International Journal of AgriScience Vol. 4(10): 452-462, October 2014 *www.inacj.com*
ISSN: 2228-6322© International Academic Journals

Levels of Pesticide Residues in the Eastern Arc Mountains Part of Tanzania

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Received in August 2014; accepted in revised form September 2014

ABSTRACT
A baseline study to document current farmers' practices in relation to the use of synthetic pesticides in vegetable and spices production was conducted in Muheza district Eastern Usambara Mountains and Kilolo district in the Udzungwa Mountains, both located in the Eastern Arc Mountains of Tanzania. The study combined assessment of vegetable growers' knowledge, attitude and practice (KAP) in selected villages and sampling and analysis of pesticide residues. Tomato production among other vegetables is the most popular enterprise grown all year round and therefore was selected as the model crop for this study. The crop is routinely sprayed using a wide range of broad spectrum pesticides from nursery up to the last harvest. In contrast, farmers in Muheza produce an array of spices but these are not sprayed with any synthetic pesticide. Analysis of clean sample extracts on a GC/ECD and confirmed on the GC/MS revealed dominance of organochlorine pesticides. Endosulfan was the only pesticide mentioned by the Kilolo vegetable growers that was detected. In general, sediment samples were found to have higher levels of pesticide residues than the other sample matrices. The implications of the findings to biodiversity conservation in the Eastern Arc Mountain hotspot are discussed.

Keywords: *Biodiversity; Conservation; Eastern Arc; Mountains; Pesticides; Tanzania*

INTRODUCTION

The Eastern Arc Mountains and the East African Coastal Forest Mosaic Hotspot (EAMCF) is one of the smallest of the 25 top Global Biodiversity Hotspots recognized by the Critical Ecosystem Partnership Fund (CEPF). It qualifies by virtue of its high endemicity and a severe degree of threat. Although the hotspot ranks low compared to other hotspots in total numbers of endemic species, it ranks first among the 25 hotspots in the number of endemic plant and vertebrate species per unit area (Myers, *et al*., 2000). It also shows a high degree of congruence for plants and vertebrates. Taking all these factors into consideration, the EAMCF Hotspot are ranked 8th in overall importance. It is also considered as the hotspot most likely to suffer the most plant and vertebrate extinction for a given loss of habitat, and as one of 11 "hyper hot" priorities for conservation investment (Brooks, *et al*., 2002). The Udzungwa and Eastern Usambara mountains that are within the EAMCF, are home to a diverse biodiversity including plants, reptiles, amphibians, mammals, birds, fish and arthropods, some of which are not found elsewhere in the world (Ehardt, *et al*., 2005). Additionally, they are water towers for over 3.0 million people and also support a large fishery industry. Out of the seven African viviparious toads listed by the IUCN as endangered, three: *Nectophrynoides asperginis, N. poyntoni and N. wendyae*; are endemic to the Udzungwa Mountains (www.earthendangered.com/profile-459.html). When originally discovered in 1996, *N. asperginis* occupied a 4ha habitat maintained by spray from falls on the Kihansi river but in 2003 was found confined to less than 2ha, this attributed partly to increased pesticide use upstream (Channing, *et al.,* 2006). Increasing wide indiscriminate use of agro-chemicals in vegetable production by smallholders, a practice that can cause direct and indirect contamination of protected areas that are important refugia and/or habitats for threatened species and functional agro-biodiversity through spray drift, seepage into ground water and food chains has not been systematically documented in the proposed study sites. Very low concentrations of pesticides in water have been shown to increase the mortality of young fish and amphibians (Picone and Van, 2002). Smallholder commercial cultivation of vegetables for urban centers has been identified as the key threat to biodiversity conservation efforts in this area (CEPF, 2007; URT, 2009). This is because increased commercial cultivation of vegetables considered

essential for production by communities living in its environs, leads to forest clearance and pollution of soil and water due to excessive use of agro-chemical inputs. Smallholder farmers in the Udzungwa and Eastern Usambara Mountains grow vegetables and spices that include tomatoes, cabbages, black pepper, brinjals, peppers, etc. and use a wide range of pesticides to control insect pests and disease that attack these crops (Ngowi, *et al*., 2007).

Although vegetable production activities are perceived as a major threat to biodiversity conservation in the EAMCF Hotspot, the current status of synthetic pesticide use (types, spray frequency, amounts and disposal) by vegetable growers and their fate (residues in produce, water and soil) in the environment and produce is not well documented. This study aimed to establish a baseline data by documenting current farmers' practices in relation to the use of synthetic pesticides in vegetable production and respective residues levels and metabolites in selected vegetables, soil, water, and sediments collected from Muheza district Eastern Usambara Mountains and Kilolo district in the Udzungwa Mountains. This study will be used for future environmental monitoring, risk assessment and development of appropriate mitigation strategies to facilitate efficient management of these biodiversity hotspots.

MATERIAL AND METHODS

Study areas

Kilolo district

The study was conducted in Mazombe, Irole and Lulanzi divisions, Kilolo district in the Udzungwa Mountains, Iringa region and Kwamhosi, Bombani and Tongwe villages Muheza district in the Eastern Usambara Mountains, Tanga region Tanzania (Fig 1).

