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Towards sustainable vegetable production around agro-pastoral dams in Northern Benin: current situation, challenges and research avenues for sustainable production and integrated dam management

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Abstract

Background: Rehabilitation and optimized utilization of agro-pastoral dams (APDs), especially for vegetable production, has been recently promoted to boost agricultural production and ensure food security in Benin. However, little information was available on APDs' agricultural potentials and knowledge of how APDs' ecosystem services were exploited by the various stakeholders, and how each stakeholder group contributed to the degradation of the common good was scanty. This study explored three APDs in northern Benin to diagnose vegetable production systems and assess producer's perception of APD degradation.

Results: The results indicated that vegetable production around the APDs was a part-time activity dominated by women, and characterized by low external input use and a diversity of African indigenous vegetables. There was a strong gender difference in cropping systems, farming practices and land access, and a significant agreement on key production bottlenecks among producers. The main constraints included conflicts with livestock herders generated by the recurrent destruction of crops and seedlings by livestock, lack of equipment, pest and disease management challenges, access to water and inputs. Water erosion and runoff, livestock, vegetable production and food crops and cotton farming around the dams were respectively perceived as factors that contribute to APDs' siltation and affect water quality. In comparison with water erosion and runoff, experienced producers and those with higher vegetable species richness were more likely to rank farming as first source of threat to APDs. Urbanization and market access were drivers of intensification of vegetable production around APDs.

Conclusions: Our findings illustrate how information on cropping and farming practices, and producers' perception can provide insights and research and development avenues for integrated dam management and sustainable production for improved food security and livelihoods. We discussed the implications of our findings and suggested a number of strategic decisions and research avenues for integrated dam management and sustainable vegetable production around APDs. Avenues for future research and development actions include: (1) a tailored and gender-specific training programme on sustainable production practices targeted to women; (2) developing scenarios of the

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desired future state for APDs by all stakeholders to work towards through collaborative actions; and (3) assessing the perception of other users on APD siltation and water quality.

Keywords: Gender, African indigenous vegetables, Urban and peri-urban agriculture, Vegetable production, Urbanization, Agro-pastoral dams, Benin

Background

Vegetables represent an important component of the diets of rural and urban households across most of Africa [1, 2]. They provide inexpensive and reliable sources of micronutrients and other nutrients essential for human health and contribute to the prevention of nutritional deficiency diseases [3–5]. In urban and peri-urban areas, vegetable production can improve food and nutritional security through increased dietary diversity and food consumption [6–8]. It is also a source of income and employment and contributes to livelihoods of many people in Africa [2, 7–10].

In Benin, vegetable production is a country-wide activity and is common in various ecologies, ranging from uplands, valleys and alluvial plains of rivers and streams to pan-like depressions of land and swampy areas [11]. Main vegetable farming systems include extensive rainfed systems, intensive irrigated system common on sandy soils in the coastal parts of the countries and around large cities, and valleys and lowlands systems. In southern Benin, vegetable production is intensive and represents an important income generation activity and employment opportunity [12]. In northern Benin, this activity is mainly observed in inland valleys and around agro-pastoral dams (APDs), where it represents one of the main dry season activities, the main source of fresh vegetables, and a reliable source of income for the rural population [13–15]. Despite its importance in terms of geographical scope, vegetable production in Benin is not sufficient to cover the national demand year-round [11]. Consequently, seasonal importations of some vegetables (such as tomato and onion) occur even though vegetables produced in Benin are often exported to neighbouring countries (e.g. Nigeria) [11].

In 2007, the Government of Benin identified the promotion and intensification of vegetable production value chain as a mean not only for increasing the domestic supply of vegetables but also for economic growth through revenues generated from exportations to regional as well as international markets [11]. To this end, rehabilitation and optimized utilization of ecosystem services provided by APDs was one of the strategies identified and promoted by the government [11, 14] through various programmes such as the Food Security through Agricultural Intensification Programme (PSAIA: *Programme de Sécurité Alimentaire par l'Intensification Agricole*), Emergency Support Programme for Food Security (PUASA: *Programme d'Urgence d'Appui à la Sécurité Alimentaire*), and Agricultural Diversification through Valorization of Valleys Programme (PDAVV: *Programme de Diversification Agricole par la Valorisation des Vallées*). However, little information was available on the agricultural potentials of APDs. In addition, the understanding of how ecosystem services provided by APDs were exploited, who were the different stakeholders and what were their interests was scanty.

