



Effects of Sweet Potato (*Ipomea Batata*) Production on the Empowerment of Women Farmers in Delta State, Nigeria

¹Aneneokeakwa. J.E. (Ph.D); ²Oyibo, Ogheneakpobor; ³Chukwukelu, Ifeanyi; & ⁴Diabuah, S. C.

¹Department of Home Economics, Federal College Of Education (Technical), Asaba ^{2,3,4}Department of Agricultural Education, Federal College Of Education (Technical), Asaba.

Abstract

The study ascertained the effects of sweet potato production on empowerment of women farmers in Delta State. Multi-stage sampling procedure was used to select respondents for the study. The sample size consist of two hundred and fifty (250) sweet potato women farmers from 8 communities in the two (2) Agro-ecological zones of Delta State. The data collected were analyzed through the use of frequency count, percentage, mean and standard deviation The result found that sweet potato has immensely contributed to the income level of women farmers to a very large extent with grand mean score of 1.79. The major activities perform by sweet potato farmers include sweet potato farming, processing and marketing; respondents agreed that acquisition of farmland is a major problem to sweet potato production by women farmers among others. The following recommendations were made; that agricultural extension agencies should intensify efforts on creating awareness on improved technological approaches to farming especially to the women to support their efforts in sweet potatoes farming among others.

Keywords: Effect, Sweet potato, production, empowerment, women farmers

Introduction

Sweet potato is among the world's most important food crops, owing to its nutritional value and higher yield (Mwanja, Goler and Gugu, 2017). Sweet potato ranks second among the world root crops on the bases of its economic importance.(Okonmah and Eruotor,2012). In terms of cultivation, developing countries are the biggest sweet potato cultivators in the world. It is grown in many regions and ecological zones of the developing countries (Olapade and Ogunade, 2014; Odebode, Egeonu and Akoroda, 2008). The crop is now cultivated in developing countries than any other root crop (International Potato Center-CIP, 2005a). Nigeria is one of the major sweet potato producers in the world. The country is the second leading sweet potato producer in the world, after China (Mwanja *et al.*, 2017; Egbe, Afuape and Idoko, 2012). Presently, the country produces about 3.69 million metric tons/year of sweet potato as reported by (Oyibo 2019,Mwanja *et al.*, 2017; FAOSTAT, 2017; Egbe, Afuape and Idoko, 2012).

Sweet potato leaves, shoots and tuberous roots are of tremendous use for both humans and livestock's. It serves as staple food crop in tropical areas and much part of the sub-tropics

(Ogundele, Idowu & Badmus, 2008; Odebode *et al.*, 2008). In sub-Saharan Africa, supported that it is primarily cultivated for human consumption Mmasa (2014). In East AfricaI sweet potato vine tips and leaves are eaten wildely as vegetable (Wariboko & Ogidi, 2014; Meludu, 2010). In Nigeria, sweet potato is commonly consumed in boiled,fried or rosted (Okonmah and Eruotor,2012). Divers products have been produced from sweet potato,these includes cakes'kunnun zaki', chips,doughnut, sweetener, livestock feed among others Odebode (2008a). Thus, sweet potato production is viable farming business for reducing poverty (in terms of food security and income generation) in rural areas.

Women farmers are vital in the world's food crop production. They represent approximately 50%of the world food production (FAO, 2011b) and approximately 43 - 48% of the total agricultural worker force in the world (Akter, Rutsaert, Luis, Htwe, San, Raharjo & Pustika, 2017; Doss, 2014; Sraboni, Malapit, Quisumbing & Ahmed, 2014). According to Banmeke (2003), women farmers supply more than 30 percent of the agricultural labour in Latin America,

31 percent in the Middle East and 60 to 80 percent in Asia and sub-Saharan Africa. United Nations Development Project-UNDP (2013) and reported in Ozoya (2016) opined that women farmers account for 80-90% of food (sweet potato inclusive) producers in sub-Saharan Africa. Nungo, Ndolo & Hagenemana (2000) supported that in Africa, sweet potato is primarily women's crop from planting, harvesting to marketing. However it is pertinent to note that women have less control over decision, income, choices, assets and productive resources. They have inadequate access to land and credit facilities (Ayoade, 2012). FAO (2009b) in Oyesola and Ademola (2012) reported that women do not have access and control over asset (with respect to land and fund) as men. Hence, the need for women empowerment in order to enhance their production capabilities.