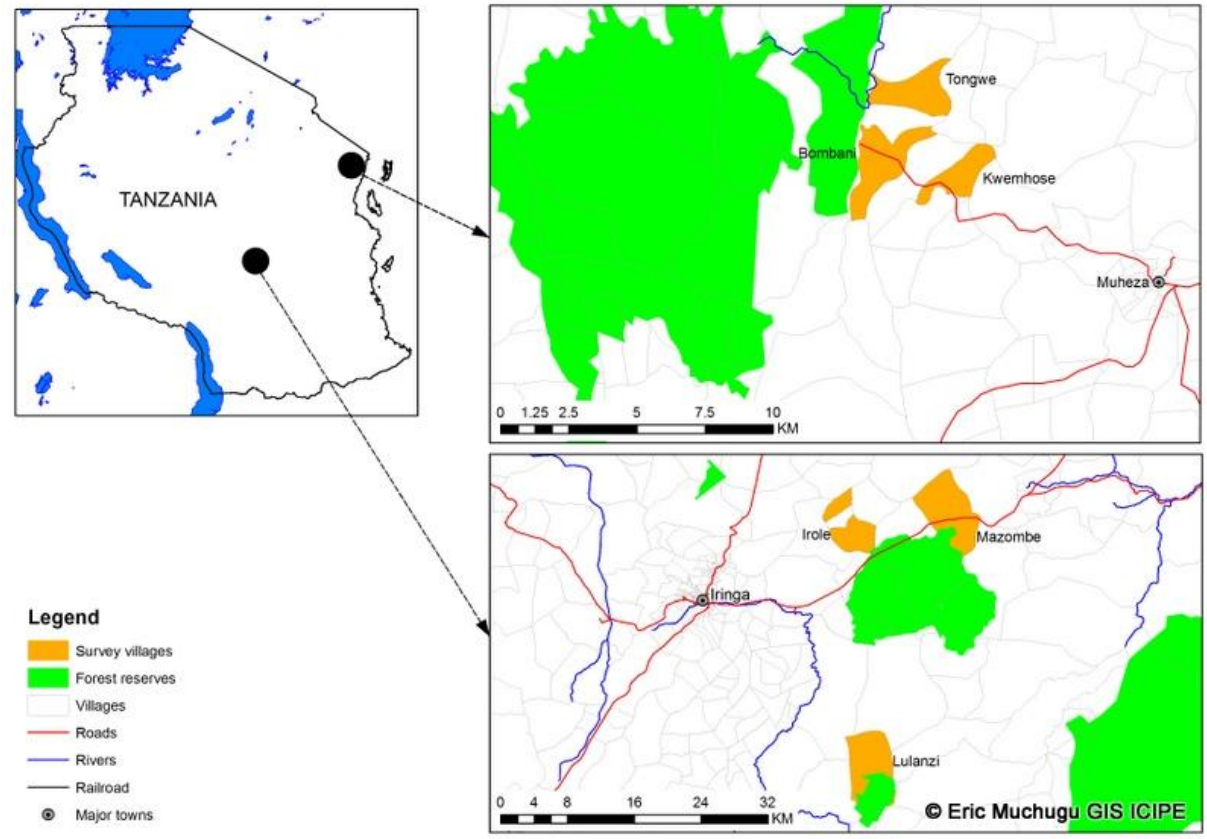


Fig. 1. Study sites

The study sites were purposely selected across altitudinal gradient: Mazombe (1387m.a.s.l), Irole (1552m.a.s.l) and Lulanzi (2045m.a.s.l) in Kilolo district to represent low, medium and high altitudes. The district is a major producer of a variety of vegetables that are sold in urban centers including Dar es Salaam, Iringa, Dodoma and Morogoro. Decline in soil fertility, water availability and increased insect pests and diseases pressure have been listed as the key production constrains.

Vegetable producers in this area are known to use a wide range of synthetic pesticides in production.

Muheza district

The Eastern Usambara Mountains are almost entirely within Muheza district in Tanga region. The mountains rise to a peak altitude of 1,506 m at Mt Nilo (EAMCEF, 2005-2007). The study was conducted in Kwamhosi, Bombani and Tongwe villages, the area famous for organic production of different spices that are sold on the domestic and international markets (Ruijter and Ayo, 2010) and therefore no pesticides are used.

Data collection

A two-stage data collection approach was used (1) to document current farmers' knowledge, attitudes and practices (KAP) on the use of synthetic pesticides in vegetable and spice production (2) sampling and analysis of pesticide residues and metabolites in produce, soils, sediments and water.

KAP study on the use of synthetic pesticide in vegetable production

Information on farmer's knowledge, practice and attitudes (KPA) on pesticide use was collected through focused group discussions with farmers and village agro-chemical dealers in their respective villages and divisions. The information was collected in the last week of February and first week of May 2009 in Kilolo and Muheza districts respectively using a semi-structured questionnaire.

Sampling and analysis of pesticide residues and metabolites

Samples were collected randomly from farms in the study sites by gloved hands taken at four different points to make a composite sample. Samples were wrapped in aluminum foil, placed into polyethylene bags and packed into a cooler box ready for transportation. Water samples were collected in a 1 L teflon-stoppered bottle.

GC sample analysis

All samples were analyzed in a Gas Chromatography (GC) in their final volume of 2 mL (cyclohexane/acetone 9:1) in the vials (Akerblom, 1995, Marco and Kishimba 2007). The volume that was injected in the GC-ECD for each sample was 2 µl using auto sampler Varian model CP-8400.

Pesticide identification

Pesticides were identified by comparing the retention times of the sample analyte to those of the reference standard solutions run in parallel and at similar conditions with the samples. For specificity, the pesticides in samples were eluting at the same retention time as the one in the standard solution. The relative retention times were calculated and matched with the values according to Akerblom 1995. Details of the sampling procedures, storage, extraction and cleanup is given in the supplemental data.

Quality control and assurance procedures

Quality control and assurance procedures included replicate sampling, extraction and analysis for all samples on the GC-ECD and involved matrix spike with a substitute standard prior to extraction to check extraction efficiency and recoveries. This was accomplished by spiking respective standards of pesticides under investigation and following the same extraction and analytical procedures as for the samples. Pesticide free samples were also incorporated as blanks, and these together with external standards were used to determine the detection limit of pesticides. Furthermore, reference standards were used to identify and quantify the levels of pesticide residues on the GC-ECD and confirmatory test using GC-MS.

REULTS

KAP study

Kilolo district

A variety of vegetables were reported to be grown in the study villages but tomato was ranked as the most popular vegetable in Mazombe and Irole divisions and second in Lulanzi (Table 1). Tomato was the most sprayed crop because is attacked by a wide range of insect pests and diseases.

