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Pesticide use among smallholder rice farmers in Tanzania

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Abstract In an interview study conducted among smallholder rice farmers in Rufiji, Tanzania coastal mainland, and in Cheju, Zanzibar, farmer's pesticide use and risk awareness were assessed. The farmers generally lacked knowledge or possibilities to manage the pesticides as prescribed by the manufacturers. Few farmers knew what kind of pesticides they were using and had never seen the original packages, as pesticides were usually sold per weight or already diluted without labeling. Protective equipment was rarely used since they were not aware of risks associated with pesticides or did not know where to purchase protective gear. Only half of the farmers were aware of pesticides' health hazards and few associated pesticides with environmental problems. The pesticide use was relatively low, but based on farmers' pesticide handling and application practices, health risks were a major concern. Most farmers did not believe in successful rice cultivation without using pesticides to control pests. However, estimated yields did not differ between pesticide users or farmers using conventional methods or neem tree extract. To avoid negative effects on human health and the environment, the farmers need basic education and better assistance in their farming practices and pesticide management.

Keywords Human health · Risk awareness · Zanzibar · Rufiji

1 Introduction

Rice is one of the major staple foods that are produced in Tanzania (FAOSTAT 2008) by the country's smallholders that make up a vast majority of the total population (MAFST

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2003). The total production of rice is the fourth most important among crops besides cassava, maize, banana, and sugarcane (FAOSTAT 2008). Rice is especially valued in the coastal zone that is dominated by the Swahili culture, influenced by Arab merchants (Walshaw 2010), and is the single most important crop in Zanzibar Islands (NLUP 1995). Pesticide use on the rice fields of Zanzibar has been recorded since 1977 and was in the beginning subsidized by the Zanzibar government, and therefore, pesticides were easily available to most farmers (Mohammed 1990). Less is known about the previous pesticide use in remote areas of Tanzania mainland.

Negative effects of pesticide use in paddy field rice cultivations have been reported throughout the world (reviewed by Abdullah et al. 1997). Even though many rice farms along the Tanzanian coast are rain-fed-lowlands (NLUP 1995), their closeness to water bodies could make the use of pesticides problematic. Pesticide use in rice production may not only negatively affect the surrounding environment but can also harm human health and have a negative impact on farmers' productivity (Antle and Pingali 1994). When health effects on rice farmers in the Philippines were considered, the net benefits of insecticide use were even negative (Pingali et al. 1994). Several African studies have reported very poor pesticide handling practices and low risk awareness among farmers in general (Matthews et al. 2003; Mmochi and Mberek 1998; Hanshi 2001; Ngowi 2002). This uninformed pesticide management is a serious threat to public health and can create environmental problems.

1.1 Rice farms in Rufiji (mainland Tanzania) and Cheju (Zanzibar)

The mangrove forest of the Rufiji delta is the largest in East Africa (Masalu 2003) and is generally little affected by human activities (Turpie 2000). Some 36 000 inhabitants (Turpie 2000) live in the 53,000-ha large mangrove-covered part of the Rufiji delta (RDC 2007a) and depend on a variety of natural resources from the mangroves. Rice farming is the most important activity in the northern part of the delta, followed by fishing and sales of mangrove woods (Taylor et al. 2003). A large majority of the households (76%) cultivate rice within the mangroves (Turpie 2000), using 4,450 ha of the total mangrove area of 48,030 ha for farming (pers. com. Rufiji District mangrove office; Wang et al. 2003). It is only during the rain period from January to June that salinity conditions suitable for rice farming occur in the delta (RDC 2007a). A frequent use of pesticides to combat mangrove crabs in the mangrove rice farms in the Rufiji Delta (Mwevura 2007) has raised concern of potential effects on human health and the estuarine environment. Chemical analyses of pesticide residues in the surrounding environment of the rice farms have also detected a current use of, for example, lindane, organophosphates, and metabolites of persistent organochlorines (Mwevura 2007).

