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Temporal Variation of Macronutrients in Arable Niches Exploited by Zimbabwe's Semi Arid Smallholder Farmers

***Chikuvire T.J.[1] and S. Mpepereki[2]**
[1]Department of Crop Science, Bindura University of Science Education, P. Bag 1020, Bindura, Zimbabwe.
[2]Department of Soil Science and Agricultural Engineering, University of Zimbabwe, P. O. Box MP 167, Mt Pleasant, Harare, Zimbabwe.
*Corresponding Author: E-mail address; tjchikuvire@yahoo.co.uk; tchikuvire@buse.ac.zw
Mobile; +263 773 718 339

ABSTRACT

In Zimbabwe, most smallholder farmers are located on areas with nutrient poor sandy soils and sporadic marginal rainfall. In such environments, low input agriculture is prevalent. The objective of this study was to assess temporal variation of soil macronutrients with depth across arable niches exploited by these smallholder farmers. A two stage cluster sampling technique was used to randomly select nine farms with four predominant niches. Composite samples at five soil depths from each niche were obtained before and after a period of two cropping seasons in mid-November. These were analysed for soil pH, total organic carbon, total nitrogen, available P, exchangeable K, Ca, and Mg. Rainfall was recorded for the two cropping seasons. Results showed that the first season had a total rainfall of 658 mm while the ensuing was above normal with 51% more. Farmer cultivation and niche management on soil nutrient status over this period showed no significant changes at various depths for soil pH, total nitrogen, available phosphorus and exchangeable potassium. Soil pH and these nutrients, though at low levels, suggested stable systems. Total carbon, exchangeable calcium and magnesium had significant niche by period interactions ($p< 0.05$). Their overall distribution patterns with depth after two years were variable. The relative increase of these nutrients was mainly in homestead surroundings and under P. curatellifolia. While niches under P. curatellifolia benefited from litter-fall, homestead surroundings mostly benefited from inadvertent disposal of household refuse and ash. Gradual mobility down the soil profile of Ca and Mg was attributed to above normal rainfall in the second season. Large input application of organic amendments in all niches and especially the open sandy patches are required in order to improve the C content, reduce leaching of exchangeable bases and thereby improve soil fertility.

KEY WORDS: Temporal variation, Macronutrients, Smallholder farmers, Niche, Semi-Arid Area

INTRODUCTION

Evidence exist that within the domain of agro ecosystems, field variation and spatial heterogeneity induced by either pedogenic or anthropogenic factors are more likely than homogeneity [1, 2, 3]. In Zimbabwe, most smallholder farmers are located in areas with sporadic and marginal rainfall and nutrient poor sandy soils derived from granite [4, 5]. In such farming environments low input agriculture is prevalent and smallholder farmers adapted, through time, numerous coping strategies and technologies. Some of the strategies especially by the resource poor farmers deliberately exploit field variation and spatial heterogeneity [6, 7, and 8]. Some studies revealed that cropping systems by smallholder farmers were generally sustainable as farmers were ingenious in their approach to soil fertility management using a variety of locally derived resources [9, 10]. Some studies observed that farmer-resource endowment induced soil fertility gradients across arable fields which are large enough to affect crop response to fertilisation [11]. The resources commonly at farmers' disposal but in variable amounts include organic soil fertility amendments such as livestock manure, leaf litter, termitaria soil, household waste, composts, crop residues and inorganic fertilizers [12]. These are selectively applied and premised on farmers' perception of spatial variability of soil fertility in the field, preferred cropping patterns and quantities of available soil amendments [13]. Meanwhile, a review on popular myths around soil fertility management highlights the importance of nutrient stocks in assessing soil sustainability or eliciting fertilizer recommendations [14]. Information on relative fluctuation of nutrients in spatially variable field areas that are differentially exploited by farmers for food security sheds more light for appropriate management of these nutrients. This could be through provision of a focussed base for delineating niches for sustainable soil fertility management. The objective of this study was an assessment of temporal variation of soil macronutrients with depth across arable niches exploited by smallholder farmers in a semi-arid area of Zimbabwe.

