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Full Length Research Paper

Assessment of farming practices and uses of agrochemicals in Lake Manyara basin, Tanzania

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This study was conducted to assess farming practices, agrochemical usage and environmental pollution in Manyara basin, Tanzania. Field surveys, interviews, questionnaires and Lake Manyara nutrient analysis were used in data collection. The highest number (95%) of households grew crops, namely, maize, rice, banana and vegetables with median farm size of 3 ha. Irrigated farming was common (75%) which enhanced cultivation on same piece of land up to 6 times a year. Farmers indiscriminately used pesticides, namely, insecticides (50%), fungicides (37.5%) and herbicides (12.5%). Uses of endosulfan in vegetable farms poses public health threats to consumers. Most respondents (85%) applied insecticides in vegetables up to 4 times per cropping season. Excessive use of pesticides and haphazard disposal of pesticide remnants and containers caused environmental pollution. The average amount of acaricides used was 1109±915 ml (mean ± SD) per livestock keeper per month per. Most farmers (78%) used inorganic fertilizers and animal manure (43.4%). Low levels of ammonium (3.6±3.1 µg/L), nitrate (1±0.8µg/L) and phosphate (36.1±42 µg/L) were recorded in the lake. Easy access to agrochemicals, limited knowledge of pesticide on environmental health and limited extension services were factors for indiscriminate uses of agrochemicals. Increasing farmers awareness and training aimed at sustainable agriculture, agrochemical uses and integrated pest management is suggested.

Key words: Fertilizers, irrigation, pesticides, unsustainable agriculture, vegetables.

INTRODUCTION

Agriculture (crop production and animal husbandry) is the core of economy and the largest employer in Tanzania and it contributes up to 50% of National Gross Domestic Product (GDP) (MAFS, 2002). More than 80% of the population in Tanzania lives in rural areas and they are mainly dependent on Agriculture (MAFS, 2002). Like other developing countries in the world, Tanzania has been experiencing rapid human population growth of which by 2002 was 37 million (URTNC, 2002). This increase in human population goes along with increased food demand. In order to increase crop production there have been land-use intensification with permanent annual or multiple cropping (Mati, 2005). The common agricultural practices undertaken by the population is subsistence farming dominated by smallholder farmers who cultivate less than 2 ha per household (Salami et al., 2010). Subsistence farming in the country is characterized by poor production which partly may be caused by poor farming practices, poor soil infertility, pests, poor infrastructure and insufficiency of extension officers (Mati, 2005; Ngowi et al., 2007). Unsustainable agriculture is the big problem in particular the wetland areas where excessive exploitation of water resource for irrigation and deforestation are among the problems (Shayo, 2006).

Indeed, occurrences of pests and diseases have lead to increased indiscriminate use of pesticide and other agrochemicals. The problem is serious in areas where irrigated farming is practiced because of multiple cropping. High levels of pesticides uses in smallholder vegetable farmers in Northern Tanzania have been reported (Ngowi et al., 2007). Furthermore, since 1992

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the use of pesticide has rapidly increased following agrochemical trade liberalization in the country (Ngowi, 2002). From 2000 to 2003 the imports of pesticides increased from 500 to 2500 tonns and by 2006, a total of 682 different types of pesticides were registered (Pesticide and Poverty, 2006) The amount and intensity of pesticide use varies across the country. For example, Arusha is the leading region in pesticide trading and utilization in Tanzania because of its favourable climate for agriculture (Pesticide and poverty, 2006). Both small and large scale farms are reported to indiscriminately use large quantities of different pesticides (Ngowi et al., 2007). For example, in a preliminary survey made in January 2010 at Mang'ola areas in Arusha, pesticides costs of up to 12,000 US$ per household-farm per year in Mang'ola areas in Arusha (Personal observation). Furthermore, vegetable farming is highly practiced by small scale farmers in the region who frequently use pesticide without knowing their impact on human health and the environment (Ngowi, 200; Ngowi et al., 2007).

Furthermore, poor soil fertility as drawback to production has also been previously reported in areas with intensive unsustainable agriculture whereby farmers are necessitated to use organic and inorganic fertilizers (Mati, 2005; Salami et al., 2010). However, average rate of fertilizer use in Tanzania is significantly below consumption rates (about 10 kg ha^{-1}) as opposed to 18 kg in Africa and 94 kgin the world (World Bank, 2000). Fertilizer consumption rate in Tanzania increased significantly from 83,392 metric tons in 2003/2004 to 146,000 in 2006/2007 while the supply increased from 112,000 metric tons in 2003/04 to 287,763 metric tons in 2006/2007 (Shetto et al., 2007). Of particular concern, the use of commercial fertilizer is done without proper advice from agricultural officers (Isham, 2002; Mati, 2005). Misuse including over- and under-dosing, mixing of different fertilizers may have impacts to the crop production and environment at large.

Because of its soil fertility and arable irrigatable land Lake Manyara basin in particular Mto wa Mbu ward at the foot of the Rift Valley escarpment has recently attracted many immigrants from all parts of Tanzania (Rohde and Hilhorst, 2001). The estimated Lake Manyara basin immigration rate is 4.5% (Norconsult, 2001). Land use has been intensified and irrigated farming is adversely practiced in the area. The irrigated lands are located at the interface between pastoral and agricultural societies which results to conflicts between cultivators and livestock keepers over pasture-land and water resources. On the one hand, agricultural practices and overgrazing on the plateau have a direct bearing on soil fertility and the hydrological regime which supports this intensive irrigated agriculture at the escarpment foot. Unfortunately, factors creating environmental problems are the same as those required for growth in agricultural production.

While increased agriculture and agrochemical uses are generally considered a panacea for farmers' to increased production; farming practices, use of the agrochemicals and possible environmental pollution from agriculture in Manyara basin has not been investigated. The current study was conducted to assess the smallholder farming practices, usage of agrochemicals and their possible pollutions to the environment. It is envisaged that information presented in this study will contribute to our understanding of agricultural situation in Lake Manyara basin and the possible types of agrochemical pollutions released to the environment. This may be useful as baseline information for sustainable agriculture, identify specific constraints and opportunities for appropriate and sustainable agriculture in the basin aimed at increased production, and safeguard the public health and conservation of fragile Lake Manyara ecosystem.