Zanzibar Islands, including Zanzibar and Pemba Islands, is a part of the United Republic of Tanzania. The larger of the two islands, Zanzibar Island, comprises an area of 153,340 ha (NLUP 1995) and has a total population of 621,000 (NBS 2002). The main sources of income are agriculture and fishing (NLUP 1995). About 34% of the land in Zanzibar Island is used for agriculture, of which 3,500 ha are rice cultivations (NLUP 1995). Cheju, together with Mahonda, is the largest monoculture and connected rice field areas on the island, comprising ca 1,000-ha rain-fed and irrigated plots (Institute of Marine Sciences of Zanzibar GIS Database 2010; Mmochi and Mberek 1998; pers. com. Agricultural Officer, Central District). The drainage basin of Cheju is Chwaka Bay, which is considered a nationally important fishing ground (ICAM 1996). Ninety percent of the pesticides imported to Zanzibar Island are utilized for agricultural purposes, mainly in the

big monocultures of rice, sugarcane, and citrus fruits (Mmochi 2005). There have been reports of fish and shrimp mortalities in the mangroves of Chwaka Bay that coincide with the application of pesticides and fertilizers on adjacent rice fields (Mmochi 2005).

The objective of this interview study was to assess farmers' pesticide management in the two areas Cheju (Zanzibar) and Rufiji (Tanzania), where rice cultivation is the main source of income and pesticide use potentially can cause health problems and environmental effects. More specifically, the aims were to investigate and compare the extent and measures taken to control pests, pesticide use and handling practices, and the farmer's pesticide safety and risk awareness. The two study sites differ with regard to farming methods, environmental location, access to infrastructure, and management systems.

2 Materials and methods

2.1 Study sites

2.1.1 Rufiji

Rufiji District is one of six districts of the coastal (Pwani) region in Southeast Tanzania. The interviews were conducted in eight villages in the northern parts of the delta, which together have a total population of approximately 18,000 (RDC 2007b; NBS 2002). In 1990, about 5,000 farmers were active cultivating rice in the mangrove. Today, these figures are estimated to be slightly higher (pers. com. F. Sima, Rufiji District Mangrove Officer). The Rufiji District is found at the bottom of the district development rankings, particularly regarding adult literacy, water, and sanitation (NBS 2002). There are also problems with health care and high rates of child mortality, as well as infrastructure, with roads and electricity largely lacking (RDC 2007a).

The 84 interviews conducted in Rufiji were distributed among the villages as follows: Nyamisati ($n = 31$), Kikale ($n = 10$), Mchungu ($n = 4$), Mtunda ($n = 11$), Ruaruke[1] ($n = 9$), Salale ($n = 5$), Mfisini ($n = 6$), and Kiomboni ($n = 8$). All interviews were conducted in June and July 2008.

2.1.2 Cheju

Cheju, located in the Central District of Eastern Zanzibar Island and situated next to the village Jendele, was the main area for investigation, where about 4,200 farmers are cultivating 1,000 ha of irrigated and rain-fed lowland rice (Institute of Marine Sciences of Zanzibar GIS database 2010; Mmochi and Mberek 1998; pers. com. Agricultural Officer, Central District). The farmers here generally have better living standards than in Rufiji with, for example, access to electricity, roads, and agricultural extension officers (employed by the Plant Protection Department to support farmers with agriculture and pest management). A total of 22 rice farmers ($n = 22$) were interviewed during the period of November and December 2007.

[1] Ruaruke is located outside of the delta and lacks mangroves but was included in the study since a large proportion of the village's inhabitants grow rice in the mangroves of the other villages.

2.2 Interviews

The interviews were based on both questionnaires with open-ended questions and semi-structured interviews in Kiswahili using interpreters. The interpreters were well informed with the purpose of the study. Interviews with the Clinic Officer of the Nyamisati hospital and the nurse in Mfisini, Rufiji, were also held in Kiswahili using interpreter but without questionnaires.

The farmers in Zanzibar were interviewed on their rice fields, at the agricultural office in Cheju or in the closest village (Jendele), whereas most of the interviews in Rufiji were conducted in the villages and very few were conducted on the rice fields. Since the location of the rice farm was not equivalent to the village of residence, there was an uneven distribution of respondents between the villages. The large sample size in Nyamisati was due to the larger population compared to other villages in Rufiji.

The interviewed farmers were selected together with a representative from each village/area according to sex, age, and type of farming, in order to get a representative selection of respondents. The interviews with the farmers contained questions on personal information (age, marital status, education level, household size), background information (profession, income, cultivation details, eating habits), pesticide use, and risk awareness.

