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Geospatial Distribution of Some Phosphorus and Potassium Forms as Influenced by Period of Irrigation in the Kano River and the Hadejia Valley Irrigation Schemes, Nigeria.

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ABSTRACT

This study was carried out at Kano River Irrigation Project (KRIP) (latitudes 11º 36′ 0.05″ N to 11º 49′ 57.97″ N and longitudes 8º 28′ 17.02″ E to 8º 29′ 41.82″ E) and Hadejia Valley Irrigation Project (HVIP) (latitudes 12º 17′ 48.75″ N to 12º 24′ 58.28″ N and longitudes 9º 51′ 31.29″ E to 10º 2′17.42″ E). The soils are largely deep, well-drained Calcic Luvisols. The aim was to assess the geospatial distribution of some plant-nutrition related forms of P and K. A total of 37 and 19 irrigation sectors were identified in KRIP and HVIP respectively. Google earth was used to tag 109 and 41 sampling points randomly within both developed and undeveloped sectors of KRIP and HVIP respectively. With the aid of projects' sitemaps, the sectors were demarcated into six periods of irrigation: 0 years (Non -irrigated), 1-10 years, 10-19 years, 20-29 years, 30-39 years and ≥ 40 years as applicable. GPS was used to track the tagged points at the time of sampling. Surface soil samples were collected by augering to 30 cm depth with fabricated steel augers. Samples were analyzed for physical and chemical properties. Available (AP) and total (TP) forms of P as well as water soluble (WSK), exchangeable (Ex. K) and non-exchangeable (NEK) forms of K were analyzed. Basic soil properties were compared by ANOVA using JMP version 12. Geostatistical analysis and Geospatial variability of various forms of P and K were performed with the GS+ software (version 10). Ordinary Kriging was used for the spatial interpolation. Texturally, the soils of the KRIP was sandy loam while that of the HIVP was predominantly sandy clayey loam. The pH (mean = 6.68) and EC (mean = 0.21 dsm^{-1}) values across the sites indicated that despite the years of irrigation the areas are not under immediate salinization risk. There was no any specific pattern of distribution of basic cations in both the two schemes. There is an observable tendency in the distribution of the forms of P and K evaluated of their being at higher concentrations in longer-periods irrigated lands in both the scheme. The nugget to sill ratio revealed a strong spatial dependence (< 25 %) for WSK. Moderately spatial dependence (25 to 75 %) was observed for available P, total P, non -exchangeable K and exchangeable potassium. It was concluded that there may be a stronger influence of the irrigation method on the spatial distribution of the forms of the nutrients over other factors such as parent material and weathering.

1. Introduction

Phosphorus (P) and potassium (K) are two plant nutrient elements in soil with highly variable chemical behaviour that affect their dynamics and availability. Depending on bio-geochemical factors and management practices, the two elements may also be highly variable in their forms and distribution over space and time. P is one of the major soil nutrients that limit agricultural production in many regions of the world (Wang and Zhang, 2010) which, there-

In some Nigerian soils, in addition to P, K availability is further compounded by variable and low distribution (Idiagbor *et al.,* 2009). Under irrigation, negative mineral element balance is a widespread feature, especially in the tropical environment. These negative balances are due to extensive farming, excessive leaching, soil degradation, plant removal without fertilizer application, and low purchasing power to replenish depleted mineral elements in the system (Ngailo *et al.*, 1999; Sanchez, 2002).
The Kano River Irrigation Project (KRIP) and its Hadejia Valley (HVIP) counterpart with some several thousand hectares of developed and cultivated agricultural land are two large-scale irrigation schemes in Nigeria that have existed for up to 40 years. The area has irrigation potential of 125000 and 87000 ha in the KRIP and HVIP respectively. It is one of the most successful irrigation schemes in West Africa (Danbuzu, 2011).

Flood irrigation in general and specifically as it is being practiced in KRIP and HVIP is associated with periodic submergence of the soil surface with water that flows into the field under gravity. Excess water is drained by drainage canals that run adjacent to the crop plots at the lower slope. The frequency of irrigation is relative to the crop under cultivation and may range from permanent flooding for rice to few and several days for other cereals and vegetables. The soils may therefore, be subjected to alternate wetting and drying which may induce many biochemical processes that may affect nutrient dynamics. Venterink *et al.* (2002), are of the opinion that it is plausible that along with mineralization, immobilization of P will increase with wetness. They, however, pointed out that data on the biogeochemistry of K in soils in relation to soil irrigation are scanty and therefore, availability of K for plants in relation to soil wetness is still poorly understood.

Due to inherent spatial variability of soils, not all areas of a field may require the same level of nutrient inputs. Small-scale farmers, however, possibly due to lack of such knowledge may apply fertilizers uniformly across farm fields. Large spatial variability of nutrients in agricultural soils may not allow standard fertilization practices to be efficient and without risks at the regional scale and even at the field scale (Wang *et al.,* 2009); in which cases geo-statistical approaches including non-parametrical statistical estimator like weighted moving average and or parametrical land-statistical approaches such as Kriging and Co-Kriging methods can be used. These are now important guiding tools for efficient agricultural soils management for cost-effectiveness and environmental safety. Therefore, assessing the spatial variability of soil chemical properties is crucial to efforts designed to introduce sustainable cropping systems, especially for developing countries such as Nigeria.
The aim of this study was therefore, to assess the distribution of some principal forms of P and K relevant to plant nutrition in relation to periods of irrigation in the schemes using geostatistical tools. This information will be valuable to both farmers and irrigation managers in the schemes for critical decisions such as fertilizer management and environmental safety strategies.