Empowerment is defined as the capacity to translate choices into desired actions and outcomes given the opportunity structure within which one operates (Akter, Rutsaert, Luis, Htwe, San, Raharjo, Pustika, 2017; Alsop et al., 2006). Empowerment in agriculture is generally viewed as one's ability to make decisions on matters related to agriculture as well as one's access to the material and social resources needed to carry out those decisions (Alkire et al., 2013).

Women empowerment entails providing more opportunities for women through greater self-reliance (Momsen, 1991). This can be viewed from various perspectives. It can be either empowering them economically, politically, socially or culturally (Banmeke, 2003) which would invariably lead to improvement in their livelihood.

Sweet potato production possess the prospective of being widely used to empower women farmers. This is because of its wide range of desirable attributes such as: easy propagation; ability to be cultivated in divers soil types; minimal input requirements; drought tolerance; high yield achieved within a short growing season; tolerant to insects and diseases; and relatively good yield in marginal fertile soils (Amengor, *et al.*, 2016). Egeonu (2011) substantiated that sweet potato has few natural enemies and grow well in poor soils (with little fertilizer), with diverse farming conditions. Therefore, the use of fertilizer, insecticides, pesticides, herbicides is rarely needed, making it an attractive cash crop. Affirming this, Odebode *et al.* (2008) opined that it is an attractive cash crop for farmers because of its low input requirement. It can be cultivated twice in a year (Ogundele *et al.*, 2008), with high

productivity per unit area of land and of time. Its cultivation is very beneficial in area where land is scarce(Oyibo, 2019).

Literatures have established a number of ways through which women can be empowered. One of such is when their livelihood is enhanced, as well as having access to productive resources and opportunities (Wouterse, 2016; Ogunbameru & Idrisa, 2013. In Nigeria, sweet potato production offers a possible livelihood option and has been identified as an alternative to ensure empowerment of women (Odebode, 2008b). This is because it is a crop with many health (Ogundele *et al.*, 2008b), socio-economic (Olapade & Ogunade, 2014; Onumah, Dipeolu & Fetuga, 2012) and environmental (Odebode *et al.*, 2008) benefits. However, in spite of these desirable features of sweet potato, it has not gained the desired eminence among farmers (majority of who are women) in Delta State, Nigeria.

Crops with similar features have been utilized as means for women empowerment in developing countries of the world (Oyibo,2019). For example, rice cultivation has been used as an intervention inThailand Indonesia, Myanma and Philippines and has empowered women rice producers. Consequently,this resulted in improved access to productive resources as well as ownership of such resources, improved decision making power, better access to income, greater control over household income and being active members as well as playing strong leadership roles in agricultural and non-agricultural organization (Akter, *et al*). This is an indication that given an enabling policy environment in Delta State, sweet potato can be utilized as a means for empowerment of women. However, the potential of sweet potato production at achieving such an end has not been explored.

Various studies related to sweet potato production have been reported in Nigeria.Adewumi and Adebayo (2008) assessed profitability and technical efficiency of sweet potato production in Nigeria. Mbanaso, Agwu, Anyanwu & Asumugha (2012) also assessed the level of adoption of sweet potato production technology by farmers in the southeast agroecological zone of Nigeria. However, there is scarcity of information on effects of sweet potato production on women fermers empowerment in Delta State of Nigeria. It is against this backdrop that this study is designed to answer the following research questions:

1. What are the contributions of sweet potato production to the income of women farmers in the study area?
2. What are the major economic activities performed by women in sweet potato production in the study area?
3. What are the factors hindering women farmers empowerment in the study area?

METHODOLOGY

The study was conducted in Delta state of Nigeria. Delta State is divided into three agroecological zones by Delta Agricultural Development Programme (DADP). The population for this study consist of all sweet potato women farmers in Delta state of Nigeria.

Multi-stage sampling procedure was used to select respondents for the study. In the first stage, two ADP zones in Delta state were purposively selected based on high predominance of sweet potato production. Delta Central and Delta South zones were selected. Delta Central and Delta South zones have 10 and 6 blocks respectively.

In the second stage, altogether 6 (38%) blocks also with highest prominence in sweet potato production were purposively sampled. Ughelli South and Ethiopie East from Delta Central Zone and Patani and Bomadi from Delta South Zone were selected. Each block has an average of eight cells.

