USING SHUTTLE RADAR TOPOGRAPHIC MISSION IMAGERY TO IDENTIFY INLAND VALLEY AREAS AND THE SOIL SUITABILITY STUDIES FOR VEGETABLE PRODUCTION IN AKURE SOUTH LOCAL GOVERNMENT AREA NIGERIA

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Abstract

The Shuttle Radar Topographic Mission (SRTM) imagery was used in 2012 to identify stream courses in Akure South Local Government Area (AKSLGA) where Akure (Latitute $7^0$15’N and Longitude $5^0$15’E) the capital of Ondo State Nigeria which had witnessed a tremendous urban sprawl in the last twenty years was located. The cultivation of vegetable in the inland valley areas was a way to improve the income and diet of the city dwellers. The polygonized boundary of AKSLGA which was superimposed on SRTM image was extracted out while the focal statistics, the contour lines at an interval of 10 m and the stream courses were generated using the Spatial Analyst Tools in ArcMap. The streams were each buffered at a distance of 100 m to generate the inland valley areas using the Analysis/ Proximity/ Buffer Tools. The soils were generally sandy loam while the average bulk densities and gravel content values were 1.53 g/cm^3 and 9% respectively. The nutrient concentration showed mean values of 1.02 %, 11.2 ppm, 0.25 cmol/kg, 3.77 cmol/kg, 1.66 cmol/kg and 3.32 % for nitrogen, phosphorus, potassium, calcium, magnesium and organic matter respectively which were suitable soil conditions for vegetable production.

Keywords: SRTM, inland valley soils, soil suitability, vegetable production

Introduction

The starch rich staple foods such as cassava, yam, rice and maize prepared in various recipes, dominated the diet of most Nigerians and several Africans for which therefore the consumption of indigenous vegetables would serve as cheap and important source of protein, vitamins, minerals and amino acids (Adekayode and Ogunkoya, 2011; Omara-Achong et al., 2012). The nutritive value of vegetables had also been documented in previous report (Bodroza-Solarov et al., 2008; Song et al., 2010). Fruits and vegetables had been confirmed to furnish valuable dietary nutrients and also contributed vital elements to chronic disease prevention for heart disease, hypertension, certain cancers, vision problems of aging and a reduction in the risk of developing Type 2 diabetes (Ogunlesi et al., 2010). The consumption of vegetables in diet had been reported to protect the human body from degenerative diseases as the main protective action of vegetables had been attributed to the antioxidant present in them (Stratil et al., 2006). The investigation carried out by Bressani et al. (1993) showed that amaranth protein was close to those of animal origin products while the high vitamin C content of amaranth had also been previously reported (Condes et al., 2009; Tironi and Anon, 2010).

The reports on the chemical composition of vegetables indicated orange and yellow vegetables and fruits including carrots, spinach, pumpkins and red peppers to be rich sources of beta-carotene while the dark green leafy vegetables were rich sources of lutein and zeaxanthin (Liu, 2013). The previous analysis result obtained in De-Lannoy (2001) on the composition of amaranth vegetable indicated one hundred grams to contain 3.6 to 4.6 g protein, 154 to 410 mg calcium, 2.9 to 8.9 mg iron, 5.7 to 6.5 mg beta-carotene, 23 to 64 mg vitamin C respectively.

The previous reports had indicated the ideal topography for vegetable production to be nearly flat to slightly sloping, well drained and low areas because the efficacy of crop maintenance, irrigation and harvest operations would be greatly enhanced in fields with such topography (Udoh, 2005; Enete and Okon, 2010). The identification of such inland valley soils with the use of remote sensing and geographic information system technique had been reported in previous investigation (Ishaya and Mushi, 2008; Gumma et al. 2009). The generation of landscape configuration using Shuttle Radar Topographic Mission (SRTM) to display upland and valley areas was reported in Rodriguez et al. (2006) while the accuracy of vertical quality and the potential to derive terrain attributes from the digital elevation model obtained by contour lines from SRTM was reported on a digital soil mapping in Brazil (Neumann et al., 2012). The SRTM had been described to provide three-dimensional models with two spatial resolution of 1 arc-s (30 m) and 3 arc-s (90 m) with horizontal datum WGS84 and vertical datum WGS84/EGM96 with relative vertical accuracy on the order of 5 m (Smith and Sandwell, 2003)

The use of buffering technique in assessing inland valley soils was described in Correll (2005) and the buffered zone included the stream bank and areas where the water table was near the surface.

