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Assessment of the Environmental Impacts of Irrigation Water Use by Smallholder Farmers in Gem Rae Irrigation Scheme, Kenya

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Abstract

Kenya places a lot of emphasis on the reduction of poverty in order to improve livelihoods of the people. In order to accelerate this, the government of Kenya has adopted a strategy to revitalize Agricultural sector through irrigation development among other strategies. Irrigation provides the best option for intensification of agricultural production since options of achieving the same through rain fed agriculture are almost exhausted. The study reviewed experience with irrigation projects in Kenya with particular attention to smallholder irrigation in Gem Rae. It examined the environmental impacts such as siltation, soil erosion and public health impacts associated with irrigation development. The study used cross-sectional survey technique in which a sample of 119 smallholder farmers practising irrigation interviewed using a structured questionnaire. All chairmen of scheme management committees were involved in a group discussion. Data was analysed using frequencies and percentages. The study revealed that impacts such as siltation, water borne diseases, soil erosion, water supply and loss of biodiversity were statistically significant. There was increased water borne diseases as result of irrigation development. This resulted in public health hazards, reduced labour supply and low scheme production levels. The study further showed that these impacts had adverse negative effects on the level of household rice production and household incomes to smallholder farmers in the study area. From the study,

it proved that the future development of smallholder irrigation needs to factor in the social economic and environmental trade-off of irrigation in the suitability criteria for its development. Also measures such as construction of earth dams, use of protective clothing, fish farming, issue of title deeds, construction of water intake and infrastructure development among others should be considered in order to mitigate the negative impacts for better management of irrigation schemes in Kenya for sustainable food production and poverty alleviation.

Key words: Environmental impacts, smallholder farmers, poverty alleviation, sustainable food production, household incomes

INTRODUCTION

Kenya has a total land area of 582,646 square kilometres of which, about 99,050 square kilometres (17%) is classified as medium to high agricultural potential experiencing at least 700mm of rainfall per annum. The remaining 83% is classified as Arid and Semi-Arid Lands (ASAL) and needs some irrigation for meaningful farming to take place. Irrigation is necessary in order to increase food production to provide food security to support the rapidly growing population, and ensure economic growth in the dwindling land holdings of high to medium potential areas. To ensure household food security and improved living standards of the rural population, the government and donor agencies continue to support the development of smallholder irrigation schemes (Gichuki *et al*., 1992). This is due to their ease of management and because they have direct impact on the livelihood of rural households.

Gem Rae irrigation scheme is one of the smallholder irrigation schemes in Kenya in which farmers' groups manage irrigation water on their own and share development costs among themselves. The farms are of variable sizes and are operated by farmer's organisation within the scheme. The area is within Lake Victoria basin. It receives a mean annual rainfall of 1250mm with peaks in April and November. The area is characterized by unreliable rainfall with constant floods, which displaces residents almost yearly. Other characteristics include resource degradation through soil fertility loss, destruction of natural vegetation and loss of biodiversity. Irrigation therefore became necessary, not only to increase agricultural production but also to control flood occurrence. The produce from the scheme is used to meet subsistence demands as well as for domestic market. However, most residents of this place and particularly those who practice farming as a full time occupation are still food insecure and live below poverty line. Increasing agricultural productivity will be necessary for increased food production and poverty alleviation in the area. Irrigation development can achieve this but only if it is done sustainably. The sustainability of irrigation projects depends on the taking into consideration of environmental effects as well as on the availability of funds for the maintenance of the implemented schemes (FAO, 1997).

The need for expansion of irrigation in areas with irrigation potential while encouraging introduction of supplemental irrigation in medium to high rainfall areas to guard against crop failure and ensure high quality produce is paramount. The Economic Recovery Strategy for Wealth and Employment Creation (2003-2007), targets the development and rehabilitation of irrigation schemes in the country to increase production of strategic crops such as horticulture, cotton and rice. The National Development Plan (2002-2008) also emphasizes creation of an enabling environment to accelerate irrigation development in the country. The Kenya vision 2030 document envisages a transformation of agriculture from the current practices to a more commercially oriented agriculture (GOK, 2007). The agriculture sector remains a key pillar of the Kenyan economy contributing about 25 percent of GDP. However, productivity in the sector is significantly lower (2-3 times) than international benchmark countries. The sector possesses additional opportunities to unlock potential of Kenyan land

with a strong need for legal and institutional reforms. Among other areas, the document proposes a strategy to prepare new lands for cultivation by strategically developing irrigable areas of Arid and Semi-Arid Lands (ASALs) for both crops and intensified livestock production. It also proposes an increased access to markets particularly to small holders through establishment of aggregators. The aggregators are expected to greatly improve the supply chain, eliminate middlemen and hence benefit the farmer through higher producer prices.

However, it is important to observe that irrigation activities, whichever type practiced is likely to affect the natural ecological systems in the irrigation areas. This could adversely affect human beings, plant and animal life (Odhiambo *et al*., 1991). These effects on natural ecological systems are referred to as environmental impacts. These impacts may be positive or negative and can be socio-cultural, physical, biological or chemical (Yabann, 1996). The benefits of irrigation are many and include food security, increased incomes, and employment creation among others. The negative impacts may affect food production, the very commodity irrigation was designed to achieve. Despite the growing evidence on the environmental impacts of irrigation, many governments look to irrigation schemes for improving food security of the country; improving incomes of the peasant farmers, and contributing to the development of the national economy (Haile, 1988), without paying adequate attention to the social, cultural and environmental sustainability of the scheme.
This paper reviews the environmental impacts associated with irrigation water use in Gem Rae irrigation scheme and how they can be mitigated for sustainable development of irrigation activities to enhance household food security.