2. Materials and Methods

2.1. Description of the study area

The study was carried out at KRIP located between latitudes 11º 36′ 0.05″ N to 11º 49′ 57.97″ N and longitudes 8º 28′ 17.02″ E to 8º 29′ 41.82″ E and HVIP located between Latitudes 12º 17′ 48.75″ N to 12º 24′ 58.28″ N and longitudes 9º 51′ 31.29″ E to 10º 2′ 17.42″ E (Figures 1 and 2).

The KRIP and HVIP sites are dominated by granitic and sedimentary formations respectively (McCury, 1976). The soils are largely deep, well-drained Calcic Luvisols (Malgwi, 2001). Temperatures are hot throughout the year at average of 25 ±7^{o}C with mean annual rainfall of 500 – 760mm (Ojanuga, 2006).

2.2. Reconnaissance and Sampling Point Selection

Reconnaissance visit to the project areas was conducted and a total of 37 and 19 irrigation sectors were identified in KRIP and HVIP respectively. Google earth was used to tag 109 and 41 sampling points randomly within both developed and undeveloped sectors of KRIP and HVIP respectively (Figures 1 and 2). With the aid of projects' site maps, the sectors were demarcated into six periods of irrigation: 0 years (Non-irrigated), 1-10 years, 10-19 years, 20-29 years, 30-39 years and ≥ 40 years as applicable (Figures 3 and 4). GPS (Garmin etrex 20) was used to track the tagged sampling points at the time of sample collection.

2.3 Soil Sampling and Handling

Surface soil samples were collected at the tagged points by auguring to 30 cm depth with fabricated steel augurs. Samples were bagged in aerated jute bags. The samples were shade dried, crushed gently with porcelain pestle and mortar and sieved through 2 mm mesh prior to analysis. The fine earth separate was labelled and stored in plastic bottles for detailed laboratory analysis.

2.4. Laboratory Analysis

Particle size distribution was determined using Bouycous Hydrometer method (Gee and Or, 2002).The Textural classes were determined using the USDA textural triangle. Soil pH was determined using a glass electrode pH meter (JENWAY 3520 MODEL) in a ratio of 1:2.5 both in water and in 1.0M KCl. EC was then measured by the electrical conductivity meter (DDS-307 MODEL). Total nitrogen (TN) content of the soil was determined using the Macro-Kjeldhal technique as described by Bremmer (1996). Exchangeable acidity was determined by the method of Anderson and Ingram (1993). Organic carbon of the soil sample was determined by the wet oxidation method of Walkley and Black (1934) as described by Nelson and Summer (1982). Exchangeable bases (Ca, Mg, K and Na) in the soil were extracted with 1N ammonium acetate (1N NH_4OAc) solution, buffered at pH 7.0 as described by Anderson and Ingram (1993). Concentration was determined with Atomic Absorption Spectrophotometer (BUCK SCIENTIFIC MODEL, 210 VGP). Effective cation exchange capacity (ECEC) was determined from the summation of the exchangeable bases. Available Phosphorus was extracted using the Bray 1 method (Bray and Kurtz, 1945) while total P was determined by the digestion method using

