Environmental Systems Research

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Economic value of water harvesting for climate-smart adaptation in semi-arid Ijara Garissa, Kenya

J. Mwaura[1*], J. Koske[2] and B. Kiprotich[2]

Abstract

Background: The semi-arid Ijara experienced erratic and declining rainfall whereas temperature increased, triggering extreme weather events shocks. Given the shocks that outwitted traditional coping mechanisms, pastoralists spontaneously took to water harvesting pans as adaptation strategy. The spontaneity translated into unclear costs benefits which the study clarified by isolating them for analysis and also measured the strategy's viability. The design used was costs-benefit-analysis, complemented by the regional financial market-driven 15% discounting rates. Also co-ordinated regional downscaling experiment models were used to ascertain climate performance and projection. Household questionnaire was administered to 240 calculated from 9000 farmer population.

Results: Annual water pan cash flow netted present value US$ 5393 and 57% pastoralists had embraced agro-pastoralism. Land size inadequacy and the communal tenure upset 86.26% users and 53.08% lacked requisite skills. Other challenges were feed deficit at 30.41%, and diseases 20.41% in that order. Benefits from harvesting water exceeded costs, making the investment viable for adaptation.

Conclusion: Considering the limited adaptation capacities, disease control and feed deficit costs, policies need to focus on formulating climate-smart water harvesting technologies, improve feed to include revitalizing traditional grazing management practices. Other pertinent investment opportunities include strategic value-chain linkages and infrastructure as well enriched soil stabilization using multi-benefits crops and generation and consistent use of weather data.

Keywords: Water harvesting pan, Costs benefits, Adaptation, Net present value, Agro-pastoralists

Background

Impacts of climate change and variability affect agricultural productivity which depends directly on climatic conditions hence increasing adaptation costs (Rosenzweig et al. 2008; Skiba et al. 2012; European Union 2014; IPCC 2014). At a warming rate exceeding 3 °C, virtually all of the present maize, millet, and sorghum farmlands in sub-Sahara African countries such as Kenya could become unviable, thereby escalating economic costs and uncertainty (Schaeffer et al. 2014). The risks expose the ASALs in the region to the challenge of exponential costs occasioned by unreliable, highly variable, and scarce rainfall for their livestock and crop production (Tol et al. 1998; Bhatt et al. 2006; Cooper et al. 2012). Apart from high costs of production, temperature for instance, affect the cropping pattern and type of livestock kept whereas rainfall amount, distribution, reliability and intensity determine the crops grown, livestock kept and soil treatment required (Jaetzold and Schmidt 1983; Obanyi et al. 2009). Consequently, when climate change variability affects temperature, rainfall, land, energy and wind, it ravages the very core of economic productivity benefits and increases costs of adaptation astronomically. However, much as the impacts are ravaging, they provide opportunities from returns arising from implementation

*Correspondence: jmwauram@gmail.com
[1] Kenya Agricultural and Livestock Research Organization, P.O. Box 230, Garissa 70100, Kenya
Full list of author information is available at the end of the article

of climate-smart adaptation strategies, which benefits traditional coping could not provide.

The semi-arid Ijara falls within the 95,000–120,000 km^2 water catchment that is drained by the 1000 km long River Tana that arises from Aberdare Ranges in central Kenya. The river essentially defines the ecosystem in which about a million people i.e. pastoralists, agro-pastoralists and fisher-folk depend on its flooding regime for their livelihoods. However, increasingly uncertainty about the river's flooding regime affected both crop and livestock production, necessitating sustainable rain water harvesting.

Water harvesting adaptation strategy

Rain water harvesting and storage capacity remains extremely low in Kenya even though the country is water-stressed with per capita availability of 647 m^3, which is less than the UN-recommended 1000 m per capita (Republic of Kenya 2010). Water harvesting is the collection of runoff instead of it being left to cause erosion for productive purposes that reduce costs. In the semi-arid drought-prone areas where it is widely practised through water pans, water harvesting doubles as a direct productive form of soil and water conservation. Consequently, both yields and reliability of production can be significantly improved with this method. Water harvesting techniques have been used for millennia for domestic, agricultural, pastoral, and commercial water needs. In Kenya, development projects by county government, NGOs, national and international organizations, state ministries, and other agencies increasingly look into rain water harvesting as a decentralized solution to Kenya's water needs (Black et al. 2012).

In Ijara, water sources are either natural or manmade. Natural sources are River Tana, *laghas* and Lakes Jerrei and Hadi within Boni forest. Man-made sources are mainly dug water harvesting pans and shallow wells. In the larger Ijara sub-county, there are twenty water pans spread in Bothai, Handaro, Kotile and Sangole-Ijara whose individual capacities range between 10 and 30 m^3. But the economic study purposely selected Handaro dam based on the numerous livestock and crop agricultural activity that it supports. Also it is the one dam whose construction factored in both crop and livestock whereas other water pans in the area focused on livestock. Water pans serve the major proportion of the sub-county and are key influencers on population distribution, schools, health facilities and administration posts mainly as check against insecurity (GoK 2008). Although River Tana avails water at source to Ijara, it does not currently legally fall under the sub-county. This illegality precipitates occasional pastoralist-farmer-livestock conflicts. Other negative environmental impacts as a result of water resources utilization include ecosystem degradation as a result of unplanned watering point, degradation of water pans due to poor or lack of a management system, underutilization of lakes Jerrei and Hadi, dismal coverage by portable water and siltation. Lack of the management has resulted in under-utilization of the rather endowed pasture area, while areas in the sub-county with proliferation of water points are degraded due to over-use (IUCN 2014).

