Academic
Journals

ABOUT JAERD

The Journal of Agricultural Extension and Rural Development (JAERD) is published monthly (one volume per year) by Academic Journals.

Journal of Agricultural Extension and Rural Development (JAERD) is an open access journal that provides rapid publication (monthly) of articles in all areas of the subject such as Impact monitoring and evaluation system for farmer field schools, Metals in bio solids-amended soils, Nitrogenous fertilizer influence on quantity and quality values of balm, Effect of irrigation on consumptive use, water use efficiency and crop coefficient of sesame etc.

The Journal welcomes the submission of manuscripts that meet the general criteria of significance and scientific excellence. Papers will be published shortly after acceptance. All articles published in JAERD are peer-reviewed.

Journal of Agricultural Extension and Rural Development

ARTICLES

Full Length Research Paper

Value of modern extension methods in improving image and quality of extension: Perception of extension agents in Trinidad and Tobago

Jeet Ramjattan[1], Wayne Ganpat[2] and Ataharul Chowdhury[2,3*]

[1]Land and Fisheries, St. Augustine and Ministry of Agriculture, University of West Indies, Trinidad and Tobago.
[2]The University of the West Indies, St. Augustine, Trinidad and Tobago.
[3]University of Guelph, Ontario, Canada.

Agricultural extension services have undergone a significant transformation in order to effectively address issues of poverty and hunger. It is expected that modern methods of extension will improve image and quality of extension services offered in low-income regions. In Trinidad and Tobago, vibrant and transformative initiatives include institutional pluralism, farmer-led methods, farmer field schools, plant clinics, Information Communication Technologies (ICTs) and value chains. However, public sector extension organization is struggling to take up necessary roles and apply new competencies necessary for the success of these modern methods. In this context, this study was undertaken to investigate the perception of extension agents of the value of modern extension methods in improving image and service quality of the extension services in Trinidad and Tobago. Descriptive statistics and Ordinary Least Squares (OLS) regression analysis were conducted to analyze data collected during March and May 2015 using a structured, self-reporting questionnaire from 106 extension agents. The findings of the study indicated that extension agents held positive perceptions of the value of modern methods in improving image and service quality. Age, education and experience are important predictors of perception of modern methods. Agents belonging to the medium experience (5.1 to 10 years) group had more formidable perceptions about the value of modern methods in improving image and service quality. Supervisors and managers had a positive perception of the value of modern methods. The study argued for a capacity development initiative using a strategy of coaching and training and targeting new entrants and middle aged extension agents.

Key words: Modern extension methods, Image Perceptions, Quality of Extension Services, Trinidad and Tobago.

INTRODUCTION

The recent transformations of agricultural extension services require changes in attitudes, skills and capacities of extension agents. This change is necessary to adequately respond to the shift from the technology transfer model to facilitating extension services among various stakeholders which will ultimately benefit farmers and producer organizations (Swanson and Rajlahti, 2010). Jones and Garforth (2006) affirm that while

information and knowledge transfer through institutional training was the main function of extension systems, it is now evolving into a system that uses several adult education and experiential learning methods to empower farmers and thus improve livelihoods. Extension delivery systems have shifted from a focus on production. The emphasis is now placed on knowledge intensive methods and practices that bring systemic interaction among a multiplicity of actors aimed at collaborative learning and holistic development (Birner et al., 2006; Chowdhury et al., 2013; Davis and Sulaiman, 2014).

The extension, as a facilitating service system comprising diverse actors is yet to be proven as the most effective reform in low and middle income countries. Public sector organizations are struggling to build capacities of new methods and tactics in those countries (Allahyari, 2008; Mangnus and Bitzer, 2016). Extension agents are facing ambiguity and challenges in the face of changing extension practices from a technology transfer model to facilitating systems in Argentina (Landini, 2015).

An effective extension system contributes to achieving food security in low and middle income countries (Chowdhury et al, 2012; Mangnus and Bitzer, 2016). The absence of an effective extension system can lead to an impoverished rural life, uninformed farmers and an underdeveloped agriculture sector in a country (FAO, 2014). The questions pertaining to the quality of service, technical competency and performance are being raised as extension agents are looked upon with low esteem by farmers as a result of limited transfer of information between research and extension. Extension providers operate as change agents at the level which directly impacts the intended beneficiaries. As such, the development of rural livelihoods is directly reflected in the quality of services they provide (Rivera and Qamar, 2003; Anderson and Feder, 2004; Chikaire et al., 2011).

It is necessary to have a long-term strategy to improve the capacities of extension agents to address issues which limit agricultural development (Magoro and Hlungwani, 2014). There is an urgent need for a long-term competencies development strategy of extension professionals focusing on skills needed to work with groups, coordination and networking abilities, service attitudes and professionalism (Kibwika et al., 2009; Chowdhury et al., 2014). Reforming these areas, and redefining the role of government and private sector extension services is the key to meet the global challenges of poverty, food security, developing human resources and environmental conservation (Cristóvão et al., 2012; CTA, 2012).

Like many other low and middle-income countries, the agricultural sector remains important to the national economy of Trinidad and Tobago. The development in the sector, according to the Ministry of Finance and the Economy has yielded a positive growth of domestic agriculture with the generation of surplus output for export. The growth of the sector has contributed to increasing GDP to more than 0.6 percent. Despite the crucial role assigned to agricultural extension it has been facing numerous challenges. The public extension system, a predominant extension model in the Caribbean, is being criticized for its failure to deliver efficient and relevant services to the beneficiaries (Ganpat, 2013). The service personnel in the public extension system are stated to be without clear mandates and policies. They possess low competencies, lack motivation and have undefined roles.

The current situations, therefore, raised questions about extension agents' performance and efficiency levels in Trinidad and Tobago. Attributed to these apparent inefficiencies is the fact that Ministry's extension staff are often engaged in many non-extension administrative type activities which results in officers spending less time on the actual advisory duties thus they are unable to adequately focus on assisting farmers to solve their problems (Spence, 2010). All these factors have contributed to unsatisfactory growth and development of the sector and as such the contribution to GDP remains low and farmers are not satisfied with the quality of the extension services (Qamar, 2013).

To address these concerns, the extension services in Trinidad and Tobago have been expanding its basket of extension methods such as, pluralistic service delivery (involving multiple service providers), farmer field schools, plant clinics, discovery learning, Information and Communication Technologies (ICTs) and value chain extension (Ganpat, 2013). Agricultural extension agents need to take up new roles such as, building new strategies, alliances, technologies and priorities in order to improve the service quality and image of the organization. Following global initiatives (e.g. World Bank, 2011; Bentley et al., 2015; Chowdhury et al., 2015), there are multidisciplinary collaborative efforts to develop agricultural knowledge provision databases using ICTs (AgriNett, 2014).

The image of an extension organization can be referred to as the sense of organizational staff (self-image) and other stakeholders (external image) about identity, organizational culture and functions of the organization to serve effectively to its constituencies (Van den Ban and Hawkins, 1996; Leeuwis and Van Den Ban, 2004; Bartunek, 2014). If staff of an extension organization can differentiate between 'what they are supposed to do' and 'what they actually do' it can lead to improvement of

*Corresponding author. E-mail: atahar77@yahoo.com; chowdhua@uoguelph.ca

individual and organizational performance. As an extension organization is not a homogenous entity, staffs of an organization are likely to find themselves in a state of conflicting situations about how they perceive the image of the organization and the jobs they perform (Leeuwis and Van den Ban, 2004). The perception of extension staff about their image, especially when this differs from 'what they actually do' and 'what they are supposed to do', acts as catalyst for reflexive evaluation of professional practices. The recent changes require that extension services be context-specific since good extension practices cannot be standardized (Landini, 2015). The effective delivery of the services also depends on, among others, psychological states of extension agents about the organization they serve and the quality of the services being provided (Leeuwis and Van den Ban, 2004; Landini, 2016; Faure et al., 2016). There is a lack of research to investigate the perceptions of extension agents about the value of new methods and techniques in improving the image and quality of services in Trinidad and Tobago. Therefore, the study is aimed at determining the perceptions of extension agents about the value of modern methods in improving image and quality of services provided in Trinidad and Tobago. The study also seeks to determine factors that influence the perceptions of extension agents about the value of modern methods for image and service quality improvement.

METHODOLOGY

Sampling

The study was conducted in Trinidad and Tobago where the public sector agricultural extension service is organized into ten agricultural districts. The extension system of Trinidad and Tobago follows a pluralistic model with the Ministry of Food Production as the primary extension service provider. Other service provider includes private and state assisted organizations, producer organizations and to some extent research institutions. The sampling framework consisted of extension agents of the public, state assisted and private extension services of Trinidad and Tobago. The response rate was 96% which resulted in data collection from 106 extension agents.

Data collection

Data were collected during March and May, 2015 using a structured, self-administered and pilot-tested questionnaire. Two Likert type scales were used. One to measure agents' perception of the value of modern methods in improving image and the other to measure the agents' perceptions of the value of modern methods in improving the quality of extension services offered. Each scale had four response options such as, (4) = strongly agree, (3) = agree, (2) = disagree and (1) = strongly disagree. Respondents were asked to rate their level of agreement to each of the 11 questions. We followed reverse scoring which is a well-established method of measuring psychological variable (Edwards, 1957; Rosen et al., 2013). A positively worded question referred to an item where

'strongly agree' was scored 4, while a negatively worded question considered an item where 'strongly disagree' was scored 4. Each response was then converted to a number in the response scale previously provided and responses for negatively worded questions were reversed to match the response scale for the positively worded questions.

These scales were validated by a panel of six experts in the field of extension which comprised extension directors, university lecturers with experience in the Trinidad and Tobago extension system. The survey instrument also captured demographic, socio-economic, job related information (Table 1). The instrument was pre-tested with ten extension agents and adjustments were made accordingly.

Data analysis

The data were coded and analyzed using analytical software the Statistical Package for the Social Sciences (SPSS), Version 22. A descriptive analysis such as, means, frequencies and percentages was conducted for the agents' perception. In the analysis model, we considered summated score of individual items for measuring dependable variables. There is a long standing debate about use of appropriate measure for analyzing the data obtained from the rating scale. The single item measure does not fulfill the conditions of a parametric test (Alexandrov, 2010) but summated score of individual item can be used for parametric test (Sullivan and Atino, 2013). Following this, multiple regression analysis was conducted to determine the factors influencing perception of extension agents of the value of modern methods for image and service quality improvement.

The majority of the extension agents in Trinidad and Tobago (88%) were from the public extension – Ministry of Food Production (MFP), followed by 8% from private input suppliers and 4% from state-assisted agencies. Most extension agents belonged to the category field agents (47%). Most of the extension agents attained tertiary level education, 27% possessed diplomas, 26% possessed associate degrees, 24% possessed undergraduate degrees, and 18% held postgraduate degrees and of the field agents 5% had other certificates (secondary school education alone).

Some 34% of the extension agents had 6 to 10 years work experience, 29% had 1 to 5 years work experience, 19% were in the 11 to 15 years work experience and 18% had over 16 years work experience.

The highest percentage of extension agents (53%) fit into the age category range from 31 to 45, 26% fall into the 18 to 30-year age categories and 21% into the 46 to 60-year age category range. In the category of gender, there slightly were more males (54%) than females (46%).

RESULTS

Perception of the value of modern methods in improving image and quality of extension services

The results indicate that agricultural extension agents had a strong positive perception about the value of modern extension methods in improving the image of extension services (Table 2; overall mean score for perception of image is 2.80). Examining specific statements revealed that the specific areas which they perceived help improve the image of their service (Table 2). Extension agents perceived that modern extension methods helped making information accessible to their

Table 1. Description of independent variables and specification for use in multiple regression analysis.

Explanatory variables	Catergories of sample	Specification	X_i
Age[a]	18 to 30 years; 31 to 45 years; 46 to 60 years	1 – If 18-30 years 0 – Otherwise	X_1
		1 – If 31-45 years 0 – Otherwise	X_2
Gender	Male Female	1 – If male 0 – Otherwise	X_3
Service provider[b]	Ministry of Food production (Public); Private input suppliers; State assisted	1 – If Private input suppliers 0 – Otherwise	X_4
		1 – If State assisted; 0 – Otherwise	X_5
Position in organisation[c]	Managerial level; Supervisory level; Field level	1 – If Managerial level 0 – Otherwise	X_6
		1 – If Supervisory level 0 – Otherwise	X_7
Education	Secondary; Diploma; Associate degree; Undergraduate degree; Post graduate degree	1 – If Secondary 2 – If Diploma 3 – If Associate degree 4 – If UG degree 5 – If PG degree	X_8
Experience[d]	5 years and less; 6 to 10 years; Over 10 years	1 – If 5 years and less 0 – Otherwise	X_9
		1 – If 6 to 10 years 0 – Otherwise	X_{10}
Expertise	Crop; Livestock	1 – If crop 0 – Otherwise	X_{11}

clients (67% agents agreed) (Table 2). This might be due to the fact that extension agents started using different types of ICTs in face-to-face (e.g. multimedia presentation) and virtual methods of extension (e.g. social media, website, learning repositories). Using ICTs extension agents were able to deliver different information in a readily accessible format. A majority of the extension agents (84%) were in agreement that they were able to achieve satisfaction and respond to client's needs by using modern extension methods. Over 90% of agents attribute the use of modern methods in solving client's problem and improving their satisfaction (Table 2).

However, only one-third of the respondents agreed that their job provided opportunities to practice the skills obtained in the provision of modern extension methods. Agricultural extension agents in Trinidad and Tobago are expected to perform many non-extension activities (e.g. accounting and regulatory duties). This might conflict with their schedules of services to farmers and create obstacles to apply their skills in provision of modern extension methods.

On the other hand, there was a high overall agreement among extension agents about the quality of the service provided as indicated by a high overall mean value (2.883) (Table 2). The analysis of individual statements indicated that the majority of extension agents were in agreement that modern extension methods helped them in improving quality of several service areas such as, meeting clients' needs, increasing efficiency, knowledge and skills of the agents and contributing to institutional development goals (Table 2). This suggests that the majority of agents recognized improvements in their job satisfaction which reflects improvements in the quality of

Table 2. Perception of extension agents of the value of modern methods in improving image and service quality.

