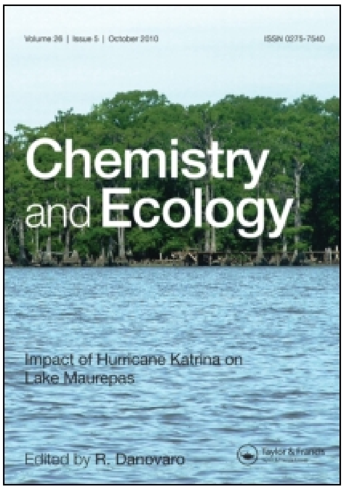


**Chemistry and Ecology**
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

# Seasonal variation of nitrate-N in surface and ground-waters of South Western Nigeria: a preliminary survey

Toyin A. Arowolo[a]
[a] Department of Environmental Management & Toxicology, University of Agriculture, Abeokuta, Nigeria

**To cite this Article** Arowolo, Toyin A.(2005) 'Seasonal variation of nitrate-N in surface and ground-waters of South Western Nigeria: a preliminary survey', Chemistry and Ecology, 21: 2, 83 — 89
**To link to this Article: DOI:** 10.1080/02757540412331335997
**URL:** http://dx.doi.org/10.1080/02757540412331335997

*Chemistry and Ecology*
Vol. 21, No. 2, April 2005, 83–89



# Seasonal variation of nitrate-N in surface and ground-waters of South Western Nigeria: a preliminary survey

TOYIN A. AROWOLO*

Department of Environmental Management & Toxicology, University of Agriculture, P M B 2240, Abeokuta, Nigeria

*(Received 22 June 2004; in final form 25 November 2004)*



Two surveys of nitrate-N concentrations in surface and ground water in Ogun and parts of Lagos and Oyo States of south-western Nigeria were undertaken between October 1997 and December 1998, and between July 2000 and May 2001 (covering both dry and rainy seasons). The study was conducted to ascertain the extent of nitrate-N pollution of the surface/ground water in some parts of the three states. Seventy-two water points (33 rivers/streams, 21 wells and 18 boreholes) were sampled three times during each of the two seasons. Nitrate-N was detected in all the river/stream samples analysed with concentrations ranging from 0.5 to 15.3 mg/l and 1.0 to 7.7 mg/l during the rainy and dry seasons, respectively (average value 2.7 and 2.4 mg/l for rainy and dry season, respectively). 98.5% of the rivers/streams sampling points contained nitrate-N in amounts equal to or less than 10 mg/l. 88.1% of wells and 97.2% of boreholes had a nitrate-N content less than 5 mg/l. Nitrate-N concentrations in the sampled wells ranged from 1.4 to 7.4 mg/l and 1.1 to 6.0 mg/l during the rainy and dry seasons, respectively (average value 2.6 and 2.2 mg/l, respectively). The sampled boreholes had a lower nitrate-N concentration ranging from 0.1 to 5.2 mg/l and from below the detection limit to 5.0 mg/l during the rainy and dry seasons, respectively (average value 1.8 and 1.6 mg/l, respectively). Nitrate-N concentrations in boreholes were below detection limit in 22% of the samples. Generally, for most of the sampling points, nitrate-N concentrations were slightly higher during the rainy season compared with the dry season. The present results indicated that nitrate-N concentrations in all the water points (except one) were below the World Health Organization (WHO) maximum acceptable limit in potable waters (10 mg/l). Therefore, contamination of the surface and ground water of the study area is not indicated. This study provides background data against which future changes in nitrate-N concentrations of surface and ground waters in the study area can be measured.

*Keywords*: Nitrate-N; Surface-water; Groundwater; Nigeria

## 1. Introduction

The past few decades have seen a progressive increase in the level of nitrate in underground and surface waters in many parts of the world [1–9]. This has been due partly to the formation of nitrogen oxides by fuel combustion and their deposition as a component of acid rain, partly to increases in sewage recycling, but mainly to the increased use of nitrogen-based fertilizers [5].

*Email: tarowolo@yahoo.com

*Chemistry and Ecology*
ISSN 0275-7540 print/ISSN 1029-0370 online 
http://www.tandf.co.uk/journals
DOI: 10.1080/02757540412331335997

Other anthropogenic sources that have also been implicated include sewage treatment effluent, storm water, industrial and drainage outfalls, etc.

