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Nutrient (NPK) and (C_{org}) Losses via Surface Run-Off in Urban Agriculture (UA) of Kabul, Afghanistan

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Abstract

The constructed areas in Kabul city have been encircled by urban fields. Rainfall always contributes to crop productions and sedimentations in streams, water courses, and in Kabul River. The fields are regularly used for fresh vegetables and cereals productions which rely on the use of night soil and city bio-wastes. The run-off erosion degrades environment by contamination of surface and underground water, Kabul River and other low Laying water bodies. A study on "Organic matter and nutrient (NPKC) losses via run-off in the UA of Kabul" was conducted on 2012-2015 to quantify NPK and C_{org} losses via runoff in the urban fields of Kabul. Four endemic crops of Kabul Province were planted in the rotation. The total average soil losses in two farms (n= 27) in the duration of three years were 248.48 kg ha^{-1}. Wheat and millet had 14.46 and 15.11%, barley and maize had 21.55, and 21.02% soil losses, respectively. In control plots of college farm 23.89%, Guzargah farm 30.86% and combined losses in both farms were (27.86%). The average total N, P, K losses were 0.19 Kg ha^{-1}, 0.013 kg ha^{-1}, 0.27 kg ha^{-1}, and C_{org} 2.61kg ha^{-1}, respectively. Statistically the variation showed significant differences ($P \leq 0.05$.

INTRODUCTION

Kabul, one of the highest capitals in the world, with its current population of 4.2 million (CSO. 2014/2015) is located at 18.0 m a s l. Kabul's soil has developed under arid and semiarid climatic condition. Unplanned use of city bio-wastes and sewage water for irrigation remained always main sources of nutrients imbalance in the urban soil (Safi *et al.*, 2010). The elemental overloaded sewage waters increase the materials toxicities in the soil during irrigation which degrades the environment. Despite of economic losses, leaching of nitrite, nitrate, phosphate, and ammonium contaminate surface and underground water. It is reported that Kabul basin is indicating deposits including sand, silt and clay which have been imported from the surrounded mountains originated by carbonates, marls, sand stones and from melted magma karsts. Ground water in some places of Kabul city is affected by sedimentation which contained toxic materials such as NO_2, NO_3, Bo_2 and other soluble contaminants (Initial Environmental Examination., 2011; Mohummad *et al.*, 2014). The 10.8% contaminated wells of Kabul with nitrate can be good example (Houben, 2005). Leaching of nitrate, phosphate and ammonium in the vegetable production areas were reported high too (Safi *et al.*, 2011). Contamination of Kabul River in the low laying area of Peshawar with some toxic elements was also reported. (IUCN, Pollution and the Kabul River, 1994). This can be solved by study of the current ongoing farming system and applying different practices such as soil and crop management, soil erosion control will increase soil productivity. Chaudary and Shafiq reported that crop management is one of the best ways of soil erosion control (Chaudhry and Shafiq, 1986). The practice of good cultivation combination, optimum sowing method, use of mulching; disclose crop cultivation and precise use of chemical and organic fertilizers may enhance soil protection (Khan et al. 2007).

Lack of researches, experts and other professional staff in the country or missing proper developmental budget of the government for research has made soil preservation in the country especially in urban area of Kabul impossible, so far. Based on the following highlighted problems we have studied organic matter and nutrient removal via surface run-off to the streams, rivers, ponds and water bodies and its consequences in the future urban dwellers' life.

The applied city bio-wastes, and sewage sediments are vulnerable to the erosion and are easily removed by run-off water. The transportation of such materials to the water courses, streams and canals may cause pollution and degrading the environment. The polluted environmental negative effects are obvious in the health of inhabitants. (Safi, 1998).

In the cereal areas (due to lack of water for irrigation), the cropping system is mostly mono cropping. After crop harvest, the field is left unplowed and is intensively grazed by local animals. The crop residues used by animal or being collected by local poor people for heat generation in their kitchens. The exposed soil surface remains very sensitive to the wind and water erosion. The subsequent sedimentation in the irrigation systems and even in electric generating dam cause huge economic losses to the investments. Filling of Naghlo, Daronta and Sarobi dam can be one of the best examples in the country.