MATERIAL AND METHODS

Study area description

The study was conducted in Mutoko communal area in Mashonaland East province in the North Eastern part of Zimbabwe. Much of the communal area is in agro-ecological Region IV with the South West portion in agro-ecological Region III. The communal area is suitable for both semi-intensive and semi-extensive agriculture [15]. Annual rainfall ranges from 650-700 mm. The study area is underlain by granitic rocks of the Basement Complex with scattered and localised intrusions of dolerite [16]. The soils, cultivated for over eighty years, are predominantly granite derived coarse sands of low inherent fertility mainly used for dryland cropping of maize. Other crops grown are pearl millet, finger millet, groundnuts and to a small extent sunflower and cotton [17]. Vegetables and mangoes (*Mangifera indica* L.) contribute significantly to the local economy. Farmers rear livestock such as cattle, goats, sheep and pigs.

Site Selection, soil sampling and analysis

The study was restricted to Charewa Ward in three villages of Chapfika, Chigaba and Samatanda. A two stage cluster sampling technique was used to randomly select eight six farms. Farmers participated in the identification of niches that caused variability in crop growth and development. Four predominant niches were selected on the basis of their prevalence in fields within farms and across different farms. A new population of 63 farms with predominant niches was established. From this population, a sample of nine farms was randomly selected for monitoring. Sketch maps of all farmers' fields were made and the predominant niches were identified as homestead surroundings, termitaria environments, areas under *Parinari curatellifolia* and open sandy patches. These niches were continuously cultivated by the farmers and received amendments according to how farmers perceived the soil fertility status of the niches.

At the beginning of the cropping season, in mid- November and after a period of two years in the same month, composite samples for soil chemical characterization were collected from each type of niche in the nine farms. Soil was sampled in each niche from five points at five depths of 0-20 cm, 20-40 cm, 40-70 cm, 70-100 cm and 70-130 cm using an auger. Subsamples for each depth were collected after thoroughly mixing the soil. Composite samples for each niche were drawn from the mixed subsamples. The collected composite samples were air dried and passed through a 2 mm sieve prior to chemical analysis. Samples were analysed for total organic carbon by a wet oxidation method [18], total nitrogen by the method where total nitrogen in digested samples was determined calorimetrically [19]. Available P was determined calorimetrically [20]. Exchangeable K, Ca, Mg were determined after extraction with 1 M ammonium acetate solution, adjusted to pH 7 [19]. Soil pH was measured using 0.01 M $CaCl_2$ in a 1: 20 soil to solution ratio. Rainfall data for the two cropping seasons were recorded.

Data Analysis

Soil macronutrients changes after two growing seasons were analysed using combined analysis of variance, a general linear model, using SPSS Version 16. Graphs of means of macronutrients levels were plotted to show changes in trends of micronutrient levels by depth in different niches where a significant ($p<0.05$) interaction existed after two years.

RESULTS

Rainfall

The first season had a total rainfall of 658 mm while the ensuing season had 51% more rainfall of 993 mm. The second rainfall season was an above normal one while the first was a relatively shorter one (Figure 1). Highest amounts of rainfall were received in the first half of the first season while season two received highest amounts in its second half, after 23rd January. Towards the end of the rainfall season in weeks 21 and 22, season two received more than 800% more rainfall than season one and also continued into weeks 23 and 24, receiving 38 mm, whilst season one had ended.

Macronutrient content in niches

Nutrient content varied with the type of niche. The total nitrogen content was relatively high in the 0-130 cm depth of termitaria environments but low in the rest of the niches which had almost the same quantities (Table 1). The 0-20 cm depth had higher nitrogen content than any other depth across all niches. This trend remained the same after a period of two years as indicated by no significant ($p < 0.05$) change in the relative quantities and distribution of total N down the 0-130 cm profile.

The available phosphorus decreased with depth in all niches except in termitaria environments where it steadily increased with depth. In the first year the total amount of available phosphorus in the active rooting zone (0-40 cm) as a percentage of available phosphorus in the 0-130 cm depth, was in order from highest: homestead surroundings (61.6%)>under *P. curatellifolia* (55.2%) >open sandy patches (52.2%) >termitaria environments (37.7%). This trend in the entire 0-30 cm depth was not significantly ($P<0.05$) different after two years (Table 1).