S/N	Statements	Frequencies					Mean ± SD Score	Overall mean score
		SA	A	DA	SDA	Total		
	Perception of value of modern methods for improvement of image							
1	As information becomes more accessible to clients the extension agent's role becomes more important.	12 (11.32)	59 (55.66)	27 (25.47)	8 (7.55)	106 (100.00)	2.708± 0.773	
2	I am able to improve client satisfaction by applying modern methods of extension.	13 (12.26)	70 (66.04)	20 (18.87)	3 (2.83)	106 (100.00)	2.877±0.641	2.801
3	Using new extension methods allows more efficient response to clients.	19 (17.92)	71 (66.98)	16 (15.09)	0	106 (100.00)	3.028±0.586	(0.646)
4	If problems are solved using modern methods this would lead to a positive image by clients.	39 (36.79)	60 (56.60)	7 (6.60)	0	106 (100.00)	3.301±0.595	
5	My job makes good use of my skills in modern extension methods	4 (3.77)	30 (28.30)	43 (40.57)	29 (37.36)	106 (100.00)	2.085±0.936	
	Perception of value of modern methods for service quality improvement							
1	I am able to improve the quality of services offered to clients, using new methods.	32 (30.19)	61 (57.55)	10 (9.43)	3 (2.83)	106 (100.00)	3.151±0.701	
2	I can contribute to national agricultural development goals by using new methods.	26 (24.53)	68 (64.15)	11 (10.38)	1 (0.94)	106 (100.00)	3.123±0.615	
3	I am better able to meet the clients' needs when modern methods are used.	23 (21.70)	66 (62.26)	16 (15.09)	1 (0.94)	106 (100.00)	3.047±0.642	2.883
4	I am encouraged to find new and better ways of doing things when modern methods are applied.	23 (21.70)	70 (66.04)	11 (10.38)	2 (1.89)	106 (100.00)	3.075±0.627	(0.546)
5	I believe my knowledge and skills can be improved by using new methods.	35 (33.02)	63 (59.43)	8 (7.55)	0	106 (100.00)	3.255±0.592	
6	I am not very interested in learning modern methods of extension.	6 (5.66)	16 (15.09)	47 (44.34)	37 (34.91)	106 (100.00)	1.915±0.856	

SA: Strongly agree; A: agree; DA: disagree; SDA: strongly disagree. Figures in parentheses indicate per cent to total response. SD: Standard deviation.

the services they offer.

Factors influencing perception of the value of modern extension methods to improve the image and quality of extension service

The findings of the Ordinary Least Square Regression (OLS) analysis using summated scores for image and service quality perception are presented in Table 3. The perception of service quality model fitted on the total response score showed a good fit explaining that 61 per cent of the variation (the value of adjusted R^2 is 0.616) in the dependent variable due to changes in the independent variables. The perception of image model fitted on the total response score showed a good fit explaining that 54 per cent of the variation (the value of adjusted R^2 is 0.545) in the dependent variable due to changes in the independent variables. Thirteen explanatory variables were used in both models: age, gender, management level, supervisor level, private service provider, education, experience (5 years and less), experience (5.1 to 10 years) and livestock expertise. Out of thirteen variables, five variables had significant relationships with value of modern extension methods in improving the perception of image and eight variables had significant relationship with the value of modern extension methods in improving perception of service quality.

The findings indicated that the extension agents aged 18 to 30 years had unfavourable image perception compared to the older group of extension agents (45+). The effect of age is positive for the elder group. Therefore, where image perception is concerned there would be a positive impact for these agents. The extension agents with medium levels of experience (5.1 to 10 years) had a better perception of value of modern extension methods for both image and service quality improvement, as compared to those highly experienced (over ten years) agents. However, it was found that those with a medium age (31 to 45 years) had significantly better perception of value of modern methods for service quality improvement alone. This indicates that as extension agents gain practical experience in employing modern methods of extension, positive perceptions of value of modern methods for improvement of image and service quality develops.

The findings revealed that extension agents with

Table 3. Determinants of image and service quality perceptions of extension agents.

Factors	Perception of image			Perception of service quality		
	Coefficients	t	Sig.	Coefficients	t	Sig.
Constant	36.237** (6.566)	5.519	0.000	14.403** (0.740)	19.477	0.000
Age: 18-30 years[a]	-6.548* (3.028)	-2.162	0.033	-0.329 (0.341)	-0.963	0.338
Age: 31-45 years[a]	1.805 (2.391)	0.755	0.452	-0.591* (0.269)	-2.194	0.031
Gender	4.012* (1.698)	2.363	0.020	0.605** (0.191)	3.164	0.002
Service: State[b]	1.180 (4.591)	0.257	0.798	0.016 (0.517)	0.030	0.976
Service: Private[b]	20.331** (3.488)	5.829	0.000	0.310 (0.393)	0.790	0.432
Position: Managerial[c]	18.006** (4.654)	3.869	0.000	1.798** (0.524)	3.430	0.001
Position: Supervisory[c]	0.330 (2.516)	0.131	0.896	1.871** (0.283)	6.604	0.000
Education	-1.631 (0.929)	-1.755	0.083	0.336** (0.105)	3.207	0.002
Experience: 5 years and less[d]	4.226 (2.735)	1.545	0.126	0.725* (0.308)	2.352	0.021
Experience: 5.1 – 10 years[d]	6.279* (2.428)	2.586	0.011	0.543* (0.273)	1.985	0.050
Expertise: Crop	-0.643 (2.102)	-0.306	0.760	-0.353 (0.237)	-1.492	0.139
Expertise: Livestock	-2.704 (2.626)	-1.030	0.306	0.943** (0.296)	3.190	0.002
Adjusted R^2	0.545			0.616		
F	10.680**			13.969**		
N	106			106		

Figures in parentheses indicate Standard Errors; *Significant (P≤0.05); **Highly Significant (P≤0.01); [a]ref. category - 46 to 60 years; [b]ref. category - Ministry of Food Production ; [c]ref. category - Field Agents; [d]ref. category: Over 10 years.

livestock expertise had a very positive perception of modern methods for service quality improvement. Agents with livestock expertise as compared to those with crop and general extension expertise perceived that the use of modern extension methods improved the quality of the extension services offered to the clients. The perception of extension managers about value of modern extension methods in improving image and service quality were positive as compared to the extension field agents. This suggests that the managers viewed modern extension methods as initiatives which essentially enhanced the image of extension and created significant improvements in the quality of extension services offered. The results further showed that in comparison to the field agents, the extension supervisors held positive perception of the value of modern methods for improvement of the extension service quality. Managers and supervisors supported the use of modern extension methods as a means to improve the quality of the service delivered by their agents. The findings, therefore, indicate that younger and middle aged extension agents should be targeted for coaching and capacity building support on use of modern extension methods in Trinidad and Tobago.

The extension agents working in private sectors considered the use of modern extension methods to be very important for improving image of the service. Results showed a positive and highly significant coefficient when perception of private extension agents was compared with the perception of the public extension agents. With respect to service quality the analysis found that education was a significant predictor positively associated with agents' perceptions of using modern extension methods in delivering extension services. This suggests that extension agents with higher education have better perception about how modern extension methods lead to better service quality.

DISCUSSION AND CONCLUSION

The findings of the study add important insights into on-going global and regional discussions surrounding competencies development of use of modern extension methods from personal and psychological perspective of extension agents (Landini, 2015; Davis and Sulaiman, 2014; Chowdhury et al., 2014; Strong et al., 2014; Kibwika et al., 2009). Overall, there is a positive perception of the extension agents that modern extension methods contribute to improving image and service quality in Trinidad and Tobago. Extension agents who use modern extension methods improved access of relevant and timely information to their clients which led to a positive perception of the value of modern extension methods to improve the quality of services being offered. Nevertheless, a majority of them perceived that they could not utilize their skills and competencies due to their involvement in non-extension activities. This can be related to what Strong et al. (2014) reported that extension agents recognized the value of ICT but were less likely to report intentions to use technology with client.

There are several factors which significantly influenced

the extension agents' perception about image and service quality as it relates to the use of modern extension methods. Age and experience are important predictors for developing a favourable perception of the value of modern methods in improving image and service quality perception. The findings are in line with Akinsorotan and Oladele (2009) who revealed that extension agents developed better perception of organizational value as they gain more experience. The present study indicates that middle-aged (e.g., 30-45 years) extension agents developed better perception of the value of modern extension. Most notably, the agents at their later years of career (46 to 60 years' experience category) were less motivated to use the advanced methods; indicating that technical confidence plays a key role. It is likely that agents belonging to this category did not perceive learning and adopting new methods of technology dissemination as part of a learning context which could enhance image and service quality outcomes. As such, continuous training to include motivation for this category may help in this regard.

Extension supervisors and managers perceived new methods as valuable tools for improving image and service quality and overall development of the extension services. The findings suggest that supervisors and managers should identify and provide the necessary training opportunities for personal growth and develop-ment of junior field agents. The findings echo with the policy suggestion for developing capacity of new hires of extension agent through appropriate educational training and coaching so that they realize the value of modern methods and techniques (Kibwika et al., 2009; World Bank, 2012; Davis and Sulaiman, 2014). Education played an integral part in agents' perception of value of modern methods in improving image and service quality. This is supported by the study of Strong et al. (2014) who concluded that education background of the Caribbean extension officer was a key predictor for developing competencies of ICT and other relevant methods. On the issue of gender, mostly males were positively recognising and then endorsing new extension methods as a means to improve service quality and image. This is in contrary of the findings of Akinsorotan and Oladele (2009) who reported that sex has nothing to do with the organizational value.

Overall the findings reconfirm that an extension organization is not a homogenous entity as individuals working in the organization usually recognize ongoing practices from a differential psychological and personal state (Leeuwis and Van den Van, 2004; Akinsorotan et al., 2009; Landini, 2015). Also, such a predisposition might differ between organization and the subject matter. For instance, the study indicated that private sector agents had positive perception of the value of modern methods in improving image of service. Moreover, extension agents working in the livestock sector had positive perception of the value of modern methods in

improving service quality. Abdel-Ghany (2014) reported that it is necessary to identify employees' readiness, beliefs and resistance before introducing modern methods of extension, for instance, mobile extension in the New Valley governorate, Egypt. In the Latin American and Caribbean (LAC) context, it is necessary that psychological dispositions of public sector extension agents favour use of new modes and methods of extension. Otherwise, it may lead to rejection and ultimately failure of current reforms that are being pursued (Landini, 2015, 2016). Therefore, it is recommended that extension service institutions should perform evaluations to determine the capacity of agents to enable them to utilize the acquired skills in improving job performance and enhancing the quality of services offered by the extension services of Trinidad and Tobago. The importance of continued use and practice of modern methods and the need to reinforce the sustained provision of supporting infrastructure has been emphasized by the agents' positive indications.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Abdel-Ghany MMM (2014). Readiness for change, change beliefs and resistance to change of extension personnel in the New Valley Governorate about mobile extension. Annals of Agril. Sci. 59(2): 297-303.

AgriNeTT (2014). AgriNeTT: A Caribbean Agriculture Knowledge E-Portal. Accessed March 28, 2015. http://sta.uwi.edu/rdifund/projects/agrinett/projects.asp.

Akinsorotan AO, Oladele OI (2009). Organizational values perceived as evident among extension agents of agricultural development program in Nigeria. Agric. Trop. Subtrop. 42(3):110-117.

Alexandrov A (2010). Characteristics of Single-Item Measures in Likert Scale Format. Elect. J. Bus. Res. Methods 8(1):1-12.

Allahyari MS (2008). Redefining of Agricultural Extension Objectives towards Sustainability in Iran. Am. Eur. J. Agric. Environ. Sci. 4(3):349-353.

Anderson JR, Feder G (2004). Agricultural extension: Good intentions and hard realities. World Bank Res. Observ. 19(1):41-60.

Bartunek J (2013). Organizational and Education Change: The Life and Role of a Change Agent Group. New York: Taylor & Francis.

Bentley J, Chowdhury A, David S (2015). Videos for Agricultural Extension. Note 6. GFRAS Good Practice Notes for Extension and Advisory Services. Lindau, Switzerland: GFRAS.

Birner R, Davis K, Pender J, Nkonya E, Anandajayasekeram P, Ekboir J, Cohen M (2006). From Best Practice To Best Fit: A Framework for Designing and Analyzing Pluralistic Agricultural Advisory Services Worldwide. Accessed January 2017 from http://www.ifpri.org/publication/best-practice-best-fit-framework-designing-and-analyzing-pluralistic-agricultural-0.

Chikaire J, Nnadi FN, Nwakwasi RN, Ejiogu-Okereke N (2011). The Changing Roles of Agricultural Extension to Achieve Food Security and Improve Rural Livelihoods in Imo State, Nigeria. Researcher 3(10):41-48.

Chowdhury AH, Aktar R, Sarker MA, Miah MAM (2012). Video, Learning and Food Security- New Thinking for Supporting Farmer-to-Farmer Learning in Bangladesh. Bangl. J. Ext. Educ. 24(1, 2):53-73.

Chowdhury AH, Hambly Odame H, Thompson S, Hauser M (2015). Enhancing Farmers' Capacity of botanical pesticide innovation

through video-mediated learning in Bangladesh. Int. J. Agric. Sust. 13(4):326-349.

Chowdhury AH, Hambly Odame H (2013). From Output-based to Process-based Monitoring of Agricultural Extension Project: Lessons from Bangladesh. J. Int. Agric. Educ. Ext. 20(2):154-156.

Chowdhury AH, Hambly Odame H, Leeuwis C (2014). Transforming the Roles of a Public Extension Agency to Strengthen Innovation: Lessons from the National Agricultural Extension Project in Bangladesh. J. Agric. Educ. Ext. 20(1):7-25.

Cristóvão A, Koutsouris A, Kügler M (2012). Extension systems and change facilitation for agricultural and rural development. In Darnhofer I, Gibbon D, Dedieu B. (Eds.), Farming Systems Research into the 21st Century: The New Dynamic Springer Netherlands. pp. 201-227.

CTA (2012). Agricultural Extennsion. A Time for Change. Linking Knowledge to Policy and Action for Food and Livelihoods. The Technical Centre for Agricultural and Rural Cooperation (CTA), accessed December 10 2014 from http://www.cta.int/images/docman-files/policy_papers/agricultural_extension.pdf.

Davis K, Sulaiman VR (2014). The New Extensionist: Roles and Capacities to Strengthen Extension and Advisory Services. J. Int. Agric. Ext. Educ. 21(3):6-18.

Edwards AL (1957). Techniques of Attitude Scale Construction. New York: Appleton- Century Crafts, Inc.