Table 1 Types of vegetables grown in Mazombe, Irole and Lulanzi and farmer ranking

Division	Vegetable types and ranking
Mazombe	Tomato[1], onion[2], sweet pepper[3], cabbage[4], spinach[5], Ethiopian mustard[6]
Irole	Tomato[1], Chinese cabbage[2], Ethiopian mustard[3], spinach[4], cabbage[5], carrot[6] and sweet pepper[7]
Lulanzi	Cabbage[1], tomato[2], Irish potato[3], carrot[4], spinach[5], Chinese cabbage[6]

Ranking order based on the most to the least important [1-7]

The key pests affecting tomato production in Mazombe and Irole were reported as diseases: early blight, Alternaria solani (Ell & Martin) Sor and late blight, *Phytophthora infestans* (Mont.) de Bary, Septoria leaf spots, -*Septoria lycopersici* (Spegazzini) and insect pests; grasshoppers, elegant grasshopper,

Zonocerous spp, cutworm, *Agrotis* spp and aphids. In Lulanzi division, bacteria wilt,*Ralstonia solanacearum* (Smith) and fungal disease, aphids, red ants and fruit worms, *Helicoverpa armigera* Hübner, were the most damaging pests. Irole farmers also mentioned soil mealy bugs and cutworm.

Variations in tomato cropping patterns and seasons between the three divisions were recorded (Table 2). During the dry season, farmers in Mazombe and Irole plant tomatoes and other vegetables in valley bottoms or flood plains where they rely on natural moisture or water diverted from rivers/streams, rain harvested water, swamps, springs and small shallow wells in wetlands.

Table 2 Tomato cropping seasons in Mazombe, Irole and Lulanzi

Division	Rainy season	Dry season with supplementary irrigation*/wetlands
Mazombe (1387m.a.s.l.)	Planting in December-March; harvesting April/August	Planting in August harvesting in December/January
Irole (1552m.a.s.l)	Planting in November harvesting in March/April; second planting in March harvesting in July/August	Planting in July harvesting in November/December
Lulanzi (2045m.a.s.l)	Planting in October/November harvesting in March/April	Planting in August harvesting in December/January

*water sourced from streams, ponds, rivers and rain harvest

We investigated the types of pesticides used, spray frequency and mixing. A wide range of pesticides, largely fungicides and insecticides are used (Table 3). We observed that Kilolo tomato farmers had access to 10 different active ingredients (a.i.) in 21 trade names in any one season and that chlorothalonil and metalaxyl/mancozeb products based formulations were more commonly mentioned both contributing 38% of all products accessible to farmers. It was followed by lambda-cyhalothrin and profenophos (28%), mancozeb (9%), endosulfan, chloropyrifos, dimethoate, triadmenol and triadimefon at 5% each.

Additionally, choice of a product to purchase was guided by trade names and product prices (farmers change from one trade name to the other without knowing that they are still applying the same active ingredient depending on price). Blanket spraying (prophylactic application) from germination to last harvest, was a common practice. During rainy seasons, farmers sprayed once or twice per week depending on the amount of rain and timing relative to when the crop was last sprayed. In dry seasons spraying was done once every two weeks. Tank mixtures of insecticides and fungicides were a common practice to reduce spraying costs. Information on how to use pesticides was obtained from pesticide vendors and from reading information product labels found on packages/containers.

Alternatives to synthetic pesticides

Farmers in Lulanzi explained that they practice some alternatives to synthetic pesticides for the control of some of the diseases and insect pests of tomato. The most important one was crop rotation used to control tomato wilt in the following combinations (i) tomato-maize-tomato (ii) tomato-onion-tomato (iii) tomato -3 years fallow-tomato. Other popular alternatives included uprooting of affected plants and use of wood ashes. Farmers in Mazombe and Irole explained that they did not practice alternatives to synthetic pesticides e.g. use of wood ash for insect control because they considered these alternative methods not effective and were perceived as outdated methods of controlling diseases and insect pests.

Muheza district

The most popular spices grown in this area include black/white pepper, lemon glass, ginger, cinnamon, cardamom and vanilla. Black pepper was the commonest commercial spice in Kwamhosi, Bombani and Tongwe villages. Farmers informed that black pepper is a perennial crop that takes 2.5-3.0 years from planting to the first harvest and can survive for more than 100 years.

Although insect pests and diseases are a constraint to production of spices in Muheza, use of agro-chemical inputs particularly pesticides in production was uncommon. Several challenges to the production of black pepper were mentioned by the farmers as insect pests such as grasshopper, mealy bugs, red and black ants, and snakes. Others are prolonged droughts, high costs of maintenance especially pruning the black pepper nursing trees and lack of reliable markets for their produce.

Asked about the use of synthetic agrochemicals in the production of spices, all groups interviewed informed that no farmer use pesticides or inorganic fertilizers in production. The participants informed that they apply botanical extracts of neem, castor-oil or pawpaw to control key pests. Others use a combination of wood ashes, replanting, burning of affected plants, maintain cleanness of farms through

appropriate weeding and mulching, all of which contribute to soil improvement. A few farmers select and plant less pest susceptible cultivars.

Analysis of pesticide residues and metabolites

Pesticide residues detected in water samples

The study included a total of 20 water samples, 10 from Kilolo and 10 from Muheza. Nine samples were collected during the rainy season and 11 during the dry season. Samples were analysed and the following pesticide residues were detected: γ-HCH, β-HCH, α-endosulfan, β-endosulfan, *p,p'*-DDT and *p,p'*-DDE. All these pesticide residues were detected at both sites and seasons except β-HCH which was only detected in samples collected from Muheza and β-endosulfan and *p,p'*-DDE which were detected only in samples from Kilolo.