Generally, exchangeable potassium decreased with depth in around homestead surroundings and under *P. curatellifolia* whilst it remained constantly low in open sandy patches. Exchangeable potassium increased with depth in termitaria environments. In the first year, the total exchangeable K in the active rooting zone (0-40 cm) as a percentage of the exchangeable K in the 0-130 cm depth was in the order from the highest: homestead surroundings (43%)>under *P. curatellifolia* (42%)>open sandy patches (40%)>termitaria environments (34%). After a period of two years, there was no significant change in the distribution of exchangeable potassium (Table 1).

A comparison of soil pH values for homestead surroundings and termitaria environments indicated that the mean soil pH for the two niches were significantly different ($p < 0.001$) from each other. The effect of depth on soil pH was not significant for the two niches. Homestead surroundings and termitaria environments had the highest overall soil pH. Open sandy patches and under *P. curatellifolia* had lowest soil pH. This trend of soil pH variation however, did not differ significantly after a period of two years (Table 1).

Total carbon had a significant niche by period interaction ($p < 0.01$). First, the total C in the 0-20cm depth of open sandy patches in the first season was higher (0.75 cmolkg^{-1}) than that in the same depth (8.52cmolkg^{-1}) after two years (Figure 2). The overall distribution pattern of total C down the soil depth of 130 cm was also different after two years in niches under P. *curatellifolia* mainly in the 0-70 cm depth. Whilst total C in the 0-20cm depth of these niches was highest, it declined to 2.63 cmolkg^{-1} in the 40-70 cm depth. However, after two years, the total C in the 0-20 cm had declined but it increased in the 20-70 cm depth. In termitaria environments, the total C in the 0-100 cm was lower than that before the two years elapsed.

Exchangeable calcium showed a significant ($p<0.05$) niche by period interaction. Exchangeable Ca in the 70-100 cm depth of open sandy patches was higher (1.1 cmolkg^{-1}) in the first year than after two years (0.72 cmolkg^{-1}) (Figure 3). In the first year, exchangeable Ca in the 20-40 cm depth of homestead surroundings was much higher (4.12 cmolkg^{-1}) than that in the 40-70 cm depth (1.53 cmolkg^{-1}). After two years, the exchangeable Ca in the 40-70 cm increased to 2.81 cmolkg^{-1}. In the first year and Under P. *curatelifollia*, exchangeable Ca in the 70-100 cm depth was similar to that in the last 100-130 cm depth (1.08 and 1.54 cmolkg^{-1}) but in the second year that in the 70-100 cm depth was much lower (0.99 cmolkg^{-1}) than exchangeable Ca in the100-130 cm depth (1.99 cmolkg^{-1}). Exchangeable Ca in termitaria environments after two years remained similar to that in the first year only in the 0-20 cm depth. It however declined at depth below 40 cm after two years (Figure 3).

Exchangeable magnesium in niches significantly ($p<0.01$) interacted with depth during the years under study. In the 0-20 cm depth it was relatively higher in the first year (0.85 cmolkg^{-1}) than it was after two years (0.76 cmolkg^{-1}) in open sandy patches (Figure 4). Within this same niche and in the 100-130 cm depth, exchangeable Mg was relatively lower in the first year (0.18 cmolkg^{-1}) than it was after two years (0.21 cmolkg^{-1}). Major shifts in the distribution of exchangeable Mg occurred in the 0-70 cm depth of homestead surroundings over the two years. In the first year, exchangeable Mg was relatively high in the 0-20 cm depth and steadily declined up to the 40-70 cm depth. After two years, exchangeable Mg in the 0-20 cm depth had declined whilst it relatively increased in subsequent depths up to the 70-100 cm depth. In termitaria environments, the distribution of exchangeable Mg after two years was almost the same as that exhibited by exchangeable Ca.

