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# Soil characteristics in the floodplains of Munawar Tawi in Rajouri, Western Himalayas, India

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## Abstract

**Background:** In Himalayas, particularly Jammu and Kashmir, where 85% of people depend on agriculture and allied sectors, 70% of agriculture is rain-fed. While the Himalayas, highly seismic, contribute highest in sediment transported to the world oceans, surface soil is under threat due to erosion, and Rajouri district in western Himalayas is no exception. Various factors, especially land use pattern and climate change, further affect the soil fertility and nutrient contents. However, information on essential nutrients in the soil across the region is meager.

**Methods:** We examined soil texture, soil type, lime status, pH, EC and select nutrients in January (non-cropping season) and June (cropping season) in paddy/wheat fields in Rajouri town, and its upstream and downstream locations. We also examined area under major crops, yield and fertilizer inputs from 2000 to 2012.

**Results:** Wilcoxon signed-rank test, a non-parametric statistical hypothesis test used when comparing two related samples, showed that pH, EC, K, Zn, Fe and Mn are higher in January than in June while OC, N, P, Na, Mg, Ca and Cu are vice versa. Kruskal–Wallis test, another non-parametric statistical hypothesis test used when comparing more than two related samples, showed nutrients varying significantly from upstream to downstream in both the seasons. Area and yield under rice, wheat and maize cultivation during 2000–2012 did not show any significant change. During the period, while significant increase in N and P input was seen, micronutrients remain neglected. Correlation matrix shows significant relation among the nutrients in January and June. In the case of rice, the yield was significantly positively correlated with area under cultivation, but in the case of wheat, the yield was negatively correlated with the area.

**Conclusions:** The study presents baseline information on soil characteristics across seasons and locations in Rajouri. It highlights the inadequacy of the official database and need for generating accurate data on crops and yields that are more authentic.

**Keywords:** Agriculture, Western Himalayas, Soil Nutrients, Yield, fertilizer inputs, climate, Rajouri

## Background

Agriculture productivity is greatly determined by quality of the soil, especially availability of the nutrients. It plays key role in economy and overall social well-being of India (Mall et al. 2006). Growing population in the country demands an annual yield of 5 metric ton to meet the future needs compared to the average annual

productivity of 3.1 metric tons during 1968–2008 (Singh 2008). That requires improvement in the soil quality, the key element in sustainable agriculture (Warkentin 1995). Ecosystem function, process and attributes of soil are described by its quality (Larson and Pierce 1994; Doran and Parkin 1994; Karlen et al. 1997). Yield efficiency of soil can be based on availability of nutrients in the soil and categorizing soil accordingly is important for appropriately planning agriculture (Gregorich and Carter 1997). From 1970 to 2000, increase in the yield is reported worldwide due to intensified crop management,

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improved germplasm, higher fertilizer inputs and cultivation of two or more crops a year (Cassman 1999). In India with the arrival of high yielding varieties, addition of macronutrients such as N, P and K fertilizers raised productivity by fourfolds, which in turn, however, led to deficiency of micronutrients in most of the soil (Singh 2008).

Agriculture globally is vulnerable to climate change (IPCC 2014). In India, predicted loss, due to global warming, during 2080–2100 in crop productivity ranges from 10 to 40% (Rosenzweig and Parry 1994; Fischer et al. 2002; Parry et al. 2004; IPCC 2014). Significant fall in production of pulses, tomatoes, onions, garlic, cereals (Samra and Singh 2004) and drop to the tune of 4–5 million tons of wheat is estimated with 1 °C rise in temperature (Saini and Nanda 1986; Aggarwal 2008). The Himalayas is recognized as highly vulnerable to climate change due to its special ecosystem features such as geological dynamic nature, earthquakes, landslides, heterogeneous geography, ecological fragility, diversity of species, highly variable climatic regime, and harsh living conditions and economic marginality of the local inhabitants (Dortch et al. 2009; Hubbard and Shaw 2009; Xu et al. 2009; Tse-ring et al. 2010). More than 85% of the population in the Himalayas depends primarily on agriculture and allied sectors for livelihoods, and industrial activity in the area is almost nothing. Impacts of climate change tend to be severe on people relying on rain-fed agriculture for a living (Gentle and Maraseni 2012). Since agriculture based livelihood of people is vitally linked with essential nutrients in the soil, it is important to estimate requirement of fertilizers for appropriate nutrient management in the agriculture fields (Tandon and Tandon 1995; Das et al. 2009). Studies from northwestern Himalayas, particularly from Jammu & Kashmir (J&K), on agriculture with respect to soil characteristics, nutrients, crop yields, fertilizer inputs and climate change are scarce. Therefore, for the present study, essentially to create baseline information on the soil characteristics of the area, we examined select parameters in the paddy/wheat fields in the flood plains of the river Munawar Tawi flowing through Rajouri, Western Himalayas, India. The parameters examined were soil texture, type, lime status, pH, electrical conductivity (EC), organic carbon (OC) and essential nutrients (Na, Mg, Ca, N, P, K, Cu, Zn, Fe and Mn). In addition, we examined the relations among the area under cultivation (rice, wheat and maize), their respective yields and inorganic fertilizer inputs.