Faure G, Davis KE, Ragasa C, Franzel S, Babu SC (2016). Framework to Assess Performance and Impact of Pluralistic Agricultural Extension Systems: The Best-fit Framework Revisited. Washington: International Food Policy Research Institute.

Ganpat W (2013). History of Agricultural Extension in Trinidad & Tobago. Kingston, Jamaica: Ian Randle Publishers.

Jones GE, Garforth C (2006). The history, development, and future of agricultural extension. In Improving Agricultural Extension: A Reference Manual, Edited by Bentz, RP. Rome: Food and Agriculture Organization of the United Nations.

Kibwika P, Wals AEJ, Nassuna-Musoke MG (2009). Competence Challenges of Demand-Led Agricultural Research and Extension in Uganda. J. Agric. Educ. Ext. 15(1):5-19.

Landini F (2015). Different Argentine Rural Extensionists' Mindsets and Their Practical Implications. J. Agric. Educ. Ext. 21(3):219-234.

Landini F (2016). How to be a good rural extensionist. Reflections and contributions of Argentine practitioners. J. Rural Stud. 43:193-202.

Leeuwis C, Van den Ban A (2004). Communication for Rural Innovation: Rethinking Agricultural Extension. Oxford: Blackwell Science.

Magoro D, Hlungwani SS (2014). The Role of Agriculture Extension in the 21 Century: Reflections from Africa. Int. J. Agric. Ext. 2(1):89-93.

Mangnus E, Bitzer V (2016). Extension in Motion. KIT working paper 2015-4. Amsterdam: Royal Tropical Institute.

Qamar MK (2013). World Wide Extension Study-Trinidad and Tobago. Accessed January 8 2014 from http://www.g-fras.org/en/world-wide-extension-study/central-america-and-the-caribbean/caribbean/trinidad-and-tobago.html#ict

Rivera WM, Qamar MK (2003). Agricultural Extension, Rural Development and Food Security Challenge. Rome: Food and Agriculture Organization.

Rosen LD, Whaling K, Carrier LM, Cheever NA, Rokkum J (2013). The Media and Technology Usage and Attitudes Scale: An empirical investigation. Com. Hum. Behav. 29(6):2501-2511.

Spence J (2010). Developing the Agriculture Sector. The Trinidad Express, September 15, 2010. Accessed June 12 2014 from http://www.trinidadexpress.com/commentaries/_Developing_the_agriculture_sector-103021374.html

Strong R, Ganpat W, Harder A, Irby TL, Lindner JR (2014). Exploring the Use of Information Communication Technologies by Selected Caribbean Extension Officers. J. Agric. Educ. Ext. 20(5):485-495.

Sullivan GM, Artino ARJ (2013). Analyzing and interpreting data from likert-type scales. J. Grad. Med. Educ. 5(4):541-542.

Swanson BE, Rajalahti R (2010). Strengthening Agricultural Extension and Advisory Systems:Procedures for Assessing, Transforming, and Evaluating Extension Systems. Agriculture and Rural Development Discussion Paper 45. Washington, D.C: World Bank.

Van den Ban AW, Hawkins HS (1996). Agricultural Extension (2nd edition). Oxford: Blackwell Science.

World Bank (2011). ICT in Agriculture: Connecting Smallholders to Knowledge, Networks and Institutions. Washington DC: The World Bank.

World Bank (2012). Agricultural Innovation Systems. An Investment Sourcebook. Washington DC: The World Bank.

Journal of Agricultural Extension and Rural Development

Full Length Research Paper

The tomato leafminer (*Tuta absoluta*) (Lepidoptera: Gelechiidae) attack in Nigeria: effect of climate change on over-sighted pest or agro-bioterrorism?

Borisade, O. A.[1*], Kolawole, A. O.[2], Adebo, G. M.[2] and Uwaidem, Y. I.[1]

[1]Department of Crop Science and Horticulture (Crop Protection Unit), Ekiti State University, Faculty of Agricultural Sciences, Ado Ekiti, Nigeria.
[2]Department of Agricultural Economics and Extension Services, Ekiti State University, Faculty of Agricultural Sciences, Ado Ekiti, Nigeria.

The tomato leaf miner (*Tuta absoluta*) destroyed tomato plants in seven of the Northern states in Nigeria, and has been found in two other states in the South in 2016. The study assessed the incident of the tomato leafminer attack using a questionnaire survey in one of the affected states, for a case study of the problem. A short literature review on bio-ecology of *T. absoluta* was also conducted, and responses to questionnaires were presented. It appeared that knowledge of farmers on pests and management procedures was poor. The results showed that farmers were not properly oriented on pest reporting, and many farmers were unaware of the existence of government pest support programs. Pest monitoring programs and post attack response systems were found inadequate. Many farmers perceived that the pest was new while some respondents reported that similar attacks occurred on their farms in the previous year. Most respondents declined to answer questions on the possibility of agro-bioterrorism being the cause of the attack. We found a lacuna in the government policy which could be potentially exploited by agro-terrorists to inflict attack on crops in a new dimension, but there is no evidence of agro-terrorism in relation to attack on tomato by *T. absoluta* in Nigeria. The findings could be useful in the development of pest mitigating strategies in agro-dependent developing countries.

Key words: *Tuta absoluta*, agro-terrorism, climate change, pest development, tomato.

INTRODUCTION

Nigeria is the largest producer of tomato in Africa, and also contributes significantly to the production of other major agricultural commodities (FAO, 2014). Agro-ecological regions within the country are diverse, and different regions possess environmental advantages in terms of climatic favourability and soil adaptability for the

production of specific crops. The Northern regions are the main producers of tomatoes (Etebu and Enaregha, 2013).

However, Nigeria is not included in the list of countries exporting tomatoes, and huge amount of money is spent on tomato importation annually. Significant parts of annual production are lost to post-harvest spoilage due to poor handling, microbial deterioration, absence of storage facilities and processing industries (Bello et al., 2016; Etebu et al., 2013). The revived interest of the government to diversify the economy and the strong consideration for agricultural intensification probably inspired the emergence of the African largest tomato processing factory in Nigeria that is capable of adding values to the produce.

During the 2016 tomato season, a sporadic attack by invasive tomato leafminer, *Tuta absoluta*, nicknamed 'tomato ebola' occurred in the Northern parts of the country, where tomato production was most concentrated (Villareal, 1980). The pest caused over 80% loss of tomato production in the first cycle, and resulted in shortage of raw materials supply to the newly developed tomato processing industry, which subsequently closed-down.

Insect pests severely undermine agricultural productivity in Nigeria, and severity of attacks may be exacerbated by climate change related factors. However, the development of the tomato leaf miner was considered sudden and viewed by many stakeholders as an act of sabotage or agro-terrorism, targeted against agricultural production in Nigeria. Agro-bioterrorism is an intentional spread of pathogens or pests to livestock or crops in order to cause economic harm (Wilson et al., 2000). Agriculture can be a perfect target of bioterrorism, particularly in developing nations that lack adequate agro-biosecurity apparatus to notice and prevent attacks. Infective pathogens and developmental stages or adults of major insect pests of crops may be stealthily released by agro-bioterrorists to inflict speedy and colossal damage.

The incident occurred in the Northern part of Nigeria that has witnessed in the past six years various degrees of instability and terrorist attacks, adding to the suspicion of an attack. There were insinuations that the attack was a deliberate act, targeted at coercing growers and the government into adopting Genetically Modified (GMO) Seeds (Anon, 2016; Jibrin, 2016). Agro-bioterrorist agents were suspected to be responsible for the release of *T. absoluta* to undermine local production and technically, to enforce adoption of genetically modified (GMO) tomatoes which cannot replicate. The implications therefore could be a perpetual dependence of Nigerian tomato growers on GMO seeds of resistant hybrids (a form of horticultural colonialism). The use of Terminator Seed Technology (TST) to destroy indigenous tomato landraces in developing countries, and the implications on food security and biodiversity of plant species have been reported (Yusuf, 2010).

T. absoluta had not been officially reported as a potential threat to tomato production in Nigeria before 2016 (EPPO, 2016). Currently, it has emerged as a major threat to sustainable production of tomato in Nigeria. Thus, there is the need to conduct scientific investigations to establish whether the tomato producing agro-communities in Northern Nigeria have been living silently with *T. absoluta* (Brevault et al., 2014; Russell IPM, 2015) without noticing its presence until crops were devastated or Nigeria was agro-terrorized to sabotage sufficiency in tomato production in order to renew dependence on tomato importation.

The aim of this study was to conduct a short review of the ecology of *T. absoluta* in Africa, its biology on tomato and available control measures. The study sought for Information on the level of awareness of pest attacks, pest reporting, and crop biosecurity and protection systems in Nigeria as well as functionality of government quarantine policies.

METHODOLOGY

The study area

The survey was conducted in Plateau state Nigeria. Tomato production in the agro-ecological area comprise of irrigated and rain-fed farms. A major part of Plateau State is on high elevation, and has the lowest temperature records in Nigeria. In the dry season, the average daily temperature is often less than 24°C.

Sampling procedure

A purposive sampling technique (Guarte and Barios, 2006) was used to select tomato farms in one of the affected states for a case study. The selection was based on the records of *T. absoluta* attack in 2016 cropping season. The study sought for information on the level of awareness of pest attacks, pest reporting, and crop biosecurity and protection systems in Nigeria as well as functionality of government quarantine policies. Specifically, the farmers were interviewed to find out essentially their

1. knowledge of pest identification in general
2. Whether *T. absoluta* attack was witnessed in the time past.
3. Whether they are aware of any government institutions that conduct routing pest survey
4. Availability of extension services and pest reporting systems
5. Response of the government to the latest attack and prevention and control programs in place
6. Level of awareness on agro-bioterrorism as a likely cause of the invasive pest attack.

LITERATURE REVIEW

Ecology of *T. absoluta*

The tomato leaf miner, *T. absoluta* (Meyrick) (Lepidoptera: Gelechiidae) originated from South America (Desneux et al., 2011). It is a major pest of tomato capable of causing 80 to 100% damage in the absence of efficient control measures. After it was detected in Eastern Spain in 2006, it has invaded other parts of the world. *T.*
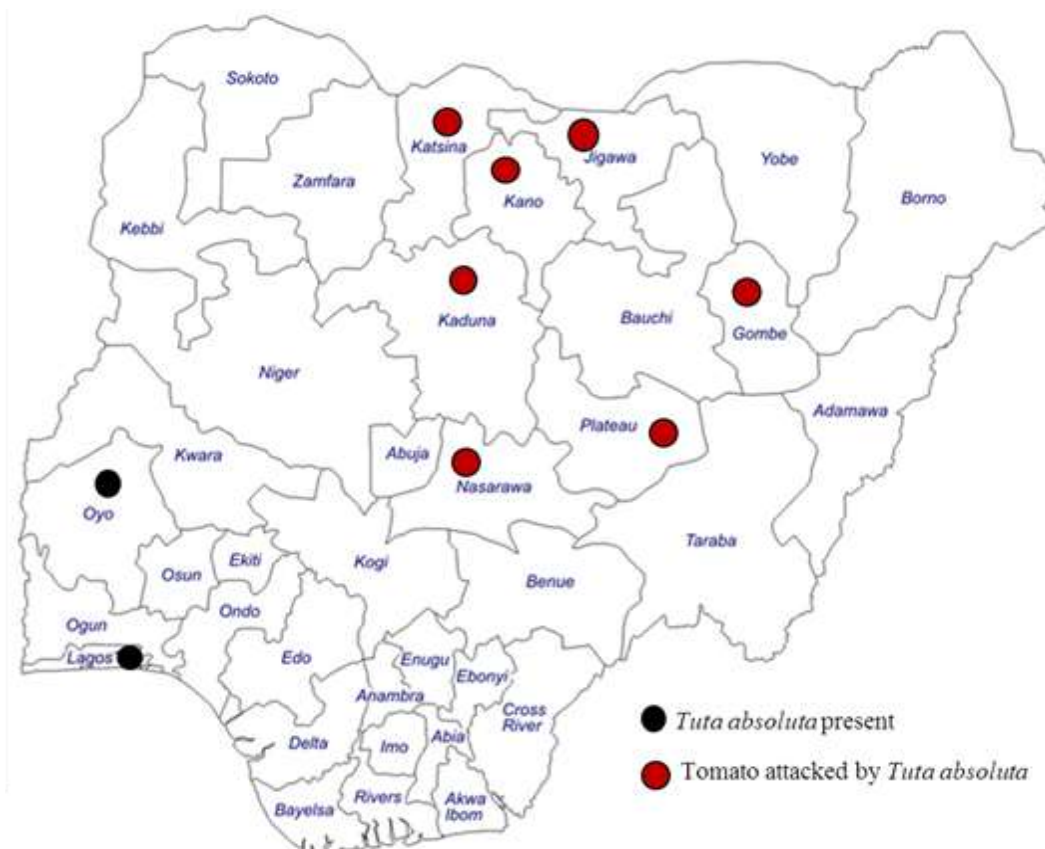
Figure 1. Map of Nigeria showing States where *T. absoluta* is present or caused economic damage to tomato plants.

absoluta outbreak was first reported in two West African countries: Niger and Senegal (EPPO, 2014; CABI, 2016) before its attack on tomato in Nigeria (EPPO, 2016). Currently, it has been found attacking tomato in the northern parts of Nigeria: Jigawa, Kano, Katsina, Kaduna, Plateau, Gombe and Nasarawa States. It has also been sighted in two other states in the South West; Lagos and Oyo (Figure 1)

Biology and description of *T. absoluta*

The pestiferous stage of tomato leaf miner moth is the larvae. Adult females release sex pheromones, comprising of two potent chemical compounds identified as tetradecatrienyl acetate and tetradecatrienyl acetate, to attract male insects to exhibit mating behaviours and copulation (Vacas et al., 2011).

Female insects begin mating at 1 to 2 days of emergence, and oviposition commence within 24 to 48 h after mating. About 96% of the eggs are laid within 7 days, and it is estimated that a female insect lay between 250 to 300 eggs in its life time. At temperatures between 25 to 30°C, the eggs hatch in 6 to 7 days into larvae (CABI, 2016).

Larvae pass through four instars, which is completed in approximately 20 days. *T. absoluta* has been reported to exhibit differentiated behaviour of pupating depending on the environment. The last instar larvae is capable of secreting cocoon and pupate in the soil, buried 1 to 2 cm deep or on leaf surface (CABI, 2016).