The use of fertilizers has revolutionized crop production systems and resulted in higher crop yields obtained today compared with a generation ago. However, low crop prices combined with high land and machinery costs encourage farmers to cultivate fields right up to their margins, thus promoting runoff from fields to waterways. The prevalence of nitrate in ground and surface waters has therefore become a major environmental concern. The relationship between N fertilization and nitrate leaching has been extensively reviewed [10–13]. However, in many tropical African countries, little or no validated information is available on the magnitude of the nitrate leaching and its effect on the quality of underground water [14].

Although nitrate is only one of the environmental issues related to water quality, its presence in drinking water is of concern because of its toxicity, especially for young children. Excess in rivers and lakes encourages water plants to flourish and algae to "bloom" [5, 15]. Currently, there is concern over the increasing concentrations of nitrate present in groundwater aquifers that are used as sources of potable water. In 1984, the WHO introduced guidelines on permissible nitrate-N levels in drinking water [16].

In developing countries, most of which are characterized by huge debt burdens, population explosion and rapid urbanization, people have little or no option but to accept water sources of poor quality, due to a lack of better alternative sources or due to economic and technological constraints in treating the available water adequately before use. In many rural communities in Africa, the village streams are usually the main source of water for domestic use with or without supplementary hand-dug wells and borehole sources. In Nigeria, for example, it is estimated that only 48% of the inhabitants of the urban and semi urban areas and 39% of rural areas inhabitants have access to a potable water supply [17]. This is usually supplemented with water from hand-dug wells and borehole sources. It has been reported that some communities in Botswana, Senegal and Tanzania habitually drink well water with several hundred milligrams of nitrate per litre [18]. Gupta *et al.* [19] reported that people in several villages in India regularly consume water containing up to 500 mg/l nitrate. It is therefore highly desirable that the amounts of nitrate in ground and surface waters be monitored closely in the developing countries. The data presented here provide a background series of values against which any changes in the future can be compared.



## 2. Material and methods

### 2.1 *Study area*

Nigeria is located approximately between latitude 4° and 14° north of the Equator, and between longitude 2°2′ and 14°30′ east of the Greenwich meridian. It is bordered to the north by the Republics of Niger and Chad, to the south by the Atlantic Ocean, to the east by the Republic of Cameroon and to the west by the Republic of Benin. The population is more than 100 million, spread unevenly over a national territory of 923,770 km$^2$. The climate, which affects the quality and quantity of the country's water resources, results from the influence of two main wind systems: the moist, relatively cool, monsoon wind which blows from the south-west across the Atlantic Ocean towards the country and brings rainfall, and the hot, dry, dust-laden Harmattan wind which blows from the north-east across the Sahara desert with its accompanying dry weather and dust-laden air. Nigeria has abundant water resources, although these are unevenly distributed over the country. The major drainage system in the area of study (south-western Nigeria) is the Atlantic Drainage System (West of the Niger), which is made up of the Ogun, Oshun, Owena and Benue Rivers. The drainage system terminates in the Atlantic Ocean with an extensive network of delta channels. Two principal climatic seasons can be recognized in the study area. The wet season starts in April and lasts until October or November and has a rainfall with a characteristic bimodal distribution with peaks in June and September and a period of lower precipitation in August (called August break). A significant portion of the rains comes as relatively intense thundershowers, often with moderate to strong, gusty winds. December through March constitutes the major dry season. The average annual rainfall of the study area is more than 900 mm.

### 2.2 *Sampling*

Water samples from ground and surface waters were collected from different locations in three states, Lagos, Ogun and Oyo, during the period October 1997 to December 1998 and July 2000 to May 2001 (covering both dry and rainy seasons). Seventy-two points (33 Rivers/Streams, 21 Wells and 18 Boreholes) were sampled, three times during each season. Water was collected from the water points as follows:

(1) River and streams: Samples collected from the swift flowing section of the stream/river just below the water surface.
(2) Wells: Samples collected by using a clean bucket or container attached to the end of the rope, which was used to draw up water.
(3) Boreholes/tap water: All the boreholes were fitted with either a hand-pump or a motorized submersible pump. Samples were collected after allowing for 3–5 min of continuous pumping or running of the tap.