Data collected were analyzed using descriptive statistics, and one-way ANOVA was computed with the free software R version 2.8.1. Before analysis, the data were tested for normal distribution and homogeneity of variances. Data that were not normally distributed were tested for best transformation method using a Box-Cox and thereafter square-root-transformed according to the best method indicated.

3 Results

3.1 Background information on interviewed farmers in Rufiji and Cheju

Even though there were differences between the two studied areas Cheju (Zanzibar) and Rufiji (Tanzania) in terms of both natural and institutional setup, the respondents were sharing similar demographic traits (Table 1). All interviewed farmers were cultivating rice, and a majority had farming as their main occupation and as main source of income. The average plot size was relatively small, 1–5 acres, sometimes even smaller. The minimum requirement of a plot size to sustain a family of 5 people has been estimated to 1.5 acres (NLUP 1995). As in most areas where the Swahili culture is the dominant, rice was one of the major staple foods produced and eaten by the farmers in both Rufiji and Cheju. A majority of the interviewed farmers were using some kinds of pesticides.

3.2 Rufiji

3.2.1 Background information on rice farmers in Rufiji

The farmers in Rufiji were often farming far away from their home village, resulting in many of them spending 6 months or more in the field, away from their families. In addition to farming, many were involved in other activities, such as fishing, making straw mats, selling food on the market, and small business, when they were not cultivating rice. Most of the rice yield was consumed in the family, and a majority of them could satisfy their own household needs for rice with their cultivations. Although most farmers wanted to

Table 1 Demographic characteristics of rice farmers in Rufiji (n = 84) and Cheju (n = 22)

Variable	Rufiji (%)	Cheju (%)
Sex	$n = 84$	$n = 22$
Female	51	32
Male	49	68
Age	$n = 83$	$n = 22$
<20	6	36
21–40	38	59
41–60	42	5
61–	11	–
Do not know	3	–
Marital status	$n = 81$	$n = 22$
Married	90	90
Divorced	2	5
Widowed	2	5
Single	6	–
Household size	$n = 81$	$n = 22$
1–5	28	27
6–10	70	50
11–	2	23
Level of education	$n = 83$	$n = 21$
No education or quran school	43	24
Primary school not completed	3	29
Primary school completed	49	14
Secondary school not completed	2	24
Secondary school completed	3	9
Size of plot	$n = 83$	$n = 22$
<1 acre	7	36
1–5 acres	87	64
6–10 acres	6	–
Occupation	$n = 83$	$n = 22$
Farmer	100	100
Additional occupation	65	32
Cultivating rice	$n = 83$	$n = 22$
	100	100
Years of farming	$n = 83$	$n = 22$
1–10 years	45	45

Table 1 continued

Years of farming	$n = 83$	$n = 22$
11–20 years	20	23
21–30 years	17	14
31–	18	18

expand their rice plots in order to increase rice yields, almost all felt that it would not be possible, mainly due to governmental restrictions and lack of space.

3.2.2 Pesticide use in Rufiji

3.2.2.1 Problems in mangrove rice farming Rice farmers in the mangrove delta of Rufiji faced several difficulties on their farms, which included the presence of crabs, hogs, monkeys, and weeds (Table 2). Almost all farmers had problems with crabs grazing on rice seedlings, but were affected to different extent. Most farmers took measures to control the crabs, for instance by using pesticides, conventional methods based on feeding crabs with rice husks, removing them manually or building fences around the farm land, or by using neem tree extract (Table 2). Most farmers found synthetic pesticides most effective against mangrove crabs and did not believe in successful rice cultivation without any measures against the crabs.

A majority (81%) of the farmers estimated a loss of 75% or more of their yields if pesticides were not used. However, their estimated annual rice yields did not differ significantly between pesticide users (10 rice sacks/acre) and farmers using conventional methods (12 sacks/acre) or neem users (11 sacks/acre) (ANOVA, $p = 0.51$).

A few farmers also used an unidentified powder pesticide which they referred to as "pig poison" (possibly a rodenticide) that they mixed with fruits and used as bait for hogs. Although weeds troubled approximately half of the farmers, most weeding was done manually. Only one farmer (in Kikale) used herbicides (not mentioned by name). Rice plant diseases bothered a few farmers that saw no solution for the diseases (Table 2).

