-carbonate extractable phosphorus (P) ($NaHCO_3$-P) and ammonium acetate extractable potassium (K) (NH_4OAc-K) according to methods mentioned by US Salinity Laboratory Staff, 1954. The work was carried out at Engro Soil Testing Laboratory, Multan and the Soil and Water Testing Laboratory, Lahore. For determining EC, soil suspensions were prepared in distilled water in a soil to water ratio of 1:1. A detail of the sites sampled is provided in Table 1.

Table 1. Detail of soil samples collected from flood affected areas.

District	No. of UCs* affected	Total affected area (ha)	No. of sites sampled
Attock	10	2,866	5
Bahawalpur	16	21,261	0
Bhakkar	64	99,060	0
Chiniot	60	7,056	0
DG Khan	237	148,146	17
Faisalabad	23	7,014	0
Gujrat	13	659	0
Gujranwala	18	4,925	0
Jhang	322	179,062	10
Jhelum	73	2,826	0
Kasur	20	2,482	0
Khanewal	4	24,000	0
Khushab	125	59,104	5
Layyah	70	143,500	15
Mandi Bahauddin	26	20,300	0
Mianwali	154	31,945	10
Multan	97	75,718	10
Muzaffargarh	493	400,260	22
Narowal	26	1,113	0
Nankana Sahib	50	6,376	0
Rahi Yar Khan	145	136,046	10
Rajanpur	370	355,984	22
Sargodha	152	109,191	20
Sialkot	32	6,339	0
TT Singh	12	4,430	0
Total	2,612	1,853,875	146

*UC: Union Council.

The historical data published by the Soil Fertility Research Institute, Punjab had been averaged over Tehsil (district levels), hence it cannot be used as a reference for comparison between soil analysis before and after the flood. The analysis of actual soil beneath the deposited layer was, therefore, used as a benchmark for assessing changes in soil properties caused by the compound effect of mud/silt deposition on soils of the affected areas and the leaching effect as a result of the heavy flooding. Descriptive statistical parameters such as range (between minimum and maximum values), mean and standard deviation were used to interpret the data.

Possible interferences of the post-flood soil analysis

1. The samples were collected after water had leached/evaporated from the affected areas. This essentially means leaching of a significant volume of water through the soil profile, which must have resulted in the leaching of salts. This is expected to yield such estimates of the presence of soluble salts in these soils, which may not be truly representative of these soils in pre-flood conditions. In the absence of any other suitable benchmark for comparison in pre- and post-flood scenario, however, the status of soluble salts in the lower layer determined from these samples is used as a reference.

2. Leaching of potassium and organic matter to some extent is also expected from both layers due to heavy flooding.

Results and discussion

The soil samples were analyzed for soil fertility parameters used by the Soil Fertility Research Institute, Punjab viz. EC, pH, organic matter (%), soil test level of $NaHCO_3$-P and NH_4OAc-K expressed as parts per million (ppm) and Saturation Percentage (SAT). SAT is defined as the moisture content of a soil sample that has been brought to saturation by adding water while stirring, and is an indicator of textural class and water holding capacity. A statistical overview of the data is provided in the Appendix, while

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individual parameters are presented in figures and discussed in the following sub-sections.

Depth of deposited material

The depth of deposited material was measured and noted at each site, through color distinction and visual observation by the sample collector. The layer of dark colored structureless muddy mass was considered as "deposited material" (Photos 1). Overall, the depth ranged from a minimum value of 2.5 cm to around 30 cm. A thickness was considered representative of a site only if it was widely present there. Greater thickness of deposited material observed in smaller isolated depressions were ignored. Overall, the mean thickness of deposited material was around 15 cm, with a standard deviation of around three. It was observed that thickness of deposited material was higher in areas along the Indus River (Layyah, DG Khan and Muzaffargarh) than areas influenced by flooding from other rivers. This was mainly because of the extent and degree of flooding, which was higher in the Indus River during 2010 than in other rivers.