New plastic bottles with hard plastic screw caps were used for sample collection. The bottles were thoroughly cleaned by washing, soaked in 10% nitric acid and thereafter thoroughly rinsed with deionized distilled water. Before sampling, bottles were rinsed twice with the water to be sampled. The sample bottles were filled to the brim with the water sample and then securely capped, leaving no air space. During transit from collection site to the laboratory, samples were stored in ice-cooled boxes. To minimize any change in the nitrogen balance through biological activity, water samples were analysed promptly after sampling.

The sodium salicylate spectrophotometeric method was used to determine the amount of $NO_3$-N in the water samples. In this method, the sulphosalicylic acid, prepared *in situ* from salicylic acid in the concentrated sulphuric acid medium, is nitrated to give 2-hydroxy-3-nitro-5-sulphobenzoic acid, the anion of which, in solution at high pH, is intense yellow. The intensity of the yellow colour is proportional to the nitrate concentration in the sample and bears a linear relationship. Measurements were made at a wavelength of 420 nm. The precision of the method was generally $<5\%$, and the recovery of standard solution spikes was in the range 96–98%.

## 3. Results and discussion

The distribution of nitrate-N concentrations in the 72 water points studied is shown in table 1, while table 2 shows the summary statistics of nitrate-N in the water samples studied and compares the results for the rainy and dry seasons. No significant difference was observed in the results obtained for the two sampling periods, October 1997 to December 1998 and July 2000 to May 2001. The results were therefore collated. Ninety-one percent of the rivers/streams sampling points had nitrate-N concentrations lower than 5 mg/l. WHO [16] recommended a

Table 1. Distribution of nitrate-nitrogen concentrations in the water points studied.

| Nitrate-nitrogen content (mg/l) | 0–2.5 | 2.6–5.0 | 5.1–7.5 | 7.6–10 | 10–12.5 | >12.5 |
|---|---|---|---|---|---|---|
| *Rivers and streams* | | | | | | |
| Number of water points | 50 | 10 | 2 | 3 | 0 | 1 |
| Percentage (%) of water points | 75.8 | 15.2 | 3.0 | 4.5 | 0 | 1.5 |
| *Wells* | | | | | | |
| Number of water points | 36 | 1 | 5 | 0 | 0 | 0 |
| Percentage (%) of water points | 85.7 | 2.4 | 11.9 | 0 | 0 | 0 |
| *Boreholes* | | | | | | |
| Number of water points | 32[a] | 3 | 1 | 0 | 0 | 0 |
| Percentage (%) of water points | 88.9[a] | 8.3 | 2.8 | 0 | 0 | 0 |

[a]Include samples with nitrate-nitrogen levels below detection limit.

maximum limit for nitrate in drinking water of 10 mg/l as N. In all, only in one sampling point was the nitrate-N concentration found to be higher than 10 mg/l, and this would make the water at this sampling point unsuitable for direct domestic use. Nitrate-N was detected in all the river/stream samples analysed, with concentrations ranging from 0.5 to 15.3 mg/l and 1.0 to 7.7 mg/l during the rainy and dry seasons, respectively (with average values of 2.7 and 2.4 mg/l for the rainy and dry season, respectively). These levels of nitrate-N in the rivers sampled are within the range reported by UNEP [20].

The majority of wells (88.1%) and boreholes (97.2%) had a nitrate-N content lower than 5 mg/l. Nitrate-N concentrations in the sampled wells ranged from 1.4 to 7.4 and from 1.1 to 6.0 mg/l during the rainy and dry seasons, respectively (with average values 2.6 and 2.2 mg/l, respectively). The sampled boreholes had a lower nitrate-N concentration ranging from 0.1 to 5.2 mg/l and from below the detection limit to 5.0 mg/l, respectively (average values 1.8 and 1.6 mg/l, respectively). It was observed that nitrate-N concentrations in boreholes were typically low and were below the detection limit in 22% of the samples. At no time was the concentration of nitrate-N in all the sampled wells and boreholes as high as 7.6 mg/l, which is lower than the safe limit for potable water.