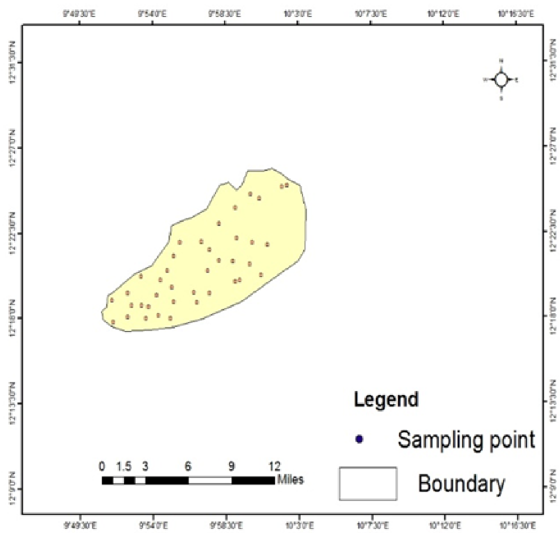

Figure 1: Project site map (HVIP) showing sampling points

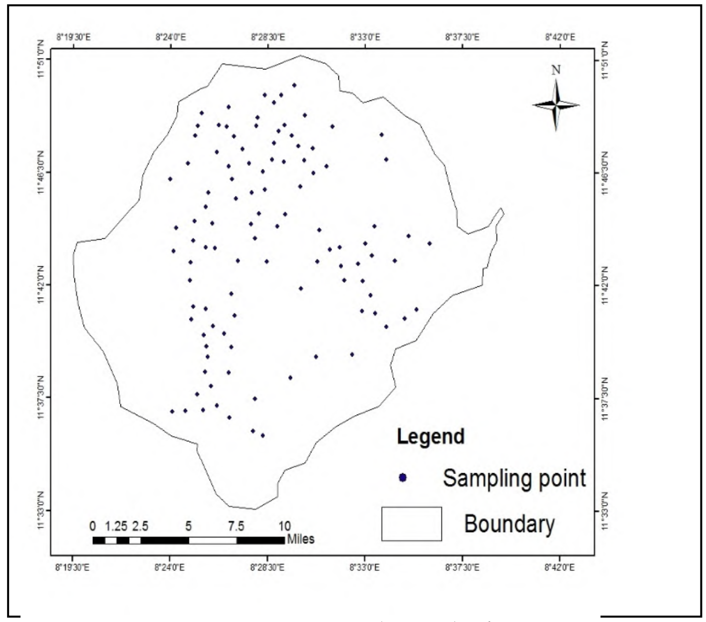

Figure 2: Project site map (KRIP) showing sampling points

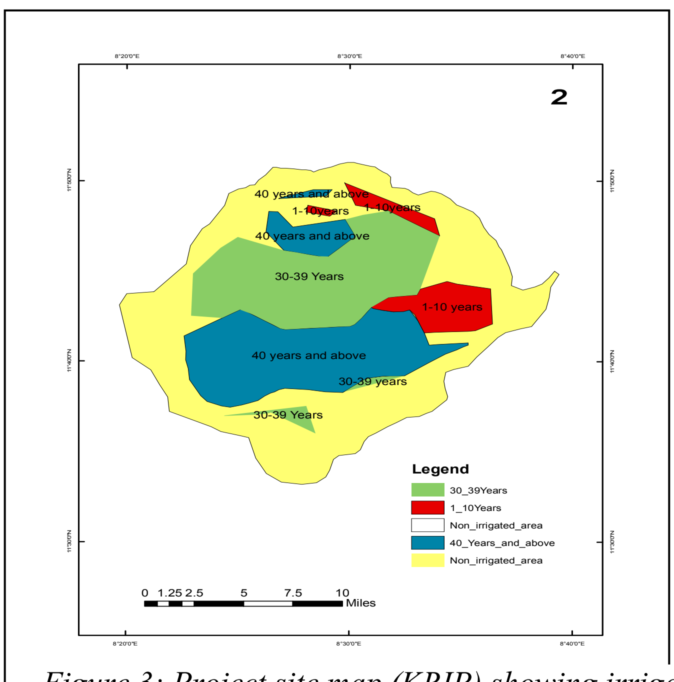

Figure 3: Project site map (KRIP) showing irrigation periods demarcation

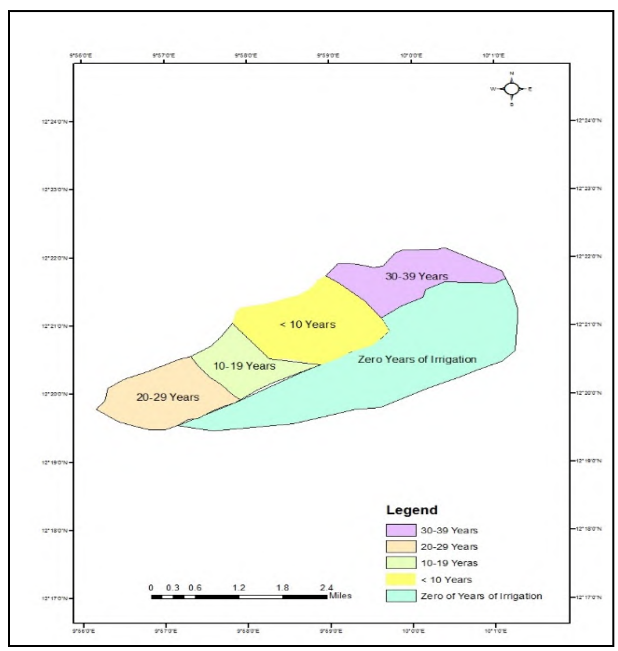

Figure 4: Project site map (HVIP) showing irrigation periods demarcation

Concentration was read using Spectrophotometer (22PC MODEL at 860nm wavelength).

Water soluble K was extracted by shaking 2 g soil with 20 ml deionized water (Pratt, 1965). Non-exchangeable K was extracted by boiling 1M HNO3 for 1 hour in a soil: solution ratio of 1:10. The content of K+ in the filtrated extract was determined by the Atomic Absorption Spectrophotometer (BUCK SCIENTIFIC MODEL 210 VGP).

2.5 Data Analyses

Basic soil properties were compared by ANOVA using JMP version 12. Geostatistical analysis and Geospatial variability of various forms of P and K were performed with the GS+ software (version 10). Each parameter was analyzed separately using the software. Data were subjected to modular analyses in the form of linear, Gaussian, exponential and spherical models. The model with the highest R2 value for each parameter indicated the fitted model. Distribution maps were produced with ArcGIS software (version 10.2). Ordinary Kriging was used for the spatial interpolation. Leave-one-out cross-validation was then performed to check the interpolation quality. The potential soil properties influencing forms and content of phosphorus and potassium in Kano-Hadejia river valley was determined using Pearson correlation.

3. Results and Discussion

Texturally, the soils of the KRIP was sandy loam while that of the HIVP was predominantly sandy clay loam. The two schemes are located on the up and downstream sectors of the Kano-Hadejia River system respectively. Clay and silt materials washed from the KRIP and their subsequent deposition at the HVIP sites by both drain and river flows could have facilitated the more clayey nature of the latter. The pH and EC values across the sites indicated that despite the years of irrigation the areas are not under immediate salinization risk, probably due to the textural classes that enhances internal drainage and the provision of surface drain canals across the irrigated fields.

The only statistically significant variations among the basic soil properties evaluated across all the irrigation periods at both the schemes were the EC, OC and TN. All the three properties were increasing with increasing years of irrigation at both the schemes. A probable explanation for the enhanced N and OC content with increasing year of irrigation may be due to enhanced biomass production and changed vegetation composition as highlighted by Venterink *et al*. (2002). According to them, this is part of the general reasons that cause eutrophication in frequently wetted soils such as wetlands.