MATERIALS AND METHODS

Study area

The study was conducted in 2008 in selected villages of Lake Manyara basin in northern Tanzania (Figure 1). The basin extends from 3°05' to 4°05 South and 35°51' to 36°372' East.

Lake Manyara is among the alkaline-saline lakes found within the Rift Valley of East Africa. There are a number of rivers which drain into the lake namely Mto wa Mbu, Simba, Kirurumo, Msasa, Endabashi, Iyambi, Magara and Makuyuni which are also used for irrigated farming by the local community around. The climate of the area is semi arid with two distinct rainy seasons, short rains in October to December and long rain start in March to May (Rohde and Hilhorst, 2001) with a mean annual rainfall of about 700 mm. The soils vary from alkaline to non-saline-alkaline in reaction. In addition the soil textures of the area are clay, clay-loam, loam, loamy/sand-loam and sandy-loam/sandy-clay-loam. Soils vary from fertile highly erodible volcanic material, to a variety of moderate to low fertility sedimentary and basement soil (Cohen et al., 1993).

Study population

The study involved five villages within Lake Manyara basin namely Barabarani, Migombani, Majengo (in Mto wa Mbu ward), Losirwa and Mayomayoka (Figure 1). The livelihood of the people in the study area depended mostly on agriculture, fishing and petty trades. There are a number of hotels, safari companies, tourist camps and souvenir markets which provide some employment and income opportunities to the residents.

Data collection

Sociological data

Purposive sampling technique was used for selection of the study villages because they were within Manyara basin and easy accessibility. Simple random sampling technique was used for households selection from where respondents were recruited. Information from village leaders, agricultural extension and livestock officers were used to generate a list from which the sampling of households was used. The study household inclusion criteria were farming, use of agrochemicals and willingness to participate in the study. A few people (<5%) who declined to participate in the interview on different grounds were replaced by another households randomly selected from the list. A total of 80

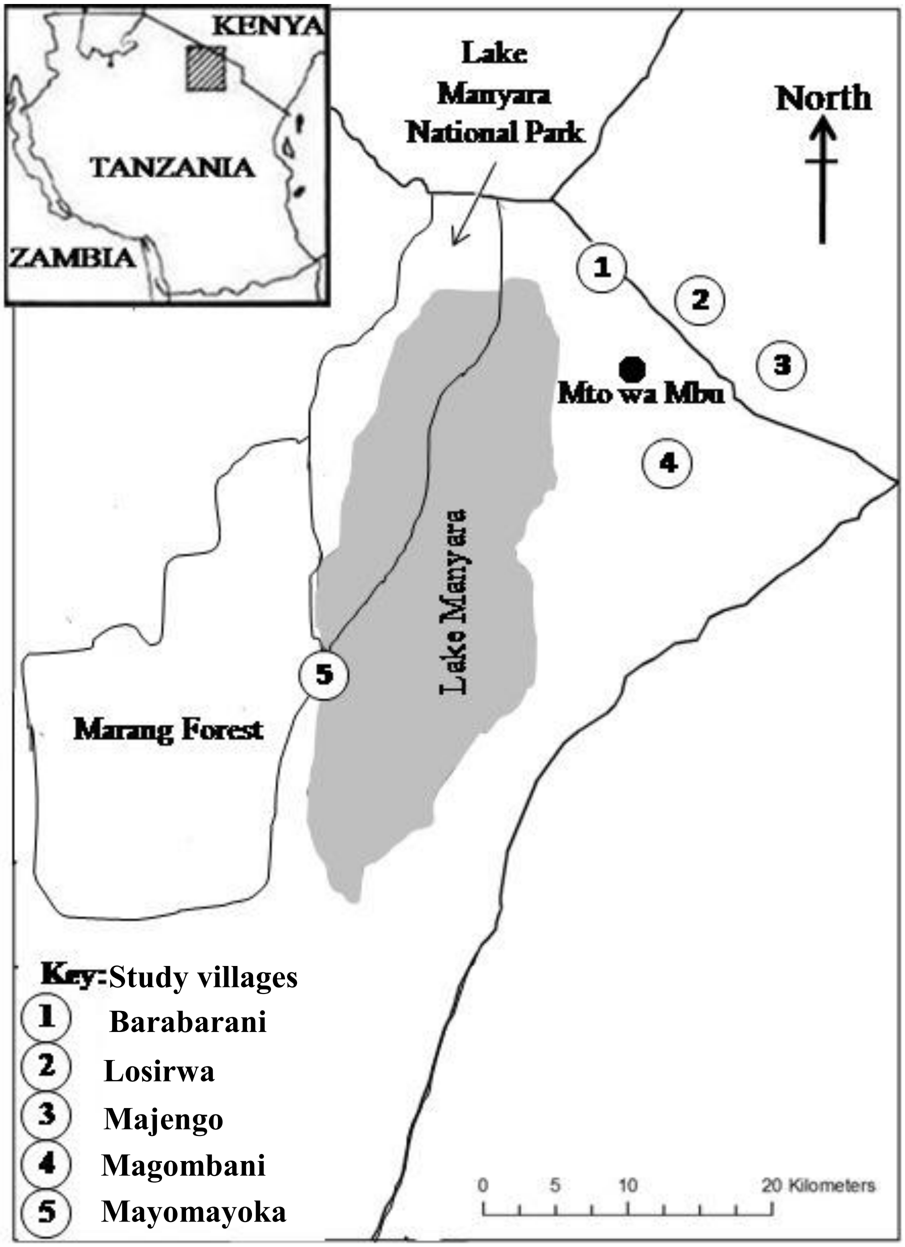

Figure 1. Map showing the study villages around Lake Manyara (*insert*: map of Tanzania with shaded region to indicate the relative location of the study area).

households from the selected villages were involved in the study The number of selected households varied between villages because of differences in populations and number of people involved in farming activities.