3.2.2.2 Pesticide application The farmers' knowledge about the used chemicals was very limited. Few knew the commercial names or the active ingredient of the pesticides that they were using, and therefore, only a few pesticides were specified during the interviews (Table 3). Often they referred to them in general terms as "DDT", "crab medicine", or "coffee medicine". Most farmers knew that DDT was banned for agricultural use in Tanzania. The general use of the term "DDT" indicates DDT's former status as it was commonly used in the delta before the national ban in 1989 (Mmochi and Mberek 1998). On the question for how long they had been using the pesticides that are used today, many answered more than 20 years or for a long time.

Most farmers had never seen the original packages of the pesticides as they usually bought them already diluted or as an undiluted liquid or powder in small quantities. Often, they reused empty water bottles without proper labeling of the new content. The retailers were either local villagers or visiting vendors. Only 30% of the farmers were going to Dar es Salaam or to the nearest towns, Kibiti and Ikwiriri, to purchase unbroken original pesticides packages. Those who did were often also diluting and selling the pesticides themselves to other farmers in their home villages. Most farmers had not received any recommendation for the pesticide they were using. Instead, they were either testing the

Table 2 Experienced pest problems and measures taken to control pests in Rufiji and Cheju

Variable	Rufiji (%)	Variable	Cheju (%)
Experienced pest problems ($n = 83$)		Experienced worst pest problems[a] ($n = 13$)	
Crabs	100	Insects/larvae	62
Hogs	68	Rats	23
Monkeys	52	Birds	8
Weeds	52	Plant diseases	8
Plant diseases	28	Weeds	8
Birds	12		
Insects/larvae	6	*Most targeted pests*: insects and weeds	
Measures taken against crabs ($n = 83$)		Measures taken against pest problems	
Pesticides	84	Pesticides ($n = 22$)	82
Conventional method	8	Manual weeding ($n = 19$)	95
Neem tree extract	4		
No method	4		
Pesticides used ($n = 84$)		Pesticides used ($n = 18$)	
Insecticides	100	Insecticides	89
Herbicides	1	Herbicides	67
Other (used against pigs)	4	Rodenticides	17

[a] Even though most farmers experienced weeds, it was not considered as one of the worst problems, since several measures could be taken against the pest

Table 3 Substances in use mentioned during the interviews with farmers in Rufiji and Cheju (chemical classification from Tomlin 2000)

Commercial name	Active ingredient	Chemical group	Type of pesticide
Rufiji			
Criozon	Diazinon	Organophosphate	Insecticide
Karate	Lambda-cyhalothrin	Pyrethroid	Insecticide
Sumithion	Fenitrothion	Organophosphate	Insecticide
Dume	Dimethoate	Organophosphate	Insecticide
Ninja	Lambda-cyhalothrin	Pyrethroid	Insecticide
Cheju			
Satunil	Propanil	Anilide	Herbicide
	Thiobencarb	Thiocarbamate	Herbicide
2,4-D	2,4-D	Aryloxyalkanoic acid	Herbicide
Gramazon	Paraquat	Bipyridylium	Herbicide
Dimeothoate	Dimethoate	Organophosphate	Insecticide
Malathion	Malathion	Organophosphate	Insecticide
Lambdacal	Lambda-cyhalothrin	Pyrethroid	Insecticide
Thiodane	Endosulfan	Organochlorine	Insecticide
Thionex	Endosulfan	Organochlorine	Insecticide

The results originate from very few respondents as farmers rarely knew the commercial names of the pesticides they used

pesticide themselves or learning from other farmers. Some farmers were simply buying what was available.

Most farmers applied pesticides only during the planting season (January to March), with varying frequency (1–40 times per season), sometimes very intensively but most commonly 1–3 times per season (Table 4). Some farmers concentrated their application to low tides, others to high tides. The most common application method was to mix the pesticide with rice husks that were distributed inside or on the boundaries of the farm. Only a few farmers applied pesticides with sprayers (Table 4). The amount of pesticides applied was determined through trial and error, the amount of crabs, or information from other farmers. The application was performed equally by both men and women. Occasionally, children were also present during application.