Objectives and justification for the study

Study questions and objectives were informed partly by data collated from stakeholder registers at the ministries of agriculture and livestock in Ijara which indicated 9000 farmers were active in both crop agriculture and livestock. The objectives were to asses' costs benefits, viability for water harvesting adaptation and whether benefits exceeded costs. A rapid vulnerability assessment was done up-front to determine what crop and livestock strategies were used. From the review it was clear that the population depended on the water pan for domestic, agriculture and livestock use. Water pans in Ijara are strategically positioned to hold-back surface run off, contain underground water and stabilize soils in situ and downstream. Also, the water facilities offer a much-needed source of water to livestock, wildlife, domestic use and crop agriculture. However, neither the costs of implementing the pans nor the benefits gained from the use were clear; given the strategies were spontaneously undertaken which necessitated the economic analysis, so as to inform planning, and policy framework. The analysis focused on Handaro water pan due to the combination of livestock and agriculture activities that took place around it as was anticipated at the planning stage.

Methods

Study area

The study sites were Bothai, Handaro and Ijara divisions in Ijara sub-county. The sites were purposefully selected based on vulnerability assessment carried out with stakeholders up front whose results are indicated in Table 1. The larger Ijara in Garissa locates between latitude 1°, 7′ S and 2°, 3′ S and longitudes 40°, 4′ E and 41, 32′ east and covers 11,332 km^2. It is administratively divided into seven divisions that border Fafi sub-county to the north, Lamu County to the south, Tana River County to the west and Republic of Somalia to the east (Fig. 1).

Biological and physical attributes

The vegetation is generally acacia species of shrubs and grasses particularly star and elephant species. Nearly a quarter of the sub-county is covered by the forest, which is an indigenous open canopy forest that forms part of the Northern Zanzibar-Inhamdare coastal forest mosaic.

Table 1 Summary climate related impacts factors as felt in Ijara

Usage	Quantity M^3	
Rainfall reduction	✓	✓
Erratic rainfall		
Increased rainfall intensity	✓	✓
Sporadic but slightly increased rainfall	✓	✓
Temperature increase	✓	✓
Drought	✓	✓
Prolonged drought incidences after El-nino	✓	✓
Floods/sea water intrusion inland	✓	✓
Unpredictable wind direction	✓	✓

The climatically strategic position, places Ijara in agro-ecological zones IV to VI gradually changing to V and VI, moving away from Boni forest which is influenced by coastal climate. Temperatures range from 15 to 38 °C and the average relative humidity is 68%. The soils are mainly pulverized and acidic with high heavy metal toxicity and P-fixation. The main constraints in the soils are high acidity and low soil organic matter (Obanyi et al. 2009). As for rainfall trend, the IPCC AR4 total annual precipitation projections suggest increases by about 0.2–0.4 percent per year particularly along the coastline where projects sites locate. However, the increase may be annulled by the increased evapo-transpiration resulting from rising temperatures. Rainfall in the area has increasingly become uncertain and the trend analysed using KMS data (40 years) period indicate a definite decline (Fig. 2). However, predictions from across all models indicate an upward trend in rainfall with the area becoming increasingly wet and humid from year 2030. Also recent co-ordinated regional downscaling experiment (CORDEX) models study by Climate Prediction and Applications Centre (ICPAC 2013) clearly showed the performance of