DISCUSSION

Farmers' cultivation and their niche management on soil nutrient status over a period of two growing seasons showed no significant changes at various depths on soil total nitrogen, available phosphorus, exchangeable potassium and soil pH. This might be an indication that regardless of the farmer's soil fertility management strategy, levels of N, P and K in the niches remained stable but relatively low. This might be due to outflows from the soil systems in form of grain and crop residue removal and nutrient leaching that were compensated for by addition of compound fertilizers especially Compound D (8% N; $14P_2O_5$; $7K_2O$), a basal fertilizer. The N, P, K in termitaria environments and soil pH were generally higher than in other niches indicating potentially better productivity than the rest of the niches [21]. The soil pH of open sandy patches though stable over two years was generally the least (5.4) and liming would benefit crops mostly grown in this niche.

Table 1. Soil nutrients in the 0-130 cm depth of niches in first year and after two years. (s.e. in parenthesis)

Nutrient	Period	Homestead surroundings	Termitaria environment	Under P. *curatellifolia*	Open sandy patches
Total nitrogen (Mg/ha)	First year	0.621 (0.048)	1.051 (0.143)	0.645 (0.048)	0.573 (0.048)
	After 2 years	0.597 (0.048)	0.812 (0.096)	0.692 (0.048)	0.549 (0.024)
Available phosphorus (ppm)	First year	26.96 (3.243)	19.98 (2.570)	15.21 (1.457)	12.06 (0.976)
	After 2 years	25.75 (2.414)	18.06 (2.507)	16.33 (2.137)	13.73 (1.434)
Exch. Potassium (cmol/kg)	First year	0.24 (0.015)	0.32 (0.032)	0.16 (0.008)	0.10 (0.009)
	After 2 years	0.23 (0.016)	0.30 (0.024)	0.17 (0.006)	0.09 (0.005)
Soil pH	First year	7.0 (0.107)	7.4 (0.019)	5.6 (0.060)	5.4 (0.071)
	After 2 years	7.0 (0.093)	7.2 (0.029)	5.6 (0.069)	5.4 (0.093)

The relative increase of total C, exchangeable Ca and Mg was noted in homestead surroundings and under P. *curatellifolia* after two years. Higher C content in the 0-20 cm depth could have been from direct additions in form of household waste in homestead surroundings and leaf litter under P. *curatellifolia* [2, 13]. The increase in C from the 20-40cm to the 40-70 cm depth under P. *curatellifolia* after two years could have been due to proliferation of roots that contributed soil organic matter. Though relatively large levels of carbon were in the 0-40 cm depth in most of the niches, decreases in the upper soil surface (0-20 cm) after two years and enrichment of the lower depths could be attributed to downward translocation due to the cumulative effect of precipitation in homestead surroundings and under P. *curatellifolia*. This subsequently indicated that if at all organic additions were applied in the two niches the carbon input showed a negative balance in the upper soil layer (0-20 cm) after two years. The overall marginal decrease of carbon over two years in the 0-40 cm depth of open sandy patches hints at high input rates of organic matter required to shift the apparent equilibrium.

In homestead surroundings, significant input of Ca was reflected by high concentration in the upper soil layer and its gradual mobility down the soil profile. The homestead niche mostly benefited from inadvertent disposal of household refuse and ash [2, 13]. High calcium levels partly explain the relatively higher soil pH in homestead surroundings than under P. *curatellifolia*. Despite the gradual downward movement of Ca attributed to leaching under P. *curatellifolia* in the 70-70cm depth, maintenance of similar Ca levels in the surface soil might be due either to continuous supply through decomposition of organic matter mainly litter-fall or additions as inorganic fertilizers.

