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Pesticide Use Practices and Effects on the Wetland Biodiversity of Ndop, North West Region of Cameroon

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Authors' contributions

This work was carried out in collaboration among all authors. Author NTN designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript. Authors PBAF and MNT managed the analyses of the study. Author FN managed the literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Aims: The aim of this study was to evaluate farmer's pesticide use practices and their effects in the wetland of Ndop.

Study Design: A cross sectional study was carried out from January to August 2019 in Ndop, North West Region of Cameroon.

Methodology: Questionnaires were administered separately to 382 rice and 100 vegetable farmers, and descriptive statistics was used in analyzing the results. Specifically, the Chi-squared statistic was used to determine the nature of the relationship between the variables.

Results: The results showed that most of the crop fields (95.6%) lack a buffer zone since most farms were adjacent to water bodies (0 ≥farm ≥1 m). Farmers (100%) washed and rinsed

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knapsack sprayers in nearby water bodies. A majority of the farmers (71.3%) burnt or threw empty pesticide containers in open fields, water bodies, or nearby bushes. Both rice farmers (83.5%) and vegetable farmers (100%) reported that pesticides kill non-target organisms (fish, frogs, toad, snakes, birds, etc.) resulting into a drastic population decline in the wetland. A majority of the farmers (85.2%) no longer do fishing in the paddy fields because of the frequent fish decline caused by pesticide usage. *Clarias gariepinus* constituted 56% of the fish species harvested from the paddy fields and a drastic population decline was observed by the farmers. The average fish catch per month was low (12.22 kg ± 7.47 SD) relative to the past when pesticides were not used during cultivation. There was a significant difference between training and environmental awareness of pesticides ($X^2 = 28.98$, $p = 0.001$).

Conclusion: These results indicate an urgent need for a post-pesticide registration management strategy to ensure a sustainable management and conservation of the wetland resources of Ndop.

Keywords: Wetland; pesticides; fish catch; ecosystem conservation.

1. INTRODUCTION

Wetlands play a substantial role in ecosystem functioning and services because of their high productivity, rich species biodiversity, and contributions to global food security [1,2,3]. Across the globe, most freshwater wetland ecosystems have been transformed into crop fields to boost agricultural productivity. This wetland transformation alters their rich natural species composition and structure, though their rare and characteristic secondary species are worth protecting [1]. Generally, agricultural intensification, including pesticide usage, degrades the wetland habitats and reduces or changes their species biodiversity [4]. Globally, pesticides remain the most effective, reliable, and economical method of pest control [5]. Nevertheless, they cause undesirable effects such as; ozone depletion and biodiversity losses, as well as air, soil, and water pollution. Also, pesticides affect non-target organisms in the aquatic and terrestrial ecosystems [6,7,8]. In the wetland agro-ecosystems, pesticides affect non-target organisms through undesirable exposures to contaminants in water bodies, runoffs, and spray drift [9]. Lately, the chances of pesticide contamination in the Ndop flood plain of Cameroon are very high since crop cultivation has become very intensive to meet the urban food demands. Moreover, the government now subsidizes or provides pesticides to farmers who have never undergone official training on pesticide use practices [10]. These factors have encouraged the frequent and indiscriminate use of pesticides, resulting in toxic concentrations in the fragile wetland ecosystem of Ndop. Several studies in Cameroon have explored the farmer's pesticide use practice, knowledge or perception and the human and environmental effects of pesticides [11,12,13]. Such comprehensive information can assist in designing a pesticide post-registration management plan for risk reduction, sustainability, and biodiversity conservation. However, limited research has been done on the environmental effects of pesticides on the Ndop paddy wetland –the second-largest rice-producing scheme in the country. This study evaluated pesticide use practices and impacts in the wetland ecosystem of Ndop, North West Region of Cameroon.