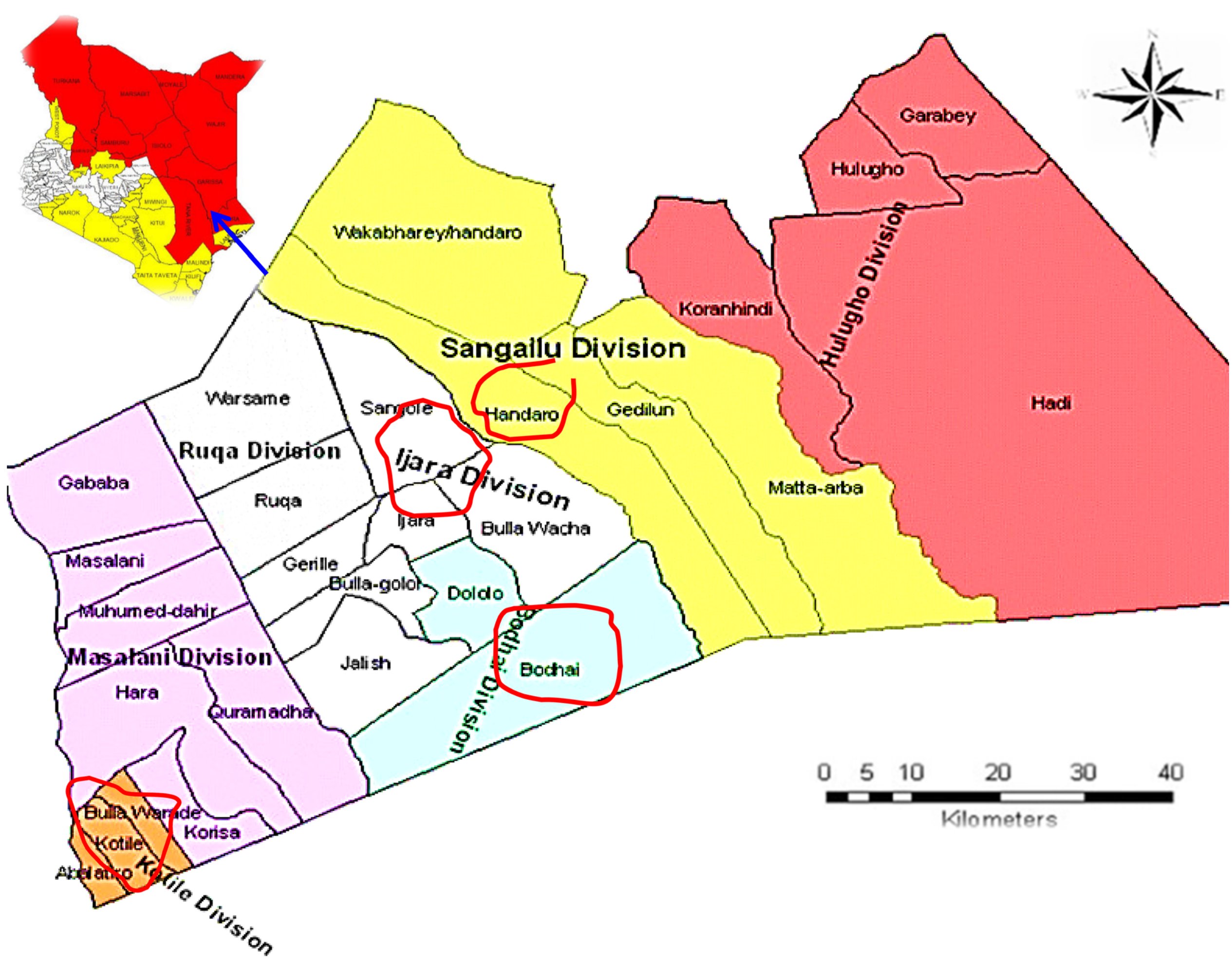

Fig. 1 Kenya Map showing Ijara and study sites

models in projection, effectively reproduced the annual rainfall cycle of the Ijara sub-county (Fig. 3). Costs of climate adaptation are likely to have further positive impact as the spatial rainfall assessment confirms the presence of Inter-Tropical Convergence Zone (ITCZ) as large scale signal causing the two rainfall seasonality of March, April, May (MAM) and October, November, December (OND). These changes in OND MAM seasons will alter agricultural calendar and productivity in Ijara given traditionally OND rainfall has been comparatively higher.

Temperature trend in Ijara

Temperatures ranged 20–38 °C with the hottest being September, January and March, while April to August was relatively cool. The prediction on mean temperature in the region indicated increase by the end of the