### Study area

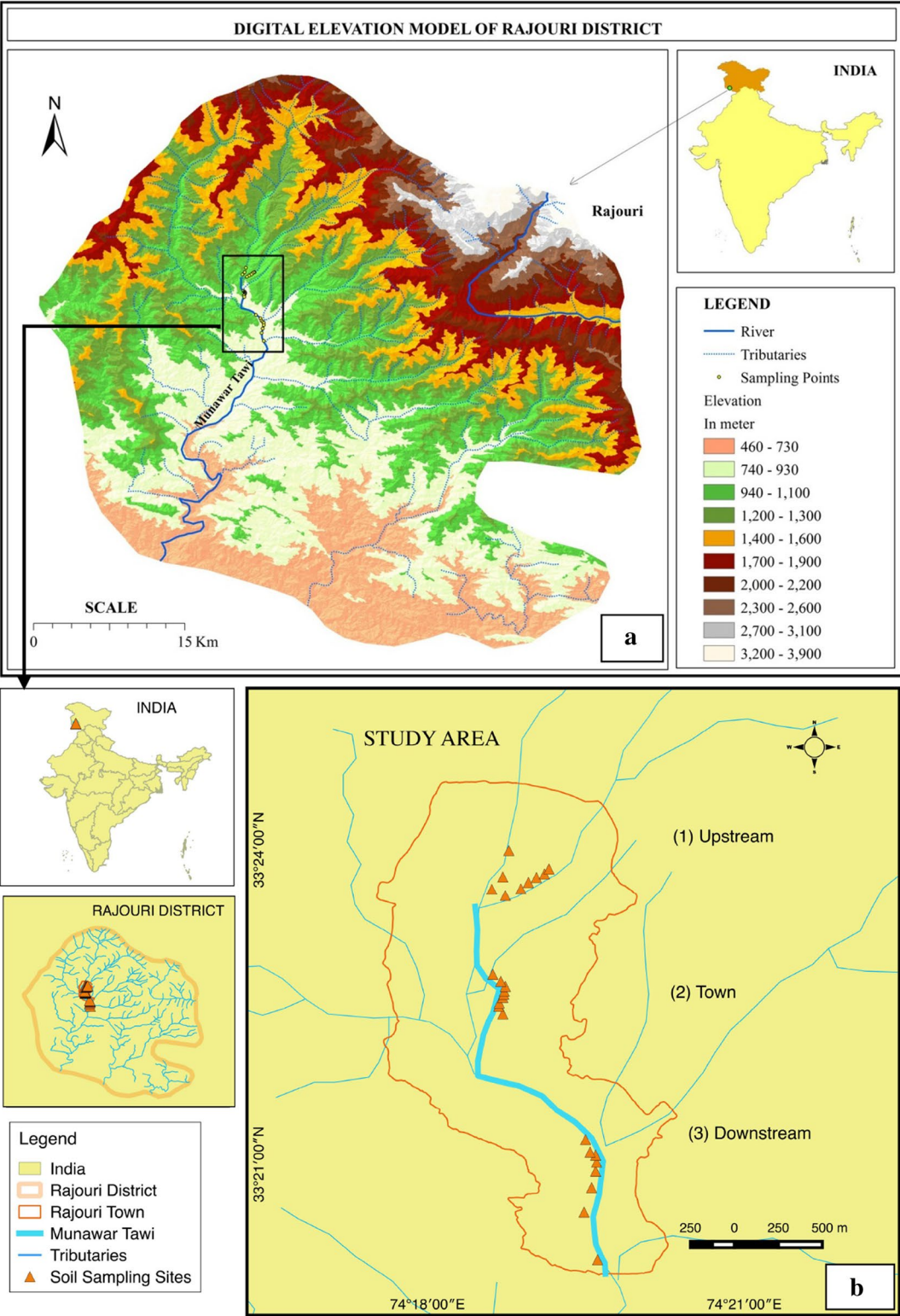
Rajouri town lies towards west of Jammu city (150 km), J&K, India. The Rajouri district, spread over 2769 Km<sup>2</sup> (Latitude 33°34'N–33°04'N, longitude

74°10'E–74°37'E), ranges in altitude from 460 to 3900 mASL (Fig. 1a). In 2011, the total population in the district was 619,266, of which more than 80% is rural. The decadal growth rate in population during 2001–11 was 28%. The climate in the district ranges from semitropical in the south to temperate in the north. Rajouri town falls in the temperate region. The district receives rainfall from the southwestern monsoon from June to August. Average annual rainfall varied from 689 to 1293 mm during 2002 and 2014. The economy of the district is primarily agricultural, with rice, wheat and maize being major crops. Cereals, millets, pulses, green leafy vegetables, condiments, spices, and fruits such as guava, mango, banana and walnut are also cultivated (Digest of Statistics 2012). The agriculture fields largely are spread along the banks of the river Munawar Tawi. In the district, 97,845 ha (Digest of Statistics 2012) is under wheat (46.3%), maize (47.67%), rice (5.41%), bajra (pearl millet-0.56%) and other millets (0.03%). These fields follow more or less the same cropping pattern. Rice and maize are cultivated during rainy seasons (May–September), and wheat in winter (October–April). Maize is grown in upland areas away from irrigation sources. Paddy, raised close to streams and the river, mainly is sown with the onset of the southwestern monsoon. The paddy fields are either flooded or irrigated with water from the river Munawar Tawi, which serves as the prime source of water for the district, including its domestic and drinking needs.

Geological formations of Rajouri district vary from older metamorphic and crystalline in upper north to Murree group and Siwalik towards south in Rajouri town and its surroundings. About 80% of the district is covered by Murree group of rocks (pink sandstone and clay) of late Eocene to the early Miocene period (Kishor and Shashi 2002). A geological map of the district is shown in Additional file 1: Figure S1. The sampling sites representing rice, maize and wheat fields thus have same types of soil and geology as the general geological setup of the district.

### Methods

Croplands along the banks of Munawar Tawi in Rajouri town, its upstream and downstream locations were selected for sampling soils (Fig. 1b). Soil samples were collected from three sites in the crop fields using a scoop. The first site lies in the upstream of the town and it could be considered as least urbanized. The second sampling site is in the town that is most urbanized part in the study area, and the third site is in the downstream of the town and is lesser urbanized than the second. The distance between each of these sites varied from 3 to 6 km. From each site, nine samples were collected (total 27 samples



**Fig. 1** **a** Elevation profile of the Rajouri district/Munawar Tawi basin. **b** Sampling sites in Rajouri town with its periphery, from location one (upstream) to two (highly populated area) and three (downstream)

during one season across three locations) from the corners and center of the field. Samples, each 0.5 kg, were collected in triplicates from a depth of 0.1–0.2 m, packed in zip-lock bag (airtight polyethylene bags) and transported to the laboratory for processing. The collections were done between 11:00 and 15:00 h in January representing post harvesting period and June representing sowing period. In the lab the soil samples were air dried at room temperature (Jackson 1973), mildly ground using a mortar and pestle and strained using a 2 mm sieve (Tandon 2005). Then the sieved soil, less than of 2 mm size, were stored in acid-washed labeled plastic containers until further analysis.

Soil texture was determined by particle fractionation (BS-1796:1962, Allen and Hajek 1989). Soil type, was determined by color matching the samples spread in a plastic tray taking the Munsell soil color chart as reference and noting down the color codes. Lime status was estimated by determining OC content using the method of Bailey (1993). A calibrated pH meter (Digital Electronics-7007) was used to record the pH and a calibrated Digital Conductivity Meter (DI-9009) was used to record the EC (Tandon 2005). To estimate N, P, K, Na, Ca, Mg, Li, Cu, Zn, Fe and Mn, soil samples were extracted with 1 M neutral Ammonium Acetate solution (Prusty and Azeez 2007). Extractions, done by stirring 10 g of air-dried soil samples in 100 ml of the extractant for 20–30 min, were filtered and the filtrate was stored in pre-cleaned plastic vials. All reagents were prepared using double distilled water and AnalaR grade chemicals.