The dominated slopes of the land in the cereal areas of Kabul were between 0.5 – 2% which shows that cereal areas in contrast to the field of vegetables and vineyards was highly erosive. This indicates that organic and inorganic surface materials are highly transportable in the cereals system. Despite of soil removals, there is possibility of creating rills and gullies in the surface of the land which may create constraints for irrigation and operating farm machineries.

In addition, monocropping is enhancing the soil erosion followed by impediment for furrowing and irrigation of the field. Lacking data on nutrient losses via torrential rainfall in the urban area of Kabul made it difficult to plan cultivation with reduce erosion. Our study will explore the amount of organic matter (C_{og}) and crop nutrients leaving the fields via run-off.

The major objectives of the study were:

1. Measurements of the soil and organic matter removed by runoff.
2. Measurements of crops nutrients (N, P, K, C) in the sediments.

3. Identifying the factors that influence soil and nutrient erosion losses due to runoff
4. Explaining how runoff, soil erosion and nutrient loss are related.
5. Comparison of the nutrient lost by runoff versus nutrient obtained by production.

The aim of this research was control economic losses of the farmers', protect Human Health and environmental degradation.

MATERIALS AND METHODS

Geographic Location of The Area and Site Selection

Greater Kabul is located in a valley, bordered by high mountain ranges. The average annual precipitation of 300-330 mm occurs mainly from November to May and the surrounding natural semi-desert steppe vegetation provides vast grazing grounds for small and large ruminants for three summer months. Average annual temperature varies between 10°C to 13°C with a relative humidity of 54% (Grieser *et al.*, 2006; Houben and Tunnermeier 2005), (1957-1977). During the latest study of the author (April 2008-March 2010) the climatic conditions were with an average annual rainfall of 176 mm and 346 mm, a relative humidity of 45.3% and, an average temperature of 14.8°C drier and hotter than normal (Safi *et al.,* 2011).

In the study area rain-fed wheat (*Triticum aestivum* L.) is grown on 6% of the cultivated land and harvested between July and August, while irrigated wheat, potato (*Solanum tuberosum* L.) and fresh vegetables occupying 94% of the land were harvested between May and October. Irrigation systems are fed by diverted rivers and the traditional underground 'Karez' channel systems. Average cultivated land of a farm household is 0.2 ha, but a few large households had irrigated farms >1 ha. The livestock sector in the Kabul region is dominated by cattle (including dairy cows) and sheep, but also comprises goats, donkeys, horses and poultry.

Basic socio-economic data on Kabul's UPA systems were reported by Safi which indicated that the vegetable farming system in the highly populated areas along the Kabul River (34°29' 59.76" N, 69°09'22.06" E; 1,765 m alttitude from sea level) where plot sizes range from 54 -1,000 m^2 and the most important species are radish (*Raphanus sativus* L), coriander (*Coriandrum sativum* L), leek (*Allium ampeloprasum* var. *porrum* L), onion (*Allium cepa* L), carrot (*Daucus carota* L.), turnip (*Brassica compestris* var. *rapa* L.), eggplant (*Solanum melongena* L.), spinach (*Spinacia oleracea* L.), pepper (*Capsicum annuum* L.), lettuce (*Lactuca sativa* L.), mint (*Mentha arvensis* L.), garlic (*Allium sativum* L.), cabbage (*Brassica oleracea* L.), pumpkin (*Cucurbita moschata* L.), tomato (*Lycopersicon esculentum* L.), and forages. Farm work, product sales, and input acquisition keep farmers busy throughout the year.

The cereal production area (34°28'45.96"N, 69°12'54.94"E; 1,767 m alttitude from sea level) is in the southern part of the city. It obtains its irrigation water from the Char Asyab district in the spring season, but during summer the amount of available water is insufficient for irrigation. This area has no proper drainage and in spring occasional rainfall events may lead to flash floods that rush through the low laying areas. At plot sizes of 100 - 2,000 m^2 the local cropping system is dominated by wheat, followed by potato, onion, turnip, corn (*Zea mays* L.), and forages. This system is largely subsistenceoriented whereby open land is used by pastoralists whose animals are freely grazing in the city surroundings.