The pupation lasts 10 to 11 days for female insects while adults may take 11 to 13 days thus, enabling female insects to emerge first from the same batch of eggs. Under laboratory conditions, the longevity of adults was reported as 30 to 40 days. The duration of developmental cycle is modulated by environmental temperature, and developmental times of 76.3 and 39.8 days have been reported at 14°C and 19.7°C respectively.

At optimum temperature of 27°C, the developmental time was 23.8 days. For as long as food is available, larvae have been reported to refrain from entering diapause, and 10 to 12 over-lapping generations occurring all year round have been reported in South America. *T. absoluta* eggs are elliptical in shape, and laid in clusters. The colour of the eggs may vary but they are often oyster-white or bright yellow, turning dark in the embryonic stage, and almost black towards eclosion.

The newly emerged larvae are whitish, and subsequent instars could turn greenish or pink depending on the host plant and the available food; leaflet or ripe fruit. Pre-pupae are often lighter than the actively feeding first to fourth instars, with a distinguishing pinkish colour on the dorsal part. The pupae are obtecta with initial green colouration which over time become brown near adult emergence. Adult moth is about one centimeter in size, and has silvery or greyish scales with alternating light and dark segments (CABI, 2016).

Host range of *T. absoluta*

T. absoluta is a major pest of tomato (*Solanum lycopersicum*) in all agro-ecological regions of the world where it occurred, it is capable of attacking and subsisting on other wild members of the

Solanaceae including *Solanum nigrum, Solanum elaeagnifolium, Lycopersicon puberulum, Datura stramonium, Datura ferox* and *Nicotiana glauca* (Garcia and Espul, 1982). Other non-solanaceae host plants include the slender amaranth (*Amaranthus viridis*) (Amaranthaceae), common sowthistle, (*Sonchus oleuraceus*) and common cocklebur (*Xanthium strumarium*) both of which belong to the family Asteracea, Wild mustard (*Sinapis arvensis*) (Brassicaceae) and the bind weed (*Convolvulus arvensis*, which is a member of the family Convolvulaceae. There are also a few reports of *T. absoluta* attack on potato (Garlaza, 1984; Pereyra and Sánchez, 2006). *T. absoluta* shows preference for new buds, flowers and new fruits thereby making it easy to detect on affected plants. The characteristic mines on plant leaves are also an indicator of attack in addition to appearance of black frass on fruits where infestation is severe (Tropea et al., 2012).

Methods of control

Many control options including cultural, chemical, pheromone based strategies and biological control, which is basically the use of natural enemies of the pest have been found effective. Farm sanitation practices, pruning of leaves that show symptoms, removal and destruction of infested plants as well as ploughing, and soil solarization have been shown to significantly reduce attack by the pest. The elimination of wild and other alternative hosts on which the pest subsists in off-season periods are capable of breaking the life cycle, and have been found effective when the cropping cycle of the major hosts, especially tomato and potato are alternated with other crops that are non-host plants (Cabello et al., 2009; González-Cabrera et al., 2011; Guedes and Picanco, 2012; Cocco et al., 2013).

In severe incidents of *T. absoluta* attack, chemical control using cabaryl, pyrethrin and deltamethrin, have been reported. Extensive use of chemical insecticides in many parts of Africa where there were severe *T. absoluta* attack led to registration of several varieties of chemical insecticides. Where chemicals were used extensively for a prolonged period of time, their effectiveness were reported as low or moderate due to the cryptic nature of the larvae and high reproductive rates (Silva et al., 2011). Other control methods being developed for the management of *T. absoluta* include the use of semiochemicals, especially sex pheromones, to lure adults into traps (Chermiti and Abbes, 2012; Mafra-Neto et al., 2013; Comparros_Megido et al., 2013).

Releases of irradiated and sterile males (Cagnotti et al., 2016) are also being developed as an eco-friendly management option. Biological control using entomopathogenic fungal species, particularly the anamorphs of Hypocreales, *Metarhizium anisopliae* has been reported (Contreras et al., 2014). The use of fungal biocontrol agents (BCAs) will be especially effective where abiotic interactions, temperature and relative humidity fall within the range that is required for infectivity (Borisade and Magan, 2015) and sporulation or secondary spread (Borisade and Magan, 2014).

Many natural enemies of *T. absoluta*, particularly parasitoids and nematodes have been identified, and many are being evaluated for their biocontrol potentials. Development of resistant tomato varieties which are high in zingiberin or acyl sugar contents are being explored to reduce oviposition and feeding by the larvae. Integrated Pest Management (IPM) systems are also being developed for different crops in agro-ecological regions with long experience of *T. absoluta* attacks.

RESULTS

Demographic profile of respondents

Seventy questionnaires were randomly distributed for the survey and sixty of the completed questionnaires representing the areas where the pest attack occurred were returned, amounting to a response rate of 75% (Table 1). In addition to this, some farmers who declined to complete the questionnaires gave their opinions verbally. All the participants in the survey were above 18 years in age and there was no imposition of upper age boundary. Female participants represented 30% of the sample size. Five percent of the participants had secondary education while the remaining 95% consisted of people with post-secondary education or trainings. Majority of the participants (90%) in the post-secondary education category studied agriculture or trained in agriculture-related disciplines while the remaining 10% was an equal split between other specializations and unspecified disciplines, but practicing tomato farming.

Experience on general insect pests of tomato and leaf miner

Table 2 appraised the level of knowledge of the tomato farmers on entomological pest incidents, correctly identifying the damage symptoms, and the pests. The majority of the farmers (65%) operate small scale farms or backyard-cultivated tomato stands, while 15% have commercial farms. Others have a few stands of tomato plants growing around their homes. Eighty percent of the respondents had at a time experienced insect pests attack on their crops.

20% were unsure whether their plants were at any time attacked by insect pests, and 15% were either unable to describe the pest or the damage it caused. When asked for description of the pests and assessment of damage, fifty percent of the farmers (n=30) described tomato symptoms which are often associated with *Fusarium oxysporum* f. sp *lycopersici* wilt disease rather than foliar pest attacks. Fifteen percent of the respondents observed disappearance of the green or chlorophylous layer of their tomato leaves.

10% of the farmers reported that fruits were bored, and there were signs of gnawing on leaves. Twenty five percent of the farmers were unable to make specific description of the nature of damage. Majority of the farmers (65%) had no prior experience of *T. absoluta*, 35% are informed about the invasive pest and 10% reported that the pest caused a significant damage within a limited area before the severe outbreak which occurred in 2016 (Table 3).

80% of the respondents considered the tomato leaf miner a new pest in Nigeria, and chemical control only were employed in the management of tomato pests.

Existence and efficiency of pest control system

Majority of the respondents (80%) indicated that there were no pest control experts, and 90% have not reported

Table 1. Demographic profile of respondents

Variable		Frequency	Percentage (%)
Age	<18	0	0
	≥18	60	100
Gender	Male	42	70
	Female	18	30
Education level	Secondary	3	5
	Post-secondary	57	95
	Agriculture/Agriculture related	54	90
Field of specialization	Non-Agriculture	3	5
	Unspecified	3	5

Table 2. Scale of farm and experience of the respondents with entomological pests in general.

Variable	Frequency	Percentage (%)
What is the scale of your farm?		
Few stands in my backyard/Small scale	39	65
Found some tomato stands growing around my house	12	20
Commercial farm	9	15
Has your tomato been attacked by insect pests before?		
Yes	48	80
No	12	20
Were you able to identify the pest?		
Yes	21	35
No	39	65
Can you describe the nature of damage observed?		
Chlorosis, spot and rottening	27	45
Wilting and eventual death	3	5
Green surface eaten up and leaves became transparent	9	15
Fruits bored and the inside was eaten up	6	10
I cannot describe	15	25
On which of the following parts of the tomato was the damage or insect presence?		
Leaf	39	65
Stem	3	5
Fruit	18	30
When were the times you experienced the pest attacked?		
Earlier than 2013	12	20
Between 2014-2015	33	55
Year 2016	15	25

pest problems on their farms (Table 4). When asked about quarantine services offered by Government Departments, 40% were unsure whether they exist while 20% who answered 'yes' were against the 40% of the respondents that certainly indicated that quarantine personnel were non-existent. Significant number of the respondents (80%) agreed that government quarantine departments were not functional. On questions of

Table 3. Response to questions on level of awareness of tomato leafminer.

Variable	Response	Frequency	Percentage (%)
Have you heard of the tomato leaf miner?	Yes	21	35
	No	39	65
Do you consider tomato leaf miner a new pest in Nigeria?	Yes	48	80
	No	12	20
Has it ever infested your crops?	Yes	6	10
	No	54	90
If yes, did you initiate a control?	Yes	6	100
	No	0	0

Table 4. Response to questions on presence and efficiency of public pest control experts.

Variable	Response	Frequency	Percentage (%)
Is there any pest control expert in your area?	Yes	12	20
	No	48	80
Did you ever report any pest attack to pest experts?	Yes	6	10
	No	54	90
Are there government quarantine personnel in your area?	Yes	12	20
	No	24	40
	Not sure	24	40
Are the qarantine officers and pest control experts functional?	Yes	12	20
	No	48	80
Are there functional government quarntine policies in Nigeria?	Yes	24	40
	No	36	60

functionality of government quarantine policies, majority (60%) of the respondents indicated failed policies while the remaining 40% considered the policies working.

Agricultural bioterrorism

Table 5 shows the response of the farmers to questions that are related to the possibility of agro-bioterrorism being the cause of the loss of more than 80% of annual production of tomato in the first cycle to *T. absoluta* within the Northern agro-ecological area. Relatively fewer respondents were willing to answer questions on different aspects of the topic and spoke their opinions only verbally. Agro-bioterrorism as a term or as a concept was strange the respondents. Forty two percent of those attended to questions on the topic were aware that bio-terrorism can be potentially used to undermine agricultural production, through the internet, books and multimedia. However, 37.5% believed that the Nigerian incident was an act of bioterrorism while many considered it a natural occurrence.

DISCUSSIONS

This study reviewed the general biology and distribution of the invasive tomato pest, *T .absoluta* in Nigeria and its probable pathway into the country. The survey assessed the incident of attack on tomato in the Northern agro-ecological areas in order to understand the cause of the sudden epizootics, knowledge of farmers on agricultural insect pests, functionality and efficiency of pest control systems in Nigeria, operationality of pest prevention mechanisms, pest attack response systems, quarantine policies and post-attack capabilities. Drawing on the results of the survey and the peculiarity of the scenario, the nature of threats to agriculture in developing nations-Nigeria being a case study, would be discussed.

The majority of tomato growers in the region are peasants and practice agriculture as their secondary profession. This reflected in the scale of farms, where only 15% could be rated as commercial. Pest and disease attacks had occurred at various times in the past and it appeared that supports to farmers in form of provision of extension services, pest identification and

Table 5. Response to questions on agro-bioterrorism.

Variable	Frequency	Percentage (%)
Have you heard of agricultural bioterrorism before?		
Yes	8	42
No	11	58
If yes, where did you learn about it?		
Internet	6	75
Books	1	12.5
Multimedia	1	12.5
Do you think the tomato pinworm incident was somehow a delibrate attack?		
Yes	3	37.5
No	5	62.5

management were seriously lacking. However, the symptoms of pest damage which occurred earlier than 2016 as described by some respondents: loss of chlorophyll layer of tomato leaves due to insect feeding (leaf mining) and presence of worms in the fruits, are characteristic of tomato pinworm infestation. While the majority of the farmers regarded *T. absoluta* a new pest, a few confirmed earlier attacks which were controlled using insecticides. It appeared that pest attacks were not being reported and many of the growers were unaware of existence of pest control experts or quarantine services.

The sudden scarcity of tomato which was associated with the pest attack in 2016 may not only be a reflection of the magnitude of attack but also a sudden positive change in the economic value of the crop, when value addition industry capable of utilizing significant parts of annual produce sprang-up. Before the evolution of tomato processing industries, more than 60% of annually produced tomato was lost to post-harvest spoilage. The excess production used to buffer the effect of field pest attack on local supplies. The new tomato industry probably mopped up the annual excess, such that the effect of pests on productivity became apparent and probably affected the local demand and supply patterns that resulted in the hike in price of fresh tomatoes. Increase in crop value is capable of changing the status of attacking pests from 'potential pest status' to the status of a 'serious pest', when little damage become economically injurious. However, *T. absoluta* is a serious pest of tomato in all agro-ecological regions of the world where it occurred.

Currently, *T. absoluta* is much restricted to the Northern agro-ecological areas that serve as the major hub of tomatoes that are consumed in the south and other parts of Nigeria. Movement and spread of invasive entomological pest species are directly associated with transportation of products infested with the eggs, developmental stages and adult insects. The optimum temperature for the development of *T. absoluta* is 27°C,

which is within the ambient temperature range in all agro-ecological regions of Nigeria- a guarantee for a potential spread to all parts of Nigeria over time, particularly in the absence of an effective quarantine system.

Based on the spatial pattern and the scales of tomato cultivation, challenges are expected in the management of *T. absoluta,* which has relatively high fecundity rate and short reproductive cycle. Sixty five percent of the growers produce at the level of 'backyard farming' while 15% have a few uncultivated stands around homes. Few-stands-around-home scale of farm is likely to present problems that are very similar to the effect crop left-overs in pest management. The few tomato stands around homes and backyard farms could serve as pest-reservoirs that are capable of relaying pests into another production cycle, thereby potentially posing dangers to commercial farms which might have earlier succeeded in suppressing pests.

The entrance corridor of *T. absoluta* into Nigeria have not been studied, but tomatoes were imported into Nigeria from some West African countries, including Niger that has records of the presence of *T. absoluta.* Problems of invasive insect species are expected to get worse in developing countries with relatively poor quarantine systems. The results of the survey in part, suggested that *T. absoluta* was present in Nigeria earlier than 2016. The environments in which crops would be grown within the next decade are expected to change significantly in relation to climate. The effect of climate change, especially increased temperature, erratic rainfall and wide relative humidity fluctuations could adversely affect ecological barriers and lead to emergence of new pests that are likely to get adapted to new crops. Pest dynamics are also expected to be modulated under a climate change scenario (LaštůVka, 2009; Dhaliwal et al., 2010).

All aspects of pest development-oviposition rates, time to eclosion, duration of life cycle and longevity of adults are affected by temperature (Cuthbertson et al., 2013).