Of the available primary macronutrients, N was determined by Micro-Kjeldahl method (Jackson 1973) using micro-Kjeldahl KEL PLUS (Model Kes06L) and P was determined by stannous chloride method (Bray and Kurtz 1945) using UV–VIS Spectrophotometer (Model: Lambda 35 UV/VIS spectrometer). Na, K and Li were determined by Flame photometry (Allen and Hajek 1989; Subba Rao 2001) using Systronics Flame Photometer-128. Ca and Mg were determined by EDTA titration (Allen and Hajek 1989). Total organic carbon and organic matter was determined by wet digestion following Walkley and Black (1934) method. Atomic absorption spectrophotometer (AAS Model-SenSAA GBC Equipment GBCHG 3000) was used to determine micronutrients Cu, Zn, Fe and Mn (Lindsay and Norvell 1978; Berrow and Stein 1983).

A test of normality performed on data on soil characteristics showed non-normal distribution. Hence, non-parametric tests Wilcoxon signed-rank test and Kruskal–Wallis rank test were conducted to assess the overall variations in the soil parameters across the seasons (January and June) and locations (Rajouri town, its upstream and downstream). Pair-wise Pearson's

correlations (2 tailed) were performed among all the parameters (Krumbein and Graybill 1965) in January and June. To examine the relations among areas under crops, yield and fertilizer inputs over the past decade available data (2000–2012) collated from the respective government line departments/agencies (agricultural, statistical, Irrigation/flood control and Indian agricultural meteorology station), in the district (Digest of Statistics 2012) were used. Linear regression was performed on the area under crop, yield and fertilizer inputs in rice, wheat and maize cultivation during 2000–2012. A correlation matrix was prepared depicting area vs. yield (in rice, wheat and maize cultivation), and yield vs. inputs of N, P, and K fertilizers.

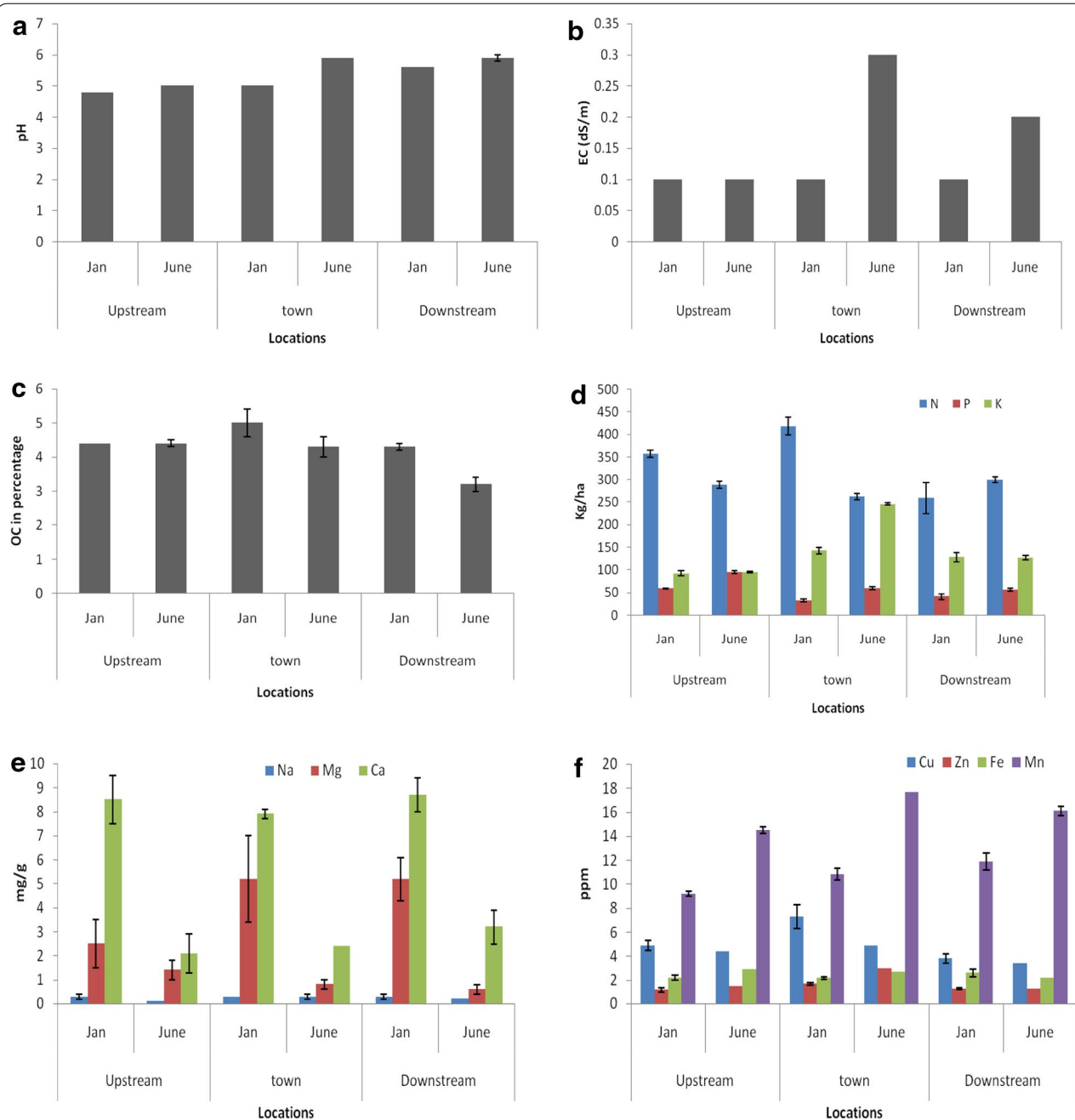
## Results

The concentrations of both macro and micronutrients in the soil under agriculture along the banks of Munawar Tawi in Rajouri town, its upstream and downstream locations during January and June 2014 is presented in Fig. 2. The soil is clay loam, black, non-calcareous and acidic. The pH was in the range 4.8–5.7 in January and the range was wider in June. EC ranged from 0.05 to 0.29 dS/m. OC was in range of 4.1–5.2%. Na in soil was in the range of 0.09–0.4 mg/g. Mg and Ca were 0.49–7.4 and 1.6–9.8 mg/g respectively. The ranges in concentration of primary macronutrients N, P and K were 212–451, 30–99 and 85–250 kg/ha respectively. The micronutrients Cu, Zn, Fe and Mn were 3.4–8.5, 1.0–3.0, 2.0–3.0 and 9.0–17.7 ppm respectively.

