Sustainable Rain-Water Harvesting Strategies: Lessons and Opportunities for Developing Societies Africa

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Abstract **:**The demand and supply of water in both developed and developing societies has wanting however, the challenges on use and need have tended to be similar. This study sought to explore technologies and sustainable techniques for rain-water harvesting as its main aim. Various societies over time have used their indigenous methods, and this study sought to explore through case surveys as its design in both developed and developing societies on methods both indigenous and modern techniques that have been used. Indigenous systems have been used in Nigeria, Ghana Malta among other countries. In developed societies modern techniques have been used in the United Kingdom over a period of three decades. Further-mention is this study on Livestock Water Productivity in India and how it can be relevant to Sub-Saharan countries mainly in arid and semi-arid regions (ASAL) on rain water harvesting and use. The strategies, lessons and best practices using a sustainable resources theory and its practice as well as analysis have been used. Various lessons have been given for adoption and implementation in sustainable living and learning for developing societies as Kenya.
Keywords: Developing societies, rain-water harvesting, sustainable techniques

I. INTRODUCTION

Kenya is a victim of climate related disasters as 70 per cent of all disasters happening in the country are done to climate change. Globally Kenya ranks 50 in the number of people affected by climate disasters. The frequencies, extent of coverage, timing and severity have change, and seriously eroding people's coping and adaptive capacity. In arid and semi-arid lands (ASALS, droughts are an inherent part of life in the past decade, drought episodes were experience in 2001, 2003, 2006, 2009, 201 and recently in 2016. In addition, major floods occurred in 2006 and 2010 as heavy rains often followed periods of prolonged drought. The prolonged drought of 2008-2011 was one of the worst in Kenya as its impact costed about Ksh 1.2 billion and slowed down GDP growth by an average of 2.8 per cent per year. The UN Office for the coordination of Humanitarian Affairs estimates that the government allocated Ksh. 18 billion to drought response in 2011 alone. The bulk of these funds were used in famine relief (Nyangena, 2014).[1]

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In Kenya, besides economic loss, drought is responsible for the rising number of climate refugees and migrants, as communities move to less hostile environments and often this exerts pressure on natural resources and results in resource use conflicts or human-human and human wildlife conflicts. In addition, the environmental impacts of drought have included wind erosion, reclining wetlands and poor sanitation. In some areas of the country, drought catalyzes desertification and loss of biodiversity, (ibid).

Access to water in Kenya stands at 53%, however, the target has been 80% from 53% to 100% the conversation that is ongoing in the water sector overtime. Further, 46% of the populations do not have access especially in informal or unplanned settlements. Access to water in Kenya has been strengthened by the constitution 2010 which guarantees the right to water in Article 43. In essence right to water in Article 43. In essence there has been the need for citizens to be informed regularly about the status of the water sector and what plans there are to sustain this important resource called water (Gakubia, 2016).[2]

In 2011 in Kenya, the government recognized the problem of drought and launched a 10-year programme on ending drought emergencies campaign, to consolidate the drought mitigation measures based on experiences acquired over the years through the campaign. It was expected that drought will no longer remain a humanitarian emergency. Further, during the same period, the National Drought Management Authority (NDMA) was established to provide the institution framework to combat drought (Nyangena, 2014). Further, NDMA, just provides the framework for the country to fulfill the international obligations under the Hyogo Framework for Action. The Measures have been important, especially in the ASALS, as they are in line with Article 43 of the constitution which requires the state to take legislative, policy and other measures to achieve the progressive realization of the human rights including the right to freedom from hunger.In Kenya, some agencies established on the same note have included, the National Drought and Disaster contingency fund to finance drought management in livestock, agriculture, water and sanitation, health, education and early warning systems (ibid). The Kenya Food Security Meeting (KFSSM) and its technical

a run, the Kenya Food Security steering Group (KFSSG), the Kenya Red Cross and the National Disaster Operations Centre have all be involved in essence, drought management measures should target the underlying causes of community vulnerability where, there should be innovations to encourage new patterns of responses by increasing participation and social organizations at the local level. Further, traditional social networks used by various communities to survive drought, or as early warning systems should be strengthened as appropriate, since drought is closely associated with water deficit, increasing the country's water storage capacity would greatly ensure rapid expansion of irrigable land and reduce over dependence on rainfed agriculture. It means also that shall-scale dams in pastoral areas should be constructed and be accompanied by other measures such as establishment of disease –free zones, improvement of breeding services and promotion of efficient marketing to increase livestock production. It means also that improving drought assessment capacity and intensifying research on appropriate responses should be an integral part of any drought management agenda (ibid).