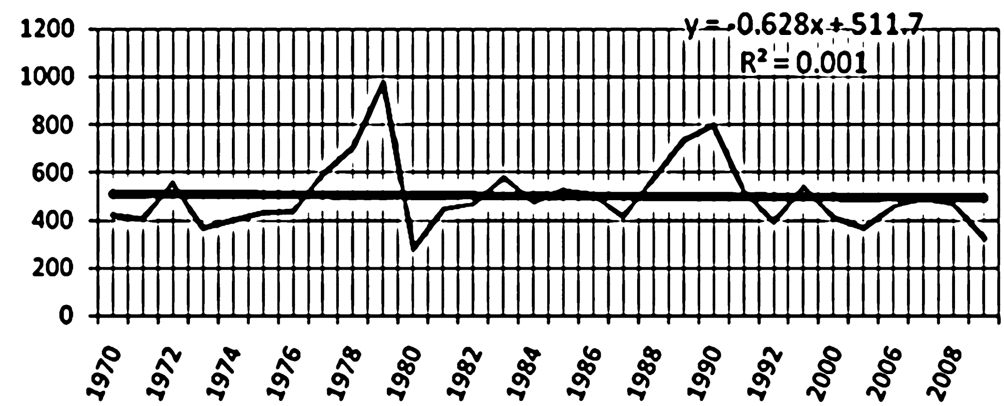

Fig. 2 Rainfall trend 1970–2008; Ijara station

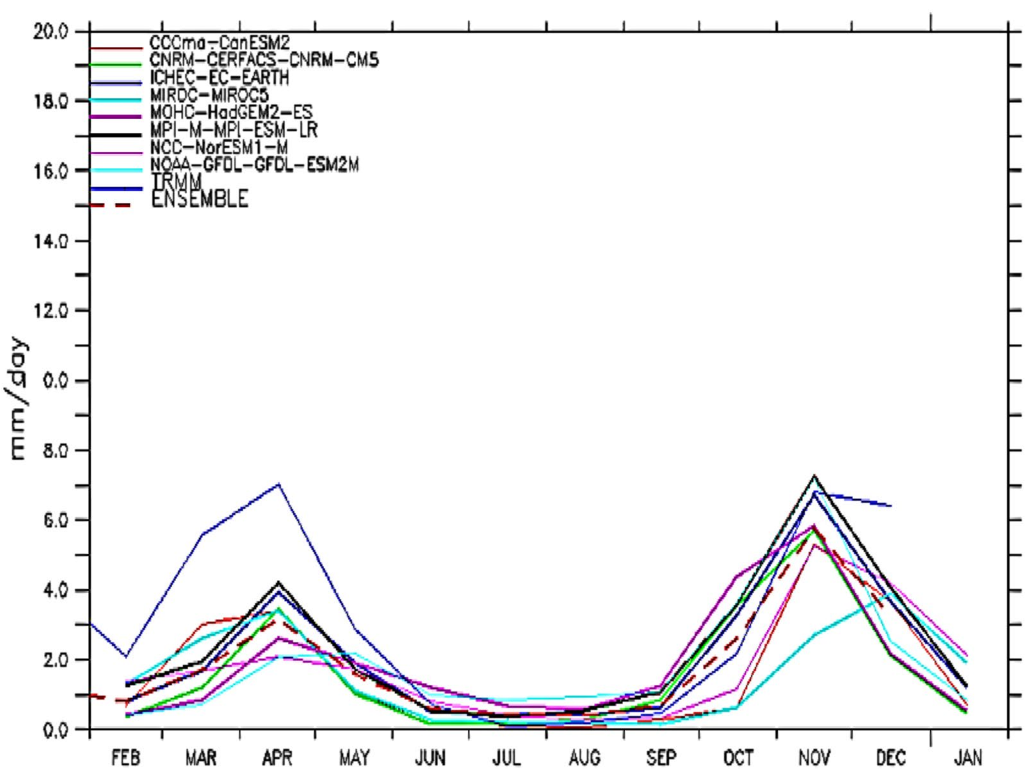

Fig. 3 CORDEX model assessment of the annual rainfall cycle, Garissa County

twenty-first century. The positive trend line was evident from the long term observed records from Garissa MET Station (Fig. 4). The rise in temperature predicted at 2–4 °C by 2100 denote dramatic impacts on vital sectors, chiefly agriculture, with likely virulent effects on the already vulnerable communities (Cooper et al. 2012) particularly in the ASALs such as Ijara, where Handaro harvesting water pan under study locate. The strategy denote shift from the traditional coping and by bolstering cost-effective adaptation whose costs and benefits are clear, it is feasible to thwart anticipated climatic-variability damage by 2030 (Chaisemartin et al. 2010).

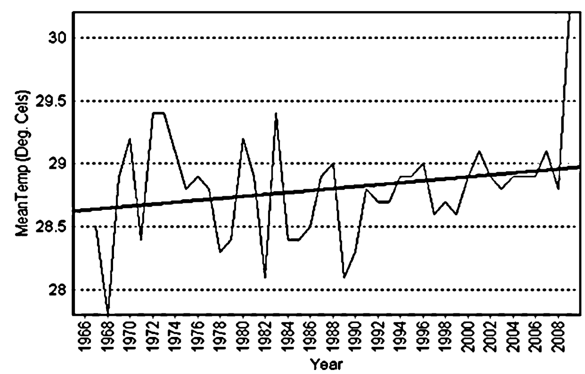

Fig. 4 Mean annual temperature trend (1966–2008)

Socio-economic characteristics

The total population in Ijara sub-county is 92,663 comprising of 50,165 male and 42,498 female. The area's population growth rate is 3.7% (KNBS 2012) while poverty index stood at 63% with over 90% depending on pastoralism (GoK 2005). There are 13,180 households with an average size of 6 members. The number of female headed households is 4006 and children headed households 572 (Ijara District Strategic Plan 2005–2010). Approximately 640 people are disabled while about 1246 children need special attention. The sources of income in the sub-county are as follows; 60% (agriculture, mainly livestock); 20% (rural self-employment); and 15% (wage employment) (GoK 2009). The key drivers of poverty in the sub-county include poor governance and weak institutions; high population growth rate; high illiteracy levels; limited access to capital and markets; poor infrastructure; ecosystem degradation; inter-clan-ethnic conflicts; cyclic complex disasters primarily drought and floods; and over-reliance on livestock (Ijara District Strategic Plan 2005–2010).