Both quantitative and qualitative data collection methods were used to obtain primary data. The standardized questionnaire, with structured and semi-structured questions was the main instrument which involved face-to-face interviews with one respondent from each of the selected households. The household heads were the targeted respondent (father or mother) and in case of absence, another permanently resident-adults (> 18 years) in the households took part in the interview. The questionnaire was designed in English and translated into Kiswahili, a national language, which is understood by majority of the respondents in the study areas. The information collected included respondent's socio-demographic variables, crops and livestock production practices from 2006 to 2008, irrigated farming and uses of agrochemicals (Table 1). While conducting interviews, direct observations were made on livestock kept, crops grown and agrochemicals available at the farm on the day of visit.

In-depth interviews with key informants were used to complement the questionnaire results. Information on the climatic conditions (rain season, dry season and temperature), types of crops grown in the locality, water resource and irrigation, types of livestock kept and uses of agrochemicals were gathered from agricultural and livestock officers. Agrochemical shop owners and/or sellers in the study villages served as sources of information on the type, amount and seasonal sells of agrochemicals.

Table 1. Type of information collected during the survey.

Type of information	
Respondent's socio-demographic variables	Gender, age, occupation, education, village residence duration and address
Crop production practices from 2006 to 2008	Crops grown, farm/land size, farm distance from Lake Manyara/rivers, soil erosions, and problems with crop production
Irrigation farming	Crops irrigated, farm size, type of irrigation, cropping seasons, water sources and availability
Livestock production practices from 2006 to 2008	Types and number of animals, grazing system, water availability, acaricide uses (type, amount and frequency)
Uses of agrochemicals in agriculture	Types of agrochemicals and management: Pesticide uses (types, sources, use frequency, application methods, handling, disposal of containers and awareness of pesticide environmental pollution. Fertilizer uses (types, sources, use frequency and availability)

Water quality in Lake Manyara

Three off-shore sampling sites, (about 200 m from shoreline) were established and monthly samplings was done from July 2007 to June 2008. Water quality parameters such as pH, dissolved oxygen and conductivity were measured *in situ* using a portable water quality checker (Horiba U-10, Kyoto, Japan). Salinity was measured using a hand refractometer. Water samples for the determination of nitrate, nitrite, ammonia and soluble reactive phosphorus (phosphate) were taken at a depth of 25 cm below the water surface. About 100 ml water samples were immediately filtered through 0.45 µm pore sized membranes filters using a vacuum pump. The water samples were kept in acid-cleaned plastic vials and inorganic nutrient concentrations were determined as described by APHA (2005).

Data analysis

Sociological quantitative data were analysed using Epi Info version 6 (Coulombier et al., 2001). Descriptive statistics of different factors were computed to obtain proportions and their 95% confidence intervals (CIs) where necessary. Differences between proportions were examined using Chi-square test at critical probability of $P < 0.05$. Because of similarities in farming activities and socio-cultural factors, all the respondents were considered as one population during data analysis and there were no comparisons between villages. Descriptions of qualitative data were made based on their thematic contents. For the purpose of data analysis, the months of October - December and March - May were considered as rainy season while the rest of the months were regarded as dry season.

RESULTS

Crop production in the study villages

The age of the respondents was 47±14 (mean and standard deviation SD) and mostly (75%) were males. Majority (84%) of the farmers had primary education and the mean duration of respondents lived in Manyara basin was 31±14 years (range of 2 to 75 years). Crop production was the main source of food and means of income generation as it comprised a significantly ($P<0.05$) high proportion (95%) of the households investigated. The main crops produced were maize, rice, banana and vegetables (tomatoes, spinach, egg plant, peppers, green peppers, okro, onions, and carrots). Other crops grown were sunflower, cotton, tuber crops (cassava and sweet potatoes), fruits (oranges, mangoes and pawpaws), sugarcane, millets, and legumes (beans and groundnuts). Most of the farmers grew more than one crop at a time. The median farm size was 3 ha (range 0.25 to 100 ha per farmer). The median farm size per crop is shown in Table 2. The median farm distance from Lake Manyara was 6 km (range 0.5 to 20 km). Many of the respondents (68%) reported to have their farms going up to the hill side and there were limited means to overcome the problem of soil erosion. Several rivers and streams passed through the farms from which farmers intensively used the water for irrigation. In most cases, the median distance from river banks to the farms was 0.2 km (ranged from 0.01 to 6.0 km). Trees and other natural vegetation along the river banks were cleared off to get more land for cultivation. However, some of the farmers had their crops such as banana grown close to river banks, contrary to the established bylaws at Mto wa Mbu ward that prohibit cultivation at least 4 m on either side of the river. In some places, however cultivation had gone up to the catchment areas, a practice which destroyed water sources. Floods were reported to be common in low land areas especially during long rains and sometimes caused severe damages to crops and other property.

All the farmers mentioned poor soil fertility and pests are major limiting factors for crop production. However, other problems mentioned included lack of agricultural

Table 2. Common crops grown in study villages between 2006 and 2008 (n = 80).

Crop	Number of respondents (%)	Median farm size (ha)	Range (ha)	Number of crop cycle year
Maize	71(88.8)	2.0	0.25-160	2
Rice	55(68.8)	1.0	0.25-6.0	2
Banana	35(43.8)	1.5	0.5-10	Throughout
Vegetables	44(55.0)	0.5	0.25-2.0	2-6
Sunflower	6(7.5)	1.5	0.5-6.0	1
Cotton	5(6.3)	2.0	2.0-5.0	1
Tubers	6(7.5)	1.0	0.25-5.0	1
Fruits	4(5.0)	1.5	0.5-2.5	1
Sugarcane	3(3.8)	1.0	1.0-10	2
Millets	6(7.5)	1.5	1.0-4.0	1
Legumes	49(61.3)	1.5	0.25-60	2

extension support due to shortage of extension officers (60%), limited markets for their crops (51%), drought (64%) and scarcity of agrochemicals (8%). It was reported that the drought was associated with shortage of rainfall. This assertion was supported by the fact that the short rains of October/December were becoming rare, thereby prolonging the dry season in the basin.