METHODS AND MATERIALS

Field Sites

The study was carried out in Gem Rae irrigation scheme. The site was chosen for the study because it is a smallholder irrigation scheme: irrigation management system that has shown tremendous expansion in Kenya and is managed by individual farmers. The scheme also practices flood/basin irrigation, a system that is believed to be associated with a lot of environmental consequences.

Gem Rae is a rice-growing scheme close to Lake Victoria, about 30 kilometres from Kisumu. It is in North Nyakach Location, Nyakach district, Kisumu County, Kenya. The water source for the scheme is the River Awach. Topography across the scheme is flat with an average gradient of about 0.5% and prior to irrigation the area was mainly wetland with periodic flooding. The prevailing soils across the scheme are medium to heavy, dark grey or black clay soils suitable for rice cultivation. The scheme is in the lower midlands agro-ecological zone classified as humid/arid. Mean annual precipitation is 1250mm with peaks in April and November. The rainfall pattern is highly variable, however, with monthly maximum typically two or three times the mean. Temperatures are fairly constant throughout the year with monthly maximum ranging from 25ºC and 35ºC.

The current irrigated area is approximately 90 ha with a total of 270 plots averaging 0.3 ha. There are 250 landowners. A further 28 ha is occupied by out growers on the fringe of the scheme making use of excess water from Gem Rae and flow in the river downstream of the intake.

Survey Study

The study employed a cross-sectional survey research design to collect data from the sample size of 120 smallholder farmers. This type of design involves data collection in only one survey round (Casley & Kumar, 1988). Surveys are important in research and have been found to be effective in describing characteristics of population under study (Kathuri & Pals, 1993; Fraenkel & Wallen, 2000). They are cost effective and also exploratory enabling the researcher to make inferences though not to the level of cause and effect (O'Connor, 2002).

The collection of primary data relied on a rapid assessment procedure using structured questionnaire addressed to farmers within the study area and interview schedule to guide a focus group discussion with leaders of scheme management committees. Data was collected at one point in time from a purposive sample of 119 households. Simple random sampling was done on the sample frame to select the required sample. The data was then summarized, coded and entered into the computer where analysis of quantitative data was done using the Statistical Package for Social Sciences (SPSS). Frequency and percentages were used for analysis of data. Qualitative data from focus group discussion was analysed using checklist.

GENERAL CHARACTERISTICS OF SMALLHOLDER FARMERS IN THE STUDY AREA

Age Distribution of the Farmers.

The 23.5% of farmers interviewed indicated that they were between the ages 34 – 41 years. This is a prime age when the farmers are active and can work for long hours and for many years. This is an important aspect for sustainable food production. Such people are also ready to adopt technologies delivered to them. Figure 1 present the frequencies and percentages of age group of the farmers interviewed. Farmers who are within the age group 18 – 43 years tend to be more active in practical, as compared to older farmers. It can however be seen from Figure 1 that majority of the farmers interviewed (66.4%) had the age of forty-two years and above. This is an aging group and may be detrimental to sustainability of production. However, groups with majority of members within similar age group are expected to be more effective. This is because members of the same or similar age group tend to have similar interests.

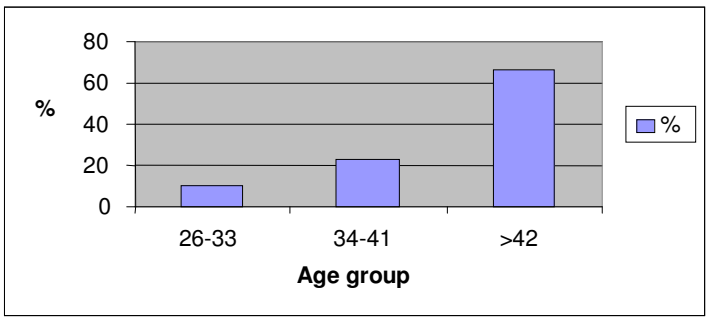

Figure 2: Age of the farmers

Length of Time Stayed on the Farm

Table 1 indicates that 33.6% of the farmers interviewed had stayed in the scheme for over forty-one years whereas 51.1% of women farmers interviewed said that they had stayed in the scheme since marriage. Farmers were asked to indicate the number of years they had stayed in the scheme. This one was done to determine the originality of the respondents. This would then be used to gauge the sustainability of rice production in the scheme. This is because the original inhabitants of the scheme are likely to spend their entire lifetime there and would like to reap the benefits of the scheme for long. This may be as opposed to the emigrants who may not have incentive to improve land for production. Most of the

respondents were found to be original residents of the scheme. Table 1 presents the length of time the farmers had stayed in the scheme.