Research design

The study design was survey via purposeful sampling to identify focus groups and expert key informants for in-depth investigation given both categories were especially informative on costs benefits of water harvesting adaptation in use (Neuman 1997; Creswell 2014). For purposes of generalization inferential statistics were used to make deductions and generalizations about the whole population. The results were presented in form of tables, and figures. The quantitative and qualitative interview tools were handy in interrogating costs and benefits of water pan. Cost benefit analysis was used to compare the present value of a stream of benefits to a stream of costs. These values were discounted to calculate the present value of future costs and benefits. Adaptation costs quantified were those on planning, land preparation, fencing, seeding and labour, whereas adaptation benefits were water for domestic and livestock use, incomes from sale of agricultural products around Handaro water pan and time saved from trekking far for water which is invested in other economic pursuits.

Sample size and sampling

The sample was arrived at using a table developed by applying the formulae for determining sample sizes for known populations as shown below (The NEA research bulletin 1960; Neuman 1997): The formula discussed was used to determine the sample size drawn from a finite population of 9000 households in Ijara:

$$\text{Size} = \frac{X^2NP(1-P)}{d^2(N-1)+X^2P(1-P)}$$

where: X^2 is the value of Chi square @DF = 1 for desired confidence level for 0.10 = 2.71. N is the population size which in this case is 9000 households. P population proportion (assumed to be 0.50). D is the degree of accuracy (expressed as a proportion).

For purposes of the analysis, the following values were used for the parameters in the formulae. For purposes of the analysis, the following values were used for the parameters in the formulae:

i. Took the value of the Chi square (X^2) at degrees of freedom = 1 at the desired confidence interval of 0.10 which when looked up at the Chi square distribution table yields 2.71.
ii. In addition N was considered; being the population under study, that is 9000 households actively engaged in farming.
iii. Took the population proportion to be 0.50.
iv. The degree of accuracy expressed as a proportion, was calculated as 0.00523. Given the above values, the following was arrived at:

$$Size = \frac{2.71 \times 9000 \times 0.5(1-0.5)}{0.0523^2(9000-1) + 2.71 \times 0.5(1-0.5)}$$
$$= \frac{2.71 \times 9000 \times 0.5 \times 0.5}{0.00274 \times 8999 + 0.677}$$
$$= \frac{6097.5}{24.65726 + 0.677}$$
$$= \frac{6097.5}{25.33426}$$
$$= 240(\text{Roundedtothenearestwholenumber}).$$

Of the 13,180 households in Ijara; only 9000 actively engage in either livestock or crop farming. Given the sample population is 9000, sample size n = 240 households, for the selected sites in Handaro, Ijara and Bothai were purposefully drawn assigning 80 households per site. Random sampling was then applied to select the 80 households from total population of each of the three sites.

Data instrumentation, analysis and presentation

Structured questionnaires were administered to 240 pastoralists and agro-pastoralists in Bothai, Ijara and Handaro divisions of the larger Ijara sub-county. The questionnaire development procedure was a kin to works by Thrusfield (1986) and Osotimehin et al. (2006) and included open and closed-ended types of questions. The variables in the study were costs, benefits and adaptation (independent variables). The desired phenomenon (dependent variable) was sustainable social welfare and upped resilience. Statistical package for social science (SPSS Version 18) and Excel software packages were used to analyse the data. The methodology used to calculate economic returns was cost benefit analysis (CBA) employing the net present value (NPV) tool to show strategy viability. As described below, the study used the Krutilla and Fisher model Krutilla (1975) to interrogate the cost-benefit analysis (CBA) through the net present value to determine whether the water pans costs would be profitable compared to the baseline or "without the adaptation" or "alternative intervention". Building on works by Myers and Allen (2005) the cash flows were discounted at the market rate as appropriate cost of capital as follows:

$$NPV = CF_0 + \frac{CF_1}{(1+K)^1} + \frac{CF_2}{(1+K)^2} \cdots + \frac{CF_n}{(1+K)^n}$$

where *NPV = Net present value, CF_o, CF_1, $CF_{2\ldots}$ CF n, are the cash flows (Monetary costs-Monetary benefits) for periods t = 0, 1, 2... n K = the discounting factor also known as the opportunity cost of capital.* NPV = Present Value of future cash flows–Investment. NPV Decision Rule: If NPV $\geq$ 0 then investment in a strategy is considered viable and acceptable.

The study sought to unveil the costs and benefits from livestock feed enterprises, water pans and aloe crop and to relate them to the awareness level to the overall climate change adaptation. The following financial indicators were evaluated for the adaptation:

i. Cash flow was used as a measure of the balance between revenues and costs, with appropriate accounting for depreciation and liabilities. The discount rate used was 15% being the prevailing interest rate in the financial markets which rates decline over time (Myers and Allen 2005);
ii. Net present value (NPV) tool was used being the sum of revenues and costs over time, based on an assumed discount rate, referenced to the present (the first year);
iii. Payback period factored in was 5–10 years being the period in which it is expected that the cash inflows will outgrow the recurrent costs and provide desirable returns for the investment.