Irrigated farming was common at Mto wa Mbu ward where farmers produced crops throughout the year with very high intensity of cropping (same piece of land was cultivated up to 6 times a year). A significantly high ($P<0.05$) number (75%) of respondents practiced rudimentary irrigation particularly during dry seasons. The main source of water for irrigation was from rivers Mto wa Mbu, Simba and Kirurumo. Crops which were grown under irrigated farming were rice (78%), banana (70%), maize (50%), vegetables (68%), beans (34%), potatoes (5%), fruits (4%) and sugarcane (3%). Nevertheless, the common vegetables grown under irrigated farming included tomatoes, onions, cabbages, spinach, carrot, sweet pepper, broccoli, eggplant, cauliflower, lettuce and snap beans. The farm size under irrigation per household ranged from 0.3 to 3 ha. On average, the duration that respondents were involved in irrigated farming was 12 years. They practiced canal irrigation which was built from the river banks through the farms and back to the river of which the destination point was Lake Manyara. There were 11 main water canals with 42 tertiary canals which utilized water from Simba, Kirurumo, Mto wa Mbu rivers and Miwaleni reservoir. Up to 92% ($P<0.05$) of the farmers reported that water for irrigation was not enough and conflicts among themselves on water usage was common. The agricultural extension officers reported that irrigated farming dates back in 1955, but was more expanded during 1980s by ILO project whereby up to 2500 ha were under irrigated farming. Currently, up to 1200 ha are under traditional irrigation systems in the Mto wa Mbu valley (Yanda and Madulu, 2005). In the southern part of the lake Lake Manyara, there is Kiru valley along river Kiru, which has about 10,000 ha identified for irrigation and already 2500 ha are under traditional irrigation systems (Yanda and Madulu, 2005).

Usage of agrochemical in crops at Lake Manyara basin

All the interviewed farmers reported to use agrochemicals for their crops. The main groups of agrochemicals used included insecticides, fungicides, herbicides and fertilizers (inorganic and organic manure). Table 3 presents different types of pesticides, amount used per year, target pests/diseases and the crops in which the pesticides are applied. Acess to agrochemicals for farmers was within easy reach since most of them were readily available at Mto wa Mbu small town. The primary sources of agrochemicals in the farming areas were agrochemical shops (90%) and general shops (10%). Carbofuran was the only WHO Class Ib (highly hazardous) recorded pesticide in use. Majority of the pesticides were in Class II (moderately hazardous) and a few in Class III (slightly hazardous) or U (Unlikely to present acute hazard). Of the agrochemical used; 21 types were insecticides, 15 fungicides, and 4 herbicides. The study showed however that, of the types of pesticide formulation used; most of them were insecticides (50%), fungicides (37.5%) and herbicides (12.5%). The highest proportions and quantities of insecticides used were organophosphates and pyrethroids. Endosulfan (Thionex®), an organochlorine pesticide was the frequently used insecticide particularly in vegetables (Table 3). Among the groups of fungicides; mancozeb and copper based products were the mostly used products against crop fungi. Glyphosate isopropylammonium (Kalachi®), isopropylamine salt of glyphosate (Round up®) and 2, 4-dichlorophenoxy acetic acid (Balton®) (2, 4-D Amine) were the other commonly used herbicides (Table 3).

The distribution of patterns of pesticide use and

Table 3. Average annual usage of insecticides, herbicides and fungicides in study villages between 2006 and 2008.

Pesticide type	Trade name	Common name	Chemical group[a]	WHO hazard class[b]	Amount (kg or L) used per year	Target pests/diseases	Crop used
Insecticides	Selecron (L)	Profenofos	OP	II	619	Whitefly, spidermite, fruit-borer, stem-borer, , thrips, aphids and various other insects	Vegetables, legumes
	Karate (L)	Cyhalothrin lamda	P	II	565	Armyworm, beetles, stem-borer, caterpillar, cutworms, larger-grain-borer, weevils, aphids, fruitfly, spidermite and stalkborer	Cotton, vegetables, legumes, fruits, cereals
	Dimethoate (L)	Dimethoate	OP	II	154	Aphids and mites	Vegetables, legumes, fruits, cereals
	Bamethrin (L)	Deltamethrin	SP	II	150	Aphids and various insects	Vegetables, legumes, cotton, fruits
	Thionex (L)	Endosulfan	OC	II	940	American-bollworm, aphids, mites, insects, leafminer , stalkborer	Vegetables, legumes, cotton
	Helarat (L)	Labda-cyhalothrin	P	II	175	*Helicoverpa armigera* and thrips	Vegetables, legumes, cotton
	Rogor (L)	Dimethoate	P	II	128	Stalkborer, aphids and mites	Vegetables, legumes, fruits, cereals
	Dursban (L)	Chlorpyrifos	OP	II	108	Stem-borer, cutworms, armyworm, bollworm, thrips, beetle, aphids, leafminer, stalkborer and fruit worms	Vegetables, legumes, fruits, cereals, sugarcane
	Zetabestox (L)	Zeta-cypermethrin	SP	II	102	Various insects	Cotton, vegetables, legumes
	Antokil (L)	Chlorpyrifos	P	II	165	Stem-borer, cutworms, armyworm, bollworm, thrips, beetle, aphids, leafminer, stalkborer and fruitworms	Vegetables, legumes, fruits, cereals, sugarcane, banana plantations
	Diazinon (L)	Diazinon	OP	II	120	Stalkborer, stem-borer, leafhopper, leaf-miner and beetle	Vegetables, legumes, fruits, cereals, sugarcane

Table 3. Contd.

