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PETROL FILLING STATIONS' LOCATION AND MINIMUM ENVIRONMENTAL SAFETY REQUIREMENTS IN OBIO AKPOR LGA, NIGERIA

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Abstract

The study examines the proliferation of petrol filling stations in relation to the minimum environmental safety requirements by the Department of Petroleum Resources (DPR) that 'distance from the edge of the road to the nearest pump and from the next petrol filling station should not be less than 15 and 400 meters respectively. The Global Positioning System (GPS) was used to acquire the coordinates of each filling station in the study area and then imported to the ArcGIS 9.3 software environment. Distances between filling stations from the road and from each other were determined using the ArcGIS 9.3 measurement tool alongside buffering analysis in respect to their coordinates. The Z ratio analytical technique was used to examine the conformity of petrol filling stations to the required distance of 400m and 15m from each other and from the road respectively as stipulated by DPR amendment decree 37 of 1997. Findings from the z ratio analysis at 152 degree of freedom and 95% confidence level reveals that the petrol filling stations in the study area neither conform to the required distance of 400m apart nor conform to the required distance of 15m from the road. Thus, the study recommends, among others, the need for the regulatory agency, DPR, to improve their capacity in enforcing the compliance of petrol filling stations with laid down regulations.

Keywords: *Proliferation, regulatory agency, petroleum, filling stations, safety requirements,*

Introduction

Nigeria is blessed with abundant natural resources and at present, she is the ninth world producer and sixth world exporter of crude oil (CBN, 2010). Despite this, population growth rate has continued to outpaced the ability of Government to build essential infrastructures, enact and enforce legislation needed to make life in safe, rewarding and healthy (W.H.O, 2010). This rapid growth rate of most urban centres has increased the use of automobiles, generators and other petroleum demanding plants. The pathetic power situation in Nigeria has exacerbated the increasing demand for petroleum products, leading to the proliferation of petrol filling stations and consequently, with less consideration of the minimum environmental safety requirements for their operations (Afolabi, Olajide & Omotayo, 2011). Safety practices in locating petrol filling stations are of utmost importance in preventing hazards and reducing potential risks that could affect humans and their environment.

In most large urban areas of Nigeria, there is high demand for land for socio-economic services that are in high demand. This high land demand often results to land scramble and illegal conversion of land uses, leading to haphazard development and the deliberate location of petrol filling stations in unsuitable areas that are highly vulnerable to hazard (KASUPDA, 2009). Several problems have come to be associated with these poorly located filling stations. Today, this has become an important social issue requiring the attention of social critiques and researchers alike. For example, Samuel (2011) acknowledged the significant contributions of petrol filling stations' location to traffic congestion, pollution, and fire. The dimension and extent of the problems depend on the criteria or variable such as location, size and set back from the road. Thus, it is imperative to study spatial location of petrol filling stations in Obio Akpor Local Government Area in order to determine how they conform to the locational guidelines set by the regulatory bodies.

Study Area

The Study area is one of the 23 local governments of Rivers state, found in the south southern part of Nigeria, otherwise called the Niger Delta Region of Nigeria, located approximately between latitude 4^0 45" N through 4^0 56" N and longitude 6^0 52" E through 7^0 6" E. It has a general elevation of less than 15.24m above mean sea level (Oyegun & Adeyemo, 1999). It is bounded by Ikwerre LGA to the north, Port Harcourt LGA to the south, Oyigbo LGA to the east Emohua LGA to the west, as shown in figure 1.

Data Analysis

The petroleum filling station amendment decree no. 37 of 1977 safety rules and regulations stipulate site inspection by DPR of proposed filling station, so as to among other things, issue report on the following basic requirements: -

(i) Size of the proposed land site.
(ii) Whether site lie within pipeline or electricity high tension cable Right Of Way (ROW).
(iii) Distance from the edge of the road to the nearest pump (not less than 15 meters).
(iv) The number of petrol stations within 2km stretch of the site on both sides of the road will not be more than four, including the one under consideration.
(v) The distance between an existing station and the proposed one will not be less than 400 (four hundred) meters.
(vi) The drainage from the site will not go into a stream or river.
(vii) In some instances where site is along Federal Highway, a letter of consent from the Federal Highway is required.
(viii) DPR guided/supervised EIA study of the site by DPR accredited consultant.

This study is concerned with regulation number iii & v which state that:

a) The distance from the edge of the road to the nearest pump will not be less than 15 meters.
b) The distance between an existing station and the proposed one will not be less than 400m (four hundred meters)

Buffering technique in the GIS environment was used to analyse the spatial conformity of petrol filling stations across the study area in relation to required standards.

Table 1 Names and coordinates of Filling Stations in Obio Akpor LGA

S/N	Name	Eastings	Northings	S/N	Name	Eastings	Northings
1	Lopec	6.927306	4.885861	80	Con Oil	6.922167	4.875278
2	African Petroleum	6.927861	4.885833	81	Chiford Oil	6.92525	4.872972
3	Wilife	6.934361	4.884583	82	Ogiosam Petres	6.92925	4.857583
4	Perhoo Integrated Resources Ltd	6.935639	4.884111	83	Jack Petroleum Ltd	6.941694	4.843528
5	Matsgal	6.950022	4.877259	84	Cima Petrol Station	6.939194	4.870528
6	African Petroleum	6.951917	4.8775	85	Heiman's Oil	6.940417	4.870444
7	Salzaman Nigeria Ltd	6.958111	4.874	86	Mein Oil	6.942222	4.870167
8	MRS	6.962639	4.871861	87	Con Oil	6.942833	4.870139
9	Fidelity Oil	6.969811	4.868611	88	MRS	6.943361	4.870111
10	NNPC	6.969389	4.870417	89	NNPC	6.965472	4.8625
11	Cima	6.973917	4.869833	90	Forte Oil	6.968278	4.858111
12	Mobil	6.975333	4.869694	91	NNPC	6.976306	4.828889
13	Mac King Petroleum	6.978472	4.869306	92	Propel	6.977861	4.818222
14	Chiosa	6.98125	4.867917	93	Anele Oil	6.967111	4.828472
15	Sobaz	6.983861	4.860528	94	Rhodax Oil and Gas	6.9625	4.826389
16	Total	6.983528	4.861917	95	Oando	6.961222	4.825389
17	U.D. Uko	6.984139	4.868694	96	Forte Oil	6.958778	4.822556
18	Clendac Oil	7.001122	4.862722	97	African Petroleum	6.954167	4.816389
19	Geogal Chucks Associates	7.02475	4.859167	98	Alanco Ent. Nigeria Limited	6.948972	4.814111
20	Mikab Ventures	7.028333	4.859833	99	Dabatt	6.94325	4.812278
21	So	7.037778	4.862222	100	Biddel	6.939444	4.809472
22	Propel	7.038861	4.8625	101	Onava Oil	6.959694	4.823139
23	Dose Marine	7.042306	4.863306	102	Gamag Oil	6.964944	4.827583
24	King Petrol	7.052344	4.878003	103	Lumco	6.966	4.827889
25	Read Logistics	7.050831	4.882	104	KBJ	6.971111	4.828639
26	Celek Oil	7.050539	4.882431	105	Tonnino West Co.	6.978278	4.818861
27	Rosco	7.050281	4.882944	106	Roma	6.975917	4.840278
28	Sams P Nigeria	7.030639	4.906417	107	Mrs	6.974889	4.846667

	Limited						
29	Buela Resources	7.030083	4.907889	108	Stonefield	6.980528	4.844444
30	Total	7.031514	4.920531	109	Forte Oil	6.987944	4.837194
31	Apmich	7.030333	4.915722	110	Total	6.984694	4.833694
32	Bonit Oil	7.042333	4.892778	111	Sobaz Oil	6.987056	4.835778
33	Ekoil	7.042556	4.892472	112	Dan Dollars	7.000639	4.832111
34	Eromo Energy Resources Ltd	7.048056	4.886111	113	YKC	6.982111	4.845583
35	Con Oil	7.049547	4.883944	114	Bobby Petroleum Ltd.	6.973194	4.854778
36	Zelu Oil	7.051861	4.879361	115	Jorax Oil Petroleum	6.966639	4.860583
37	Sobaz Oil	7.055944	4.8645	116	Con Oil	6.966139	4.861556
38	Ben Oil	7.033528	4.862194	117	Forte Oil	6.925222	4.873306
39	Johny Son Oil	7.033528	4.861583	118	Mark Valley	6.922611	4.875556
40	Palflox	7.027861	4.860139	119	Gamag Oil Nigeria Ltd.	6.91325	4.876278
41	Viv King Nigeria Ltd	7.012111	4.885056	120	Hydropet	6.909417	4.881917
42	Owo Oil	7.0135	4.874056	121	Con Oil	7.028083	4.838917
43	Palflox	7.012972	4.878528	122	Total	7.029306	4.839444
44	Unity Garden	7.013472	4.871583	123	MRS	7.038972	4.843694
45	Chieson Nigeria Ltd	7.008083	4.865528	124	Con Oil	7.045917	4.846556
46	Forte Oil	7.002472	4.885139	125	Forte Oil	7.048528	4.847722
47	Mobil	7.002389	4.889611	126	Propel	7.060556	4.851361
48	Forte Oil	7.002444	4.893333	127	Sobaz Oil	7.069778	4.856389
49	Adoks Oil	7.002056	4.896028	128	Oyichiri Mega Station	7.082361	4.859889
50	NNPC	7.001583	4.898139	129	KS	7.089	4.861472
51	Owoma Petroleum	7.001417	4.898528	130	Gabbey	7.093028	4.862556
52	Con Oil	7.001222	4.892317	131	Pinnacle	7.096111	4.863417
53	Amandah	7.0005	4.903083	132	Jezco Oil Nigeria Ltd.	7.097694	4.863861
54	Mein Oil	7.00025	4.902222	133	Mobil	7.097806	4.864444
55	Ronel Oil	7.001694	4.895639	134	CMC	7.097111	4.864222
56	Ibuomi	7.002194	4.892528	135	MRS	7.092528	4.863083
57	NNPC	7.002778	4.882833	136	Propel	7.063639	4.854222
59	Total	7.00175	4.877778	137	Avina	7.062833	4.853556

60	NNPC	7.000778	4.876583	138	NNPC	7.062222	4.853139
61	Wolbet	6.999944	4.875528	139	Total	7.041083	4.845222
62	Machison	6.995444	4.867722	140	Oando	7.021583	4.835778
63	Clendac Oil	6.994639	4.86775	141	Mobil	7.036028	4.83725
64	Matebot	6.990333	4.868306	142	MRS	7.025806	4.835833
65	Gamag Oil	6.986778	4.868694	143	Total	7.023944	4.835861
66	Total	6.986	4.868833	144	Oando	7.022417	4.856861
67	Nna-Nosike Oil	6.985389	4.868944	145	Starchem	7.039722	4.842972
68	I.C. Ejezie	6.983806	4.869139	146	Yemsonat	7.058806	4.826139
69	Citizens	6.982639	4.869361	147	Chelsea Oil	7.063417	4.827972
70	Con Oil	6.977917	4.869833	148	KOP	7.050833	4.819194
71	Planet Oil	6.979028	4.86975	149	Zacosem Energy Services	7.059639	4.814167
72	NNPC	6.971583	4.870667	150	Tani Tobi	7.040917	4.843444
73	Pamel Resources	6.961889	4.872667	151	Juhel	6.904833	4.901972
74	Chieson Nigeria Ltd	6.95025	4.878222	152	AP	6.913917	4.894361
75	NNPC	6.945972	4.880361	153	Conoil	6.916944	4.898167
76	Kingsize Oil	6.944806	4.880944				
77	Whiz Oil	6.942722	4.881944				
78	Uyi Oil	6.931389	4.885528				
79	Directed Oil	6.910556	4.879667				

Source: Authors' Field Work, 2014

Table 2 Measured Distances of Petrol Filling Station from another using their Coordinates in ArcGIS 9.3

S/N	Petrol Filling Station Distances from another (m)		Petrol Filling Station Distances another (m)
1	61.83	80	57.85
2	61.83	81	41.88
3	149.03	82	1741.48
4	151.51	83	2089.44
5	111.47	84	136.86
6	202.14	85	136.86
7	441.73	86	70.91
8	121.59	87	55.28
9	207.05	88	127.55
10	205.78	89	325
11	158.34	90	577.58
12	158.34	91	84.81
13	77.42	92	139.71
14	220.68	93	180.98
15	157.5	94	180.98
16	157.5	95	122.9
17	62.43	96	634.01
18	827.86	97	634.01
19	354.57	98	521.83
20	61.88	99	521.83
21	123.88	100	122.9
22	123.88	101	123.35
23	392.32	102	123.35
24	160.77	10	446.78
25	57.43	104	84.81
26	57.43	105	680.47
27	62.11	106	675.55
28	173.19	107	214.08
29	535.25	108	184.02
30	535.25	109	342.53
31	44.03	110	184.02
32	44.03	111	1508.56
33	287.48	112	214.08
34	137.59	113	662.35
35	160.77	114	119.51
36	1402.03	115	119.51
37	69.39	116	41.88
38	69.39	117	57.85
39	61.88	118	483.07
40	716.41	119	281.76
41	276.15	120	153.51

42	500.34	121	153.51
43	281.54	122	112.21
44	827.86	123	317.44
45	258.37	124	317.44
46	326.95	125	268.74
47	91.18	126	723.03
48	61.28	127	766.92
49	45.23	128	430
50	45.23	129	82.51
51	113.06	130	139.3
52	96.23	131	63.93
53	96.23	132	63.93
54	61.28	133	78.76
55	113.06	134	82.51
56	258.37	135	115.52
57	172.35	136	83.71
58	147.36	137	83.71
59	147.36	138	119.59
60	90.63	139	264.19
61	90.63	140	756.5
62	483.06	141	206.22
63	87.02	142	206.22
64	69.77	143	366.31
65	69.77	144	112.21
66	62.43	145	551.59
67	131.88	146	551.59
68	123.67	147	1179.61
69	77.42	148	1114.39
70	244.76	149	114.28
71	77.42	150	1313.89
72	244.76	151	430.04
73	121.59	152	545.97
74	111.47	153	173.19
75	145.53		
76	145.53		
77	258.23		
78	343.3		
79	281.76		
		Σx	43602.84

Source: Authors' Field Analysis, 2014

The Z ratio analytical tools was used to determine the level of conformity of petrol filling stations to the required distance from the road as stipulated by DPR guidelines for approval to construct and operate petroleum products petrol filling station amendment decree no. 37 of 1977 safety rules and regulations iii stated that: The distance from the edge of the road to the nearest pump will not be less than 15 meters.

Table 3 Measured Distances of Petrol Filling Stations from the Road

X	Actual Distance from Road (m)		Actual Distance from Road (m)
1	9.7	79	8
2	8.94	80	4.85
3	9.03	81	4.21
4	31	82	5.45
5	10	83	16.98
6	9	84	8.89
7	7.05	85	7
8	15.39	86	12.72
9	15.64	87	10.1
10	15.72	88	3
11	20.61	89	18.3
12	18.64	90	8
13	17.96	91	7
14	6.16	92	5
15	15.48	93	6
16	23.3	94	19.1
17	9.54	95	12.2
18	8	96	6
19	17.64	97	12.18
20	22.73	98	4.49
21	12.25	99	8
22	10.03	100	15.9
23	15.92	101	5
24	10	102	15.7
25	5	10	5
26	8	104	7
27	7	105	15.1
28	10	106	5
29	6.85	107	17
30	13	108	6.7
31	8	109	8.7
32	14.74	110	4.2
33	11.9	111	12.4
34	21.92	112	13.8
35	5	113	3
36	3.09	114	2.4
37	16.17	115	2
38	15	116	7.6

39	6.96	117	7.2
40	9.41	118	4
41	15.81	119	3
42	8.71	120	18.7
43	15.1	121	20.3
44	9.82	122	9
45	15.48	123	18.1
46	5	124	21.1
47	8	125	15.8
48	12	126	24.5
49	15.53	127	4.1
50	15.75	128	23.6
51	15.6	129	10
52	15	130	7
53	6.94	131	7.1
54	9.45	132	10.5
55	9.71	133	12.1
56	4.29	134	8
57	19.57	135	8
58	7	136	12
59	2	137	15
60	11.5	138	22
61	15.2	139	18.4
62	8	140	11.2
63	6.7	141	15.8
64	8	142	8
65	7	143	6.9
66	12.13	144	6
67	12.48	145	8.9
68	13.3	146	15.7
69	15	147	6
70	19.1	148	6.6
71	16	149	9
72	17	150	20
73	4.39	151	6
74	15.6	152	28
75	15.3	153	4
76	15		
77	4.57		
78	7.19	Σx	1721.56

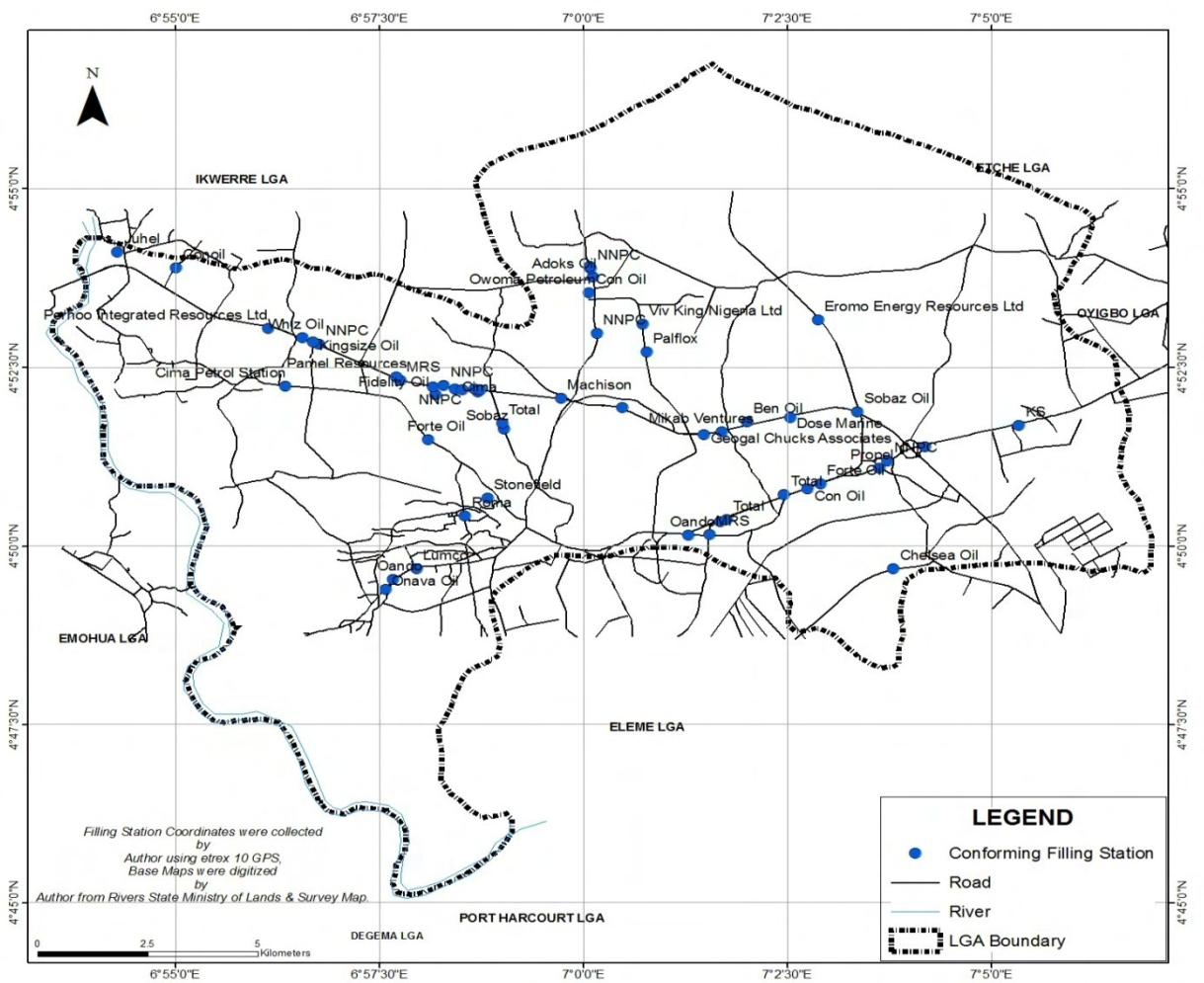
Source: Authors' Field Analysis, 2014

Degree of freedom = N-1= 153-1=152

Z critical = 1.65

Z calculated = 0.33

Since z critical is greater than z calculated at 152 degree of freedom, at 95% confidence level, hence the distance from the road among petrol filling stations in Obio Akpor Local Government Area do not conform to the required standard.