Table 1 : Length of time the farmers had stayed in the scheme

Time (years)	**Percentage**
21-30	2.5
31-40	11.8
>41	33.6
Since Marriage	52.1
Total	**100**

Level of Education of the Respondents

Figure 2 shows that 55% of the farmers interviewed had at least primary level of education and another twenty-two farmers (18.5%) had secondary school level of education. Those with secondary level of education and above were 21.9%. It can be noticed that Figure 2 presents the frequency and percentages of these levels of education of farmers. The farmers with high level of education are expected to have high intellectual capacity. This high level of education enhances the understanding of information given and should also improve the farmer's level of participation in agricultural activities.

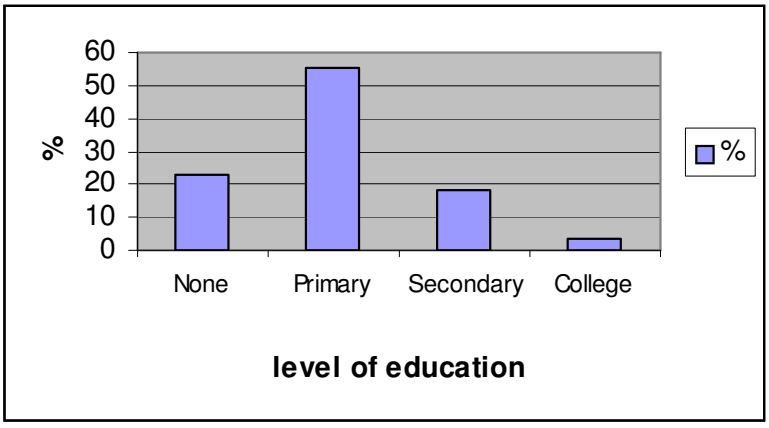

Figure 3: Level of education of the farmers

Gender Distribution

More than half of the farmers interviewed (53.8%) were female compared to 46.2% being male. The gender distribution of the farmers interviewed is shown in Table 2. This is an indication that women play a significant role in scheme management and operations,

especially in situations where men are on off-farm employment or are looking after livestock. The intensification of agricultural production, which goes hand in hand with irrigation, results in considerably more work for smallholder households. Women were observed to be having bigger workloads, as they were also responsible for all domestic duties such as fetching water and firewood. Women were also represented in scheme management committee. This was observed since the treasurer of scheme management committee was a woman. However there is need for an increased representation of women in the scheme management committee since they are the majority. The traditional attitude of the scheme communities towards women's roles needs to be investigated, so that appropriate approaches to encourage their participation are identified.

Table 2: Gender Distribution of Farmers

Gender	Frequency	Percentage
Male	55	46.2%
Female	64	53.8
Total	**119**	**100.0**

Household Size

It is indicated that 37.0% of the farmers interviewed had household size of between seven and ten people. 36.1% of the farmers interviewed had between four and six people in their households. Household size refers to the number of dependants in the household including children and relatives staying within a household. In many cases, the household size provides a measure of the availability of family labour for farming activities. However, with the large household sizes coupled with occasional poor crop harvests, most farmers indicated having problems in meeting food demand for the household members. Some farmers talked of caring for the children orphaned as a result of HIV/AIDS related infections. Figure 3 presents the household sizes of the farmers interviewed.

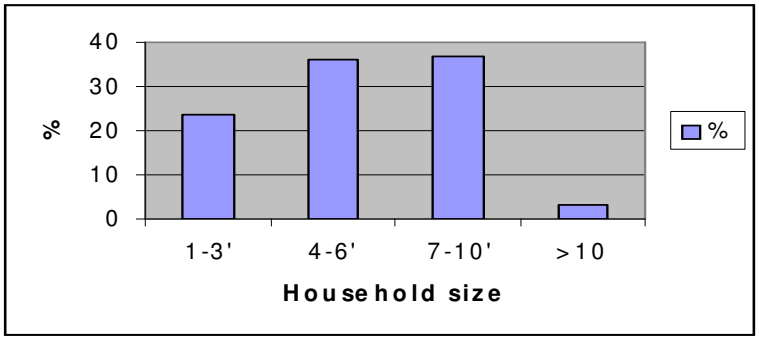

Figure 4: Household sizes of the farmers

RESULTS & DISCUSSIONS

ENVIRONMENTAL IMPACTS IN GEM RAE IRRIGATION SCHEME

Introduction

This section highlights the results of the study in relation to the objectives of the study. It presents analysis of environmental impacts of the scheme operations, public health issues in the scheme and environmental management. The data was collected from 119 household

heads out of the target population of 120 household heads practising smallholder irrigation in the scheme. This presented 99% response rate which was high enough to guarantee acceptability of te study results.

Water Logging

Flooding and drainage problems are normally experienced by irrigation schemes located in flat topography such as Gem Rae. Of those interviewed, 97.5% of the scheme farmers mentioned that the problem results in increased number of mosquitoes and labour inputs. This leads to low crop production. The problem of water logging however does not entirely arise from scheme implementation but was already common to the area due to constant flooding as reported by 95.8% of all the scheme farmers interviewed. The incidence of water logging was common during rainy season as a result of floods but since irrigation is carried out during dry season the few cases of water logging could not be linked to irrigation development, in any case irrigation development play a role in flood control other than just to increase production of rice in the study area. The problem however interferes with scheme operation and performance through structural and crop damage. Some farmers especially those whose plots are adjacent to the river had since abandoned their plots due to floods.