Figure 1. Rainfall distribution of two successive seasons on adjacent villages of Chigaba, Chapfika and Samatanda

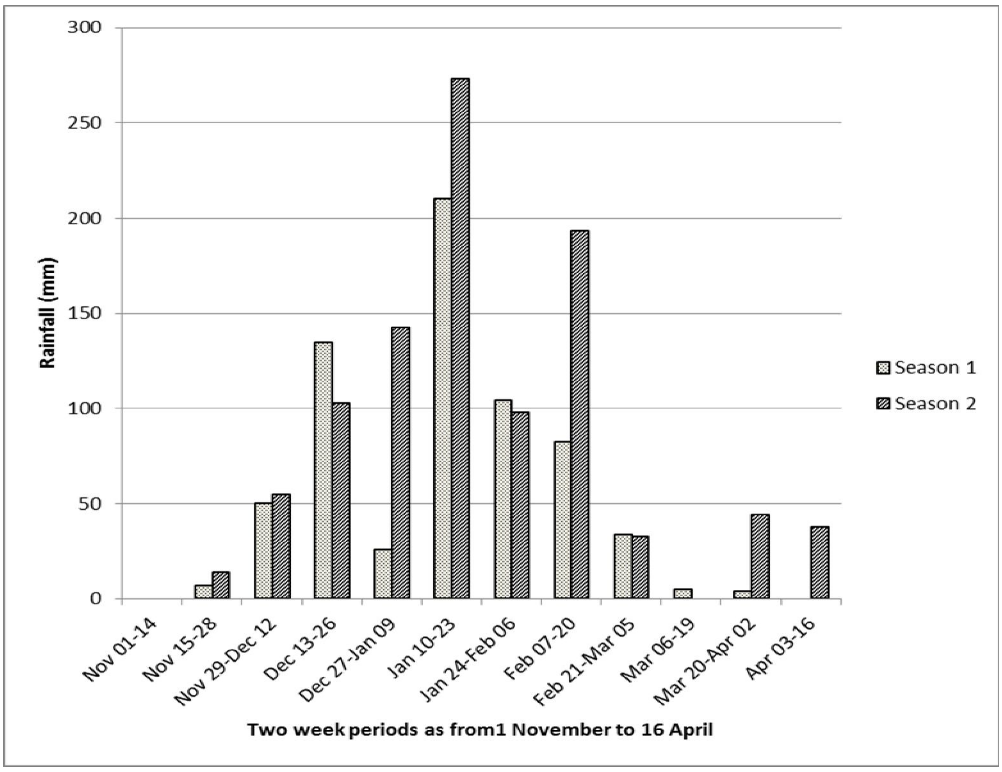