Globally, sustainable development goal no. 6 has emphasized on clean water and sanitation, to achieve universal and equitable access to safe and affordable drinking water for all, achieve access to adequate and equitable sanitation and hygiene for all and end open defecation, paying special attention to the needs of women and girls and those in vulnerable situations, improving water quality by reducing pollution, eliminating dumping and minimizing release of hazardous chemicals and materials having the proportion of untreated wastewater substantially increasing recycling and safe reuse globally, substantially increase water-use efficiency across all sectors and ensure sustainable withdrawals and supply of freshwater to address water scarcity and substantially reduce the number of people suffering from water scarcity, implementing integrated water resources management at all levels, including through trans boundary cooperation as appropriate, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, acquitters and lakes, expand international cooperation and capacity, building support to development countries in water and sanitation related activities and programmes, including water harvesting, declination, water efficiency, wastewater treatment, recycling and reuse technologies as well as support and strengthen the participation of local communities in improving water and sanitation management (WASREB, 2016).[3]

Measuring sustainability, the challenge has been varied. For instance, some link it to environmental impact based on population, affluence and technology that is;

I	=	P x A x T
		Where;
I	=	Environmental impact
P	=	Population
A	=	Affluent
T	=	Technology

(Ehrlich and Holden, 1974 cited in Kerr C, 1990)

Further some link sustainability to health,
Health = Water + sanitation + hygiene education
(Kerr C, 1990) [4]

II. Problem Definition

In Kenya, according to the National Water Services Strategy (NWSS-2007 to 2015), Kenya's target for water and sewerage services in the urban setting was 80% and 40% respectively, however, only 15% of utilities met this target. In 30% of utilities, more than 50% of the water produced is lost through physical and commercial losses with only 10% (8184) of the utilities meeting the Non- Revenue Water (NRW) country's target of 30% by 2015. On the other hand, only 40% of the utilities are able to cover their operations and management costs.

In Kenya besides, the increased investment for infrastructural expansion and rehabilitation, the real potential in Kenya's urban water sector lies in reducing wastage, improving service quality, maximizing on consumer contribution and improving cash flows to accelerate access to water. It can also leverage on programmes like the Kenya out-put-based Aid (OBA), Aid on Delivery (AOD) programme, or on commercial financing. Also critical is a proper legal and institutional framework, proper sector policies, and incentives for utilities to perform (extend services to the poor, build capacity and network also have financial sustainability. Therefore with the recent enactment of the water act 2015, the sector now has a better instrument to guide its operations.

However, concerns in the Kenya vision 2030, National Development Plan seeks to make water and basic sanitation available to all by 2030. The total cost of investment and rehabilitation needed in water supply is estimated at Ksh 1.7 trillion; national water master plan (NWMP 203). According to the Kenya water master plan, 2030, the available government budget is Ksh 592.4 billion, which leaves a shortfall of Ksh 1.2 trillion. This gap could be plugged partly by increasing sector efficiency, maximizing consumer contributions through tariffs, and encouraging private funding.

In essence, requirements for commercial financing may include; conducive operating and legal environment for bank lending, utilities to continue operating at arm's length as autonomous entities that can borrows, ring fencing of revenue, urban utilities to be managed in business-like manner, tariff setting to allow for funds to leverage more borrowing and not politicized as well as independent regulation (WASREB, 2016).[3]