Year 2016 showed peculiar long periods of relatively high temperature (Salau et al., 2016) and draught, capable of affecting insect development. Regional evidence of climate change in Nigeria had previously been reported (Odjugo, 2010). The effects could either be positive or negative depending on the insect and its optimum temperature requirements. CABI (2016) reported significant variabilities in the time taken by *T. absoluta* to complete its life cycle under different temperature and relative humidity regimes. The rate of development of pests also varies with the invaded plants. There are possibilities that the species of tomato being cultivated in the affected areas were especially favourable to *T. absoluta* development. Megido et al. (2013) studied the propensity of tomato leaf miner to develop and different tomato varieties, and found significant variabilities in developmental rates and magnitude of attack.

Despite the possibility that *T. absoluta* may have invaded Nigeria earlier than 2016, the magnitude of attack, population dynamics and the timing were a serious concern. Although there is lack of pest documentation and monitoring in Nigeria, the pattern of attack was considered a terrorist act by some respondents. Unfortunately, many of the respondents declined to respond to questions on agro-bioterrorism for unknown reasons. A few of the respondents confirmed that their crops were overwhelmingly invaded by pests from growers who deliberately left their farms to pests without initiating control measures. However, there is no evidence of agro-terrorism in Nigeria. The farmers who abandoned their farms were probably frustrated, and could not afford the extra cost of fumigation, since the crops were already economically injured.

Within the context of the findings in the current study, a typicality of Nigerian government policies on crop production, the freedom of individuals to embark on crop production without license and the absence of enforcement of growers to comply with standard pest management guidelines, a farm that is abandoned because of severe attack by invasive pests species may pose a significant threat to neighbouring farms. This Nigerian scenario may exemplify the vulnerabilities of other agro-dependent developing nations in West Africa, where crop production licenses are not compulsory.

Agro-bioterrorists employ a variety of approaches to achieve their desired goals after conducting a comprehensive study of the premises that can be exploited covertly. Agro-bioterrorism as earlier defined in the Introduction Section: 'deliberate introduction of exotic biological agents to undermine agri-business' and several of the views expressed in the work of Hassler (2003) on agro-bioterrorism share a common intersection: 'introduction of exotic biological agents', here considered as 'classical agro-bioterrorism'.

The descriptions of some of the respondents resembled a scenario where growers were contracted to cultivate large expanse of tomato in *T. absoluta* endemic areas and deliberate abandonment of the farms for the pests to breed and evade other areas. This can be classified as bio-augmentation and bio-conservation of existing invasive pest numbers to wreak havoc- may be a potentially new form of agro-bioterrorism, which does not involve the introduction of new pest species.

However, the reasons for the abandonment of some tomato farms in the survey area could not be substantiated as intentional, ruling out the possibilities of a terrorist act. The lack of license and appropriate documentation of farm locations could create a hurdle for pest management departments to effectively monitor pest development, which may result into serious and widespread invasions.

CONCLUSION

Development of new tools for rapid detection of pests, effective monitoring systems, pest identification and reporting are very crucial. The time between introductions, whether by intent, accident or natural causes and detection are very important in controlling spread. Issuance of licenses to growers could help in the development of data base of existing farms and their locations, which are necessary in pest surveillance and enforcement of standard operating procedures capable of minimizing pest attacks. Investments in infrastructures capable of increasing pest prevention and preparedness are very important. Training of pest attack respondents and increase in budget on basic research are capable of strengthening post-attack responses and capabilities. Industries with huge investments on tomato processing and value addition in Nigeria may also need to invest significantly in pest management to complement public efforts to militate pest problems.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

REFERENCES

Anon (2016). The real cause of *Tuta absoluta,* 'Tomato ebola' nairaland.com/3162517/dangote-fgn-conspiracy-exposed-real

Bello OB, Ullah H, Olawuyi O, Adebisi O (2016). Microorganisms causing post-harvest tomato (*Solanum lycopersicum* L.) fruit decay in Nigeria. Scientia 13(2):93-96.

Borisade OA, Magan N (2014). Growth and sporulation of entomopathogenic *Beauveria bassiana, Metarhizium anisopliae, Isaria farinosa* and *Isaria fumosorosea* strains in relation to water activity and temperature interactions. Biocontrol Sci. Technol. 24(9):999-1011.

Borisade OA, Magan N (2015). Resilience and relative virulence of strains of entomopathogenic fungi under interactions of abiotic stress. Afr. J. Microbiol. Res. 9(14):988-1000.

Brevault T, Sylla S, Diatte M, Bernadas G, Diarra K (2014). *Tuta absoluta* Meyrick (Lepidoptera: Gelechiidae): a new threat to tomato

production in Sub-Saharan Africa. Afr. Entomol. 22(2):441-444.

Cabello T, Gallego JR, Vila E, Soler A, Del Pino M, Carnero A, Polaszek A. (2009). Biological control of the South American tomato pinworm, *Tuta absoluta* (Lep.: Gelechiidae), with releases of *Trichogramma achaeae* (Hymenoptera.: Trichogrammatidae) in tomato greenhouses of Spain. IOBC/WPRS Bull. 49:225-230.

CABI (2016). Invasive species compendium: Tomato leaf miner (*Tuta absoluta*). http://www.cabi.org/isc/datasheet/49260

Cagnotti CL, Andorno AV, Hernández CM, Paladino LC, Botto EN, López SN (2016). Inherited sterility in *Tuta absoluta* (Lepidoptera: Gelechiidae): Pest population suppression and potential for combined use with a generalist predator. Florida Entomol. 99(1):87-94.

Comparros Megido R, Haubruge E, Verheggen F (2013). Pheromone-based management strategies to control the tomato leafminer, *Tuta absoluta* (Lepidoptera: Gelechiidae). A review. *Biotechnologie, Agronomie, Société et Environnement Biotechnol.* Agron. Soc. Environ. 17(3):475-482.

Chermiti B, Abbes K (2012). Comparison of pheromone lures used in mass trapping to control the tomato leafminer *Tuta absoluta* (Meyrick, 1917) in industrial tomato crops in Kairouan (Tunisia). EPPO Bull. 42(2):241-248.

Cocco A, Deliperi S, Delrio G (2013). Control of *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in greenhouse tomato crops using the mating disruption technique. J. Appl. Entomol. 137(1-2):16-28.

Contreras J, Mendoza JE, Martínez-Aguirre MR, Garcia-Vidal L, Izquierdo J, Bielza P (2014). Efficacy of enthomopathogenic fungus *Metarhizium anisopliae* against *Tuta absoluta* (Lepidoptera: Gelechiidae). J. Econ. Entomol. 107(1):121-124.

Cuthbertson AG, Mathers JJ, Blackburn LF, Korycinska A, Luo W, Jacobson RJ, Northing P (2013). Population development of *Tuta absoluta* (Meyrick) Lepidoptera: Gelechiidae) under simulated UK glasshouse conditions. Insects 4(2):185-197.

Desneux N, Luna MG, Guillemaud T, Urbaneja A (2011). The invasive South American tomato pinworm, *Tuta absoluta*, continues to spread in Afro-Eurasia and beyond: the new threat to tomato world production. J. Pest Sci. 84(4):403-408.

Dhaliwal GS, Jindal V, Dhawan AK (2010). Insect pest problems and crop losses: changing trends. Indian J. Ecol. 37(1):1-7.

EPPO (2014). EPPO Reporting Service, No. 2014/015. Paris, France: European and Mediterranean Plant Protection Organization.

EPPO (2016). EPPO Global database (available online). Paris, France: EPPO. https://gd.eppo.int/

Etebu E, Enaregha E (2013). Postharvest Quality of Commercial Tomato (*Lycopersicon Esculentum* Mill.) Fruits Brought into Yenagoa Metropolis from Northern Nigeria. J. Biol. Agric. Healthcare 3(11):2224-3208

Etebu E, Nwauzoma AB, Bawo DDS (2013). Postharvest spoilage of tomato (Lycopersicon esculentum Mill.) and control strategies in Nigeria. J. Biol. Agric. Healthcare 3(10):51-61.

FAO (2014). Food and Agriculture Organization of the United Nations. Food Security Statistics-Nigeria. faostat.fao.org

Garlaza J (1984). Laboratory assessment of some solanaceous plants. Possible food-plants of the tomato moth *Scrobipalpula absoluta* (Meyr.)(Lepidoptera: Gelechiidae). *Idia*, (421/424):30-32.

García MF, Espul JC (1982). Bioecología de la polilla del tomate (*Scrobipalpula absoluta*) en Mendoza, República Argentina. *Rev. Investigaciones Agropecuarias-INTA*, *17*.

González-Cabrera J, Mollá O, Montón H, Urbaneja A (2011). Efficacy of *Bacillus thuringiensis* (Berliner) in controlling the tomato borer, *Tuta absoluta* (Meyrick)(Lepidoptera: Gelechiidae). BioControl 56(1):71-80.

Guarte JM, Barios EB (2006). Estimation under purposive sampling. *Communications in Statistics—Simulation and Computation®*, 35(2):277-284.

Guedes RNC, Picanço MC (2012). The tomato borer *Tuta absoluta* in South America: pest status, management and insecticide resistance. EPPO Bull. 42(2):211-216.

Hassler K (2003). Agricultural Bioterrorism: Why It Is A Concern And What We Must Do. Army War Coll Carlisle Barracks Pa. ADA415398

Jibrin I (2016). Monsanto's Plot to Take Over Nigeria's Agriculture. Daily Trust. allafrica.com/stories/201607250604.html

LaštůVka Z (2009). Climate change and its possible influence on the occurrence and importance of insect pests. Plant Protection Sci. 45:S53-S62.

Mafra-Neto A, De Lame FM, Fettig CJ, Munson AS, Perring TM, Stelinski LL, Vargas RI (2013). Manipulation of insect behavior with specialized pheromone and lure application technology (SPLAT®). Pest Manage. Nat. Prod. 1141:31-58.

Megido RC, Brostaux Y, Haubruge E, Verheggen FJ (2013). Propensity of the tomato leafminer, *Tuta absoluta* (Lepidoptera: Gelechiidae), to develop on four potato plant varieties. Am. J. Potato Res. 90(3):255-260.

Odjugo PA (2010). Regional evidence of climate change in Nigeria. J. Geogr. Regional Plann. 3(6):142-150.

Pereyra PC, Sánchez NE (2006). Effect of two solanaceous plants on developmental and population parameters of the tomato leaf miner, *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae). Neotrop. Entomol. 35(5):671-676.

Russell IPM (2015). The tomato leaf miner moth http://nigeria.tutaabsoluta.net/2015/12/17/hello-world

Salau OR, Fasuba A, Aduloju KA, Adesakin GE, Fatigun AT (2016). Effects of Changes in ENSO on Seasonal Mean Temperature and Rainfall in Nigeria. Climate 4(1):5.

Silva GA, Picanço MC, Bacci L, Crespo ALB, Rosado JF, Guedes RNC (2011). Control failure likelihood and spatial dependence of insecticide resistance in the tomato pinworm, *Tuta absoluta*. Pest Manage. Sci. 67(8):913-920.

Tropea Garzia G, Siscaro G, Biondi A, Zappalà L (2012). *Tuta absoluta*, a South American pest of tomato now in the EPPO region: biology, distribution and damage. EPPO Bull. 42(2):205-210.

Vacas S, Alfaro C, Primo J, Navarro-Llopis V (2011). Studies on the development of a mating disruption system to control the tomato leafminer, *Tuta absoluta* Povolny (Lepidoptera: Gelechiidae). Pest Manage. Sci. 67(11):1473-1480.

Villareal RL (1980) Tomatoes in the tropics. Bowker Publishing Company. 1980.

Wilson TM, Logan-Henfrey L, Weller R, Kellman B (2000). Agroterrorism, biological crimes, and biological warfare targeting animal agriculture. Emerg. Dis. Anim. pp. 23-57.

Yusuf M (2010). Ethical issues in the use of the terminator seed technology. Afr. J. Biotechnol. 9(52):8901-8904.

Full Length Research Paper

Patterns and problems of domestic water supply to rural communities in Enugu State, Nigeria

Obeta Michael Chukwuma

Hydrology and Water Resources Unit, Department of Geography, University of Nigeria, Nsukka, Enugu State, Nigeria.

This study investigated the patterns, problems and options for improved domestic water supplies to the rural communities of Enugu State, Nigeria. The purpose of the study was to determine the gap between supply and demand, physical and socio-economic variables that influence the supply situation and suggest options for improved water supply in the area. Data on water use habits were collected from 340 households, in 17 autonomous communities through the use of questionnaire and oral interview. Additional data were collected though field observations, from three FGDs and from relevant records at the offices of the Enugu State Water Corporation. The data were analyzed through the use of inferential and descriptive statistical tools. The results of the study revealed that wide gaps exist between water supply and demand in all the sampled communities. The water schemes developed by governments and NGOs are largely non-functional. The quantities of water demanded and supplied vary widely. The mean household water demand was found to be 13685.5 lpd against the supply 9028.8 lpd, leaving a daily household deficit of 4656.9 lpd. Over 50% of the population access less than halve of the 115 L per person per day recommended by the federal government of Nigeria. .32% of the respondents rely on private boreholes for their water needs; 26.5% depend on water vendors, while the rest depend on contamination-prone streams, rivers, unlined and unprotected wells, harvested and stored rain water etc. Principal Components Analysis reduced the 20 physical and socio-economic variables accounting for water supply problems in the area to five underling dimensions which accounted for 85.9% of the problems, leaving 14.1% to other variables not used in the study. Suggestions for improved household water supply in the area were advanced.

Key words: Rural communities, water supply, supply deficits, constraints, policy options, Enugu state.

INTRODUCTON

According to WHO (2015) about 663 million people worldwide had no access to adequate drinking water supplies, and nearly half of the people using unimproved water sources live in sub- Saharan Africa (UNICEF, 2015). Although, Nigeria is blessed with abundant water resources (estimated at 226 billion cubic meters of surface water and about 40 billion cubic meters of ground water) her rural populations are largely deprived and lack access to adequate water supplies (Adah and Abok, 2013). About 65 million Nigerians have no access to safe

E-mail: michael@yahoo.com. Tel: +234(0)813-2974-076.

Plate 1. Abonyi River-a major source of water for many rural communities in the study area.

and adequate water supplies; the number rose dramatically to 90 million in 2015 (UNICEF, 2015).