Levels and distribution of pesticide residues detected in water samples

In Kilolo the mean levels of pesticide residues and their concentration range detected during the rainy season were: γ-HCH 0.07 (0.04-0.1), α-endosulfan 0.25 (0.03-0.52), β-endosulfan 0.01 (0.01), *p,p'*-DDT 0.16 (nd-0.16), and *p,p'*-DDE 0.04 (nd-0.04) µg/l. During the dry season was: γ-HCH 0.13 (0.03-0.37), α-endosulfan 0.43 (0.28-0.89), β-endosulfan 0.04 (0.01-0.06), *p,p'*-DDT 0.04 (0.01-0.08) and *p,p'*-DDE 0.29 (0.01-1.16) µg/l. In Muheza, during the rainy season were: γ-HCH 0.03 (0.01-0.05), β-HCH 0.07 (0.02-0.11), α-endosulfan 0.12 (0.04-0.41) and *p,p'*-DDT 0.03 (0.02-0.03), µg/l. During the dry season were: γ-HCH 0.08 (0.03-0.25), β-HCH 0.05 (0.03-0.06), α-endosulfan 0.26 (0.19-1.44) and *p,p'*-DDT 0.03 (0.02-0.04) µg/l.

Table 3: Pesticides commonly used on tomato production in Kilolo district and their respective active ingredients as indicated on product labels as of February-March 2009

Pesticide's Trade Name	Active Ingredient	WHO Toxicity Class*
Helarat 5 EC	Lambda-cyhalothrin 5 g/L	II
Profecron 720 EC	Profenophos 720 g/L	II
Dursban 400 EC	Chloropyrifos 400 g/L	II
Profit 720 EC	Profenophos 720 g/L	II
Kungful 5 EC	Lambda- cyhalothrin 5 g/L	II
Dume 400 EC	Dimethoate 400 g/L	II
Selecron 720 EC	Profenophos 720 g/L	II
Bayfidan 250 EC	Triadimenol 250 g/L	III
Bayleton wp 25 EC	Triadimefon 25 g/L	III
Dithane 800 EC	Mancozeb 800 g/kg	III
Farmerzeb800 EC	Mancozeb 800 g/kg	III
Ridomil MZ 68 WG	Metalaxyl-M 40 g/L + Mancozeb 640 g/kg	III
Banko 500 SC	Chlorothalonil 500 g/L	III
Banko 720 SC	Chlorothalonil 720 g/L	III
Linkonil 50 SC	Chlorothalonil 50 g/L	III
Lincomil MZ 68 WG	Metalaxyl 80 g/kg + Mancozeb 640 g/kg	III
Ivory 72 WP	Metalaxyl 80 g/kg + Mancozeb 640 g/kg WP	III
Victoria 72 WP	Metalaxyl 80 g/kg + Mancozeb 640 g/kg WP	III
Thionex 35 EC	Endosulfan 35 g/L	II
Karate 5 EC	Lambda-cyhalothrin 5 g/L	II
Pilarich 500 SC	Chlorothalonil 500 g/L SC	III

*2000 The British Crop Protection Council. The pesticide Manual 12th Edition edited by C.D.S. Tomlin. ISBN 1 901396 12 6. According to this classification, II denotes highly toxic and III moderately toxic products.

The mean levels of pesticide residues in water samples collected from Kilolo and Muheza in both seasons were compared (Fig 2). All the pesticide residues had the mean levels higher in samples collected from Kilolo than Muheza in both seasons. Also statistical analysis showed higher mean levels of pesticide residues for samples collected from Kilolo than Muheza with the mean difference of 0.052 for the rainy season and 0.076 for the dry season. However, the differences were insignificant at the two- tailed p value of 0.336 for the rainy season and 0.359 for the dry season.

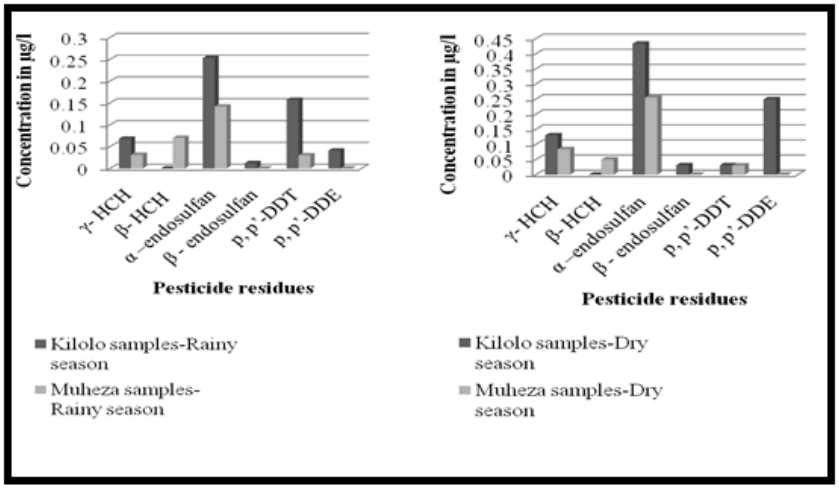


Fig. 2. levels of pesticide residues for water samples during rainy and dry season (µg/l) wet weight

Pesticide residues detected in soil samples

A total of 21 soil samples were collected and analysed for pesticide residues. Ten samples were collected from Kilolo and 11 from Muheza. Among these, 10 were collected during the rainy season and 11during the dry season. The detected pesticide residues were: Kilolo samples: γ-HCH, β-HCH, α-endosulfan, β-endosulfan, *p,p'*-DDT and *p,p'*-DDE, Muheza samples: α-endosulfan, β-endosulfan and *p,p'*-DDT.

Levels and distribution of pesticide residues detected in soil samples

Pesticide residues that were detected in samples collected from Kilolo had the mean levels and their concentration range as follows: rainy season: γ-HCH 4.22 (0.94-6.78), β-HCH1.05 (nd-1.05), α-endosulfan 8.89 (2.14-31.35), β-endosulfan 0.51 (0.44-6.43) and *p,p'*-DDT 5.12 (1.08-9.15) µg/kg; dry season: γ-HCH 2.684 (1.55-3.62), α-endosulfan 11.82 (6.17-21), β-endosulfan 0.48 (0.36-0.66), *p,p'*-DDT 1.03 (0.36-1.6) and *p,p'*-DDE 9.62 (8.59-10.64) µg/kg. In Muheza the mean levels of pesticide residues and their concentration range detected during the rainy season were: γ-HCH 3.47 (2.55-4.86), α-endosulfan 8.16 (1.95-22.21), β-endosulfan 0.34 (0.05-0.64) and *p,p'*-DDT 1.15 (0.72-1.57) µg/kg. During the dry season: γ-HCH 2.05 (0.35-4.25), α-endosulfan 4.12 (1.52-7.22), β-endosulfan 0.33 (0.07-0.75) and *p,p'*-DDT 0.61 (0.21-1.17) µg/kg were detected.