Source: Authors' Field Analysis, 2014

Figure 7 Conforming petrol filling stations in Obio Akpor Local Government Area to distance from the road

The above shows the conforming petrol filling stations in the area to required distance from the road.

Recommendations

This study therefore make the following recommendations to ensure public safety in the light of the findings: improved public participation in environmental monitoring and auditing of hazarduous public facilities; improved project screening techniques and tools to reduce risks; improved enforcement of all applicable legislations and procedure for locating petrol filling stations.

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Similarity of interests between governments and its impact on their bilateral relations: Case study of China-Sri Lanka relations

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Abstract

With China's rising as a global economic and political power, it is normally accepted that its leadership's impact in international politics has expanded significantly. Nonetheless, precise investigations of China's effect on small states are uncommon and for the most part constrained to inquiries with respect to similarity of interests between China-small states and its impact on their bilateral relations. This paper seeks to add to the literature on China's international affairs ascend a more extensive viewpoint. Drawing on voting information from the United Nations General Assembly for the most recent decade, it investigates the credibility of diverse clarifications for interest similarities, economic, diplomatic, strategic and military relations and bilateral relations. The outcomes further demonstrate that similarity of interests appear support to China directing sound relations with small states in international politics.

Key wards: China, interest similarity, UN General Assembly, voting data, bilateral relations, small states

Introduction

Small states have votes in the United Nations and other global organization, and in that capacity, can be valuable partners. Sometimes small states are chosen to essential chairmanship; for instance Jamaica has led the security council of the UN on two events, and additionally the G-77 and Non-Aligned Movement and small powers have held the presidency of the UN General Assembly. The driving force of the China's engagement with smallstates is the unresolved dispute about the status of Taiwan and its diplomatic recognition by a few small states. Twenty-three nations that still recognize Taiwan, nineteen of them are small states[1]. China's contemporary relations with Sri Lanka have been depicted as 'Models of good relations between small state and big power'[2].China has been a valuabletrading partner for Sri Lanka, with an expansive and developing trade surplus in China's favour in the most recent couple of years. In the meantime it has additionally been a huge source of investment and international economic assistance to Sri Lanka. For China, some assistance in seeking core interestshas not been confined to global high politics. The minimal methodical examination exists on why different states align with China. The few studies that exist arrive at opposing conclusions as well as only concentrate barely, on the subject of regardless of whether China's economic power is interpreted into direct political impact. They treat option causes, if by any stretch of the imagination, as auxiliary.

The aim of this exploration is therefore to add to studding so as to fill this whole the similarity of interests influence in interstate bilateral relations that focus on PRC–Sri Lanka relations. Be that as it may, systematicinvestigations of China's impact on amicable relations with small powers are still uncommon.

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[2]. Ivan Campbell, Thomas Wheeler, Larry Attree, Dell Marie Butler and Bernardo Mariani, (2012), China and Conflict-Affected States: Between Principle and Pragmatism, Safeworld, p.32.

The study's independent variable measures Sri Lankan government's similarity of interests with the PRC on depend on United Nations General Assembly vote records. The voting information for the years 2005-2014 is taken from the Index to Proceedings of the General Assembly. Utilizing UNGA votes in favor of figuring similarity of interests with China bears the point of preference that information is accessible for all conditions of universal framework, and a for long time period. In spite of the fact that the votes in the General Assembly are regularly condemned as absolutely typical, the information accompanies two further focal points, for one, it is less bended accurately in view of the more typical nature of UNGA votes. Then again, UNGA votes uncover a higher fluctuation than other foreign policy decision. The resolution themes focus on international security, humanitarian and other political issues.

This research paper uses recorded votes from 63rd and 66th sessions of the UNGA (These regularly sessions started in 2008/2009 and 2011/2012), to evaluate Sri Lanka's relative interest similarities with China. The level of interest similarities with Sri Lanka's voting example is measured for PRC, as an individual member of the UNGA, giving a rundown which similarities or dissimilarities of two nations altogether of their relative concurrence with Sri Lanka's reality view as reflected in resolutions received by the UNGA.

The methodology utilized here includes correlation of agreement and disagreementbetween China and Sri Lanka. The quantity of times two member states voted oppositely is subtracted from the quantity of times they voted closeness. Abstentions by one country yet not the other are disregarded.

Similarity of interests between China and Sri Lanka

The UNGA offers a legitimate and precise forum for examining the policy positions of countries in comparative perspective of the number and various issues on which votes are recorded and the high degree of members by countries in those votes. Any requires choice among the different organs, exercises and decisions.

The role-call and recorded votes taken in plenary present helpful summaries of voting alignments inside of the UNGA and make up the standard information from which the data here is assembled votes taken in the UNGA put into a global setting the perspectives of a variety of countries, which can be measured and compared at reliably all through the range of issued raised. Both super power and small states can be investigated on the same issues following an UNGA vote offers a straightforward and direct "Yes", "No" or "Abstain" from which information can be measured. The voting of UNGA has equivalent weight for all countries. It is sensible to estimate that Sri Lanka would vote most intimately with China that has a similar economic, cultural and ideological foundation.

Utilizing this methodology discussedin the introduction, a helpful estimation can be made of how firmly different nations voted with Sri Lanka. The table 1 demonstrates the pertinent figures for the China-Sri Lanka voting example in the United Nations General Assembly.

Table 1

UNGA voting comparison between Sri Lanka and the PRC

Session	63rd(2008/09)	66th (201/12)
Sri Lanka and the PRC both voted "Yes"	66	58
Sri Lanka and the PRC both voted "No"	03	02
Sri Lanka and the PRC both voted "Abstain"	01	03
Total resolutions on which the two agreed	**70**	**63**
Sri Lanka voted "Yes" the PRC voted "No" Sri Lanka voted "No" the PRC voted "Yes"	01	00
Total Resolutions on which the two disagreed	**01**	**00**
Agreement (70/63) – Disagreement (01/00)	**69**	**63**

Source: Author's own compilation

There are various things to note about this table. Most clearly, Sri Lanka of course was the nation which voted most intimately with the PRC. A closer examination of the 63rd session's voting conduct demonstrates that of the seventy events when both nations voted, Sri Lanka and PRC agreed69 times, while one abstained. The voting pattern of the 66th session demonstrates that of the 63 events when both nations voted, Sri Lanka and China agreed all resolutions that were 63 times.

While an investigation of the level of similarity of interests between Sri Lanka and China in the course of the most recent fifteen years gives an expansive review of the general patterns in UNGA voting. V.B. Tikhomirov, in a 1981 investigation of voting in the UNGA, offered a helpful division of issues into a set number of policy areas[3]. They cover all resolutions adopted by the UNGA, and are sufficiently expansive to incorporate growing differing qualities of issues. Table 2 demonstrates the distribution of resolutions adopted by vote in each issue area in 63rd and 66th sessions.

[3]. Tikhomirov, Vladislav B., Quantitative analysis of Voting behavior in the General Assembly, Policy and Efficacy studies, No. 2, UNITAR Research Dept., New York, 1981.

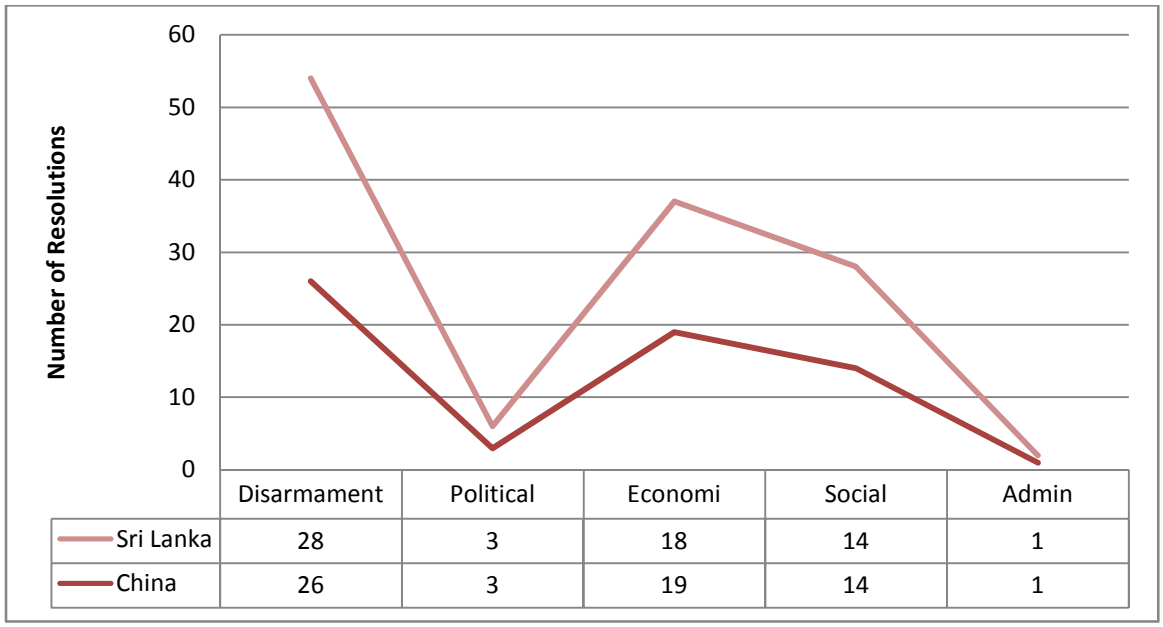
Table 2

2 Table, Total resolutions on which Sri Lanka and China voted by issue 63rd and 66th sessions

Session	63rd CH SL		66th CHSL	
Disarmament & International security	26	28	19	18
Political & Decolonization	03	03	04	04
Economic & Financial	19	18	14	15
Social Humanitarian & Cultural	14	14	14	14
Administrative & Budgetary	01	01	02	02

Source: Author's own compilation data collected from Index to proceedings of the UNGA 2008/2009& 2010/2011

Figure: 1, Resolutions on which Sri Lanka and China voted by issue in 63rd session



From table 2 and figure 1, there are clear that the issue of disarmament and international security made up the biggest extent of resolutions adopted by vote in 63rd and 66th sessions. The political and administrative issues took centrality decrease in both nations. Most different issues have kept up a moderately steady number of resolutions in both sessions. The issues of the economic and financial related made up the second biggest extent of resolutions in 63rd and 66th sessions when social and humanitarian issues made up the third place of China and Sri Lanka. In terms UNGA voting, this may show that the issue of disarmament and international security, Political and decolonization and social and humanitarian issues has been critical in the PRC and Sri Lanka Relationship.

Figure 2 – 6 show the general similarities in voting behavior between Sri Lanka and the People's Republic of China in the 63rd, 64th, 65th, 66th, 67th, 68th UNGA sessions and the way the issues of internati security, political, economic, social and humanitarian policy areas played a in the similarities. Given this confirmation, it is reasonable to infer that the policy issues of political, social and economic played a key part in adjusting the voting similarities of Sri Lanka and China on UNGA resolutions with respect to one another. On the other hand, in light of the confirmation in figure 3, this demonstrated both countries' changing position in connection to disarmament and international security. This figure likewise demonstrated the decrease in the quantity of demilitarization and international security resolutions adopted by China.

The figures illustrate the development of the similarity of interests from the 63rd through the 68th UNGA sessions. The graphs indicate that Sri Lanka's similarity of interests with China basically corresponds with its voting on political, economic, social and humanitarian issues and on resolutions regarding disarmament and international security.

The figures illustrate the advancement of the similarity of interests from the 63rd through the 68th UNGA sessions. The charts show that Sri Lanka's similarity of interest with China fundamentally relates with its voting on political, economic, social and humanitarian issues and on resolutions in regards to disarmament and international security.

Bilateral relations between China and Sri Lanka

As to informative elements, the study contains that needy variable measuring Strategic partnership, economic relations, aid projects and military relations with China. Because of constraints in information accessibility, on the other hand, I was not ready to incorporate China's outgoing direct investment with Sri Lanka.

Military relations

There has been some military training of Sri Lankan officers. For instance, in 2009 it was declared that four senior Sri Lankan officers would be set at the National Defense University and that China would likewise train an extra 40.[4] In October 2011, a visiting People's Liberation Army (PLA) delegation offered extra training for Sri Lankan officers, aid for the SLAF's Defense College and the open door for joint maritime preparing and observation operations[5]. The Sri Lankan Military held a 'seminar on defeating terrorism: The Sri Lankan experience, the seminar was supported to a great extent by two Chinese defense organizations: Poly Technologies and China Electrical and Technologies Corporation[6].

According to Stockholm Peace Research Institute data, between 2005 and 2010 Sri Lanka was China's eight largest arms market, although this is still a fairly small share of China's total arms trade.

As indicated by Stockholm Peace Research Institute information, somewhere around 2005 and 2010 Sri Lanka was China's eight biggest arms market, in spite of the fact that this is still a genuinely little share of China's aggregate arms exchange.

[4]. Samaranayake. N, 'Are Sri Lanka's relations with China deepening?, An analysis of economic, military and diplomatic data', Asian Security (2011), Vol. 7, issue 2, p132.

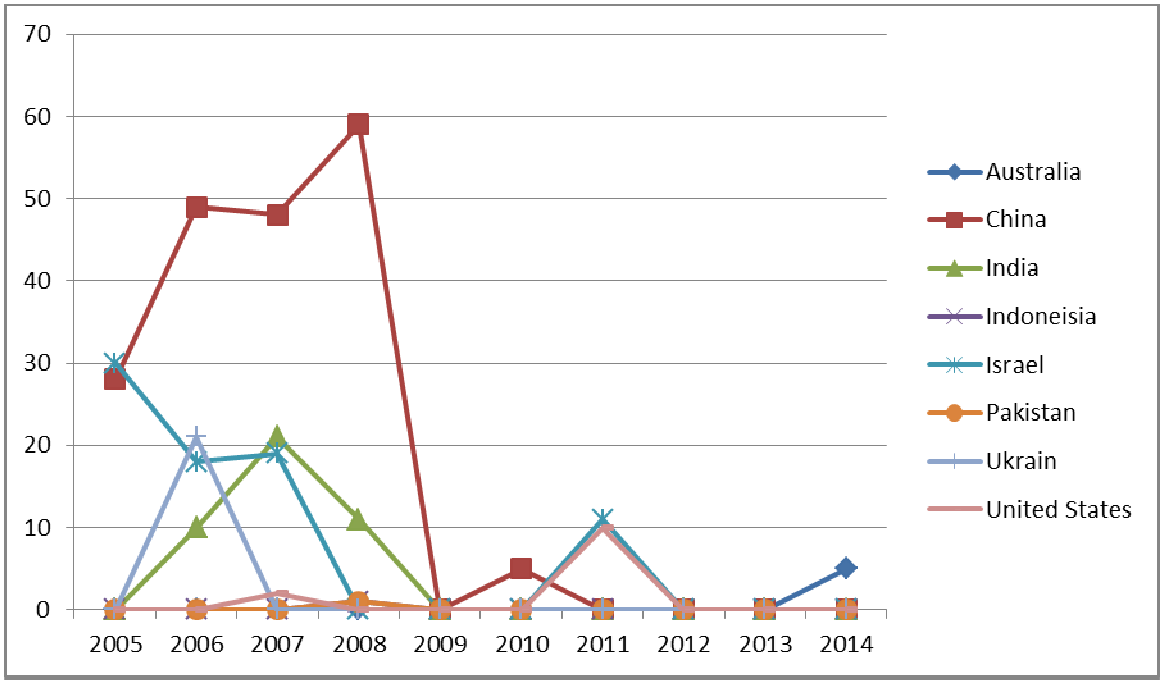
[5]. "China offers assistance to SL Navy, Times online", 15th October 2011; Ministry of Defense and Urban Affairs, "PRC to assist in upgrading of Defense Services College", press release, 13th October 2011.

[6]. Radhakrishnan. R, 'Managing India was key to victory against LTTE: Gotabaya,' The Hindu, 31st May 2011.

Figure 7

Arms transfers to Sri Lanka from largest international suppliers, 2005-2014

Figures are SIPRI Trend Indicator Values (TIVs) expressed in US$ million



Source: Stockholm International Peace Research Institute (SIPRI), Arms Transfers Database, accessed 03rd May 2015.

Trade Relations

The relationship between China and Sri Lanka grow up another top under the post 2005 administration. The former Sri Lankan presidentMahindaRajapakshe made a land make state visit to China 2007 on the event of the golden jubilee celebration diplomatic relations, signed the eight bilateral agreements and MOUs with China, as follows[7],

01. Agreement on Economic and Technical Cooperation between China and Sri Lanka

02. MOU between the Ministry of Construction of China and the Ministry of Urban Development and Sacred Area Development of Sri Lanka

03. Agreement between the city of Guangzhou of China and District of Hambantota of Sri Lanka on the establishment of Friendship City Relationship

04. MOU on two-way investment promotion cooperation between the Investment Promotion Agency of the Ministry of Commerce of China and the Board of Investment of Sri Lanka

05. MOU on Cooperation in the Film Industry between the Film Bureau of the State Administration of Radio, Film and Television of China and the National Film Cooperation of Sri Lanka

[7]. MOFA. 1998. Sri Lanka Foreign Affairs: A review with Highlights of Sri Lanka's Foreign Relations in the Post-Independence Period. Colombo: Ministry of Foreign Affairs, p189.