The high soil fertility status of inland valley soils which revealed the agricultural potential was discussed by Mustapha (2007) and Adigbo et al. (2011). The suitability of inland valley soils for increased okra production was reported in Nosiru et al. (2012) while Omara-Achong et al. (2012) in the investigative survey of indigenous vegetables species in parts of Cross River State, Nigeria, emphasized the availability of rich lowland soils as favourable factor in vegetable production. The inland valley areas in Nigeria which was popularly called fadama were identified as resource potential for food crop production and eight of such coordinating fadama areas identified and funded by the Federal Government of Nigeria were Sokoto Basin, Chad Basin, Middle Niger Basin, Southwestern Zone, South Central, South eastern and Basement Complex (Adigbo et al., 2011). The small holders who cultivated fadama inland valley soils used low input technology and were able to meet the needs of Nigeria for vegetables as importation of fresh vegetables were uncommon (Oladoja et al., 2005).

The objectives of this research were to produce a contour map and generate stream courses in Akure South Local Government Area from SRTM imagery and buffer the identified streams as inland valley soils for vegetable production.

Description of the Study Area

The study area was the Akure Local Government Area which was one of the 774 Local Government Areas in Nigeria and where Akure (Latitute $7^0$15’N and Longitude $5^0$15’E) the capital of Ondo State Nigeria was located. The climate was tropical with rainy season of eight months (March to October) and a dry season of four months (November to February), a mean annual precipitation of 1000 to 1250 mm and a mean annual temperature of about 27^0C. The soil charactierisation as previously reported on soils of Southwest Nigeria by Smyth and Montgomery (1962) and updated in Periaswamy and Ashaye (1983) revealed soil type extensively occurring in Akure area to be Egbeda, Olorunda, Iwo, Ibadan, Balogun and Akure series. The 2006 Nigeria National Population Census indicated Akure LGA had a population figure of 353,211 made up of 177,716 females and 175,495 males. .

Generation of elevation data and stream courses from Shuttle Radar Topographic Mission (SRTM) image

The SRTM image of part of South West Nigeria (path 190, row 055) at 90 m resolution was downloaded from the Global Land Cover Facility/SRTM imagery site (USGS and Japan ASTER Programme, 2003). The downloaded image which was in geographic coordinate systems was transformed to the projected coordinate systems of WGS 1984 UTM Zone 31N using the sequential procedure of Data frame/Properties/Predefined Tools in ArcMap. The polygonized boundary of the project site was superimposed on the SRTM image and the boundary extracted out using the Spatial Analyst/ Extraction by Mask Tools in ArcMap.

The image focal statistics were generated using Spatial Analyst /Neighbourhood/ Focal Statistics Tools in ArcMap while the contour generated at an interval of 2 m with the Spatial Analyst/Surface/ Contour Tools. The stream courses were generated with the use of Fill and Flow Tools respectively in Spatial Analyst/ Hydrology Tools in ArcMap.

Buffering of streams

The streams were each buffered at a distance of 100 m to generate the lowland valley areas using the Analysis/ Proximity/ Buffer Tools.

Soil sampling and laboratory analysis

Soil samples to a depth of 30 cm from four locations in the buffered zone of each stream were taken for laboratory analysis. Soil samples were air-dried and sieved through a 2 mm sieve and analysed for the physical properties of particle size and bulk density and the chemical properties of nitrogen, phosphorus, potassium and organic matter content following the laboratory procedures described by Carter (1993). The particle size distribution was determined using 50 g of soil in 0.1M NaOH as dispersing agent using Hydrometer (ASTM 1524) methods. Organic carbon was determined by oxidising soil sample with dichromate solution and later titrated with ferrous sulphate solution. The total nitrogen was determined using micro-kjeldahl method and the available phosphorus determined by the Bray P-1 method. The exchangeable cations were extracted by leaching 5 g of soil with 50 ml ammonium acetate at pH 7 and the potassium in the leachate determined with a flame spectrophotometer.