2. METHODOLOGY

2.1 Study Site

The Ndop floodplain in the North West Region of Cameroon (Fig. 1) is an inter-basin (13000ha) that stretches from latitudes 5^o42^o and 6^o10^oN to longitudes 10^o11^o and 10^o40^oE [14]. The floodplain lies between West of Mt. Bamboutous, Northwest of Mt. Sabga, North of Mt. Oku, the Northeast of Wainamah hills and East of the Mbam Massif [15]. These mountains discharge numerous rivers and streams that flow to recharge the Baminjim dam, giving the wetland, characteristics that favour crop production throughout the year [14]. The Ndop floodplain has two seasons - short dry season (from mid-November to mid-Match), and a long rainy season (from mid-March to mid –November). The mean annual temperature is 26^oC, and rainfall is the subequatorial monsoon type with an annual average of between 2,500 and 3,000 mm per year and a mean value of 1,540 mm/year [16]. The floodplain has about 13,123 rice farmers, grouped under 188 Common Initiative Groups (CIGs) [3]. Apart from agriculture, fishing is one of the main activities in the paddy fields, and *Clarias gariepinus* (catfish) and *Oreochromis niloticus* (tilapia) are the main fish species harvested from the wetland.

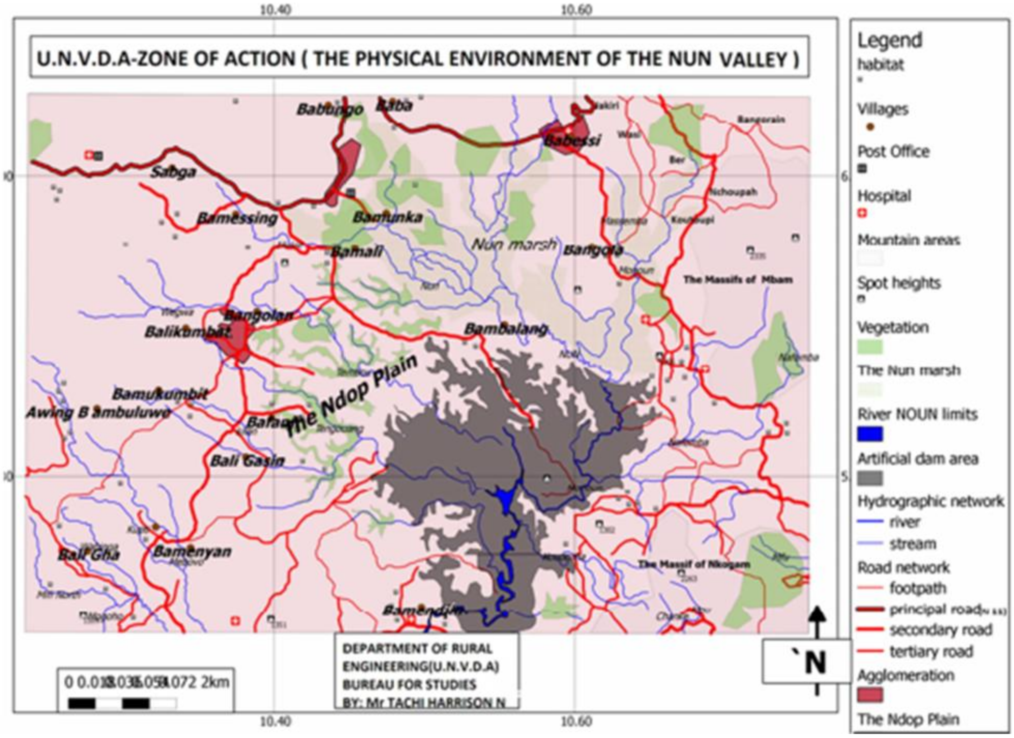

Fig. 1. Map of Ndop floodplain, North West Region, Cameroon
Source: Upper Nun Valley Development Authority, (UNVDA) Ndop (2016)

2.2 Determination of Sample Size

The sample size of rice farmers was determined using the following formula [17]:

$$n = \frac{(z^2 \times p \times q \times N)}{e^2(N-1) + z^2 \times p \times q}$$

Where; n = Sample size; Z = Std Variate at a given confidence limit (1.96 at 95%); p = Sample proportion = 0.5; q = (1-p) = 0.5; N = Size of population = 13,12; e = Maximum error = 0.05. The sample size of vegetable farmers was arbitrarily chosen, since there was no reliable estimate for the number of vegetable farmers, as farmers were not grouped into CIGs.