Results and discussions

Vulnerability, risk assessment and identification of strategies

At the pre-field phase of the study rapid household vulnerability assessment was conducted followed by adaptation options selection. Farmers in the three project sites concurred on the following; (1) rainfall had declined and become more erratic both in intensity and spatial (2) temperature was on positive trend, frequent and prolonged droughts threatened agriculture livestock productivity (3) wind direction was increasingly unpredictable and affected rainfall distribution or its failure altogether (Table 1). Identification of water harvesting pans, as adaptation option was finalized in a participatory manner

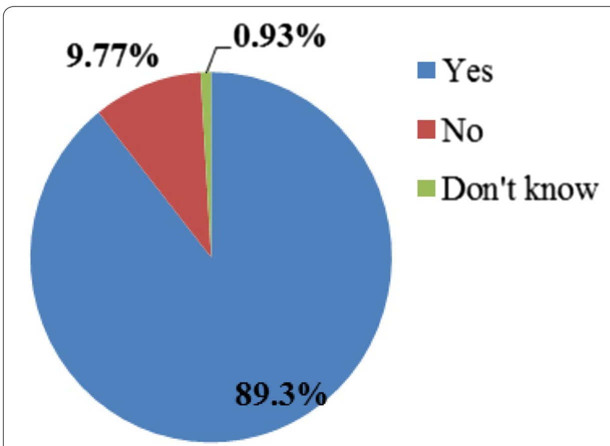

Fig. 5 Economic effects of water pan on crop production

based on the vulnerability assessment results. Other considerations included the economic study timelines, viability of the identified option particularly costs and benefits.

Economic analysis of water pan adaptation strategy

Water pans in Ijara serve the major proportion of the sub-county and are key influencers on population distribution, schools, health facilities and administration posts (GoK 2008). Only 15% of the total population has portable water (Ijara district strategic development plan 2002–2008). Besides River Tana, Lakes Jerrei and Hadhi, Ijara has 20 water pans. Water availability tackles farmer-pastoralist conflicts which in turn curtails ecosystem degradation due to unplanned watering points. Other water challenges include, siltation, degradation of water pans resultant to poor management (GOK 2008). The water pan presented impacts costs to include acquisition of land, steep capital outlay, attracting informal settlement around it and possible emissions from the many livestock and wild game that congregate around it daily. These are some of the benefits and costs that the study assessed to ascertain economic viability of the adaptation strategies in use. Although water needs in Ijara are acute specifically for livestock, domestic and crop farming, the study explored broader economic water values as use values are inter-linked. The values were generally classified as use and non-use values. Within use values, there were direct (consumptive e.g. irrigation) or (non-consumptive e.g. water for aesthetic). Non-use values (existence, bequest, philanthropic) were of ethical concerns and altruistic preferences stemming from self-interest and non-direct use values (Kerry et al. 2004). Of greater interest in Ijara was consumptive water use value given its scarcity and high demand for livestock, domestic and subsistence crop farming. Currently that demand is met by 20 water pans constructed over the years largely through external aid complemented by labour and goodwill from local community. The study focused on Handaro water pan constructed in 2009 by the Ministry of Agriculture through NALEP programme with Handaro community contributing labour, but remained largely unclear about the costs of implementing the pan and benefits that accrued thereof.

Handaro water harvesting pan is in *Bulla* Handaro in Sangailu division of Ijara sub-county. The area covers 2470 km^2, a population 12,534 persons who are served by the water pan. The pan has capacity 30,000 m^3: top (90 × 120 m^2, bottom 80 × 100 m^2 depth 3 m, side slopes 1:2, and cost USD 99,399 to construct (Ijara District Strategic Plan 2005; Ministry of Water and Irrigation 2009). Estimated water loss through evaporation was 7.5 m^3, with the same amount earmarked for domestic, livestock and irrigation. The sizeable water source was constructed to mitigate for the 3–4 years cyclic drought experienced in the area affecting the community lifestyle and settlements as they were forced to migrate in search of water and pasture and sustenance (GOK 2008). Also the facility construction factored in both crop and livestock whereas other water pans in the area focus on livestock. Given the water stress, women and girls bore the blunt as they were culturally bound to fetch water, 20–30 km away. Based on the dual initial expectations on the pan, and the numerous livestock and crop agricultural activity it supported, the economic analysis focused on it (Table 2).

Major problems experienced before the water pan was constructed were acute water shortage, as indicated by 36.66% of the households, food shortage 24.16%, socio-economically valuable time wasted trekking for water 9.16%, livestock diseases and deaths 8.33% and 12.08% respectively (Table 3).