	Profecron (L)	Profenofos	P	II	143	Whitefly, fruitfly, spidermite, fruit-borer, stem-borer, insects, thrips, aphids and diamondback moth	Vegetables, legumes, fruits, cereals, sugarcane, banana plantations
	Furadan (Kg)	Carbofuran	C	Ib	254	Stalkborer, millipedes, other foliar biting, chewing and sucking insects, nematodes and various soil insects	Vegetables, legumes, fruits, cereals, sugarcane, banana plantations
	Malathion dust (Kg)	Malathion	OP	III	192	Grain insects	Maize, beans
	Shumba super (Kg)	Fenitrothion + Deltamethrin	OP/SP	II	145	Larger-grain-borer	Maize, beans and other legumes, disinfect stores for grain storage
	Akheri powder (Kg)	Carbarly + Lamdacyhalothrin	CA/SP	II	32	Household and animals insects	Animals like dogs, cats, chickens
	Actellic super (Kg)	Pirimiphos-Methyl	OP	III	21	Weevils and other grain insects	Maize, beans and other legumes, disinfect stores for grain storage
	Carbaryl dust (Kg)	Carbarly	CA	II	52	Household and animals insects	Animals like dogs, cats, chickens
	Sevin dust (Kg)	Carbarly	CA	II	55	Household and animals insects	Animals like dogs, cats, chickens
	Agita (L)	Thiamethoxam	N	NK	3	Household insects like flies	Household control of flies
	Super pygrease (L)	African pyrethrum	P	II	9	Flies in animals	Control of flies in animals
Herbicides	Kalachi (L)	Glyphosate	OP	III	452	Weeds	Different crops
	Balton (2,4-D Amine) (L)	2-4 amine	AA	II	331	Weeds	Different crops
	Round up (L)	Glyphosate	OP	III	338	Weeds	Different crops
	Mamba (L)	Glyphosate	OP	III	200	Weeds	Different crops
Fungicides	Victory (Kg)	Metalaxyl	A	NK	1400	Blight and spidermite	Vegetables, legumes

Table 3. Contd.

	Farmerzeb (Kg)	Mancozeb	C	III	501	Fruitfly, blight, downy-mildew, leaf-rust and wilting	Vegetables, legumes, fruits
	Red copper (Kg)	Copper oxide	Cu	III	560	Leaf-rust and blight	Vegetables, legumes, fruits
	Cuprocaffaro (Kg)	Copper oxychloride	Cu	III	210	General fungal infection	Vegetables, legumes, fruits
	Blue copper (Kg)	Copper sulfate	Cu	II	370	Leaf-rust and blight	Vegetables, legumes, fruits
	Dithene (Kg)	Mancozeb	C	III	1596	Fruitfly, blight, downy-mildew, leaf-rust, wilting	Vegetables, legumes, fruits
	Antracol (L)	Dithiocarbamate	D	III	165	General fungal infection	Vegetables, legumes and other horticultural crops
	Ridomil (Kg)	Metalaxyl + mancozeb	C	II	127	Blight, spidermite	Vegetables and other horticultural crops
	Bayleton (L)	Tridimefon	T	III	65	Blight	Vegetables, legumes and other horticultural crops
	Indofil M-45 (Kg)	Mancozeb	C	III	52	Blight	Vegetables, legumes and other horticultural crops
	Ivory 80 WP (Kg)	Mancozeb	C	III	145	Blight	Vegetables, legumes and other horticultural crops
	Linkonil (Kg)	Chlorothalonil	OC	NK	63	Blight	Vegetables, legumes and other horticultural crops
	Thiovit (Kg)	Sulphur	S	U	124	Blight, leaf-rust, brown rot scab and mildew	Vegetables, legumes and other horticultural crops
	Bravo (Kg)	Chlorothalonil	OC	NK	115	Blight	Vegetables, legumes and other horticultural crops
	Rova (Kg)	Chlorothalonil	OC	NK	12	Blight	Vegetables, legumes and other horticultural crops

[a] C: Carbam ate, D: dithiocarbam ate, P: pyrethroid, OC: Organochloride, OP: organophosphate, A: acylalanine, AA: aryloxyalkanoic acid, SP: synthetic pyrethroid, CA: Carbarly, N: neonicotinoids, Cu: inorganic-copper, T: tridimefon, S: Sulphur, [b] 1b = highly hazardous; II = Moderately hazardous; III = slightly hazardous; U = unlikely to present acute hazard in normal use; NK = not known. L): Liquid formulation quantified in litres, (Kg): solid formulation quantified in kilograms.

Table 4. Distribution of patterns of pesticide use and management in a sampling (n =80) of farmers in study villages.

Variable	Total respondents	
	Number	%
1. Source of knowledge on type, application and handling of pesticides		
Agrochemical shops	60	75
Extension officers	36	45
Label on packages	21	26
Fellow farmers	20	25
Own experience	4	5
2. Timing of pesticide application		
(i) Insecticides		
Presence of pests	49	61
Degree of pest infestation	14	18
Date of transplanting	17	21
Others (season of the year, changes of weather, etc)	11	14
(ii) Fungicides		
Rainy season	43	54
Dry season	17	21
Any period of the year	8	10
(iii) Herbicide		
Rainy season	32	40
Dry season	9	11
Any period of the year	11	14
3. Disposal of empty pesticide containers		
Throw away	40	55
Burning/burying in pits	28	35
Put in other uses/give to others	8	10
4. Knowledge on pesticide environmental effects		
Knowledgeable	19	24
Not knowledgeable	61	76

management is shown in Table 4. The knowledge on the type, handling and applications of pesticides to most of the respondents (75%) was obtained from the agrochemical shop owners. Most respondents (85%) reported to use insecticides routinely and the frequency of use was up to 4 times per cropping cycle particularly in vegetables. However, higher uses of pesticides were reported during the rainy seasons. This findings was supported by higher sales (72%) of pesticides recorded in agrochemical shops during the rainy seasons.