2.3 Data Collection

A cross-sectional study was conducted from January to August 2019 in the Ndop wetland. The sampling technique was convenient, and about 382 rice and 100 vegetable farmers were interviewed separately since the two groups of farmers were not mutually exclusive. The questionnaires were semi-structured with open-and-close-ended questions, with four categories of questions; (i) household socio-economic and farm characteristics of respondent farmers (i.e., age, sex, educational background, size of the farm under cultivation, stakeholders, etc.); (ii) pesticide use practices and management (i.e., types of pesticide, application scheme, and disposal pesticide containers, etc.) iii) perception and observable effects of pesticides on the environment (the effect of pesticides on non-target organisms soil, water, and air, etc.) and iv) fishing in the Ndop wetland.

2.4 Data Analysis

Data obtained from questionnaires were input in the IBM-SPSS for Windows version 21.0. Summary statistic was used to present the means (± standard deviation) and frequency distributions of pesticide use and perceptions among farmers. The chi-squared test statistics χ^2, at a statistically significant value p-value = 0.05, was used to determine associations between variables such as; farmers' training and either knowledge of pesticides or management practices, or awareness of the effects of pesticides on human health and the environment etc.

3. RESULTS

3.1 Farmers' Demographic Information

About 56.5% of rice farmers were males and, 43.5% were females, while almost all vegetable farmers (97%) were males since vegetable farming is a labour intensive activity. Most rice and vegetable producing farmers were within the age range of labor force (26-45 years) (Fig. 2). Vegetable farming is a recent activity relative to rice farming. Paddy farming was the main livelihood activity for more than 90% of the farmers, and 69.6% of the farmers had been farming for 1-15 years.

Most farmers had attained only the primary education and, few farmers have reached the university level of education (Fig. 3). The mean number of years of rice farming experience was 13.48 ± 9.60 years and, the maximum was 40 years, while the mean number of years of vegetable farming experience was 3.15 (± 1.40 years) and the maximum was 15 years. The mean-plot size owned by rice farmers was 0.83 ± 0.77 ha with the maximum being 6 ha, while the mean farm size owned by vegetable farmers was 0.92 ± 0.75 ha with the maximum being 4 ha. Most rice farmers (68.8%) owned a minimum of 0.8 ha, while 62.4% of vegetable farmers owned 0.5 -1 ha of the vegetable farm. The rice fields were along the banks of water channels/streams (0≥paddy fields≥ 1 m) while most vegetable farms (90.5%) were 0.5-5 m away from water bodies during the dry season.