A close examination of the results obtained showed that 18 (out of 21) wells had nitrate-N concentrations below 2.5 mg/l in the two seasons. The remaining three wells, which were located at Abule Egba in Lagos, had nitrate-N concentrations between 5.3 and 7.4 mg/l in the rainy season and between 4.5 and 6.0 mg/l in the dry season. Further analysis of the results obtained showed that two of the boreholes in Abule Egba, Lagos contained high levels of nitrate-N (4.9, 5.2 and 4.6 and 5.0 mg/l). The three wells and two boreholes are located

Table 2. Mean, standard error of the mean, median, minimum and maximum concentrations (mg/l) of nitrate-nitrogen in water samples.

| | Rivers and streams | | Wells | | Boreholes | |
|---|---|---|---|---|---|---|
| | Rainy[a] | Dry[a] | Rainy[a] | Dry[a] | Rainy[a] | Dry[a] |
| Mean | 2.7 | 2.4 | 2.6 | 2.2 | 1.8 | 1.6 |
| SE | 1.1 | 0.68 | 0.67 | 0.65 | 0.80 | 0.87 |
| Median | 1.9 | 1.8 | 2.0 | 1.8 | 1.7 | 1.5 |
| Minimum | 0.5 | 1.0 | 1.4 | 1.1 | 0.1 | nd[b] |
| Maximum | 15.3 | 7.7 | 7.4 | 6.0 | 5.2 | 5.0 |
| Number of sampling points | 33 | 33 | 21 | 21 | 18 | 18 |
| Number of samples | 99 | 99 | 63 | 63 | 54 | 54 |

[a]Season.
[b]Not detected.

very close to a landfill site. The results obtained for the area therefore showed the effect of leachate from a landfill site. Nitrate concentrations were highest in sampling points closest to the landfill. Therefore, location of landfill sites in living areas may pose possible health risks to residents of the area because of pollution of the groundwater. In comparison, the results obtained in this study are lower than those obtained by Mbonu *et al.* [21] for the basement complex region of North Central Nigeria. The reasons for the difference can be attributed to differences in climate, geology, mode of community settlements and agricultural practices.

It has been widely reported in the literature that wells located 30 m or less away from pit latrines/city drainage sites of animal husbandry (mainly piggery and poultry farms) and septic tanks may be contaminated by nitrate. Also, nitrate levels may be high in lakes and groundwater receiving continuous discharge of raw or untreated sewage or waste waters leaching from pit latrines, soakaways, or garbage dumps [22–24]. Also, domestic and industrial point sources of effluents may cause high nitrate levels in receiving rivers during periods of low rainfall when the rivers are providing inadequate dilution. High nitrate levels in surface and ground water may also derive from surface runoff water that has picked up organic material and nitrate from soil or agricultural fertilizers [18]. In eastern Botswana, Hutton *et al.* [25] attributed widespread and severe nitrate contamination of shallow village ground-water supplies to pollution emanating from pit latrines.



The results obtained for most of the sampling points during the rainy season show a marked seasonal pattern. It was observed that nitrate concentrations were slightly high at the beginning of the rainy season (April) and highest in June/July when possibly all the applied fertilizers have been washed into the stream as a result of the heavy erosive rainfall condition. The nitrate values decrease towards the end of the rainy season. No such clear pattern was obtained for the dry season. This may be due to the fact that during the rainy season, rainfall exceeds evapotranspiration, so water flows downward, deeper than the crop root level, and nitrate leaching increases significantly, resulting in both increased surface and groundwater nitrate levels. No significant difference was observed in the means for the two seasons for each type of water point studied.

The high values obtained at the beginning of the rainy season could also be due to the fact that during the hot dry season, the tropical climate tends to favour a high evaporation rate. Under this condition, Stephens [26] suggested that it is possible that evaporation draws soil nitrate towards the surface. This influence is likely to be important only in the upper 30 cm of soil, so that nitrate accumulates at the soil surface. The early rains will then wash this surface-accumulated nitrate into rivers/streams. Therefore, the nitrate levels in streams/rivers waters peak as the higher rainfall washes out nitrate from the land into the rivers. It is also important to note that while rainfall may dilute and weaken the effects of point-source pollution, it also increases the contribution of non-point sources or diffuse pollution through land runoff from agricultural fields and leachates from refuse dumps.