Figure 2: Variation of Carbon with depth across niches over a two year period

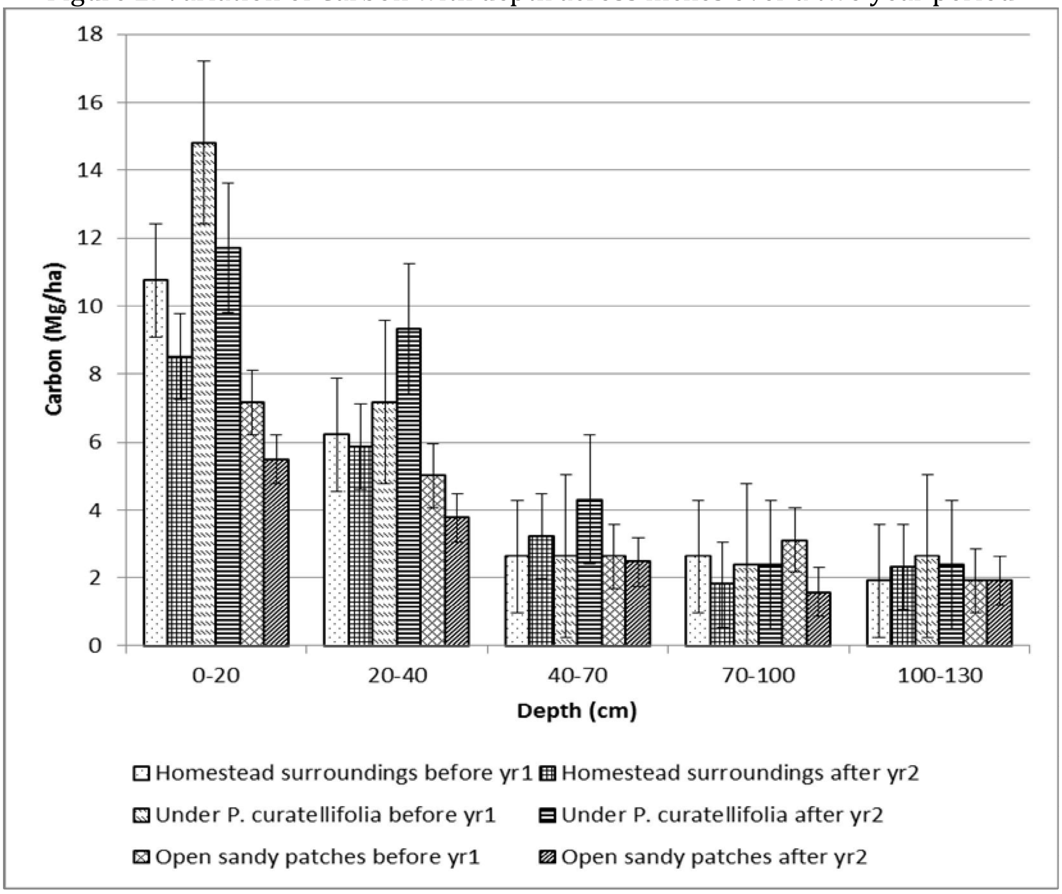


Figure 3: Variation of