In essence in Kenya in the last decade, drought episodes were experienced in 2001, 2003, 2006, 2009 and 2011. In addition major floods occurred in 2006 and 2010 as heavy rains often followed periods of prolonged drought. The prolonged drought of 2008-2011 was one of the worst in Kenya's history. Its impact costed about Ksh. 1.2 billion and slowed down GDP

growth by an average of 2.8 per cent per year. The United Nations Office for the coordination of humanitarian Affairs estimates that the government allocated Ksh. 1.8 billion to drought response in 2011 alone. The bulk of these funds were used on famine relief. Further, apart from economic loss, drought is responsible for the rising number of climate refugees and migrants, as communities move to less hostile environments and often this puts pressure on natural resources and results in resource-use conflicts (human- and human wildlife). Environmental impacts of drought have included wind erosion, reclining wetlands and poor sanitation. In some areas of the country, drought catalyzes desertification and low of biodiversity. A recent drought in Turkana County affected 400,000 people and more than 35,000 children were forced to stay out of school due to food insecurity (Nyangena, 2014). Therefore this study seeks to be an eye opener on the techniques for rainwater harvesting based on the above challenges in Kenya and other developing societies.

Objective of the study

The main objective of the study was to describe the main sustainable rain water harvest strategies that are applicable in developing societies.

Theoretical framework

Sustainable resource theory

This theory has been linked to scarce resource theory; unlike for one major point; the concern for the long-term versus short-term agenda. The theory was emphasized by Thurow in 1993, as cited in Swanson 2007),[5] while evaluating organizational performance. Thurow 1993:16 says, "In the future, sustainable advantages will depend on new processes, technologies and less on new product technology. New industries of the future will depend on the brain power. Man-made competitive advantage of Mother Nature (natural – resources endowment or history (capital endowments)". Earlier resource-based view by Barney 1991:10, had emphasized on the same; just like Graut, 1991. This view point is the sustainability link that had been put forward by Bruntland commission and Report in 1987.

III. Materials and Design

He study adopted survey design involving global regions mainly developing societies with one developed country global regions as its population on strategies adapted in rain water harvesting. Survey design was appropriate because of the research and the ethical concerns that needed to be brought out and its validity, rather than other approaches that may be used (Sapsford, 2004).[6] Further content analysis also consists of scoring specific information that is required. The advantage of this method is on revelation of what was initially considered as descriptive study (Isabel, Luis & Isabel, 2011).[7] This methodology is appropriate for disclosing important information required for benchmarking and it has been employed by (Xiao, Yang and Chow, 2004).[8] Validity and reliability of the study has been based on content, criterion as well as contrust.

IV. Discussions

Some Global Sustainable Projects and Strategies

Among the innovative projects may include:

i) **Rain water harvesting technologies**. This is done in Africa by Amsha Africa as well as in Smart Agriculture, Florida State and Oklahoma in the United States of America. Among the best practices by Amsha Africa include:

a) Runoff rain water harvesting technology is practiced in rural Africa; here cemented rectangle – like hole almost one metre or so deep.

b) Water pans; here a hole or pond dug in the ground, used to collect and store surface run-off from uncultivated grounds, roads, ridges or laggas. It can be square, rectangular or round. Common ones hold 400 to 1000 metres cubed.

c) Plastic- lined underground tank; here runoff water is directed into an underground tank dug into the ground. The advantage of a tank is that it is covered. This stops water from being lost into the air by evaporation. As long as the manhole entrance into the tank is well secured, it is also safer for children. Life span can extend up to 20 years before repair.

Traditional rural African rain water harvesting strategies included from banana stems and leaves, also from backs of trees and leaves also clean utensils placed on roofs of buildings among others.

ii) **Irrigation-related activities**; for instance in the world 144 million of land is cultivated under rice, while Asia produces more than 90% of world's rice. (FAO, 2010). In addition, Israeli-based technologies on customized irrigation in conjunction with the private sector are other techniques, commonly used. Other countries including Uzbekistan, Egypt, Lesotho and Honduras in Lempira are practicing irrigation.