More than half of the farmers (68%) used 3,000 TZS ($\sim$2 USD) or less per acre in a season on pesticides. No one mentioned spending more than 25,000 TZS ($\sim$17 USD) per acre in a season. Half of the farmers wanted to use more pesticides if they could, a few were uncertain, and the rest thought the present use was sufficient.

3.2.3 Pesticide safety and risk awareness

Safety instructions were seldom (50%) included when pesticides were purchased. When provided, verbal recommendations from retailers or labels on the package were most common. Retailers recommended to keep pesticides away from children, to wear gloves, and to wash hands after use. Written safety instructions were often only in English, which could not be understood by the farmers, who often were illiterate. However, a majority of the farmers thought it was important to follow safety instructions (Table 5), and many requested more information and advice on pesticide use.

More than half of the farmers did not use any protective equipment during mixing or application of pesticides (Table 5). The pesticides and rice husks were often mixed together with their bare hands, and just half of them specifically mentioned that they washed their hands afterward. Kitchen utensils were often used for preparing the mixtures. Only two respondents mentioned that they had specific buckets for pesticides.

Table 4 Pesticide application regimes in Rufiji and Cheju

Variable	Rufiji (%)	Variable	Cheju (%)
Time of application ($n = 57$)		Time of application ($n = 18$)	
Planting season (Jan–Mar)	63	Commonly applied 1–2 times per planting season, 1 season for rain-fed and 2 for irrigated	
- during low tide	19		
- during high tide	11		
Application frequency ($n = 31$)		Application frequency ($n = 18$)	
1–10 times per season	77	Once per year	17
11–20 times	13	Once per season (two seasons)	33
>21 times	10	More than once per season	22
(average 10 times)		When problem occur/when needed	17
Application method ($n = 72$)		Application method ($n = 18$)	
Diluted pesticides mixed with rice husks	82	Spraying (knapsack sprayer)	100
Spraying	8	(some hired a person for spraying)	

Table 5 Safety instructions, protective equipment, pesticide storage and waste management, and experienced health problems of rice farmers in Rufiji and Cheju

Variable	Rufiji (%)	Variable	Cheju (%)
Information received on handling ($n = 68$)		Information received on handling ($n = 15$)	
Yes, when purchasing	43	Yes	47
Yes, sometimes	6	Yes, from extension officers	33
Not sure	6	Yes, from other farmers	7
No	46	No	33
		Do not handle pesticides themselves	20
Importance of following safety instructions ($n = 53$)		Following of instructions received ($n = 12$)	
Yes	91	Yes	75
No	4	No	8
Maybe	6	Do not handle pesticides themselves	17
Use of protective gear ($n = 71$)		Use of protective gear ($n = 14$)	
Yes	32	Yes	21
No	68	No	79
		Not available	29
Type of safety equipment used ($n = 46$)		Type of safety equipment used ($n = 3$)	
Wash hands	41	Mask (mentioned 3 times)	
Wear gloves (or plastic bags 6/21)	46	Gloves (mentioned 1 time)	
Mask (or kanga 2/6)	13	Gumboot (mentioned 1 time)	
Pesticide storage ($n = 75$)		Pesticide storage ($n = 18$)	
Out of reach from children	39	No storage, uses directly	28
In the farm	32	Safe place/safe place in home	44
Hole in ground	5	Special storage	28
In the house	16		
Waste handling ($n = 80$)		Waste handling ($n = 16$)	
Cans reused for pesticides	20	Cans reused for pesticides	6
Cans reused for other purposes, e.g., household	6	Cans reused for other purposes, e.g., household	19
Waste burned	11	Waste burned	13
Waste buried	19	Waste buried	19
Waste disposed in farm	14	Waste thrown away	31
Waste thrown away, e.g., river, sea, toilet, forest	21	Not dealing with the waste	13
Common experienced health problems related to pesticide exposure ($n = 13$)		Common experienced health problems related to pesticide exposure ($n = 10$)	
Stomach disturbances/diarrhea	92	Skin irritation	50
Headache	23		

Some respondents had never heard of safety equipment and could not comprehend their purpose as more than half (62%) did not see any risks with pesticide use for human health or the environment. A majority (65%) did not believe that pesticides could have any

negative effects on other organisms than the targeted pests. The respondents that wanted to use protective gear had rarely or never seen any in the area. Only 4 (of 30) considered safety equipment (gloves/masks) too expensive. Of farmers using safety equipment, gloves (or plastic bags) and masks/kanga were most common (Table 5).