Of all the parameters given in Table 1, as per Wilcoxon signed-rank test significant rise was seen in pH, EC, P, K, Zn, Fe and Mn from January to June. In contrast, from January to June N, Cu, Ca, Mg, OC and Na showed significant fall. With respect to the locations, Kruskal–Wallis test showed higher pH, EC, Fe and Mn in January in the downstream location. Ca was significantly high in the downstream location whereas N, K, Cu, Zn, Mg, OC and Na were higher in the town. P was significantly higher in the upstream. In June, Kruskal–Wallis test showed significantly higher pH, N and Ca while lower P, Mg and OC in the downstream location. In June, EC, K, Cu Zn, Mn and Na were significantly higher in town and Fe in the upstream location.

The matrix of correlations among the 13 variables for January and June is given in Table 2. In January and June, pH and EC showed significantly positive correlations with each other and with K and Mn, while their correlation was negative with P. Mg and Fe showed positive correlation with pH in January and negative correlation in June. EC showed negative correlation with N, both in January and in June. OC was positively correlated with Mg, Cu and Zn and negative with Ca. OC showed





**Fig. 2** Soil characteristics in floodplain agriculture field along the Munawar Tawi from upstream, town and downstream locations in January and June 2014 (**a–c** shows pH, EC, OC respectively; **d** shows N, P and K; **e** shows alkaline elements Na, K and Ca; **f** shows micronutrients)

interesting relation with N and P in January, N positive and P negative, and vice versa in June. N in June showed negative correlation with K, Na and micronutrients while as in January it was positive with Cu, Zn and negative with Fe. P was negative with K, Na and Mn in both the seasons though it was opposite in the case of Mg and Ca. K was positive with Cu, Zn and Fe and opposite with Mg

from January to June. Mg was positive with Fe and negative with Ca that was found negatively correlated with Cu. Among micronutrients, only Cu was found positively correlated with Zn in both the seasons.

Data collected from government records for the period 2000–2012 showed area under rice, wheat and maize and their respective yields to be insignificantly correlated with

**Table 1 Results of the Wilcoxon signed-rank test to examine significant difference in the parameters of the soil samples collected in January and June and Kruskal–Wallis test to examine the significant differences based on locations-upstream, town and downstream**

Parameters	V	P<	KS-January samples			KS-June samples		
			Chi square	df	P<	Chi square	Df	P<
pH	0	0.01	23.1782	2	0.01	18.0717	2	0.01
EC (dS/m)	21	0.01	22.2753	2	0.01	17.7693	2	0.01
OC%	361	0.01	13.7402	2	0.01	17.9528	2	0.01
N (kg/ha)	317	0.01	23.1499	2	0.01	20.7723	2	0.01
P (kg/ha)	0	0.01	20.8954	2	0.01	19.5916	2	0.01
K (kg/ha)	74.5	0.05	20.8954	2	0.01	23.2564	2	0.01
Na (mg/g)	292.5	0.01	0.868	2	0.1	16.3159	2	0.01
Mg (mg/g)	378	0.01	13.7311	2	0.01	12.8907	2	0.01
Ca (mg/g)	378	0.01	7.0301	2	0.05	8.5446	2	0.05
Cu (ppm)	346.5	0.01	22.254	2	0.01	23.2208	2	0.01
Zn (ppm)	27	0.01	18.0717	2	0.01	23.285	2	0.01
Fe (ppm)	83.5	0.01	11.6722	2	0.01	23.1924	2	0.01
Mn (ppm)	0	0.01	21.1022	2	0.01	23.2066	2	0.01

KS Kruskal–Wallis test, V Wilcoxon signed rank test, df degree of freedom and P significance

year. Average annual yield of rice, maize and wheat was 1.8, 2.07 and 1.7 ton/ha from 2000 to 2012 (Digest of Statistics 2012). Inputs of both N and P fertilizer were found increasing significantly along the years, unlike the case of K that did not show any such change. The correlation matrix between area under cultivation and yield of rice, maize and wheat showed significant positive correlation for rice, negative for wheat and insignificant correlation for maize indicating perhaps the flawed dataset published by the concerned government agencies (Table 3). Correlation of N–P–K fertilizer input with rice, maize and wheat yield was also found insignificant (Table 4), which further raises doubt on exactness of the dataset. Areas under rice, wheat and maize cultivation, their respective yields and fertilizer inputs in the district for the past decade are shown in Additional file 1: Figures S2, S3.

## Discussion

Soil fertility is a key component in its productivity and quality (Subba Rao and Sammi Reddy 2005). Despite agriculture being a prime component in Indian economy, regional database on essential nutrients in most of the areas in the country is incomplete. Soils in Himalaya are characterized by shallowness, stoniness and limited development (Gupta and Tripathi 1996). Massif of Himalayan region is young and geo-morphologically unstable and is the source of major river systems of India (Sharma and Rai 2004). Himalayas contributes mainly to runoff and sediment load in major rivers of South Asia. Of the sediments delivered to the world oceans, 80% comes from “Asian water towers”, the Himalayas, from where

the major Asian rivers originate (Chorley 1969; Immerzeel et al. 2010). Compared to the geological past the rates of erosion have increased five times (Singh et al. 1983; Rai and Sharma 1998). Rajouri falls in Western Himalaya wherein agricultural fields are lying adjacent to the riverbanks and climate change has augmented catastrophic floods in the region causing a rise in soil and nutrients loss (Sharma and Rai 2004; Editorial 2015). The agricultural fields from where soil samples were taken lie adjacent to the Munawar Tawi and its tributaries, and are susceptible to flooding especially in years of high annual rainfall. Otherwise, also water from the river is used for irrigating the field. However, during sampling these areas were neither flooded nor irrigated and was completed in a drained condition. Rajouri also falls in high seismicity area; therefore, the problem of erosion and even landslides is further acute. Erosion renders the soil unfit to cultivation, and hence establishing dataset on essential nutrients is vital to identify appropriate management measures for sustainable and profitable agriculture. Land conversion from forest to agriculture and then to housing or commercial sectors in Rajouri further degrades the available soil, nutrient contents, and fertility. Most of Rajouri is mountainous and falls under vulnerable region (Xu et al. 2009) due to climate change. In terms of primary economic activity, in Rajouri 70–80% of the people are into agriculture, higher than the national average that is only 58% (Digest of Statistics 2012; India-Brand-Equity-Foundation 2015). Of the major crops in the state (rice, wheat, and maize) the productivity of rice increased from 1057 to 1842 kg/ha and wheat from