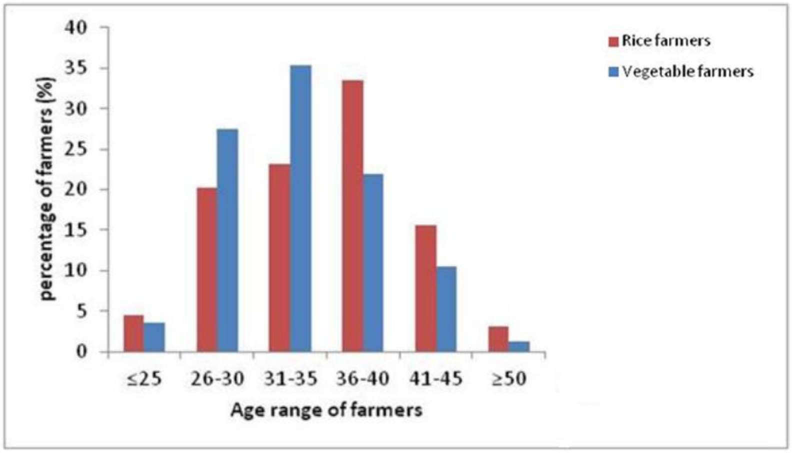

Fig. 2. Age of rice and vegetable producing farmers in Ndop

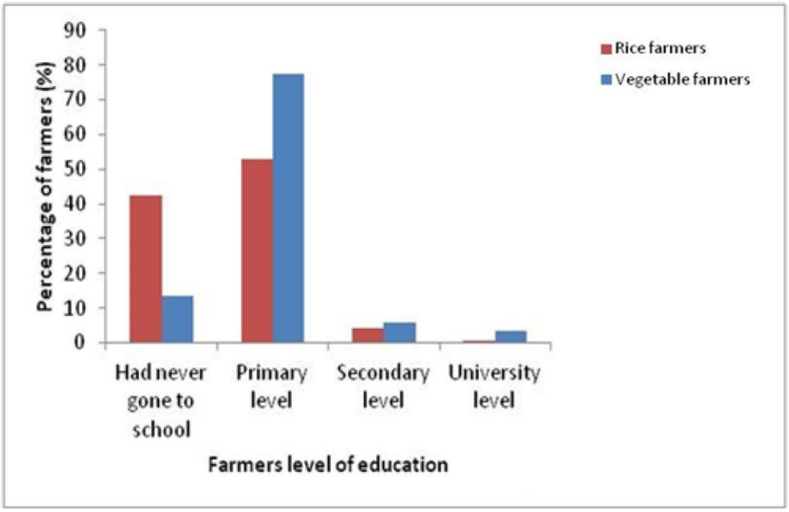

Fig. 3. Level of education of rice and vegetable producing farmers in Ndop

Most rice farmers (67.6%) have used pesticides for 3-6 years, and the mean duration of pesticide use was 4.06 years ± 2.03 SD and the maximum number of years of pesticide use was 20 years. Comparatively, most vegetable farmers (50.3%) have used pesticides for 5-8 years and the average number of years of pesticide use was 6.5 years ±1.40 SD) (Fig. 4). Most rice farmers (94.5%) and vegetable farmers (71.3%) had poor knowledge of pesticide handling.

3.2 Pesticide Stakeholders and Source of Information on Pesticides

Pesticide stakeholders in the Ndop floodplain included: the government through the Ministry of Agriculture and Rural Development (MINDER) and the Upper Nun Development Authority (UNVDA) - an agro-industrial corporation that supervises rice farmers; non-governmental organizations (NGOs), local pesticide vendors; farmers; bystanders and the inhabitants. The government (UNVDA) subsidized or provided pesticides to rice farmers on a credit basis. Farmers were the main pesticide stakeholders because they were the end-users who frequently uses pesticides to control insect pests and diseases of crops. The local pesticide vendors (13 vendors) have never undergone official training on pesticide management practices. Most rice farmers (81.6 %) obtained information on pesticide selection from their friends and neighbours , while some vegetable farmers (65.3 %) relied on their experience to select the pesticide. Likewise, most paddy farmers (76%) and vegetable farmers (57.5%) mostly obtained information on doses of pesticides from the others farmers, their friends and pesticide deallers, who have no clear idea on the doses of pestidides application for the control of insct pests and diseases.

3.3 Types of Pesticides Used by Farmers

Farmers in the study area are now using 37 pesticide formulations containing 17 active ingredients (a.i): three herbicides, seven fungicides, and seven insecticides (Table 1) during rice and vegetable production in the wetland. Based on the WHO classification of chemical hazards, the pesticides used were class II and III pesticides (Table 1). Glyphosate was present in seven formulations, and almost every farmer (93.2%) used glyphosate during crop field preparation. Rice farmers (100%) used only herbicides during cultivation. Paddy farmers (100%) used 2, 4-D Amine formulations (herbextra and decaplant) to control or kill broadleaf weed during rice cultivation. Comparatively, vegetable farmers (100%) used herbicides, fungicides, and insecticides during vegetable cultivation. Mancozeb (45.7%) and cypermethrin (78.5%) were the most frequently used fungicides and insecticides formulations during vegetable production.