The depth to which soil is normally tilled is around 15-20 cm. This means that in areas where thickness of deposited material is higher than 15 cm, the tillage operations undertaken for the initial cropping seasons will remain confined to soil at this depth, and that crop growth may be affected by its properties, such as lower organic matter, soil test P levels, and the massiveness of its structure indicated by higher values of Saturation Percentage (discussed in the following sections). Farmers in these areas should be recommended to undertake deep plowing as soon as possible and adopt a manuring program for such soils to improve soil physical condition such as massiveness, which seriously hampers crop production due to restricted drainage, water movement and root growth. Manuring will also improve microbial activity in these soils and will help in the early improvement of organic matter status of these soils towards the sufficiency range.

Photo 2. *A ruined cotton field due to flooding in Rajanpur Area. Photo by Z. Ahmad.*

Electrical conductivity and soil reaction (pH)

It was observed that, overall, EC and pH values were lower in the deposited material compared to the actual soil below (Fig. 1A and 1B, respectively). This may be partly because of the relatively inert nature of deposited material and partly because of the leaching effect over the period of heavy flooding on these soils (Eulenstein *et al.,* 1998). Similarly, one can expect that values of EC and pH observed for soil beneath the deposited material may not give a true picture of its salt status in pre-flood conditions because of the effect of flooding. It is clear from the data that upper soil surface of these areas have largely become clear of any risk of soil salinity or alkalinity, and hence may be considered more productive for crop production with respect to these parameters.

Soil test levels of organic matter, P and K

Floods are expected to alter nutrient availability of soils, due to leaching of water soluble nutrients and due to the chemical composition of transported material deposited in the plow layer of the soil (http://www.gov.mb.ca/agriculture/crops/cropproduction/faa18s00.html). Data given in the Appendix and expressed graphically in Fig. 1C, 1D and 1E show that deposited material contained lower amounts of organic matter and P, while it was richer in soil test K compared to the soil below.

An interesting observation in these data is the wide ranges and higher values of Standard Deviations in these parameters in the deposited material (see Appendix) which was unanticipated because of expected homogeneity of transported material, at least in adjacent areas. Lack of homogeneity in observed values of these parameters in the deposited layer can be explained by assuming that this layer may not consist completely of transported material. It may rather be a layer predominantly consisting of transported material mixed homogeneously with some portion of the uppermost soil layer. This mixing would have resulted in a distinguishable color imparted by transported material,

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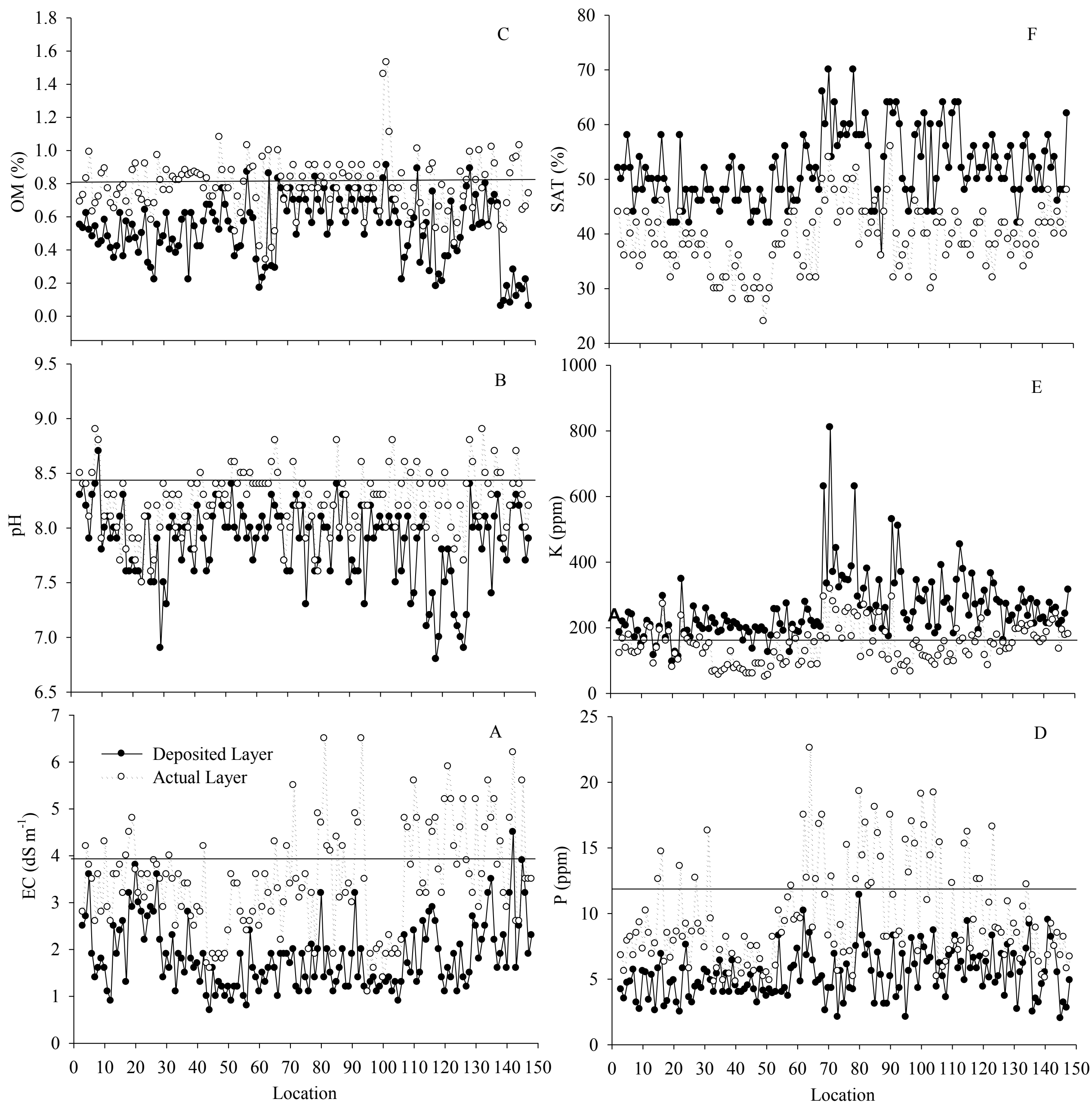