The severe drought experienced in Benin in the 1970s has compelled the government to create and promote APDs to provide drinking water for livestock and to boost livestock production [14]. Later, other activities have been developed around APDs including fishing, rice farming, tree seedling nurseries, domestic activities and uses such as washing and cleaning, and uses for road and house construction [14, 16, 17]. In addition, APDs have been invaded by crocodiles, which are protected species and thus require conservation [18]. Recent investigations conducted by Kpéra et al. [17] in the Municipality of Nikki, North East Benin have shown that APDs are used for drinking water for livestock and local communities, fish production, swimming, bathing, washing and cleaning, road and house construction and vegetable production. Today, the waterholes have become vital assets for local people's livelihoods and are considered as a public good by a diverse range of stakeholder groups [16, 17]. Currently, diverse stakeholders, usually with conflicting goals and interests, are found around APDs. The main stakeholder groups include herders, vegetable farmers, food crop and cotton farmers, domestic users, fishermen, dam management committee members, and crocodiles [13, 16, 17]. These conflicting uses and interests may affect water quality, result in siltation of dams, and limit the dams' ability to provide ecosystem services [15, 17, 19]. Therefore, there is a need for an inclusive and integrated management approach to optimize dam use and sustainably harness ecosystem services provided by APDs for agricultural and economic development [13]. This requires further understanding of how each stakeholder group is currently exploiting the APDs' benefits and potentially contributing to the degradation of the common resource.

In this study, we explored three APDs in the Municipality of Nikki in northern Benin to diagnose vegetable production systems around APDs and assess producers' perception of APDs degradation. This will provide further insights into how vegetable production can be an integral part of APD management strategies in northern Benin. The specific objectives of this diagnostic study are to (1) characterize cropping systems with a focus on gender and producers' organizations around APDs, (2) identify constraints hindering vegetable production around APDs, and (3) assess vegetable producers' perception of dams' siltation and water quality.

Methods

Study area

This study was conducted around Nikki, Sakabansi, and Fombawi APDs in the Municipality of Nikki (9°56′2″N and 3°12′16″E), located in the Department of Borgou in northeastern Benin. The Municipality of Nikki holds 20 APDs. The three dams were selected based on previous studies [14, 17] that revealed intensive dry season vegetable production activities around the dams. Furthermore, the three APDs vary in terms of the type of dyke, the capacity and importance of the watershed, the market access and urbanization level, and the number of vegetable producers involved. Nikki is the district capital of the Municipality of Nikki and is considered as a more urbanized area compared to Sakabansi and Fombawi villages, which are rural settings. The features of the APDs [17] are presented as follows: (1) located within the boundary of Nikki town, the Nikki agro-pastoral dam was constructed in 1972 and renovated in 1996. It has a capacity of 257,000 m^3 and a watershed area of 120 km^2 [14]. The Nikki APD is 1 km from the town. The vegetable plots are located upstream of the dam. There are two vegetable producer associations in Nikki: *Ansouroukoua*, created in 1990 with 20 members and now consisting of 150 members (130 women and 20 men), and *Donmarou*, created in 2007 and consisting of 50 members (40 women and 10 men) [19]. The members have access to markets in Nikki town and in Chikandou (Nigeria, 22 km away). (2) Constructed in 1985 and covering 1 ha, the Sakabansi agro-pastoral dam has a capacity of 200,000 m^3 surrounded by a watershed of 20 km^2 [14]. The dam is 3 km from the village of Sakabansi, which has a local market. The Sakabansi vegetable producer association, named *Ankua mon*, was created in 1998 and now has 30 members (29 women and 1 man) [19]. The association was restructured in 2004 to help members to obtain support for seeds and training in farming practices. The vegetable production plots are located upstream of the Sakabansi dam. (3) Constructed in 1989, the Fombawi agro-pastoral dam has a capacity of 17,000 m^3 and a watershed of 2.4 km^2 [14]. It is 500 m from the village of Fombawi, which has a local market. Thirty-three women, working in the association *Angara debu*, farmed around the dam, with plots located downstream. Because of the perennial destruction of the plots by local livestock, vegetable farmers in Fombawi did not cultivate during the data collection phase of this study.