Nevertheless, the timing of pesticides application mostly depended on presence of pests in different crops and their potential damages to the crop as well as farmers' perception regarding pest management practices. Most of the farmers applied pesticides by use of Knapsack sprayers and the sprayers washings was done in rivers. Remnants of pesticides were discarded in the farm by pouring them on the ground or burying. Disposal of the empty pesticide containers was mainly throwing away in farms and waste pits (55%). The majority of the respondents (76%) were unaware of the effects of pesticides to the environment.

As a measure to poor soil fertility, farmers' approaches included application of inorganic fertilizers (78%) and animal manure (43.4%). Eleven percent of the farmers did not take any measures to improve soil fertility as they believed that the practice of land fallowing and incorporation of crop residues in the soil and other decaying vegetations corrects the problem of soil fertility. Eight types of inorganic fertilizers were used (Table 5). Nitrogenous commercial fertilizers were frequently used particularly urea. The reports from the agrochemical

Table 5. Average annual usage of fertilizer in study villages between 2006 and 2008.

Trade name	Ingredients	Amount (Kg or L) used per year
Booster (L)	Nitrogen, phosphorous, potassium and trace elements	2680
Urea (Kg)	Nitrogen	45000
CAN (Kg)	Calcium and nitrogen	6600
SA (Kg)	Ammonium sulphate	5650
NPK (Kg)	Nitrogen, phosphorous and potassium	2100
Vigimax (L)	Trace elements, vitamins, amino acids	91
Agrofeed-Mukpar (L)	Potassium, Phosphorus, Nitrogen and trace elements	189
Animal Manure (Kg)	Mostly nitrogen and phosphorous	200 000 – 500 000

(L): Liquid formulation quantified in litres, (Kg): Solid formulation quantified in kilograms.

shops showed that 66% of the total sales were recorded during the rainy season reflecting high fertilizer applications in farms. However, animal manure was the most commonly (68.5%) used organic fertilizer by majority of the interviewed respondents. An estimated annual manure usage in the five study villages was estimated at 300 000 - 500 000 kg as was reported by the agricultural officer was 200,000 – 500, 000 kg in the five study villages (Table 5).

Livestock production in the study villages

Of all the respondents, 59% were engaged in livestock keeping. Domestic animal kept included cattle, sheep and goats, poultry (local chicken and ducks) and others (pigs, donkeys and rabbits). The numbers of different livestock kept in 2006 to 2008 are shown in Table 6. It was found that there was a decreasing trend of number of livestock kept between 2006 and 2008. All livestock keepers reported not to use Lake Manyara as drinking water for their animals but rather they used rivers, streams, dams and tap water. A significantly ($P<0.05$) high number (91.3%) of the livestock keepers extensively grazed their animals within Manyara basin. Tick infestation was a major problem a major problem on livestock particularly in cattle keepers and 90% of interviewee reported to control ticks by using different acaricides (pyrethroid and organophosphate) particularly in cattle. The types (frequency) of acaricides used included alphacypermethrin (71.4%), lambda-cyhalothrin (19%), amitraz (4.8%) and cypermethrin (4.8%) (Table 7). The amount of acaricide used per month per household was 1108.5±915 ml (mean ± SD). Majority of livestock keepers (72%) reported to use acaricides twice and thrice a month during the dry and rainy season respectively.

Water quality of Lake Manyara

Water quality characteristics for Lake Manyara, which were recorded during the study period are shown in Table 8. On average, low levels of ammonium (4±3 µg/L), nitrate (1±0.8µg/L), nitrite (4±0.3 µg/L) and phosphate (36.4±42.0 µg/L) were recorded in 2007/08. Significantly ($P < 0.05$) higher phosphate concentration (53.2±52.0 µg/L) was recorded during rainy season compared to the dry season (16 ±9 µg/L). There was no significant difference in mean nutrient concentrations for ammonium, nitrate and nitrite between the dry and rainy seasons. During sampling periods, big blooms of blue-green algae (cyanobacteria) were observed covering the whole water surface especially in March, April, May and June. Most of the blooms were along the lake shore giving a characteristic foul smell and foams.

DISCUSSION

Findings from this study show that most of the residents around Lake Manyara were actively engaged in subsistence farming and livestock keeping as their major dependable rural livelihood. Intensive small scale irrigated farming was common on small pieces of land with 2 to 6 cropping seasons per year. Interestingly, pesticide uses was rampant with limited or no knowledge on the possible effects to the environment. The increased use of commercial pesticides which apart from increasing crop production, have long term negative effects on Fauna and flora, changes of soil characteristics and reduced production (Pimentel and Greiner, 1997; Edmeades, 2003). Obvious environmental destruction due to unsustainable agriculture and overgrazing was observed in the Lake Manyara basin. Notwithstanding this situation, there were no plans for intervention measures from the responsible authority probably because of limited information on the problem.

In particular, crop production constituted the source of food and income for the majority of the people. In that regard, intensified unsustainable agricultural activities on small pieces of land and in water catchments, steep slopes of mountains, mountain ranges, near river banks and around water sources accompanied with deforestation were common practices. Consequently, the

Table 6. Median number of livestock kept by respondents between 2006 and 2008.

Animal type	2006			2007			2008		
	Number of farmers (%)	Median livestock per farmer	Range	Number of farmers (%)	Median livestock per farmer	Range	Number of farmers (%)	Median livestock per farmer	Range
Cattle	23 (28.8)	12.0	1-900	23 (28.8)	12.0	1-500	24 (30.0)	11.5	2-300
Sheep and goats	25 (31.5)	20.0	2-880	26 (32.5)	24.0	2-572	28 (35.0)	25.5	2-180
Poultry	32 (40)	20.5	2-110	39 (48.8)	20.0	2-104	45 (56.25)	15.0	1-70
Others	10 (12.5)	5.0	1-38	9 (11.3)	3.0	2-27	13 (16.3)	4.0	1-20

Table 7. Average annual acaricide usage in the study villages between 2006 and 2008.