iii) **Livestock projects**

Since grazing land occupies 26% of the earth's ice-free land surface, and 33 percent of cropland is dedicated to the production of feed, similarly fodder crops represent 70% of world's agricultural area. Soils under grasslands, contain 20% of world's carbon stocks, and are at risk from land degradation. In Peru Cajamarca province, milk production increased by 25% and calves reached up to 280 kg in 20 months, instead of 30 months due to good fodder production (FAO, 2010).[9]

iv) **Fishing**

World-wide, 500 million depend directly or indirectly on fisheries and agriculture for their livelihoods. Since fish provides essential nutrition for 3 billion people and at least 50% of animal protection and essential minerals to 400 million people in the poorest countries. However, climate change has affected production as powered fishing vessels consume 41 million tones of fuel. (FAO, 2010)

v) **Other projects**; rooftops gardens in Cairo Egypt as well as national biogas programme in Vietnam and Thailand are worth emulating.

vi) **Wildlife projects**

In Africa there are many wildlife foundations especially for elephants. Among the common ones are, the African Wildlife Foundation (AWF). The David Sheldrick Wildlife Trust, William Holden Wildlife Foundation, African Conservation Foundation.
Other projects include partnership options for resource use innovation(PURI) by USAID; dealing in livestock for livelihoods, Sustainable economic Resources for Africa (SERA), International Elephant Foundation, Amboseli Ecosystem Anti-poaching project, Patty Wagstaff-lindbergh Foundation in east Africa, African Environmental Film Foundation(ARFF), Global Greengrants Funds as Well as Wetlands International, Everglands Foundation from Brazil and Bolivia. The World Conservation Union in Netherland (IUCN) also the World Conservation Union of Eastern African Regional Office (UNCN-EARO) among others.

In the United Kingdom (UK) Rainfall harvest cases have been from the roof of building, otherwise called rainwater harvesting (RWH) (Alan, 2012).[10] This strategy has been of the view of non-potable applications such as water closet (WC) slushing or garden watering. Herrman and Schmida (1999) had identified type of system as indicated below as a remedy. Storage for water supply can be compiled as (Mcmahon, (1978).[11]

$Vt = V_{t-1} + Q_t - D_t$

Subject to $o \leq V_t \leq s$

Where V_t; water storage at end of time interval t

Q_t Inflow during time interval t;

D_t demand during time interval t

S Storage capacity

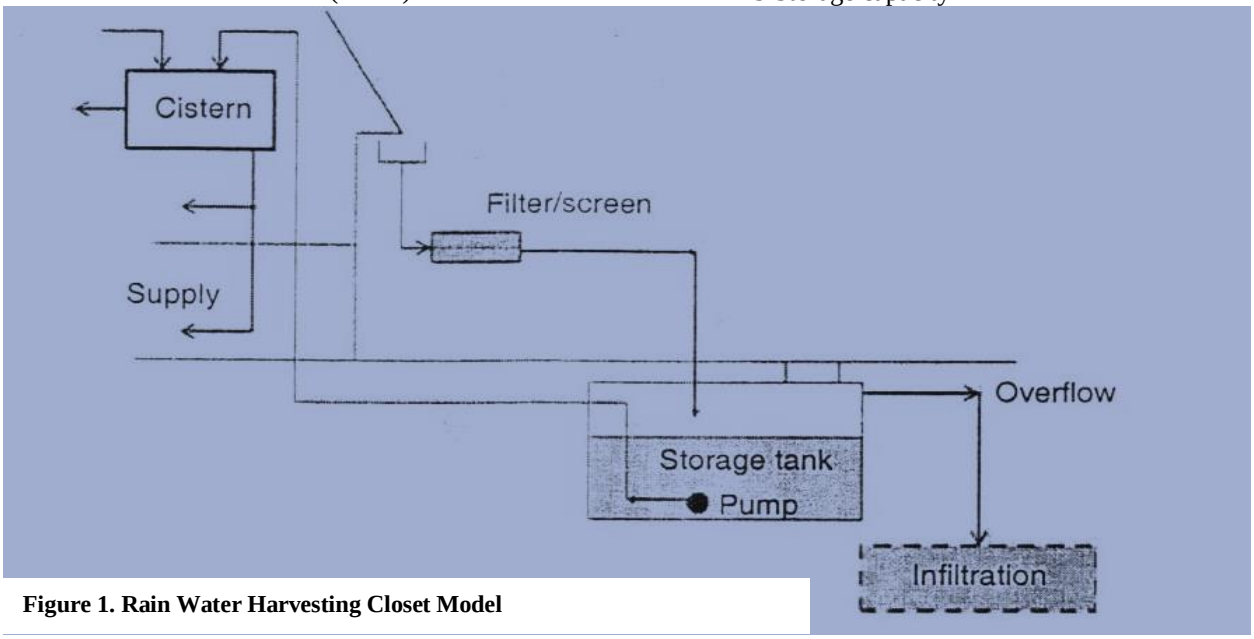

Figure 1. Rain Water Harvesting Closet Model

Source: Herrmanna and Schmida (1999)[12]