The mean levels of pesticide residues detected in both sites in soil samples were compared. As shown in Fig 3, all the detected pesticide residues had higher mean levels in samples collected from Kilolo than Muheza during the rainy season. Statistical analysis showed that the mean levels of the pesticide residues were higher in samples from Kilolo with the mean difference of 1.335. However, the differences were insignificant at the two tailed p value of 0.55.

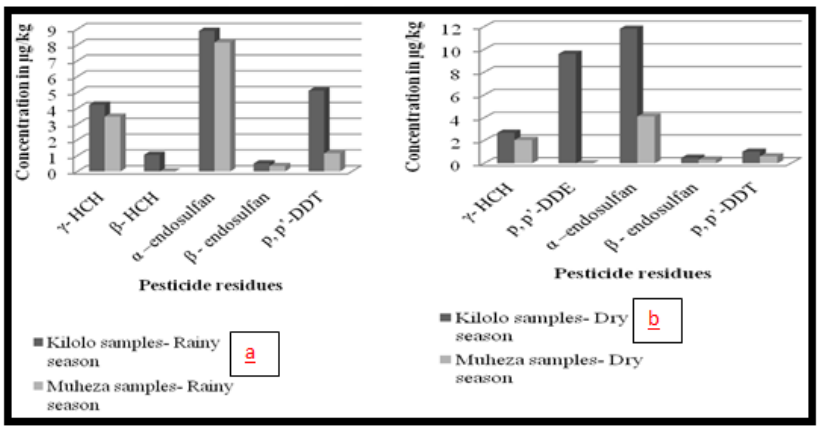


Fig. 3. Mean levels of pesticide residues for soil samples during rainy season and dry season (µg/kg) dry weight

During dry season, the mean levels of pesticide residues were higher in samples collected from Kilolo than Muheza (Fig 3a&b). However, the differences were insignificant at the two tailed p value of 0.170.

Pesticide residues detected in sediment samples

A total of 19 sediment samples were collected from the field and analysed for pesticide residues. Among these, 10 were collected from Kilolo and 9 from Muheza. 8 samples were collected during the rainy season and 11 during the dry season. Similar to the water and soil samples, γ-HCH, β-HCH, α-endosulfan, β-endosulfan, *p,p'*-DDT and *p,p'*-DDE pesticide residues were detected and confirmed in sediment samples from Kilolo and γ-HCH, α-endosulfan, β-endosulfan, *p,p'*-DDT and *p,p'*-DDE from Muheza.

Levels and distribution of pesticide residues detected in sediment samples

Sediment samples collected from Kilolo during the rainy season had their mean levels and concentration range as follows: γ-HCH 15.9 (5.44-20.67), β-HCH13.67 (nd-13.67), α-endosulfan 15.13 (7.19-31.2), β-endosulfan 1.55 (1.03-1.95) and *p,p'*-DDE 1.85 (1.59-2.1) µg/kg. During the dry season: γ-HCH 6.57 (0.71-12.29), α-endosulfan 95.64 (15.03-163.6), β-endosulfan 6.74 (1.48-17.51), *p,p'*-DDT 3.3 (0.92-5.3) and *p,p'*-DDE 37.18 (12.51-81.89) µg/kg.

For Muheza, samples collected during the rainy season; their mean levels and concentration range were: γ-HCH 11.48 (4.72-21.14), α-endosulfan 10.52 (3.55-18.67) and β-endosulfan 1.19 (1.01-1.76) µg/kg. During the dry season γ-HCH 5.38 (1.95-8.87), α-endosulfan 32.66 (4.79-81.72), β-endosulfan 1.19 (1.15-1.24), *p,p'*-DDT 1.84 (nd-1.84) and *p,p'*-DDE 13.03 (6.87-19.19) µg/kg were detected.

The mean levels of pesticide residues detected in sediment samples were compared between the sampling sites. As shown in Fig 4a, all the pesticide residues detected during the rainy season had higher levels in samples collected from Kilolo than Muheza. Statistical analysis indicated the mean levels being higher in samples collected from Kilolo with the mean difference of 4.957 µg/kg. However the differences were insignificant at the two tailed p value of 0.2683. During the dry season, all the pesticide residue levels were higher in samples collected from Kilolo (Fig 4b) but the differences were insignificant at the two tailed p value of 0.333.

Pesticide residues detected in tomato samples

Samples of tomatoes were only collected from Kilolo. A total of 14 samples were collected and analyzed for pesticide residues. Six samples were collected during the rainy season and 8 during the dry season. Similar to the water, soil and sediment samples, γ-HCH, β-HCH, α-endosulfan, β-endosulfan, *p,p'*-DDT and *p,p'*-DDE pesticide residues were detected in all samples (Fig 5a).