These constraints are of concern particularly in the face of prediction of higher temperature of 4 °C by 2100 (IPCC 2007). Adapting to the warmer climate through implementation of strategies such as Handaro water pans is costly but adapting is imperative as costs of not doing it will be much more. What these costs mean for ASALs such as Ijara is that adaptation is a must and must be done now, approaching it via tackling roots of poverty through development projects which are to be done differently, not business as usual way. In this resilience enhancing interventions land is a central factor of production and maximizing land use will catalyst poverty reduction as well as support desired adaptation, barring stringent tenure system. As an ASAL, land in Ijara is communally owned and governed by customary land law that accords rights to every community

Table 2 Handaro water pan capacities

Usage	Quantity m^3
Domestic, livestock and irrigation	7.5
Estimated evaporation loss	15
Estimated seepage loss	7.5
Required storage capacity of Handaro Pan	30

Data source ministry of water and irrigation, Ijara

Table 3 Challenges encountered before water pan

Challenges	Freq	%
Animal diseases	20	8.33
Attacks from wild animals	23	9.58
Shortage of food	8	24.16
Water shortage stress	88	36.66
Wasted time trekking for water	22	9.16
Livestock deaths	29	12.08
Total	240	100

member but lacks incentives and sanctions for efficient utilization and management (GoK 2004). All the households reported that water pans were constructed in their areas as a response to adverse effects of climate change on their lives and livestock. However, the number of water pans differed in that some areas had only one water pans while others more. Out of the total number of household 98.3% were aware that ownership rested with the community. The high rate of awareness portended well for sustainability given water pans requires regular management to include periodic de-siltation.

As for Water pan excavation 92% household were aware that it was by mechanical means and only complemented by 4% manual excavation. Ninety-five percent of the households appreciated that water pan costs of maintenance were firmly in the hands of respective community. On Water pan excavation 92% households were aware that it was by mechanical means and only complemented by 4% manual excavation. Ninety-five percent of the households appreciated that water pan costs of maintenance were firmly in the hands of respective community. Up to 84% local communities appreciated that that if the water pans were not maintained, they would remain useful only for 1 year. This result indication is critical as it does flash grave consequences in the event of non-maintenance as is the case for most water pans in Ijara sub-county. The study focused on Handaro water pan mainly because of current usability and potential to support continued adaptation. It was excavated by Ministry of Agriculture through NALEP program in 2009.

Key socio-economic benefit from water pan was the increase in cattle per household at the rate of 3 heads after water pan was available; the number of sheep rose by 4 heads while goats increased by 5 heads. The increase represents increased incomes in livestock which is welcome input from water pan strategy.

Costs and benefits of Handaro water pan use

Breakdown of costs as obtained from key informants from the Ministry of Water and irrigation, Ijara and Garissa indicated that Handaro Water pan cost US$105263. Key cost streams in its construction were excavation, bush clearing, fencing, and labour (Table 4). Excavation was clearly high capital outlay costs but benefits exceeded costs as from year two on based on revenue netted from agri-business and other activities it supported. Before construction of the water pan households had to walk 15–30 km daily in search of water for domestic and livestock use but the pan has reduced the distance to less than 4 km for most households. Also the study clarified that the typical water pan holds water for a mean period of 10 months. This translates to a total value of water impounded to an average US$18701 for that period of time. The value was arrived at by asking the respondents how much it would cost them to obtain the same amount of water from water trucking services available in the sub-county. This is a welcome saving as recent costing of Emergence Water Trucking showed that the cost of 1 m^3 of water after being trucked to a location 65 km away from the water source was 160% times more than the same amount of water at the source. However not many households in the area were aware of these costs least of all the excavation costs as 15% specified they were aware but 81.66% indicated unawareness.

Table 4 Willingness to pay for water

Response	Frequency	Percent
No	50	21.74
Yes	180	78.26
Others	10	
Total	240	100

Further, US$18083 was the total sum respondents would be willing to pay for the same volume of water if they were to purchase it in terms of jerry cans to irrigate their crops, water their animals and for household consumption. The sum total of such expenditure yielded monetary benefits derived from the use of the water pan. This was the response derived from the direct question put to the respondents in terms of how much they would pay (Table 4) in which 78.26% were willing to pay.

Additionally, the water pan generated monetary benefits drawn from household savings from labour, sales of crops around water pan, domestic water use and income from other economic activities through time saved.

Equal to 79.58% households indicated water was not used for irrigation while 17.08% differed (Table 5). The implication here is that, crop farming was not a major activity and was comparatively a recent innovation.

The cash flow of costs and benefits

The following are the Water pan costs and benefits for Handaro water pan mechanically excavated with capacity 30,000 m^3. The 5–10 year period is the interlude in which the water pan can last under good maintenance in

Table 5 Water use on irrigation

Responses	Frequency	Percent
Yes	41	17.08
No	191	79.58
Total	232	96.66
System	8	3.34
Total	240	100

order to supply the same level of economic benefits. The water pan can last for twenty years under good maintenance in order to supply the same level of economic benefits. The analysis considered the cash flows for a ten year period applying the NPV formulae discussed earlier: Net present value of cash flow, investment decision being if NPV ≥ 0 then the adaptation is economically feasible. The net present value from the investment was US$5393, which being greater than zero, meant water pan as adaptation strategy was economically viable.