The vineyards for raisin grape production (34°34′12.27″N, 69°14′13.15″E; 1,758 m a.s. l.) with plot sizes of 200-6,497 m^2 have a well-established irrigation infrastructure. For these access to the city's solid organic waste inputs is hampered by Kabul's international airport separating this area from the city center. In the spring, irrigation water for this area comes from Kabul River and during the remainder of the year from sewage water of residential areas complemented by sewage sludge compost.

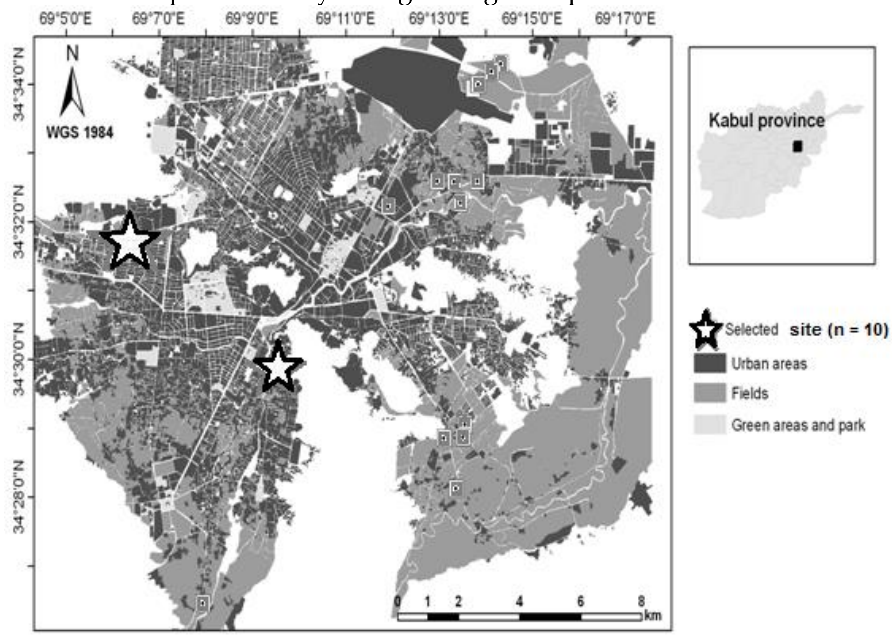

Figure 1: Map of Greater Kabul in Afghanistan showing the location of the selected research sites.

Layout of The Experiment

Design RCB, 5 treatments were replicated 3 times
Plot size: 1.5x2 = 3 m^2
Treatments: Wheat, Maize, Barley, Millet and Control
Slope; Average slope 0.5 – 1% (Sharma**,** 2007)
Plot to plot distance: 0.3 m
Distance between replications was 0.50 m
All plots were marked prior to the cultivation. Polyethylene plastic buckets and siphons were installed properly in each plot and were covered with plastic sheet.

Measurements of Sedimentations

Subsequent to the rainfall, the sedimentations have been collected and transferred to the laboratory; conical flask and filter paper were used for filtration of the sediments. The filtered material dried in room temperature. Subsequently the dried soil samples of each plot (treatment) were stored in polyethylene bottles and sealed until analysis of N, P, K and C.

Chemical Analyses

Total soil N and total soil C were determined by a Vario MAX CN/CHN/CNS analyzer (Elementar Analyses system GmbH, Hanau, Germany). Plant available soil P and K were determined using the CAL method (Hoffmann, 1991) at 460 nm and by flame photometry (Auto Cal 743, Instrumentation Laboratory, Milan, Italy), respectively. Organic matter (OM) was determined according to the method described by Close and Menke (Close and Menke, 1986). A conversion factor of 1.724 from OM to C_{org} was used based on the assumption that OM contains 58% of organic C (Nelson and Sommers, 1996).