3.2 Variability of Some Principal Cations with Irrigation Periods

Irrigation Period (Years)	Sand (%)	Silt (%)	Clay (%)	Texture Class	pH (H_2O)	EC (dSm^{-1})	O.C (g kg^{-1})	T.N (g kg^{-1})	E.A $cmol_{(+)}$ kg^{-1}
KRIP									
≥40	68.00	19.00	13.00	SL	6.82	0.318a	4.515a	0.789a	0.355
30-39	72.00	17.00	11.00	SL	6.69	0.264b	4.184a	0.807a	0.315
1-10	68.00	18.00	14.00	SL	6.73	0. 257b	4.418a	0.795a	0.418
0 (non-irrigated)	72.00	18.00	10.00	SL	6.48	0.176c	2.475b	0.600b	0.363
SE ±	2.49	1.686	1.403		0.260	0.081	0.683	0.135	0.038
HVIP									
30-39	43.00	19.50	37.50	SCL	6.310b	0.407a	9.800a	1.225a	0.400
20-29	48.00	25.5	26.5	SCL	6.972b	0.345b	5.850a	0.700b	0.200
10-19	52.00	27.00	21.00	SCL	6.746b	0.321b	5.986a	0.750a	0.229
<10	53.00	28.00	19.00	SCL	7.171a	0.322a	5.657a	0.750a	0.257
0 (non-irrigated)	50.00	28.00	22.00	SCL	6.198b	0.097c	0.343b	0.093b	0.365
SE ±	9.19	3.69	5.41		0.260	0.058	1.070	0.138	0.127

Key: EC= Electrical Conductivity, SL = Sandy loam, SCL = Sandy clayey loam, OC= Organic Carbon, TN= Total Nitrogen EA=Exchangeable Acidity, SE±= Standard error of mean. Values followed by the same letter in the same column within the same scheme are not different at p ≥ 0.05

Table 2: Variability of some principal cations in the soils of the irrigation schemes

Irrigation Period (Years)	EX.Na	EX.Ca	EX.Mg	Av.Zn (mg/kg)	Av.Cu (mg/kg)	Av.Mn (mg/kg)	Av.Fe (mg/kg)
Kano River Irrigation Project (KRIP)							
40 and Above	0.098	2.325b	0.886	5.468a	0.184	4.799b	9.773c
30-39	0.107	2.810a	1.048	4.306b	0.184	4.821b	10.394b
1-10	0.092	1.759c	0.864	3.471b	0.191	5.513b	10.758b
0 (non-irrigated)	0.082	2.874a	0.863	3.864b	0.189	7.742a	12.500a
SE ±	0.011	0.343	0.094	0.322	0.011	0.372	0.848
Hadejia Valley Irrigation Project (HVIP)							
30-39	0.101b	2.964a	1.292a	4.772b	0.196	4.032d	9.583c
20-29	0.098b	2.036c	0.875b	3.636d	0.211	4.355c	11.250b
10-19	0.121a	2.479b	0.881b	5.649a	0.192	4.700b	11.667b
<10	0.147a	3.000a	1.167a	5.000b	0.175	4.562b	12.143a
0 (non-irrigated)	0.102b	2.239b	0.851b	4.447c	0.167	5.063a	11.449b
SE ±	0.023	0.639	0.209	0.780	0.029	0.554	3.241

Key: Ex.Na = Exchangeable Na, Ex.Ca= Exchangeable Ca, Ex. Mg = exchangeable Mg, Av.Zn = available Zn, Av.Cu = available copper, Av.Mn = available Mn, Av.Fe = Available Fe. Values followed by the same letter in the same column within the same scheme are not different at $p \geq 0.05$

There was no any specific pattern of distribution of these cations in both of the two schemes. The metals were however, evaluated because of their tendencies to affect the forms of, especially P, Ca, Fe, Mn and Zn were found to be having remarkably high concentrations at both schemes due probably to parent material and management practices such as fertilization. The lack of effect of irrigation activities on the concentration of these cations was portrayed by the concentration of some of the cations, more especially Fe and Mn at both the schemes were non-irrigated sites and areas with shorter irrigation histories were found to have the highest and statistically different concentrations. There is a tendency for some major cations to be low in irrigated fields especially such fields that are under year-round cultivation due to intensive leaching and crop uptake as was highlighted by Camona *et al* (2004). Although the concentration of most of the available forms of the elements may be regarded as low to moderate (Landon, 1991), there is however, an observable tendency in the distribution of the forms of P and K evaluated of their being at higher concentrations in longer-periods irrigated lands in both This is most especially applicable to nutrient forms that are more readily available such as AP, WSK and Ex. K. There is also an observable build-up of TP in both schemes with extended periods of irrigation. It has been asserted that P and K availability may increase with frequent re-wetting (Venterink *et al.,* 2002). Chepkwony *et al.* (2001), indeed showed an increased P-availability for plants after soil drying and re-wetting. Liu *et al.* (2017), have also indicated that high water content under frequent irrigation leads to greater P mobility and loss through runoff. Frequent application of fertilizer P during the year-round production and the availability of cations to bind it as insoluble fraction may have facilitated the higher build-up of TP in the areas with longer histories of irrigation in both the schemes. Liu *et al.* (2017), found out that among all forms of irrigation they evaluated, furrow irrigation led to the greatest accumulation of TP at topsoil layer.

3.3. Variability of Different Forms of P and K with Periods of Irrigation

The variability of the different P and K forms evaluated with irrigation periods in both schemes is presented in Table 3.