3.4 Pesticide Application Scheme

All herbicides were applied twice a year at intervals of 180 days, during rice cultivation. During the vegetable growing seasons, fungicides and insecticides were applied 16 times, at an average time interval of 5 days (Table 2). Most farmers (60.5 %) never respected the respective standard recommended doses of pesticides. Rice farmers (98.7%) preferred individual/single herbicides application, while vegetable farmers (95%) preferred a combined application of fungicides and insecticides. Glyphosate, 2, 4 D –amine and chlorothalonil, scored the highest single-application dose, respectively (Table 2). Emamectine benzoate, fipronil, imidacloprid, metalaxyl, and paraquat dichloride had lower respective recommended doses. Farmers applied the higher concentration of most pesticides (over 70.58%). For instance, farmers doubled the single application doses of chlorothalonil, carbendazim, and lambda-cyhalothrin. Cypermethrin was applied to vegetables four times in recommended doses.

3.5 Disposal of Empty Containers and Excesses

A majority of the farmers (71.3%) buried, burnt, or threw empty pesticide containers in open fields (farms, streams, and bushes) (Fig. 5). One-fifth of the farmers burnt pesticide containers. However, some farmers disposed of the empty pesticide containers in trash houses constructed by UNVDA, and others reused the empty pesticide containers to drink water, palm wine, or to keep salt, sugar, and seasoning cube ("maggi") (Fig. 3). All farmers (100%) washed and rinsed Knapsacks in the flooded fields, water canals, nearby streams, or rivers. Farmers (100 %) either repeatedly sprayed their paddy fields with pesticide leftovers or threw pesticide leftovers in water bodies and bushes.

Table 1. Types of pesticides used by rice and vegetable producing farmers in the Ndop floodplains

S/N	Trade name of pesticides	Chemical group	Active ingredient (s) (a.i)	WHO classification of pesticides by hazard*
		Fungicides		
1	Agri-Fos 400 SL		Potassium Phosphite	III
2	Beauchamp 72 % WP	Inorganic	Copper oxide; 600 g/kg	III
3	Platineb 80 WP	Carbamate	Maneb 800 g/kg	III
4	Cotzeb 80 WP	Dithiocarbamate	Mancozeb 800 g/kg	III
5	Mancostar 80 WP	Dithiocarbamate	Mancozeb 800 g/kg	III
6	Mancozan Bleu	Dithiocarbamate	Mancozeb 800 g/kg	III
7	Penncozeb 80 WP	Dithiocarbamate	Mancozeb 800 g/kg	III
8	Ivory 80 WP	Dithiocarbamate	Mancozeb 800 g/kg	III
9	Monchamp 720 WP	Dithiocarbamate	Mancozeb 60 %+ Metalaxyl 12 %	III
10	Ridomil gold Plus 66 WP	Phenylamide/Inorganic	Metalaxyl; 120 g/kg Copper oxide; 600 g/kg	III
11	Banko plus	Organochlorine/ Carbamate	Chlorothalonil 550 g/l +Carbendazime 100 g/l	III
12	Balear 720 SC	Organochlorine	Chlorothalonil 720 g/l	III
		Herbicides		
13	Herbextra	Alkylchlorophenoxy	2, 4-D Amine Salts 720 g/l	II
14	Decaplant 720	Alkylchlorophenoxy	2, 4-D Amine Salts 720 g/l	II
15	Gramoxone	Herbicide/Bipyridylium	Paraquat dichloride 200 g/l	II
16	Clean farm	Herbicide/ Phosphanoglycine	Glyphosate 75.7 %W/W	II
17	Glycot	Herbicide/ Phosphanoglycine	Glyphosate 480 g/l	II
18	Glyphader	Herbicide/ Phosphanoglycine	Glyphosate 360 g/l	II
19	Finish	Herbicide/ Phosphanoglycine	Glyphosate acid 680 g/kg	II
20	Plantop	Herbicide/ Phosphanoglycine	360 g/l glyphosate	II
21	Quick clear	Herbicide/ Phosphanoglycine	Glyphosate 360 g/l	II
22	Roundup 360 SL	Glycine derivative	Glyphosate 360 g/l	II
		Insecticides		
23	Caiman B 50 Wg	Avermectin	Emamectine benzoate 50 g/kg	III
24	Capsidor 50 SC	Phenylpyrazole	Fipronil 50 g/l	II
25	Cigogne 360 EC	Pyrethroid	Cypermethrin 360 g/l	II
26	Cigogne 50 EC	Pyrethroid	Cypermethrin 12 g/l	II
27	Cypercot	Pyrethroid	Cypermethrin 10 %	II
28	Cypercal 50 EC	Pyrethroid	Cypermethrin 50 g/l	II
29	Cyperplant 50 EC	Pyrethroid	Cypermethrin 50 g/l	II
30	K-Optimal	Pyrethroids/ Neonicotinoid	Lambda-Cyhalothrin 15 g/l +Acetamiprid 20 g/l	II