Results

Figure 1 shows the contour map of Akure South Local Government Area as generated from SRTM at an interval of 10 meters with the lowest and highest elevation of 250and 440 m above sea level respectively at various locations. Figure 2 shows the stream courses as generated with the application of Fill and Flow Tools respectively in Spatial Analyst/ Hydrology Tools in ArcMap while Figure 3 shows the buffered streams with the buffered zone round the streams at 150 m from each stream and delineated as the inland valley areas

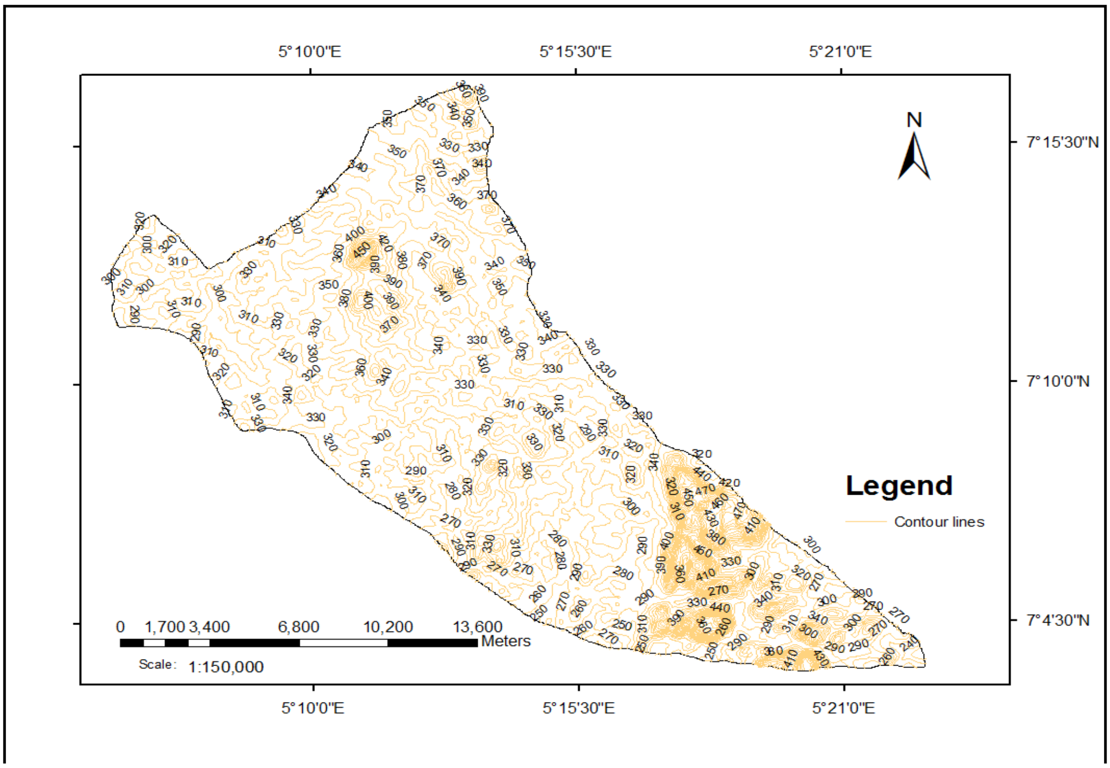

Figure 1: The contour map of Akure South Local Government Area

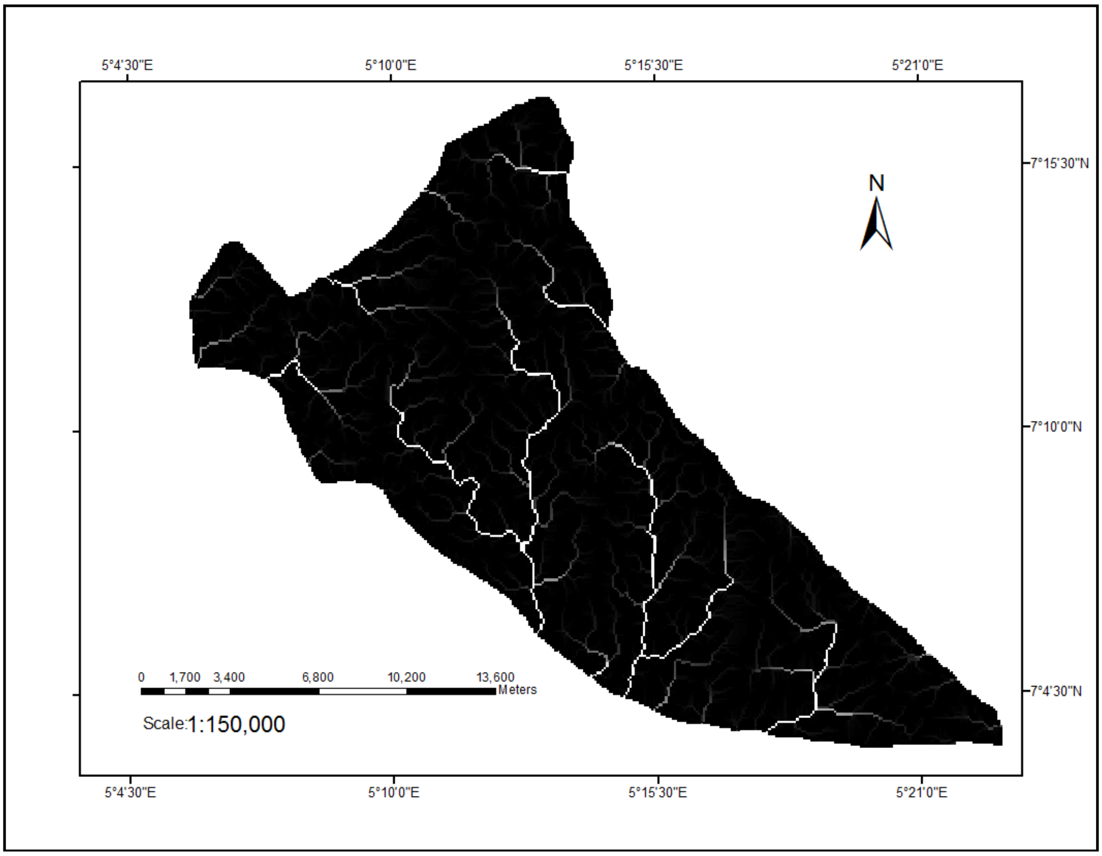

Figure 2: Courses of major streams in Akure South Local Government Area as generated from