Data collection

The research was carried out in two phases: an exploratory survey and an in-depth survey. The exploratory survey aimed to obtain an overview of the organization of vegetable producers operating around each dam, identify stakeholders and key informants and investigate vegetable producers' perceptions of the main source of dams' siltation and factors that affect water quality. Focus group discussions with representatives of the vegetable producer associations around each dam and participant observation were used to collect information in this phase. During the focus group discussions, participants were asked to list and rank the main source of dam's siltation in each village. In the in-depth phase, semi-structured individual interviews were conducted with 70 respondents using a questionnaire. Participants were selected using a purposive sampling [20] of 37 (18 males and 19 females) out of 200 producers in Nikki, 15 out of 32 females in Fombawi (men are not involved in vegetable production there), and 18 (17 females and the only 1 male) out of 30 producers in Sakabansi. To be included in the sample, the respondent has to be a vegetable producer around the APD, belong to a vegetable producer association and be willing to be involved in the study. Key informants and association leaders were also interviewed to obtain follow-up information and for triangulation. The farm plot size of 55 producers was measured in Nikki and Sakabansi. Fertilizers and pesticides used by vegetable producers were recorded in the three villages. The main subjects of the questionnaires included socio-economic characteristics of respondents, cropping systems with emphasis on diversity of vegetables cultivated, soil fertility management and irrigation practices, pest and disease management practices, constraints that hindered their production, organization of the producers around the dams and respondents' perception of how vegetable production could affect APD quality. The respondents were asked to prioritize by scoring and ranking their constraints on a 10-point scale (from very high importance = 1 to little importance = 10). The perceived sources of silting of each APD were also prioritized by producers using the ranking method. In this regard, each producer was asked to list the perceived main sources of the dam's siltation, rank them and indicate whether his/

her activity could affect the dam's water quality and siltation and other APD ecosystem services (e.g. habitat suitability for crocodiles and fish).

Data analysis

We used descriptive statistics to characterize vegetable species diversity and farming practices patterns around the three APDs. To compare the total land area between female and male vegetable farmers and among surveyed villages, we performed a two-sample Wilcoxon test after checking for normality and homoscedasticity assumptions (which were not met) [21]. To test whether farming practices used by producers were independent of gender and villages where they were operating, we used Fischer's exact test instead of a Chi-square test since some cells of the contingency table had frequencies less than five, and these cells represented more than 20% of the total number of cells in the contingency table [21, 22]. The same approach was used to test whether the vegetable species cultivated by a producer was independent of the producer's gender and the village in which he/she was operating. We used a generalized linear model with the Poisson error structure and a log link function [22] to test whether the number of vegetables cultivated varied between women and men producers and among villages. To understand how difference in access to land affects the diversity of vegetables cultivated, we ran Pearson correlation test between the number of vegetables cultivated and the total land size. We computed the Kendall's coefficient of concordance (W) [23] to test whether there was agreement among vegetable producers regarding the ranking of the constraints hindering their activity around APDs. We used simple logistic regression to test whether the probability that a vegetable producer perceived that his/her activity (vegetable production) affected APD water quality and crocodiles and contributed to dam siltation (dependent variable) was affected by respondent's age, gender, experience in vegetable production around the dam, position related to the dams (upstream vs. downstream), vegetables species richness (number of vegetables cultivated), and village in which he/she operates (each as independent variable). For the logistic regression, we used a generalized linear model with a binomial error structure and a logit link function [22]. We used multinomial logistic regression [24] to test whether the probability that a given source of dam siltation (perceived by vegetable producers) is ranked as the first source (dependent variable) is affected by participant's age, gender, experience in vegetable production around the dam, position related to the dams, vegetables species richness, and village where he/she operates (independent variables). We assigned water erosion and runoff (one of the dependent variable categories) as a baseline against which all other categories were compared [24]. All statistical analyses were performed using R software version 3.0.2 [25].