Fig 1. Comparison of EC (A), pH (B), OM (C), P (D), K (E) and SAT (F) values obtained from deposited material and actual soil mass across all 146 sites. Lines in Fig. A, B, C, D and E represent the sufficiency range as per benchmarking used by the Soil Fertility Research Institute, Punjab.

while the original soil mass mixed in this layer would have imparted its characteristics vis-à-vis these soil parameters, hence yielding a wider variation of values.

The data clearly indicate that organic matter and soil test P in the upper deposited layer was invariably in the deficient range, while soil test K was in the sufficiency range as per benchmarking used by the Soil Fertility Research Institute, Punjab and indicated as separating lines in Fig. 1C, 1D and 1E. For crop production, therefore, farmers in these areas should be recommended to increase nitrogen (N) and phosphorus (P) usage in their fertilizer practice, while use of potassium (K) can be avoided for a few seasons. Farmers should manage their resources by saving from their expenditure on K to spend more on N and P. However, for high K requiring crops, which are prevalent in these areas, such as sugarcane and orchard fruits, site specific recommendations should be followed. Early and frequent green manuring is also recommended for early rehabilitation of these soils with respect to organic matter and soil

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structure and texture.

Soil Texture indexed by saturation percentage

Data provided in the Appendix and expressed graphically in Fig. 1F suggest that the layer containing deposited material had a relatively higher saturation percentage indicative of heavier soil texture and massive soil structure. This is to be expected because of the fine nature of suspended material, which is transported by water and settles when flooded water leaches or evaporates in situ.

This massiveness of structure and heaviness of soil texture is detrimental to crop production because it restricts drainage and air movement, prevents root growth and inhibits microbial activity. Farmers in these areas should be recommended to incorporate green manure and farmyard manure for early rehabilitation of their fields. The sooner the physical conditions of their flood affected soils are improved, the better position they will be in to exploit positive changes in their soils brought about by floods, such as reduced risk of soil salinity and alkalinity and improved K status.

Conclusion

Vast areas of crops were devastated by the 2010 flood in Pakistan. Soils were affected both by the transport of large quantities of suspended silt and mud, which were deposited on cultivable lands, and the leaching effect caused by the heavy flooding.

The upper massive layer of mud/silt does not consist of 100 percent transported material. It seems to be a homogenized mixture of original surface layer soil and transported material.

Generally, flooding caused a reduction in soil salinity and alkalinity parameters, while the soil layer containing deposited material was invariably deficient in organic matter and soil test P, but was higher in soil test K, and in fine particles causing heaviness in soil texture.