SRTM

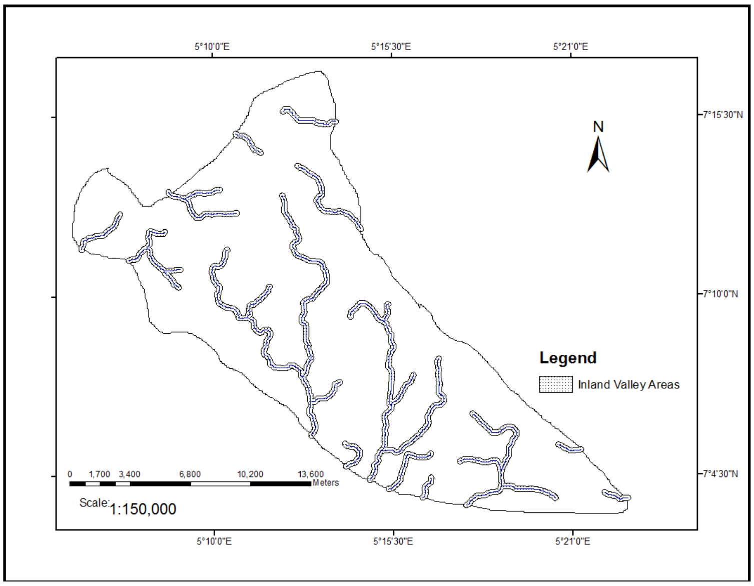

Figure 3: The streams buffered at 150 m to create the inland valley areas

Table 1 shows the physical and chemical properties of soil samples taken at twenty seven locations and made into nine composite. The soils were generally sandy loam while the bulk densities ranged from 1.52 to 1.54 g/cm^3 with an average value of 1.53 g/cm^3. The average gravel content was 9 % and ranged from 8 to 10 %. The pH range of 5.8 to 6.5 indicated the soil to be of medium to slight acidity. The nutrient concentration showed mean values of 1.02 %, 11.2 ppm, 0.25 cmol/kg, 3.77 cmol/kg, 1.66 cmol/kg and 3.32 % for nitrogen, phosphorus, potassium, calcium, magnesium and organic matter respectively.