Results

Land access and diversity of vegetables cultivated around agro-pastoral dams

Vegetable production around the APDs was a part-time activity dominated by women (73% of respondents). More than 90% of the respondents indicated that they were part-time vegetable farmers. Only one man was involved in vegetable production around Sakabansi's APD, while no men were involved in Fombawi. It was around Nikki's APD that men were actively involved in this activity, representing about 49% of the respondents in that area. The respondents' ages varied from 16 to 78 years, with an average age of 44 ± 13.51 years. They have been involved in vegetable production around APDs since on average 8 ± 5.25 years (ranging from 1 to 25 years). There was a large variation in cultivated land size, which ranged from 92 to 2500 m^2. The overall average cultivated land size was small (412.6 ± 429.85 m^2). However, the land size was significantly affected by gender (Wilcoxon test $W = 142.5$, $p < 0.001$, Fig. 1a) and varied significantly between APDs (Wilcoxon test $W = 534.5$, $p < 0.001$, Fig. 1b). Men had larger plot sizes (669.2 ± 590.1 m^2) compared to women (277.2 ± 226.7 m^2). The average land size around the Nikki dam (523.5 ± 484.4 m^2) was higher than in Sakabansi (184.56 ± 90.1 m^2). To better capture how the large variation in land size was reflected through gender difference, we categorized producers into three groups based on their land sizes (Fig. 2): large vegetable producers (more than 1000 m^2 of land), medium vegetable producers (plot size between 500

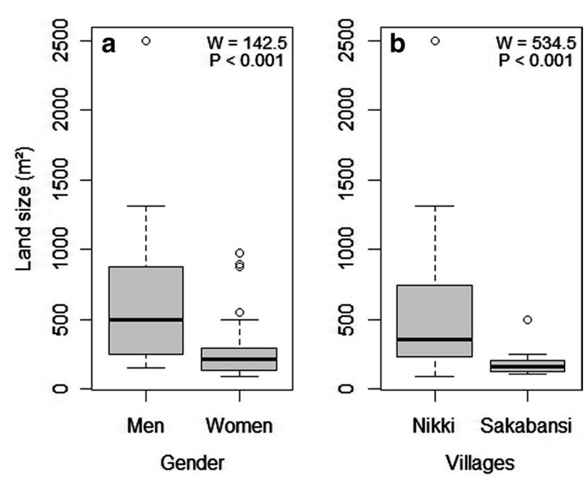

Fig. 1 Variation in land size between **a** women and men vegetable producers, and between **b** Nikki and Sakabansi villages

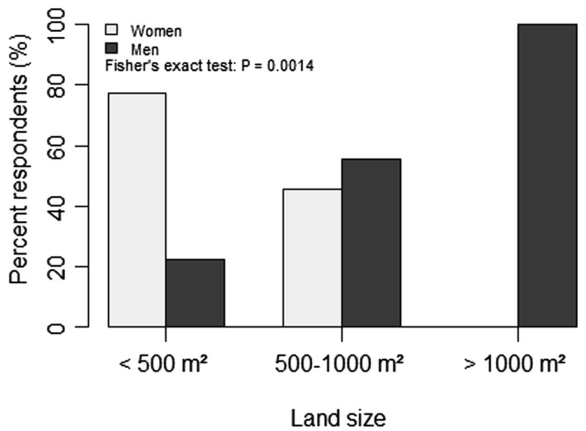

Fig. 2 Gender difference in land access for vegetable production around the agro-pastoral dams of Nikki and Sakabansi

and 1000 m^2), and small vegetable producers (plot size less than 500 m^2). Again, there was a significant gender-dependence in land size for vegetable production around APDs (Fisher's exact test; $p = 0.0014$, Fig. 2). Up to 77% of producers who had less than 500 m^2 were women, while farmers with more than 1000 m^2 were exclusively men. Fifty-five per cent of medium size farmers were also men. Additional file 1: Table S1 shows a summary of the descriptive statistics of the socio-demographic and bio-physical characteristics of the respondents.

Overall, 16 vegetables species were cultivated around the three APDs, from which about 63% were African indigenous vegetables (Table 1). Eleven vegetables were among the most cultivated (see Fig. 3) with amaranth (*Amaranthus cruentus* L.), black benniseed (*Sesamum radiatum* Schumach. & Thonn.) and okra (*Abelmoschus esculentus* (L.) Moench) as the top three vegetables cultivated around the APDs. They were cultivated respectively by 91, 70 and 56% of the respondents. The number of vegetables cultivated per producer varied from one to eight, with an average of 4.37 ± 1.84 vegetables per producer. In Nikki and Sakabansi, there was a significant correlation between land size and the number of cultivated vegetables ($r = 0.48$, $p = 0.0001$), indicating that producers with large plot sizes seemed to cultivate the highest number of vegetables. There was no significant difference between men and women ($Z = -1.291$, $p = 0.197$) and among villages ($Z = 0.341$, $p = 0.733$) for the number of cultivated vegetables. However, the type of vegetables cultivated was dependent on gender (Fisher's exact test; $p = 0.0077$) and village (Fisher's exact test; $p < 0.0001$). The most cultivated vegetables by women producers were amaranth, black benniseed, okra, jute mallow (*Corchorus olitorius* L.) and Roselle (*Hibiscus sabdariffa* L.). False sesame (*Ceratotheca sesamoides* Endl.) was exclusively cultivated by women. The most cultivated vegetables by men were pepper (*Capsicum frutescens* L.), amaranth and okra. In Fombawi and Sakabansi, the most cultivated vegetables were similar and included amaranth and black benniseed, while in Nikki, they included amaranth and pepper. Furthermore, false sesame was exclusively cultivated in Sakabansi, while African eggplant (*Solanum macrocarpon* L.) was cultivated only in Nikki. Additionally, cabbage (*Brassica oleracea* L.) was mainly cultivated by producers around Nikki APD. Tomato (*Lycopersicon*