In Malta an Island most rainwater harvesting technologies have been sustainable indigenous technologies on the Maltese Islands whose rain is isolated and spread over a short period of time are have not been adequate. Initially the model of harvesting rain water was that of Munasinghe (2001), [13] that is;

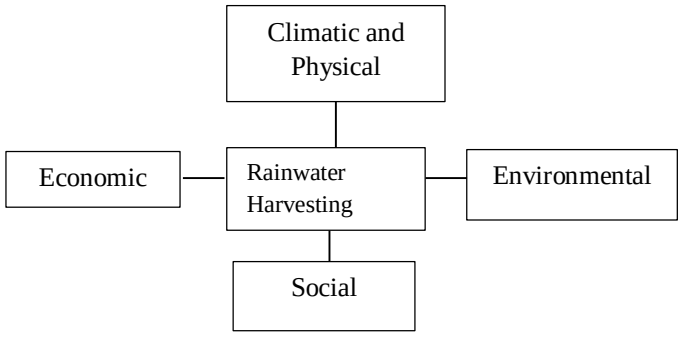

Figure 2. Rain Water Harvesting structure

However, the many challenges in all the spheres have provided the interventions by giving alternatives as provide below.

- Semi-permeable surfaces: these would allow for rainwater percolation to be caught in culverts of reservoirs below ground. This would work well in a car-centric community like the Maltese Islands that makes use of large areas for the sake of parking spaces, but seems to lack the imagination to adapt below ground reservoirs to aid the water issue. The benefit of this practice would be that the semi-permeable surfaces allows for filtering of water from large sedimentation, requiring some polishing and making it perfectly viable to be used and apportioned where needed while reducing stress from ground water. Additionally monitoring and combining the capacity and annual collection would also allow the harvesting and retention of water at key areas to be apportioned and used by agriculture during the summer months as needed.
- IKS model: this concept has value for the case of Malta on two fronts. On one hand, the historically adapted practices such as dams, cisterns and aqueducts could hold greater value when coupled with innovative cutting edge technology to maximize efficiency in Rain Water Harvest (RWH) catchment, storage and distribution. On the other hand, the focus of endorsing and pushing of indigenous flora and agriculture could help in enriching a depleting ecological system while also shifting to a demand management frame of mind which is sorely needed when considering the incremental use from the agricultural sector.
- Green roofs: these allow for embellishment through added greenery, and the possibility for minor agricultural uses of large areas. Additionally, they allow a reduction of storm water flowing, enhance rainwater catchment (Fewkes, 2012),[14] recharge ground water and reduce CO_2 emissions through plant air filtration (Getter and Rowe, 2006) and improve thermal comfort in buildings (Kohler et al., 2002).[15] The flexibility and implementation of such technology is versatile and offers multiple benefits. It is recommended that plants or vegetation used on Maltese green roofs are endemic or well adapted to the climate to ensure that the water needs of such vegetation is not detrimental to the potential water that could be harvested. (ibid)

These examples, at macro as well as micro level, could be implemented sporadically across the Maltese Islands to allow for an augmented RWH trend, aiding the Maltese Islands to increment water flow recharges as well as ground water stock, while giving rise to new water supplies that could curb a decreasing ground water supply.

