Journal of
Current Opinion in Crop Science
Journal homepage:: www.jcocs.com

RESEARCH ARTICLE

Suitability Assessment of Soils of Selected Areas of Benue State, Nigeria, for Maize Production and their Management Implications

A. Ali[1], M. Usman[2*], B. Adejo[3]

[1]Department of Soil Science, Federal University of Agriculture, Makurdi, Nigeria
[2]Department of Agricultural Science Education, Federal College of Education (Technical), Potiskum, Nigeria
[3]Department of Agricultural Education, College of Education, Oju, Benue State, Nigeria

ABSTRACT

Suitability assessment of soils of selected local government areas (LGAs) of Benue State, Nigeria was carried out to determine the soil types, fertility status and suitability level for maize cultivation. The study locations were Obagaji, Agatu LGA; Igumale, Ado LGA; Ugbokpo, Apa LGA; Idekpa, Ohimini LGA; Orokam, Ogbadibo LGA and Adoka, Otukpo LGA. Soil samples (representative of the entire fields) collected from farmer's cultivated maize fields and adjacent non- cultivated fields in each of the study location. The soil types and degradation status of the soils were assessed on the basis of the results of the soil properties by FAO. Suitability ratings of the soils were determined using soil type, non-parametric (conventional) and parametric methods. Results indicated that soils of Adoka, Idekpa and Obagaji were highly degraded with respect to bulk density. Fertilization and incorporation of organic manure will be required for optimum production of maize on the soils investigated.

Keywords: Suitability assessment; Maize Production; Management Implications

Article history:

Received: February 15, 2021
Accepted: March 17, 2021
Published: March 25, 2021

Citation:

Ali, A., Usman, M., & Adejo, B. (2021). Suitability Assessment of Soils of Selected Areas of Benue State, Nigeria, for Maize Production and their Management Implications. *Journal of Current Opinion in Crop Science, 2*(1), 110-117.

*Corresponding author e-mail address: usmanm2020@gmail.com (M. Usman)

INTRODUCTION

In order to meet the demands of an ever-growing human population, the land's ability for greater crop production is decreasing (Lal, 1994). Studies show that soil erosion, unsustainable tillage, and overgrazing have significantly reduced soil productivity on over 10% of the world's vegetated land (Lal, 1994). Soil degradation is the loss of soil quality due to improper agricultural, pastoral, commercial, or urban use. Carbon dioxide emissions from human activities are increasing soil depletion. Degradation includes physical, chemical, and biological. Deficiencies in soil fertility, structure, and organic matter are all examples of soil depletion (Charman and Murphy, 2005). Safe soils are vital for food and fibre production, as well as adequate water supply. Soil ecosystem services are vital to the carbon, water, and cultural cycles (Charman and Murphy, 2005).

However, in the current land-scarce condition, expanding agriculture to satisfy rising demand is problematic (Fischer et al., 2002). According to Teklu (2005), increased agricultural productivity is critical to reducing chronic hunger and food insecurity in developing countries. As a result, choosing the right crop for a given location should be carefully considered. Environmentally sound, socially acceptable, and commercially viable crop production (Addeo et al., 2001). It assesses how well a land unit's qualities fulfil the criteria for a certain land use.

Crop and soil/land factors dictate appropriate land usage. Soil spatial features are required for many land management applications (Burrough, 1996; Udoh and Ogunkunle, 2012). No such data are available for adequate planning in the study areas. Land management systems that can govern land degradation processes and production will primarily rule provided land use sustainability (Smyth and Dumanski, 1993 and FAO, 2006). Sustainable agriculture can be achieved by classifying and using lands according to their capacities. Thus, the goal of this study is to assess the soil type, fertility state, and suitability for maize cultivation in the study areas.

MATERIALS AND METHODS

Benue State lies on latitude 6° 25'N and 8° 25'N and on longitude 7° 47'E and 10° 00'E in the central part of Nigeria (Nyagba, 1995; Ali et al., 2020). It falls within the Koppen's Aw climate classification, which experiences marked wet and dry seasons. This is reflected in the denser nature of the vegetation (Ologunorisa and Tersoo, 2005).