Trade name	Common name	Chemical group	WHO hazard class	Amount in litres used per year
Ectomin (L)	Cypermethrin	SP	II	890
Dominex (L)	Alphacypermethrin	SP	II	1230
Grenade (L)	Lambda-cyhalothrin	SP	II	850
Tix fix (L)	Amitraz	OP	II	440
Almatix (L)	Amitraz	OP	II	540
Alphatix (L)	Amitraz	OP	II	35
Amitix (L)	Amitraz	OP	II	18

SP: Synthetic pyrethroid, OP: organophosphate , L: liquid formulation quantified in litres.

Table 8. Water quality parameters for Lake Manyara during dry and rainy seasons.

Water paramter	Annual average	Dry season	Rainy season
	Mean±SD	Mean±SD	Mean±SD
pH	9.6±0.4	9.4±0.4	9.8±0.3
Salinity (‰)	14±7.1	13.1±7.1	14.4±7.7
Conductivity (mS/cm)	24±11.2	21.0±5.9	26.5±15.0
Dissolve Oxygen (mg/l)	11.0±2.5	10.5±2.0	11.6±3.0
Ammonium (µg/l)	4±3.1	3.2±2.9	4.1±3.6
Nitrate (µg/l)	1±0.8	1.0±1.0	0.7±0.6
Nitrite (µg/l)	0.3±0.3	0.4±0.3	0.3±0.3
Phosphate (µg/l)	36.1±42.0	16±9.3	53.2±52.0

negative effects on biodiversity and general water resource sustainability were evident. Clearance of natural vegetation in river banks encourages more water loss due to evaporation and probably was among the causes of frequent floods in the study areas. However, obvious soil erosions which were observed in Manyara basin were partly caused by poor cultivation and extensive grazing of large herds of cattle. This may possibly be the cause of reported Lake Manyara siltation, eutrophication and fertilization; the factors reported to foster proliferations of phytoplankton in particular cyanobacteria in water bodies and other water weeds in lakes (Anderson et al., 2002). The rampant uncontrolled agriculture was however; speculated to be due to poverty, poor policy governing agriculture and land use, low level of awareness on sustainable land use, agriculture and environmental management.

Irrigation farming is a common agricultural practice in Lake Manyara basin which have developed rapidly during the last 50 years and attracted many immigrants from all parts of Tanzania (Rohde and Hilhorst, 2001). The irrigation system is uncontrolled or semi-controlled and uses rudimentary technology of abstracting and distributing irrigation water to the farm plots mostly by gravity off-takes and subsequently led into the canal network. Sometimes farmers draw water from the rivers using buckets and in some cases they used motorized water pumps. Rice, maize and banana and vegetable farming constituted the main crop grown under irrigated farming as was previously reported by Ngowi et al. (2007). Increased demand for vegetables in growing cities like Arusha has made many more farmers to engage in vegetable farming since they fetched good price in the markets. Up to six cropping seasons per year were recorded to some vegetables like spinach. However, it was found that water shortage for irrigation especially during the dry season was a major limitation to sustain such high intensity cropping. Indeed, during our survey conflicts among farmers over water distribution and uses for irrigation were common especially during the dry seasons. Key informants (agricultural officers) reported that the problem was partly caused by increased number of water users which overwhelmed the river water resource for irrigation. Moreover, the decreased volume of water flow in rivers during recent years, land degradation due to cultivation and extensive livestock grazing and deforestation in water catchment areas were earmarked in this present study. Due to water scarcity, especially during the dry seasons, almost all the water flowing in the rivers was used for irrigation. Such kind of water use for irrigation in the basin has been implicated for the frequent drying up of Lake Manyara.

Yield losses by insects, diseases, weeds and birds are estimated to vary between 10 and 90% in sub-Saharan Africa (Youdeowei, 1989). In that regards, chemical pesticide use is a common practice to control pests and diseases in crops cultivated in Tanzania. Specifically, in Lake Manyara basin, the reported pest problems caused higher uses of pesticides in particular insecticides. These results are comparable to the published findings by Ngowi et al. (2007) and Obopile et al. (2008) though different from what was reported by Ntow et al. (2006) who found higher uses of herbicides by vegetable farmers in Ghana. This may suggest the magnitude of the pest problem in the study area. On other hand, the routine high use of pesticides reported by majority of respondents with the application frequency of up to 4 times per cropping season particularly in vegetables could be due to ignorance. Poor education background could partly contribute since 84% of the farmers were primary school leavers who might not be able to read or understand pesticide labeling and instructions on use since are written in English. Although it is undeniable that vegetable crops need large quantities of pesticides for control of pests and diseases, it remains doubtful whether all the sprays were really necessary. The easy access to the agrochemicals in the local market, limited knowledge of pesticide environmental effects, possibly unrealized agrochemical expenses and the associated public health effects may be among the factors for indiscriminate uses of agrochemicals. This present study has observed that pesticides were readily available in agrochemical retail shops and there were also pesticide vendors who practiced measuring out quantities of the pesticides from larger containers and sale to farmers at different measurements. However, the other possible cause of indiscriminate use of pesticide could be shortage of extension staff that could accordingly advice the farmers on other alternative methods for pest controls (Wilson and Tisdell, 2001). For example, integrated pest management (IPM) and organic agricultural strategies could be the alternatives to excess use of pesticides (Wilson and Tisdell, 2001).

Most pesticides used were in Class II meaning that has moderately hazard effects to the environment. In addition, most insecticides were in the group of organophosphate and pyrethoids which are easily degradable in the environment. However, the use of carbofuran which is in Class Ib (highly hazardous) may have serious impacts to the environment and public health. Carbofuran is a potent cholinesterase inhibitor and has a potential of causing morphological malformations, reduced growth rate and mortality to fish and amphibians (Giuseppina et al., 2005). The effects of exposure even of a short duration can be delayed but there is a possibility of cumulative effects (Gupta, 1994). Granular carbofuran was however, applied to control soil dwelling and foliar feeding insects and nematodes such as rootworm, wireworms, boll weevils, aphids, and white grubs on a number of crops. Its high solubility and low absorption coefficient in soils carbofuran, has the potential to contaminate lakes, streams, and groundwater with detrimental effects on environmental fauna and flora.