The following are some other recommendations that could also play an important role in the initiation of a unified RWH and holistic water management strategy. (Frank and Ians, 2014) [16]

- Enhance enforcement with all stakeholders to a degree that the misuse or abuse of ground water is seen as a criminal act to the extent of fines and or jail time.
- Enhance regulation an policies that actively require follow through and setup incentives for developers to invest cisterns and wells as well as secondary water systems for the occupants, be they homes or apartments. Additionally, incentives for PV panels could be extended to domestic wells. If both programmes are too costly to be run concurrently, then these can be rotated annually or biannually.
- Allowing WSC to charge a small amount for sewage treatment to become more sustainable with regards to its role and operations. Subventions are not a final solution; WSC needs to be given the managerial space to balance its books while fulfilling its social obligation. Additionally, a polluter pay system may be introduced.
- NGO's should try and have a common ground perspective on water issues as such an alignment would aid public consultation processes with the inter-ministerial committee.
- Businesses and industries should also be given incentives to invest in RWH as this may be of advantage to them within their own operations in the long run. Consideration to isolate industrial sewage water from the main sewage affluent, if feasible, to facilitate treatment and reuse of main sewage effluents should be vetted.
- A modular set of campaigns across various social groups to educate residents and awaken a

conservative nature and understanding of water issues, its scarcity and its importance. As the needs and uses are many, the campaigns should be diversified to reflect it and promote a cultural shift.

- Future environmental decision-making processes on problem-oriented matters need to acknowledge community values and to find more effective ways by which the general public is encouraged to participate in consistent, robust and meaningful ways as from the initial stages; such approaches are known to yield better results (Harding, 2005).[17]

In India study on the effects of smallholder farmers access to livelihood capital for instance land, livestock and water on livestock productivity that water management based interventions include; key agricultural activities that enhance sufficient and timely water supply and efficient uptake by the plants especially by rice and wheat crops, which compares with improved feed quality and animal productivity, the study suggested that improvement of water productivity of feed changes with livestock water productivity value significantly as compared to other interventions (Amare, Floriane and Khan, 2011).[18]

In Africa mainly Sub-Sahara Africa including Nigeria institutional capacity challenges on water resources management have included (Sharma, 1996). [19]

- People are unaware that water is a finite resource with supply constraints, that it has a scarcity value, and that there is a cost to using it;
- Lack of understanding of the consequences of deforestation and land degradation on the quantity and quality of water;
- Inadequate capacity building and neglect of traditional knowledge bases as well as gender issues;
- Management of water resources is highly fragmented among sectors and institutions and there is excessive reliance on public sector services; and
- Weal institutional and implementation capacities.

However in Nigeria techniques have involved; water storage techniques including inside drum, jerry can, plastic bowl, buckets, local pots, surface tanks among others. Among the methods commonly preferred were jerry cans at 29.5% and inside drum at 26.2%. (Gbadesign and Olorunfeni, 2011) [20]

Indigenous technologies in Nigeria of water harvesting have included, pit chlorination, solar disinfection, simple sand filters, nylon filters, tagging harvesting of ground water and recharging of ground water among others successful techniques in rainwater harvesting in in Ekpoma state, however, the Nigerian government is yet to assist people fully in terms of materials in harvesting the rain water say the corrugated iron sheets, cement and blocks used in the construction of the reservoirs (Getter and Rowe, 2016). [21]

In Ghana, indigenous agriculture systems mainly, where farmers plans multiple indigenous drought resilient crop varieties and by employing different rounds of seeding or staggering planting between multiple farms. Farmers also apply indigenous forms of organic manure, checking soil erosion through grass strips and stone terracing and adopting paddy farming for improving soil and water conservation towards enhancing plant adaption to drought. These strategies are better applied to reduce vulnerability which is mainly the cause of natural disasters, UNDP, 2004 P11, [22] and Emmanuel (2013).[23]

In Kenya Water Services Trust Fund (WSTF) is the Kenyan State Corporation mandate to finance water and sanitation services for the poor and underserved communities in rural and urban areas. In addition, the water bill 2017. The mandate of the fund has been to provide conditional and unconditional grants to the countries and to assist in financing the development of an management water services in the marginalized and underserved areas; including, community level initiatives for the sustainable management of water resources, development of water services in rural areas considered not to be community viable for provision of water services by licences, and development of water services in the under-served for urban areas. (Shaiye, 2015).[24]

Further, the stakeholders of WSTF have included, county government stakeholders under devolved structures, water resources management authority who assists the authority in developing sub-catchment management plans (SCMPS) and provides oversight for water resources management, water services

boards who in the past have been overseeing the community organizations in rural programmes, and water services providers in the urban programmes, water services providers who implement and provide water and sanitation services in urban and now also rural areas where relevant, community groups (CORUA and CBUS) who participate in implementation of their projects in rural areas as well as other government and private sector institutions for instance in health, education, management organizations (NGO) and others (ibid).