The parent materials forming soil in Benue State are large of sedimentary origin. These produce the deep loamy soils, the basis of agricultural production in most parts of the state. Generally, there are about seven different soil classes distributed across the state. These include Lithosols, Aerosols, Fluvisols, Cambisols and Regosols (BENSEPA, 1999). However, the most extensive is the Luvisols occurring mostly in the state's western and southern parts.

The soils are fine-textured with poor internal drainage. The soils' common feature is the movement of clay within the soil profile-the present results in the relatively compact illuviated clay or duricrust. The agronomic significance of the deep-seated duricrust is that it often produces perched groundwater sources, which are essential sources of capillary water, supporting farming activities.

The topsoil is low in organic matter content. The state is located within the guinea savanna belt, which is also the broadest agro-ecological and vegetation zone in Nigeria and is characterized by heterogeneous species of scattered trees and grasses (Nyagba, 1995 and Usman et al., 2021).

The study locations included six local government areas of Benue state, namely Obagaji, Agatu LGA; Igumale, Ado LGA; Ugbokpo, Apa LGA; Idekpa, Ohimini LGA; Orokam, Ogbadibo LGA and Adoka, Otukpo LGA (Figure 1). Soil types, fertility status and the level of soil degradation in these areas were assessed, and their suitability for the growth of maize determined.

Soil samples were collected from corn fields in each of the six local government regions using core samples. Three soil samples were collected from different portions of the field and utilised as a field representative. Similarly, three composite soil samples were collected from non-cultivated fields next to each study site.

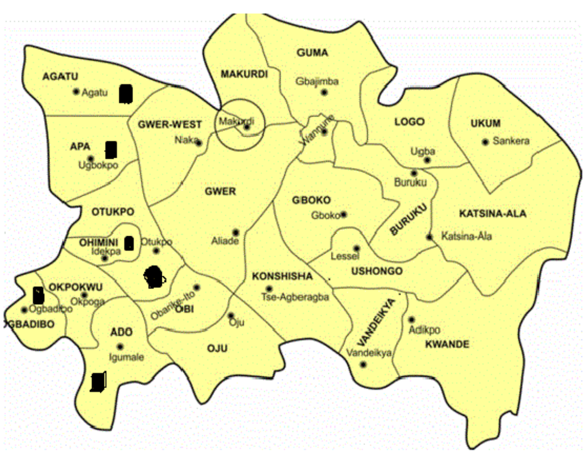

Figure 1. Study areas of Benue State.

The bulked samples were air-dried before being lightly crushed. The samples were processed for laboratory testing after a 2 mm sieve. To determine bulk density, core samples were cut to the core height (g/cm3). Pd = 2.65 g/cm3 soil particle density (Usman, 2020). The constant head process was used to calculate Ksat. Page et al. (1982) described the Walkley and Black method. It was determined by the macro Kjeldahl method (Udo et al., 2009). Page et al. (1982) employed the Bray 1 method to assess available phosphorus. IITA (1979) employed ammonium acetate solution to measure cation exchange capacity and exchangeable acidity. IITA (1979) defined the ammonium acetate extraction procedure for evaluating exchangeable cations. An atomic absorption spectrophotometer analysed the cations (AAS). Soaking the soil in 1 N KCl and titrating the extract with a standard NaOH solution estimated the exchangeable acidity. Al3+ was reported as milliequivalents of the acid used, and H+ was measured. In milliequivalents per 100 g soil

The degradation status of the soils and was divided into four groups of degree of degradation as shown in Table 1.

To develop suitability classes for different mapping units, soil suitability was focused on soil types and matching soil properties and crop requirements. The traditional (non-parametric) (FAO, 2006; (Ogunkunle, 1993; Udo et al., 2009). A four-class framework was developed based on the analysis of data collected on the physical, chemical, and nutritional characteristics of the soil. The grounds were classified according to their suitability by comparing their components to the crop specifications under investigation. The soil suitability class was demonstrated by its most restrictive characteristics. As a result, the letters S1, S2, S3, and N will stand for "extremely," "moderately," "marginally," and "not suitable," respectively (Udoh and Ogunkunle, 2012; Raji, 2016). Table 2 shows the important limits for understanding levels of analytical parameters at the study sites.