Table 1 Diversity of vegetable species cultivated around the agro-pastoral dams of Nikki, Fombawi, and Sakabansi

Common names	Scientific names + authorship	Family	Type/origins
Amaranth	*Amaranthus cruentus* L.	Amaranthaceae	Indigenous/traditional
Black benniseed	*Sesamum radiatum* Schumach. & Thonn.	Pedaliaceae	Indigenous/traditional
Okra	*Abelmoschus esculentus* (L.) Moench	Malvaceae	Indigenous/traditional
Pepper	*Capsicum frutenscens* L.	Solanaceae	Indigenous/traditional
Jute mallow	*Corchorus olitorius* L.	Tiliaceae	Indigenous/traditional
Lettuce	*Lactuca sativa* L.	Asteraceae	Exotic
Tomato	*Lycopersicon esculentum* Mill.	Solanaceae	Exotic
Roselle	*Hibiscus sabdariffa* L.	Malvaceae	Indigenous/traditional
African eggplant	*Solanum macrocarpon* L.	Solanaceae	Indigenous/traditional
Cabbage	*Brassica oleracea* L.	Brassicaceae	Exotic
False sesame	*Ceratotheca sesamoides* Endl.	Pedaliaceae	Indigenous/traditional
Carrot	*Daucus carota* L.	Apiaceae	Exotic
Lagos spinach	*Celosia argentea* L.	Amaranthaceae	Indigenous/traditional
Green beans	*Phaseolus vulgaris* L.	Leguminosae	Exotic
Egusi	*Cucumeropsis mannii* Naud.	Cucurbitaceae	Indigenous/traditional
Onion	*Allium cepa* L.	Alliaceae	Exotic

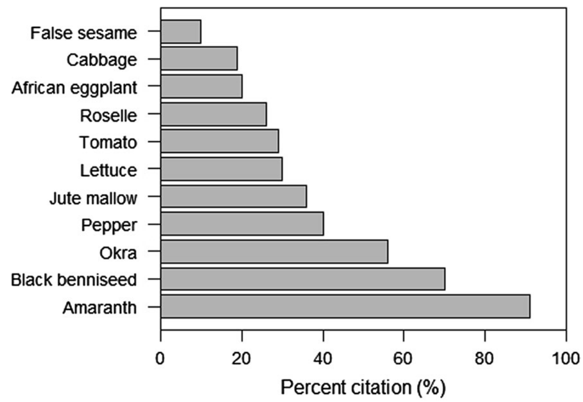

Fig. 3 The most important vegetables cultivated around the agro-pastoral dams of Nikki, Fombawi, and Sakabansi

esculentum Mill.) and Roselle were mainly cultivated in Nikki and Sakabansi.