According to FAO (2010), rain-fed agriculture is now 20% in developing countries. Further, if improved water harvesting and retention strategies such as pools, dams, pits, retaining ridges among others and water – use efficiency (irrigation systems), then agriculture land in developing countries can generate 130% more yields than rain fed systems. This will require expansion of efficient management technologies and methods especially those relevant to smallholders, which is fundamentally essential.

In Africa organizations and foundations engaging in wildlife management and conservation are far many than water harvesting strategies yet human – wildlife conflicts have been on the increase. Kenya has 3% of forest cover compared to the recommended 10%. And since forest cover is linked to climate, unfriendly climate conditions in terms of drought and flooding has been evident in Kenya recently than before. In the same way media reports of elephants destroying farm lands is on the increase as the search for water intensifies. It is for this reason that recently Cable Network News (CNN), in its documentary 'Inside Africa', says elephants and livestock battle for water in East Africa. Inside Africa revealed that drought means people and elephants have to use the same water points. Elephants are some of the first of the animals to feel the effects. Similarly,
livestock herders are forced to take their animals to water holds in protected areas;
similarly, elephants are destroying farmers' crops as they search for food, (Wither E. (2011). [25]

In Kenya the overall water masses are only 11,230 square kilometers, for the available population, the use of by animals agriculture, energy and even health and public sector safety besides the basic financing requirement as indicated below which is a major challenge and a source of vulnerability in a bid to achieve sustainable development in Kenya.

Table i. Status of Kenya; facts and figures

Water - 11, 230 square kilometers
National parks - 25, 334 square kilometers
Others - 54,082square kilometers
Total - 582,647 square kilometers

Source: Kenya National Bureau of Statistics, 2009 [26]

Table ii. Vulnerability Assessment in Kenya (ROK, 2013) [27]

No	Sector	Vulnerability	Adaptation assessment
1	Agriculture	▪ Poverty among the small scale subsistence farmers. ▪ Farming in the marginal rainfall areas. ▪ Over-cultivation and land degradation ▪ Inadequate technologies to improve production ▪ Limited in-economic diversification ▪ Weak integration of indigenous knowledge on the use of climate information to maximize agriculture production.	• Adoption of drought resistant/escaping crops. • Soil conservation measures. • Adoption of appropriate agricultural techniques and water conservation technologies. • Crop diversification in subsistence farming. • Alternative means of income generation for subsistence farmers.

			• Enhanced public education and awareness raising on effective use of climate information
2.	Water Resources	• Population increase in the marginal areas leading to increased demand for water. • Over-cultivation in slopping areas leading to flash floods and siltation of rivers and reservoirs- Deforestation in the water catchment areas. • Inefficient utilization of available water, e.g. irrigation methods. • Water pollution, especially by industries.	• Enhance water harvesting and conservation methods • Increased afforestation especially in the water catchment areas. • Zoning of environmental significant sites • Exploitation of underground water especially in the marginal rainfall areas. • Adoption of irrigation technologies that lead to water conservation. • Policies and measures that enhance water quality. • Good soil conservation practices in agriculture. • Public education and awareness raising.
3.	Energy Resources	• Deforestation especially in the hydropower dams catchment areas. • Over cultivation resulting in siltation of rivers and dams. • Inefficient utilization of biomass for energy • Poverty leading to over exploitation of biomass.	• Increased afforestation and reforestation. • Good agricultural practices and soil conservation. • Adoption of biomass energy efficient stoves (appropriate energy conservation measures). • Enhance/diversify alternative income generation activities (AIG) • Increasing exploitation of renewable energy resources such as wind, solar and geothermal energy. • Enhance energy efficiency in industrial and commercial operations • Public education and awareness raising.
4.	Health and public safety	• Inadequate health services especially in rural areas. • Increased prevalence of diseases related to climate change • Poverty especially among rural communities.	• Provision of adequate health service in rural areas • Adequate response strategies to the outbreak of climate related diseases.