Table 1: The physical properties of the soil

Sampling Points	Sand %)	Clay (%)	Silt (%)	BD (g/cm^3)	Gravel (%)
1	75	13	12	1.54	9
2	69	12	19	1.54	10
3	72	12	16	1.54	9
4	74	13	13	1.54	10
5	76	13	11	1.54	9
6	71	14	15	1.54	8
7	65	13	22	1.52	9
8	68	13	18	1.52	8
9	70	14	16	1.52	8

Table 2: Chemical properties of the soils

Sampling Point	pH	Organic Matter (%)	N (%)	P (ppm)	K (cmol/kg)	Ca (cmol/kg)	Mg (cmol/kg)
1	5.8	3.17	0.96	10.40	0.23	3.50	1.59
2	6.2	3.39	1.03	11.13	0.25	3.75	1.70
3	5.9	3.23	0.98	10.61	0.23	3.57	1.62
4	6.1	3.36	1.02	11.02	0.24	3.71	1.69
5	6.0	3.27	0.99	10.71	0.24	3.61	1.64
6	6.1	3.24	1.02	11.20	0.25	3.80	1.62
7	6.5	3.47	1.09	11.98	0.27	4.07	1.73
8	6.2	3.30	1.04	11.42	0.26	3.88	1.65
9	6.5	3.43	1.08	11.87	0.27	4.03	1.72

Discussion

The contour lines generated with the Spatial Analyst tool in ArcMap followed the explanation in Rabus et al. (2003) and Javis et al. (2008) on the generation of contour from SRTM data. The method which produced more accurate contour lines than the traditional approach of digitizing an existing topographic map enabled the varying of contour intervals for a more detailed outlook of the landscape configuration. The contour lines were produced as shape file from SRTM data through a conversion via the contour tool in the ArcGIS Spatial Analyst extension. Nag et al. (2013) in the previous study of the hydrological modeling of watershed used the contour map generated from SRTM image to generate the topography of the Wochhu river basin in Bhutan.

The hydrological modeling that produced the stream courses in Figure 2 corroborated the procedures on watershed delineation and parameterizations carried out using cartographic DEM derived from digital topography and SRTM elevation data (Akbari et al., 2012). The generation of the stream courses followed the procedures in the application of spatial analyst tool in ArcGIS (ESRI, 2004). The previous investigation with similar hydrological observation was the use of SRTM data and ArcGIS 10 spatial analyst tools in the morphometric analysis of stream order and stream length in the Kosasthalaiyar sub basin in the Chennai basin in India (Nayar and Natarajan, 2013). The hydrology tool in the spatial analyst toolsets was used to model the flow of water to create a stream network across the surface (ESRI, 2014).

The buffering as performed using the Analysis/ Proximity/ Buffer Tools corroborated the previous procedures adopted in the use of line-based road network buffers (Oliver et al., 2007) and the classification of buffered zone along stream courses as fadama soils (Adekayode and Ogunkoya, 2009).

The soil nutrient concentration with average values of 1.02 %, 11.2 ppm, 0.25 cmol/kg, 3.77 cmol/kg, 1.66 cmol/kg and 3.32 % for nitrogen, phosphorus, potassium, calcium, magnesium and organic matter respectively indicated soil nutrient level to be of medium productivity which with the application of manure will be highly productive as Fadama soils. Previous investigation reported by Lawal et al. (2010) on the fertility status of inland valley soils discussed the improvement of soil fertility of fadama soils through the incorporation of manure while the adoption of “Sawah” farming system in inland valley soils characterized by nutrient replenishing mechanism was also discussed in Buri et al. (2012).

Conclusion

The contour map generated from SRTM indicated elevation ranges of 250and 440 m above sea level respectively at various locations. The total area of 3, 487.2 hectares generated as buffered zones round the identified streams constituted the inland valley areas and the potential areas for the production of vegetables and other dry season crops.

References:

Adekayode, F.O. and Ogunkoya, M.O. The use of Geographic Information Systems (GIS) in estimating a potential fadama land area for inland farming: The buffering technique. Journal of Food, Agriculture and Environment (JFAE), Volume 7 (3&4): 705 – 709, 2009.