Nigeria did not meet the MDG target of halving by 2015 the population without adequate access to improved drinking water sources. She ranks behind many other sub- Saharan African countries such as Ghana, Rwanda, Botswana, and Sierra Leone in access to potable water (Marks et al., 2013). A significant proportion of the Nigerian rural population continue to use rivers, ponds, lakes and harvested rain as their main sources of water supply (Ezenwanji, 2012) (Plate 1). This category of Nigerians faces great risks to their health and wellbeing (Obeta and Chukwu, 2013).

Nigeria has a large rural sector and relatively a small urban population (Utube, 2002). The rural areas generally exhibit great poverty, decayed infrastructure, poor health conditions, low access to social facilities and ignorance as a result of varying degrees geographical and political isolation (Obeta, 2009). The rural areas have long been neglected and deprived (FAO, 2005). According to Goni (2006), the negligence has led to rural-urban migration which in turn has created problems for both urban and rural areas. The current situations in some states and communities of Nigeria, serve as tragic examples of pains and sufferings experienced by people. In Yobe, Borno, Adamawa Zamfara and Jigawa states, for instance, water shortages have aggravated the refugee and food crises, forcing some residents to migrate southwards (Goni, 2006; Abaje et al., 2009). In Bama community (Borno State) polluted water remains the most important cause of poor health, food insecurity and low

pace of socio-economic development (Toyobo and Taniowo, 2011).

The limited access to water supplies by a significant proportion of the Nigerian rural population has been blamed on institutional and socio-economic factors (Ezenwaji et al., 2016). Toyobo and Tanimowo (2011), attributed the prevailing water poverty in many rural communities of Nigeria, to poor sustainability of water infrastructure, paucity of funds, inadequate technology and lack of political will. Adah and Abok (2011) and Ezenwanji (2004) blamed engineers for poor quality construction while Gbadegesin and Olorundemi (2007) attributed the problem to inadequate community participation. Nyaba (2009) attribute the general poor service delivery in the Nigerian water sector to rent-seeking and poor governance of safe drinking water to a large segment of the Nigerian rural population to inefficient system management which does not take into cognizance the sustainability of the supply system for future generations.

Our study area is predominately rural with about 78% of the population living in rural areas. For a sizable proportion of the population, the major sources of water are unprotected wells, streams, ponds, private boreholes and harvested rain water (Plate 2). Drinking water from these sources are not regulated by federal and state agencies and typically do not receive same level of monitoring and treatment as drinking water supplied by public water supply agencies. These sources harbor water-borne disease because they are also exposed to contamination by both natural and anthropogenic factors.

Plate 2. Adada Stream; another source of water for many river bank communities.

Nwankwo (2014) studied the adverse effects of these sources on inhabitants' health and found that they constituted an important hindrance to their productive abilities. Ezenwanji (2012) studied the community-based water service providers in the state and discovered that they lack the capacity to carry out administrative operation and maintenance functions and that these adversely affect the sustainability of water supply services in the area He observed that service providers in the state need regular and structured support that goes beyond ad-hoc technical assistance. The existing situation should not continue the way they are since it will adversely affect national development. Therefore, this study is set out to investigate the pattern, problems and strategies for rural water supply in the state in order to characterize them and to suggest measures which can improve water services delivery in the area.

Olaleye (2010) and Akpomunie (2010), have noted that the provision of adequate, clean, reliable, and potable water in Nigerian rural areas remains a challenge which needs to be tackled considering the fact that a larger percentage of the population live in rural areas. When the water is inadequate, people are compelled to use contaminated water which may later create health problems, including the outbreak of diseases (Marks and Davis, 2012). As the population and the demand for safe drinking water increase in Enugu state, it is important to advance strategies that may lead to more efficient and sustainable supplies. The findings of this work will, in addition, contribute to the knowledge base for future research and development of water supply systems in the state and, indeed, to the successful implementation of the post-2015 rural development agenda.

Area of study

Enugu state, is located approximately between latitudes 05.55` and 07.08` and longitudes 06.35` and 07.55`. The state is bounded in the east by Ebonyi State; in the west by Anambra State; in the north by Benue and Kogi States; ad in the south by Imo State. Currently, the state is composed of seventeen local government Areas, namely Igbo-Eze north, Igbo Eze South, Nsukka, Uzo-Uwani, Udenu, Isi-Uzo, Nkanu East, Nkanu West, Awgu, Ani-Nri, Enugu di, Ezeagu, Oji River, and Igbo-Etiti local government areas (Figure 1).

The state has an area of about 9,102 square miles or 14,563.2 km^2, and a 2014 projected population of 4.3 million, 78.2% of which live in the rural areas (Nwankwo, 2014). The study area lies within the Koppen Tropical Rainy Af climatic zone of the Koppen classification (Oformata, 2002). The climate is tropical with high temperatures and high humidity as well as marked wet and dry season; though there are variations between north and south. The average temperature for every month is above 18.5^{o}C and there is adequate moisture in the area between March and November. The highest temperatures are recorded between the months of March and April. Precipitation varies widely in both time and space, ranging from less than 850 mm per annum in the extreme north to 1050 mm in the south (Oformata, 2002).

The state is drained by numerous rivers, principally the Ebonyi, Adada, Ajali, Ivo and their numerous tributaries. Many of the tributaries are seasonal. The vegetation varies mainly with the rainfall and with topography. Natural vegetation is denser in the south and at the valleys and sparse at the north and at the top of the

Table 1. Respondents indentified causes of water shortages in the area.

S/N	Reported causes of water shortage in the area
1	Long distances to the main source of water for the households.
2	Long waiting tie for water collection in the area
3	Limited number of O & M activities performed at the community level.
4	High Number of technical faults that occur in reported in the area.
5	Long waiting time for faults to be restored
6	Few number of times public raps run in a weak
7	Limited number of public water taps available at community level
8	Limited number of functional public boreholes
9	Poor yields from wells
10	Limited number of public functional storage facilities at the community level
11	Long distances travelled to get spare parts.
12	Limited number of water source caretakers at community level
13	Limited number of public water supply facilities at the community level.
14	Few numbers of times public water facilities are maintained in the area.
15	Limited number of functional public water taps
16	Few number of elected Village Water Community (VWC) members
17	Large number of abandoned public water facilities at the community level
18	Limited number of water projects sponsored by Donor Agencies
19	Non provision of up-front capitals for O&M of facilities at the community level
20	Inability of pubic water projects to function satisfactorily for a long time

highlands (Nzeadibe and Ajaero, 2010). Generally, the rural areas have similar physical and socio-economic characteristics. For instance, many of the rural residents have easily accessible, nearby, clean or hygienic water sources. Sources of such water vary widely from direct rainfall to water from runoffs, rivers, streams, boreholes, wells, and seepage. Many suffer from avoidable water related diseases (Mozie, 2011). Despite a process of industrialization extending to the creation of the state in 1986, agriculture remains the fundamental economic activity in all the local government areas. The leading economic crop is the oil palm which is grown in every part of the state. Cassava, yam, rice and maize are the most important food crops. The average life expectancy in the mid-1990s was 47 for men and 49 for females.

METHODOLOGY

Qualitative data were generated through a combination of primary and secondary sources. Household water use habits and the factors limiting water supply were sourced through questionnaire administration, oral interviews, personal observations, three focus group discussions (FGDs) and from records in state's Water Corporation headquarters. We visited all the three rural water supply zones in the state at Enugu, Nsukka, and Udi to extract useful information from official records, observe existing water supply infrastructure as well as to interview the principal zonal officers of the State Water Corporation. A total of 340 households from 17 rural communities were sampled. The main selection criteria for the communities were: (1) The existence of a public water scheme, and (2) A population between 1000 and 2500.

Relevant data on the perceived causes of water supply shortages in the area were collected through in-depth interviews with household heads and the zonal staff of the State Water Corporation (Table 1). The information generated is connected with a wide range of historical, institutional, organizational, managerial, social, technical, and environmental factors. The reported explanatory variables for the prevailing water shortages in the area are defined and parameterized in section four.

Principal Component Analysis (PCA) was employed to analyze the above variables. PCA is a data reduction tool that is frequently employed by scholars to summarize and analyze large data set (Anyadike, 2009). In this study PCA was employed to identify the principle dimensions of the selected variables responsible for water shortages in the study area. PCA was executed using the Statistical Package for the Social Sciences (SPSS) version 16, based on the Kaiser's normalization and rotated variable maximization (va Analysis (PCA). PCA is a data reduction tool that is frequently employed by scholars to summarize and analyze large data set (Marks et al., 2013). In this study PCA was employed to identify the principle dimensions of the selected variables responsible for water shortages in the study area. PCA was executed using the Statistical Package for the Social Sciences (SPSS) version 16, based on the Kaiser's normalization and rotated variable maximization (varimax) principle. Only variables Eigen-values above unity with 5% or more explanatory powers were considered in this work.

RESULTS AND DISCUSSION

Sources of water supply in the area

Field evidences revealed that private boreholes, water
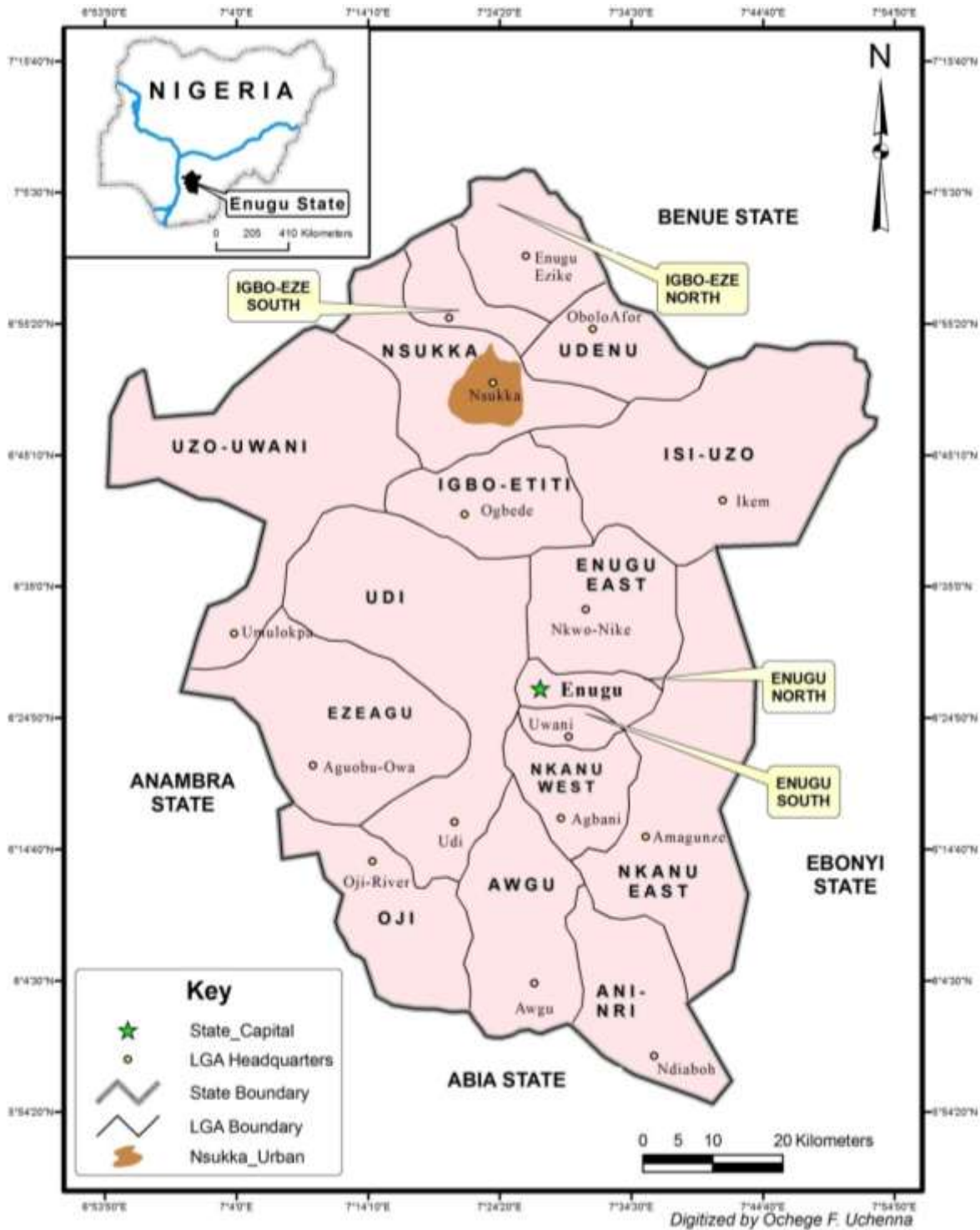
Figure 1. Map of Enugu State showing the local government areas. Source: GIS Unit, Department of Geography, University of Nigeria, Nsukka.

vendors, hand-dug wells, natural springs and rivers, harvested and stored rain water and public water schemes are the major sources of water supply for the rural population in the study area. Most of the communities in the area where perennial streams are available (Ikem, Eziagu, Isi Uzo Iwollo) depend on streams, and rivers for most of their water needs (Figures 1 and 2). Majority of the sampled communities are