RESULTS AND DISCUSSION

The physical properties of the soils of the study sites (Table 3) showed that the soils of the study sites were loamy sand except for Ugbokpo soils which were sandy loam. The maize field in Ugbokpo had the least permeability (24.8 cm hr^{-1}), while the highest was obtained from Obagaji (43.3 cm hr^{-1}). The chemical properties of the study areas are presented on Table 4. Most of the soils ranged from slightly acidic to neutral across the fields. The variation in pH could be attributed to rainfall patterns, parent materials, and the amount and source of organic matter in the soil. The pH ranges in the fields are ideal for crop growth and microbial activity. Amount of available N ranged from 0.006 % at Igumale to 0.009 % in Ugbokpo. Organic carbon ranged from 1.35 % at Ugbokpo to 1.98 % at Igumale. Nitrogen levels in the soils were extremely low, which indicates poor soil fertility; therefore, there will be a need for nitrogenous fertilizers application for a successful crop production in the locations (Ojeniyi, 2010 and Ali et al., 2019). Potassium values varied from none to slightly to moderately degraded. With the exception of Ugbokpo, all of the study sites had high levels of organic carbon. The soils had a high organic matter content in all of the areas.

Table 3. Physical properties of soils of the study areas

Location	Crop	BD gcm^{-3}	Ksat cm hr^{-1}	Permeability cm hr^{-1}	Sand (%)	Silt (%)	Clay (%)	Textural class
Ugbokpo	Maize	1.53	0.45	24.8	68.0	22.0	10.0	Sandy loam
Igumale	Maize	2.45	0.31	28.4	88.0	10.0	02.0	Loamy sand
Obagaji	Maize	2.51	0.75	42.3	89.6	07.2	03.2	Sand
Adoka	Maize	3.45	0.59	28.5	75.0	15.0	10.0	Loamy sand
Orokam	Maize	1.52	0.77	28.7	69.0	18.0	13.0	Loamy sand
Idekpa	Maize	2.50	0.49	34.0	88.5	07.2	04.3	Loamy sand

Available P ranged from 0.34 mg kg^{-1} at Obagaji to 1.02 mg kg^{-1} in Orokam. In similar vein, the maize fields had high available P in all the locations with the exception of Adoka. Sulphur in the soils ranged from 0.33 mg kg^{-1} at Igumale to 1.54 mg kg^{-1} in Ugbokpo. Calcium ranged from 2.7 mg kg^{-1} at Adoka to 4.2 mg kg^{-1} at Idekpa. Magnesium level was high in the fields

Table 4. Chemical properties of soils of the study areas

Location	Crop	pH	OC	TN	P	S	K	Na	Mg	Ca	CEC	BS	EC	SAR	ESP
		(H_2O)	(%)	←			(mg kg^{-1})				→	(%)	(mScm-^{1})	(cmol kg^{-1})	(%)
Ugbokpo	Maize	6.98	1.35	0.009	0.59	1.54	0.23	0.20	2.60	2.80	8.21	71.01	196	0.12	2.44
Igumale	Maize	6.21	1.98	0.007	0.53	0.37	0.34	0.29	3.10	3.40	8.88	80.29	093	0.16	3.27
Obagaji	Maize	6.32	1.73	0.006	0.63	1.06	0.32	0.27	3.20	3.98	7.95	97.74	080	0.14	3.40
Adoka	Maize	6.45	1.64	0.007	0.36	0.96	0.25	0.23	3	3.8	8.23	88.46	100	0.12	2.80
Orokam	Maize	6.06	1.61	0.006	1.02	0.84	0.25	0.22	2.5	2.9	7.84	74.87	070	0.13	2.81
Idekpa	Maize	6.73	1.75	0.008	0.78	1.08	0.31	0.27	3.0	3.9	8.88	84.23	126	0.15	3.04

Table 5. Hydraulic conductivity rating of the soils of the study areas

Location	Crop	K_{sat}(cm hr^{-1})	*range	*class
Ugbokpo	Maize	0.45	0.13 – 0.51	Slow
Igumale	Maize	0.31	0.13 – 0.51	Slow
Obagaji	Maize	0.75	0.51 – 2.0	Moderately slow
Adoka	Maize	0.59	0.51 – 2.0	Moderately slow
Orokam	Maize	0.77	0.51 – 2.0	Moderately slow
Idekpa	Maize	0.49	0.13 – 0.51	Slow