Although the concentration of most of the available forms of the elements may be regarded as low to moderate (Landon, 1991), there is however an observable tendency in the distribution of the forms of P and K evaluated of their being at higher

Table 3: Variability of P and K forms with irrigation periods at the schemes

Irrigation Period (Years)	A.P (mg/kg)	T.P (mg/kg)	WSK $cmol_+ kg^{-1}$	NEK $cmol_+ kg^{-1}$	EX.K $cmol_+ kg^{-1}$
	KRIP				
40 and Above	6.704b	74.65a	0.138a	0.035b	0.296b
30-39	6.567b	62.79b	0.139a	0.037b	0.291b
1-10	6.139c	67.83b	0.118b	0.035b	0.301a
0 (non-irrigated)	7.276a	53.61c	0.131a	0.046a	0.302a
SE ±	0.422	8.96	0.019	0.006	0.016
	HVIP				
30-39	6.343c	64.560a	0.195a	0.048	0.340c
20-29	7.463a	51.839b	0.107c	0.036	0.307d
10-19	6.399c	40.934c	0.191a	0.051	0.390a
<10	6.577b	33.654d	0.173a	0.060	0.412a
0 (non-irrigated)	6.609b	28.846e	0.169b	0.049	0.360b
SE ±	1.616	13.187	0.065	0.013	0.037

This is most especially applicable to nutrient forms that are more readily available such as AP, WSK and Ex. K. There is also an observable build-up of TP in both schemes with extended periods of irrigation. It has been asserted that P and K availability may increase with frequent re-wetting (Venterink *et al.,* 2002). Chepkwony *et al.* (2001), indeed showed an increased P-availability for plants after soil drying and re-wetting. Liu *et al.* (2017), have also indicated that high water content under frequent irrigation leads to greater P mobility and loss through runoff. Frequent application of fertilizer P during the year-round production and the availability of cations to bind it as insoluble fraction may have facilitated the higher build up of TP in the areas with longer histories of irrigation in both the schemes. Liu *et al.* (2017), found out that among all forms of irrigation they evaluated, furrow irrigation led to the greatest accumulation of TP at topsoil layer.

3.4 Geostatistical Analysis of Spatial Distribution of P and K forms

Geostatistics was used in describing the spatial variation of each form of P and K evaluated. The result is as shown in Table 4. The nugget to sill ratio revealed a strong spatial dependence (< 25%) for WSK.

Moderately spatial dependence (25 to 75 %) was observed for available P, total P, non-exchangeable K and exchangeable potassium. Based on the results the Gaussian model was chosen as the best fitted model of variogram for the various forms of the P and the K. The implication of this result is that these forms of nutrients especially those with lower sill to nugget ratio are vulnerable to factors that determine spatial occurrence. In the case of this study, such factors are specifically intrinsic factors as determined by parent material and rate of weathering; and extrinsic factors as determined by management activities such as irrigation and fertilization. Similar observations were made by Blanchet *et al.* (2017) for the spatial distribution of forms of K in the Fribo region of Switzerland. They highlighted that such distribution is complex especially in the context of the extent of the influence of each factor especially within group of related parameters.

Table 4: Geostatistical Parameters of Soil properties at KRIP and HVIP

Soil properties	Model Type	Nugget (Co)	Sill (Co+C)	Range(m)	Nugget/Sill (%)	R^2	Spatial dependence	Interpolation technique
A.P(mg/kg)	Gaussian	1.999	3.999	0.930	50	0.552	Moderately	Ordinary
T.P(mg/kg)	Gaussian	1309.00	2619.00	3.462	50	0.527	Moderately	Ordinary Kriging
EX.K(cmol/kg)	Gaussian	0.004	0.0043	1.278	93	0.724	Weakly	Ordinary Kriging
WSKcmol/kg	Gaussian	0.0001	0.200	0.897	0.05	0.661	Strongly	Ordinary
NEK(cmol/kg)	Gaussian	0.0005	0.001	3.462	50	0.259	Moderately	Ordinary Kriging

3.5. Spatial distribution of P and K forms in different periods of irrigation

Spatial distribution of available P in KRIP (Figure 5) concentration (7.360 to 13.012 mg/kg) to be highest at 40 years and above, 30-39 years and some parts of 1-10 years of irrigation period and non-irrigated area. Low values (2.269 to 6.432 mg/kg) were observed at 1-10 years of irrigation and some part of 40 years and above of irrigation period.

For HVIP the Spatial distribution of available P (Figure 6) showed high concentration (5.834 to 11.936 mg/kg) at 30-39 years, 20-29 years, 10-19 years and some part of non-irrigated area. Low values (3.263 to 5.261 mg/kg) were observed at < 10 years of irrigation and non-irrigated area, with some patches at 30-39 years of irrigation period.