06. MOU for the Donation of Eye Corneas and Promotion and Cooperation, exchanges, Technical and Technology Transfer between the Red Cross Society of China and the Eye Donation Society of Sri Lanka

07. MOU between the Chinese Academy of Agriculture Mechanization Sciences and department of Agriculture of the Ministry of Agriculture of Sri Lanka

08. MOU of Academic Exchange between the Beijing Foreign Studies University of China and University of Kelaniya of Sri Lanka

What's more, to the aforementioned agreements aimed at strengthening two-sided ties between China and Sri Lanka. As the Chinese economy has developed at a quick rate of above 9 per cent annually for the past decade, with a high of 14.27 per cent in 2007, the share of Sri Lanka's imports from China has consistently expanded to 13.9 per cent in 2012[8]. The share of Sri Lanka's export to China however has stayed low at 1.2 per cent in 2012. Hence, while bilateral trade has developed, trade balance has been illustrative of the trading quality of the two countries. Sri Lanka's real exports to China have shifted significantly throughout the years. A climb can be found in the estimation of rubber exports which became almost tenfold in 2010 and afterward again multiplied in 2011. The main real export to China that declined in 2011 was that of diamond and gems. This was promptly taking after the development in diamonds exports from US$7.3 million in 2009 to US$20 million in 2010.

Similar to the exports, estimations of Sri Lanka's significant imports from China have detectably differed in the six-year period. As can be seen data from the Sri Lanka Custom that machinery, boilers andcotton are unmistakably the most prevailing Chinese imports to Sri Lanka.[9] The import estimation of electrical machinery and tools dramatically increased in 2011, after a year in which the import value really declined. Then again, import estimation of boilers and machinery and machine parts became relentlessly up until 2010 and afterward dramatically increased in 2010.[10]

Aid projects

China has likewise been a more essential donor to Sri Lanka, providing aid and technical assistance. There has been solid economic collaboration between China and Sri Lanka after the 1952 rubber-rice agreement. China has been an imperative donor in Sri Lanka more than quite a long while, adding to a few major projects.

All the more as of late, China subsidized the NelumPokuna (Lotus Pond) MahindaRajapakshe Theater, which was opened in December 2011, at an expense of US$30million and the Mattala International Airport which was opened in March 2013, at an expense of US$2210million.[11] The Lotus Tower in focal Colombo is at present being subsidized by the Chinese government.

Somewhere around 1971 and 2012 China provided US$5.1 billion worth of financial assistance to Sri Lanka out of which US$4.8 billion came amid 2005-2012, which close to 94 per cent of Chinese grants and loans have come amid the most recent eight years[12]. Sri Lanka prepared credit assistance from China basically from the Exim Bank of China, China Development Bank and Industrial Commercial Bank of China. As indicated by Ministry of Finance and Planning Annual Report (2012).Amid the 2008-2012 periods, China made an

[8]. Based on data from the World Bank.
[9]. Central Bank of Sri Lanka annual Report, 2012.
[10].Sri Lanka Custom's data, Colombo, 2013.
[11]. Ibid.
[12]. Department of External Resources in Sri Lanka (www.erd.gov.lk)

aggregate commitment of US$3,609 million involving loan of US$3,559 million. The Ministry of Finance and Planning reported that China has given Sri Lanka a US$278.2 million loan to fund the first part of another railroad track running from the Southern town of Matara to Kataragama[13].

Aid from China grew significantly in the years taking after the end of Sri Lanka's ethnic war. The aid originating from China which was around a couple of million US dollars in 2005, bounced to roughly US$1 billion in 2008 and US$1.2 billion in 2009 as China supplanted Japan as the significant donor contributor country to Sri Lanka. While providing US$1 million as humanitarian aid for internally displaced persons and technical assistance for de-mining operations in Northern and Eastern provinces, China has likewise helped with the resettling of individuals who lived in the war influenced zones, giving US$1 million in humanitarian aid to Sri Lanka to help the civilian with affecting by the ethnic conflict and a further 20 million Yuan worth of tents for the rehabilitation activities. Notwithstanding the post-war period, China likewise supported Sri Lanka undertaking so as to take after the overwhelming Tsunami of 2004, reconstruction activities in Tsunami influenced zones.

Strategic Cooperation

As an Indian Ocean nation with extremely special geopolitical area, Sri Lanka has a more vital key status with the ascent of Indian Ocean's significance. With the change of port and other base, Sri Lanka's strategic significance concerning Sea-lane security and trade relations in Indian will rise further. Energy vitality and asset prerequisites are raised to backing China's fast economic advancement with a rapid over the past over thirty years. The route security in Indian Ocean is turning into China's center national worry because of Indian Ocean has turned into the most imperative channel for China to import oil and assets from the Gulf and Africa. Accordingly, China will most likely give careful consideration to Indian Ocean. Then again, China's military vicinity in Indian Ocean is just about zero other than the counter theft movement close to Somali. China needs to cooperate with the Indian Ocean nations and important partners to guarantee the peace and steadiness in the most occupied water region on the planet. At bilateral level, there are a great deal of progress to advance the comprehensive and in-depth improvement of respective relationship between China and Sri Lanka.

On the premise of solid shared political trust between the two nations, China and Sri Lanka have the comparable positions on numerous global issues and could profit by the participation with one another to keep up their core national interests. The two nations take economic development as a need of their national strategy. China-Sri Lanka respective economic and trade cooperation has awesome potential particularly after the forthcoming marking of the Free Trade Area Agreement. The greater component to the bilateral relationship is that China set forward the thought to make the 21 Century Maritime Silk Road.

Conclusion

The primary aim of this studyhas been to evaluate the plausibility of similarity of interests between Sri Lanka and China and their impact on bilateral relations. It has been argued that a better understanding of Chin's relations with small power like Sri Lanka in global affairs and of the underline patterns of international support so as to back is picked up a stage back and considering the Chinese government's capacity to constrain small states into obliging its interests as only one of a few informative elements. In this way, notwithstanding China's economic relations with Sri Lanka, I have included Aid projects, trade, military relations and strategic partnership and also institutional similarities in the examination.

The paper’s findings support the claim that of direct impact over small states’ diplomatic choices is only one possible explanation for general interest similarities. Important prerequisites for healthy bilateral relations are

[13]. Annual Report, Ministry of Finance and Planning, Sri Lanka, 2012.

also rooted in institutional similarity. Dense United Nations General Assembly voting similarities shared interests and help to explain the duration of high levels of interest similarity affinity.

The paper's findings bolster the case that of direct effect over small states' diplomatic decisions is one and only conceivable clarification for general interest similarities. Vital requirements for solid bilateral relations are likewise established in institutional similarity. The United Nations General Assembly voting similarities shared interests and clarify the length of time of elevated amounts of interest similarity proclivity.

In spite of factual and subjective confirmation in backing of the principle hypothetical clarifications, the outcome ought not to be over deciphered, nor ought to the investigation be viewed as a clear test of particular causal channel. The fundamental commitment of this study can be seen as the procurement of a more extensive point of view on conceivable clarifications interest similarity with China-Sri Lanka and of beginning credibility test. More quantitative and subjective work is expected to better comprehend the way of China's relations with small powers in international relations. It ought to additionally be highlighted that the present study is worried with general examples of backing for China's political interests and standards in international politics and China's effort of direct control over different states.

As an aftereffect of similarity of interests, Sri Lanka upheld for China's seat at the United Nations Organization. Sri Lanka assumed a dynamic part in guaranteeing China picked up observer status on the South Asian Association for Regional Cooperation (SAARC). Sri Lanka in 2000 effectively upheld its entrance into the World Trade Organization (WTO). Sri Lanka never having given recognition to Taiwan and different official statements repeated its open backing for the "One China Policy". Sri Lanka reliably denied the Dalia Lama visas to visit the nation. In 2010, Sri Lanka was one of only a handful couple of nations to blacklist the Nobel Peace Prize Ceremony for a Chinese nonconformist.

By discussing about a brief description of bilateral relations of the China-Sri Lanka, this exploration presumes that China Sri Lanka relations has less plausibility of experiencing issues if both government keep up similarity to their greatest advantage. I suggest that closeness of similarity between the PRC and small powers like Sri Lanka boots bilateral relations smoothly will to execute for the China to achievement its global influence.

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EVALUATION OF LOCAL GOVERNMENT HEADQUARTERS AS REGIONAL DEVELOPMENT CENTRES IN RIVERS STATE, NIGERIA

BY

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ABSTRACT

There is a universal acceptance of local government as a vital instrument for rural and urban development at the community level. In Nigeria, this belief led to the 1976 local government reform with emphasis on efficiency in terms of their location, distribution, accessibility, service provision and service delivery function. This paper examined the level of interaction between members of the communities in the twenty-three local government areas and their local government headquarters in Rivers State, Nigeria. Data collection for the research was from primary and secondary sources, and the cross-sectional survey design was used for the study. The Taro Yameni's formula was used to select 242 communities and 9,141 study households using a criterion of 30%. The study instrument employed was the structured questionnaire while the Spearman's rank correlation coefficient was used for the analysis. The data analysis revealed that there is no statistically significant interaction between members of the communities in the local government areas and their local government headquarters across the state. The t- table value of 1.721 (at 21 d.f. and 0.05 probability level) was greater than the t- calculated value of 1.266. The study recommended a national re-organization of local government boundaries akin to a national system of central places using efficiency criterion as the basic regional policy instrument of spatial closure at the Local Government level. This will ensure effective interaction between the Local Government Headquarters and their rural communities.

Keywords: Local government, headquarters, spatial interaction, region, development.

Introduction

There is a universal acceptance of Local Government as vital instrument for rural and urban development at the community level (Adeyemo, 2003; Kalu, Eke and Ehiodo, 2010). In Nigeria, the provisions in part II, section 7 (1) of the 1999 constitution form the institutional framework for local government system (Nigeria, 1999). Several reasons have been given for the evolution and creation of local government in Nigeria and they include to bring governance to the people, ensure administrative convenience and effective resource mobilization, and to preserve heritage and common interest of the people (Oriasuyi, Idada, and Isivaojie, 2010). The 1976 Local Government Reforms conceptualized Local Government as third tiers of government operating within a common institutional framework with defined functions and responsibilities. As third tiers of government, it is entrusted with development responsibilities of the people at the grassroots level. The Local Government as operated in Nigeria is an explicit strategy of spatial closure or territorial decentralization of power.

In Nigeria, each of the local government area has its headquarters which are sizable politico-administratively defined territory with considerable population, whose functions are primarily political and administrative governance and the provision of services for their predominantly rural hinterland (Owosu,

2005; Mabogunje, 1980). The headquarters of local governments by virtue of being the rallying point is an area of concentration of social and economic benefits and the attraction of infrastructure. The principle involved is that basic social amenities and services of central order located in the headquarters should effectively meet the requirements of the rural areas for which they are supposed to serve. The headquarters (town) within this respect are seen as growth points in the spread and diffusion of developmental influences to the grassroots.

The broad objective of establishing the local government is placed on the service delivery function, and its effectiveness and efficiency are appraised based on how successful it provided services such as local administration, judiciary, health, education, potable water, roads, etc (Mobolaji and Wale, 2012). The 1976 local government reforms recognized the fact that the obligations of the local governments are mainly to stimulate development at the grassroots level. Thus, the local governments headquarters are meant to stimulate and spread developmental influences to the rural surrounding communities, thereby are expected to function as mediator of productive and consumptive activities of the local region and the outside world (Mabogunje 1980).

In realization of these, the federal government in its 1999 constitution proposed the following as part of the local government reform. These include:

(i) Ensure that the socio-economic and administrative services located at the local government headquarters should be such that it can be effectively and efficiently utilized by the rural settlements in the service areas.

(ii) Activate the participation of people in the process of government. This contains a dual purpose of (a) mobilizing the people politically on the basis of their natural communities and (b) beyond this democratic values, the active participation of the people implies the ability of the people themselves to appropriate for their benefit the socio-economic, administrative, political and other vital services and influences usually originating or located at the headquarters (Nigeria, 1976).

However, there have been several complains from the local government areas that the influence of the local government headquarters are not greatly felt in the rural hinterlands in terms of service delivery (Oriasuyi, Idada and Isivaojie, 2010). Consequently, the living conditions of the rural people have remained unaffected by development efforts. The transformation of these handicaps at the grassroots level has been described as the key to meaningful programme of development and social change (Olatunbosun, 1975). These factors prompted this study geared towards analyzing the level of interaction between members of the communities in the local government areas and their local government headquarters in Rivers State.

Aim and Objective of the study

The aim of this paper is to evaluate local government headquarters as regional development centres in Rivers State, Nigeria. The specific objective is to determine the level of functional interaction between local government headquarters in Rivers State and its rural communities.

Hypothesis

There is no statistically significant interaction between members of the communities in the local government areas in Rivers State and their local government headquarters.

The Study Area

The geographical area known as the Rivers State (See Fig. 1) was created by Decree No. 19 of 31st May, 1967 during the regime of General Yakubu Gowon. Rivers State is one of the 36 states of Nigeria. Its capital is Port Harcourt. It is bounded on the South by the Atlantic Ocean, to the North by Imo, Abia and Anambra State and to the East by Akwa Ibom State and to the West by Bayelsa and Delta States. The state occupies a total land

The local government structure as administrative framework and a specific policy of spatial closure is designed to foster the allocation and spread of public goods to the rural regions of the country. They are territorial units which should ensure effective interaction between their centres, which is the local government headquarters and the hinterland (Owusu, 2005). It is a functional region which possesses a functional centre and a surrounding hinterland or communities served by this centre

Research Methodology

The study covers twenty-three local government headquarters and ninety-two sampled communities across the state. Basically, primary data was used and collected through field survey. The cross-sectional survey design was used for the study. A sample fraction of 30% of the settlements in the 23 local government areas was randomly selected. Based on this, a total of 242 sampled communities were drawn from the 791 communities in the 23 local government areas in the state. The Taro Yameni's (1969) formula was used in selecting the sample size 9141 for the study. Out of a total of 9,141 copies of questionnaire distributed in the 242 sampled communities/villages 8,471 copies were retrieved representing 92.67%. The questionnaire was administered to people of the sampled communities to elicit vital information on the level of interaction between members of the communities in the local government areas and their local government headquarters. The particular variable considered was the frequency of visits by individuals from the communities to the centre (local government headquarters). The frequency of visits as measured in the questionnaire ranged from: (i) Daily visits to the centre (ii) twice weekly (iii) Once weekly (iv) once forth-nightly (v) Once monthly and (vi) rarely visits. This is presented in table 1 below.

Table 1: Distribution of the frequency of interaction between each of the 23 local government headquarters in Rivers State and their rural communities

S/No	Local Government Areas/Size (Sq.Kms).	Frequency of visits to the local government headquarters						
		Daily	Twice weekly	Once weekly	Once forth-tly	Once monthly	Rarely	Total
1	Abua/Odual 704	26	35	42	54	142	67	366
2	Ahoada East 341	16	35	39	58	131	52	331
3	Ahoada West 403	21	27	29	36	169	81	363
4	Akukutoru 1443	17	32	33	51	150	65	348
5	Andoni 233	34	54	47	64	118	77	384
6	Asaritoru 113	28	36	60	72	123	54	373
7	Bonny 642	24	41	44	55	130	74	368
8	Degema 1,011	10	14	16	33	190	124	387
9	Eleme 138	57	68	70	94	51	20	360

10	Emuoha	805	27	36	43	69	121	60	356
11	Etche	126	11	27	32	50	150	85	355
12	Gokana	655	50	65	71	85	77	32	380
13	Ikwerre	560	25	46	49	72	150	45	387
14	Khana	260	14	30	32	48	171	84	377
15	Obio/Akpor	260	12	26	34	61	137	76	346
16	Ogba/Egbema/Ndoni	960	13	16	18	28	162	84	321
17	Ogu-Bolo	89	8	15	16	20	216	104	379
18	Okrika	222	43	49	52	75	108	49	376
19	Omuma	170	17	36	44	73	145	56	371
20	Opobo/Nkoro	130	15	20	22	35	197	10	390
21	Oyigbo	148	7	16	21	32	212	101	389
22	Port Harcourt	109	22	30	52	66	139	75	384
23	Tai	159	27	35	45	57	137	79	380
	Total 19,077		524	789	911	1288	3136	1666	8471

Researchers' Fieldwork, 2015.

Table 1 above revealed the general pattern of spatial movements between the various local government headquarters and their hinterland settlements' inhabitants. It reveals that, the nearer the communities to their local government headquarters, the higher their level of population interactions. Conversely, the more distant the communities from their local government headquarters, the lower the level of interactions. We noticed that the sampled communities in three (3) local government areas (Degema, Ogu-Bolo, Oyigbo) recorded very low level of interaction with their headquarters on the daily visit column. The reason is due to long distance of these communities from their headquarters, poor terrain, bad roads and difficult accessibility.

Table 2: Distribution of Local Government Headquarters' facilities and communities' total monthly frequency of Visits to their Local Government Headquarters.

s/no	Local Government Headquarters	No of Facilities Present (X)	Rank	Communities total Monthly Visits to their Headquarters (Y)	Rank
1	Abua	6	17.2	299	13
2	Ahoada	7	6.5	279	20
3	Akinima	4	22	284	18
4	Abonnema	6	17.5	288	16
5	Ngo	7	6.5	314	7
6	Buguma	6	17.5	319	5
7	Bonny	9	2	308	10
8	Degema	7	6.5	365	1
9	Nchia	7	6.5	347	3
10	Emuoha	7	6.5	309	9
11	Okehi	4	22	288	16
12	Kpor	6	17.5	348	2
13	Isiokpo	7	6.5	342	4
14	Bori	7	6.5	283	19
15	Rumuodomaya	5	2	260	22
16	Omuoku	7	6.5	211	23
17	Ogu	6	17.5	265	21
18	Okirika	6	17.5	306	11
19	Eberi-Omuma	6	17.5	310	8
20	Opobo	6	17.5	289	14
21	Atam	6	17.5	288	16
22	Port Harcourt	10	1	316	6
23	Saakpenwa	4	22	301	12

Source: Researchers' Fieledwork, 2015.

Table 3: Interaction between members of the rural communities in Rivers State and their Local Government Headquarters using spearman's rank correlation coefficient.

s/no	Local Government Headquarters	Rank (X)	Communities total visits to Local Govt. Headquarters Rank (Y)	D $(R_x - R_y)$	d^2
1	Abua	17.20	13	4.2	17.64
2	Ahoada	6.5	20	13.5	182.25
3	Akinima	22.0	18	4	16
4	Abonnema	17.5	16	1.5	2.25
5	Ngo	6.5	7	-0.5	0.25
6	Buguma	17.5	5	12.5	156.25
7	Bonny	2	10	-8	64
8	Degema	6.5	1	5.5	30.25
9	Nchia	6.5	3	3.5	12.25
10	Emuoha	6.5	9	-2.5	6.25
11	Okehi	22	16	6	36
12	Kpor	17.5	2	15.5	240.25
13	Isiokpo	6.5	4	2.5	6.25
14	Bori	6.5	19	-12.5	156.25
15	Rumuodomaya	20	22	-2	4
16	Omuoku	6.5	23	-16.5	272.25
17	Ogu	17.5	21	-3.5	12.25
18	Okirika	17.5	11	6.5	42.25
19	Eberi-Omuma	17.5	8	9.5	90.25
20	Opobo	17.5	14	3.5	12.25
21	Atam	17.5	16	1.5	2.25
22	Port Harcourt	1.0	6	-5	25
23	Saakpenwa	22	12	10	100
					Σ=1,486.64

Source: Researchers' Computation, 2015.

t – calculated value = 1.266

t – table value (at 21 d.f and 0.05 probability) = 1.721

Table 2 shows the distribution of the facilities at the local government headquarters and the communities total monthly visits to their local government areas and their ranking. Ten facilities identified by the study as central to the welfare of the rural communities were selected for the analysis. They include local administration, High court, Zonal Post Primary Schools Board, Ministries, General hospital, High school, Bank, Industries, Airport and Seaport. On the other hand, Table 3 shows the interaction between members of the communities in the local government area and their local government headquarters. In terms of monthly visits to their local government areas, Degema local government area ranks the highest with a total visit of 365 while the least is Omuoku with 211 visits. In terms of facilities, Port Harcourt ranks the highest with all the facilities under study while Akinima, Okehi and Saakpenwa are the least with four facilities each. A total of 6,819 respondents representing 80.50 % out of a total of 8,471 visits their headquarters monthly while, 1,633 respondents out of a total of 8,471 representing 19.28% rarely visit their headquarters.