Statistical Analyses

Analyses of Variance (ANOVA), Multivariate Analyses of Variance (MANOVA), and Univariate Analyses of Variances (UANOVA) were performed using SPSS (Version 18.0, SPSS Inc., Chicago, IL, USA) to determine the significance of differences between the different treatments for soil and nutrient control.

RESULTS

Status of Precipitation in The Duration of Research

The annual data of six meteorological stations (Badam Bagh, Darul aman, Gulkhana, Kabul station, Paghman station and Qargha station; USGS, 2012-2014) revealed that total amount of rainfall had optimum distribution and intensity throughout the three years which decline the possibility of soil erosion. The rainfall occurred in January, February, March, and April had finer distributions, but precipitations on May with its higher intensities and amounts caused erosion. Rainfall in June, July had less amount, intensity and distribution but rainfall of August, September, October, November and December with increased amount and less distribution showed high soil erosion. As a whole, on the year 2012, amount of rainfall was more (43.87%) than 2013 (33.44%) and 2014 (22.67%). Despite of the amount of rainfall, intensity and distribution, there are few factors which influence runoff and soil erosion such as: soil properties, soil structures, soil water holding capacity and field slopes.

Total Soil Losses (N=15, 12, 27) Via Surface Run-Off Water On (2012-2014) In College of Agriculture Farm and Guzarghah Research Station.

The total average soil losses in the College Farm (n= 15) in 2012 – 2014 was 192.14 kg ha^{-1} (table 1). Soil losses from different treatments range 16.96 – 23.89%. Barley had minimum soil losses (16.96%), maize, millet, and wheat with soil losses of 21.90, 18.89, and 18.36% had medium, respectively, but control plot with soil losses of 23.89% showed maximum soil erosion via run-off in the College Farm.

The total average soil losses in Guzargah farm (n= 12) were 318.91 kg ha^{-1}. Soil losses from different treatment range 11.11 – 30.88%. Wheat had minimum soil losses (11.11%), Barley, Maize, and Millet had medium soil losses of 25. 06, 20.37 and 12.66%, respectively. While, control plot with soil losses of 30.86 showed maximum soil erosion via run-off.

The total average soil losses from two farms (n= 27) in the duration of three years was 248.48 kg ha^{-1}. Soil losses in different treatment range 14.46 – 27.86%. Wheat and millet had minimum soil losses of 14.46 and 15.11%. Barley and maize had medium soil losses of 21.55, 21.02%, respectively, while, the control plot had shown maximum soil losses (27.86%) via runoff.

Table 1: Annual soil losses (n=6, 12, 9) via run-off (2012-2014) in the college of agriculture farm and guzarghah research station.

Year	Farm	Treatment	Mean (Kg ha^{-1})	Std. Deviation	N
Total	**College Farm**	Barley	32.59	36.87	15
		Control	45.90	33.86	15
		Maiz	42.07	40.52	15
		Millet	35.27	38.0	15
		Wheat	36.30	34.36	15
	Guzargah Farm	Barley	79.74	61.83	12
		Control	98.41	75.20	12
		Maiz	64.95	47.84	12
		millet	40.37	24.21	12
		wheat	35.44	20.06	12
	Total	barley	53.55	54.03	27
		control	69.24	60.97	27
		maiz	52.24	44.57	27
		millet	37.54	32.13	27
		wheat	35.92	28.39	27

$P \leq 0.05$

Total nutrient (n, p, k, c) losses (n=75, 60) via run-off (2012-2014) in the college of agriculture farm and guzarghah research station.