**Table 2 Correlation matrix of organic and inorganic contents in agricultural soil in the floodplains of Munawar Tawi during January and June 2014**

	pH	EC	OC	N	P	K	Na	Mg	Ca	Cu	Zn	Fe	Mn
January													
pH	1												
EC	0.845 <sup>a</sup>	1											
OC	−0.297	−0.027	1										
N	−0.754 <sup>a</sup>	−0.388 <sup>b</sup>	0.726 <sup>a</sup>	1									
P	−0.437 <sup>b</sup>	−0.709 <sup>a</sup>	−0.521 <sup>a</sup>	−0.108	1								
K	0.472 <sup>b</sup>	0.711 <sup>a</sup>	0.588 <sup>a</sup>	0.173	−0.890 <sup>a</sup>	1							
Na	0	0.226	0.098	0.049	−0.440 <sup>b</sup>	0.125	1						
Mg	0.507 <sup>a</sup>	0.556 <sup>a</sup>	0.432 <sup>b</sup>	−0.172	−0.757 <sup>a</sup>	0.629 <sup>a</sup>	0.341	1					
Ca	0.178	0.151	−0.389 <sup>b</sup>	−0.293	0.440 <sup>b</sup>	−0.245	−0.189	−0.426 <sup>b</sup>	1				
Cu	−0.473	−0.104	0.896 <sup>a</sup>	0.808 <sup>a</sup>	−0.509 <sup>a</sup>	0.436 <sup>b</sup>	0.285	0.25	−0.416 <sup>b</sup>	1			
Zn	−0.104	0.286	0.613 <sup>a</sup>	0.555 <sup>a</sup>	−0.641 <sup>a</sup>	0.612 <sup>a</sup>	−0.044	0.326	−0.405 <sup>b</sup>	0.693 <sup>a</sup>	1		
Fe	0.641 <sup>a</sup>	0.552 <sup>a</sup>	−0.362	−0.666 <sup>a</sup>	−0.301	0.03	0.450 <sup>b</sup>	0.591 <sup>a</sup>	−0.037	−0.368	−0.175	1	
Mn	0.858 <sup>a</sup>	0.889 <sup>a</sup>	−0.002	−0.363	−0.537 <sup>a</sup>	0.679 <sup>a</sup>	−0.027	0.466 <sup>b</sup>	0.187	−0.209	0.141	0.427 <sup>b</sup>	1
June													
pH	1												
EC	0.470 <sup>b</sup>	1											
OC	−0.555 <sup>a</sup>	0.297	1										
N	−0.166	−0.762 <sup>a</sup>	−0.635 <sup>a</sup>	1									
P	−0.977 <sup>a</sup>	−0.414 <sup>b</sup>	0.562 <sup>a</sup>	0.139	1								
K	0.644 <sup>a</sup>	0.887 <sup>a</sup>	0.245	−0.815 <sup>a</sup>	−0.604 <sup>a</sup>	1							
Na	0.608 <sup>a</sup>	0.816 <sup>a</sup>	0.154	−0.589 <sup>a</sup>	−0.577 <sup>a</sup>	0.813 <sup>a</sup>	1						
Mg	−0.769 <sup>a</sup>	−0.243	0.504 <sup>a</sup>	−0.055	0.789 <sup>a</sup>	−0.395 <sup>b</sup>	−0.37	1					
Ca	0.450 <sup>b</sup>	−0.186	−0.610 <sup>a</sup>	0.325	−0.531 <sup>a</sup>	−0.037	−0.208	−0.770 <sup>a</sup>	1				
Cu	−0.2	0.664 <sup>a</sup>	0.871 <sup>a</sup>	−0.848 <sup>a</sup>	0.25	0.613 <sup>a</sup>	0.403 <sup>b</sup>	0.272	−0.523 <sup>a</sup>	1			
Zn	0.346	0.889 <sup>a</sup>	0.539 <sup>a</sup>	−0.911 <sup>a</sup>	−0.289	0.936 <sup>a</sup>	0.720 <sup>a</sup>	−0.148	−0.26	0.848 <sup>a</sup>	1		
Fe	−0.726 <sup>a</sup>	0.194	0.917 <sup>a</sup>	−0.475 <sup>b</sup>	0.766 <sup>a</sup>	0.039	−0.082	0.647 <sup>a</sup>	−0.650 <sup>a</sup>	0.811 <sup>a</sup>	0.384 <sup>b</sup>	1	
Mn	0.832 <sup>a</sup>	0.844 <sup>a</sup>	−0.056	−0.612 <sup>a</sup>	−0.781 <sup>a</sup>	0.925 <sup>a</sup>	0.826 <sup>a</sup>	−0.518 <sup>a</sup>	0.084	0.334	0.769 <sup>a</sup>	−0.252	1

OC organic carbon, EC electrical conductivity

<sup>a</sup> Correlation is significant at  $p < 0.01$  level<sup>b</sup> Correlation is significant at  $p < 0.05$  level**Table 3 Correlation between area under cultivation of rice, maize and wheat and their respective yields**

Year	Area		
	Rice	Maize	Wheat
Yield			
Rice	0.853**		
Maize		0.561	
Wheat			−0.677*

\* Correlation is significant at  $p < 0.05$  level\*\* Correlation is significant at  $p < 0.01$  level**Table 4 Correlation matrix between fertilizer input with yield of rice, maize and wheat**

Year	Yield		
	Rice	Maize	Wheat
Fertilizer			
N	−0.334	−0.01	−0.079
P	−0.371	−0.122	−0.11
K	0.15	−0.185	−0.229

675 to 1701 kg/ha from 1964 to 2011 and 1964 to 2012 in Jammu region within which the study area falls. Agricultural fields, largely free of anthropogenic pollution for

there are no industries and urban centers in its upper reaches, receives sewage and domestic wastes only on reaching the Rajouri town. These wastes (Sewage, domestic and commercial) dumped directly into Munawar Tawi at Rajouri town, could possibly enter only nearby and

downstream agricultural fields. Thus, studies in future need to address these aspect along with varying levels of nutrients, in the precincts of the town due to its growing population and consequent economic activities, and its possible consequences.