The foremost recommendation to farmers of these areas should be to improve physical condition of the soil through deep plowing and manuring/green manuring.

Rationalization of resources for nutrient application is also recommended in favor of N and P at the cost of K during the initial cultivation phase. Potassium requirement of high K requiring crops prevalent in these areas, such as sugarcane and orchard fruits, should be provided with site specific recommendations.

References

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Rehman, H., and A. Kamal. 2005. Indus Basin River System – Flooding and Flood Mitigation. http://www.riversymposium.com/2005/index.php?element=38.

United State Salinity Laboratory Staff. 1954. Diagnosis and Improvement of Saline and Alkaline Soils USDA. Handbook 60 Washington D.C.

Useful links

Impact of Flooding on Soil Fertility in the Red River Valley of Manitoba. http://www.gov.mb.ca/agriculture/crops/cropproduction/faa18s00.htm.

The formation of Himalayas. http://library.thinkquest.org/10131/geology.html. ■

IPI Events

October 2011

International Symposium on "Role of Potassium in Sustaining the Yield and its Quality", Kandy, Sri Lanka, 27-29 October 2011. Jointly organized by the International Potash Institute, University of Sri Jayewardenepura, Sri Lanka and Department of Agriculture, Sri Lanka. For more details see IPI website or contact Dr. Baladzhoti Tirugnanasotkhi, IPI Coordinator East India, Bangladesh and Sri Lanka. ■

Spring 2012

International Symposium on "Management of Potassium in Plant and Soil Systems in China". The symposium is jointly organized with the International Potash Institute, Soil Science Institute, Nanjing, Chinese Academy of Sciences and the China Agriculture University. For more details see IPI website or contact Mr. Eldad Sokolowski, IPI Coordinator China. ■

Other Events

The 9th New Ag International Conference & Exhibition will be held in Athens, Greece, during 28-30 June 2011.

For more details see conference website. ■

APPENDIX to Research Findings "Impact of Alluvial Deposits on Soil Fertility during the Floods of 2010 in Punjab, Pakistan": Statistical overview of EC, pH, organic matter and soil test P and K measured at 146 selected sites in areas affected by the 2010 floods.