The data Analysis revealed interesting results, that using different cereal crops in the rotation had significant effect on erosion control of two sites. The soil losses data (table 1) and their subsequent (table 2) nutrient analysis revealed that total N losses was 0.19 Kg ha^{-1}, college farm had minimum losses (29.44%) as compared to the Guzargah farm (70.55%). However, the two farms had identical climatic conditions. Statistically the variation showed significant differences ($P \leq 0.05$)

The total P losses from the two farms were 0.013 kg ha^{-1}. College farm showed minimum losses (25.22%). Guzargah farm had maximum losses (59.52%). Statistically the variation of P losses between two farms was significant ($P \leq 0.05$). The total losses of K from the two farms were 0.27 kg ha^{-1}. College farm showed minimum losses (41.9%). And Guzargah farm had maximum losses (58.0%). The variation of K losses between two farms were significant ($P \leq 0.05$). The total losses of C_{og} in the two farms were 2.61kg ha^{-1}. College farm showed minimum losses (42.01%). While, Guzargah farm had maximum losses (58.0%). the variation of C_o losses between two farms showed significant differences ($P \leq 0.05$).

DISCUSSION

The average data of six meteorological stations indicated that urban areas of Kabul received rainfall with normalize distribution, intensity and duration in 2012 – 2014. The amount of rainfall 2012 (43.87%) was higher than 2013 (33.44%) and 2014 (22.67%). It is obvious that annual rainfall with normalize distribution and intensity may not generate surface run-off. However, the available data of rainfall and erosion were not consistent, because there was more rainfall but less erosion.

Possible reason should be flat surface of the land with slope of 0.5-1 which was confirmed by Romkens (Romkens *et al.*, 2001), who reported that level lands, smooth surfaces, short running surface for water, decreases soil erosion. Furthermore, it was also confirmed by Ziadat and Taimeh (Ziadat and Taimeh., 2013). Ziadat reported that rainfall intensity increases soil erosion. Fields covered with vegetation especially, prior to the rainfall season decrease soil erosion, the results were also confirmed by some other articles (Defra, 2005; Ali *et al.*, 2007).

Table 2: Nutrient (N, P, K, C) losses (n=75, 60) via surface run-off on (2012-2014) in college of agriculture and guzarghah research station.

Nutrient	Amount	Research Station	Mean	Std. Deviation	N
N kg ha-1	Total	College farm	0.06	0.05	75
		Guzargha farm	0.14	0.09	60
		Total	0.09	0.08	135
P kg ha-1	Total	College farm	0.0	0.0	75
		Guzargha farm	0.01	0.01	60
		Total	0.01	0.01	135
K kg ha-1	Total	College farm	0.01	0.01	75
		Guzargha farm	0.02	0.01	60
		Total	0.01	0.01	135
C kg ha-1	Total	College farm	1.29	1.22	75
		Guzargha farm	1.79	1.33	60
		Total	1.51	1.29	135

$P \leq 0.05$

Total average soil losses (n=15, 12, 27) via surface run-off on (2012-2014) in the college of agriculture farm and guzargah research station.

The total soil losses (n=15) were calculated under different cropping systems (wheat, barley, maize, millet and control) which were: total soil losses in College of Agriculture farm was 192 kg ha-1 in 2012-2014. Barley plots contributed (16.96%), maize, millet, and wheat plots revealed 21.90, 18.89, and 18.36% soil losses, respectively

The total average soil losses in Guzargah farm were 318.91 kg ha-1. Wheat had minimum soil losses (11.11%), Barley, maize, and millet, had 25.06, 20.37 and 12.66% medium soil losses, respectively.

The total average soil losses in two farms (n= 27) in the duration of three years were 248.48 kg ha^{-1}. As a whole, wheat and millet had 14.46 and 15.11% minimum soil losses, barley and maize had medium 21.55, and 21.02% soil losses, respectively. Our results became more interesting by observing amount of soil losses in the control plot of college farm 23.89%, Guzargah farm 30.86% and combined losses from both farms were (27.86%).

Possible reason for the variation of soil erosion in different treatments could be the soil properties, soil structure and soil water holding capacity. The second factor could be surface soil status; Michael reported that amount and status of the soil surface in the field should not be ignored (Michael, et. al., 1999). In this regards Limon, Neun and Micle pointed out that leaving more crop residues in the surface of soil, minimum tillage, should have its role in the control of soil erosion (Lemunyon, no date).