Adekayode, F.O. and Ogunkoya, M.O. Comparative effects of organic compost and NPK fertilizer on soil fertility, yield and quality of Amaranth in southwest Nigeria. International Journal of Biological and Chemical Sciences, 5(2):490-499, 2011.

Adigbo, S.O., Wakatsuki, T., Odedina, J.N., Fabunmi, T.O. and Adigbo, V.B. Exploiting the Potentials of Inland Valleys of Nigeria for Poverty Alleviation. Proceedings of the Environmental Management Conference held at the Federal University of Agriculture, Abeokuta, Nigeria, pp. 465 – 478, 2011. http://www.unaab.edu.ng

Akbari, A., Samah, A.A. and Othman, F. Integration of SRTM and TRMM data into the GIS-based hydrological model for the purpose of flood modeling. Hydrology and Earth System Sciences Discussions, 9: 4747-4775, 2012.

Bodroza-Solarov, M., Filipcev, B., Kevrezan, Z., Mandic, A. and Simurina, O. Quality of bread supplemented with popped Amaranthus cruentus grain. Journal of Food Process Engineering, 31:602-618, 2008.

Bressani, R., De-Martell, E.C.M. and De Godinez, C.M. Protein quality evaluation of amaranth in adult humans. Plant Foods for Human Nutrition, 43(2): 123-143, 1993.

Buri, M.M., Issaka, R.N., Wakatsuki, T. and Kawano, N. Improving the productivity of lowland soils for rice cultivation in Ghana: The role of the 'Sawah' system. Journal of Soil Science and Environmental Management, volume 3(3): 56-62, 2012.

Carter, M. R. Soil Sampling and Methods of Soil Analysis. Canadian Society of Soil Science.Lewis Publishers, London.823pp, 1993.

Condes, M.C., Scilingo, A.A. and Anon, M.C. Characterization of amaranth proteins modified by trypsin proteolysis structural and functional changes. Food Science and Technology, 42(5):963-970, 2009.

Correll, D.L. Principles of planning and establishment of buffer zones. Ecological Engineering, 24: 433-439, 2005

De-Lannoy, G. Leaf Vegetables. Raemaekers RH (ed). Goekint Graphics nv: Belgium, 1540pp, 2001.

Enete, A.A. and Okon, U.E. Economics of Waterleaf (Talinum triangulare) Production in Akwa Ibom State, Nigeria. Field Actions Science Reporting, Volume 4.factsreports.revues.org/438 2010.

ESRI.ArcGIS Spatial Analyst.Advanced Raster Spatial Analysis, 2004.
www.esri.com/library/brochures/pdfs/spatialanalystbro.pdf

ESRI.ArcGIS Spatial Analyst Overview, 2014.
www.esri.com/software/arcgis/extension/spatialanalyst

Gumma, M., Thankabail, P.S., Fujii, H. and Namara, R. Spatial Models for Selecting the most suitable areas of rice cultivation in the Inland Valley wetlands of Ghana using Remote Sensing and Geographic Information Systems. Journal of Applied Remote Sensing, Volume 3, 033537: pp. 1-21, 2009.

Ishaya, S. and Mashi, S.A. Using GIS to map fadama areas in the Central Abuja, Nigeria. Journal of Sustainable Development in Agriculture and Environment, 3(2): 110-118, 2008.

Javis, A., Reuter, H.I., Nelson, A. and Guevara, E. Hole-filled SRTM for the globe, Version 4, CGIAR-CSI SRTM 90m Database, 2008.http://srtm.csi.cgiar.org

Lawal, A.F., Omotesho, O.A. and Adewumi, M.O. Land use pattern and sustainability of food crop production in the Fadama of Southern Guinea Savanna of Nigeria. African Journal of Agricultural Research. Volume 5 (3): 178-187, 2010.

Liu, R.H. Health Promoting Components of Fruits and Vegetables in the Diet. Advances in Nutrition, 4: 3845 – 3925, 2013.

Mustapha, S. Fertility status of Fadama Soils in Dass Local Government Area of Bauchi State, Nigeria.Journal of Sustainable Development in Agriculture and Environment.Volume 3; 104 – 111, 2007.