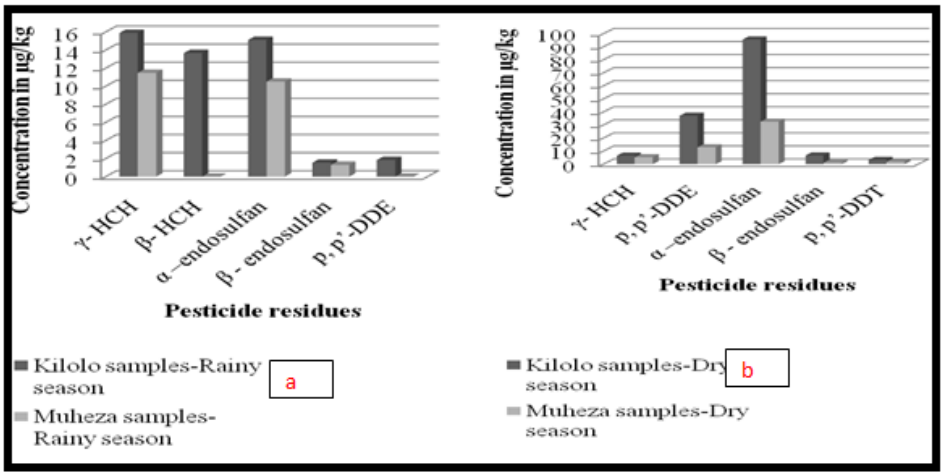


Fig. 4 Mean levels of pesticide residues for sediment samples during rainy and dry season (µg/kg) dry weight

Levels and distribution of pesticide residues detected in tomato samples

During the rainy season, only γ-HCH, α-endosulfan, β-endosulfan and *p,p'*-DDT were detected. Their mean levels and concentration ranges were: γ-HCH 1.76 (1.2-2.67), α-endosulfan 2.1(0.77-4.33), β-endosulfan 0.11 (0.02-0.19) and *p,p'*-DDT 0.44 (nd-0.44) µg/kg. The mean levels and concentration

ranges during the dry season were: γ-HCH 0.66 (0.41-0.99), β-HCH 0.41 (0.25-0.59), α-endosulfan 2.83 (1.02-5.47), β-endosulfan 0.22 (0.15-0.29), *p,p'*-DDT 0.51 (0.3-0.72) and *p,p'*-DDE 0.36 (0.23-0.49) µg/kg (Fig 5a).

Pesticide residues detected in black pepper samples
Black pepper samples were only collected from Muheza. A total of 10 samples were collected and analyzed for pesticide residues. Five were collected during the rainy season and five during the dry season. Only four pesticide residues (γ-HCH, α-endosulfan, β-endosulfan, and *p,p'*-DDT) were detected in the black pepper samples (Fig 5b).

Levels and distribution of pesticide residues detected in black pepper samples
The same pesticide residues were detected in both seasons. Their mean levels and concentration range were: rainy season γ-HCH 1.44 (0.21-2.77), α-endosulfan 1.79 (0.46-4.97), β–endosulfan 0.08 (0.02-0.15), and *p, p'*-DDT 0.09 (0.03-0.13) µg/kg; dry season γ-HCH 0.52 (0.08-1.53), α-endosulfan 1.72 (0.49-4.63), β-endosulfan 0.21(0.01-0.36) and *p,p'*-DDT 0.38 (0.05-0.74) µg/kg.

DISCUSSION

Farmers' practices particularly the use of systhetic pesticides in vegetable production, have been an issue of concern to all those involved in the management of the Udzungwa Mountains biodiveristy hotspots. Use of pesticides in agricultural production systems in the environs of ecologically important and fragile ecosystems are widely implicated as major sources of environmental pollution and threat to non-target organism (Castillo *et al.*, 2000, Dabrowski *et al*, 2002; Mwevura *et al*., 2002, Mullin *et al*., 2010, Nonga *et al*., 2011, Kihampa *et al.*, 2010). The results of our study provide evidence that some of the products currently used by vegetable growers in the area, notably endosulfan, lambda cyhalothrin, profenophos, chloropyriphos and dimethoate have high ecological and environmental risk potentials that requires immediate redress to avoid a crisis. In the study area these products are repeatedly and indiscriminately applied in time and space. This is exacerbated by the fact that pesticide rotations are based on trade names and not on active ingredient and that pesticide mixtures are commonly used. Additionally, vegetable growers hardly observe proper disposal of pesticide remains and packaging materials/containers, which are additional sources of environmental contamination.

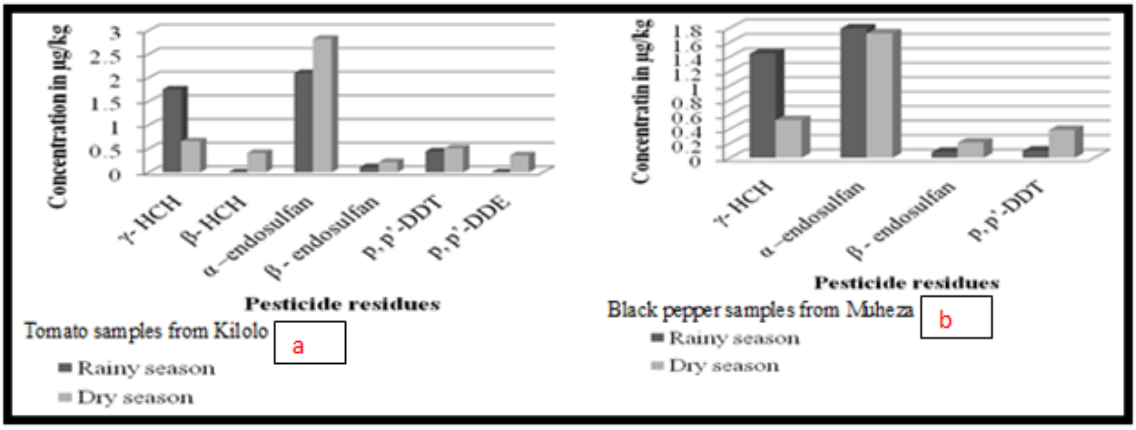


Fig.5. Mean levels of pesticide residues for tomato and black pepper samples during rainy and dry season (µg/kg) dry weight

The current farmers' practices are a result of inadequate knowledge on proper selection, use and handling of synthetic pesticides within the community, an issue that requires redress. Evidence from elsewhere indicates that some pesticides when applied in mixtures have higher direct effects on zooplanktons, phytoplanktons, periphytons and larval amphibians (Hayes *et al*., 2006, Relyea 2009). The gradual disappearance of the Kihansi spray, *N. Asperginis*, could be due to increased pesticide use in vegetable production upstream and the environs of the Kihansi river as alleged by Channing *et al.*, 2006, which should be further investigated. Mixtures of multiple pesticides, a common practice by the vegetable growers in Kilolo district is likely to pose cumulative effects on frogs; studies have observed tadpoles taking long to metamorphose into frogs and when they do are smaller, this decreases their ability to catch prey and avoid predators (Science daily, 2006, Wikipedia, 2012). In our KAP study dry season tomato production is done in swampy areas and river beds where frogs have their natural shelters and thus

are directly exposed to the threat. Pesticide runoff into water bodies can be highly lethal to other aquatic life; they can cause fish kills and their accumulations kill off zooplankton, the main source of food for young fish (Helfrich *et al*., 1996, PAN North America, 1999).