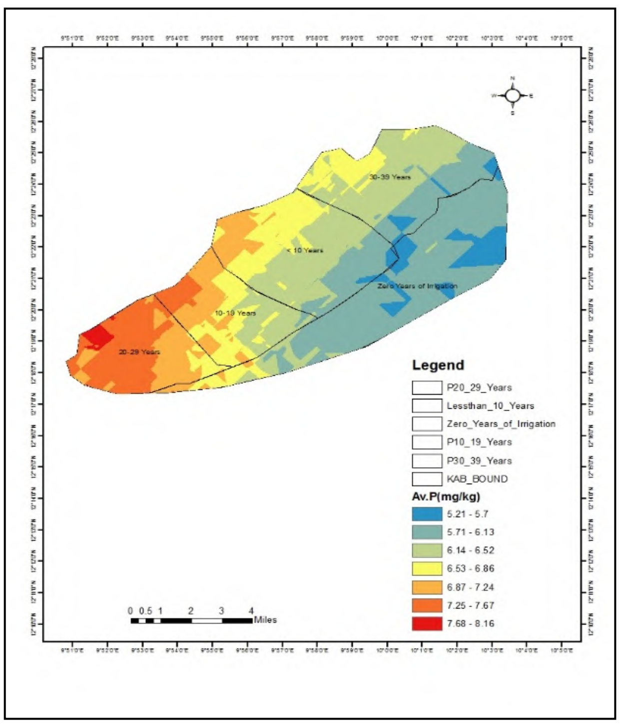

Figure 5: Spatial concentration of Av. P in relation irrigation period in HVIP

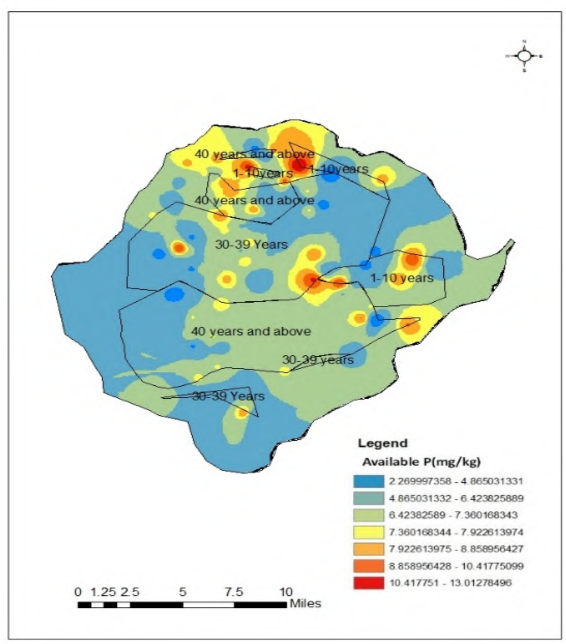

Figure 6: Spatial concentration of Av. P in relation irrigation period in KRIP

Spatial distribution of total P in KRIP (Figure 7) showed high concentration (56.93 to 185.99 mg/kg) at 40 years and above, 30-39 years, 1-10 years of irrigation period, While low concentration (10.342 to 47.662 mg/kg) were found at non-irrigated area, with some small patches of high concentration. For HVIP the spatial distribution of total phosphorus (Figure 8) showed high concentration (27.607 to 55.919 mg/kg) at 30-39 years, < 10 years of irrigation period. Low values (0.038 to 25.419 mg/kg) were observed at 20-29 years, 10-19 years of irrigation period and non-irrigated area.

The low to moderate concentrations recorded across irrigation periods were similar to Mustapha et al. (2007) who have reported similar accumulation of various forms of P in Fadama soils which are soils with remarkably high moisture content throughout the year.

According to Yang (2011) total P distribution is significantly affected by irrigation system and period as such this may explain the variability in the spatial distribution of the total P and subsequently the available P which is a fraction of the total P.

The spatial distribution of WSK at KRIP is shown in Figure 9. The pattern is also similar at HVIP (Figure 10). Variability exist in the pattern this K form is spatially distributed. From the figure, however, it could be discerned that the predominance of higher concentrations is at non-irrigated area and at areas with fewer years of irrigation. Addition of large volume of water to the soil as is the practice in both the schemes may favour accumulation TP as postulated by Liu et al. (2017). According to them long term irrigation may harden the soil and restrict the mobilization and transport of P into soil profiles. They also reported that AP movement was limited to the surface horizons under high soil moisture and poor aeration conditions as is the case with the prolonged irrigation being practiced in the schemes.