The nitrate ion, being negatively charged, is not specifically adsorbed by most soils and, being very soluble in water, is subject to being leached downwards. This is particularly the case in the wet tropics whenever there is a sufficient excess of rainfall as may occur during the growing season. Therefore, the applied nitrate not taken up by the plant can be leached into the groundwater. This, however, depends on soil texture, rainfall, N-fertilization and type of crop. However, for now, it appears that fertilizer use is below the optimum in many parts of Nigeria partly because of its limited availability and high price. Adetunji [14] observed that the contribution of nitrate to the surface water in a continuously cropped lowland area of South Western Nigeria appears insignificant (less than 10 mg/l). Addiscott *et al.* [15], in their comprehensive book on the nitrate problem, pointed out that the common perception that nitrate leaching equates directly to over-use of fertilizer nitrogen is too simplistic. The authors showed that the use of fertilizer nitrogen leads to enhanced mineralization of soil nitrogen, and that it is this process, rather than direct leaching of fertilizer nitrogen, which is responsible for much of the increased nitrate leaching.

Finally, although the surface and groundwater in the studied area contained nitrate at concentrations below the WHO recommended acceptable limit, there is a risk that with increasing use of inorganic fertilizer and ever-expanding settlements with consequent bush clearing, the nitrate concentration in the surface and ground water will increase in future. This calls for a more rigorous policy to protect the aquifer systems by mapping out protection zones around water points. However, problems of nitrate pollution in waters are less acute for river waters than for ground-waters because significant reduction in nitrate concentration can occur in surface water systems as a result of uptake by aquatic plants and bacteriological denitrification.

## 4. Conclusion

All the results obtained clearly show that all the water points sampled (except one) are below the WHO maximum acceptable limits for potable water. However, the increasing importance of surface/ground water sources in many tropical countries suggests that close attention should be paid to nutrient use within the agricultural sector, sewage effluents, land disposal of domestic waste (caused by rapid urbanization), and industrial waste (solid and effluents) because they may result in future contamination of natural water resources. Therefore, there is a need to continue to monitor nitrate concentrations in both surface water and groundwater supplies in order to ensure that it does not rise beyond the WHO safe limit.

The issue of environmental pollution in Nigeria, especially sanitation and waste disposal, is a major problem. Therefore, the location of boreholes/wells outside and, where possible, upstream of built-up areas may be usefully employed in rural water supply schemes as a method to minimize the risk of localized groundwater pollution. The potential impact of intensive agriculture on shallow groundwater cannot be overemphasized. However, nitrogen-fertilizer use and manure recycling are likely to increase if we are to feed the rapidly increasing population in developing countries. It is important to establish a water-quality protection infrastructure framework and regulation to minimize groundwater contamination in the future.



## Acknowledgements

The author is indebted to the Royal Society of Chemistry (UK) for supporting the first part of this research study through the award of a research grant. Additional laboratory facilities were provided by the Chemistry and EMT Departments of the University of Agriculture, Abeokuta, Nigeria. Special thanks to Mr Sola Soyombo, Mrs M. Jaji and many other students who assisted with sample collection and part of the analysis.

## References

[1] K. E. Black, J. A. H. Lowe, M. F. Billett, M. S. Cresser. Observations in the changes in nitrate concentrations along streams in seven upland moorland catchments in Northeast Scotland. *Water Res.*, **27**, 1195–1199 (1993).

[2] D. J. A. Brown. Effect of atmospheric N deposition on surface water chemistry and the implications for fisheries. *Environ. Pollut.*, **54**, 275–284 (1988).

[3] A. C. Edwards, P. A. Chambers. Quantifying nutrient limiting conditions in temperate river systems. In P. M. Haygarth, S. C. Jarvis (Eds.), *Agriculture, Hydrology and Water Quality*, CAB International, Wallingford, UK, pp. 477–493 (2002).

[4] A. C. Edwards, K. Pugh, G. Wright, A. H. Sinclair, G. A. Reaiss. Nitrate status of two major rivers in N.E. Scotland with respect to land use and fertilizer additions. *Chem. Ecol.*, **4**, 97–107 (1990).

[5] D. Forman, S. Al-Dabbagh, R. Doll. Nitrates, nitrites and gastric cancer in Great Britain. *Nature*, **313**, 620–625 (1985).