exchangeable Calcium with depth across niches over a two year period

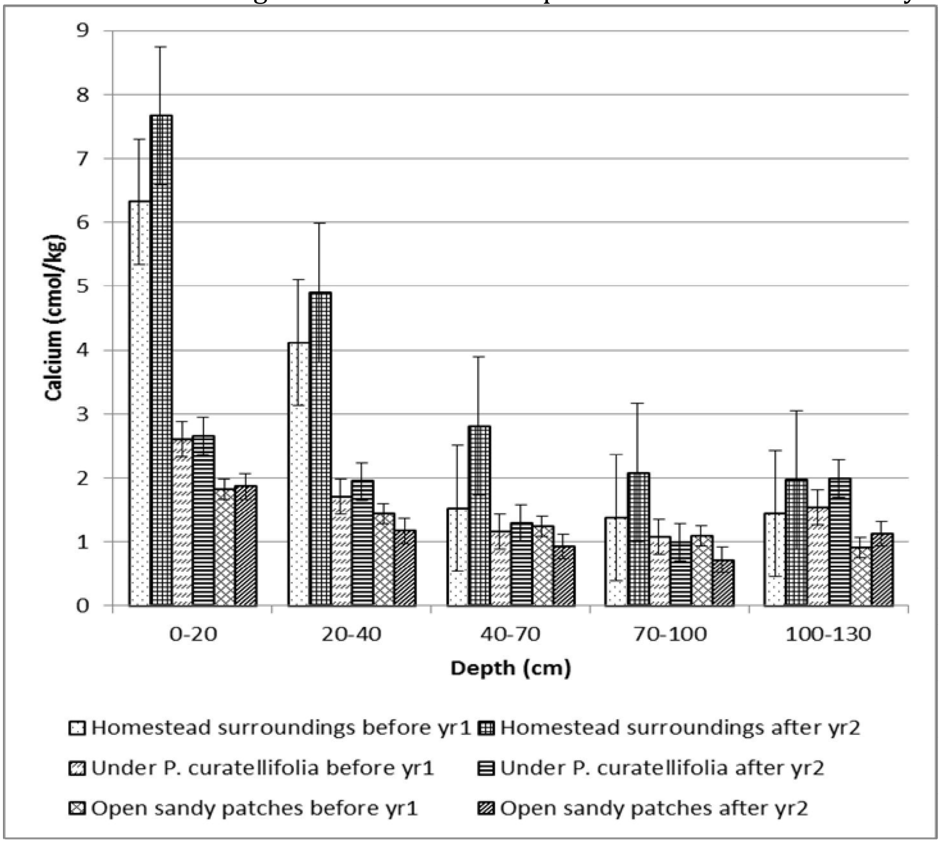
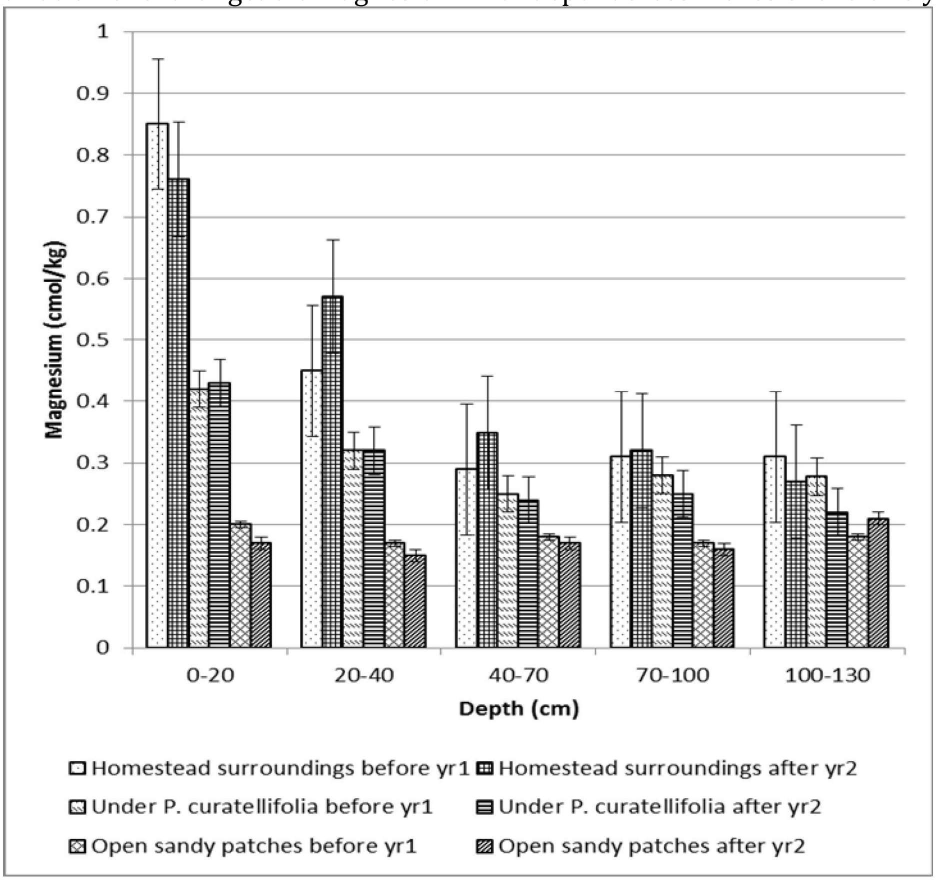