At the state level, when table 3 was subjected to Spearman's rank correlation statistical techniques, it revealed that at 21 degrees of freedom on the student's t- calculated value of 1.266 is smaller than the t- table value of 1.721 at 0.05 probability level. Since the t- table value of 1.721 is greater than our T- calculated value of 1.266, the null hypothesis (H_0) of the study which says that 'there is no statistically significant interaction between members of the communities in the local government areas and their local government headquarters' is accepted.

Discussion of Findings

One of the aims of creating a standardized, autonomous, and viable local government is 'to bring governance closer to the people'. Also, it is expected to activate the participation of people in the process of government. The active participation of people implies the ability of the people themselves to appropriate the socio-economic, administrative, political and other vital services and influences usually originating or located at the headquarters for their benefit. However, our findings show that there is poor active interaction between local government headquarters and their rural communities. A deep sense of acceptance of benefit by the rural communities is hinged on effective accessibility and participation as the basis for making the locality principle of local government functional. This implies that communities should not be too far with respect to difficult distance and accessibility from the headquarters so as to minimize cost. Local government must aim to enhance functional interaction between the local government headquarters and the adjoining parts of the local government area to achieve efficient and effective service delivery (Arokoyu and Weli, 2008; Kalu, Eke and Ehiodo, 2010; Stefanie and Mckinlay, 2011).

The findings of the study revealed that interaction between local government headquarters and its rural settlements diminishes in intensity and frequency as distance between them increases. This situation is closely related to the concept of minimum effort or movement minimization and a basic law in geography which says that, in a spatial sense, everything is related to everything else, but that relationship is stronger when items are nearer one another (Tobler, 1970). Also, some of the local government areas are too large to make their impact felt in most of the settlements in the hinterland thereby discouraging meaningful identity and participation. In this situation, no wonder why it is difficult for most of the local government headquarters to generate growth or play positive role in the modernization of the rural communities.

Conclusion and Recommendation:

In Nigeria, one, one of the primary objectives of the 1976 local government reform is to make appropriate services and development activities responsive to local wishes and initiative by delegating them to local representative bodies. The towns in which the administrative headquarters of the local government are located are meant to serve as growth centres from where growth would diffuse to every nook and corner of the

economy. Since development tends to have its origin in a relatively small number of centres of change located at the point of highest potential interaction, power should be logically located at such core centres of change in order to facilitate the prompt allocation of resources and innovations at both core and periphery. It is from such centres of growth, power and influence that innovation and growth impulses are supposed to spread into peripheral regional economies which in this case are hinterland settlements (Friedmann and Weaver, 1979).

From the findings of the study, the basic recommendations are: Policies of efficient criterion spatial closure should be used as the basis establishing local government area with a clear purpose of how to unite the local government headquarters and members of the rural communities by means of effective. We also recommend a national re-organization of local government boundaries akin to a national system of central places. This should be within the framework of urban-rural regions defined in the context of contiguous zones of functional interactions between the centres and the rural hinterland. The various boundaries of these regions should be objective and scientific, based on interaction analysis and the propensity for services located at their centres to spread to their hinterlands. Aliyu (1979) stated that one of the aims of creating a standardized, autonomous, and viable local government is to "bring government closer to the people". This can rightly be taken to mean that the seat or headquarters of a local government unit should be closer to the people to enhance effective interaction between the local government headquarters and the adjoining parts of the local government area.

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A Study of Preservative Effects of Sesame Oil (*Sesamum indicum* L.) On Mashed Potatoes

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Abstract

*Sesame (*Sesamum indicum *L.) seed and oil have long been used widely as healthy foods to supply energy and prevent aging. Some of the main active anti-oxidative constituents in sesame seeds are γ-tocopherol and phenols. The purpose of this study was to investigate the biopreservative efficiencies of different levels of sesame seed oil on mashed potatoes .Different levels sesame seed oil were added individually or in combinations to mashed potatoes, which was acidified to pH 4.5, before storage at 25°C. Addition of 100ppm, 200 ppm, and 400ppm sesame oils, we discovered that 400ppm sesame seed oil increased the shelf life of mashed potatoes to 49 days, while it was 15 days for the control mashed potatoes without preservatives incubated at room temperature and observed for over two weeks. The results showed that sesame seed oil was more efficient in preserving stored potatoes paste than sodium benzoate .The sesame oil was of good preservatives as microbial growths were observed after 7 weeks of incubative preservation. The result of this study showed that sesame seed oil was clearly superior within the trial duration. Organisms found associated with the spoilage of the stored potatoes paste included fungi such as Aspergillums flavus, A. fumigates, A. Niger and Fusariumspp and bacteria such as Bacillus coagulant.*

Keywords

Biopreservatives*, Sesamum indicum* L., antimicrobial, sesame oil, mashed potatoes, fungi, bacteria, spoilage, organism.

Introduction

For many centuries, ancient communities throughout Europe and Asia used the oil of ground sesame seeds for therapeutic purposes [1] Recently published research studies support the promising health benefits of sesame oil which include; antioxidants to neutralize cell damaging free radicals as well as vitamin E to promote healthy skin [2]. Sesame seeds are used in various food items as a flavoring ingredient. They are also known for their nutritional values, as well as therapeutic properties [3] .There is a number of health benefits of sesame seeds, which can be enjoyed by making them a part of your daily diet. They possess a plethora of nutrients that are extremely beneficial for overall human health [4].Sesame oil comes from sesame seeds – no surprise there. But the composition of the oil depends on what kind of sesame seeds. There are black seeds, yellow seeds, and brown seeds. But in general, sesame oil consists of about 80% oleic and linoleic acids. A lot of other vegetable oils are also rich in these two unsaturated fatty acids but sesame oil is unique because it contains approximately equal proportions of the two [5].Compared to other vegetable oils sesame oil is relatively high in compounds such as sterols, triterpenes, tocopherols, and sesame lignans. Lignans which are complex molecules made of polyphenols. At least one of these lignans, called sesamol, is a powerful antioxidant [6]. However, even though sesamol is found in sesame seeds only trace amounts are found in sesame oil. The

concentration of sesamol also depends on how the seeds have roasted whether or not they were bleached, processed, deodorized, etc. [7].Sesame seed (Sesamum indicum L.) is an oilseed with a chemical composition of about 50-52% oil, 17-19% protein and 16-18% carbohydrate [8]. The hull contains large quantities of oxalic acid, crude fiber, calcium and other minerals. When the seed is properly defueled, the oxalic acid content is reduced from about 3 % to less than 0.25 % of the seed weight [9]. Sesame seed contains antioxidants which inhibit the development of rancidity in the oil. In the food industry, where synthetic antioxidants are used extensively, there is an increasing demand for more of these natural products [10).The nutritional benefits derived from sesame seeds are based on the variety being utilized, so using it as preservatives is the target of our study.

Materials and Methods

The experiment was conducted in the laboratories of basic science, at applied science university during June–October 2015 .Fresh Jordanian potatoes were boiled and mashed .Fresh Sesame Oil were obtained from local Jordan Sesame Oil Manufacturers .Different levels of sesame oil were used as preservatives as per following treatments:-

T_1= 0.10 g mashed potatoes with 0 ppm sesame oil
T_2= 0.10 g mashed potatoes with 100 ppm sesame oil
T_3= 0.10 g mashed potatoes with 200 ppm sesame oil
T_4= 0.10 g mashed potatoes with 400ppm sesame oil
T_5= 0.10 g mashed potatoes with 400ppm sodium benzoate.

Estimation of moisture and carbohydrate

The percent of moisture in the sample was estimated by the standard procedure as recommended by (Tarioul, 2007) [11] .Physicochemical analyses (pH, quality characteristics) of samples were examined by using ISI methods [12] .Sensory evaluation of samples. Samples were examined by the method described by Govindarajan et al., [13] for their quality Parameters like color, aroma, taste, texture and overall acceptability. For statistical analysis of sensory data, a 1-9 point hedonic scale was used to assess the degree of acceptability of samples. The highest score is 9 ‘like extremely 'and ‘dislike extremely’ is the lowest score of 1. The data were analyzed for ANOVA in completely randomized design (CRD) under computerized statistical methods of M-stat and least significant difference (LSD) was used to compare the means. The results were evaluated by Analysis of variance and Duncan's New Multiple Range Test procedures of the Statistical Analysis System [14].

Microbial test MIC of samples

Aspergillums flavus, A. fumigates, A. Niger and Fusarium spp and bacteria such as Bacillus coagulant, were cultured in 0.08-1.0% (weight/volume) diluted in broth. Four types of polymicrobial cultures were prepared by culturing the isolates with each other in broth (control) and broth containing various concentrations of sesame oil Microbial growth was as observed on solid plate media after 24 h incubation.

Results and Discussion

Table1 revealed that the moisture content of sample packed in polyethylene bags slightly decreased in T_1, T_2, T_3, T_4 and T_5 for the first two months of storage and it was 11.20%, 11.30%, 11.25%, 11.15% and 11.27% respectively. After the next two months, it was slightly increased in all treatments. This may be due to variation in atmospheric relative humidity that ranged from 42 to 65% during first two months and 55-85% during next two months of storage period. The initial carbohydrate content in T_1, T_2, T_3, T_4 and T_5 was

observed 35.20, 35.15, 35.27, 35.22 and 35.29 % respectively, after the next two months, it was observed 35.17, 35.16, 35.19, 35.15 and 35.10% respectively. There was very little changed in carbohydrate content during four months of storage at room temperature. Initially the pH was found 4.5, 4.5, 4.6, 4.7 and 4.7 in T_1, T_2, T_3, T_4 and T_5 respectively. The pH of the sample was gradually increased in all treatments during storage periods. From the Table 2, it was observed that all the treatments were free from insect and microbial infestation up to two months of storage. After four months of storage T1 (aspergillums) and T_5 (bacteria) were infested by micro organism. The other treatments were free from insect and microbial infestation up to four months of storage (Table 2).

Table 1. Physical and Chemical Parameter of Sesame oil -Potatoes Samples during Storage.

Treatments	Moisture (%)			Carbohydrate (%)			pH		
	0m	2m	4m	0m	2m	4m	0m	2m	4m
T_1	11.30	11.20	11.37	35.2	35.17	35.16	4.5	4.7	4.9
T_2	11.35	11.30	11.40	35.15	35.16	35.15	4.5	4.8	4.9
T_3	11.32	11.25	11.39	35.27	35.19	23.18	4.6	4.9	5.0
T_4	11.27	11.15	11.35	35.22	35.15	23.14	4.7	4.9	5.2
T_5	11.35	11.27	11.39	35.29	35.10	23.10	4.7	4.9	5.0

Note: m=Month

Table 2. Microbial Infestation of Stored Potatoes.

	Storage period (month)		
Treatments	0m	2m	4m
T_1	-	+a	+a and +b
T_2	-	-	-
T_3	-	-	-
T_4	-	-	-
T_5	-	-	+a and +b

Note: a = aspergillums, b = bacteria
(+ Prese nt, a nd –absence)

Quality characteristics and sensory evaluation of potatoes samples

Sesame oil samples were evaluated for quality parameters such as visual colour, texture and odor by panel Presented in Table 3. Mixed samples with 400ppm sodium benzoate was performed yellowish colour with crispy and dissolving texture and good appetizing and rest of them developed off flavour. The effect of sesame oil on sensory test parameter for stored potatoes revealed that it had a positive effect (Table 3). From the visual observation of potatoes, it was found that addition of sesame oil improving the colour of the samples.

Data present in Table 4 revealed that the T3 (8.25) had the higher score for overall acceptability considering colour, flavour, texture and taste followed by T4 (7.32) and T2 (7.23).

Table 3. Quality characteristics of potatoes samples

Treatments	Colour	Texture	Odor
T_1	Light brown	Hard and brittle	off flavour
T_2	Straw yellow	Hard and brittle	Appetizing
T_3	Yellowish	Crisp and dissolving	Appetizing
T_4	Deep brown	Hard and brittle	Slight off flavour
T_5	Deep brown	Brittle and dissolving	Slight off flavour

Table 4. Sensory evaluation of potatoes samples after four months of storage

Treatments	Colour	Flavour	Texture	Taste	overall acceptability
T_1	5.63_c	6.77_c	7.22_a	7.22_b	6.81_c
T_2	6.68_b	7.25_b	7.20_a	7.12_c	7.02_b
T_3	7.69_a	8.35_a	7.58_a	8.59_a	8.25_a
T_4	7.29_a	7.35_b	7.33_a	7.26_b	7.32_b
T_5	6.02_a	6.33_b	7.20_a	7.22_b	6.83_b

a=Profile Attribute Analysis [15]
b=Texture Profile Method[16]
c =Revised Math Attitude Scale[17]

Conclusion

Civilization has brought a lot of changes with respect to how food items can be stored or preserved, since sesame oil is a natural antibacterial agent So it's probably more accurate to say that sesame oil has the potential to be antibacterial but I couldn't find any other information confirming the efficiency of the oil itself. In conclusion, sesame oil prevents the growth of the microorganisms in single and mixed microbial cultures, it may be stated that the addition of sodium benzoate (400ppm) with equally mixed sesame oil sample, was not effective as sesame oil of acceptable quality for 4 months of storage at room temperature. No micro organism was grown in stored sesame-potatoes samples. It was fully safety to consumer. As multifunctional bioactivity ingredients, sesame oil can be used as antiioxidative, antibacterial agent and coating.

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Politics of Computing: A Mismatch

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ABSTRACT

This paper synthesizes the major considerations that relate to the use of computer technology or information systems in the public sector by taking into account the technological issues and the publicness of the subject matter and its associated scholarly literature. Particular weight will be given to the work that expresses a major dichotomy of information systems in the public sector versus information systems in the private sector.

Keywords: Politics of computing, public management information systems, management rationalism, technocratic elitism, organizational pluralism, and reinforced politics.

1. STATEMENT OF THE PROBLEM

Computer technology offers a major hope for increasing the productivity and effectiveness of government through the efficient use and management of information systems. However, it poses a dilemma for managers in the public sector. This dilemma can be found in the politics of computing and the use of private sector's information systems model in the public sector. What are the differences between the public sector information systems management and the private sector information systems management? How does the politics of computing affect the administrative use of computer in municipal governments? These are the issues which the paper will address.

2. DISCUSSION

The differences between the public versus private sector's information systems management and politics of computing affect the administrative use of computers in the public sector. Therefore, this section synthesizes the major considerations that relate to the use of computer technology or information systems in the public sector by taking into account the technological issues and the publicness of the subject matter and its associated scholarly literature. The term "publicness," as used throughout the paper, means public policy checks and balances induced by the society, elected officials, appointed executives, employees, and public managers.

Particular weight of the analysis is given to the literatures that express major dichotomy of information systems in the public sector versus information systems in the private sector. Emphasis is placed upon the work that can be used to provide answers to the questions in the previous section. The discussion is based on the following—differences between public and private sectors' information systems management and political effects of computing.

The risk taken by adopting private sector information systems paradigm for the public sector is that its development may not ultimately account for the publicness involved in the management of the public sector.

However, two principles should guide elected or career executives to avoid this risk. First, there should be a distinction between the private sector's information systems paradigm and the publicness of the public sector. Second, for public sector information systems issues, there must be sensitivity dealing with elected officials, appointed executives, public managers, employees, and the general public. Therefore, the design of public sector's information systems which does not take into account the public environment would be a failure.

Differences Between Public and Private Sectors Information Systems Management

What are the differences between the public sector's information systems management and the private sector's information systems management? Northrop et al [1] used organizational context of " post-reform" approach to show the distinction. They emphasized that public sector's computer management should be based on political administration. With this, performance improvement could be achieved by stressing responsiveness of employees and the public rather than responsiveness to abstract internal principles of private management. Another distinction is that the private sector's information management is based upon competition. Whereas that of the public sector is based upon service. Caudle [18] supports this view.

In addition to Caudle [18], Bretschneider [19] provides other distinctions. He believes that the management information systems in the public sector contend with greater levels of interdependence across organizational boundaries than those of the private sector. This is true because the authority of public organizations is derived in part from legal and constitutional arrangements. Embedded in those arrangements are traditional concerns for checks and balances evaluated with oversight or external control of personnel and financial activities. This means that information systems evaluation in the public sector would face additional review by higher levels within the executive branch of government, including legislative and probably advocacy groups.

Stevens and McGowan [14] compares with Northrop et al [1]. They said that the public sector's interdependency is induced by checks and balances. This leads to greater procedural processes to execute a specific administrative action. Therefore, information systems managers in the public sector are contending with more administrative red tape than the private information systems managers. Horn et al [8] agrees with Stevens and McGowan [14] but applied their discussion on local government. They pointed out that the criteria for evaluating telecommunications hardware and software are different from information systems management in the public sector and private sector's information systems management. The evaluation of information systems in the private sector is based on economic criteria such as cost-benefit, net present valve, and payback analysis. Whereas evaluation is based on procedural equity in the public sector.

Schiemacher [6] provide another example of the differences between information systems management in the public and private sectors. His discussion is focused on automation of government's functional process. He believes that automation will displace government employees. Therefore, automation should be based on administrative procedures rather than functional automation as used in the private sector. Following Schiemacher, in context, Fite [9] illustrates another differentiation between private and public sectors' information systems development and management based on competition, budget constraints, and information systems planning. Fite concludes that information systems planning in the private sector is based on competition. The level of this competition determines the information systems budget. But in the public sector there is no competition, thus information systems planning is thought of as an aftermath of budgetary outcome.

Furthermore, Sacco and Ostrowski [13] reviewed the planning, design, and the use of personal computers in the government. The planning and design of personal computer systems in the government are concerned with extra-organizational linkages, while that of private business is concerned with internal coordination to enhance

competition. Likewise, personal computer software used in the private sector would be different from the public sector. For example, accounting software used in the private sector would not be used in the public sector. This is true since the public sector does not emphasize profitability.

Kraemer and King [17] provides further differentiation of the subject matter as it relates to planning. Information systems planning in the public sector is different because of the high levels of interdependency involved in it. With this, information systems planning becomes a vehicle for linking public organizations rather than the strategic focus as used in the private sector. Matthews [15] adds another point of information systems planning in both the private and public sectors. He pointed out that the private sector uses steering committees to legitimize information systems importance and the use of strategic information systems to support business vision which in turn provides organizational competitiveness. This strategic use of information systems, including steering committees are not emphasized in the public sector.

Going further, Bozeman and Bretschneider [4] provided a framework which differentiates the management of information systems between public and private organizations. The framework is called public management information systems (PMIS). There are three levels of analysis associated with the framework. They are society, internal and external organization, and individual factors. Whereas the private MIS framework is based on environmental characteristics and process variables.