[6] S. S. D. Fosters, L. R. Bridge, A. K. Geak, A. R. Lawrence, J. H. Parker. The groundwater nitrate problem: a summary of research on the impact of agricultural land use practices on groundwater quality between 1976 and 1985. In *Hydrological Report British Geological Survey No. 86/2, 95 pp.* (1986).
[7] M. H. Miller. Contribution of nitrogen and phosphorus to subsurface drainage water from intensively cropped mineral and organic soils in Ontario. *J. Environ. Qual.*, **8**, 42–48 (1979).
[8] P. Millburp, J. E. Richards, C. Gartky, J. Pollock, H. O'Neill, H. Balky. Nitrate leaching from systematically tilled potato fields in New Brunswick, Canada. *J. Environ. Qual.*, **19**, 448–454 (1990).
[9] G. G. Wright, A. C. Edwards, J. G. Morrice, K. Pugh. North East Scotland river catchment nitrate loading in relation to agricultural intensity. *Chem. Ecol.*, **5**, 263–281 (1991).
[10] D. B. Davies, R. Sylvester-Bradley. The contribution of fertilizer nitrogen to leachable nitrogen in the UK: a review. *J. Sci. Food Agric.*, **68**, 399–406 (1995).
[11] T. R. Owen, S. Jurgens-Gschwind. Nitrates in drinking water. *Fertil. Res.*, **10**, 3–25 (1986).
[12] W. H. Prins, K. Dilz, J. J. Neeteson. *Current Recommendations for Nitrogen Fertilization within the EEC in Relation to Nitrate Leaching (Proceedings No. 276).* The Fertilizer Society of London, London, pp. 3–27 (1988).
[13] B. Singh, G. S. Sekhon. Nitrate pollution of groundwater from farm use of nitrogen fertilizers – a review. *Agric. Environ.*, **4**, 207–225 (1978–1979).
[14] M. T. Adetunji. Nitrogen application and underground water contamination in some agricultural soils of South Western Nigeria. *Fertil. Res.*, **37**, 159–163 (1994).
[15] T. M. Addiscott, A. P. Whitmore, D. S. Powlson. *Farming, Fertilizers and the Nitrate Problem*, CAB International, Wallingford, UK (1991).
[16] WHO. *Guidelines for Drinking Water Quality, Vol. 1, Recommendations*, WHO, Geneva (1984).
[17] Federal Republic of Nigeria (FRN). *Federal Ministry of Water Resources. Department of Water Supply and Quality Control, National Water Supply and Sanitation Policy*, 1st edn, Federal Ministry of Water Resources, Abuja, Nigeria (2000).
[18] R. G. Feachem, D. J. Bradley, H. Garelick, D. D. Mara. *Sanitation and Disease: Health Aspects of Excreta and Wastewater Management.* John Hopkins University Press, Baltimore, MD (1983).
[19] S. K. Gupta, R. C. Gupta, A. K. Seth, A. B. Gupta, J. K. Bassin, A. Gupta. Adaptation of cytochrome – $b_5$-reductase activity and methaemoglobinaemia in areas with a high nitrate concentration in drinking water. *Bulletin of the World Health Organization*, **77**, 749–753 (1999).
[20] UNEP (United Nations Environment Programme). *Environmental Data Report (93/94)*, Blackwell, Oxford (1993).
[21] M. Mbonu, Y. Travi, R. Guiraud. Groundwater quality in the basement complex region of North-Central Nigeria: A precursory survey of nitrate concentration. In *Water Quality Monitoring and Environmental Status in Nigeria, FEPA. Monograph 6*, E. O. A. Aina, N. O. Adedipe (Eds.), FEPA, Abuja, Nigeria (1996).
[22] M. Berwick. Nitrate levels in groundwater from the Aleuve Senegal. *Progress in Water Technology*, **11**, 117–120 (1979).
[23] N. J. Nicholson. A review of the nitrate problem. *Chem. Ind.*, **6**, 189–195 (1979).
[24] E. B. Schalscha, I. Vergara, T. Schirado, M. Morales. Nitrate movement in a Chilean agricultural area irrigated with untreated sewage water. *J. Environ. Qual.*, **8**, 27–30 (1979).
[25] L. G. Hutton, W. J. Lewis, A. C. Skinner. A report on nitrate contamination of groundwaters in some populated areas of Botswana. Geological Survey, Unpublished Report No. BGSD/8/76, Lobatse, Botswana (1976).
[26] D. Stephens. Upward movement of nitrate in a bare soil in Uganda. *J. Soil Sci.*, **13**, 52–55 (1962).