Cropping systems and farming practices around agro-pastoral dams

The cropping system patterns were gender- and village-dependent (Fisher's exact test; $p = 0.0454$ and Fisher's exact test; $p = 0.004$ respectively). Monocropping and intercropping were practised mainly by women, while the majority of men practised crop rotation. In Nikki, more producers were involved in crop rotation than in Fombawi and Sakabansi. However, more producers were involved in monocropping and intercropping in Fombawi and Sakabansi than in Nikki. Similarly, soil fertility management practices were gender- and village-dependent (Fisher's exact test; $p < 0.0001$ and Fisher's exact test; $p < 0.0001$, respectively). Men used mainly chemical fertilizers for soil fertility management, while women relied mainly on organic fertilizers. In cases where women used chemical fertilizers, it was usually in combination with an organic one. Producers in Fombawi and Sakabansi used mostly organic fertilizers for managing the fertility of their soil, while producers in Nikki relied on both organic and chemical fertilizers. Organic fertilizers used around the APDs included cattle and small ruminant manure, household waste, and occasionally poultry manure. Chemical fertilizers included urea and NPK. Pest and disease management practices were also gender-dependent (Fisher's exact test; $p < 0.0001$) and village-dependent (Fisher's exact test; $p < 0.0001$). Women applied neem (*Azadirachta indica* A. Juss) leaves and seed extracts, wood ashes, and prophylactic practices, while men relied more on chemical insecticides for pest and disease management. Chemical insecticides and neem extracts were mainly used by producers in Nikki, while producers in Fombawi and Sakabansi applied wood ashes and prophylactic practices. Regarding irrigation, 75% of our respondents used buckets associated with cans with holes and 25% of them used watering cans. In Fombawi and Sakabansi, producers used water directly from the dams to water their crops, while in Nikki, all the producers used water from small wells and boreholes they had created in the dams' watercourse.

Constraints faced by vegetable producers around agro-pastoral dams

Several constraints affected vegetable production around APDs in the Municipality of Nikki (Table 2). Overall, there was a significant and strong agreement on the ranking of the constraints affecting vegetable production around the APDs among the respondents (Kendall's coefficient of concordance $W = 0.68$, $p = 0.031$). The first

Table 2 Ranking of constraints to vegetable production around the dams of Nikki, Sakabansi, and Fombawi

Constraints	Nikki ($n = 37$)		Sakabansi ($n = 18$)		Fombawi ($n = 15$)		Overall ($n = 70$)	
	Mean rank	Ranking	Mean rank	Ranking	Mean rank	Ranking	Mean rank	Ranking[a]
Conflict with livestock keepers	3.28	4	1.67	2	1.00	1	2.38	1
Lack of equipment	3.22	3	1.33	1	2.33	2	2.54	2
Access to water	1.78	1	6.06	6	6.70	6	3.94	3
Pests and diseases	3.16	2	5.94	5	4.17	4	4.09	4
Access to inputs (seed, fertilizer, and pesticides)	5.59	5	3.78	3	5.07	5	5.01	5
Access to credit	5.69	6	6.94	10	3.20	3	5.48	6
Vegetables stolen	5.95	7	6.56	7	6.73	7	6.27	7
Conflicts with crocodiles	8.01	8	3.78	3	9.23	10	7.19	8
Access to land	8.81	9	9.56	9	7.30	8	8.68	9
Access to market	9.50	10	9.39	8	9.27	9	9.42	10

[a] Kendall's $W = 0.68$, p value $= 0.031$

five challenges were related to conflicts with livestock keepers, lack of production equipment and tools, access to water, pest and disease management challenges, and access to inputs (seeds, fertilizers and pesticides). Conflicts with livestock keepers were serious challenges that vegetable producers were facing around APDs, especially in Fombawi and Sakabansi, where it was ranked as the first constraint. The conflicts were usually generated by the destruction of crops and seedlings by livestock during their movement to the waterholes for drinking. The fences that producers of Fombawi had created to cope with this challenge were repeatedly destroyed, leading to the interruption of the vegetable cropping around the dam in this village during the period of data collection. Lack of equipment and materials for production was ranked as the second most important constraints. This constraint was ranked as the first, second and third most important constraints in Sakabansi, Fombawi, and Nikki, respectively. Most of the producers used rudimentary tools for cropping (e.g. watering tools). Access to water, especially at the peak of the dry season, was ranked third overall but was the main constraint in Nikki. Indeed, all the producers in Nikki had dug small wells and boreholes in the dams' watercourse from which they obtained water for the crops. At the peak of the dry season, those wells dried up and it became very difficult for them to water crops on a regular basis. Pest and disease pressure was ranked fourth and was a serious challenge for farmers in Nikki as they ranked it the second most important constraint. Difficulty in access to improved seeds, fertilizers, and specific pesticides for vegetable cropping was ranked fifth by producers. It was the third most important challenge for producers in Fombawi. In fact, most of the farmers produced their own seeds. Only a few producers, typically in Nikki, bought improved seeds of lettuce, cabbage, and tomato. However, they explained that seeds were not always available. Chemical fertilizers used were usually the ones intended for cotton cultivation. Similarly, some of the pesticides used were also labelled for cotton cultivation (see Additional file 1: Table S2 for a list of cotton-labelled pesticides used by some vegetable famers around Nikki APD). Other constraints mentioned included access to credit, land and market, thefts of vegetables and conflicts with crocodiles (see Table 2).