At the third stage, fifteen farmers with highest prominence in sweet potato production from each of the selected block were purposively sampled. Ewu and Okwagbe from Ughelli South block, Okpara Inland and Oria-Abraka from Ethiopie East blocks in Delta Central Zone; and Abare and Koloware from Patani block, Kpakiamia and Akugbene from Bomadi blocks in Delta South Zone was selected.

The fourth stage will involve generating the total number of sweet potato women farmers in the selected cells. Lastly, from the list of women sweet potato farmers of the selected cells, women sweet potato farmers were randomly selected from each of the selected cells for analysis using proportionate sampling technique. This gave the total number of respondents (women sweet potato farmers as the unit of analysis) that formed the sample size for the study which is 250. Primary data was used for this study. Data in this study were collected by the use of quantitative and qualitative research

methods. The data collected were analyzed through the use of frequency count, percentage, mean and standard deviation.

The presentation is in line with the research questions that guided the study.

Table 1: Mean and standard deviation on the contributions of sweet potato farming in empowering women farmers in Delta State

S/N	Statements	LE	NE	VLE	LGE	Mean	SD
14	Sweet potato production has contributed to increase in the income of your household?	116	56	35	43	.98	1.14
15	Sweet potato production has contributed to improved food security of the household.	120	57	33	40	3.03	1.12
16	Sweet potato production has contributed to improved clothing of the household.	119	53	35	43	2.99	1.14
17	Sweet potato production among women farmers has reduced the burden on their husbands.	119	53	36	42	3.00	1.14
18	Sweet potato production among women farmers has brought about financial dependency of spouse.	121	54	34	41	3.02	1.13
GRAND MEAN						3.00	1.13

Source: Field survey, 2020.

Note: LE: Large Extent, NE: No Extent, VLE: Very Large Extent, LGE: Largest Extent

Table 1 shows the mean and standard deviation on the contributions of sweet potato production to income level of women farmers in Delta State. The result revealed that on all the items, respondents agreed that sweet potato has

contributed to the income of potato farmers in the area to a very large extent (VLE) with mean response score from 2.98-3.03 respectively. The grand mean score of 3.00 is a further indication that sweet potato has immensely contributed to the income level of women farmers thereby making them financially independent. The rating of standard deviation which range between 1.12-1.14 is an indication that the respondents were not far apart in their responses. Thus, analysis of data suggests that sweet potato has immensely contributed to the income level of women farmers in Delta State to a very large extent.

Table 2: Percentage responses of women sweet potato farmers on their major economic activities

SN	Items	Yes (%)	No (%)
1	Sweet Potato Farming	200 (80)	50 (20)
2	Processing of sweet potato	210 (84)	40 (16)
3	Marketing of sweet potato products	180 (72)	70 (28)

Source: Field survey 2020

Table 2 revealed the major activities of sweet potato farmers in the study area. Majority (80%) of women in the study area are sweet potato farmers while 20% are not. 84% of the women farmers are also involved in processing sweet potato into food and industrial products while 16% of the women are not and 72% of the majority are into selling and marketing of sweet potato products while 28% are not into selling and marketing of sweet potato products.

Mean and standard deviation on factors that inhibit women empowerment in the study area

S/N	Statements	A	SA	D	SD	Mean	SD
19	Acquisition of farmlands is a major problem to sweet potato production by women farmers	85	77	40	48	2.80	1.11
20	Access to information on modern ways of sweet potato production by women farmers	90	73	40	47	2.82	1.12

21	Most sweet potato farmers are illiterate who cannot apply modern techniques in sweet potato production.	84	78	40	48	2.79	1.11
22	Inability to get access to extension officers on techniques of sweet potato production	89	73	41	47	2.82	1.11
23	Non-availability of cheap labour by women farmers on sweet potato production.	83	78	41	48	2.78	1.11
24	Inability to access credit facilities from banks to finance sweet potato production	88	75	40	47	2.82	1.11
25	Non-availability of storage facilities of product	83	77	40	50	2.77	1.11
26	Assistance from FGN, State Government, Local government, ADP/CBN to finance sweet potato production	87	73	40	50	2.79	1.13
27	Effects of disease/pests on sweet potato production	81	77	44	48	2.76	1.10
28	Inability to access the right insecticides/pesticides to combat the effects on sweet potato production	86	73	40	51	2.78	1.13
Grand Total						2.79	1.11