Results reveal that 78.1% of all the farmers interviewed said that they use dykes and bands around homes and rice fields to control floods. They however claimed that these measures were expensive in terms of labour input. Also 20.2% of all the framers interviewed would leave the water to drain naturally due to lack of finance to engage labour. Figure 4 presents the causes of water logging in the scheme.

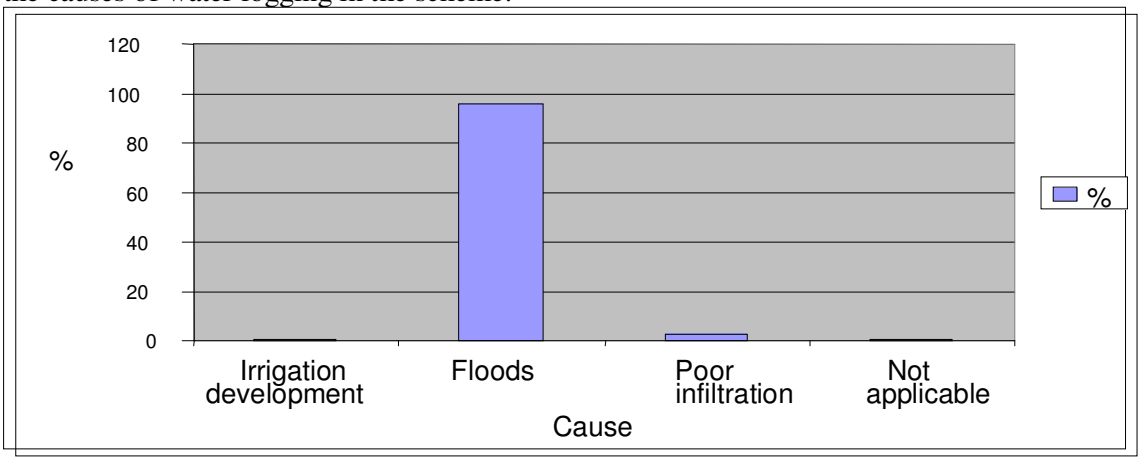

Figure 5: Causes of water logging

Siltation

Siltation of canals was found to be a very big problem in Gem Rae irrigation scheme. This was particularly evidenced by an intake at River Awach that has since been abandoned due to high load of silt. Farmers found it labour intensive to keep on de-silting every planting season leading to abandonment of the intake. Siltation is mainly dependent on the origin of the irrigation water, which determines the sediment load but can also be influenced by other factors such as poor maintenance of canals and destruction of canal by livestock

The findings indicate that 89.9% of all the farmers interviewed blamed the problem on poor farming methods upstream, leading to collapse of riverbanks hence high sediment loads. When asked to respond on the extent of the effect of siltation on farm activities, 91.6% of all the farmers interviewed reported that the effect was negative with increased seriousness of flooding and water shortage in the scheme.

Field observations show a build up of sediments in slower moving areas of the water channels and a shrinking of the river in sections close to irrigation main canals. These results corroborate the findings by Urama (2005) that indicated that the water flow rates in the headrace canal are higher than in the secondary canals, thus sediments settle out in areas where the flow velocity decreases, changing the river flow regime. These changes are partly responsible for water supply problems especially to the downstream users. Frequent clogging of irrigation abstraction structures by soil sediments during the life of the projects was reported by farmers.

However, a positive effect is the deposit of nutrient carrying silt in the scheme plots that replenishes the soil nutrient content, improving crop performance. On the estimated cost of maintaining these canals during plating season, 70.6% of all the farmers interviewed said that the cost was high since de-silting 20 metres of canal would cost about Kenya shillings 100. This increases the cost of production. Figure 5 highlights the sources of silt in the scheme.

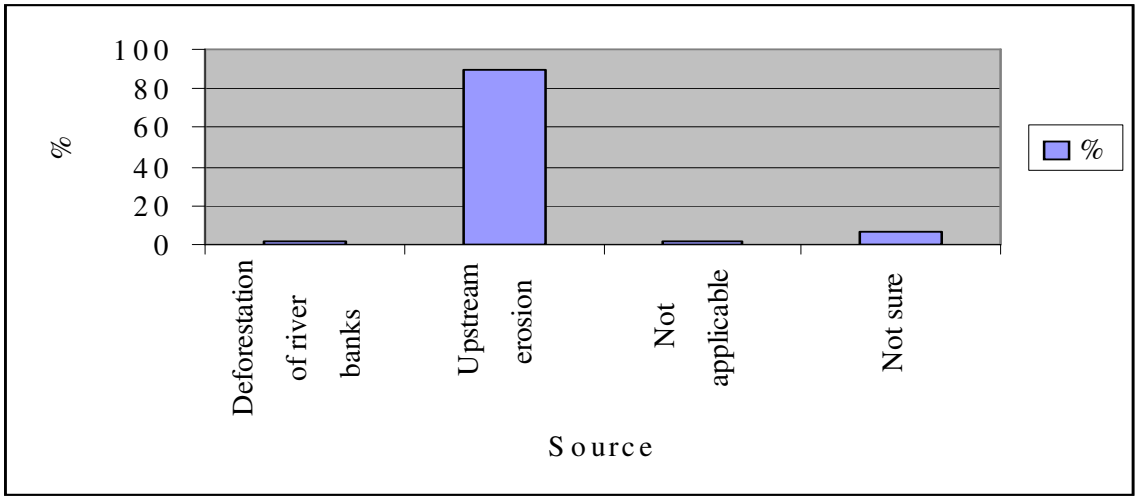

Figure 6: Sources of silt

Water use conflicts.