Table 6. Soil quality indicators for soil degradation assessment

Location	Crop	BD (g/cm^{3})	Ksat (cm hr^{1})	BS (%)	TN (%)	P (ppm)	K (Cmol/kg)	ESP (%)	OM (%)
Ugbokpo	Maize	1.53	0.45	55	0.94	0.59	0.55	5.5	2.34
Igumale	Maize	2.45	0.31	56	0.72	0.53	0.25	6.5	3.43
Obagaji	Maize	2.51	0.75	59	0.62	0.63	0.21	8.9	2.99
Adoka	Maize	3.45	0.59	53	0.68	0.36	0.17	8.5	2.84
Orokam	Maize	1.52	0.77	48	0.57	1.02	0.2	8.0	2.79
Idekpa	Maize	2.5	0.49	55	0.84	0.78	0.23	6.6	3.03

ranging from 2.4 mg kg^{-1} at Adoka to 3.4 mg kg^{-1} Igumale. SAR ranged from 0.12 Cmol kg^{-1} at Ugbokpo and Adoka to 0.17 Cmol kg^{-1} in Idekpa. ESP ranged from 2.44 % at Ugbokpo to 3.82 % at Igumale. Base saturation (Table 4) rated high in Ugbokpo (60 – 80 %) and very high in the other areas (> 80 %). The hydraulic conductivity of the soils was majorly moderately slow in all the fields (Table 5). In line with Usman et al., (2021), cultivation had no defined effect on this property. The land use type also has no effect on the soil conductivity. This allows moderate conductivity of water through the soils for optimal crop production (Franzluebbers et al., 2004).

CEC is the number of cations a soil can hold in exchangeable form at a particular time is an indicator of soil fertility. For the soils under study, they had low and very low CEC. This is an indication of general low fertility of the soils. The available soil phosphorus was low however with high organic matter content which is in contrast with the very low levels of CEC in these soils.

In terms of degradation rating, the soils were very highly degraded with respect to phosphorus ratings across all the fields. The high degradation status of phosphorus of the soils indicates low phosphorus which could be as a result of the poor use of fertilizers by farmers of the study areas. Hence for sustainable crop production phosphorus fertilization will be required. For Potassium which varied from non-slightly degraded to moderately degraded, minimal level of potassium fertilization will be required for sustainable crop production (Prasad and Singh, 2000 and Ali et al., 2017). These soils are moderately degraded probably due to the return of K taken up by plants to the soils in plant residues as it is reported that only 20 -25 % of K taken up by plant moves to the grain, the remaining remains in the stalk. Table 6 showed the degree of degradation based on the soil quality indicators (Table 7). Bulk density in Ugboko and Igumale were moderately degraded while those of Adoka in both fields were highly degraded. Orokam indicate none to slight degradation. Phosphorus was highly degraded in all the fields. Organic matter was none to slightly degraded while in Ugbokpo it was moderately degraded. The potassium and base saturation were none to slightly degraded while nitrogen in the fields were all very highly degraded indicating poor nutrient status which cannot support growth of plants. The land qualities and characteristics of the study sites (Table 8) were matched with the land use requirement of maize resulting in various suitability classes. Results indicate that the soils of Ugbokpo, Igumale, Adoka, Orokam and Idekpa were all presently not suitable for the production of maize with limitations of low levels of P, N and coarse rock fragments.

Table 7. Assessment for individual soil quality indicators (QI)

Location	Crop	Tillage	BD	K_{sat}	BS	TN	P	K	ESP	OM
Ugbokpo	Maize	NT	MD	NSD	NSD	VHD	VHD	NSD	NSD	MD
Igumale	Maize	NT	MD	NSD	NSD	VHD	VHD	NSD	NSD	NSD
Obagaji	Maize	NT	HD	NSD	NSD	VHD	VHD	NSD	NSD	NSD
Adoka	Maize	NT	HD	NSD	NSD	VHD	VHD	NSD	NSD	NSD
Orokam	Maize	NT	NSD	NSD	NSD	VHD	VHD	NSD	NSD	NSD
Idekpa	Maize	NT	MD	NSD	NSD	VHD	VHD	NSD	NSD	NSD

Key: BD= Bulk density, Ksat= Saturated hydraulic conductivity, BS= Base saturation, TN= Total nitrogen, P= Phosphorus, K= Potassium, ESP= Exchangeable sodium percentage, OM=Organic matter. MD = Moderately Degraded, NT = Non-cultivated, CT = Cultivated