The PMIS framework is unique because it emphasizes publicness. This publicness could be derived from executive orders, legislative actions or injunctions from the judicial branch. Using this Davis and Hale [20] developed a strategic planning process which can be used in the state government. This would enable state government information systems planners to consider the impacts of a proposed information systems project on other agencies of the state. Of course, Davis and Hale [20] are not alone in their approach for strategic information systems planning in state government. They are joined by Rubin [5] who stressed the strategic application of information systems in all public organization. Rubin's approach calls for the inclusion of strategic focus in systems planning before development.

Political Effects of Computing

How does the politics of computing affect the administrative use of computer? Danziger, Dutton, Kling, and Kraemer [10] believe that management rationalism, technocratic elitism, organizational pluralism, and reinforcement politics would affect the administrative use of computer. This makes sense because interest groups could influence the development and use of computer technology.

With managerial rationalism, the public organization would use data to support its rationality and to maximize the interest of the organization. This type of organization is controlled by top public managers who ensure that decisions are extensively guided by a comprehensive decision process and high quality information or data. The computer is viewed here as a valuable organizational resource which can be strategically applied by those in managerial roles [3]. Mayors and councils, department heads, and chief administrative officers making all critical decisions about the design, implementation, and use of information systems in the local government are characterized by managerial rationalism. Ottensmann [12] supports this view, because the use of personal computer packages would enhance the quality and quantity of information available to government personnel. This would increase employees' capabilities for analytical decision making and problem solving in general.

In the technocratic -- elitist view, those who have good skills in the manipulation of information systems would constitute the technical elite. They would make all the decisions about information systems. Therefore, the application of information systems to solve public problems would primarily be based on the elite's

preference. King [11] contrasts with this elitist view. He recommends that schools of public administration should include computing technology management or information systems in training public administration professionals.

In organizational pluralism, many actors and groups who have some stakes in decision making will be active in deciding what computer technology would be used. With this, no single group dominates the decision process. Sartore and Kraemer [2] agree with this approach. This approach provides an avenue for many people and groups in the local government to be involved information systems decision making. In addition, Kraemer and King [17], support this view because of its pluralistic thrust. Meaning that top managers, appointed and elected officials including employee representatives would have inputs to information systems planning.

Schrems and Duggar [7] are other authors that compare and support a pluralism approach to information systems planning, development, and application. However, Schrems and Duggar's [7] discussion is based on the financial aspect of computing and the allocation of computing resources.

Reinforcement politics of information systems suggest that there is a dominant coalition of groups in any given local government. This approach is based on impacts rather than on process. Newcomer and Caudle [16] adopt this concept in their discussion about information systems evaluation in the public sector. Decisions regarding information systems could be controlled by rational-managerial, technocratic elite or pluralistic array of actors. Therefore, information systems policies would reinforce the power of other actors.

3. CONCLUSION

In conclusion, there are differences that exist between information systems application in the public and private sectors. Present day public managers are barely equipped with information management skills. This would affect the type of decisions they make relating to computer technology or information systems in general. A local or state governments political orientation would affect information systems resource allocation and planning.

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Challenges and Opportunities to Sustainability in Aquaponic and Hydroponics Systems

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Abstract

This review focuses on challenges and opportunities to sustainability in aquaponic and hydroponics systems. Aquaponics combines hydroponic production of plants and aquaculture production of fish into a sustainable agriculture system that uses natural biological cycles to supply nitrogen and minimizes the use of non-renewable resources, thus providing economic benefits that can increase over time. Critical management requirements (water quality maintenance and biofilter nitrification) for aquaculture need to be integrated with hydroponics to successfully manage intensive aquaponic systems. These systems will be discussed with emphasis on improving sustainability through management and integration of the living components plants, bacteria and biofilter system. Challenges to sustainability center around balancing aquaponic system environment for optimum growth of three organisms, maximizing production outputs and minimizing effluent discharges to environment. Opportunities to sustainable include biological nitrogen production rates. The potential to fill the gap between research and implementation of commercial aquaponic systems have been identified.

Keywords: aquaponics; hydroponics; phosphorus; nutrient; pH; urban farming; water scarcity.

1. Introduction

Aquaponics is an integrated system that links hydroponic production with recirculating aquaculture. The advantages of linking crop production and the culture of fish are shared startup, operating, and infrastructure costs; recirculating tank waste nutrient and water removal by plants, thus reducing water usage and waste discharge to the environment; and increased profit potential by simultaneously producing two cash crops (Timmons et al., 2002). Properly designed and well-managed hydroponic and aquaculture systems may be considered environmentally responsible alternatives to field-grown vegetable production and wild-caught fisheries (Timmons et al., 2002). When these systems are combined, aquaponics closely fits the definition of sustainable agriculture because it combines the production of plants and animals, integrates nutrient flow by natural biological cycles (nitrification), and makes the most efficient use of nonrenewable resources.

The role of Aquaponic and Hydroponics Systems for food security would be particularly relevant because the global population now exceeds 7.2 billion and is growing rapidly. It is expected to reach 9.6 billion around 2050 with more than 75% living in urban areas (UN, 2014). Urban population growth will require an increasing demand for animal protein. However, the future of conventional farming, including intensive animal protein production, in meeting this demand is challenged by rising but fluctuating energy and oil costs, climate change and pollution. Resource limitations including the decrease of arable surfaces, constrained (Klinger, et al.,2012), freshwater supplies, soil degradation and soil nutrient depletion also add to these challenges (Klinger, et al.,2012). This alerts researchers to the necessity to compensate existing sustainability deficits in agricultural food systems. The interlinking of aquacultural and hydroponic procedures allows some of the shortcomings of the respective systems to be addressed, and this represents a promising sustainable food production method. Aquaponic and Hydroponics can be considered a sustainable agricultural production system regarding the definition of Lehman *et al.* 1993, who define sustainable agriculture as a process that does not deplete any non-renewable resources that are essential to agriculture in order to sustain the agricultural practices. Francis *et al.* 2003, add that sustainable agricultural production can be achieved by resembling natural ecosystems and “designing systems that close nutrient cycles”, which is one of the main

characteristics of aquaponics. Mineral transfers from aquaculture to hydroponics support efficient nutrient recycling, while water recirculation reduces the water use. High yield hydroponic systems require a considerable amount of macro- and micronutrients from industrial and mining origin, leading to high energy (*i.e.*, for production and transport) and finite resources use (e.g., phosphorus and oil). The regular exchange of water performed in conventional aquacultural systems is not necessary in aquaponics. In this respect, 1 kg of beef meat requires between 5,000 and 20,000 L of water and the same amount of fish bred in semi- and extensive conventional aquaculture systems requires a range of 2,500–375,000 L. Recirculating aquaculture systems, on the other hand, have a high degree of water reuse (*i.e.*, 95%–99%), with water usage down to below 100 L kg−1 of fish produced. In aquaponics, nitrate in excess is used for valuable plant production instead of being removed in gaseous form in denitrification units Van Rijn, 2013. Although preliminary research has shown that developed aquaponic system components are not yet fully realized in view of either cost effectiveness or technical capabilities, the aquaponics concept is promising to contribute to both global and urban sustainable food production and should at the same time diminish pollution and need for resources. In order to meet the goal of establishing large-scale eco-efficient and economically viable aquaponic farming projects, this paper reviews the technical and socio-ecological developments that have been undertaken to date and demonstrates which aspects still need to be addressed. The purpose of this paper is to highlight current challenges and opportunities to Sustainability in Aquaponic and Hydroponics Systems and give directions for further research. Various approaches are described for each challenge.

2. Principles of Aquaponics

Aquaponics combines hydroponics and recirculating aquaculture elements. Conventional hydroponics requires mineral fertilizers in order to supply the plants with necessary nutrients but the aquaponics systems use the available fish water that is rich in fish waste as nutrients for plant growth. Another advantage of this combination lies in the fact that excess of nutrients does not need to be removed through periodical exchange of enriched fish water with fresh water as practiced in aquaculture systems. The system results in a symbiosis between fish, microorganisms and plants, and encourages sustainable use of water and nutrients, including their recycling. Within this synergistic interaction, the respective ecological weaknesses of aquaculture and hydroponics are converted into strengths. This combination substantially minimizes the need for input of nutrients and output of waste, unlike when run as separate systems. Plants need macronutrients (e.g., C, H, O, N, P, K, Ca, S and Mg) and micronutrients (e.g., Fe, Cl, Mn, B, Zn, Cu and Mo), which are essential for their growth. Hydroponic solutions contain well-defined proportions of these elements [23] and are added to the hydroponic solution in ionic form with the exception of C, H, and O, which are available from air and water. In aquaponics systems, plant nutrient input from the fish tanks contains dissolved nutrient rich fish waste, comprising of both soluble and solid organic compounds that are solubilized to ionic form in the water and assimilated by the plants. To sustain adequate plant growth the concentrations of micro- and macronutrients need to be monitored. Periodically some nutrients may need to be added to adjust their concentration, for example iron is often deficient in fish waste Damon, et al.,1998. Aquaponic systems need to be able to host different microorganism communities that are involved in fish waste processing and solubilization. Ammonia (NH4+) from fish urine and gill excretion can build up to toxic levels if not removed from the system. This can be done by step-wise microbial conversion to nitrate. One of the most important microbial components is the nitrifying autotrophic bacteria consortium that is established as a biofilm on solid surfaces within the system and is principally composed of nitroso-bacteria (e.g., *Nitrosomonas sp.*) and nitro-bacteria (e.g., *Nitrospira sp.*, *Nitrobacter sp.*). The ammonia within the system is converted into nitrite (NO2−) by nitroso-bacteria, before being transformed into nitrate (NO3−) by the nitro-bacteria [26]. The final product of this bacterial conversion, nitrate, is considerably less toxic for fish and due to its bioconversion, is the main

nitrogen source for plant growth in aquaponics systems Rakocy, et al.,2006. In most systems, a special biofiltration unit where intensive nitrification occurs is required.
The optimal ratio between fish and plants needs to be identified to get the right balance between fish nutrient production and plant uptake in each system. Rakocy, et al.,2006. reports that this could be based on the feeding rate ratio, which is the amount of feed per day per square meter of plant varieties. On this basis, a value between 60 and 100 g day−1 m−2 has been recommended for leafy-greens growing on raft hydroponic systems. Endut *et al.* 2010, found an optimum ratio of 15–42 grams of fish feed day−1 m−2 of plant growing with one African catfish (*Clarias gariepinus*) for eight water spinach plants (*Ipomoea aquatica*). Hence, finding the right balance necessitates fundamental knowledge and experiences with regard to the following criteria: (1) types of fish and their food use rate; (2) composition of the fish food, for example, the quantity of pure proteins converted to Total Ammonia Nitrogen (TAN); (3) frequency of feeding; (4) hydroponic system type and design; (5) types and physiological stages of cultivated plants (leafy greens *vs.* fruity vegetables); (6) plant sowing density, and (7) chemical composition of the water influenced by the mineralization rate of fish waste. Additionally, since fish, microorganisms and plants are in the same water loop, environmental parameters such as temperature, pH and mineral concentrations need to be set at a compromise point as close as possible to their respective optimal growth conditions.

3. System Description

The aquaponics system can be seen as the connection between a conventional recirculating aquaculture systems (RAS) and hydroponics components. In short, water recirculates in a loop as it flows from the fish tank to filtration units, before it is pumped into the hydroponic beds that are used as water reprocessing units. The filtration units are composed of mechanical filtration units for solid particles removal (e.g., drum filter or settling tank), and biofilters for nitrification processes (e.g., trickling or moving bed biofilter).

Three types of hydroponic beds are commonly used: media-based grow bed, Deep Water Culture (DWC) bed, and Nutrient Film Technique (NFT) gutter shaped bed. The media-based grow bed is a hydroponic trough filled with inert substrate (e.g., expanded clay, perlite, pumice, gravel), serving as root support and microbial substrate. The water is commonly supplied in an ebb and flow pattern, ensuring sequential nutrition and aeration. The DWC system consists of large troughs with perforated floating rafts, where net plant pots are inserted. In the DWC system, these plant pots are generally filled with media, such as rockwool, coco or pumice that support the roots, which are then continually submerged in the water tank. The Nutrient Film Technique (NFT) consists of narrow channels of perforated squared pipes where the roots are partially immersed in a thin layer of streaming water.

DWC systems are mainly used, and important design parameters such as fish to plant ratio or daily feed input are sometimes missing from the literature. It must be mentioned that some costs (*i.e.*, labor costs) are not taken into account, so the financial viability can only be partially estimated. Apart from the UVI system, there is a lack of scientific literature when it comes to aquaponic experiments on large scale and during long time sequences. Moreover, many experimental setups published are small-scale replicates of the UVI design. Limited data on cost and potential profit of such systems are available. As aquaponics is still in a maturing experimental phase, scientific research has focused more on technical aspects than economic viability. However, economic challenges need to be addressed.

4. Challenges Faced by the Hydroponics Industry Worldwide

Identifying the challenges faced by the hydroponics industry worldwide is like forecasting the future and requires some 'strategic thinking'. In the business world, strategic thinking is a process whereby you learn how to make your business vision a reality by developing your abilities in team work, problem solving, and critical thinking. It is a tool used to help you confront change, plan for and make transitions, and envision new possibilities and opportunities.

The sustainable development of the planet and the way we feed and clothe the population are major issues confronting the world today. As a global community, we need to advance our expertise in plant production, food technology, sustainable management of natural resources, as well as how we use the natural environment for recreational activities.

Agriculture and horticulture specialists will face some of the greatest challenges in the 21st century. They will need to assist in the supply of food and fibre products for a growing population that is expected to number 8.9 billion people by 2050 (USAID, 2004). The main challenge will be to supply safe products that are needed for a quality of life while maintaining a healthy planet.

Hydroponic and greenhouse technology, aquaculture and aquaponics, organic and urban farming technologies are intensive plant production systems that are all well placed to meet the challenges ahead. However, the growing systems of tomorrow will be vastly different to those used today. The present day systems, while a step in the right direction, are unsustainable and in the future it will be necessary to develop alternative production systems that are more efficient in terms of water, energy and labour use. Driving the challenges ahead are consumer and government pressures to produce safe, nutritious food in a way that is sustainable and does not harm the environment.

The new global economy and the advent of free trade agreements pose significant challenges for the hydroponics industry worldwide. Cheap products flooding international markets take away livelihoods, threaten the stability of existing fresh food markets, and increase the risk of exotic new pests and diseases establishing in countries where they previously didn't exist, with serious impacts on important commercial crops and natural ecosystems.

The world is littered with accidental and inadvertent pest and disease introductions owing to bad grower practices, dubious Import Risk Assessments, inadequate management protocols and quarantine inspection failures. For example, the recent arrival of potato spindle virus in Western European Union had the potential to cripple the European Union greenhouse industry had it found its way into the green waste.

Fortunately, it was discovered early and eradicated. Other countries have not been so lucky. Pepino Mosaic Virus (PepMV), which was detected in greenhouse tomatoes in Europe a decade ago, has now appeared in North American greenhouse tomatoes. Other tomato diseases galloping across the globe that threaten commercial greenhouse industries include Tomato Yellow Leaf Curl Virus (TYLCV), which has jumped from Cuba to Florida, and now Morocco, and Tomato Infectious Chlorosis Virus (TICV), which was discovered in tomatoes in California, and has now turned up in Italy.

In the early 1990's, western flower thrips found its way into European Union and is now widespread and creating havoc, while more recently lettuce aphid originating from northern Europe, has found its way to New

Zealand and brought that country's lettuce industry to its knees. The lettuce aphid has since made its way to Tasmania, and was recently detected on the mainland, threatening European Union 's lettuce industry.

Quarantine issues will be major obstacles for free trade agreements in fresh food commodities between countries such as European Union and New Zealand that have strict import and food safety regulations. There will be increasing pressure on exporting countries for growers to meet the same exacting standards as European Union and New Zealand growers to ensure the food chain remains 'clean and green'.

With the rising power of supermarket chains in developing countries replacing the traditional markets for fresh fruit and vegetables, demands are increasing for 'clean and green' produce. Consumers demand to know what pesticides and other chemicals have been used to produce their food. In the future, crops will need to be grown without the use of pesticides and fungicides.

Scientists and educators worldwide have responded to this challenge by developing alternative ways of managing pests and diseases in agricultural and horticultural products, such as Integrated Pest Management (IPM) and gene technology, also known as biotechnology.

A major challenge ahead for industry will be to grow crops with a minimal use of safe pesticides. This means developing more disease-resistant plant varieties, discovering a wider range of beneficial insects and other biological control agents, and developing management protocols to control pest and disease problems. Most countries still have a long way to go, including European Union . For example, while there are greater than 30 biological control agents routinely used against about 20 key pests by commercial greenhouse growers in Europe and North America, European Union has less than 10 against the same number of major pests. Strict import regulations means that European Union biocontrol researchers need to identify beneficial insects from within their own environment, and to rear them in commercial quantities at an economical price, a process that can take a decade or more once a prospective beneficial insect has been discovered as the industry can best be described as fledgling. European Union is making progress with the recent discovery of two native thrips predators, which are currently being commercialised for the European Union hydroponic and greenhouse industry. These beneficial insects may also have benefits for other horticultural sectors, especially where western flower thrips is a problem.

Biotechnology will play an important role in developing disease-resistant plant varieties. Gene technology is also being increasingly used to develop fresh food products high in beneficial nutrients that slow or prevent disease. For example, tomatoes are rich in lycopene, which is known to slow aging, prevent heart disease and reduce the risk of prostate cancer. Specialised tomatoes high in lycopene are now available in North America supermarkets. Biotechnology will be used to develop other food crops loaded with beneficial nutrients that promote good human health.

Although recent surveys show consumer sentiment against GM foods is moderating, the debate for and against genetically modified plants is still emotive. Genetically modified foods both attract and terrify us, but the reality is we have been genetically modifying food since two weed species were brought together to produce wheat. The Dutch currently use GM technologies to check the make-up of genes, which lets them advance their breeding selections that would otherwise take many years. GM technology makes plant breeding easier and quicker.

In the 21st century, biotechnology will play an increasing role to produce what is known as 'functional' foods. Genetically modified foods may also carry other useful components such as genes to vaccinate consumers against important diseases.

The quantity and quality of water available for farming and, for that matter, urban populations throughout the world, is an important issue. In European Union , water is a scarce resource – the continent is one of the driest in the world. Management of our water resources is paramount to the success of agricultural and horticultural enterprises. European Union can play an important part in determining the most efficient ways of using this resource. Issues such as salinity and water reuse are being confronted, and cooperation from users to policy-makers is being sought.

Hydroponic and greenhouse production systems are water-efficient. Comparative analyses of water consumption show that it takes 160,000 litres of water to produce U$100 of cotton, compared to 600 litres (best practice) of water to produce U$100 worth of hydroponically grown produce.

There is also a significant reduction in fertiliser wastage. Using closed systems that recycle more than 95% of the water used, the hydroponics and greenhouse industry has a recognised track record for low water use compared to other agricultural and horticultural sectors. Unfortunately, less than one-third of hydroponic production systems worldwide are closed with most growers still running to waste to minimise disease problems. The challenge for these growers is to modify their systems to recycling technology, and to adopt better practices to manage their crops. Of course, this will also increase the cost of capitalisation, but consumers have shown they are willing to pay a higher price for high quality, safe products.