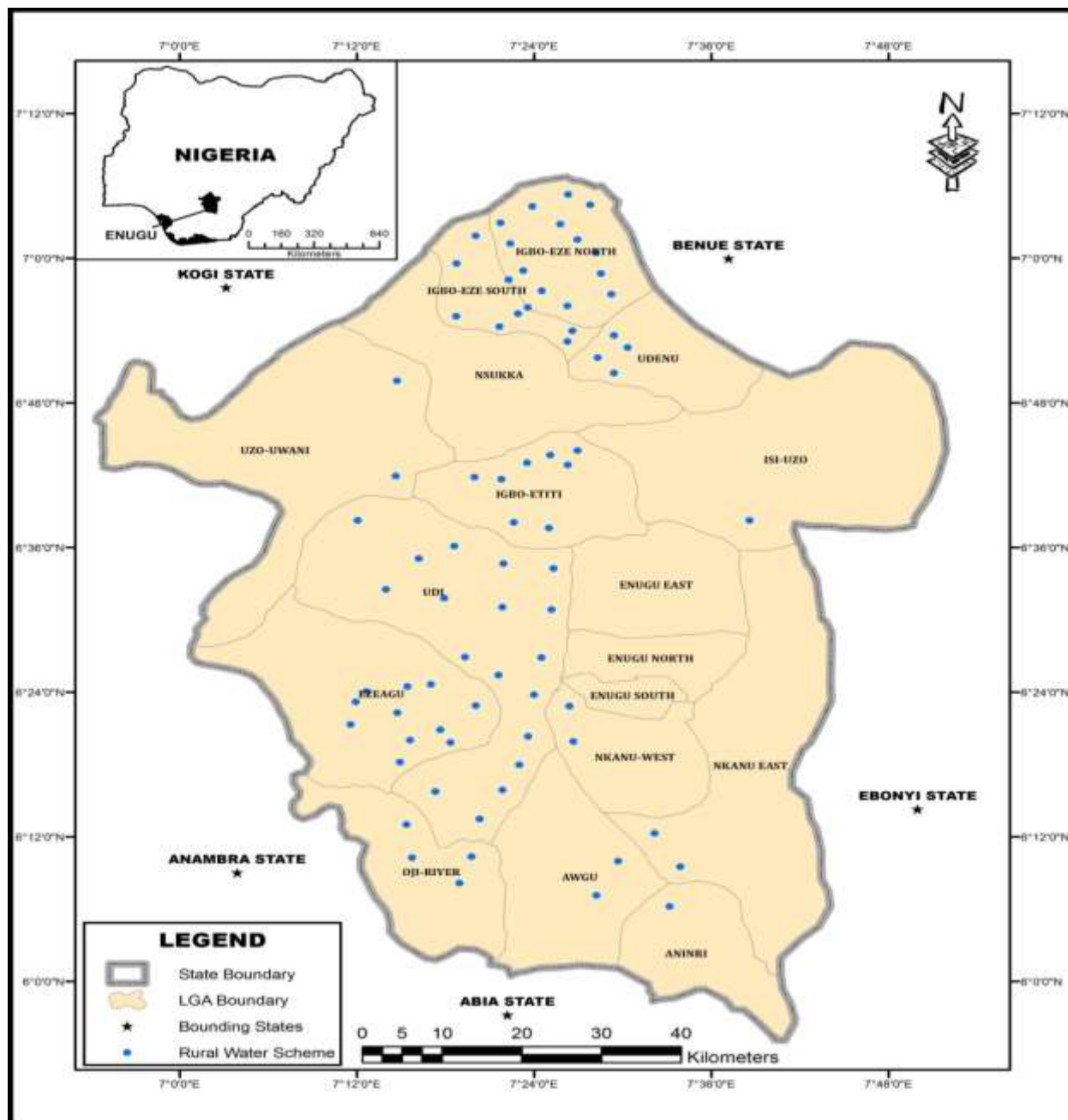**Figure 2.** Location of rural water supply schemes in Enugu State. Source: Enugu State Water Corporation, Headquarters, Enugu (2014)

deficient in surface water resources (streams) and few available ones are unreliable, especially during the dry seasons. The hand-dug wells are unlined and unprotected. The pattern of dependence on the water sources in the area is illustrated in Figure 3.

As shown in Figure 3, private boreholes are the primary source of water for majority of the respondents (32%). Many of the respondents would have preferred public taps from government-developed boreholes but majority of them are not functional (only 3 of 17 schemes are functional). Therefore, they turn to private boreholes which are readily available, yield relatively high quality water, located within trekking distances and are generally affordable .About 26% of the respondents percentages availed other sources such as water vendors, 12% from rivers/streams/lakes, 10% from wells, 8% from public taps and 6% each for harvested/stored rain water and ponds respectively. It was clear from personal
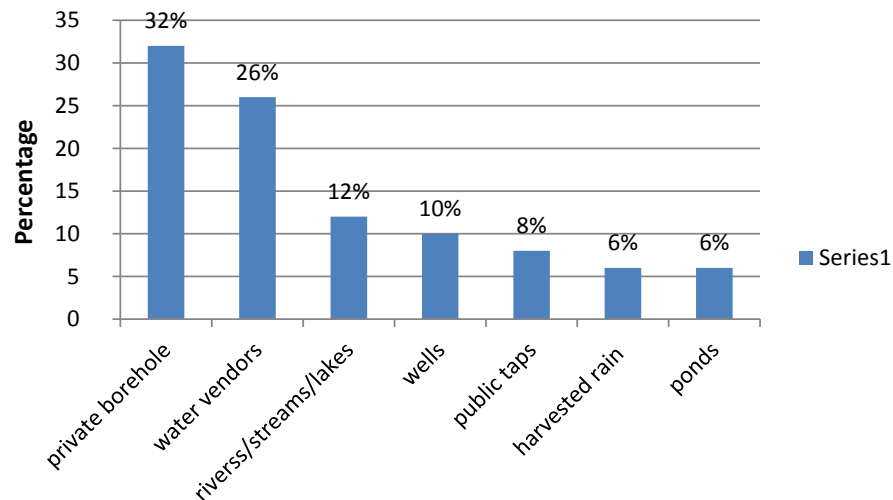
Figure 3. Pattern of dependence on available water sources in the study area.

observations that most of the wells are unlined and shallow. Also the streams, having thick brown colour, are not good water sources, but they are the only sources available in some communities; in such areas women and children use plastic buckets to collect water for domestic uses.

The rural water schemes in the area were developed by Enugu State government through the State Water Corporation. The schemes are located mostly in the central, surface water deficient Local Governments Areas of Igbo Eze North, Igbo Eze South, Udenu, Igbo Etiti, Udi, Ezeagu, and Oji River (Figure 2).

Out of the 76 rural water schemes shown in Figure 2, 17 households were sampled as, explained above and used in this study. Table 2 shows the statistics of the communities hosting the schemes, their population range and their prevalent sources of water supplies to the citizens.

Four of the Local Government Areas (Enugu North, Enugu South, Enugu East and Nsukka) are largely urbanized .Interviews held with the zonal water engineers revealed that Enugu State Water Corporation has, historically, been more involved in developing and maintaining water supply schemes in these urbanized local governments than in the rural communities. Consequently, many households at the periphery of these urban areas prefer water sources from the near-by urban areas mainly determined by several interesting factors such as previous experience with rural water schemes, financial status, gender, and distance from the source and weather conditions.

Patterns of water demand and supply in the study area

The general patterns of water demand and consumption in the sampled communities were examined here. Table 2 provides a summary of the demand-consumption characteristics, the quantities demanded and supplied, the supply deficits as well as the percentages of demand satisfied by supply in the 17 sampled communities.

As shown in Table 2, the quantity of water demanded is more than the supply in all the sampled communities; indicating shortage of water supply generally in all the sampled communities. Also the quantity demanded vary widely among the 17 communities, this may be due to the variations in the intensity of natural and socio-economic conditions. Ngwo community has the highest of water demanded while Umundu has the lowest. This could be due to large concentration of functional and high yielding boreholes, owned largely by the private sector (firms, religious organizations, wealthy individuals, NGOs, etc) in Ngwo and the near absence of such facilities in Umundu. Households in Oji River and Ovoko communities also demand relatively high amounts of water. Both communities have many households that engage in local industrial activities (garri, cassava), processing of oil palm products, wood works, clay products etc). These could make them demand more water than other communities.

The amount of water supplied to the sampled communities also varied (also as amount demanded), but are generally below demand. None of the communities was supplied the quantity it needs. Again Ngwo community has the highest mean household and per-capita water supply while Umundu and Obukpa had the least. The differences in amount supplied could emanate from a variety of factors such as variations in water availability. For instance, Ngwo community has the highest concentration of functional boreholes (52) in south eastern Nigeria; so the quantity supplied to the community is relatively high. Again many residents of Ngwo are top-civil servants and businessmen who have money to develop private boreholes or engage the

Table 2. Statistics of communities visited and their water sources.

Local government area	Sampled community	Opulation served*	Available Water Sources**	Leading or primary water source**
Igbo Etiti	Ukehi	14,165	River, well ,harvested rain, public taps, private boreholes, vendors	Private boreholes
Igbo Eze South	Ovoko	9,890	Well, harvested rain, public taps, private boreholes, vendors ,ponds	Private boreholes
Igbo Eze North	Ogurute	6,217	Well, harvested rain ,public taps, private boreholes, vendors ,ponds	Private boreholes
Nkanu West	Agbani	11,495	Wells, private boreholes , streams ,ponds stored, rain water, vendors	Private boreholes
Oji-River	Oji-River	16,668	River, well, harvested rain, public taps, private boreholes, vendors	Private boreholes
Udi	Udi	9,424	Public taps, water vendors, private boreholes ,stored rain water	Public taps
Isi-Uo	Ikem	13,814	Public taps, streams, water vendors	Streams
Nkanu East	Nnenwe	6,847	Public taps, streams, water vendors, private boreholes	Water vendors
Awgu	Maku	6,877	Public taps, streams, water vendors, private boreholes	Water vendors
Nsukka	Obukpa	7,997	Public taps, water vendors, private boreholes	Private boreholes
Udenu	Umundu	2,684	Public taps, water vendors, private boreholes	Private boreholes
Uzo-Uwani	Nimbo	4,737	Streams, water vendors, private boreholes	Water vendors
Ani-Nri	Mpu	3,657	Streams, water vendors, private boreholes	Water vendors
Enugu North	Ngwo-center	12,778	Public taps, water vendors, private boreholes	Private boreholes
Enugu East	Ugwugo Nike	2,548	Public taps, streams, water vendors, private boreholes	Water vendors
Enugu South	Amechi –Agu	7,238	Public taps, water vendors, private boreholes	Private boreholes
Eziagu	Iwollo	12,212	Public taps, streams, water vendors, private boreholes	Private boreholes

Source: *Enugu State Water corporation, Records and Statistics Department (2014). **Field work (2014).

services of big time water vendors or develop other alternative sources of supply. Because of these, they demand and consume more water. Similarly, residents of Oji River community are supplied with relative high quantity as the community is located close to a very large river .The river is perennial and less than 0.5 km from most parts of the community. In contrast, Umundu and Obukpa communities are located on the central, dry, surface water-deficient Nsukka plateau surface with few functional boreholes; people in this area demand and consume little water. Residents of these communities often trek over long distances (between 1 and 2.5 km) to access the water they need from commercialized private boreholes.

The spatial patterns of water demand and supply characteristics for the entire area shows that the total household water demand is 261,706 lpd, against the total household water supply of 180572 lpd, leaving a daily deficit of 81,134 L. The mean household water demand was found to be 13685.5 lpd against the mean household water supply of 9028.6 lpd; while the mean per-capita water demand was found to be 75.5 lpd against the mean per-capita water supply of 60.1 lpd, representing 84% of the per capita water needed but not met by the supplied. .The overall picture shows that the people generally do not demand much water. The level of water deficiency in the area can be appreciated in the last Colum which shows the percentage of the Federal Government

of Nigeria recommended minimum of 115 lpd, satisfied by supply in each of the sampled communities. The percentage of the recommended minimum satisfied by supply in the communities were generally low and for the entire area was found to be just 52.3%.

Analysis of the factors affecting the water supply pattern in the study area

Table 3 highlights the water shortage situation; the mean per-capita water supply was found to be only 60.1 lpd, which is just 52.3% of the Federal government of Nigeria recommended minimum of 115 lpd. As Table 3 shows, over 50% of the sampled

Table 3. Water demand and consumption characteristics in the study area.

S/N	Community	T/HH water demand in lpd	T/HH water supply in lpd	Mean HH water demand in lpd'	Mean HH water supply in lpd	Per-capita water demand in lpd	Per-capita water supply in liters	% of per-capita demand satisfied by supply	% of 115 lpd. satisfied by supply
1	Ukehi	18922	11872	946.1	593.6	118.3	74.2	62.7	64.5
2	Ovoko	22084	10592	1104.2	529.6	130.0	66.2	50.9	57.6
3	Ogurute	13204	9536	660.2	476.8	82.5	59.6	72.2	51.8
4	Agbani	14446	10096	722.3	504.8	90.3	63.1	69.9	54.9
5	Oji-River	23 886	13232	1194.3	661.6	149.3	82.7	55.4	71.9
6	**Udi**	18603	12832	930.2	641.6	116.3	80.2	69.0	69.7
7	Ikem	13490	10560	674.5	528.0	84.3	66.0	78.3	57.4
8	Nnenwe	16261	12364	813.1	618.2	101.6	68.8	67.7	59.8
9	Agwu	10264	9088	513.2	454.4	64.2	56.8	88.5	49.4
10	Obukpa	9786	8544	489.3	427.2	61.2	53.4	87.3	46.4
11	Umundu	8609	7872	430.5	393.6	53,8	49.2	91.4	42.8
12	Nimbo	12764	9440	638.2	472.0	79.8	59.0	73.9	51.3
13	Mpu	18112	11568	905.6	578.4	113.2	72.3	63.8	62.9
14	Ngwo-center	24142	14160	1207.1	708.0	150.9	88.6	58.7	77.0
15	Ugwugo Nike	15006	9840	750.3	492.0	93.8	61.5	65.6	53.5
16	Amechi –Agu	10686	93360	534.3	468.0	66.8	58.5	87.6	50.9
17	Iwollo	11441	9616	572.1	480.8	**71.5**	**60.1**	**84.0**	**52.3**
Total		**261,706**	**180,572**	**13685.5**	**9028.6**	**1627.8**	**1119.6**		
Mean		**15394.47**	**10621.9**	**805.1**	**531.1**	**95.8**	**65.9**	**72.2**	**57.3**
SD		**4887.9**	**1768.0**	**244.4**	**88.4**	**29.99**	**10.7**		
VARI.		**2.4**	**3.1**	**5.97**	**7.8**	**899.3**			

Source: Authors Fieldwork (2013-2014).

communities recorded high deficiencies of over 50% of their water needs. Evidences indicate that the effects of low access to potable water supplies are directly felt by the uses, notably women, children and young girls who spend more time travelling to collect water, often of doubtable quality and from distant sources. Reduced water availability in the area also affects the poor who do not have enough money to develop private boreholes or patronize water vendors.

The analysis of the reported explanatory variables for the prevailing water shortages in the area through the use of Principal Component Analysis (PCA) is focused here. The identified causes of water shortages were defined as shown in Table 4.