Nag, A., Penjor, K., Tobgay, S. and Jamtsho, C. Hydrological modeling of watershed using HEC-HMS software and ArcGIS. International Journal of Advanced Scientific and Technical Research, 2(3): 313-319, 2013.

Nayar, V. and Natarajan, K. Quantitative Morphometric Analysis of Kosasthalaiyar sub basin using Remote Sensing (SRTM) data and GIS technique. International Journal of Geomatics and Geosciences, volume 4(1): 89-102, 2013.

Neumann, M.R.B., Roig, H.L. and de Souza, A.L.F. Digital elevation models obtained by contour lines and SRTM/Topodata for digital soil mapping. Journal of Soil Science and Environmental Management, 3(5): 104-109, 2012.

Nosiru, M.O., Banjo, J.O.S. and Adedeji, T.O. Determinants of Improved Productivity of Okra (Abelmoschus esculentus) by Farmers in Lowland Areas of Ogun State, Nigeria. Amerivan-Eurasian Journal of Agriculture and Environmental Science, 12(12): 1572 – 1578, 2012.

Ogunlesi, M., Okiei, W., Azeez, L., Obakachi, V., Osunsanmi, S. and Nkenchor, G. Vitamin C contents of Tropical Vegetables and Foods Determined by Voltametric and Titrimetric methods and their relevance to the medicinal uses of the plants. International Journal of Electrochemical Science, 5:105-115, 2010.

Oladoja, M. A, Akinbile, L. A and Adisa, B. O. Assessment of the environmental related problems and prospects of vegetable products in peri-urban areas of Lagos State, Nigeria. Nigerian Journal of Environmental Extensions volume (5): 18-24, 2005.

Oliver, L. N, Schuurman, N and Hall, A. W. Comparing Circular and Network Buffers to Examine the Influence of Land Use on Walking for Leisure and Errands. International Journal of Health Geographics. Vol 6:41, 2007.
http://www.ncbi.nlm.nih.gov/pmc/articles/pmc2034381.

Omara-Achong, T.E., Edwin-Wosu, N.L., Edu, E.A. and Nkang, A.E. Survey of indigenous vegetables species in parts of Ogoja and calabar, Cross River State, Nigeria. European Journal of Experimental Biology, 2(4): 1289 – 1301, 2012.

Periaswamy, S.P. and Ashaye, T.I. Updated Classification of some Southwestern Nigeria Soils. Ife Journal of Agriculture 4(1&2), 25 – 41, 1982.

Rabus, B., Eineder, M., Roth, A., & Bamler, R.The shuttle radar topography mission.A new class of digital elevation models acquired by spaceborne radar. ISPRS J. Photogram. Remote Sensing, 57, 241- 262, 2003.

Rodríguez, E., C.Morris, and E.Belz, 2006: A global assessment of the SRTM performance. Photogramm.Eng. Remote Sens., **72**, 249–260, 2006.

Smith, B, and Sandwell, D. Accuracy and resolution of shuttle radar topography mission data. Geophysical Research.Letters., 30(9): 1467-1470, 2003.

Smyth, A. J. Montgomery, R. F. Soils and Land use in Central Western Nigeria, Ibadan Government Printer, pp 265, 1962.

Song, W., Derito, C.M., Liu, K.M., Liu, H.X., Dong, M. and Liu, R.H. Cellular antioxidant activity of common vegetables. Journal of Agriculture and Food Chemistry, 58: 6621 – 6629, 2010.

Stratil, P., Klejdus, B. and Kubán, V. Determination of total content of phenolic compounds and their antioxidant activity in vegetables--evaluation of spectrophotometric methods. J Agric Food Chem. 8:54 (3):607-616, 2006.

Tironi, V.A. and Anon, M.C. Amaranth proteins as a source of antioxidant peptides: Effect of proteolysis. Food Research International, 43(1): 315-322, 2010.

Udoh, E.J. Technical Inefficiency of Vegetable Farms of Humid Region: Analysis of Dry Season Vegetable Farming of Urban Women in South South Zone, Nigeria. Journal of Agriculture and Social Sciences, 1: 80 – 85, 2005.

USGS and Japan ASTER Programme, ASTER, 2003.
Scene AST_LIB_003_06262000100635,1B,ASGS,SiouxFALLS,6/26/2001.