Irrigation water shortage was found to be a problem to many farmers in the scheme. This problem was mentioned by 96.6% of the farmers interviewed. The problem is mostly 39 encountered towards the end of the growing season, which coincides with low water supply by the river. During this period, conflicts within the scheme and with surrounding non-scheme farmers are common. Most of the conflicts reported were resolved through negotiations between the parties involved at the local level and by agreeing to adopt and enforce rules. Farmers interviewed mentioned water use conflicts with upstream water users, whom they held responsible for creating serious shortages during the dry season due to poor abstraction methods.

Reports by some farmers indicated that these conflicts sometimes degenerated into physical confrontation. These results support findings by Chambers and Garwood (2000) that irrigation return flow pollutes river and streams, which are the only source of water for drinking, fishing, and swimming for the rural population. This leads to conflicts between irrigators and other users of irrigation facility, including fishermen and other farm households. Table 3 presents causes of water supply problems on the Scheme.

Table 3: Causes of water supply problems

Cause of water problem.	Frequency	Percentage
Conflicts (high demand) & dry season	68	57.2
Canal siltation	41	34.4
Dry season & canal siltation	3	2.5
Insufficiency & conflicts	2	1.7
Lack of uniformity in planting	1	0.8
None	4	3.4
Total	**119**	**100.0**

Soil Erosion

Soil erosion occurs in many parts of the country, due to improper agricultural land use, overgrazing, and bush clearing. The development of smallholder irrigation schemes may in many cases; influence the reduction of accelerated soil erosion, since irrigation plots are intensively cultivated and some form of bench terracing for erosion control has been introduced. However, erosion caused by scheme development may occur due to overgrazing around the scheme, destruction of irrigation structures by farm animals and poor maintenance of bench terraces. Of all the farmers interviewed, 88.2% mentioned that soil erosion occur especially during floods which sometimes sweep away seedlings. When erosion occurs, the topsoil, which are mostly the deposits due to siltation is swept away. This lowers the soil nutrient content leading to reduced crop performance.

When asked about the measures they put in place to check the problem, 88.2% of the farmers admitted that since flood irrigation involves use of terraces and bands to retain water, these bands were also effective in controlling erosion. They however said that grazing livestock during off-season usually destroys these structures. Figure 6 presents incidence of soil erosion in the scheme.

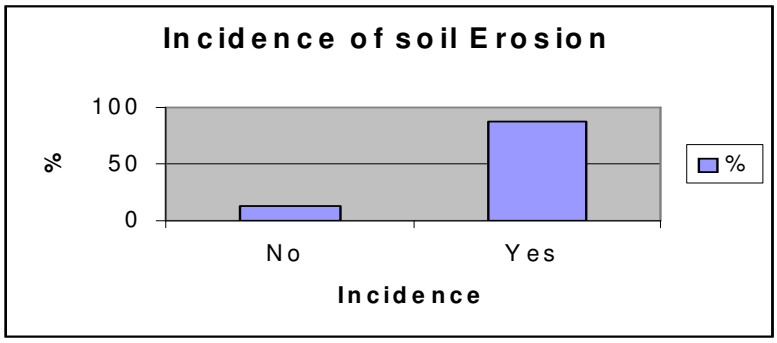

Figure 7: Incidence of soil erosion

Changing Soil Nutrient Content

About 65.5% of all the farmers interviewed indicated that the nutrient content based on crop performance had reduced that there was need for fertilizer to replenish the lost nutrients. The

plots were continuously cultivated with one crop resulting in exhaustion of nutrients. This has resulted in declining crop productivity. Comparing the quality of soil now based on the yields and the time farmers started carrying out irrigation, it was observed that the yield had tremendously gone down. The declining soil fertility is partly due to soil erosion, which ensues as a result of flooding which sweeps the topsoil. Since farmers also deal with one crop (rice), there are chances of depletion of some nutrients at certain soil levels due to nutrient uptake by these plants. Similar findings were reported by Shortle and Griffin (2001) that showed that irrigation development depletes organic matter in the soil. This is crucial because of the role of organic matter in maintaining soil fertility, soil structure and soil stability as well as its role in carbon sequestration (Wilson & Maliszewska, 1997).

It is however important to note that irrigation water is heavily loaded with sediment (silt) which recharges the soil nutrient content in the plots and this could be responsible for good crop performance as reported by 22.7% of the farmers who feel that the quality of soil is still good. Figure 7 presents the quality soil as gauged by farmers interviewed.