A majority of the farmers prioritized a safe storage place, out of reach of children, even if some stored the bottles in their house. The disposal of pesticide packages included burning, burying or throwing them in the local environment. Some containers were also reused for other pesticides or household purposes (Table 5).

Most (84%) of the farmers had not experienced any symptoms after or during pesticide use. Of those who had experienced problems, headache and stomach disturbances were most common, and it always occurred during the preparation or application of the pesticides. Their health problems normally disappeared shortly after the pesticide exposure.

3.2.4 Interviews with the clinic officer of the Nyamisati hospital and a nurse in Mfisini

The clinic officer of Nyamisati hospital, trained in diagnosing and treating organophosphate poisonings, confirmed that pesticide poisoning occurred in farmer families. Men were most commonly affected, but elderly and children sometimes also showed symptoms of intoxication. The worst form of exposure was when pesticides were swallowed. Pesticide poisonings occurred because "there is no information at all!". Since people usually drink the river water directly, there were more cases of poisoning during application time. The medical doctor believed that cases of death that he had first related to cholera (similar symptoms as pesticide intoxication) could well be cases of pesticide poisoning.

The nurse in Mfisini also confirmed pesticide poisonings, particularly among elderly and children, and especially during the planting season, but also said that it was not common that people contacted the hospitals. Because of the low educational level in the area, and absence of agricultural extension officers, it was hard to educate people about pesticides. The nurse emphasized the need for more pesticide education for both health care workers and end-users.

3.3 Cheju

3.3.1 Background information on farmers in Cheju

The farmers in Cheju mostly came from surrounding villages, but some travelled from Zanzibar town to cultivate their plot. Most farmers were solo workers, but some (5/22) were a part of a cooperative union. The farmers had irrigated plots, which were more desirable and could sustain two harvests per year, or rain-fed lowland where only one harvest per year was possible. A few farmers had plots in both areas. One plot was normally 0.25 acres, but some farmers had more than one plot.

3.3.2 Pesticide application

The main problems that the farmers were facing included pest animals, weeds, lack of rainfall, broken tractors, or lack of pesticides. The majority of the farmers were using pesticides to combat pests, and the 4 respondents who did not use pesticides would like to if they could afford it. The most commonly used pesticides were insecticides, followed by herbicides and rodenticides (Tables 2, 3). Insects and weeds were the most targeted pest organisms (Table 2). The herbicide Satunil was the single most frequently mentioned pesticide.

Several farmers cultivating irrigated plots had received advice on which pesticide to use, either from the agricultural extension officers or from other farmers (Table 5). However, farmers of the rain-fed plots complained that they were neglected by the extension officers.

Most farmers (89%) bought their pesticides in the governmental shop adjacent to Cheju. Some farmers also purchased pesticides in private shops in nearby villages, in Zanzibar town, or in Dar es Salaam. About one-third would like to use more pesticides if they could afford, another third used according to needs, and the last third would like to use less pesticides if there was a better option. Before pesticides were used in the area, the farmers experienced no problems with pests, took no measure, or used manual weeding practices. A few farmers complained about a recent increase in pest organisms and that previously used pesticides were no longer effective.

Most farmers used pesticides according to instructions, either from the bottle or from advice from others (Table 5). All pesticides were applied with knapsack sprayers (Table 4). Some hired people for the application and did not handle the pesticides directly themselves. Farmers either used all purchased pesticides directly or stored pesticide remains in a safe place in the house or somewhere else. Waste products were usually thrown away, burnt, or buried, but some farmers also reused the pesticide containers for new pesticide mixtures or other purposes (Table 5).

The majority did not see any alternative to pesticide use, and pesticides were generally perceived as more effective, compared to traditional methods (e.g., using different spices) or manual weeding. However, almost all farmers also practiced manual weeding (Table 2), even though 14 out of 18 farmers considered herbicides cheaper and more effective than manual weeding.