Furthermore, it was found that endosulfan, an organochlorine pesticide which is strictly restricted by the Stockholm convention was still on use. Endosulfan was among the frequently used pesticide and in high amount compared to other pesticides because was thought to be effective against different crop pests like aphids, thrips, beetles, foliar feeding caterpillars, mites, borers, cutworms, bollworms, bugs, whiteflies and leafhoppers. This study results consist with Ngowi et al. (2007) who also reported high usage of endosulfan by vegetables farmers in Tanzania. Elsewhere, in Ghana indiscriminate uses of endosulfan by vegetable farmers has been reported (Ntow et al., 2006). Indeed, the recently published results by Kihampa et al. (2010) showed high endosulfan residues in all soil samples analyzed from tomato fields in Ngarenanyuki, Tanzania. Endosulfan is persistent to environmental degradation compared to other classes of pesticides. It may bioaccumulate in plant and animal tissues and become concentrated in the upper part of the food pyramid (Mbakaya et al., 1994). Because of high toxicity, technical endosulfan was banned in many countries including Tanzania and its use was restricted only to cotton plantations. The high uses of endosulfan observed during this study calls for need to monitor for organochlorines and other pesticides residues on the food ingredient in areas where their usage on food crops has been demonstrated in Tanzania.

The potential for environmental pollution was noted when farmers reported to wash pesticide sprayers in rivers, discard pesticides remains and empty containers to the land. This was verified by majority of respondents (76%) being unaware of the effects of pesticides to the environment. During the survey in the farms, several pesticide containers were sometimes seen lying on the land. It is envisaged that poor disposal of pesticide remnants and containers together with indiscriminate use of pesticides in farms present a potential pollution problem to the environment and public health. In particular, the aquatic systems are likely to suffer more from the pollution because there are sinks of all pollutants which enter watercourses through different sources of pollution. The effects can also be realized in people since the Manyara wetland, rivers and lake are sources of livelihood for human communities and support varied animal and plant life. Indeed, there have been reports of mass Lesser Flamingo mortality in Lake Manyara and other alkaline soda lakes in East Africa of which pesticides are among the suspected causes (Ndetei et al., 2005). Furthermore, detection of high concentration of different pesticide residues in soil from vegetable farms at Ngarenanyuki in Manyara basin Tanzania signifies pollution to the environment from agriculture (Kihampa et al., 2010). In addition, putting the pesticide empty containers into other uses as was reported by the respondents may also be dangerous to human health. The logical generalization here is that, chemical pesticides will continue to be a major cause of water pollution through surface run-off and underground seepage unless the trend of use is controlled. The repercussions on the biological diversity of the lake are imminently far reaching and irretrievable. Therefore, these findings call for extensive research to better determine the degree of environmental contamination due to pesticides, residues of pesticides in food, human and in water.

Although the countrywide uses of fertilizer is still low, in areas with intensive agriculture uses more fertilizer than in other areas with one cropping cycle per year. Farmers in Lake Manyara basin used eight different types of inorganic fertilizers particularly of nitrogenous type. Frequent and uncontrolled uses of commercial fertilizers on the same piece of land may lead to serious interruption to the soil properties which may in turn cause reduced crop production (Edmeades, 2003). This high fertilizer uses could partly could be caused by farmers' lack of knowledge on proper use of commercial chemical fertilizers according to crop requirements. In addition, residues of such fertilizer may be carried to adjoining water bodies where may cause nutrient build up which have serious ecological impacts.

To elucidate the existing anecdotal evidences on Lake Manyara fertilization from high use of fertilizers in agriculture (Sechambo, 2001) water nutrient analysis was done during the rainy and dry season. The results revealed relatively low levels of phosphate, nitrate, nitrite and ammonium in all the seasons as was previously reported by Lugomela et al. (2006). However, a significantly higher level of phosphate level in water during rainy season may be associated with high uses of fertilizers during the season. In contrast, higher values of nitrate and phosphorus in some alkaline soda lakes in Kenya have been reported (Ballot et al., 2009; Schagerl and Oduor, 2007). The low levels of nutrients recorded in Lake Manyara while all the factors for nutrient build up were possible could be explained by several reasons. Big blooms of blue green algae (cyanobacteria) which were observed in the lake may have an influence on the uptake of nutrients in the lake. Indeed, proliferation of algae blooms in water bodies is reported to be associated with high nutrient loads and eutrophication (Paerl, 1996; Oliver and Ganf, 2000). For ammonium, the probable reason could be the high pH, which shifts the equilibrium from ammonium to volatile ammonia resulting into its rapid loss from the water (Jones and Grant, 1999). Therefore, evidences of lake fertilization may still rely on evidences of high uses of fertilizers in the farms around, poor farming practices, soil erosions and frequent floods.

Conclusions

Due to intensive agricultural activities on small catchment; reduced soil fertility, and resurgence of pests and weeds inevitably caused the high uses of agrochemicals. Massive use of endosulfan pesticide in vegetable poses a potential public health threat to the consumers. The easy access to the agrochemicals, limited knowledge of pesticide environmental effects and scarcity of extension services were among the likely causes for indiscriminate use of agrochemicals. Unsustainable agriculture and over abstraction of water from rivers for irrigation have serious negative consequences on biodiversity and threaten the sustainability of water resources in catchment areas. Therefore, farmers trainings on efficient and safe use of agrochemicals is needed so as to minimize the likely agrochemical undesirable effects. Commencement of programs on integrated pest management may give small holder farmers alternatives to uses of pesticides and minimize the detrimental effects associated with agrochemical use and ultimately reduce environmental pollution caused by farming and safeguard the public health in Tanzania.

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