In the present study, pH, EC, primary and secondary macro and micronutrients vary significantly across seasons, localities and stage of the crop. Similar observations have been reported from studies elsewhere (Trolstra et al. 1990; Wang et al. 2014). This can be due to differences in the uptake of nutrients by the crops during growing and harvesting periods, rate of fertilizer inputs and other natural seasonal variations (Gornall et al. 2010; Turner et al. 2013). In January, the water flow of Munawar Tawi is lower than in June. Increase in pH, EC, Fe and Mn towards downstream could be due to discharge of waste from the town and adjacent areas. Higher amount of N, K, Cu, Zn, Mg, OC and Na in the town area could be mainly due to municipal/domestic wastes released in the area. However higher flow of water could be leading to inflow of N from the agriculture fields in downstream locations. Ca and pH are higher in downstream location in June as well. For some of the elements, natural sources may be significant contributors, being released from the withering of the substratum and the banks. The rocks in the catchment area belong to murree group (Central Ground Water Board, Government of India 2013). P decreases in both seasons in the downstream due to lower release of detergents and wastewater in the downstream areas than town. Although changes in the above nutrients have been seen with seasons and localities in the present study, it does not allow specifying if the nutrients are varying due to crop rotation, fertilizer inputs, weather or any other physical processes. A robust dataset on pedological aspects, crop yield and area under major crops cultivated in Rajouri can be valuable as the baseline for an integrated approach to sustain nutrients balance in near future (Kumar et al. 2011).

Rice is the staple food of about 50% of the world population with a production of 618.4 million metric tons (MT) annually (IRRI 2005). Asia contributes 556.2 million MT annually in which India produces 140 million MT (MAC 2007). For various reasons, yields of rice, maize and wheat has increased worldwide during the past couple of decades (Khush 2005; Burch et al. 2007; Roberts 2009; Godfray et al. 2010). Average yield of rice/hectare in Rajouri was lower than the average for the whole India during 2000–2011 (Government of India 2010). During 2011–2012, average yield of maize in Rajouri was higher than that of India (Yadav 2015); whereas average yield of wheat is lower than the Indian average (Government of India 2015). In Rajouri, crop

yield as well as area under cultivation showed insignificant change from 2000 to 2012. However, the correlations observed in the case of present data between area under cultivation and yield, especially in the case of maize and wheat, questions the veracity of the official dataset. In the case of wheat, with the increase in the area under cultivation the yield is seen declining significantly and that possibly points to the faulty dataset consolidated and published by the government agencies, and the lack of care in preparing such a vital database. In order to improve and sustain the agriculture sector, a robust dataset is required. In Himalayas, despite increasing threats to agriculture sector due to changing land use practices, fertilizer consumption pattern and climate change, the dataset published by government agencies is apparently inadequate.

Rice yield is declining in India due to injudicious use of fertilizers (Ladha et al. 2003, 2005). In the case of Rajouri district, even after significant increase in addition of N and P, rice in the yields of rice, maize and wheat are insignificant. Incidentally, it is to be noted that higher addition of N and P could also lead to deficiency of K and micronutrients (Singh 2008; Wang et al. 2014). The prescribed usage of N fertilizer in the crop vary but on an average it is 50 kg/ha (Digest of Statistics 2012) lower than in plains (80 kg/ha, Parihar 2004). It has been also reported that adding N, while increases productivity in the early stages, later exhausts nutrients and hence cannot sustain yield by adding even P (Kanwar and Randhawa 1974; Singh 1988, 2008). Studies from northwestern India also reports decline in agriculture due to falling soil fertility, change in water table, increasing salinity, pest resistance to pesticides and degrading quality of irrigation water (Sinha et al. 1998; Tiwari et al. 2009).

Globally climate changes have grave implications on agricultural productivity, although the aggregate impact is not yet known (Gornall et al. 2010). The impacts on crop productivity vary at local to regional scale depending on the climate scenarios such as rising temperature, CO<sub>2</sub> and their interactions (Mall et al. 2006). Change in temperature and precipitation patterns also influence soil water content, run-off, erosion, biodiversity, organic carbon and nitrogen (Mall et al. 2006). Impacts also vary based on crops, level of agronomic management, region and season (Mall et al. 2006; Lobell and Burke 2009). Globally growing competition for land, water and labor from non-agriculture sectors poses a threat to the agriculture (Kumar et al. 2011). Adoption of improved soil management practices and soil restoration in view of climate change is vital to achieve global food security (Lal 2009). Hence, region-specific studies on soil problems, especially in vulnerable regions such as Himalayas are wanted.



## Conclusion

The study presents information on the soil characteristics in crop fields in Rajouri town, its upstream and downstream locations. Soil in the area is clay loam, black, non-calcareous and acidic. Statistical tests showed nutrients varying across seasons and locations significantly. Linear regression showed changes in area and yield under rice, wheat and maize to be insignificant during 2000–2012 whereas inputs of N and P fertilizer increased during the same period significantly. Increasing addition of N and P may lead to a deficiency of micronutrients in near future. The correlation matrix between areas under rice, wheat and maize with their respective yields gives contradictory results (significantly positive relation for rice and negative in the case of wheat), which raises doubt on the veracity of the dataset published by government agencies. Insignificant relation between increasing N, P fertilizer input and yields of rice, maize and wheat, contradicts with studies reported elsewhere and widely accepted conclusions, again casting doubt on official data. The present study highlight need for generating data on crops and yields that are more authentic for the western Himalayan area. This is a study first of its kind providing baseline data on soil characteristics in Western Himalayas, a highly vulnerable region for climate change impacts.

## Additional file

**Additional file 1: Figure S1.** Hydrogeology of Rajouri district (Not to scale), Source Central Ground Water Board, Government of India, 2013.  
**Figure S2.** Total Inputs of N, P and K fertilizers during 1999–2000 to 2011–2012 in Rajouri (Source-District Census Report 2011, Census of India).  
**Figure S3.** Yield of rice, maize and wheat from 1999–2000 to 2000–2012 in Rajouri (Source-Digest of Statistics, Jammu & Kashmir 2011–12).