Figure 4: Variation of exchangeable Magnesium with depth across niches over a two year period



Magnesium levels were consistent with the C and Ca levels especially in the 0-70cm of homestead surroundings. Just like for Ca, homestead surroundings had the highest Mg levels attributable to household refuse and ash and it showed greatest mobility to lower soil levels.

CONCLUSION

The study showed that in sandy areas, variability of nutrient levels was dependent on the type of niche, season and nutrient *per se*. Soil pH and nutrient levels of N, P and K, though low, remained unchanged over a two year period for all niches suggesting a stable system but total C, exchangeable Ca and Mg showed highest fluctuations. The effect of above normal rainfall in the second season influenced leaching of Ca and Mg. Leaching in open sandy patches up to a metre from the soil surface reflected low organic matter content and hence soil fertility characteristic of sandy soils. Input application of organic amendments in all niches especially open sandy patches are required in order to improve the C content, reduce leaching of exchangeable bases and thereby improve soil fertility.

REFERENCES

1. Van Oosterhought, S. (1993). Sorghum genetic resources for small scale farmers in Zimbabwe. In: Cultivating Knowledge, Genetic Diversity, Farmer Experimentation and Crop Research. deBoef W., K. Amnor, A. Bebbington (eds), Intermediate Technology Publications, Exeter.
2. Carter, S.E. and H.K. Murwira. (1995). Spatial variability in soil fertility management and crop response in Mutoko communal area, Zimbabwe. Ambio 24:77-84.
3. Tittonell, P., B. Vanlauwe, P.A. Leffelaar, E.C. Rowe and K.E. Giller, (2005). Exploring diversity in soil fertility management of smallholder farms in western Kenya I. Heterogeneity at region and farm scale. *Agric. Ecosys. Environ*. 110, 149-165.
4. Grant, P.M. (1981). The fertilization of sandy soils in peasant agriculture. *Zimbabwe Agriculture Journal* 78: 169-175.
5. Nyamapfene, K.W. (1989). Adaptation to marginal land amongst the peasant farmers in Zimbabwe. *Journal of Southern African Studies* 15:384-389.
6. Brouwer J., L.K. Fussell and L. Herrmann. (1993). Soil and crop growth micro-variability in the West African semi-arid tropics: a possible risk reducing factor for subsistence farmers. *Agriculture, Ecosystems and Environment* 45: 229-238.
7. Scoones, I. (1996). Hazards and Opportunities, Farming Livelihoods in Dryland Africa: lessons from Zimbabwe. Zed Books Ltd in association with IIED, London.
8. Chikuvire T.J., Mpepereki S, Tigere T.A. and Foti R. (2006). Exploitation of Spatial Heterogeneity for Food Security by Smallholder Farmers in a Semi-Arid Area of Zimbabwe. *Journal of Sustainable Development in Africa* 8 (2): 15-29.
9. Mombeshora, B., B. Mavedzenge, M. Mudhara, C. Chibudu, S. Chikura and I. Scoones. 1995. Coping with risk and uncertainty. *Ileia* 2 (4): 10-11.
10. Campbell, B., P. Frost, H. Kirchman and M. Swift. 1998. A survey of soil fertility management in small-scale farming systems in North Eastern Zimbabwe. Journal of Sustainable Agriculture 2:19-39.
11. Nyamangara J., E. Makarimai, E.N. Masvaya, S. Zingore and R.J. Delve. (2011). Effect of soil fertility management strategies and resource-endowment on spatial soil fertility gradients, plant nutrient uptake and maize growth at two smallholder areas, north-western Zimbabwe. *Southern Africa Journal of Plant and Soil* 28: 1-10.
12. Bradley, P.N. and P. Dewees. (1993). Indigenous woodlands, agricultural production and households economy in the communal areas. In: Bradley P.N. and K. McNamara (eds), Living with trees. World Bank Technical Paper No. 210. World Bank, Washington DC, pp 63- 137.
13. Chikuvire T.J. and S. Mpepereki. (2006b). Spatial Variability: Perceptions, Practices and Implications on Sustainability of Soil Fertility Management By Smallholder Farmers in a Semi-Arid Area of Zimbabwe. Journal of Sustainable Development in Africa 8 (2): 128-143.
14. Vanlauwe, B and K.E. Giller. (2006).Popular myths around soil fertility management in Sub Saharan Africa. Agriculture, Ecosystems and Environment 116:34-46.
15. Brinn, P.J. (1986). Communal land physical resource inventory. Mutoko district. Soil Report No 524. Chemistry and Soil Research Institute, Department of Research and Specialist Services, Harare.
16. Stagman, G. (1978). An outline of the geology of Rhodesia. Government Printer, Salisbury.
17. Ashworth, V.A. (1990). Agricultural technology and the communal farm sector, Main report, Background paper prepared for Zimbabwe Agricultural Sector Memorandum. Agriculture Division, Southern Africa Department, The World Bank, Washington.
18. Baker, K.F. (1976). The determination of organic carbon in soil using a probe-colorimeter. Laboratory Practice 25, 82-83.
19. Anderson, J.M. and J.S.I. Ingram (eds). (1993). Tropical Soil Biology and Fertility, a Handbook of Methods. C.A.B. International, Wallingford.
20. Watanabe, F.S. and S.R. Olsen. (1965). Test of an ascorbic acid method for determining phoshorus in water and $NaHCO_3$ extracts from soil. SSSA Proceedings 29: 677-678.
21. Nyamapfene, K.W. (1986). The use of termite mounds in Zimbabwe peasant agriculture. Tropical Agriculture 63: 191-192.