Vegetable producer organizations

Vegetable producers around the ADPs were organized in associations. More than 91% of the respondents were members of a vegetable farmers' group (Additional file 1: Table S1). There were two associations working around Nikki's APD, while in Fombawi and Sakabansi, one association worked around the dam in each village. Although almost all producers belonged to an association, each producer worked individually on his plot. The motivation underpinning the creation of the associations was the facilitation in access to credit and technical assistance from local banks and NGOs, extension services and development agencies. Each association was led by an executive committee whose president was usually the oldest member; the secretary and the treasurer were selected from among the members with basic educational backgrounds. To become a member of an association, the applicant should contact the executive committee who would inform the other members of the association. Based on internal discussions regarding the applicant's characters and his ability to respect the group's rules, the executive committee would later give approval or not. Once the applicant was approved, he/she would pay the membership fee, which is 500 F CFA for each of the two associations working around Nikki's dam and 1000 F CFA for each association in Fombawi and Sakabansi, respectively. In Nikki, members paid an annual membership fee (which varied from 1200 to 3200 F CFA) to both associations. The money collected was used for soya bean trading. Soya beans were bought and stored when the price was low and sold when it became high. The profit generated was used to assist members facing financial challenges and special events (such as marriage, baptism, and death). In Sakabansi and Fombawi, members did not pay an annual membership fee.

Vegetable producers' perception and knowledge of dam siltation and water quality

According to the vegetable producers, several factors contributed to dam siltation and also affected the quality of dam water and the living organisms in the dam, including crocodiles (Fig. 4). Across the three areas, these factors included water erosion and runoff,

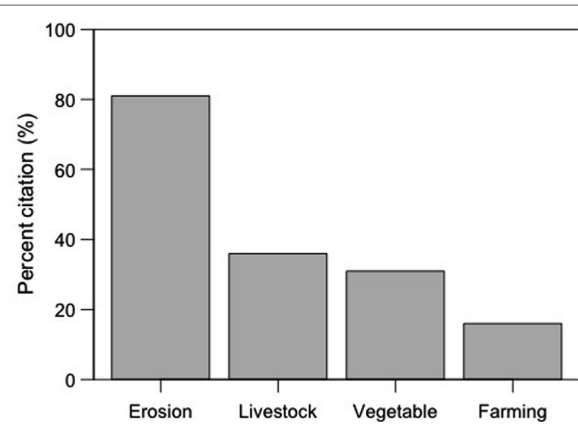

Fig. 4 Main causes of dam siltation as perceived by vegetable producers in Nikki, Fombawi, and Sakabansi

livestock, vegetable production and farming around the dams. Water erosion and runoff was cited by 81% of the respondents and approximately 50% of the respondents ranked it as the first cause of threat to the dams. They explained that due to water erosion and runoff, a considerable amount of sediment was transported into the waterhole during the rainy season, contributing to the siltation. Livestock was considered as the second most important threat to the dam siltation and quality (36% of responses) and was ranked as the first cause by approximately 23% of the respondents. The respondents explained that livestock accessed the waterholes from all sides, and this contributed to the siltation. Additionally, when drinking water, cattle defecate and urinate directly into the dams, and this can affect the water quality and subsequently the crocodiles living in the dams. Vegetable production and farming around the dams were also identified as sources of siltation and threats to the dam's water quality (31 and 16% respectively) and were ranked as the first cause by 23% and 4% of the respondents, respectively. In fact, more than 75% of the vegetable plots were located upstream of the dams (Additional file 1: Table S1). With frequent tillage, soils become more vulnerable to erosion and easily transported into the waterholes by runoff water. Furthermore, inputs used (pesticides and fertilizers) can affect the dam's water quality and subsequently the living organisms including the crocodiles. However, the likelihood that a producer perceived that his/her activity affected the dam's water quality and crocodiles and contributed to dam siltation was not affected by the participant's age ($Z = -0.176$, $p > 0.05$), gender ($Z = 1.001$, $p > 0.05$), experience in vegetable production around the dam ($Z = 0.630$, $p > 0.05$), position related to the dams ($Z = 0.087$, $p > 0.05$), vegetables species richness ($Z = -0.015$, $p > 0.05$), or the village in which he/she worked ($Z = -0.147$, $p > 0.05$, Additional file 1: Table S3).