S/N	Trade name of pesticides	Chemical group	Active ingredient (s) (a.i)	WHO classification of pesticides by hazard*
31	Killam 15 EC	Pyrethroids	Lambda-Cyhalothrin 15 g/l	III
32	Pyriforce	Organophosphorus	Chlorpyripfos ethyl 600 g/l	II
33	Epervier 220 EC	Organophosphorus/ Pyrethroids	Chlorpyriphos-ethyl 200 g/l + Cypermethrin 20 g/l	II
34	Kunfu 50 EC	Neonicotinoid/ Pyrethroids	Imidacloprid 10 g/l + Cypermetrin 40 g	II
35	Gamalin 80	Neonicotinoid/ Pyrethroid	Imidacloprid 40 g/l + Lambda cyhalothrin 40 g/l	II
36	Lamida gold 90 EC	Neonicotinoid/ Pyrethroids	Imidacloprid 30 g/l + Lambda-Cyhalothrin 60 g/l	III
37	Lambda	Pyrethroids	Lambda Cyhalothrin	II

** WHO classification, 2019 [18]*

Table 2. Farmer’s dosage of pesticides and number of applications, time interval between applications in rice and vegetable farming

Pesticide Active ingredient (a.i)	Single dose (g a.i/ha)	Recommended dose (g a.i/ha)	Average Time interval between application (day)	Total number of applications per crop cycle
		Fungicide		
Carbendazim	400	200	5	15
Chlorothalonil	2088.1	1008	5	15
Copper oxide	329.47	n.a	5	15
Mancozeb	2327.7	1600	5	15
Maneb	2137.3	1600	5	15
Metalaxyl	196.3	240	5	15
Potassium phosphite	525.3	n.a	5	15
		Insecticide		
Acetamiprid	35.3	20	5	15
Chlorpyrifos-ethyl	710.0	600	5	15
Cypermethrin	150.6	36	5	15
Emamectine benzoate	103.5	160	5	15
Fipronil	25.5	30	5	15
Imidacloprid	28.0	20	5	15
Lambda- Cyhalothrin	96.0	45	5	15
		Herbicide		
Glyphosate	3828.1	1440	180	2
2,4 D amine	2080.3	720	180	2
Paraquat dichloride	798.5	800	180	2

3.6 Farmers’ Perception of Environmental Effects of Pesticides

Less than 50 % of rice farmers were aware of the environmental effects of pesticides. Contrarily, 50.5 % of vegetable farmers were conscious of the negative effects of pesticides on the environment. Both rice (83.5 %) and vegetable farmers (100 %) reported that they had noticed dead non-target organisms like birds, snakes, frogs, toads, insects, and fish species, after herbicide applications in the rice environment of Ndop, resulting into a drastic population decline. The distribution and abundance of mushrooms have also dropped. Other observable environmental effects of pesticides reported by farmers include – soil, air and water pollution. Farmers were also able to notice a change in the soil texture (loose soil particles) and fertility. There was a significant difference between training and environmental awareness (X^2= 28.98, p = 0.001).