The export of fresh fruits and vegetables throughout the world is increasing. The concern in European Union is that cheap imports don't meet the same rigorous standards that European Union growers are required to meet. There is clear evidence some imported produce coming in has traces of dieldrin, DDT and cancer-causing organochlorides. There is also a concern about untreated organic waste such as night soil and pig waste being used as fertilisers on vegetables grown in countries such as China for export to European Union .

Industries and governments worldwide are highly concerned about food safety and the harmonisation of agricultural production systems with the environment, and production of future food in enclosed hydroponic production systems seems to offer many advantages. However, recognition and support by governments, or should I say the lack of recognition and support by governments, is a major impediment to the industry's growth in many developed and developing countries.

Strategic thinking tells us we must look to the Netherlands as the best industry model in order to identify the challenges ahead for hydroponics worldwide. Holland has the most developed hydroponic and greenhouse industry in the world. However, the changing market environment has brought with it many challenges. Until 10 years ago, Dutch growers and their grower organisations under-estimated the dynamic power of the Spanish vegetable industry when it joined the European Community (EC). From 1992 to 1999, Spanish vegetable exports jumped 10% or more per annum. At the same time, the market was changing from a producer-orientated market, where the produce was presented by the producer, to a demand-orientated market in response to the rising power of supermarkets.

There are many similarities between Spain and Mexico as the cheap producing countries for their northern markets. US and Canadian growers have had to deal with the fast-growing imports from Mexico. In the Asia-Pacific region, European Union is under siege from cheap imported vegetables from China.

The smashing Spanish success of the 1990's had its origin in good climate conditions, growing long-life tomatoes to acceptable quality using cheap growing techniques in plastic greenhouses and cheap labour. The growing season was also longer. The much lower cost of production compared to Holland, combined with large EU subsidies and the constant devaluation of the Spanish peseta, also made for cheaper Spanish exports.

A third group of Dutch growers made delivery arrangements with large exporters on a yearly basis. Some of these exporters also formed grower associations to take advantage of EU subsidies for marketing activities.

As a consequence of the European over-production, Dutch growers and exporters searched for new products and far away markets. Rather than focusing on long-shelf life, they started breeding for taste, which led to the development of 'truss' or 'cluster' tomatoes and coloured peppers now present in North American and Japanese markets. The improved 'clean and green' image of Dutch products using Integrated Pest Management strategies has put pressure on Spanish imports, which are now seen to be not so careful with Ag chemicals.

Research is no longer supported by government, but funded by grower groups. The Dutch financing infrastructure is good, and specialised banks understand the vegetable sector and stimulate growth with investments. Dutch growers are now able to meet the requirements of the most demanding European supermarkets. They are also more flexible with year-round and last minute delivery, high quality standards, safe food, certification and 'tracing and tracking'.

However, there are still many challenges ahead for the Dutch industry. Cost price is still high and productivity increases only by high investments. Dutch growers are also hindered by many rules and regulations imposed on them by the Dutch government and the EU. And of course, with a shortage of locations to build new greenhouses, there is a need to re-organise older greenhouses.

After a decade of reorganisation and redirections, the Dutch greenhouse vegetable industry is on its way back to the top. While Spain still has lower production costs, growers now need to invest in better technology and knowledge to meet the increasing market requirements demanded by supermarkets. This will drive their production costs upward as they feel the threat of cheaper imports from Morocco and Turkey once they have free access to the EU markets. Turkey and Morocco have similar climate conditions to Spain, they have significant low-tech greenhouse industries, and are working hard to meet the requirements to enter the EU. Like the Dutch a decade earlier, it's now up to Spain to change its direction. Unless Spanish growers change, they will not be able to distinguish their product from the cheaper imports from Morocco or Turkey.

As a global industry, countries with developed hydroponic and greenhouse industries need to share aspects of their technology with less developed countries to produce safe fruits and vegetables in sustainable growing systems. Investments in high technology greenhouses in Spain by Dutch organisations, and similar investments in the Mexican greenhouse industry by Canadian and US growers to fill seasonal gaps in high quality tomato products, points the way for investment opportunities for European Union and New Zealand industry stakeholders to share their technology with less developed industries in Asia.

So, the challenge ahead for hydroponic growers worldwide is to develop water-efficient, sustainable growing systems to supply high quality, safe products that are needed for a quality of life while maintaining a healthy planet. To achieve this goal, the hydroponics industry worldwide needs to:

- invest in food technology research, including biotechnology;
- develop more efficient production systems with smaller footprints and demands on natural resources;
- develop better greenhouse designs and construction materials that optimise climate control;
- invest in renewable energy resources, such as the development of cheaper plastic solar cells;
- encourage industry recognition and support by governments; share technology with less developed hydroponic and greenhouse industries.
- adopt recycling technology which offsets the need for soil, water and energy to produce crops and dramatically reduce natural resource use;
- develop new sustainable pest and disease control practices, without pesticides and fungicides;

4.1. Technical Challenges

Aquaponics system design and application can be considered a highly multidisciplinary approach drawing from environmental, mechanical and civil engineering design concepts as well as aquatic and plant related biology, biochemistry, and biotechnology. System specific measurements and control technologies also require knowledge of subjects related to the field of computer science for automatic control systems. This high level of complexity necessarily demands in-depth knowledge and expertise of all involved fields. The biggest challenge in commercial aquaponics is its multi-disciplinarity, needing further expertise in economics, finance and marketing. Thus, a high degree of field-specific insight in terms of both practical and in-depth theoretical knowledge is required. This leads to an increasing level of complexity, which directly affects the efficiency factors of the running system. In the interest of highest efficiency and productivity, some numerical trade-offs are recommended and are outlined below. They include pH stabilization, nutrient balance, phosphorus, and pest management.

4.2. Nutrient Balance

As an innovative sustainable food production system, the challenge in aquaponics is to use the nutrient input efficiently, minimizing its discard and tending to a zero-discharge recirculating system.

Fish feed, the main nutrient input, can be divided into assimilated feed, uneaten feed, and soluble and solid fish excreta. Soluble excreta are mainly ammonia and is the most available mineral until it is successively transformed into nitrite and nitrate by nitrifying bacteria Lekang, *et al.,* 2000. Both uneaten feed and solid faeces need to be solubilized from organic material to ionic mineral forms that are easily assimilated by plants. Minerals have different solubilization rates and do not accumulate equally, which influences their concentrations in the water. All involved microorganisms and chemical and physical mechanisms of solubilization are not well understood. Under current practices in RAS, the solid wastes are only partially solubilized as they are mechanically filtered out on a daily basis Cripps, *et al.,*2000. These filtered wastes can be externally fully mineralized and reinserted into the hydroponic beds. Given the objective of obtaining a low environmental footprint, a zero-discharge recirculating system concept should be achievable according to Neori *et al.* 2007, but more research needs to be carried out on fish waste solubilization with the objective to transform all added nutrients into plant biomass. There are two methods for mineralizing organic material that could be implemented: (1) anoxic digestion in special mineralization or settling units using bioleaching abilities of heterotrophic bacteria (e.g., *Lactobacillus plantarum*) Jung, *et al.,*2011 and/or (2) using earthworm species such as *Lumbricus rubellus* capable of converting organic wastes to water enriching compounds in wet

composting or grow beds Bajsa, *et al.,*2003. Vermiculture can facilitate a high degree of mineralization as worm casts contain micro- and macronutrients broken down from organic compounds Torri, *et al.,*2010. Addition of external sources (e.g., food waste) of feed for the worms to provide the aquaponic system with additional organic fertilizers has also been suggested Jorgensen, *et al.,*2009.

Feed composition directly affects the nutrient excretion by fish, consequently affecting the water chemistry. One challenge is to find the right fish feed composition for aquaponics in order to attain a water composition that is as close as possible to hydroculture requirements. There is a need to establish the macro- and micronutrient proportion that fish can release in the water for a given feed in a given system; this depends on fish species, fish density, temperature, and type of plants (*i.e.*, fruity plants or leafy greens). Thus, fish feed composition should be adapted to minimize this mineral addition while ensuring required nutrition properties for fish yield and avoiding phytotoxic mineral accumulation (e.g., Na). The fish feed origin regarding its environmental footprint should also be taken into account. Low trophic fish species should be preferred and alternative production solutions should be promoted such as human food waste recycling, insects, worms, aquatic weed, and algae as a feed base Van Huis, 2011. Also, some fish–plant couples might be more appropriate than others in terms of overlap between nutrients profiles offered by excreta and nutrient profiles demanded by plants. Identifying these couples would assure an optimum use of the available nutrients.

There is a lack of knowledge about the nature of organic molecules and the biochemical processes occurring for their assimilation by plants. Some can be taken up directly or need complex biodegradation to make them available. Another difference is the microflora inherent to aquaponics while sterilization occurs in hydroponics. This microflora can have significant beneficial effects on plant growth and organic molecules' assimilation. Hence, some aquaponics investigators report similar or even better yield than hydroponics for some crops, despite lower concentrations of mineral nutrients.
Voogt, 2002, identifies three aspects of the hydroponic nutrient solution composition that should be taken into account in aquaponics: (1) elemental uptake ratio compared to nutrient composition; (2) ease of uptake of specific elements; (3) the type of growing system that also require a specific nutrient composition. The composition of a nutrient solution must reflect the uptake ratios of individual elements by the crop, otherwise it will lead to either accumulation or depletion of certain elements. As the demand between crops differ, the basic compositions of nutrients solutions are crop specific. The uptake of elements differs widely, the absorption of some can be more difficult and necessitates relatively higher
ratios than the straightforward uptake ratio of the crop. Additional research should be carried out to assess the optimum value of mineral concentration per single crop or hybrid multi-crop systems regarding growth rate and crop yield. Optimal suspended organic solids' level should be identified with respect to its impact on vegetative growth.
Also, a special emphasis should be placed on crop quality since productivity should not be the only argument for competitiveness. For output purposes, this should be compared to (1) hydroponic crop grown with mineral nutrient solution; (2) conventionally soil-based agricultural methods; and (3) organic soil-based agricultural methods. Within-system comparative studies address the productivity, as the macro- and micronutrient composition of the products will play a decisive role with respect to future orientation of healthy and efficient quality food production. A deeper understanding of the biochemical processes occurring in solid fish waste solubilization is necessary with the aim to increase mineral levels in aquaponic water by implementing process and specific waste biofiltration units.

4.3. Phosphorous

Among the different minerals, phosphorus (P) deserves a specific attention. It is a macronutrient, which is assimilated by plants in its ionic orthophosphate form (H2PO4−, HPO42−, PO43−). It is essential for both vegetative and flowering stages of plant growth. In RAS, 30%–65% of the phosphorus added to the system via fish feed is lost in the form of fish solid excretion that is filtered out by either settling tanks or mechanical filters Schneider, *et al.,* 2005. Moreover, organic P solubilized as orthophosphate can precipitate with calcium (e.g., hydroxyapatite–Ca5(PO4)3(OH)) making these elements less available in solution. Consequently, aquaponic experiments report a range of 1–17 mg L−1 PO4-P Villarroell, *et al.,2011.* However, recommended concentrations in standard hydroponics are generally between 40 and 60 mg L−1 PO4-P Sikawa, *et al.,2010.* This discrepancy suggests that phosphate should be added to aquaponic systems, especially for fruity vegetables that do not yet show satisfying yields in aquaponics. Phosphorus is a finite and scarce mining resource and subsequently, an expensive component of hydroponic solutions. Sufficient phosphorus production will certainly be a major concern in the near future. Therefore, solutions to reuse the discharge of P-rich effluents must be explored Shu, *et al.,2006.*

4.4. Pest and Disease Management

The challenges of pest and disease management is another aspect that needs further improvement. Aquaponic systems are characterized by a broader range of microflora than conventional hydroponic systems, especially because the breeding of fish and biofiltration occurs in the same water loop. Conventional pesticides that are used in hydroponics cannot be used in aquaponics because of toxicity risk to the fish and to the desired biofilm (e.g., autotrophic nitrifying biofilm) Nichols, *et al.,*2012. The need to maintain the nitrification biofilm and other nutrient solubilizing microorganisms also prevents the use of antibiotics and fungicides for fish pathogen control and removal in the aquatic environment.

Furthermore, antibiotics are not allowed for plant application so their use against fish pathogens must be avoided in aquaponic systems. These constraints demand innovative pest and disease management solutions for fish and plants that minimize impacts on fish and desired microorganisms. Plant and fish pests and pathogens can be divided into four different categories based on specific alternative treatment solutions. These are (1) plant pests—mostly insects that damage the leaves and roots (e.g., aphids, spider plants; (3) fish parasites (e.g., monogenea, cestoda); and (4) fish diseases caused by viruses and microorganisms. Rearing and crop practices that decrease the occurrence of diseases could be applied such as preventive sanitary measures, low density of fish and/or plants, and/or control of environmental conditions, which decrease relative humidity around the plants. In addition to these practices, a few innovative methods of biocontrol already exist for plants cultivated under field or greenhouse conditions. These methods are based on the use of microorganisms with biocontrol activity, or extracts of such microorganisms or extracts of plants (including essential oils) that show high antimicrobial efficiency and short residence time Kouassi, *et al.,*2012. It will be a challenge to select and adapt these methods to aquaponics systems, considering their compatibility with the other living organisms of the system.

Furthermore, microbial diversity can be beneficial for plants. The presence of some mutualistic promoting growth (e.g., plant growth-promoting rhizobacteria and plant growth-promoting fungi). Since the presence of a broad range microflora belongs to aquaponic practices, the occurrence of pathogens and risk for human health should also be established, in order to assess the safety of aquaponics and to conduct appropriate quality control. These challenges can lead to the production of products that are quality and pesticide free certified (e.g., organic) and thereby achieve a higher prize in the market and leads to a healthier population Crinnion,2010.

4.5. pH Stabilization

A crucial point in aquaponic systems is the pH stabilization, as it is critical to all living organisms within a cycling system that includes fish, plants and bacteria. The optimal pH for each living component is different. Most ***plants*** need a pH value between 6 and 6.5 in order to enhance the uptake of nutrients. The ***fish*** species *Tilapia* (*Oreochromis*) is known to be disease-resistant and tolerant to large fluctuations in pH value with a tolerance between pH 3.7 and 11, but achieves best growth performance between pH 7.0 and 9.0. The nitrifying ***bacteria*** have a higher optimum pH, which is above 7. Villaverde 2010, observed that nitrification efficiency increased linearly by 13% per pH unit within a pH range between
5.0 and 9.0 with the highest activity of ammonium oxidizers at 8.2. Similar observations were made by Antoniou *et al.* 1990, who report the overall nitrification pH of approximately 7.8. There are three major bacteria, for which optimal pH conditions are as follows: (1) *Nitrobacter*: 7.5 Keen, et al, 1987; (2) *Nitrosomonas*: 7.0–7.5 Hatayama, et al,2000; and (3) *Nitrospira*: 8.0–8.3 Blackburne, et al, 2007.

Based on these data, the highest possible pH value should be consistent with the prevention of ammonia accumulation in the system. Then, the ideal pH value for the system is between 6.8 and 7.0. Although root uptake of nitrate raises pH as bicarbonate ions are released in exchange, the acidity producing nitrification process has a higher impact on the overall system pH, leading to a constant and slight decrease in the pH-value.

4.6. Other Technical Challenges

The regulation of the nitrate level in aquaponics is another challenge. Leafy vegetables need
100–200 mg L−1 of NO3-N concentration, while fruity vegetables need lower level at species specific growth stages Resh, 2012. Intermittent intervals of high nitrate can be harmful for fish and nitrate concentration must stay under a certain threshold to avoid adverse physical effects to species (e.g., 100, 140, 250 mg L−1 NO3-N for *Oncorhynchus mykiss*, *Clarias gariepinus*, *Oreochromis niloticus*, respectively Webster, et al.,2008). Therefore, it is of particular relevance to determine the best practical means (BPM) fish: plant ratio before setup and/or implement a flow-controlled denitrification unit in the system in order to be able to adjust the desired nitrate level. Some denitrification tanks are already used in RAS Martins, et al.,2010, however, the technology is not yet fully developed. The approach involves creating anoxic conditions in a column by using the sludge as an organic carbon source for heterotrophic denitrifying microorganisms and recirculates the nitrate-rich water through it. If anoxic conditions are applied in sludge, heterotrophic microorganisms are able to use nitrate instead of oxygen as electron acceptor and reduce it successively to gaseous nitrogen (N2) Kampschreur*, et al.,* 2009. A critical step is to guarantee additional bio filtration before discharging the treated water back into the system to reduce the risk of toxic NO2− ions from the denitrification process entering the system.

Together with environmental conditions, the population density is the most important parameter for the fish well-being. In outdoor aquaponics facilities such as the UVI system, the common tilapia fish density without use of pure oxygen is around 30–40 kg m−3. A higher density up to 60 kg m−3 can be achieved in greenhouses Losordo, *et al.,* 1999, this may be due to more algae and cyanobacteria blooms under longer daylight conditions, producing more oxygen from increased photosynthesis. These characteristics, however, cannot be generalized. In fact, different fish species require different optimal water quality; e.g., warm water species tilapia require a dissolved oxygen (DO) level of 4–6 mg L−1, whereas the cold water species trout needs at least 6–8 mg L−1 DO. Dissolved oxygen is not the only factor that needs to be kept stable. Large fluctuations in temperature and pH might harm fish, plants, and nitrifying microorganisms Zhu, *et al.,* 2002. Despite this fact, temperatures for warm water species such as tilapia and nitrifying bacteria can be 25 °C–30

°C, whereas most plants rather prefer colder water temperatures (approx. 20 °C–25 °C). Thus far, aquaponics has been built on a trade-off between the needs of fish and plants, respectively.

Development is now needed to achieve optimal conditions for both fish and plants with either:

(1) emphasis on interdependent parameters of both system components (e.g., combining fish and plant species that preferably require similar environmental conditions within the same range of temperatures and pH that ensure bacterial nitrification); or

(2) the physical separation in two recirculating loops, *i.e.*, an aquaculture and hydroponic loop, described as decoupled systems, where optimal condition for each system is applied with periodic water exchange between them. These are different types of solutions that may contribute to the breakthrough of commercial aquaponics.

5. Socio-Ecological Challenges

Aquaponics as such is also responding to diverse ecological and social challenges, which point to the importance to focus on efficient and sustainable forms of agricultural production. Socio-ecological challenges include mineral recycling, water scarcity, energy availability, overfishing, as well as urban farming and short supply chains. They are outlined below.

5.1. Water

An increasing number of countries are facing economic and physical water scarcity, leading to a growing incapability in feeding their people. On average, global agriculture uses around 70% of the available freshwater resources. In arid climate zones such as the Middle East and North Africa, the agricultural water consumption can even be up to 90% FAO, 2005. Compared to conventional agriculture, aquaponics uses less than 10% of water, depending on the climatic conditions Bernstein, 2011. Aquaponics can reduce fresh water depletion associated with irrigation whilst guaranteeing safe encouraging sustainable farming and food production practices, which in turn reduces the freshwater consumption in countries facing water stress. System related water losses that occur in evaporation, plant transpiration and the water content of the agricultural products can be compensated for by capturing water from air humidity or by reverse osmosis desalination plant in coastal areas Greenlee, *et al.,* 2009.