Sources: Field survey, 2020

Note: LE: Large Extent, NE: No Extent, VLE: Very Large Extent, LGE: Largest Extent

Table 3 shows the mean and standard deviation on constraints to sweet potato production among women farmers in delta state. the result revealed that on all the items, respondents acquisition of farmland is a major problem to sweet potato production by women farmers, access to information on modern ways of sweet potato production by women farmers, most sweet potato farmers are illiterate, and unable to access extension officers assistance, lack of credit facilities, lack of storage facilities and activities of pest and disease as problems associated with sweet potato production among women farmers in Delta state with mean rating scores ranging from 2.76–2.82. The grand mean score of 2.79 is a further indication that all the items are problems associated with sweet

potato production among women farmers in Delta State. The rating of standard deviation which range between 0.49 –1.06 is an indication that the respondents were not far apart in their responses.

Discussion of Findings

The result indicates that all the respondents agreed that sweet potato farmers in Delta State had access to farm input to a very low extent. This is contrary to the findings of Mbanaso, Agwu, Anyanwu and Asumugha (2012) who assessed the extent of adoption of sweet potato production technology by farmers in the southeast agro-ecological zone of Nigeria.

The result also revealed that, sweet potato has immensely contributed to the income level of women farmers in Delta State to a very large extent with grand mean score of 1.79. The crop helps in reducing poverty and improving food security in developing countries and post-conflict areas, particular in Nigeria. It has been a life saver in many tropical, sub-tropical and warmer temperate areas of the world, warding off famine in times of both natural disaster and war (Olapade & Ogunade, 2014). Andrade, Barker, Cole, Dapaah, Elliot, Fuentes, Gru neberg & Kapinga *et al.* (2009) corroborated this view that it increases food security in period of famine and drought.

The study revealed that the major activities in sweet potato production performed by women are sweet potato farming, processing and marketing. This is in line with the view of Osuala (1991) and Ijere (1991) who observed that women earn income through a range of economic activities such as selling (marketing of food and industrial products) and processing of sweet potato into food/industrial products. They argued that women are the backbone of agricultural economic production in Africa. Flann and Oldham (2007) emphasized this point by observing that women perform a lot of economic activities for the purpose of generating income for their family upkeep. Such activities would be in form of production, distribution, trading, food processing and likes. This is supported by Adeferison (1987) who pointed out that the major economic activities that directly add to the income of women include processing, marketing among other. He further argue that in most cases, the women use this income to supplement household upkeep, pay rent, school fees and training children. These activities undertaken by the women provide avenue for them to contribute to family and community maintenance and development. There is improvement in the standard of living and the

development of their productive capabilities. Mosher (1978) observed that activities such as agriculture, forestry, fishery, hand craft, trade and services transform the society and bring about rural modernization.

The result found that all the items; respondents agreed that acquisition of farmland is a major problem to sweet potato production by women farmers. Access to information on modern ways of sweet potato production by women farmers, most sweet potato farmers are illiterate, unable to access extension officers assistance, lack of credit facilities, lack of storage facilities and activities of pest and disease are problems associated with sweet potato production among women farmers in Delta State. This is in accordance with the observation of Kwesiga (1999) who noted that the participation of women in economic activities at all levels is hampered by factors such as limited resources, lack of government assistance, lack of training and educational opportunities, cultural values and discrimination against women. They are not allowed to own lands and they have less access to technological inputs like farming equipment.

Conclusion and Recommendations

The major economic activities recorded in this study were sweet potato farming, trading/marketing and processing into food and industrial products. These economic activities were funded by women through personal savings, family, philanthropists, co-operative societies, loan and credits. Lack of government support, corruption by programme implementers, cultural restrictions, family burden, husband influence and illiteracy/low level of education were recorded as obstacles encountered by women in economic activities.

Provision of sustainable land tenure system, soft loans and credits, training and retraining programmes, establishment of co-operative society would enhance women participation in economic activities and societal development in Delta State in particular and Nigeria in general. Community education and enlightenment by government and non-governmental organization would be of immense assistance in changing the cultural practices and belief against women in the society. This would help them manifest their inert potentials for the development of the society.