Variables x^2, x^3, x^4, x^5, x^6, x^7, x^8, x^9, x^{10}, x^{12}, x^{13}, x^{14}, x^{15}, x^{16}, x^{19} and x^{20} were abstracted from the questionnaire; variables x^1 and x^{11} were measured based on estimated distances between

households and named water sources; variables x^{17} was obtained through field observation while variable x^{19} was obtained from relevant records at the Enugu State Water Corporation. The PCA analysis generated the rotated components matrix (Table 5), in which only components with Eigen – values above unity with 5% or more explanatory powers were considered as separate orthogonal dimensions or factor components (Anyadike, 2009). As shown in Table 5, Component I has the

Table 4. Causes of water shortages in the study area.

Variable code	Variable label	Variable name
X1	DIST	Mean estimated distance in kilometer to the main source of water for the household.
X2	TIME	Mean estimated waiting time for water collection in minutes
X3	LOCAP	Number of O & M activities performed at the community level.
X4	TEFAT	High Number of technical fault reported in a month at the community level
X5	FULT	Estimated waiting time for fault to be restored in days.
X6	TAPS	Number of times public taps run in a weak
X7	NOTAP	Limited number of public water taps available at community level
X8	NOPUB	Limited number of functional public boreholes
X9	NOWEWA	Number of months wells yield water per annum
X10	NOFAS	Number of public functional storage facilities at the community level
X11	GESPAP	Estimated distance in kilometer for getting spare parts.
X12	WACAP	No of water source caretakers at community level minutes
X13	WUSUFA	Number of public water supply facilities at the community level.
X14	MAIT	Estimated number of times public water facilities are maintained in a month.
X15	NOFUP	Number of functional public water taps
X16	NOWAC	Mean number of elected Village Water Community (VWC) members
X17	ABAWA	Number of abandoned public water facilities at the community level
X18	DOWAA	Number of water projects sponsored by Donor Agencies
X19	CAPUF	Number of times up-front capitals are provided for O&M of facilities at the community level in 2015.
X20	COWAP	Number of times pubic water projects functioned satisfactorily for one month in 2015

highest number of loadings, with high positive and negative loadings on eight variables. The strongest loadings are recorded on variables 4, 7, 8, 10, 13, 14, 15 and 20. These variables relate to the limited number of public water supply facilities, poor functioning of and inadequate maintenance of water infrastructure in the study area. This component has an Eigen value of 10.400 and contributed 51.4% explanation to the variance .It is tagged the influence of technical and infrastructural shortcomings. Quality construction and regular maintenance of public water supply facilities in the rural communities under study is generally lacking. This leads to frequent breakdowns and leakages in the supply system. Evidences from the field reveal that the physical components of water infrastructure in many of the communities are inadequate, not regularly checked, maintained and repaired. The intake and reservoir structures at Oji River, Agbani and Ikem are unprotected, non- functional and dilapidated. The treatment and pump-houses at Ukehi, Umundu Iwollo, Ogurute, Obukpa and Achi experience frequent functional problems; users in these communities make their own arrangements to secure water for their families. Technical training received by VWCs members in these communities is insufficient to effectively solve existing technical problems of the water infrastructure. The old rural water supply schemes at Ovoko, Amechi, Udi and Agwu exhibit perennial technical problems which, according to the State water engineer, need partial or entire redesigning and replacement.

Component II contributed 13.8% explanation to the observed variance. The component has an Eigen value of 2.763 and loads highly on three variables, namely, variables 2, 12 and 16. Generally, these variables describe the institutional weaknesses of exiting water supply projects including the failures of VWC members in discharging their duties and responsibilities. Evidences suggest that the general poor performance of existing water supply projects at the community level is a major cause of failing water supply services in the area. This component is tagged the influence of institutional and managerial shortcomings. The capacities of existing rural water projects were found to be so limited and the workers are not motivated; leading to a general poor quality performance.

Component III contributed 8.3% to the variance. It has its strongest negative lading on variable 5, "long waiting time for faults to be restored" and an Eigen value of 1.668. The negative relationship shows that the longer the waiting time the lower the level of access to domestic water supplies .This popular observation agrees with the findings of previous workers such as 2012 and 2013. This component is tagged the influence of inefficiency in system repairs.

Component IV is defined by variable 18 (limited number of water projects sponsored by NGOs and other agencies in the area) and has an Eigen value of 1.446. The component contributed 7.2% to this variance. This component explains the impacts of limited assistance to

Table 5. Rotated component matrix scores of the variables analyzed.

Variable	Component				
	1	2	3	4	5
X1	-0.590	-0.474	-0.354	0.062	0.359
X2	-0.429	**0.764***	0.173	0.236	-0.120
X3	0.693	0.496	0.215	-0.145	-0.039
X4	**0.933***	-0.008	0.125	0.244	-0.116
X5	-0.180	-0.064	**-0.774***	0.018	0.075
X6	**0.857***	0.139	0.393	-0.030	0.057
X7	**0.909***	0.095	-0.014	0.074	-0.211
X8	**0.960***	0.045	0.057	-0.046	-0.076
X9	-0.441	-0.631	0.276	0.200	0.342
X10	**0.919***	0.267	0.073	0.076	-0.181
X11	-0.173	0.622	-0.280	0.130	0.471
X12	0.335	**0.856***	0.035	0.056	0.124
X13	**0.825***	0.238	0.175	0.345	0.127
X14	**0.965***	0.103	0.087	0.104	-0.069
X15	**0.827***	-0.035	-0.011	0.372	-0.141
X16	-0.337	**-0.736***	-0.219	-0.134	0.239
X17	-0.096	-0.088	-0.035	-0.047	**0.926***
X18	0.303	0.182	0.024	**0.879***	-0.015
X19	0.186	0.018	0.648	0.555	0.009
X20	0.**926***	0.069	0.238	0.155	-0.01008
Eigen value	10.250	2.763	1.668	1.446	1.025
% of variance explained	51.400	13.814	8.338	7.229	5.123
Cumulative % Explained	51.400	65.215	73.552	80.781	85.904

rural water services delivery in the study area, It is therefore tagged the influence of low external assistance.

Finally, component V has an Eigen value of 1.025 and contributed 5.1% to the variance. The variable has a positive high loading on variable 17 (high number of abandoned water facilities at the community level). Generally, this variable describes the insufficient capacities of exiting water supply providers in the area. Capacity constraints relate to limited resource availability (particularly skilled, experienced staff and finance) to initiate, complete and maintain rural water projects. Evidences suggest that the Enugu State government and other development agencies tend to focus more on projects completion than on the entire life cycle of rural water supply projects and that generally the communities maintenance workers rarely succeed in operating and adequately maintaining the water projects to ensure their longevity

The way forward

The factors identified and analyzed above have considerable negative effects on the sustainability and functionality of the public water projects and on the development of new ones in the study area. Evidences

show that 82.4% of the existing public water projects in the study area are partly or totally defunct. No public water project is functioning up to the designed capacity; 70.6% of the projects lack user committees. Abandoned water supply projects exist in all the sampled communities. Table 6 provides more information on the status of water supply projects in the area.

To reverse the sorry state of affairs in the rural water supply sector of the study area, the Enugu State Government needs to take a number of urgent actions.

First, the government could address the problems of functionality and sustainability of supply infrastructure in the area by initiating, implementing and institutionalizing an effective post- construction support programme. The programme must provide for effective monitoring as well as for regular repairs, maintenance and prompt replacement of parts.

Secondly, although many of the rural water schemes need repairs and rehabilitation, those described as 'too old" (Awgu, Ovoko and Amechi), ought to be reconstructed. New constructions have better chances of winning the goodwill of users and of attracting the attention and support of donors. Donors generally prefer to focus on new constructions which they consider more rewarding and easier to satisfy.

Thirdly, Enugu State Government needs to train rural

Table 6. Functional status of sampled water projects in the area.

S/N	Functional status of sampled community water projects	Number	% of the Total
1	No. of public projects functioning up to design capacity	1	5.9
2	No. of public projects requiring minor repairs	5	29.4
3	No. of projects requiring major repairs	11	64.7
4	No. of sampled households depending on public water projects		08
5	No. of sampled households depending on alternative sources		92

Source: Fieldwork (2014).

water users in system operation and maintenance and equip community-based technical operators to handle daily operation and maintenance activities of the rural water supply schemes. The existing community user committees were reported to lack the required engineering skills and knowledge to handle even minor repairs; also the zonal staffs of Enugu State Water Corporation do not carry out needed repairs promptly. Prompt and regular system repairs are necessary to ensure regular sustainable of water from public taps.

Finally, the Enugu State government needs to tackle the problems of insufficient resources and capacities in the rural water supply sector. This could be done through closer public and private partnership in water service delivery in the area. Public and private partnership may help to ameliorate the problems of insufficient public budgets and dwindling revenue as well as the problems of corruption and mismanagement which affect the efficient management of public institutions in Nigeria. The state government can develop rural water schemes and hand them over to the private sector to manage. The private sector mechanisms like competition and use of efficient management strategies may just be the panacea needed to forestall the massive and frequent failures of public rural water supply schemes in Enugu State.

Conclusion

This study focused on the patterns and problems of water supplies to communities that are predominantly rural and less industrialized. The results of the analysis show that there is a wide gap between the quintiles of water demanded and supplied and that many of the public water supply infrastructures in the area have failed completely or partially. Principal Component Analysis (PAC) reduced 20 constraining variables to household water supply to five underlying dimension which collectively accounted for 85.9% of the variance, leaving 14.1% to other variables not used in the analysis. The results of this study are important for a number of reasons. First, it provides a framework for development intervention measures in the rural water supply sector of the area. Since majority of the state's population live in rural areas, which has long been recognized to be

suffering neglect in Nigeria, any government which is interested in poverty alleviation, in empowering her citizens and in turning round the local economy must strive to find sustainable solutions to problems facing the rural areas. Secondly, the result provides the basis for comparing the rural supply in our study area with water supply situations in other developing countries. Finally, other rural communities which face similar problems in their water supply sector may also benefit from our recommendations.

Conflict of Interests

The authors have not declared any conflict of interests.

REFERENCES

Abaje IB, Ati OF, Ishaya S (2009). Nature of Potable Water Supply and Demand in Jema'a Local Government Area of Kaduna State, Nigeria. Res. J. Environ. Earth Sci. 1(1)16-21.

Adah PO, Abok G (2013). Challenges of Urban Water Management in Nigeria: The Way Forward. J. Environ. Sci. Resour. Manage. 20:111-121.

Akpomunie OB (2010), "Self-help as a strategy for rural development in Nigeria: A bottom-up Approach" J. altern. Perspect. Soc. Sci. 2(1):88-111.

Anyadike RNC (2009). Statistical Methods for Social and Environmental Sciences. Ibadan: spectrum Books, (Chapter 7)

Ezenwaji EE (2004). Water Supply, as a Strategy for Rural Development in Anambra State. J. Dev. 1(2):71-80.

Ezenwaji EE (2012). Institutional Framework for Public Water Supply and Sanitation Management. In Anyadike RC and Obeta MC. Department of Geography and Meteorology University of Nigeria Nsukka.

Ezenwaji EE, Eduputa BM, Okoye IO (2016). Investigation into the Residential Water Demand and Supply in Enugu Metropolitan Area. Am. J. Water Resour. 4(1):22-29.

FAO (2005). Plan of action for people's participation in rural development: Twenty-sixth session, FAO Conference., Rome, 9-28, Nov.

Gbadegesin N, Olorundemi F (2007). Assessment of Rural Water Supply Management in Selected Rural Areas of Oyo State, Nigeria", ATPS Working Paper Series No 49, Afr. Technol. Policy Studies Network (ATPS), Nairobi, Kenya.

Goni IB (2006). The challenges of meeting domestic water supply in Nigeria. J. Mining Geol. 42(1):51-55.

Marks SJ, Davis J (2012). Does users participation lead to sense of ownership for rural water systems? Evidence from Kenya. World Dev. 40(8):1569-1576.

Marks SJ, Onda K, Davis J (2013). Does Sense of Ownership matter for

Rural Water System Sustainability?: Evidence from Kenya. J. water, Sanit. Hyg. Dev. 3(2):122-133.

Mozie AT (2011). Analysis of settlement distribution Patter in two-terrain tracks: the Udi-Awgu Plateau and the Cross River plain in Enugu state, south Eastern Nigeria. Niger. J. Geogr. Environ. 1(1/2):237-246.

Nwankwo CF (2014). Residential Water Demand and Supply in Awgu Local Government Area, Enugu State, Nigeria. Department of Geography, University of Nigeria: Unpublished B Sc Project.

Nyaba S (2009). Review of Rural Development Policy for Sustainable Development. Presentation at the West African Regional Conference on Smart, Appropriate Technology for Rural Communities. Abuja, Nigeria.

Nzeadibe TC, Ajaero CK (2010). Assessment of socio-economic characteristics and quality of life expectations of rural communities in Enugu State, Nigeria. Appl. Res. Qual. Life 5(4):353-371.

Obeta MC (2009). The Development of Rural Water Supply Infrastructure in Nigeria. in Igbozurike I. and Onyenechere (eds.)., Rural Water Supply Niger., Owerri: Cape Publishers. pp. 402-410.

Obeta MC, Chukwu KE (2013). Water supply and Demand in Nigeria. Anyadike RNC and Obeta MC. Water resour. Dev. Manag. Niger., Merit international publication, Lagos, Nigeria. pp. 155-164.

Oformata GEK (2002). Geology in Ofomata (eds), A survey of the Igbo Nation, Africa. Onitsha: FEP

Olaleye YL (2010). The contributions of the doctrine of citizens' participation in organization and implementation of community development project" Eur. J. Sci. Res. http://www.eurojournal.com/ejsr.htm/.

Toyobo AE, Tanimowo NB (2011). Evaluation of Rural Water Supply Systems in Selected Communities in Oke-Ogun Area, Oye State, Nigeria. Glob. J. Sci. Front. Res. 11(9):1-7.

Unicef (2015). 2015 Update and MDG Assessment Progress on Drinking Water and Sanitation. A Publication of the World Health Organization (WHO) 20 Avenue Appia, Geneva.

Utube JT (2002). Water Demand in Ajegunle Are of Lagos Mainland, Nigeria. J. Dev. 3(2):60-71.

Journal of Agricultural Extension and Rural Development

Related Journals Published by Academic Journals

- Journal of Plant Breeding and Crop Science
- African Journal of Agricultural Research
- Journal of Horticulture and Forestry
- International Journal of Livestock Production
- International Journal of Fisheries and Aquaculture
- Journal of Development and Agricultural Economics