3.7 Fishing Practices in and Around Paddy Fields

Unlike before, very few farmers (14.8%) do fishing alongside paddy farming in flooded paddy fields, nearby streams, and rivers. Catfish – *Clarias gariepinus,* and the bony fish – *Oreochromis niloticus*, were the main fish species harvested from the floodplains. Most farmers (85.2%) no longer do fishing because of the drastic fish decline following the introduction of pesticides in their area. Farmers (60.8%) who were involved in fishing had fished for more than ten years. Most fish farmers (64.1%) do fishing on daily and weekly basis. *Clarias gariepinus* constituted 56% of the fish species harvested from the paddy fields, with a mean average catch of 12.22 kg ± 7.47 SD per month. However, the maximum fish catch per month was

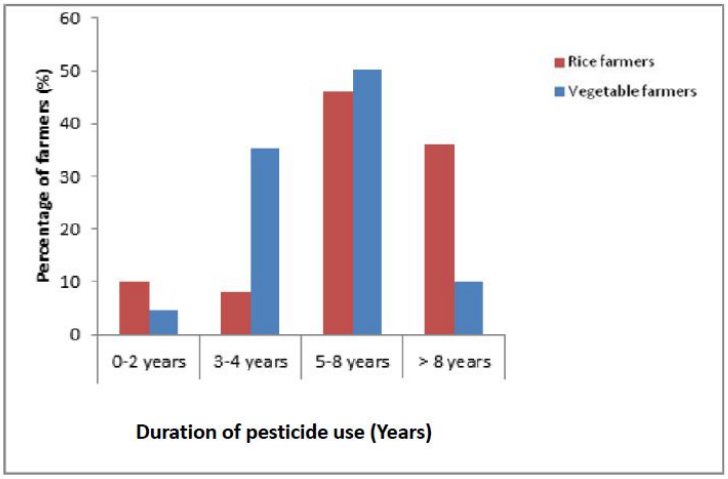

Fig. 4. Duration of pesticide used by farmers in Ndop

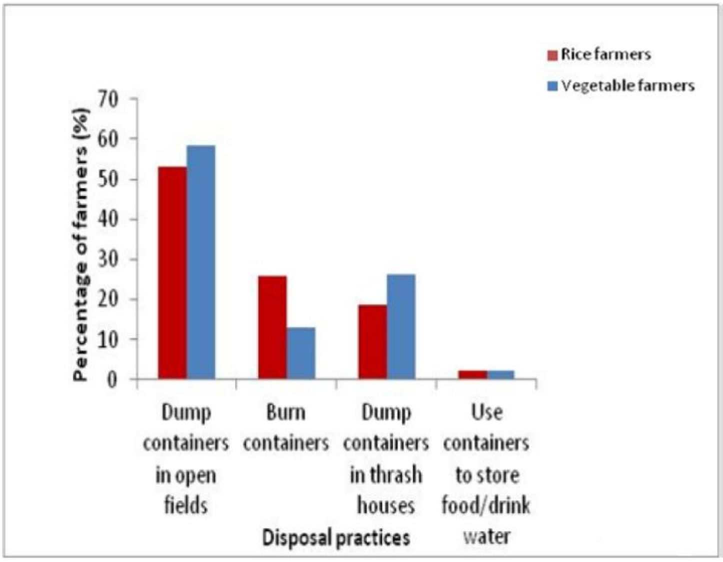

Fig. 5. Disposal practices of pesticides by rice and vegetable farmers

30.0 kg while the minimum was 0.5 kg. All farmers (100%) attested that since the introduction of pesticides in crop production in the wetland, the fish population has declined in streams and water channels in the paddy field. Farmers believed that the use of pesticides in the paddy floodplains of Ndop kills the eggs of fish, resulting in a drastic decline in fish productivity. However, most fishermen (70%) practiced unsustainable harvest.