Economic impact of water pan on crop production

The water pan provided the much-needed benefits reprieve from drought ravages and ensuing high costs of production in the area. Up to 89.3% of agro-pastoralists indicated that the water pan was economically viable. This view is supported by positive cash flow on bumper yield from on-farm pasture of 9227 kgs per ha retailing at US$0.55 from livestock feed enterprise cash flows. Most farming in Ijara is rain-fed, but due to worsening climatic conditions farmers have to adapt to irrigated farming using technologies, water pans a case in point (Fig. 5). But, even then, the study indicated that only paltry 5% did irrigation, sourcing from nearby water pan as the pans cannot sustain intensive irrigation due to high costs stemming from the rising demand for water that is shared between wildlife, domestic and livestock. However, 56% of farmers preferred water pan to appealing to the international community for emergency assistance when drought occurred as it has resulted in dependency syndrome with higher costs on life. An alternative to water pan in the area is Emergency Water Trucking (EWT) which is increasingly becoming a common method for delivering water in response to drought emergency is not necessarily cheaper. Recent costing in Mandera's Rural Agency for Community Development and Assistance (RACIDA) showed that the cost of 1 m^3 of water after being trucked to a location 65 km away from water source was 160% times more than the same amount of water at the source (FAO 2009).

Viability of the strategies for adaptation

With cash flow per year at US$5393 the study clarified that benefits from the water harvesting strategy exceeded costs incurred. The benefits from the asset included livestock value improvement, time wasted previously trekking in search of water was saved to engage other income generating activities. Additionally, the pan water was used for irrigation and supported pasture growth. Other benefits that outwitted costs were environmental benefits to include micro-climate, carbon sink, cropping whose co-benefits include green fertilisers, crop residue, manure, green cover and soil enrichment.

The study indicated that implementing water pan, effectively managed costs arising from extreme weather events, drought in particular. For long drought and floods seemed natural to life in Ijara, like other ASALs of Kenya as attested to by the five devastating droughts in the last decade; 2001, 2003, 2006, 2009 and 2011 and major floods in 2006 and 2010 (Fitzgibbon 2012). These extreme weather events dealt significant blow to the economy as was the case with the 1998/99 *El Nino* floods that stagnated ASAL economy. Given the persistence of the extreme events, economic costs of the impacts on market and non-market sectors will be a disconcerting 3% of Kenya's GDP per annum by 2030 with potential to rise to above 5% of GDP per year by 2050 (SEI 2009). And yet managing drought is an exorbitant venture as indicated by government's expenditure of over USD 10.5 million on food relief excluding contribution from development partners. Other expenditure on the same around same time was UN and GoK joint appeal in May 2000, USD 121,029,702; and an additional USD 122,650,146 spent in February 2001 (GoK 2004). Key among adaptation measures instinctively put up then to bear the blunt of these shocks were water harvesting pans, such as Handaro which was found viable investment in the study.

Conclusion and way forward for water harvesting pan strategy

Water pan net benefits exceeded costs given livestock asset value were improved as the water supported pasture growth. Also, time wasted previously trekking in search of water was saved to engage other income generating activities (Table 6). Before construction of the water pan households trekked 15–30 km daily in search of water for domestic and livestock use but the pan has reduced the distance to less than 4 km for 70% of the households. Other benefits that outwitted costs were environmental benefits to include cropping whose co-benefits included green fertilisers, crop residue, manure, green cover and soil enrichment. A key conclusion from the study was

Table 6 Number of livestock kept before and after pan

Livestock before and after pan	Mean	N	Std. deviation	Std. error mean
Cattle before pan	7.25	209	8.47	0.59
Cattle after pan	11.29	209	10.69	0.74
Sheep before pan	8.86	207	7.98	0.55
Sheep after pan	13.38	207	11.44	0.80
Goat before pan	9.76	206	8.82	0.61
Goat after pan	15.44	206	13.46	0.94
Camel before pan	3.36	153	40.42	3.27
Camel after pan	0.19	153	1.24	0.10

that with NPV of US$ 5393, Handaro water harvesting pan was economically viable as adaptation strategy, despite the initial steep costs that taper off after year two of usage. Additionally, the water pan impounds water for 10 months annually which translates to an average US$18701 for that period of time as shown by comparison of obtaining the same amount of water from water trucking services available in the sub-county. Policies need to capture the benefits and build water harvesting provision sustainability. Further, policies need to tackle impediments to community members taking up non-livestock-based opportunities for diversification.

Authors' contributions

JM developed the concept, carried out the field data collection and data analysis, and drafted the manuscript. JK and EK made comments on the manuscript. All authors read and approved the final manuscript.

Author details

[1] Kenya Agricultural and Livestock Research Organization, P.O. Box 230, Garissa 70100, Kenya. [2] Kenyatta University, P.O. Box 43844, Nairobi 00100, Kenya.

Acknowledgements

Authors wish to acknowledge Director General KALRO, IDRC for financial support under Agricultural Productivity and Climate Change in the Arid and Semi-Arid Kenya Project, KALRO Garissa for logistical support.

Competing interests

The authors declare that they have no competing interests.

Received: 7 March 2016 Accepted: 6 March 2017
Published online: 27 March 2017

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