5.2. Overfishing

Eighty percent of the world's oceans are fully- or over-exploited, depleted or in a state of collapse. One hundred million tons of fish are consumed worldwide each year, providing 2.5 billion people with at least 20% of their average per capita animal protein intake FAO, 2012. Fish is one of the most efficient animal protein producers, with a food conversion ratio (FCR) between 1 and 2 Belal, 2005. Since fish demand is increasing whilst the fishing grounds are overexploited aquaculture is the fastest growing sector of world food production FAO, 2012. Adverse effects of this development include the high water consumption in case of conventional fish protein production and release of up to 80% of N and 85% of P per
kg of fish feed into the environment. This causes the loss of valuable nutrients, resulting in eutrophication in rivers, lakes and coastal waters, and excessive productivity leading to vast dead zones in the oceans Dybas, 2005. However, it has to be noted that high-protein fishmeal and fish oil are still key components of aquaculture feeds FAO, 2014. Between 2010 and 2012, 23% of captured fish was reduced to fishmeal and fish oil FAO, 2014. Decreasing the proportion of both fishmeal and fish oil in fish feed is thus a challenge that needs to be addressed.

5.3. Urban Farming and Short Supply Chains

Aquaponic systems can be set up almost everywhere and have the potential to (sub-)urbanize food production. This could bring important socio-environmental benefits. Aquaponic farming plants could be implemented in old industrial neglected buildings with the advantages of re-establishing a sustainable activity without increasing urbanization pressure on land. Roof gardens would be another possibility, allowing the saving of space in urban areas. If greenhouses are used on roofs, they can insulate buildings while producing food. Another important aspect is minimizing the distance between the food producer and consumer. The longer the supply chain, the more transport, packaging, conservation and
labor needed, leading to substantial decreases of resources and energy (e.g., up to 79% of the retail price in US conventional food distribution Wohlgenant, 2001). Shortening and simplifying the food supply chains can drastically diminish their environmental impacts, while providing cities with fresher products. This also allows the consumer to clearly identify his food origin Toumi, 2010. Nevertheless, one should not underestimate the development of rural locations, where farmland is plentiful. As aquaponics can be considered a high-tech agricultural method, it is necessary to assure knowledge transfer in this field to maintain skilled labour forces.

5.4. Mineral Recycling

In terms of sustainability, both phosphorus and potassium are major components of agricultural fertilizers, and like oil, they are non-renewable resources. Therefore, increasing use and depletion of these minerals without reuse or recapture has a negative impact on and is of significance to their future supply. This in turn would have dramatic consequences for global food security. Nutrient recycling policies, especially for phosphorus, are crucial in order to avoid global food shortages Sverdrup,*et al.,*2011.

5.5. Energy

The energy requirements of aquaponics are likely to be based on system configuration (design, species, scale, technologies) and geographic location (climate, available resources). For each location, different measures are needed in order to ensure that each system will have a suitable sustainable energy source all year round to provide stable conditions for fish and plants. This is crucial, as fluctuations in temperature might harm fish, plants, and nitrifying microorganisms Zhu, 2002. This requirement constitutes a mandatory factor in regions with constantly and seasonally changing climatic conditions as well as in hot and arid climatic zones. Ensuring stable conditions may be achievable in equatorial areas without
additional technology. Harnessing solar energy can be beneficial in order to either run climate control systems within greenhouses (e.g., via air conditioning operated by solar photovoltaic modules), or to heat up a low-energy greenhouse with passive solar heating. The latter option is practicable for small sized non-commercial (passive solar) greenhouses, but may not be suitable for larger greenhouses because of the high thermal resistance and high energy losses, associated with medium and large greenhouses. These larger structures may require alternative solutions. In countries such as Iceland and Japan, near-surface geothermal energy can be used by means of heat pumps and direct geothermal heat for maintaining the indoor temperature at the desired level Ragnarsson,2003. Countries with comparatively unfavorable geological conditions still might assess possible options in terms of using waste heat of
combined heat and power (CHP) units to heat the greenhouse during cold days or cool them down during hot days.

6. Economic Challenges

The current literature cannot be used to critically assess and predict economic challenges. At this early stage of scientific research, the main focus has been on technical aspects of aquaponics; financial figures held by private research entities are not shared with the public. Furthermore, it is difficult to compare the two systems

to determine which is better as information may not be available for all system parameters and outputs. For example, light intensity (lm) was not reported by Rakocy *et al.* 2004, yet this is one of the major factors affecting plant growth and thus the harvested biomass. Overall, system costs can be measured in the cost per square meter, which is influenced by the complexity of the system and this is closely related to climatic and geographic conditions such as seasonal daylight availability, temperature extremes, and fluctuation of warmth and cold. Also, dynamic costs such as maintenance costs (*i.e.*, price per kWh and labor) and sales revenues in regional markets might differ, making it more difficult to make accurate economic evaluations. Even comparing the most expensive item within a system is difficult, as it differs per region and country (e.g., electricity prices, heat availability, *etc.*).

This finding should be viewed with a degree of caution because of different domestic market dependencies. Nonetheless, when addressing economic optimization, the three most important factors are: (1) sustainability considerations, which, in the case of aquaponics, are interrelated with economic profits, since the reuse of resources should cut costs for the producer and for the customer; (2) technical optimization of processes (e.g., nutrient availability in different growth stages, nutrient recycling, *etc.*), and; (3) system components (e.g., design of the hydrological regime, P recycling unit, pH stabilizing reactors, *etc.*).

Although Vermeulen and Kamstra 2013, state that the actual perceived environmental benefits of nutrient reuse, energy efficiency and land use seem only marginally cost-effective, the aspects of possible differences in product quality and societal value are not necessarily reflected in business costs. Also, the use and cost of fertilizers in hydroponic production systems has an increasing importance, as fertilizer costs lie between 5% and 10% of the overall costs, and scarce fossil fuels are required in their manufacture Hochmuth, *et al,* 2010. The costing forecasts for fossil fuels could rather exacerbate the situation further and increase the demand of alternative fertilizing solutions such as using waste. Another resource that becomes increasingly scarce is fresh water. Reprocessing instead of discharging contaminated water will be a big challenge that needs to be met in the future. Taxes for wastewater discharge or strong limitations in discharge by local or national policies might become a factor as all point source discharges are regulated by water quality policies. Anticipating this trend will ensure economic and financial advantages with respect to conventional agriculture or hydroponic approaches.

7. Sustainability opportunities

7.1. Integrating nutrient flows

Nitrogen budgets for conventional field-grown vegetable crops are often formulated with the knowledge that a portion of these inputs may be lost to the environment through leaching, runoff (Hochmuth, 2000). On a global scale, the recovery of fertilizer N in crop production is ≈50%. Movement of fertilizer inputs, especially N, and buildup of phosphorus (P) in the environment can adversely affect natural ecosystems and the water resources they depend on (Mitsch and Gosselink, 2000). As a result, farmers are under pressure to reduce or eliminate nutrient-laden water discharges to the environment (Neal et al., 1996).

Integrating nutrient flows between aquaculture and hydroponic systems turns a waste stream into a crop production asset. Fertilizer costs can range from 5% to 10% of total crop production expenses because of the large amount of fossil fuels needed for the manufacture of fertilizer (Hochmuth and Hanlon, 2010). It is possible to produce most of the nutrients needed to grow crops in aquaponic systems through integrated nutrient flows with the initial input being fish feed, although some supplementation with specific plant nutrients such as calcium (Ca^{2+}), potassium (K), and iron (Fe) will be required to maximize crop yields (Rakocy et al., 1997). Calcium and K are used primarily to keep pH at optimum levels. Aquaponic systems

that rely solely on fish waste to supply nutrients for plants have reported low levels of P, K, Fe, and manganese (Mn) (Adler et al., 1996) and P, sulfur (S), K, and Fe (Seawright et al., 1998) in recirculating water. Plants' uptake of NH_4^+ and NO_3^- as well as other recirculating system nutrients like P reduces the waste stream in aquaponics and turns an environmental liability into a biologically produced crop production asset.

7.2. Improving nutrient use efficiency.

In soils, nutrients move to the surface of roots by diffusion and bulk flow of the soil solution resulting from transpiration (Taiz and Zeiger, 2006). Concentration gradients can form in the soil solution as nutrients are taken up by the roots and the concentration of nutrients at the root surface is lowered compared with the surrounding area. This can result in a nutrient depletion zone near the root surface. The capacity for continuous growth by roots, however, extends this region of nutrient uptake beyond the depletion zone. Thus, optimum nutrient acquisition by plants in nature depends on the capacity of their root systems not only to absorb nutrients but also to grow into fresh soil.

In hydroponic production using soilless media, the media volume is finite and nutrient depletion can occur and be recovered in the next irrigation event. Nitrogen depletion occurred at lower N (90 to 175 $mg \cdot L^{-1}$) nutrient solution concentrations with intermittent fertigation of cucumber (*Cucumis sativus*) in rockwool media (Schon and Compton, 1997). Irrigation frequencies that are sufficient to prevent water stress are not necessarily adequate to prevent nutrient depletion except at high N (225 to 275 $mg \cdot L^{-1}$) nutrient solution concentrations. Therefore, it seems logical to propose that more frequent flushing of the media even with a lower N concentration solution could replenish N in the media, and if the flow was continuous, there would be no appreciable depletion of nutrients in the root zone. This reasoning could apply to all nutrients in the solution. Thus precipitation of certain nutrients at pH 8.0 may not limit the overall nutritional status of the plant, provided continuous recirculation of the nutrient solution through the root/media zone occurs.

7.3. Reducing water use and discharge to the environment.

Designing agricultural production systems for zero discharge to the environment (zero agricultural discharge system) has the potential to protect groundwater, makes water permitting easier to obtain, and will help maintain the long-term sustainability of agricultural enterprises.

Greenhouse vegetable crops such as tomato, cucumber, and pepper (*Capsicum annuum*) require as much as 1.9 L of water per plant per day near the mature stage of growth (Hochmuth, 2001a). Given recommended greenhouse plant densities (Marr, 1995), water use would be ≈4.5 $L \cdot m^{-2}$ per day. Thus a single plant moving through its growth stages may use between 0.5 and 1.9 L of water per day depending on its growth stage and size and the growing season or temperature. Water quality in aquaculture systems is maintained in part by discharging effluent and replacing it with fresh water at 5% to 10% of recirculating water volume per day (Timmons et al., 2002). If we assume an average of 1.2 L of water use per plant per day in a continuous cropping system (with early and late plant stages represented), 100 plants could satisfy the effluent discharge/freshwater replacement requirements of a recirculating aquaculture tank containing 4380 or 8760 L (at 10% or 5% replacement, respectively) without the need to discharge effluent to the environment as the plant system is absorbing the effluent.

Field-grown vegetable crops, including lettuce, tomato, pepper, and cucumber, have similar crop water requirements based on the reference crop evapotranspiration (Qassim and Ashcroft, 2006). However, plant

densities and arrangements in hydroponics are different from field production (Resh, 2004), and sizing the hydroponic sub-system may depend on plant type, density, and arrangement and their effect on water requirements. More research is needed to establish sizing guidelines for various hydroponic crops and aquaculture systems.

7.4. Importance of biofiltration to reduce NH_3 and balance N uptake.

Except for oxygen, NH_3 concentration is the most important water quality factor affecting fish (Francis-Floyd et al., 2009). Ammonia is the main excretion product from fish and a by-product of uneaten feed. Ammonia is toxic to fish at levels above 0.05 $mg \cdot L^{-1}$ (Francis-Floyd et al., 2009). The nitrification is the biological process performed by nitrifying bacteria that reduces NH_3 from the water (Gutierrez-Wing and Malone, 2006). Nitrate, the end product of nitrification, is not toxic to fish except at very high levels [channel catfish (*Ictalurus punctatus*) 96-h LC50 (lethal concentration at which 50% of the fish die in 96 h) > 6200 $mg \cdot L^{-1}$ NO_3–N, although some investigations suggest that prolonged exposure to 200 $mg \cdot L^{-1}$ NO_3–N might decrease the immune response of some fish species. Nitrate is the primary source of N for plants in hydroponic nutrient solutions at concentrations from 50 to 280 $mg \cdot L^{-1}$ NO_3–N (Resh, 2004).

Nitrogen, the nutrient required in largest amounts for the optimum production of plants, can be supplied by fish in an aquaponic system (Rakocy, 1997). Root uptake by plants of NH_4^+ may be sufficient to reduce reliance on biofilter nitrification for NH_3 removal when sufficient plants are available in aquaponic systems (Verhagen et al., 1994).

8. Education as a Necessity

To understand and implement the multidisciplinary concept of aquaponics a broad range of knowledge is required. From the theoretical perspective, the multidisciplinarity of the field and a lack of training in holistic thinking is a hurdle to fully comprehend the concept of aquaponics covering all interrelating issues. The bundling of field-specific in-depth knowledge is required in order to consolidate available scientific knowledge and evidence. At most universities, the two main disciplines, *i.e.*, hydroponics and aquaculture, are either not taught, or offered in different schools, which could complicate access and exchange of knowledge. In practice, aquaculture and hydroponic technologies are well-known. The
problem lies in the fact that those disciplines need to be connected. This lack of information-sharing shows the necessity for developing an education network dealing with the improvement of the interconnection between (scientific) disciplines involved in this field. Aquaponic stakeholders, including researchers, entrepreneurs and technicians, need to have basic knowledge covering all disciplines that are involved in this field. Furthermore, experts within every connected field are required to address specific issues within theoretical, scientific, financial as well as practical frameworks.

9. Discussion

Challenges underlying sustainable socio-ecological, technical and economic factors pertaining to aquaponics are discussed in this paper to demonstrate the need and the means of extensively investing in more research and development and education in the aquaponics sector. Taking these factors into account is necessary because a pure financial perspective faces significant constraints, notably in terms of natural resource scarcity and their long-term economic consequences. The commercial development of socially, ecologically, and environmentally sustainable aquaponic systems confronts several technical challenges that need to be addressed further: (1) improved nutrient solubilization and recovery for a better use of the nutrient input and reducing extra-mineral addition, e.g., phosphorus recycling;

(2) adapted pest management; (3) reduce water consumption to a high degree by limiting the need for water exchange; (4) use of alternative energy sources for hot/cold and arid areas (e.g., CHP waste heat, geothermal heat, *etc.*); and (5) innovative pH stabilization methods by implementing fluidized lime-bed reactors that have successfully been used in natural waters.

The systems to be developed should be universally applicable, which implies resource–economic (*i.e.*, resource-saving) production systems that can be run in arid, hot, cold, and urban areas or any combination thereof. Vermeulen and Kamstra 2013, report only a marginal cost reduction for environmental benefits of nutrient reuse and energy efficiency when aquaponics is compared to RAS and hydroponics run separately. However, this study did not take socio-ecological factors into account, such as operating in a resource (e.g., phosphorous, water) limited world. Energy cost and fertilizer prices are constantly rising and governmental policies encourage reduction of emitted pollution (e.g., tax incentive schemes), so this cost margin benefit of aquaponics is expected to rise. Although the highest financial profit margin has been shown with leafy greens, it is still necessary to determine the purpose and the scale of the respective systems before building them; the needs on a microeconomic level in terms of food self-sufficiency or local food supply might differ from profit-oriented approaches and from country to country.

10. Conclusions

In aquaponics, the grower needs to understand the fish system and the crop system and must integrate between them. Aquaponics can be a sustainable agricultural production system. Most plant nutrients can be derived from fish feed through fish digestion/excretion and biofilter nitrification, thus integrating nutrient flow. Plants can act as biofilters and take up system effluent that would otherwise be discharged to the environment. The difficulty in finding a median growing environment among plants, fish, and nitrifying bacteria culture in aquaponics has resulted in less integration of the systems than would be ideal for maximizing space and infrastructure, thus reducing the potential overall adaptability and profitability of aquaponics. We know that aquaponic systems management has been established for the lettuce/tilapia floating raft system, but more long-term research/demonstrations should be conducted on sizing and managing other aquaponic crop/fish system combinations to reduce adoption uncertainty.

Given the fact that aquaponics follows nutrient and water reusing principles, it seems to be a promising solution for sustainable aquaculture and hydroponic practices. However, further research and developments are needed as demonstrated by the challenges described in this paper. These challenges need to be resolved with the aim to establish fully controlled and standardized aquaponic systems that will be easy to handle and economically viable. The competitiveness of the production method depends on technological developments, local markets, and climatic and geographic conditions that need to be assessed and cannot be generalized. Only addressing those factors thoroughly will eventually validate aquaponics as a sustainable food production alternative.

Even though plants provide a beneficial biofiltration role, nitrification is very important for the maintenance of water quality and conversion of potentially harmful NH_3 to NO_3^-. We suggest system sustainability could be improved by maintaining water pH nearer the optimum for nitrification (pH 7.5–8.0) rather than the optimum for plant production (pH 5.5–6.5), provided plant yields are not reduced. Other hydroponic vegetable crop species should be tested under aquaponic conditions to determine how crop yields are affected by operating at pH levels more suitable for biofilter nitrification to maximize long-term sustainability.

Balancing the aquaponic system environment for the optimum growth of three organisms will be an on-going subject of research and refinement. Further aquaponic systems' adoption will require more public and private

resources to close many knowledge gaps in properly managing these systems and successfully marketing their products to the public.

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Analysis of Management Techniques on Minimization of Landslides Damages in Kandy Urban Area of Sri Lanka

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Abstract

Kandy urban area is one of the most risky areas of landslides in Kandy district. Bahirawa Kanda, Booweligoda, Suduhumpola, Thalwatta are more dangerous urban areas in this district. There are many programs have been introduced by governmental and nongovernmental organizations with the intension of minimizing the bad effects of landslides in these. Although, most of the programs were introduced some problems increased in the implementation of them. Therefore, in this study, the special attention has been drawn to inspect alternative activities, problems and weaknesses and the productivity of the strategies of landslide management in Kandy urban area. Data was collected from the people using a questioner including causes for landslides, impacts, management strategies and their shortcomings and alternative options. On the basis of field observations, the following areas are identified. They are identification of landslide areas, inspection of physical characteristics for landslides, identification of structural and nonstructural activities for landslide management. Accordingly, Kandy urban area is at higher risk for landslides. Although, most of the management systems were introduced to manage the landslides, they were not formal long lasting or permanent. The risk of landslides in kandy urban area can be minimized by controlling of informal constructions, protecting and growing of vegetation, broadening of permanent slope management systems and holding awareness programs.

Key words:- Landslides, risky areas, management strategies, damages, causes.