The third factor should be status of the seasonal rainfall which happens in different frequencies, amount, intensity, duration and time. The variations of the seasonal rainfall especially, in the arid and semi arid zones have been confirmed by Feng (Feng et. al., 2013). Furthermore, the existence of crops residues or crop growth stages may affect soil erosion rate. Slop is another erosion controlling factor which was moderate in these two farms. Wind breaker also affects soil erosion by decreasing the intensity and velocity of the raindrops on the soil surface. It would be better to search for further factors which may decrease the soil erosion and eliminate the concerns and problems. These results may have some problems. The data adopted from the meteorological station also revealed problems. To increase the viability and credibility of the data the number of metrological station should be increased.

These results have explored that growing of cereals especially, winter wheat, barley and millet in the rotation had beneficial role by protecting soil erosion. And losses of crop essential nutrient via night soil, organic matter, commercial fertilizer and so on.

The result has been confirmed by Zachar (Zachar, D. 2011). Basically, this issue was arisen in the workshop of R. C. S. (Kasper *et al.,* 2008) under the title of "Utilization of cereal as cover crops for environmental protection". In this workshop, several scientists such as thomkasper, Germy, Sangar, beennoston had participated and confirmed the content. Manor also recommended that barley, and wheat should be grown for soil erosion control and other benefits (Rasnake, *et al.* no date). The results of soil erosion control by plantation of cereals are also in line with the recommendation of G V Menreng sing (Mannering *et al.*, no date). Our results regarding the increased losses in maize plot in some years of the research has been confirmed by Ailincai (Ailincai *et al.*, 2011). He had argued that decreased losses in control plot may be related to the time of rainfall but some of the scientists discovered that cover crops always protect soil from erosion. This idea was highly contradicted with ideas which said that soil erosion is less in the fallow fields (Nabi *et al.*, 2008'; Atucha, *et al.*, 2012).

Total nutrient (n, p, k, oc) losses (n=75, 60) via surface run-off on (2012-2014) in the college of agriculture farm and guzarghah research station.

Using different cereal crops in the rotation showed significant effect on soil nutrient losses in the two sites. The nutrient losses data and their subsequent analysis revealed that total N losses was 0.19 Kg ha^{-1}, Guzargah farm exceeded N losses (70.55%), P (59.52%), K (58.0%) and C_{org} (58.0%) as compared to the college farm N, P, K and C_{org} losses by 29.44%, 25.22%, 41.9% and 42.01%, respectively. However, both farms had similar climatic conditions. Statistically the variation showed significant differences ($P \leq 0.05$). Nutrient removal due to crop harvest which is previously reported by Safi was found to be significantly higher than nutrient losses through soil erosion. This finding was confirmed by Tiwari (Tiwari *et al.,* 2009).

Possible reason for these variations should be those which were mentioned above for soil erosion. It is necessary to mention that solubility of the solvent in the saturated condition of the soil may cause erosion and will enhance nutrient leaching and percolation.

CONCLUSION AND RECOMMENDATIONS

Soil erosion via surface run-off from two farms of Kabul were neglected based on the universal soil loss equation were neglected. Under these circumstances soil erosions in the urban area of Kabul may not be risk for agricultural lands. In addition to moderate slop and little rainfall, the land status and precipitations time also affect soil losses. The most important corps which had good contributions to the control of soil erosion was wheat, barley, and somehow millet. Maize had less effect on soil erosion control.

Nutrient losses were highly related to the amount of soil which has been eroded. As a whole, Nutrient losses were neglected but there is possibility of increases by in increases of rainfall simultaneously with increase of slop. C_o was affected by run-off more than nutrients and soil. Finally, to control soil losses it is necessary to consider that decomposed organic fertilizers, and city bio-wastes should be applied in a proper time. Chemical fertilizer should be applied in proper time and doses, and the application should split in different crop growthstages. Slope of the land should be ranged about 0.1 to 2% and despite of legumes crops cereal crops should be planted in the rotation. Fields should be kept leveled, undulation of the surface must be avoided and Agro-pastoral live stocking should be balanced.

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