## Authors' contributions

Authors are required to specify individual contributions. MZ designed the research, collected and analyzed data, and wrote the paper. MAA helped in data collection. PAA contributed to design of the study, data analysis, interpretation and manuscript writing. EB helped in manuscript writing. All authors read and approved the final manuscript.

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## Competing interests

Authors must disclose all affiliations, funding sources, financial or personal relationships that could be perceived as potential sources of bias. We do not have any competing interests with respect to the article. Mr. Mohd Zeeshan worked as a research fellow on project sanctioned by DST New Delhi, Government of India. Mr. Mohd Azhar Ali worked as a volunteer in the field. Dr. P A

Azeez supervised the work and Dr. Edita Baltrėnaite helped in preparing the manuscript. The data used in the paper was collected while working for the project.

## Availability of data and materials

The dataset and materials used for the paper is available and can be shared.

## Consent for publication

Not applicable.

## Ethics approval and consent to participate

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## References

- Aggarwal PK (2008) Global climate change and Indian agriculture: impacts, adaptation and mitigation. *Indian J Agric Sci* 78(11):911
- Allen BL, Hajek BF (1989) Mineral occurrence in soil environments. *Miner Soil Environ (mineralsinsoile)*: 199–278
- Bailey JS (1993) Soil and crop analysis: a pocket manual. Department of Agriculture, Northern Ireland, Belfast
- Berrow ML, Stein WM (1983) Extraction of metals from soils and sewage sludges by refluxing with aqua regia. *Analyst* 108(1283):277–285
- Bray RH, Kurtz LT (1945) Determination of total, organic, and available forms of phosphorus in soils. *Soil Sci* 59(1):39–46
- Burch D, Lawrence G, Green GP, Ichijo K, Nonaka I, Pimentel M, Carneiro MJ (2007) World Development Report 2008: agriculture for development (No. E14 231). The World Bank, Washington
- Cassman KG (1999) Ecological intensification of cereal production systems: yield potential, soil quality, and precision agriculture. *Proc Natl Acad Sci* 96(11):5952–5959
- Central Ground Water Board, Government of India (2013) Ground water Information Booklet Rajouri District, Jammu and Kashmir, p 1–20
- Chorley RJ (1969) Water, earth, and man. A synthesis of hydrology, geomorphology, and socio-economic geography. *Water Earth Man Synth Hydrol Geomorphol Socio-Econ Geogr*
- Das DK, Maiti D, Pathak H (2009) Site-specific nutrient management in rice in Eastern India using a modeling approach. *Nutrient Cycl Agroecosyst* 83(1):85–94
- Digest of Statistics (2012) Directorate of economics and statistics, Government of Jammu and Kashmir
- Directorate of Economics and Statistics, Ministry of Agriculture, Govt. of India (2010) All India rice exporters association. <http://www.airea.net/page/62/statistical-data/all-india-area-production-and-yield-of-rice>. Accessed 10 June 2016
- Directorate of Economics & Statistics, Ministry of Agriculture, Govt. of India (2015) All India Area, production and yield status of major crops during 2012–13 and 2011–12
- Doran JW, Parkin TB (1994) Defining and assessing soil quality. *Defin Soil Qual Sustain Environ (definingsoilqua)*: 1–21
- Dortch JM, Owen LA, Haneburg WC, Caffee MW, Dietsch C, Kamp U (2009) Nature and timing of large landslides in the Himalaya and Transhimalaya in Northern India. *Quat Sci Rev* 28:1037–1054
- Editorial (2015) Sleepless in Kashmir. *The Hindu*. <http://www.thehindu.com/opinion/editorial/sleepless-in-kashmir/article7061855.ece>
- Fischer G, Shah M, Van Velthuisen H (2002) Climate change and agricultural vulnerability
- Gentle P, Maraseni TN (2012) Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal. *Environ Sci Policy* 21:24–34