Levels of pesticide residues in sample matrices and its implications to biodiversity conservation

In general sediment samples were found to have higher levels of pesticide residues than the other sample matrices most likely due to bioaccumulation (Gustafsson, 2001, Barlas, 2006). Bioaccumulation of pesticide residues is expected to pose long term threats to organisms in sediments and therefore affect the general biodiversity. Mean levels of pesticide residues in all the sample matrices were higher in samples collected from Kilolo compared to Muheza mostly because the Muheza farmers do not use pesticides in spice production as informed by the KAP study. The source of these trace amount of pesticides detected in sample matrices needs to be investigated.

Among the ten active ingredients that were recorded during the KAP study, only the metabolites of endosulfan were detected and confirmed in this analysis. The presence of the burned organochlorine pesticides may be due to their persistent in the environment (Barlow, 1985) following their use before they were burned in the 1990's as also reported by Kihampa *et al* (2010). However, detection of *p,p'*-DDT in some samples and the ratio of DDT and DDE (DDE/ DDT) being less than 1 indicate recent application of the pesticides in the environment (Pirnie, 2006), an issue that needs further investigation to ascertain their sources in the environment both in Kilolo and Muheza.

The non-detection of the other listed products during the KAP study could be due to a number of factors: their instability under certain conditions and easy of biodegradation. Cyhalothrins are fluorinated pyrethroids (Cameo Chemicals, 2008), these may have not been detected in samples due to their tendency to break down quickly in direct sunlight, usually a few days after application (Masachika, 1989; Wikipedia, 2010). Under anaerobic conditions profenophos applied to soil is rapidly degraded; studies show that after 28-30 days only small amount (0.1-1.6%) of the applied remains as parent (Pesticide Report, JMPR, 2008). The fact that only endosulfan metabolites were detected in this study is of concern to the research team because of the current farmer practices as reported above. We are therefore suggesting use of a combination of more sensitive analytical methods and analysis of pesticide residues to be carried out in the field during sampling using portable instruments such as the Field Portable HPLC model 210D. Moreover, it is important to note that sometimes it is not possible to detect all the active ingredients in the environment and their metabolite in laboratory tests, a situation also reported by Castillo *et al.,* (2000) on banana plantation in the North Atlantic zone of Costa Rica.

The environmental impact of pesticides is always greater than what is intended by those who use them. From the results of the KAP study, the pesticide residue analysis, and evidence from elsewhere some of the active ingredients, including endosulfan, chloripyrifos and metalaxyl persists in the environment (Odenkirchen and Eisles, 1998; Monkiedje *et al*., 2003). This poses a threat at different levels in the food chain (Kellogg *et al.*, 2000). Hose *et al* (2003) reported significant reduction in the abundances of invertebrate taxa following different concentrations against time exposure to endosulfan. Both endosulfan and DDT metabolites were detected in our analysis. The KAP study indicated that pesticides are sprayed from germination to the last harvest, sometimes twice a week for a crop that remains in the field for up to six months. This is more than short term exposure and thus likely to pose serious threat to a wide range of organisms in the food chain directly or through sub-lethal dosages and bioaccumulation in the environment.

Seasonal variation of pesticide residues in samples matrices

Most of the pesticide residues detected had higher levels in samples collected during the dry season. Higher mean levels of pesticide residues detected during the dry season may be due to reduced dilution effect as a result of low rains during the season. This results compares with the report by Hellar, (2000) in the assessment of pesticide residues in the sugar plantations and its enviros after long-term use in TPDC Kilimanjaro Tanzania.

CONCLUSIONS

The current farmer practices regarding pesticide selection, use and disposal of pesticide left overs and packaging material are identified as key knowledge gaps that require urgent reddress to reduce potential environmental health hazards in the study areas. Detection of DDT residues and its metabolites in both study sites, a product that was not listed during KAP study, is of great concern because it is banned for use in crop production in Tanzania. Similarly, of concern is the detection of organochlorine residues and metabolites in samples from Muheza where farmers practice organic production. These preliminary results should be used as a baseline for the formulation and development of future

monitoring and mitigation strategy to enhance coexistence of rural communities and the biodiversity hotspost in the Eastern Arc Mountains.

ACKNOWLEDGMENTS

We acknowledge the potential contribution of the late Prof. Michael A. Kishimba. The research was co-financed by Mkwawa University College of Education, The Eastern Arc Mountains Conservation Endowment Fund and the International Centre of Insect Physiology and Ecology (ICIPE).

REFERENCES

Akerblom M (1995) Environmental monitoring of pesticide residues-guideline for the SADC region. SADC ELMS monitoring techniques series 3, Maseru, Lesotho.

Barlas N, Çok I, Akbut N (2006) The Contamination of organochlorine pesticides in water and sediment samples in Uluabat Lake, Turkey. Environ Monit Assess 118: 383-391.

Barlow F (1985) Chemistry and formulation: Pesticide application, principles and practice. Oxford Science Publications

Brooks TM, Mittermeier RA, Mittermeier CG *et al* (2002) Habitat Loss and Extinction in the Hotspots of Biodiversity. Conserv Biol 16: 909–923.