		• Lack of alternative means of income especially in marginal rainfall areas. • Traditional ways of life that are not changing with time • Inadequate public awareness of disease risks. • Encroachment of wildlife parks and reserves by farmers and pastoralists.	• Availability and utilization of climate information towards preparedness • Sustainable disease vector control strategies. • Provision of clean and adequate water. • Sustainable community conflicts resolution strategies • Alternatives sources of income for communities in marginal rainfall areas. • Public education and awareness raising The above sectors are only some of the sectors

Source: Kenya Meteorological Department Annual Report 2013

Table iii. Present and future water demands by sub-sector (before water balance study)

Subsector	**2010 (MCM/Year)**	**2030 (MCM/Year)**	**2050 (MCM/year)**
Domestic	1,186	2,561	3,657
Industrial	125	280	613
Irrigation	1,602	18,048	18,048
Livestock	255	497	710
Wildlife	8	8	8
Fisheries	42	74	105
Total	**3,218**	**21,468**	**23,141**

Source: The National Water Master Plan 2030

4.3 River flow levels/volumes by basins

Table iv. Average Annual Water Availability per Drainage Basin

Drainage Basin	**Annual Rainfall (MM)**	**Surface Water (MCM)**	**Ground Water (MCM)**	**Total Water (MCM)**
Lake Victoria	1,368	1,672	116	11,788
RiftValley	562	2,784	126	2,910
Athi River	739	1,152	87	1,239
Tana River	697	3,744	147	3,891
Ewaso Ng'iro North	411	339	142	481
Total	**621**	**19,691**	**618**	**20,309**

Source: Adapted from (National Water Master Plan, 1992; National Water Master Plan (NWMP)

Afterccare, 1998;

Ground water levels by potential/volumes

Annual sustainable yield of groundwater in BCM in comparison to the annual recharge per recharge per catchment area as estimated by National Water Master Plan (NWMP) 2030.

Table v. Annual sustainable yield of groundwater compared to annual recharge (Unit: BCM).

Catchment	**2010**		**2030**		**2050**	
	Recharge	**Safe yield**	**Recharge**	**Safe yield**	**Recharge**	**Safe yield**
Lake Victoria North	1,326	116	1,251	108	1,612	140
Lake Victoria South	2,294	203	2,111	188	2,126	190
Rift Valley	1,126	102	1,126	102	1,209	109
Athi	3,34 5	305	3,303	300	3,649	332
Tana	7,719	675	6,520	567	5,840	508
Ewaso Ng'iro North	1,725	526	2,536	475	1,361	449
Total	**21,462**	**1,927**	**19,407**	**1,740**	**19,287**	**1,728**

Source: Adapted From Annual Water Sector Review 2012-2013

Table vi. Case of sustainable financing borehole in Mwatate – Kenya

	Ksh.
Licences and legal fees and water analysis	15,300
Ground water survey	10,000
Hydrological report	20,000
Equipment, tools, labour and upkeep for ground workers	68,400
Pumps, casing, concrete and labour	400,000
Total	**513,700**

(Source: Amsha Africa)

V. Conclusion

In summary, therefore in Kenya available rainwater harvesting technologies must include those offered by Shabaha engineering on small scale, Amsha Africa, future pump, Brook Sarson among others. These technologies are yet to be fully used in rainwater harvesting initiatives to a large extend. However, much newer technologies are required also in Arid and semi-arid areas (ASALs), to collect and store much rainwater besides clean siltation and use of renewable energy as solar in purifying the water. Hence the study is meant to open upon discussion, as newer technologies are adopted from other countries to reduce vulnerability in Kenya.

Therefore it is recommended that rain water harvesting strategies like those of Amsha Africa, Brook Sarson in San Diego among others be encouraged and adapted so that community and regions to specialize in it and just like using smart farms as it happens in Florida State (USA) in irrigation and rain water harvesting. Further research should be on wildlife foundation especially elephants in Africa on the need to be emphasized on water harvesting strategies as elephants need much water and a major root cause of conflict with humans.

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