3.3.3 Pesticide safety and risk awareness

The local name for pesticide was “madawa ya kilimo” (medicine/cure for crops). Even though most farmers claimed that they were following the instructions received for pesticide handling, the majority did not use protective equipment (Table 5), either they were not available or the farmers had not made up their minds yet on whether to use it or not.

Only half of the farmers perceived a risk with pesticide use. One-third of the farmers believed pesticides could affect the environment; one-third did not see any linkage between pesticide use and environmental effects, and the rest were uncertain. Some farmers could see that pesticides had effects on the soil quality, cows, frogs, and harmless insects.

4 Discussion

4.1 Pesticide use

This study revealed that a majority of the farmers cultivating rice in the Rufiji mangroves and Cheju rice farms used pesticides in order to eliminate pest organisms. Farmers in Rufiji used insecticides to mainly combat mangrove crabs, while farmers in Cheju used insecticides and herbicides against insects and weeds. In both areas, organophosphates were generally the most commonly used pesticides, agreeing with other findings of pesticide use in East Africa (Mbakaya et al. 1996). Endosulfan was the only organochlorine that was mentioned to be used during the present study. As this substance is about to be added to the Stockholm Convention of Persistent Organic Pollutants (POPs) (Kohler et al. 2008), it is worrying that it still was commonly used by the farmers in Cheju.

Local knowledge of the pesticides used in Rufiji was very limited, and most farmers bought ready-diluted or concentrated pesticides by weight from unauthorized vendors. Only a minority bought pesticides in original, labeled packages with sufficient information on content and safety instructions. The pesticide knowledge among the farmers in Cheju was somewhat higher. More farmers knew the commercial name of the pesticide they were using, and most farmers were buying pesticides from authorized vendors although the pesticides in Cheju also often were repacked.

Whereas farmers in Rufiji never seemed to have received proficient assistance in their pesticide use, the farmers in Cheju had at least one agricultural extension officer working in the area. During the 1990s, there had also been a FAO office in Cheju that was helping the farmers to reduce their pesticide use (Mmochi and Mberek 1998). This office had, however, been closed for several years when the present study was conducted (2007), and many farmers complained that they had no one to turn to if they experienced problems. In the 1990s, it was not custom for farmers in irrigated farms to use herbicides (Mmochi and Mberek 1998). This practice had changed by 2007 when at least every third farmer cultivating irrigated plots was using herbicides against weeds. The lack of assistance and encouragement may have contributed to make farmers more prone to use herbicides instead of weeding manually.

Due to primarily financial constraints, the use of pesticides was relatively low. On average, 1,000–3,000 TZS (~2 USD) was invested by farmers in Rufiji per acre per season. There is no similar estimate for Cheju; however, these farmers usually bought pesticides for 50–1,000 TZS (~0.03–0.7 USD) per purchase occassion, indicating that larger packages could not be afforded. Similar to other parts of Tanzania, farmers in both Rufiji and Cheju bought repacked unlabeled pesticides and rarely saw the original containers (Macha et al. 2001; Ngowi et al. 2001), which indicate an ignorance of pesticide manufacturers to meet the needs of end-users, by producing smaller packages (Article 8.2.8., FAO 2003).

4.2 Implications on human health and the environment

The use of pesticides in smallholder rice farming is primarily a potential health threat, rather than it is affecting the surrounding environment, since farmers were lacking assistance and knowledge. There was little or no use of protective equipment in both Rufiji and Cheju, either because they could not be bought in the nearby governmental pesticide shops (Cheju), they did not know where to get hold of them in the remote Rufiji area, or because the farmers did not believe that pesticides could have any negative effects on humans at all.

Few farmers seemed to be aware of potential health effects, although agricultural workers are considered to be at highest risk of exposure, in particular those using sprayers (Wesseling et al. 1997; Ngowi 2002). Acute pesticide poisoning symptoms are difficult to diagnose, as they may resemble common health problems, which often result in underestimations of poisonings (Clarke et al. 1997). Based on pesticide handling practices and the substances used in Rufiji and Cheju (mainly organophosphates with high human toxicity), farmers are likely to suffer from pesticide intoxication, which also could be confirmed by both farmers and medical workers. Organophosphates and carbamate esters, which now often replace organochlorine insecticides, dominate sources of intoxication (Leveridge 1996; McConnell and Hruska 1993; Thapinta and Hudak 2000). Pesticide waste and containers were often thrown into the local environment, either on the fields or directly in the river (Rufiji), where they contaminate the aquatic environment and thus constitute an exposure pathway also for non-farmers such as children playing with the containers.