4. DISCUSSION

The results of this study showed that farmers were the main stakeholders of pesticides since they heavily relied on pesticides to control crop pests [19]. From this study, farmers never respected or applied higher doses of pesticides (Table 1) because the government and NGOs subsidized or provided them with pesticides to encourage crop production. Besides, farmers obtained information on pesticide doses from colleagues who had never undergone official training [20,21,22]. Furthermore, farmers owned small farm sizes (< 1 ha) that were not expensive to manage [23]. The study results are similar to the findings made by [3] who found that farmers in the Ndop floodplain applied higher doses of some pesticides during crop cultivation. Farmers (100%) used only herbicides during rice cultivation because they probably considered that weeds were the major bio-pest constraint of rice, which might have caused significant yield losses in the past. This assertion is probably true because, in sub-Sahara Africa, weeds are the most frequent and widespread biotic constraints of rice environments and caused rice yield losses of at least 2.2 million tons (Mt) per year [24,25]. However, the study result contradicts those of [26] who reported the wide use of herbicides, fungicides, and insecticides by rice farmers in Rwanda. Interestingly nematicides (Table 1) were not used either by group of farmers in the current study, even though nematodes are cosmopolitan pests that can potentially cause significant crop yield losses. This result may be because farmers consciously paid less attention to bio-pests that have never cause substantial yield losses. From field observation, farmers in this study were ignorant of the various symptoms peculiar to particular pathogens. However, vegetable farmers used fungicides, herbicides, and insecticides to control vegetable pests (Tables 1 and 2).

There were no buffer zones between farmers' crop fields and nearby water bodies in the Ndop floodplain, increasing exposure to toxic threshold levels of pesticide residues, especially in rice fields, which became flooded lakes during peak growing season. The poor disposal practices (Fig. 3) observed in the current study was common in most developing countries [21,22,27, 28,29,30]. These poor disposal practices can potentially pose environmental risks in the Ndop floodplain because pesticides may leak from the containers to pollute ground and surface waters. The empty containers can also affect non-target organisms like fish and other aquatic life, natural pollinators (bees and butterflies), livestock, birds and beneficial soil microorganisms [31,32]. Most rice (83.5%) and vegetable farmers (100%) in this study perceived or observed some effects of pesticides on non-target organisms (birds, frogs, lizards, snakes, fish, plants, and small insects such as bees, etc.) in the wetland. Interestingly, farmers were able to deduce habitat degradation resulting from loose soil particles caused by pesticides. These observations indicate that farmers effectively contribute to strategies that aim at reducing pesticides' risks in the wetland.

Farmers (100%) associated the decline in fish catch in the Ndop paddy floodplains with pesticides use during crop cultivation. Earlier studies by [33,34] also reported a frequent fish decline resulting from pesticide runoffs from crop fields in Costa Rica. This assertion is possible because an earlier study showed that higher doses of cypermethrin posed a worse-case definite acute and chronic risk to fish in the aquatic wetland of Ndop [3]. Based on the study of [3], lower or recommended concentrations of chlorpyrifos-ethyl, mancozeb, λ-cyhalothrin, and chlorothalonil posed an acute aquatic risk. Also, the use of glyphosate-based formulations by farmers in Ndop probably contributed to the fish decline, because low glyphosate concentrations caused biodiversity loss of main phytoplankton species that supported fish production of upper trophic levels [35]. An earlier study in the paddy wetlands of Ndop showed changes in the phytoplankton biodiversity due to different land-use including pesticides [36]. However, other factors such as climate change, unsustainable fishing, and eutrophication, potentially contributed to fish production decline [30]. The significant difference between training and environmental awareness (p = 0.001) in the current study strongly suggests that designing and implementing training programs through farmer's CIGs will consequently reduce pesticide risk in the environment of Ndop.

5. CONCLUSION

The current study evaluated farmer's pesticide use practices and their effects on the wetland of Ndop, North West Region of Cameroon. Most crop fields (95.6%) lack buffer zones since the farms were between 0 to 1 meter from water bodies. Most farmers (71.3%) are poorly disposed of pesticide containers and 100% of the farmers washed and rinsed Knapsack sprayers in nearby water bodies. About 83.5% of rice farmers and 100% of vegetable farmers noticed observable effects of pesticides in the wetland. There was a significant difference between training and environmental awareness of pesticides (X^2= 28.98, p < 0.001). Most farmers (85.2%) no longer do fishing in the rice fields because of the frequent fish decline resulting from pesticide use. The average fish catch per month in the paddy fields was 12.22 kg ± 7.47 SD. These results indicate an urgent need of implementing a management strategy to ensure sustainability and the conservation of the wetland resource of Ndop, North West Region Cameroon.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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