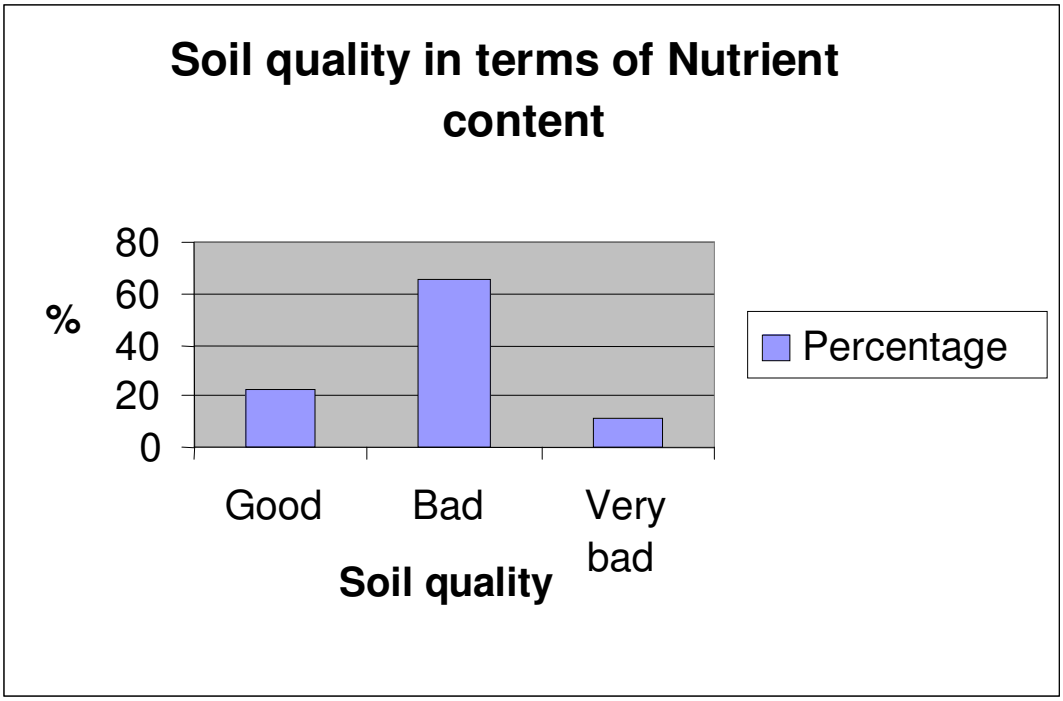

Figure 8: Soil quality in terms of nutrients

Scheme Encroachment

Scheme encroachment is attributed to irrigation scheme development in Gem Rae. This problem has been aggravated by the increased demand for scheme expansion, due to influx of people attracted by the scheme production. This has led to changes in biodiversity and loss of dry season grazing land. It should be noted that Gem Rae irrigation scheme was established by farmers themselves in farmlands that were previously under grazing and habitat for wild animals. The reduction in grazing land has resulted in higher concentration of livestock on the remaining grazing land. Consequently, the resulting overgrazing causes increased land degradation due to erosion and subsequent siltation of irrigation canals during the rainy seasons. In addition, this has caused land use conflicts due to crop damage by livestock and wildlife. Bush clearing for wood fuel harvest is a common problem in Gem Rae irrigation scheme due to sparse vegetation. This problem is enhanced by the increase in population associated with scheme development.

The findings indicate that irrigation development greatly affected plants and animals. More intensive land use, expansion of area under irrigation, drainage of wetlands, and introduction of new crops inevitably entail a decline in biodiversity or a shift in the interrelationships between species as well as loss of many species. The creation of irrigation canal network, river diversion, and flooding has destroyed the established habitats to create new ones.

Irrigation development has also led to monocropping and this has not only reduced the diversity of food crops in the local markets, but also increased the vulnerability of crops to pests and diseases. There were also observed incidences of algae growth in the irrigation drainage canals. Urama (2005) also observed that the monoculture practiced in the irrigation farms also displaces mixed cropping and agro-silvopastoral systems practiced in the river basin. Other changes reported were in the form of decline in number of fish caught in the river per year, and increase in number of waterfowl and other wild birds visiting the irrigated farms during harvesting of rice.

As in many other countries, the most important reasons for loss of biodiversity in Kenya must be sought in the expansion and intensification of agriculture (including irrigated agriculture) as well as in deforestation and overexploitation of water resources. Wildlife is seen in terms of competition for crops, and at least in part, for water, and farmers seem uninterested in observing any other plant or insect species. Figure 8 presents the magnitude of effect of irrigation on biodiversity.