Table 8. Land Characteristics used for suitability ratings of sites for maize production in the local government areas

Soil Physical Properties	Ugbokpo	Igumale	Obagaji	Adoka	Orokam	Idekpa
Texture	SL	LS	S	LS	LS	LS
Coarse fragment	68.00	88.00	89.60	75.00	69.00	88.50
Soil fertility						
CEC ($cmolkg^{-1}$)	8.21	8.88	7.95	8.23	7.84	8.88
BS (%)	71.01	80.29	97.74	88.46	74.87	84.23
OM (%)	2.34	3.43	2.99	2.84	2.79	3.03
pH	6.98	6.21	6.32	6.45	6.06	6.73
Avail P ($mgkg^{-1}$)	0.59	0.53	0.63	0.36	1.02	0.78
Total N (%)	0.009	0.007	0.006	0.007	0.006	0.008
Extractable K (mg kg^{-1})	0.23	0.34	0.32	0.25	0.25	0.31
Aggregate suitability	N_1	N_1	S_{3fr}	N_1	N_1	N_1

Source: FAO, 1990; Esu, 1991

CONCLUSION

In 2015, the suitability and fertility of soils in selected LGAs of Benue State (Ado - Igumale, Apa - Ogboko, Agatu - Obagaji, Otukpo - Adoka, Ogbadibo - Orokam, and Ohimini - Idekpa) were assessed for maize cultivation. The soils had low P, CEC, and nitrogen levels but high organic matter content. Phosphorus was highly degraded in all soils. The soils' hydraulic conductivity and exchangeable sodium % were all marginally degraded. Fields had high base saturation. Adoka's bulk density was low. Except for Obagaji soils, which were marginally appropriate for maize production based on soil type, fertility, and degradation levels. The soils of Adoka, Idekpa, and Obagaji are extensively deteriorated in terms of bulk density. Fertilization and organic manure inclusion will be necessary to grow maize on these soils due to fertility limitations. In Ugbokpo, Igumale, and Orokam, 30 kg N, 60 kg P2O5, and 30 kg K2O per hectare are advised, while in Obagaji, Adoka, and Idekpa, the same is recommended.

REFERENCES

Addeo, G. G., Guastadisegni, G., & Pisante, M. (2001). Land and water Quality for sustainable and precision farming. *World Congress on Conservation Agriculture,* Madrid, p.34 – 38.

Ali, A. Usman, M., & Ojeniyi, S.O. (2020). Effect of inorganic fertilizer on soil properties, growth and yield of maize in Makurdi, Southern Guinea Savanna Zone of Nigeria. *Asian Soil Research Journal*. 3(3): 16- 24.

Ali, A., Anjembe, B.C. , & Usman, M. (2019). Effect of fertiplus and crystallizer on soil properties and yield of white maize in Makurdi, Southern Guinea Savanna Zone of Nigeria. *Proceedings of the 43rd Annual Conference of Soil Science Society of Nigeria (SSSN)* held at University of Agriculture, Makurdi, Benue State on 15th -19th July, 2019. p.198- 207.

Ali, A., Usman, M., & Omaivboje, A. L. (2017). Effects of soil amendments on some selected soil properties and growth of green *amaranths* in Makurdi, Nigeria. *Proceedings of the 41st Annual Conference of Soil Science Society of Nigeria (SSSN)* held at Abubakar Tafawa Balewa University, Bauchi on 13th - 17th March, 2017. p.295- 300.

Benue State Environmental Protection Agency (BENSEPA) (1999). The state of the Benue environment, p.28.

Burrough, P. A. (1996). Opportunity and limitation of GIS based modeling of solute transport at the regional scale. In: D. L. Corwi and K. Loage (Eds.), *Application of GIS to the Modeling of Non-point source pollutants in the Vadose Zone.* SSSA, Madison, WI. p.373.

Charman, R., & Murphy, M. (2005). Soil quality for sustainable land management: Organic matter and aggregation interactions that maintain soil functions. *Agronomy Journal*, 94, 38-47.

Ekwue, E. I. (1990). Organic-matter effects on soil strength properties. *Soil and Tillage Research.* 16, 289–297.

Esu, I. E. (1991). Detailed soil survey of NIHORT farm Bunkure, Kano State Nigeria, Institute of Agricultural Research, Ahmadu Bello University, Zaria. p.315 – 324.