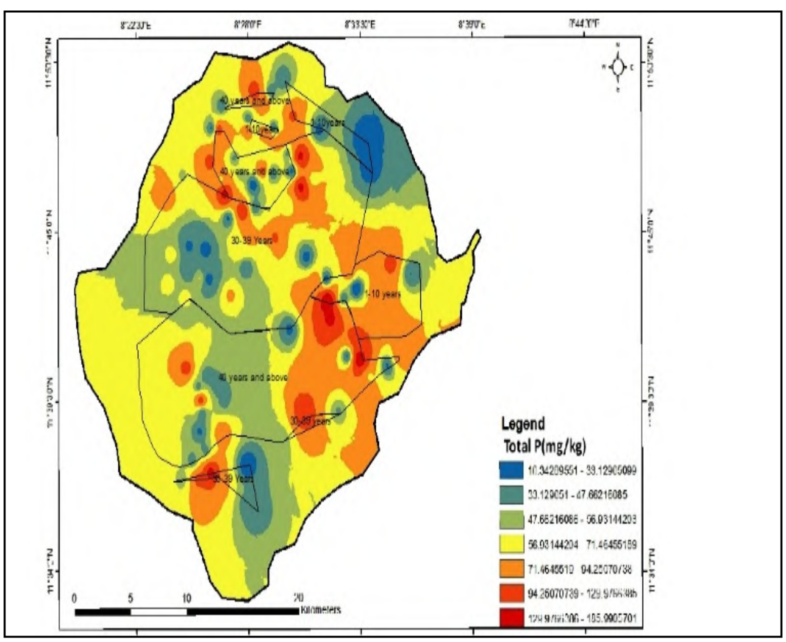

Figure 7: Spatial concentration of TP in relation irrigation period in KRIP

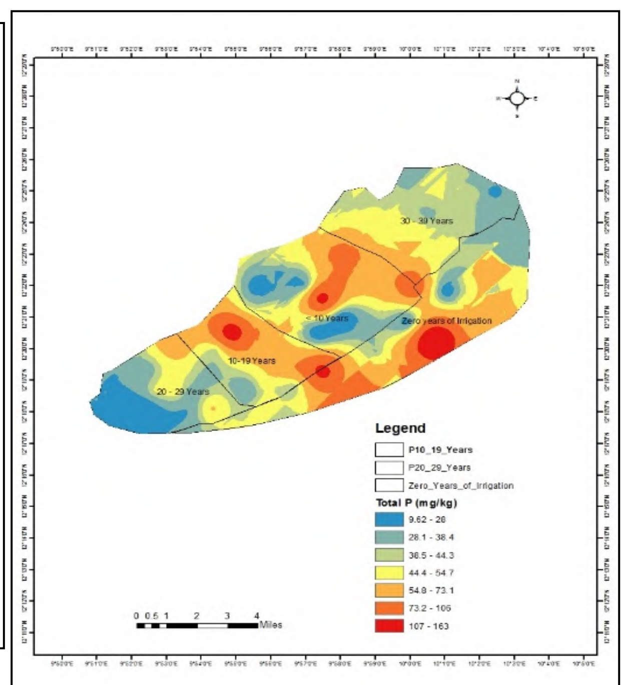

Figure 8: Spatial concentration of TP in relation irrigation period in HVIP

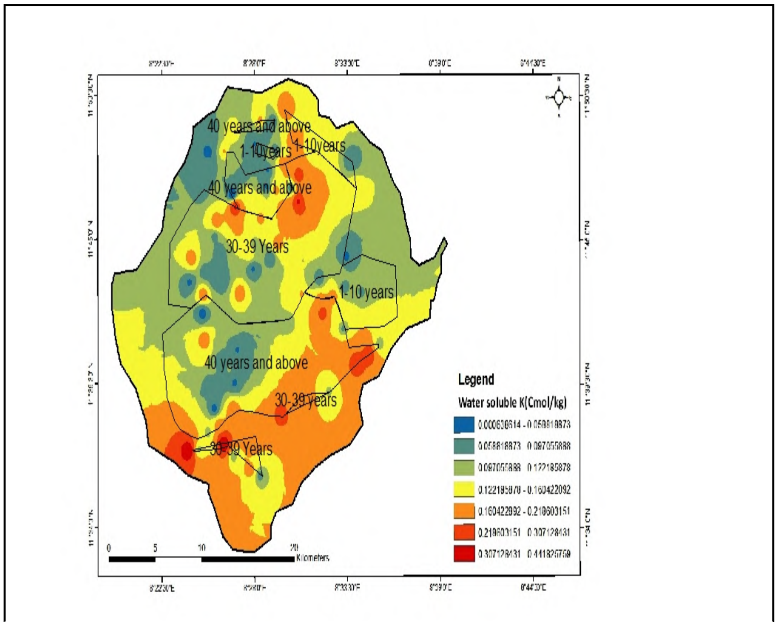

Figure 9: Spatial concentration of WSK in relation irrigation period in KRIP

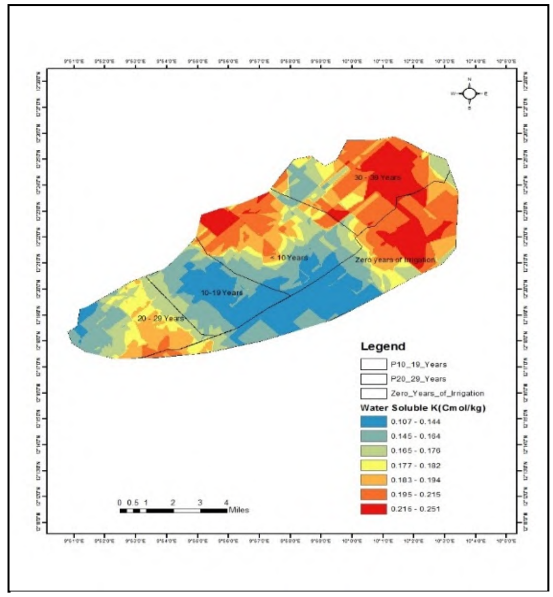

Figure 10: Spatial concentration of WSK in relation irrigation period in HVIP

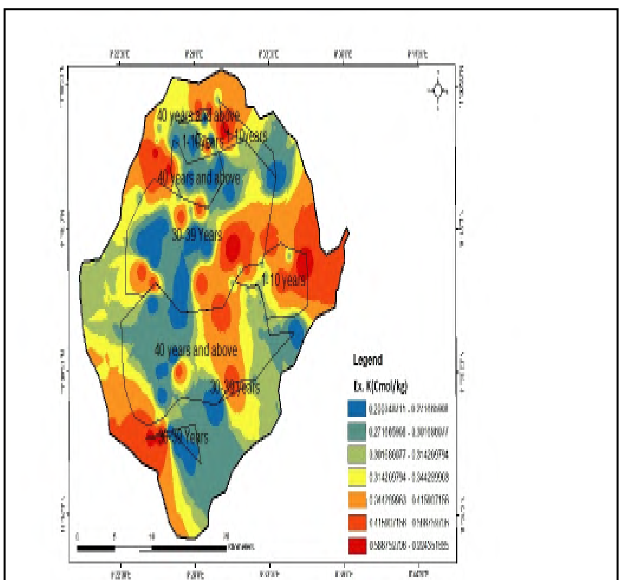

Figure 11: Spatial concentration of Ex. K in relation irrigation period in KRIP

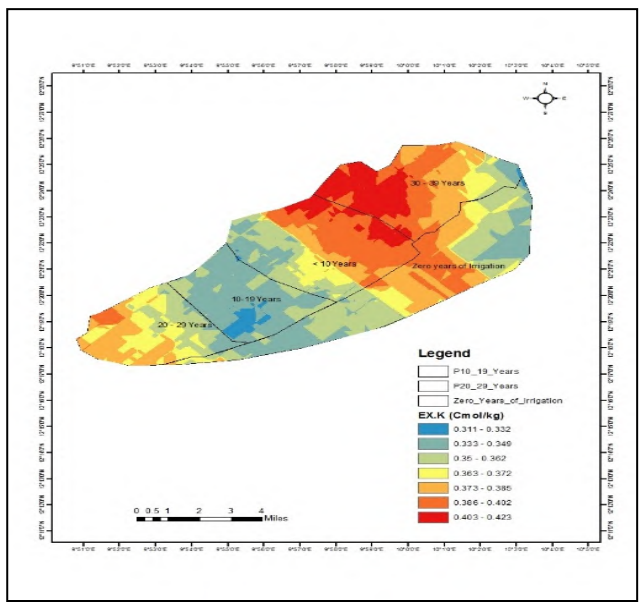

Figure 12: Spatial concentration of Ex. K in relation irrigation period in HVIP

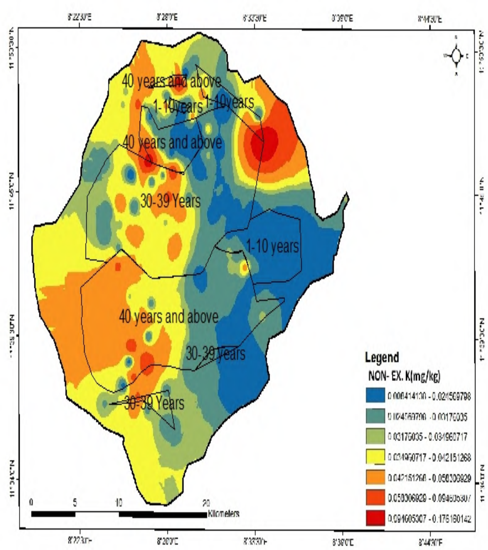

Figure 13: Spatial concentration of Non -Ex. K in relation irrigation period in KRIP

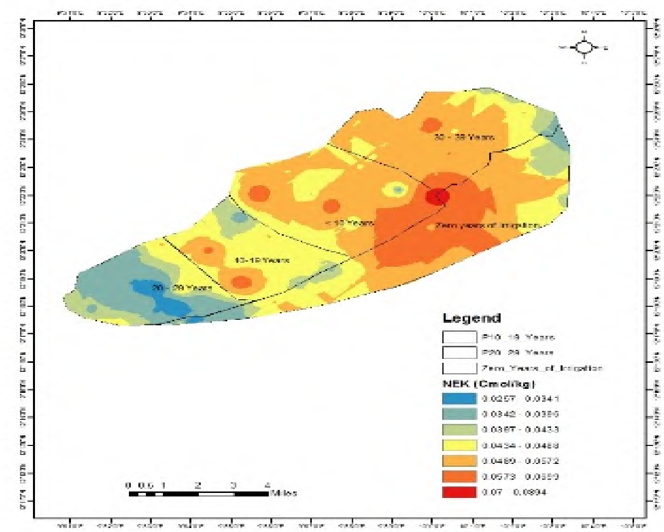

Figure 14: Spatial concentration of Non -Ex. K in relation irrigation period in HVIP

As with the WSK, the exchangeable form of K was also showing predominantly higher concentration at non-irrigated site and sites with shorter irrigation history. The distribution for the KRIP and HVIP is as shown in Figures 11 and 12 respectively. The distribution of non-exchangeable K in both the two schemes is spatially presented in Figures 13 and 14 for the KRIP and HVIP respectively. Similar to the two other forms of the element, the non-exchangeable form was also predominantly higher at the non-irrigated and the areas with shorter irrigation history. It has been asserted that K has a complex behaviour and chain of reaction in the soil (Blanchet *et al.,* 2017). Spatially, various forms of K are known to exhibit high variability in response to many factors such as parent material and degree of leaching as a factor of climate. Such variabilities exist both at both field and regional scales (Lauzon *et al.,* 2005). The factor of leaching is a very important determinant of the availability of especially WSK and Ex. K forms in most soils. Samndi and Tijjani (2014), have attributed the distribution of various forms of K along a toposequence to the degree of leaching tendency across slopes. The major factor in this result affecting the distribution of K in the result may also be the higher leaching tendency of soil under prolonged irrigation.

4. Conclusion

The findings here have revealed that there is high heterogeneity in the pattern of the distribution of these principal forms of nutrients.

With low to moderate concentration of most of the forms of the elements, especially the most readily available forms and the high spatial dependence in the manner of their distribution, it is easy to understand that the management of these two important elements may be an important focus area for the management of the two schemes. The findings here have revealed a strong influence of the method of irrigation adopted in the schemes on the overall forms of the two elements. Over time period, the method of irrigation might have probably overtaken the factors of parent material and weathering, although as highlighted above it may be complex to draw a dividing line between the intrinsic and the extrinsic factors.

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