For solution to the problems as identified from findings of the study, the researchers made the following recommendations:

1. Agricultural extension agencies should intensify efforts on creating awareness on improved technological approaches to farming especially to the women to support their efforts in sweet potatoes farming.
2. Government should provide sweet potatoes farming inputs and ensure it get to the sweet potato farmers. There should be more investment in sweet potatoes farming since it as a source of women empowerment.
3. In order to achieve rural development in Nigeria, which is to increase rural productivity and income, there is need to enhance the quality of life of sweet women potatoes farmers and meet the extension service needs of women farmers in sweet potatoes production.
4. Women farmers should be encouraged to participate more actively in farmers/social organizations since this act as effective channels for extension contact with large numbers of farmers.

REFERENCES

- Adefarison H (1987). Mobilizing Nigerian Women for Participation in National Development. In: Report of the National Seminar on Social Development Policy of Nigeria, Bauchi, 2: 14-25.
- Adewumi, M.O and. Adebayo, A.A., (2008), Profitability and Technical Efficiency of Sweet Potato Production in Nigeria. *Journal of Rural Development/Nongchon-Gyenongji*, 31:105-119.
- Akoroda, M. O. (2008). Sweetpotato in West Africa. *The sweet potato*. Loebenstein, G. and Thottappillay G. eds. BV: Springer science and Business Media, pp441-468.
- Akter, S., Rutsaert, P., Luis, J., Htwe, M. M., and Sanet. al. (2017). Women's empowerment and gender equity in agriculture: A different perspective from Southeast Asia. *Food Policy* 69(1): 270-279.
- Amengor, E. N., Yeboah, H., Fordjour, E., Acheampong, P. P., and Osei Aduet. al. (2016). Gender analysis of sweet potato production in Ghana. *American-Eurasian Journal of Scientific Research* 11(1): 13-20. DOI: 10.5829/idosi.aejr.2016.11.1.22808
- Ayoade, R., (2012), Attitude of women farmers towards agricultural extension services in Ifelodun Local Government Area Osun State Nigeria. *American journal social and management science*, 3:125-131
- Andrade, M., Barker, I., Cole, D., Dapaah, H., and Elliot et. al. (2009). Unleashing the Potential of Sweet potato in Sub-Saharan Africa: Current Challenges and Way Forward, Working Paper 2009-1, International Potato Center (CIP), Lima, Peru.
- Banmeke, T. O. (2003). Accessibility and utilization of agricultural information in the economic empowerment of women farmers in south-western Nigeria. Unpublished Ph.D. Thesis in the Department of Agricultural Extension and Rural Development, University of Ibadan, Nigeria. pp25.
- Egbe, O. M., Afuape, S. O., and Idoko, J. A. (2012). Performance of improved sweetpotato (*Ipomea batatas* L.) varieties in Makurdi Southern Guinea Savanna of Nigeria. *American Journal of Experimental Agriculture* 2(4): 573-586.