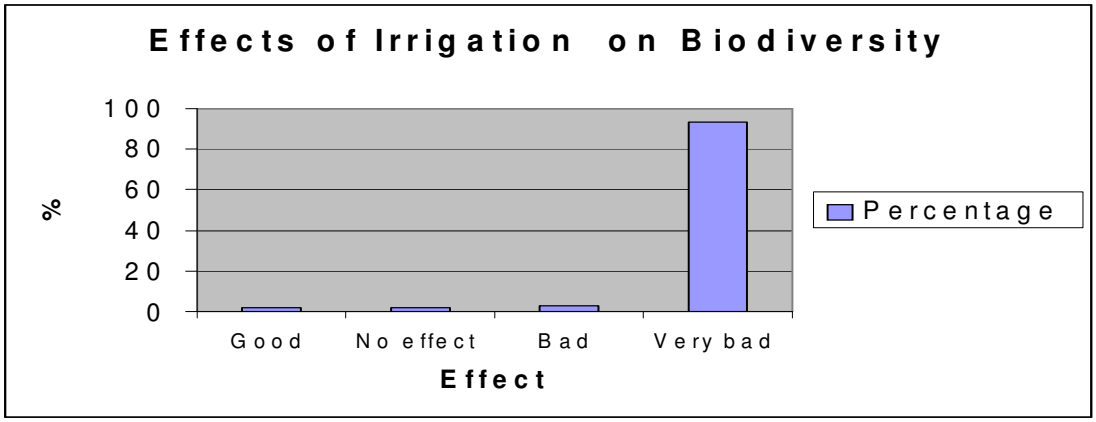

Figure 9: Effects of Irrigation on Biodiversity

Environmental Conservation Measures in the Scheme

The environmental conservation measures in the scheme is key in trying to reverse the problems that constraints the scheme. 93.3% of all the farmers interviewed indicated that they plant few trees within and around homes citing lack of land to plant trees in large scale. It is therefore important that appropriate land use systems such as agro-forestry be encouraged. This should involve planting of fast growing tree species for wood fuel. This will save on time and labour especially for women who have to walk several kilometres fetching firewood. The farmers also mentioned that the bands they construct in the paddy fields reduce the rate of soil erosion. However, this is important in providing wood fuel sources among other needs. Figure 9 presents the environmental conservation measures practiced by farmers in the scheme.

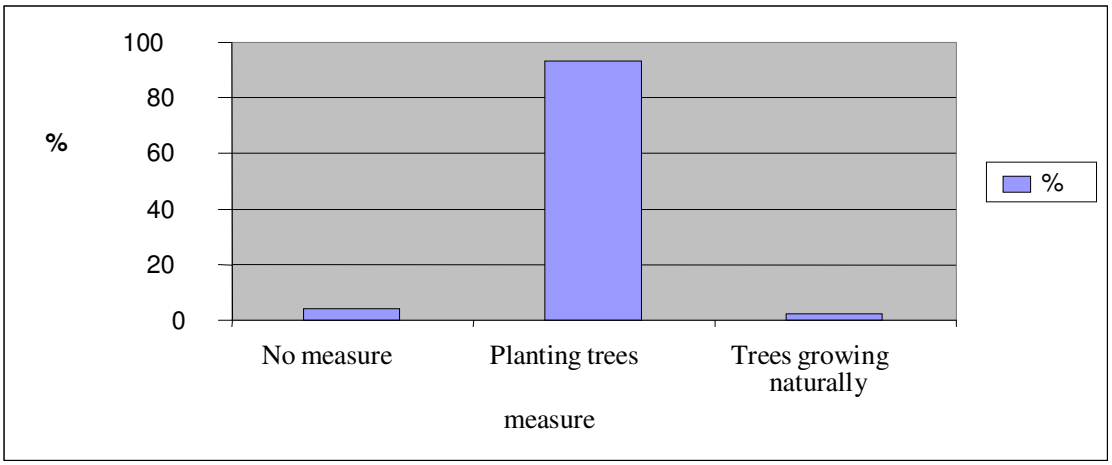

Figure 10: Environmental measures in the scheme

Water-borne/Water Related Disease.

It indicated that 97.5% of all the farmers interviewed, their family members had suffered from diseases such as malaria, dysentery and bilharzias. This shows that the accidence of water-borne disease occurrence is very severe. This is closely related with high aquatic weed growth in the scheme. The study considered the indicators, which are associated with the occurrence of the diseases. These included excessive growth of aquatic and other weeds in open earthen canals (more breeding opportunities for vectors) and adherence to recommended safety precautions during farming operations (e.g. no rubber boots worn indicating high risk of infection). The scheme had high growth of weeds such as water hyacinth in and along the canals. When asked whether they use any protective measure on their feet while in the farm about 62.2% of the farmers interviewed said they do not use any protection. About 93% of the farmers indicated that most of their family members had suffered from malaria as shown in Figure 10.

It was reported that these diseases had an effect on the farm labour supply and this impacted negatively on the yield, with 90.8% of the farmers mentioning that the magnitude of the effect was very big. This is as opposed to the idea that irrigated agriculture is designed to contribute substantially to conditions that favour good health in terms of food security, an improved infrastructure allowing better access to health services and economic progress which permits rural households a greater purchasing power for drugs and health services (WADSCO, 1981; Haile, 1988).

On mosquitoes that spread malaria, 96.6% of the farmers interviewed felt that the number had increased due to irrigation. About 79.0% of the farmers said that they were using mosquito nets. However, most farmers indicated that mosquitoes even bite early before people go to sleep and this could be the time when many people were getting infected.