1.0 Introduction

Landslide is one of the most effective natural disasters among floods, cyclones, droughts earthquakes in Sri Lanka and it is scientifically defined as " Mass wasting" i.e. according to the gravitational force, rocks and soil materials in a mountain area, flow downwards. The earth slips which occur flowing of rock masses, weathering materials, classified into various types according to their ways of movements. They are, rock falls, Rock slides, Debris flow, Bedding Glides, Debris slides, Rock creep and Bedding slumping. These types of Landslides can be broadly identified in hill country of Sri Lanka. (Dahanayake.1986 and Weerakkody.1996)

Thirty percentage of Land area of Sri Lanka is mountainous. In this area, Kandy, Nuwaraeliya, Badulla, Matale, Ratnapura, Kegalle and Kalutara are the such most risky areas for landslides. Apart from that, landslides were reported recently in the areas of Matara, Galle and Hambantota districts. (Map 1.1) The landslides which were occurred during the past years have been caused to increase the death toll and displacements of people. In 2008, number of affected people was 2068 and in 2012 it was 2890 (Table 01). The death toll in 2008, was 10 while in 2011, it was one. In addition to the death toll, damages of properties and socio-economic and environmental damages were the other impacts. (Deheragoda, 2008)

Table 01- Affected people of Natural disasters in Sri Lanka (2008-2011)

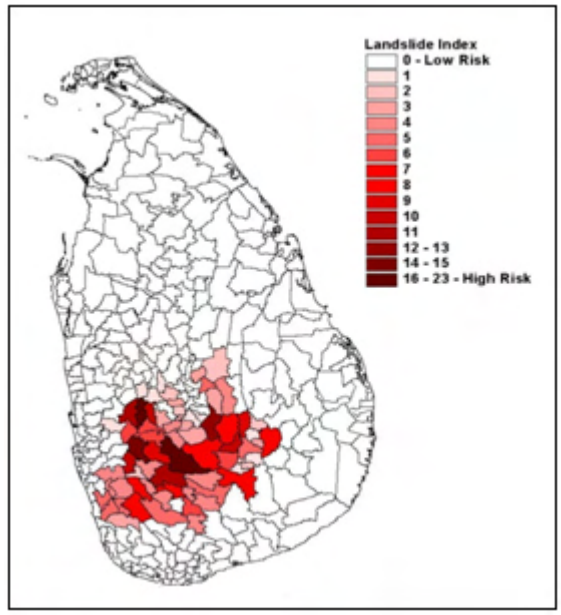
Disaster	2008	2009	2010	2011
Flood	1056740	514808	1219373	2337805
Drought	172778	146040	28306	69507
Thunderstorm	174	06	45	72
Cyclones	356700	15736	2409	00
Landslide	2068	508	1430	2890

Source: Statistic Hand Book, 2012-Statistic Department in Sri Lanka

Among the districts which are under the influence of landslides, Kandy is the highly affected district. Pahathahewahata, Galagedara, Bodhikulama, Nawalapitiya, Galaha, Bambaragoda are more vulnerable areas in this district. Among the urban areas of this district, Bahirawa Kanda Booweligoda, Suduhumpola, Thalwatta were also known as dangerous areas. With this reason, up to 1011, 380 families were affected and among them about 210 families were decided to be evacuated from such places. (Resource Profile, 2011) Therefore, it is important to identify the strategies of landslide management and to analyze its productivity in Kandy urban area.

2.0 Research problem

During the last few decades, there has been a rapid increase of landslides in central hilly area and as a result of it; there have been increased death tolls, property, socio-economic and environmental damages. Although, during last few decades the physical causes such as gradient of the land, Nature of the landforms, the rainfall, coverage of vegetation were caused the landslides, the most affective reason for the increase of landslide was human activities. For the rapid increase of landslides, the following human activities have caused. They are informal changes of terrain slopes, destruction of vegetation, informal constructions, mining of mineral and soils, constructions of reservoirs and irrigation systems. Development plans and new settlements have also caused for the above mentioned destructions. There are many programs have been introduced by governmental and nongovernmental organizations with the intension of minimizing the bad effects of landslides which are to be faced by the people. They are; Management programs which are to evacuate the people from risky areas, land use planning, constructions of engineering structures and handling awareness programs. (Bandara,1995) Although, such programs were introduced, as there were weaknesses of them, some problems increased in the implementation of them. So, It would be considered whether the expected objectives of landslide management were fulfilled. Therefore, in this study, the special attention has been drawn to the problems, weaknesses and the productivity of the strategies of landslide management and decide alternative activities' for landslide management in Kandy urban area.



Source: National Research Building Organization, Colombo.

1.1 map-Landslides Risk Areas in Sri Lanka

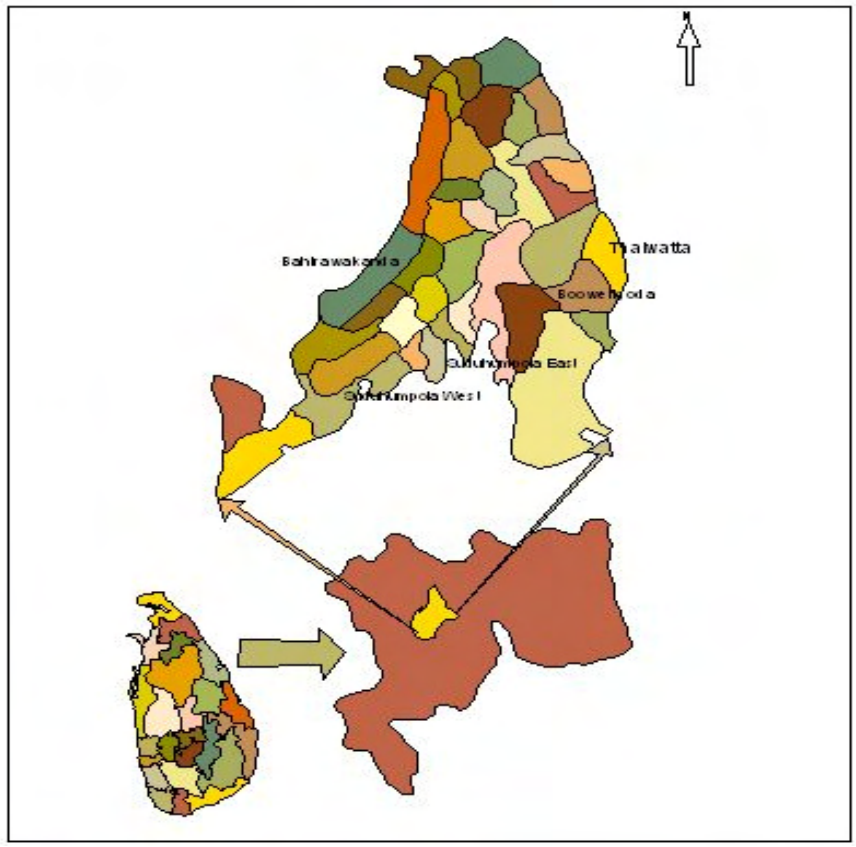
3.0 Objectives

The main objective was to analyze the productivity of the management strategies of landslides with the intention of minimizing of landslides impacts in the Kandy urban area. The specific objectives are;

(a) Identification of landslide and risky areas in Kandy urban area.
(b) Investigation of causative factors that affected to increase the landslides
(c) Determination of management strategies and problems for the minimization of landslides impacts
(d) Analysis of the strategies of landslide management in Kandy urban area

4.0 Methodology

This study with the intension of analyzing the productivity of strategies implemented on landslide management was conducted in Kandy urban area. There are ten Grama Niladari divisions identified as high risky areas for landslides and they are Suduhumpola West and East, Thalwatta, Bahirawa Kanda, Booweligoda, Gatabe, Mahaiyava, Asgiriya and Hantana area. Among them five Gramaniladari divisions which are very risky and were most affected were selected for this study. Suduhumpola east, Sduhumpola west, Thalwatta, Bahirawa Kanda and Boowaligoda are these areas. In these five Grama Niladari divisions, 20-40% families were selected for this study. Data was collected from the people using a questioner including causes for landslides, impacts, management strategies and their shortcomings and alternative options. On the basis of field observations, the following areas are identified. They are, identification of landslide areas, inspection of physical characteristics for landslides, identification of structural and nonstructural activities for landslide management. Apart from that, basic data was collected from Kandy divisional secretariat, Grama Niladari divisions, National Building Research Organizations (NBRO), Department of Statistics, Ministry of Disaster Management and from their websites. These data which were collected from above mentioned methods and places, were analyzed using SPSS and Geographical Information Systems (GIS) systems.



1.2 map-The Study area

5.0 Impacts and the risks of landslides in Kandy urban area

Among the ten Grama Niladari divisions faced for landslides in Kandy urban area, Suduhumpola east, Suduhumpola west, Thalwatta, Bahirawa Kanda and Booweligoda are the seriously affected areas. Suduhumpola East Grama Niladari division is the worst affected area and in 2000-2012, 92 landslides were reported. Two deaths, 50 houses of total damaged, 41 houses of partially damaged were identified. The main cause for the worst destructions in this Grama Niladari division was the gradient of the area. It is more than 30 degrees in75% of the area. In Suduhumpola west Grama Niladari division, during the same period there were 57% landslides and because of this, there was one death, four houses were totally damaged and 20 houses were partially damaged. In Thalwatta Grama Niladari division, in the same period 48 landslides were recorded and no deaths. Only two houses and business enterprises were damaged and 22% of houses were partially damaged. In Bahirawakanda Grama Niladari divisional area, 66 landslides were reported. One death and 28 houses were partially damaged. The main reason for these landslides in this area was informal constructions. During the same period, there were 56 landslides were reported in Boowaligoda Grama Niladari division and 17 houses were partially damaged. Apart from that, some business places were also affected.

Most number of landslides, deaths and property damages were reported in Suduhuopola east and west, Booweligoda, Bahirawa Kanda and Thalwatta Grama Niladari divisions. The main factor for these landslides is the gradient of the land which is more than 30 degrees. Although, the Suduhumpola East, Booweligoda and Thalwatta were affected because of this high gradient, in Suduhumpola West damages were high because of unauthorized forest destructions. During this period, 33% of forest destructions were reported. Unauthorized damages of the slopes for the road constructions were caused for the serious damages in Booweligoda Grama Niladari division.

In Kandy urban area, another source for these landslides is informal constructions. They are housing schemes, business places, cooperation's, industries, community service centers, schools and religious places. Especially, constructions of houses and business enterprises were the main reasons for the increasing number of landslides. According to the data produced by National Building Research Organization (NBRO) during the period of 2000-2002, there were 19967 informal constructions were made in Kandy urban area. Among them 5625 constructions were worst influenced for this danger. It is 20% of the whole constructions. 30% was home constructions, 40% school constructions, and these constructions were the most affective factors. But only 11% buildings were constructed in the places where the area is safe. (NBRO, 2006 Resource profile, 2011) Therefore, 89% of the constructions were at a risk in this area.

As a whole, in Suduhumpola East, the number of constructions with a risk is 48%, in Suduhumpola West 29%, in Thalwatta also 22%, in Bahirawakanda 38% and in Boowaligoda it is 34%. Accordingly, it is clear the more risk can be observed in Suduhumpola East and in Bahirawakanda Grama Niladari divisions. When considering all Grama Niladari divisions, relatively, there were almost 30% dangerous constructions.

Although, Human and physical factors were the reasons for the landslide risk, the main reason would be the informal constructions and cutting of the slopes in Kandy urban area. Therefore, Suduhumpola East and Bahirawakanda can be specially considered as high risky urban areas in Kandy.

6.0 Strategies of landslide management in Sri Lanka

Although, Sri Lanka was not at a risk of landslides in the past, especially in last 1800 years, the risk of landslides was increased. The main reason for this was introducing of cash crops in central hills. Destruction of forest for the cultivation of cash crops such as, tea, rubber and coffee and destruction of land slopes. Soil erosion caused for the increase of landslides. (wdrshr;ak 2000, Deheragoda,2008,). Development projects and new constructions which were commenced after introducing of rapid economic development strategies in 1977 are another reasons for the increase of Landslides. As a result of it, attention was drawn to minimize or prevent the risk of landslides and numbers of management strategies were introduced for the same.

1900-2000th decade was important period for minimizing the risk of landslides, and it was named as International Decade for Natural Disaster Reduction (IDNDR). As a result of this, attention was drawn for the landslide management strategies in Sri Lanka. The main objectives of the international statement are ;

(a) Assessment of risk of natural disasters
(b) National and local planning to prepare the people to face and prevent them
(c) To give information and warnings on disasters through the warning systems and methods

On the basis of these objectives, Sri Lanka drew the attention on the strategies to follow to manage the landslides. Accordingly, mapping of landslide areas, evacuation of people from the risky areas to settle them at safe places, to attend relief work and rehabilitation to make the people aware of landslides and holding training programs were carried out for the landslide prevention.

According to the strategies as shown by the National Research Building Organization (NBRO), it is important to plan proper drainage system by Constructing canal systems to make the water flow downwards gradually, collecting data from the Piezometer stabilized on the land, constructing catch pits helps to store the excess water preventing logging on the land. These activities have been used in the areas of Udapussallawa and Watawala.

Construction of protective bunds is another management activity. Construction of anchored tier retaining, concrete walls, Gabian walls and dumping of big boulders were such constructive methods taken place for the landslide prevention. These constructions were built up in the hilly areas of kegalle, Bulathkohupitiya, Nawalapitiya Utuwankanda etc.

Early warning systems also, stabilized to make the people aware of the risks. After the rock fall following the debris flow which at Viharagala on 16th November 1992, a early warning system was established to monitor the landslide to give early information, identification of environmental perception methods such as building cracks, slumping the houses, emerging the water bubbles from the land and the changes of animal behaviors are important.

Mapping of the hazardous zones was another activity to identify the risk area. To select the proper land areas for the development functions and resettlements is another step. Accordingly, the risk areas of landslides were mapped and identified the risk areas of 709 sq. km in Nuwaraeliya district, 920 sq. km in Badulla, 760 sq. km in Ratnapura, 272 sq. km in Kegalle, 360 sq. km in Galle, 640 sq. km in Kalutara and 320 sq. km in Matara (NBRO, 2012). In addition, growing of vegetation, developing of drainage systems, construction of protective walls, introducing of alternative drainage systems analyzing of landslide risks were the activities taken to manage the landslides in Sri Lanka.

7.0 Productivity of management strategies of landslide adopted in Kandy urban area

The strategies which were introduced to minimize or prevent the hazardous impacts of landslides in Kandy urban area can be categorized into two sections. I.e. they are structural and nun structural methods. Various types of engineering structures and land use planning methods can be identified as structural activities and awareness programs. Identification and mapping of risk areas, evacuation of the people from the risky areas and community participation for landslide management are non structural methods.

Most of the management techniques were used from the people for the minimization or prevention of the effects of landslides during or before disaster. They are covering the risk land areas from polythene sheets, construction of tents, growing vegetation and use of tires or polythene bags filled with sands. Among the above mentioned steps, use of polythene sheets is popular in Suduhumpola East West and Booweligoda. By means of covering the land with the polythene, it can be prevent water intrusion into the earth and it can be caused to minimize the immediate damage. 55% of Suduhumpola East people, 40% of Suduhumpola West people, 50% of Bahirawakanda people have used this method. But in other places, a few numbers of people have been using this method. Although, this method can be used to minimize the damages created by earth slips, it protects the land temporally. There is no possibility to control a powerful landslide. Although, people were given polythene by various institutions, their stranded is not up to here, they are not strong enough, not long lasting. Therefore, this method has not been so effective.

Another primary strategy is erecting tents on these risky areas. Apart from Thalwatta and Bahirawakanda, 10% of the people of other Grama Niladari divisions have used this method. Although, this method is relatively better than overlaying the ground with polythene, a big cost has to be spent. It is a big problem faced by the people. However, using polythene and erecting tents are the temporally solutions but they are not long lasting solutions.

Growing vegetation on the surface of the land to make the water absorb gradually into the ground, to stop the erosion of soil, to make the flowing of water downward systematically, will be successful steps to control the landslides. An effective method of controlling earth slips is growing plants with highly spread root systems and growing some kinds of grass like Illuk, Mana, Savandara etc. But only, 5-10% of people in the area have been using this successful method. The dedication of the people on this matter is not up to the level as, they don't have enough land spaces, their carelessness and the restlessness. But, this is the most effective method to control the landslides.

Another temporarily method of controlling landslide is using sand sacks and tires filled with sand. As these methods are not so successful, the interest of the people on this method is low. But constructions of bunds using boulders and make cement walls are more effective. 40-60% of people in Thalwatta and Booweligoda Grama Niladari divisions have constructed these structures to prevent the earth slips. People have faced difficulties constructing such bunds as they are very cost effective.

Apart from these self control systems, the government also, has introduced some methods to control the landslides. They are overlaying of wire mess, controlling of drainage systems parallel to the slope gradient and to connect the soil layers with the layer of mother rocks by piercing the same etc. But the attention drawn on these successful methods is not sufficient. Only in Suduhumpola with a strong drainage systems have been constructed. Overlaying of wire mess penetrating of iron bars into the land, strengthening of soil layers and overlaying of grass cubes etc. were done to manage the landslides in Peradeniya, in Kandy urban area. However, the risk of landslides is at a higher level as these kinds of the most effective methods were not used in the above mentioned five Grama Niladari divisions which is the study area.

Making the people aware of these methods should be done soon. It is necessary to have the people a good knowledge on disaster preparedness, rehabilitation and reconstructions activities. Especially people must have knowledge of signs shone before the landslides. But, only 10% of the people in the area have this kind of knowledge. This lack of understanding was also, caused to increasing the destruction of property of the people. However, aid and loan schemes were carried out offered for the people who are under the influence of earth slips. By the government and non governmental institutions. 50000 Rs as an aid and 200000 Rs as a loan were given to each family, but people of the area believe they are not sufficient enough for them.

The two strategies used to manage the risk of the landslides are to evacuate the people from the risky area and they are sent to safe places. Although, steps were taken to evacuate 110 families from the risky areas, only 40% of them have been given their concern for the same and 60% of them are totally against of this. The reasons for their dislike are, new lands are situated far away from their native lands, and the lands are not fertile enough for their cultivation purposes, financial aid is not enough to reconstruct their home, the lack of facilities to carry on their occupations and the people who have been experiencing urban facilities, do not like to go to remote areas.

8.0 Conclusions

When considering the risk of landslides in Kandy urban area in the central hills, it is clear that this area is most dangerous and also, comparing the destruction occurred in Suduhumpola East and Bahirawakanda in this area, it is at higher level. Irregular constructions in this area are the main reason for the development of the risk of the landslides and it is about 90%. Accordingly, Suduhumpola East and Bahirawakanda areas have been identified as high risky areas in the study.

Many permanent and temporary controlling systems of landslides, have been implemented in this study area. Introducing systematic drainage systems of slope management, introducing of risky areas, constructing of structural buildings, resettlement of the people at safety places, and holding awareness programs are the main strategies that have to be followed. Overlaying of polythene, fixing tents with the intension of flowing rain water, are the temporary methods to prevent the landslides and they were not so sufficient. Although, growing vegetation is a successful methods to avoids the landslides, only 5-10% of the people have followed it. Although, more efficient methods are building cement and boulder walls, only 40-60% of the people did this because of financial problems. Construction of strong drainage systems, keeping the connection between the mother rocks and the soil systems are not most effective methods. But, such durable methods were used only 20% of the total areas of the study area. Another main reason for more damages is only 10% of the people have a good knowledge of this problem.

Accordingly, Kandy urban area is at higher risk for landslides. Although, most of the management systems were introduces to manage the landslides, they were not formal long lasting or permanent. The risk of landslides in kandy urban area can be minimized by controlling of informal constructions, protecting and growing of vegetation, broadening of permanent slope management systems and holding awareness programs.

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