- Egeonu, I. N. (2011). Characterization of sweet potato (*Ipomoea batatas* [L.] clones for different end-uses. Unpublished Ph.D. Thesis in the Department of Agronomy, University of Ibadan, Nigeria. pp220.
- Food and Agriculture Organization of the United Nations. (FAO, 2011b). Women in agriculture: Closing the gender gap for development. In: The state of food and agriculture 2010– 2011. Rome, Italy: FAO
- Flann. D.K, Oldham, L (2007). Women's Economic Activities in Jordan; Research findings on Women's Participation in Micro Enterprise Agriculture, and the Formal Sector. A project report submitted to the office of Women in Development, Bureau for Global Programmes, Field Support and Research, U.S. Agency for International Development.
- FAOSTAT (2017). Retrieved, February 28, 2018, from <http://www.faostat.org/en/#data/QC>
- Ijere, M.O. (1991). Women in Co-operation. J. Centre Rural Dev. Co-operatives, Univ. Nig., Nsukka, p. 16.
- Kabeer, N. (2007). *Marriage, motherhood and masculinity in the global economy: Reconfigurations of personal and economic life* (IDS working paper 290). Sussex, UK: University of Sussex
- Mbanaso, E. O., Agwu, A. E., Anyanwu, A. C., and Asumugha, G. N. (2012). Assessment of the extent of adoption of sweetpotato production technology by farmers in the southeast agro-ecological zone of Nigeria. *Journal of Agriculture and Social Research (JASR)*12(1): 124-136
- Meludu, N. T. (2010). Proximate analysis of sweet potato toasted granules. *African Journal of Biomedical Research* 13(1): 157-159.
- Mmasa, J. J. (2014). Market potential for processed sweet potato products in Tanzania: A case of Coast, Mwanza and Shinyanga Regions. Published Ph.D. Thesis in the Department of Agricultural Economics and Agribusiness, Sokoine University of Agriculture, Morogoro, Tanzania. Pp.4
- Momsen, J. H. (1991). Women and development in the third world. London: Routledge Press, pp149.
- Mosher, A.T. (1978). Creating a Progressive Rural Structure to Serve a Modern Agriculture. The Agricultural Development Council Inc.
- Mwanja, Y. P., Goler, E. E., and Gugu, F. M. (2017). Assessment of root and vine yields of sweet potato (*Ipomoea batatas* [L.] Lam) landraces as influence by plant population density in Jos-Plateau, Nigeria. *International Journal of Agricultural Research* 12 (2): 88-92 DOI: 10.3923/ijar.2017.88.92
- Nungo, R. A., Ndolo, P. J., Kapinga, R. and Agili, S. (2000). Development and promotion of sweet potato products in Western Kenya. *Proceedings of the 13th International Society for Tropical Root Crops Symposium, Western Kenya*, pp. 90 – 794.
- Odebode, S. O. (2004). Gender issues in agricultural extension and rural development in Nigeria. *Rural development- contemporary issues and practices*. Adisa, R. S. ed. ISBN: 978-953-51-0461-2, InTech, Available from: <http://www.intechopen.com/books/rural-development-contemporary-issuesand-practices/gender-issues-in-agricultural-extension-and-rural-development-in-nigeria>
- Ogundele, G. F., Idowu, O. A. and Badmus, O. A. (2008). Utilization of sweetpotato for food production and other industrial products. In:Akoroda, M. O. and Egeonu, I. N. eds.*Sweetpotato in Nigeria*. Proceedings of the first national sweetpotato conference, pp55-57. Held at University of Ibadan, Nigeria.
- Ogunlela, Y. I., and Mukhtar A. A. (2009). Gender issues in agriculture and rural development in Nigeria: The role of women. *Humanity and Social Sciences Journal* 4(1): 19-30.

- Okonmal,L.U.,and Eruotor, P.G.,(2012), *Arable crop production*,Benin: Ethiope publishing corporation.
- Olapade, A. A. and Ogunade, O. A. (2014). Production and evaluation of flours and crunchy snacks from sweet potato (*Ipomea batatas*) and maize flours. *International Food Research Journal* 21(1): 203-208.Retrieved, October 28, 2017, from URL<http://www.ifrj.upm.edu.my>
- Onumah, G., Dipeolu, A., and Fetuga, G. (2012). Report on sweet potato value chain study: Exploring opportunities to promote greater exploitation of the benefits of sweet potato in representative states of Nigeria. Nairobi, Kenya: International Potato Center (CIP). Unpublished report.
- Osula JO (1991). Enhancing W omen’s Economic Potentials through Appropriate Technology. In: Ijere, M.O. (ed), W omen in Nigeria Economics, Enugu, ACENA Publishers, pp. 70-77.
- Ozoya, M.I. (2016). Empowerment of rural women farmers and food production in Esan West Local Government Area of Edo State, Nigeria. Unpublished Ph.D. Thesis in the Department of Sociology, Covenant University, Nigeria, pp. 1.
- Sraboni, E., Malapit, H. J., Quisumbing, A. R., and Ahmed, A. U. (2014). Women’s empowerment in agriculture: What role for food security in Bangladesh? *World Development*61(1): 11–52
- United Nations Development Project (2013). *The Rise of the South: Human Progress in a Diverse World*. Human Development Report 2013. Retrieved, July 9, 2014, fromhttp://hdr.undp.org/sites/default/files/reports/14/hdr2013_en_complete.pdf
- Wariboko, C., and Ogidi, I. A. (2014). Evaluation of the performance of improved sweet potato (*Ipomoea batatas* L. LAM) varieties in Bayelsa State, Nigeria. *African Journal of Environmental Science and Technology* 8(1):48-83