District	n	Depth	Thickness of deposited layer (cm)			EC (dS m^{-1})			pH			Organic Matter (%)			Extractable P (mg kg^{-1})			Extractable K (mg kg^{-1})			SAT (percent)		
			Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD	Range	Mean	SD
Attock	5	1	7.6-20.3	13.7	6.12	1.4-3.6	2.4	0.83	7.9-8.4	8.2	0.19	0.5-0.6	0.5	0.05	3.5-5.7	4.6	0.81	185-245	219	24.7	50-58	52.8	3.03
		2				2.6-4.2	3.4	0.67	8.1-8.5	8.4	0.16	0.6-1.0	0.8	0.14	5.6-8.2	7.1	1.03	122-178	146	24.82	36-44	40.4	3.58
Sargodha	20	1	2.5-15.2	7.4	3.2	0.9-3.8	2.4	0.81	7.5-8.7	7.9	0.33	0.2-0.64	0.5	0.11	2.5-7.6	4.4	1.51	96-348	186.5	62.05	42-58	48.2	4.85
		2				2.6-4.8	3.6	0.56	7.5-8.9	8.0	0.37	0.6-0.92	0.7	0.10	5.8-14.7	9.1	2.48	80-272	159.1	48.19	32-46	38.8	3.75
Khushab	5	1	5.1-5.1	5.1	0	1.4-2.3	1.9	0.38	6.9-8.0	7.5	0.45	0.4-0.6	0.5	0.09	4.3-3.7	5.0	0.58	195-258	215.0	26.45	46-52	48.0	2.45
		2				2.9-4.0	3.5	0.39	8.0-8.4	8.2	0.15	0.8-1.0	0.8	0.09	7.4-16.3	10.22	3.50	120-169	145.2	17.94	36-40	37.6	1.67
Mianwali	10	1	5.1-5.1	5.1	0	1.1-2.8	1.7	0.46	7.7-8.2	7.9	0.19	0.2-0.6	0.5	0.12	4.0-6.4	4.8	1.01	185-235	209.0	16.18	44-54	47.8	3.05
		2				2.5-4.2	3.1	0.55	7.8-8.5	8.2	0.24	0.8-0.9	0.9	0.02	4.8-8.2	6.0	1.16	56-127	77.5	19.62	28-38	32.2	3.05
Jhang	10	1	5.1-10.2	7.6	2.7	0.7-1.6	1.1	0.25	7.6-8.4	8.1	0.26	0.5-0.8	0.6	0.08	3.2-5.7	4.3	0.73	125-200	175.8	27.18	42-52	45.6	3.37
		2				1.6-3.6	2.2	0.72	8.1-8.6	8.3	0.14	0.7-1.1	0.8	0.11	4.9-8.2	6.5	1.25	50-90	70.5	15.71	24-32	29.2	2.35
Layyah	15	1	10.2-22.9	15.5	3.7	0.8-2.4	1.5	0.43	7.7-8.3	8.0	0.15	0.2-0.9	0.5	0.23	3.7-10.2	6.0	1.93	125-278	218.7	39.95	44-58	50.7	4.12
		2				2.2-4.3	3.0	0.56	8.3-8.8	8.5	0.12	0.3-1.0	0.7	0.24	6.0-22.6	11.8	4.24	85-195	127.5	39.18	32-44	37.9	4.17
Rajanpur	22	1	15.2-30.5	23.9	5.9	1.1-3.2	1.6	0.49	7.3-8.4	8.0	0.30	0.5-0.8	0.7	0.1.	2.1-11.4	5.3	2.25	195-810	361.0	151.73	36-70	56.5	8.39
		2				1.9-6.5	3.7	1.12	7.6-8.8	8.1	0.29	0.6-0.9	0.8	0.09	5.2-19.3	11.8	4.31	110-318	213.6	59.61	36-54	45.3	4.64
DG Khan	17	1	10.2-30.5	18.0	5.5	0.9-3.2	1.4	0.53	7.3-8.2	7.9	0.28	0.5-0.9	0.7	0.11	2.1-8.7	6.0	1.86	173-530	292.2	105.64	44-64	55.1	7.65
		2				1.1-6.5	2.6	1.45	7.9-8.8	8.2	0.25	0.6-1.5	0.9	0.26	5.2-19.2	13.1	4.46	66-294	116.5	52.44	30-56	39.6	5.21
Muzaffar garh	22	1	10.2-30.5	18.8	5.0	1.1-2.9	1.8	0.57	6.8-8.1	7.5	0.40	0.2-0.9	0.5	0.20	3.6-9.4	6.1	1.49	162-453	293.2	71.01	48-64	54.8	5.11
		2				3.2-5.9	4.4	0.81	7.7-8.6	8.2	0.27	0.4-1.0	0.7	0.15	5.6-16.6	9.8	3.23	85-227	145.2	34.68	32-44	39.5	3.26
Multan	10	1	7.6-20.3	14.5	4.2	1.6-3.5	2.4	0.60	7.4-8.4	8.0	0.27	0.5-0.9	0.7	0.12	2.5-9.2	5.2	2.23	195-315	250.7	37.45	42-58	51.4	4.99
		2				2.9-5.6	4.3	0.92	8.1-8.9	8.5	0.26	0.5-1.0	0.8	0.17	6.3-12.2	8.6	1.87	136-210	183.3	25.39	34-42	38.1	2.33
RY Khan	10	1	5.1-15.2	9.7	3.6	1.6-4.5	2.7	0.98	7.7-8.3	8.0	0.22	0.1-0.3	0.1	0.07	2.0-9.5	5.4	2.43	210-315	244.2	32.62	46-62	52.3	5.08
		2				2.6-6.2	3.8	1.26	7.9-8.7	8.3	0.25	0.5-1.0	0.7	0.19	5.1-9.2	7.0	1.37	135-243	186.8	32.49	40-48	43.3	2.91
Total	146	1	2.5-30.5	14.2	7.5	0.7-4.5	1.9	0.73	6.8-8.7	7.9	0.26	0.1-0.9	0.5	0.20	2.0-11.4	5.3	1.82	96-810	255.7	98.82	36-70	51.9	6.49
		2	7.6-20.3	13.7	6.12	1.1-6.5	3.5	1.10	7.5-8.9	8.2	0.28	0.3-1.5	0.8	0.17	4.8-22.6	9.7	3.85	50-318	148.0	58.25	24-56	39.1	5.74