FAO (Food and Agriculture Organization) (1990). Guidelines for soil description, FAO, Rome.

FAO (Food and Agriculture Organization) (2006). FAO/UNESCO Soil Map of the world, Revised Legend, World Resources Report 60, Rome, FAO. Reprinted as Technical paper 20, ISCRIC, Wageningen, p.138.

Fischer G., Velthuizen, H. V., Shah, M., & Nachtergaele, F. (2002). Global agro-ecological assessment for agriculture in the 21st century: Methodology and results. International Institute for Applied Laxenburg, Australia. Food and Agriculture organization of the United Nations Vialedelle Terme di Caracalla Rome, Italy. p.290.

Franzluebbers, A. Magdoff, F., & Ray, R. (2004). Tillage and residue management effects on soil organic matter, in: Soil organic matter in sustainable agriculture. CRC Press Inc., p.227–268.

IITA (International Institute for Tropical Agriculture) (1979). Selected methods for soil and plant analysis. International Institute for Tropical Agriculture, Ibadan Nigeria. Manual series No. 1. p.58.

Lal, R. (1994). Sustainable land use systems and soil resilience. In *Soil Resilience and Sustainable land use* (ed. D.J. Greenland & I. Szabolcs), Wallingford, UK: CAB International, p.41-67.

Nyagba J. L. (1995). The Geography of Benue State. In D. J. Denga (Ed.) "Benue State: The Land of Great Potentials" A Compendium. Calabar, Nigeria: Rapid Educational Publisher Limited. p.84 – 97.

Ogunkunle, A. O. (1993). Soil in land suitability evaluation: An example with oil palm in Nigeria. *Soil Use and Management*, 9, 35-40.

Ojeniyi, S. O. (2010). Advances in integrated nutrient management for crop production in Nigeria. *A Monograph. Dominion Pub.* Ibadan, Nigeria. p.5-6.

Ologunorisa T. E., & Tersoo T. (2005). The changing rainfall pattern and its implication for flood frequency in Makurdi, Northern Nigeria. *Journal* *of Applied Science and Environmental Management*, *10* (3), 97-102.

Page, A. L., Miller, R. H., & Keeney, D. R. (1982). Methods of soil analysis part 2. Chemical and microbiological properties. *American Society of Agronomy, Madison,* p.55.

Prasad, B., & Singh, S. K. (2000). Long term effects of fertilizers and organic manures on crop yields, nutrients balance and soil properties in rice-wheat cropping system in Bihar. In: Long- term soil fertility Experiments in Rice-Wheat Cropping System. *Advances in Soil Science,* 20, 105-119.

Raji, B. A. (2016). Land suitability evaluation of some basement complex soils in Kwara State for cassava production. *Nigerian Journal of Soil Science,* 26, 232-241.

Smyth, A. J., & Dumanski, J. (1993). An International frame work for evaluating sustainable land management. *World Soil Resources Report* 73, FAO, Rome, Italy. p.420.

Teklu, E. J. (2005). Land preparation methods and soil quality of a vertisol area in the central highlands of Ethiopia. PhD Thesis Universitat Hohenheim Stuttgar. p.310.

Udo, E. J., Ibia, T. O. Ogunwale, J. O. Ano, A. O., & Esu, I. (2009). *Manual of soil, plant and water analysis*, Lagos: Sibon books Ltd. Pp.183.

Udoh, B. T., & Ogunkunle, A.O. (2012). Land suitability evaluation for maize (Zea mays) cultivation in a humid tropical area of south eastern Nigeria. *Nigerian Journal of Soil Science, 22*(1), 1-10.

Usman, M. (2020). Evaluation of physical and chemical properties of soils in selected parts of Yobe State, Nigeria. *Amazonian Journal of Plant Research, 4*(3), 632-638.

Usman, M., Ali, A., & Agber, P. I. (2021). Effect of tillage practices on selected soil properties in sudan savanna agro-ecology of Nigeria. *International Journal of Environmental & Agriculture Research, 7*(2), 9-15.

Usman, M., Ali, A., & Agber, P.I. (2021). Productivity of sesame (*Sesamum indicum* L.) varieties as influenced by tillage practices in two agro-ecological zones of Nigeria. *Direct Research Journal of Agriculture and Food Science, 9*(2), 18-28.