Cameo Chemicals (2008) Cyhalothrin,United States National Oceanic and Atmospheric Administration. Available via DIALOG. http://en.wikipedia.org/wiki/Cyhalothrin. Cited 07 April 2012

Castillo LE, Ruepert C, Solis E (2000) Pesticide residues in the aquatic environment of banana plantation areas in the North Atlantic zone of Costa Rica. Environ Toxicol Chem 19 (8): 1942-1950

CEPF (2007) Workshop proceedings, Conservation and Management of the Southern Udzugwa mountains: The way forward. Oasis Hotel, Morogoro, 23rd March 2007

Channing A, Finlow-Bates KS, Haarklau SE, Hawkes PG (2006) The biology and recent history of the critically endangered Kihansi spray toad *Nectorphrynoides asperginis* in Tanzania. J E Afr Nat Hist 95(2): 117-138

Dabrowski JM, Peall SK, Reinecke AJ, *et al* (2002) Runoff-related pesticide input into the Lourens River South Africa: Basic data for assessment and risk mitigation at the catchment scale. Water Air Soil Pollut 135: 265-283

EAMCEF (2005-2007) Reports, Morogoro-Tanzania 2005-2007

Ehardt CL, Jones TP, Butynski TM (2005) Protective status, ecology and strategy for improving conservation of *Cercocebus sanjei* in the Udzungwa Mountains. Tanzania. Int J Primatol 26(3): 557-583

Gustafsson A (2001) Pesticides in stream and pond sediments of Vemmenhog area: A small agricultural catchment in Southern Sweden. M.Sc Thesis, Swedish University of Agricultural Sciences

Hayes TB, Case P, Chui S, *et al* (2006) Pesticide mixtures, endocrine disruption and amphibian decline: Are we understanding the impact? Environ Health Perspect. 114: 40-50

Helfrich LA, Weigman DL, Hipkins P, Stinson ER (1996) Pesticides and aquatic animals: Guide reducing impacts on aquatic systems. Virginia Cooperative Extension

Hellar H (2000) Pesticide residues in sugar plantations and enviros after long-term use: The case of TPC Ltd, Kilimanjaro region. PhD Thesis, University of Dar es Salaam

Hose GC, and Lim RP (2003) Short-term exposure to aqueous endosulfan affects macroinvertebrate assemblages. Ecotoxicol Environ saf 56 (2): 282-294

Kellogg RL, Nehring R, Grube A *et al* (2000) Environmental indicator of pesticide leaching and runoff from farm fields. United States Department of Agriculture Natural Resources Conservation Services

Kihampa C, Mato RR, Mohamed H (2010) Residue of Organochlorinated Pesticides in Soil from Tomato Fields, Ngarenanyuki Tanzania. J App Sci Environ Manage 14: 37-40

Marco JAM, Kishimba MA (2007) Organochlorine pesticides and metabolites in young leaves of Mangifera indica from sites near a point source in Coast region, Tanzania. Chemosphere (68): 832-837.

Masachika H (1989) Characteristics of pyrethroids for insect pest control in Agriculture. Pestic Sci 27: 353-360

Monkiedje A, Spiteller M, Bester K (2003) Degradation of ramic and enantiopure metalaxyl in tropica and temperate soils. Environ Sci Techn 37 (4): 707-712

Mullin CA, Frazier M, Frazier JL *et al* (2010) High Levels of Miticides and Agrochemicals in North American Apiaries: Implications for Honey Bee Health. PLoS ONE 5 (3): e9754. doi:10.1371/journal.pone.0009754

Mwevura H, Othman OC, Mhehe GL (2002) Organochlorine pesticides in waters from the Coastal area of Dar es Salaam and their effect on aquatic biota. Taz J Sci 28 (2): 116-130

Myers N, Mittermeier RA, Mittermeier CG *et al* (2000) Biodiversity hotspots for conservation priorities. Nature 403: 853–858.

Ngowi AVF, Mbise TJ, Ijani ASM *et al* (2007) Smallholder vegetable farmers in northern Tanzania: Pesticide use practices, perceptions, cost, and health effects. Science Direct 26: 1617-1624,

Nonga HE, Mdegela RH, Lie, E *et al* (2011) Assessment of farming practices and use of agrochemicals in Lake Manyara basin, Tanzania. Afr J Agric 6 (10): 2216-2230

Odenkirchen EW, Eisles R (1988) Chloropyrifos hazards to fish, wildlife and invertebrates: A synoptic review. Contamination Hazard Reviews 1035, Paluxent Wildlife Research Centre, USA. PAN-UK 2002. Available via DIALOG. www.pan uk.org/pestnews/Actives/dimethoate.htm. Cited 15 Feb 2012

PAN North America (1999) Pesticide threatening birds and fish in California:

Pesticide Report, JMPR (2008) Profenofos. Available viaDIALOG.(http://www.fao.org/fileadmin/templates/agphome/documents/Pests_Pesticides/JMPR/Report08/Profenofos.pdf. Cited 07 April 2012

Picone C, Van TD (2002) Agriculture and Biodiversity Loss: Industrial Agriculture. Life on Earth: An Encyclopedia of Biodiversity, Ecology, and Evolution, pp. 99-105.

Pirnie EF, Talley WJ, Asce M, Hundal LS (2006) Transformation of DDT and its metabolites by various abiotic methods. J Environ Eng 132: 560-564.

Relyea RA (2009) A cocktail of contaminants: How mixtures of pesticides at low concentrations affect aquatic communities. Ecology159 (2): 363-376

Ruijter J, Ayo C (2010) Golden Food Products Tanzania. Sustainable Spice Conference, Royal Tropical Institute, 12 October 2010,

Science daily (2006) Pesticide combinations imperil frogs: Probably contribute to amphibian decline. Available via DIALOG. http://www.sciencedaily.com/releases/2006/02/060202180830.htm. Cited 16 October 2007

URT (2009) Fourth National Report on implementation of Convention on Biological Diversity (CBD). Tanzania Vice Presidents' Office, Division of Environment, July 2009.

Wikipedia the free encyclopedia (2010). Available via DIALOG. www. En.wikipedia.org/wiki/pyrethrin Cited 01 March 2010