- Godfray H CJ, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Thomas SM, Toulmin C (2010) Food security: the challenge of feeding 9 billion people. *Science* 327(5967):812–818
- Gornall J, Betts R, Burke E, Clark R, Camp J, Willett K, Wiltshire A (2010) Implications of climate change for agricultural productivity in the early twenty-first century. *Philos Trans R Soc Lond B Biol Sci* 365(1554):2973–2989
- Gregorich EG, Carter MR (eds) (1997) Soil quality for crop production and ecosystem health, vol 25. Amsterdam, Elsevier. [www.agricoop.nic.in](http://www.agricoop.nic.in)
- Gupta RD, Tripathi BR (1996) Mineralogy, genesis and classification of soils of North-West Himalayas developed on different parent materials and variable topography. *J Indian Soc Soil Sci* 44(4):705–712
- Hubbard J, Shaw JH (2009) Uplift of the Longmen Shan and Tibetan Plateau, and The 2008 Wenchuan (M = 7.9) earthquake. *Nature* 458:194–197
- Immerzeel WW, Van Beek LP, Bierkens MF (2010) Climate change will affect the Asian water towers. *Science* 328(5984):1382–1385
- India, Brand, Equity, Foundation (2015). <http://www.ibef.org/industry/agriculture-india.aspx>. Accessed 27 May 2017
- Intergovernmental Panel on Climate Change (2014) Climate Change 2014—impacts, adaptation and vulnerability: regional aspects. Cambridge University Press, Cambridge
- IRRI (2005) Rice around the world. International Rice Research Institute, Philippines. <http://www.irri.org>
- Jackson RD (1973) Diurnal changes in soil water content during drying. *Field Soil Water Regime (fieldsoilwater)*: 37–55
- Kanwar JS, Randhawa NS (1974) Micronutrient research in soils and plants in India (a review). ICAR, New Delhi
- Karlen DL, Mausbach MJ, Doran JW, Cline RG, Harris RF, Schuman GE (1997) Soil quality: a concept, definition, and framework for evaluation (a guest editorial). *Soil Sci Soc Am J* 61(1):4–10
- Khush GS (2005) What it will take to feed 5.0 billion rice consumers in 2030. *Plant Mol Biol* 59(1):1–6
- Kishor K, Shashi K (2002) Early miocene cricetid rodent (mammalia) from the muree group of Kalakot, Rajauri District, Jammu and Kashmir, India. *Curr Sci* 82(6):736–739
- Krumbein WC, Graybill FA (1965) An introduction to statistical models in ecology, vol 475. McGraw-Hill, New York
- Kumar SN, Aggarwal PK, Rani S, Jain S, Saxena R, Chauhan N (2011) Impact of climate change on crop productivity in Western Chats, coastal and north-eastern regions of India. *Curr Sci (Bangalore)* 101(3):332–341
- Ladha JK, Pathak H, Tirol-Padre A, Dawe D, Gupta RK (2003) Productivity trends in intensive rice–wheat cropping systems in Asia. *Improv Product Sustain Rice–Wheat Syst: Issues Impacts, (improvingthepro)*: 45–76
- Ladha JK, Pathak H, Krupnik TJ, Six J, van Kessel C (2005) Efficiency of fertilizer nitrogen in cereal production: retrospects and prospects. *Adv Agron* 87:85–156
- Lal R (2009) Soils and food sufficiency. A review. *Agron Sustain Dev* 29(1):113–133
- Larson WE, Pierce FJ (1994) The dynamics of soil quality as a measure of sustainable management. *Defin Soil Qual Sustain Environ (definingsoilqua)*: 37–51
- Lindsay WL, Norvell WA (1978) Development of a DTPA soil test for zinc, iron, manganese, and copper. *Soil Sci Soc Am J* 42(3):421–428
- Lobell DB, Burke M (eds) (2009) Climate change and food security: adapting agriculture to a warmer world, vol 37. Springer Science & Business Media, Berlin
- MAC (2007) Agricultural statistics at a glance 2006–07. Ministry of Agriculture and Cooperation, Government of
- Mall RK, Singh R, Gupta A, Srinivasan G, Rathore LS (2006) Impact of climate change on Indian agriculture: a review. *Climatic Change* 78(2–4):445–478
- Parihar S (2004) Effect of crop establishment method, tillage, irrigation and nitrogen on production potential of rice (*Oryza sativa* L.)-wheat (*Triticum aestivum* L.) cropping system. *Indian J Agron* 49:1–5
- Parry ML, Rosenzweig C, Iglesias A, Livermore M, Fischer G (2004) Effects of climate change on global food production under SRES emissions and socio-economic scenarios. *Global Environ Change* 14(1):53–67
- Prusty BAK, Azeez PA (2007) Vertical distribution of alkali and alkaline earth metals in the soil profile of a wetland–terrestrial ecosystem complex in India. *Soil Res* 45(7):533–542
- Rai SC, Sharma E (1998) Hydrology and nutrient flux in an agrarian watershed of the Sikkim Himalaya. *J Soil Water Conserv* 53(2):125–132
- Roberts TL (2009) The role of fertilizer in growing the world's food. *Better Crops* 93(2):12–15
- Rosenzweig C, Parry ML (1994) Potential impact of climate change on world food supply. *Nature* 367(6459):133–138
- Saini AD, Nanda R (1986) Influence of temperature and light-intensity during ear growth period on grain number in wheat. *Indian J Agric Sci* 56(7):512–519
- Samra JS, Singh G (2004) Heat Wave of March 2004: Impact on Agriculture. Indian Council of Agricultural Research, New Delhi, p 32
- Sharma PSCR, Rai SC (2004) Streamflow, sediment and carbon transport from a Himalayan watershed. *J Hydrol* 289(1):190–203
- Singh MV (1988) Response of rice (*Oryza sativa*) and wheat (*Triticum aestivum*) to phosphorus and zinc fertilization in sodic soil. *Indian J Agric Scie (India)*
- Singh MV (2008) Micronutrient deficiencies in crops and soils in India. In: Micronutrient deficiencies in global crop production. Springer, Netherlands, pp 93–125
- Singh JS, Pandey AN, Pathak PC (1983) A hypothesis to account for the major pathway of soil loss from Himalaya. *Environ Conserv* 10(04):343–345
- Sinha SK, Singh GB, Rai M (1998) Decline in crop productivity in Haryana and Punjab: Myth or reality. Indian Council of Agricultural Research, New Delhi, India, p 89
- Subba Rao A (2001) Analysis of soils for available major nutrients. In: Tandon HLS (ed) Methods of analysis of soils, plants, waters and fertilizers. Fertilizer Development and Consultation Organization (FDCO), New Delhi
- Subba Rao A, Sammi Reddy K (2005) Analysis of soils for pH, EC and available major nutrients. In: Methods of analysis of soils, plants, waters and fertilizers, pp 21–59
- Tandon HLS (2005) Methods of analysis of soils, plants, waters, fertilisers & organic manures. Fertiliser Development and Consultation Organisation, New Delhi
- Tandon HLS, Tandon KS (1995) Statewise and cropwise recommendations. In: Fertiliser and integrated nutrient recommendations for balance and efficiency, pp 35–103
- Tiwari VM, Wahr J, Swenson S (2009) Dwindling groundwater resources in northern India, from satellite gravity observations. *Geophys Res Lett* 36(18). doi:10.1029/2009GL039401
- Troelstra SR, Lotz LAP, Wagenaar R, Sluimer L (1990) Temporal and spatial variability in soil nutrient status of a former beach plain. *Plant Soil* 127(1):1–12
- Tse-ring K, Sharma E, Chettri N, Shrestha A (2010) Climate change impact and vulnerability in the Eastern Himalayas-Synthesis Report. International Centre for Integrated Mountain Development, Kathmandu
- Turner BL, Yavitt JB, Harms KE, Garcia MN, Romero TE, Wright SJ (2013) Seasonal changes and treatment effects on soil inorganic nutrients following a decade of fertilizer addition in a lowland tropical forest. *Soil Sci Soc Am J* 77(4):1357–1369
- Walkley A, Black IA (1934) An examination of the Degtjareff method for determining soil organic matter, and a proposed modification of the chromic acid titration method. *Soil Sci* 37(1):29–38
- Wang X, Tong Y, Gao Y, Gao P, Liu F, Zhao Z, Pang Y (2014) Spatial and temporal variations of crop fertilization and soil fertility in the Loess Plateau in China from the 1970s to the 2000s. *PLoS ONE* 9(11):e112273
- Warkentin BP (1995) The changing concept of soil quality. *J Soil Water Conserv* 50(3):226–228
- Xu J, Grumbine RE, Shrestha A, Eriksson M, Yang X, Wang YUN, Wilkes A (2009) The melting Himalayas: cascading effects of climate change on water, biodiversity, and livelihoods. *Conserv Biol* 23(3):520–530
- Yadav OP (2015) Review of research of AICRP on Maize 2014. <http://iimr.res.in/documents/Director%20Review%20-2015.pdf>. Accessed 14 June 2016