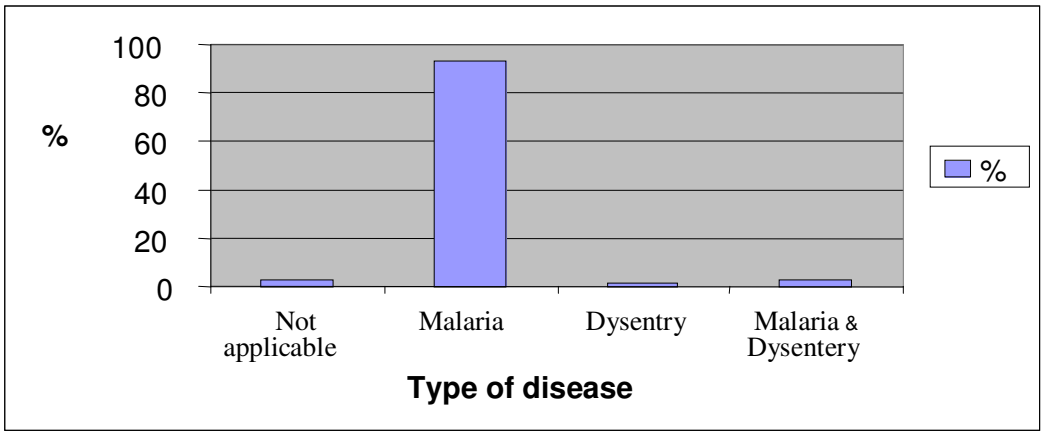

Figure 11: Type of Disease Suffered by Respondents and Family Members

HIV/AIDS Effect.

The impact of HIV/AIDS was reported in the study area where 49.6% of all the farmers interviewed said that the disease had significant effect on the yields. This is depicted in Table 4. HIV/AIDS has also become a problem because of the high number of orphans who are taken care of by their old grand parents. This pose a burden to these people resulting in increased poverty levels. HIV/AIDS is neither water-borne nor water related but because of the rate at which it spreads and kills people, it becomes a public health issue and therefore analysis of its impact in the scheme is necessary. It is a menace to many households and it is more severe in areas where the level of poverty is high particularly in the developing world. It impacts heavily on labour productivity and since the active population is at high risk of contracting the disease, sustainability of most development projects may dwindle. The grand effect of this disease is reduced yields.

Table 4: Magnitude of the Effect of HIV/AIDS on the Yield

Magnitude of effect	Frequency	Percentage
Very small	3	2.5
Not at all	56	47.1
Big	1	0.8
Very big	59	49.6
Total	**119**	**100.0**

CONCLUSION

The cross sectional analysis of environmental and household characteristic in the study area and results of interview with farmers corroborate empirical evidence found in the literature. The irrigation development had significant deleterious environmental impacts to the extent that it might preclude sustainable agriculture in irrigated areas. The environmental impacts included loss of biodiversity, increased incidence of water borne diseases, siltation, soil erosion, and water use conflicts.

The analysis found a significant decline in the fertility and structural quality of soils of the irrigated farm to the extent that can lower crop production on irrigated farms in the study area. This is perhaps the conclusive evidence on the unsustainability of irrigated agriculture in the study area. Sustainable management of agricultural land is itself a pre-requisite for sustainable agriculture and has strong links to environmental security (Asadu, 1996; Wilson,

1997). These differences in soil fertility in the irrigated farms and irreversible degradation of part of the soils in irrigated farms explain the observed decline in rice yields in the study area. The ensuing soil erosion of irrigated farms coupled with catchment degradation caused build up of silt loads in irrigation canals. This led to increased cost of production and water supply problems especially to the downstream water users. Apart from these biophysical impacts on soils, other social, economic, health, and ecological impacts observed in the study area deepens concerns for sustainable agriculture under smallholder irrigation schemes in Kenya.

Irrigation development in the study area has led to increased natural resource scarcity leading to different types of social conflicts as different stake holders (farmers, pastoralists, fishermen and households) struggled to maintain access to land and water resources. The change from communal property rights and land tenure system to individual ownership of land within the study area violated local farmers' perception of land and water resources and multifunctional assets. Land and water resources were traditionally managed not only as source of food but also for providing feed for livestock during dry season. Also these areas provided habitat for wildlife. This has since changed with encroachment taking the centre stage. As a result of this, livestock grazing around the scheme occasionally cause damage to crops leading to conflicts between pastoralists and farmers. The damage also lowers the rice yields. Wild animals such as hippopotamus were also reported to be causing great crop damages. These animals not only eat or trample crops, but also pose danger to humans when confrontations occur. This leads to human wildlife conflicts.

The health impacts of irrigation on farm household have also been negative. There were increased incidences of water borne diseases and HIV/AIDS. These significantly affected farm labour supply and efficiency. The disease also leads to change of priority setting as funds are diverted to care and treatment of the sick.

The impacts of irrigation on biodiversity have also been negative. While irrigation increased the number and diversity of bird species that visit the farms during the dry season, most terrestrial mammals migrated. Also most plant species that were present in these areas have been replaced by monocropping. However, aquatic weeds have flourished in irrigation canals, as a result of eutrophication.

On balance, the study finds that in addition to its biophysical impacts, irrigation development had other social, health, economic and ecological impacts that were found to be significantly affecting the yield of rice thereby putting the sustainable practice of arable agriculture on the irrigated soils of the study area at risk. This problem is exacerbated by the decline in farm size due to increase in population leading to intensive cultivation.

Future developments of smallholder irrigation should therefore factor the social economic and ecosystem trade offs of irrigation in the suitability criteria for its development. These considerations are critical to the success and sustainability of irrigation.

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