At both study sites, the rice plantations were directly or indirectly connected to adjacent marine ecosystems, either through tidal inundation and flooding (Rufiji) or through surface runoff and groundwater intrusion (Cheju). However, as the overall pesticide use is still limited, it does not seem to constitute a threat to the marine environment. Chemical analyses performed in the studied areas also confirm this as only low pesticide concentrations have been detected (Mmochi 2005; Mwevura 2007; Kruitwagen et al. 2008). Interviewed fishermen also describe observed fish and shrimp mortalities in Chwaka Bay as natural phenomenon, as they seem to coincide with low tide and inflow of large amounts of fresh water that may cause oxygen depletion in shallow ponds (Stadlinger 2008).

Without information labels (or unintelligible labels) and with already diluted pesticides, it is impossible for the farmers to apply appropriate pesticide concentrations. Farmers in Cheju implied an observed increase in pest organisms during the recent years, and some complained that pesticides that had been used for a long time (e.g., endosulfan) were no longer efficient, which indicates development of pesticide resistance. Application of inappropriate pesticide concentrations can accelerate resistance development and can in long terms lead to great economical, environmental, and practical problems (Denholm and Rowland 1992; Riddles and Nolan 1987). This is another strong incentive for improving today's pesticide management practices in the studied areas.

4.3 Management considerations

Despite all the risks and costs associated with pesticide use, farmers in general continue to use pesticides (Pimentel and Acquay 1992). Drivers for phenomenon comprise difficulties to go back to old practices once pesticides have been introduced and that pesticide companies promote their products as the better option over conventional methods (Wilson and Tisdell 2001). The local names for pesticides "madawa ya kilimo" (medicine/cure for crops) or "dawa ya ngowe" (medicine against crabs) indicate the farmers' inadequate understanding of the function and the potential hazard these substances constitute. As small-scale farmers invest a substantial part of their income in pesticides, it is of considerable concern that it pays off (Williamson 2005).

Development of simpler and safer pest control methods has been stressed for developing countries, where stricter regulations are difficult to implement and education alone does not improve pesticide use safety (Antle and Capalbo 1994). To improve the situation for farmers, it is important to further investigate what information and pest management options that are available and to assess the knowledge of pesticide retailers and extension officers as they constitute the main sources for enhanced farming practices.

Similar to other African studies (e.g., Nyambo et al. 1996; Obopile et al. 2008; Williamson et al. 2008), the need for implementation of integrated pest management (IPM) programmes is of great interest for these two areas, where the farmers are smallholders and can invest time to observe early occurrences of pests. The IPM initiatives in Africa today are still relatively uncoordinated and small-scaled (Williamson 2005). The estimated yield comparison of pest management methods in this study further emphasizes the potential of using alternative methods.

This study demonstrates an unsustainable, health-hazardous pesticide management and a system that has little capacity to handle the effects that an increased pesticide use would imply for human health and the environment. There is a need for improved information systems on safe pesticide management to farmers to reduce health risks, as well as at an early stage mitigate pesticide-induced environmental problems, such as resistance developments and effects on non-target organism in the aquatic ecosystems.

5 Conclusions

The pesticide use in Rufiji and Cheju is relatively low but still constitutes a health threat due to lack of information and assistance on appropriate pesticide management practices. Most farmers do not believe in successful rice cultivation without using pesticides. However, this study indicates that alternative methods and a more integrated pest management might be as effective.

The inappropriate management practices of pesticides create a risk for human health but could also develop into an environmental problem. This study demonstrates an unsustainable pesticide management and systems with little capacity to handle the effects that an increased pesticide use would imply. Tanzania's and Zanzibar's pesticide management systems need to raise the awareness levels of retailers and rice farmers of the harmful effects of pesticides on human health and environment in order to (1) reduce farmer health risks in aquatic rice farming systems and (2) obtain pesticide-induced environmental risk mitigation.

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