The ranking of factors that contributed to dam siltation and affected water quality as perceived by the producers differed slightly from one location to another (Table 3). In Nikki, the first two factors were water erosion and vegetable production, while in Fombawi and Sakabansi, the top two factors were water erosion and livestock. However, the probability that a vegetable producer ranked livestock, vegetable production or farming around the dam as the first source that affected the dam's water quality and crocodiles and contributed to dam siltation, in comparison with water erosion and runoff (reference category or baseline), was not affected by the participant's age ($p > 0.05$), gender ($p > 0.05$), position related to the dams ($p > 0.05$), or village in which he worked ($p > 0.05$, Additional file 1: Table S4) but was significantly affected by experience in vegetable production around the dam ($p < 0.05$) and vegetables species richness ($p < 0.05$, Additional file 1: Table S4). In comparison with water erosion and runoff, experienced producers and those with higher vegetable species richness were more likely to rank farming as the first source of threat to the dams.

Table 3 Ranking of the main sources of dam siltation as perceived by vegetable producers in Nikki, Fombawi, and Sakabansi

Source of dams' siltation[a]	Location		
	Nikki	Fombawi	Sakabansi
Water erosion	1	1	1
Vegetable production around dams	2	–	3
Farming around dams	3	3	4
Livestock	4	2	2

[a] Ranking based on the relative importance as perceived by vegetable farmers during focus group discussions in the different villages. Ranking scale 1–4 (1 = highest; 4 = lowest); – indicates no response

Discussion

Gender, vegetable farming systems and diversity of vegetable species around agro-pastoral dams

Vegetable production around the APDs is less intensive and characterized by low use of external inputs and rudimentary or small-scale tools and equipment. Vegetable species are dominated by African indigenous species, and the use of improved seeds is low. It is a part-time activity for the majority of people involved and represents a typical example of traditional vegetable farming systems common in West Africa [26]. Indeed, in traditional vegetable farming systems, vegetable production and marketing are undertaken mainly by women [2, 26, 27]. This is the case in Fombawi and Sakabansi, the rural areas, where this activity is undertaken exclusively by women. However, men become more involved as soon as income generation potential increases and the activity takes on a commercial orientation [27, 28]. This can explain why more men were involved in vegetable production and mainly cultivated species with high commercial or economic values in Nikki, the more urban area, with improved roads and market access.

Our results revealed that there was a strong gender difference in cropping systems and farming practices around the APDs investigated, except irrigation practices. These findings are consistent with previous studies on gender dimensions in agriculture in sub-Saharan Africa [29]. The gendered difference observed in the cropping systems may be due to differences in access to land. In fact, men had larger plot sizes compared to women, as it was also reported in vegetable production systems in Buea, Cameroon [26] and in southwestern Nigeria [30].

This supports the general gender-differentiated resource base of African farming systems [29, 31]. Thus, the fact that monocropping and intercropping were predominantly practised by women could be seen as a strategy to cope with the challenge of limited plot sizes to maximize the utilization of the small plot of land they have.

Like Reyes-García et al. [32], we found that men and women producers used different soil fertility, and pest and disease management practices. Organic fertilizers and traditional pest management practices were predominantly used by women. This may be due to difference in knowledge of farming practices and in access to information and the ability to act upon it [26, 31]. In fact, female farmers are less likely to access agricultural information and knowledge through extension services, or receive very limited access to quality services and agricultural technology information compared to their male counterparts [30, 33]. Differences in access to inputs may also play a role in the gendered nature of vegetable production around APDs [26, 29]. Indeed, chemical inputs used around the APDs are mainly those intended for cotton cultivation. In the study areas, only cotton farmers, who are exclusively men, can have access to those inputs. Furthermore, difference in access to labour can explain the gender difference in vegetable production systems around APDs. Indeed, because of the gender-differentiated nature of rural household labour shortages or the gendered nature of labour-hiring practices in African farming systems [31], women usually have less access to labour for labour-intensive farming activities.

Vegetable species cultivated around APDs were mainly leafy vegetables. Our findings also indicated that species cultivated were predominantly African indigenous vegetable species (63% of vegetables cultivated). This highlights the potential role of vegetable production around APDs towards improving food and nutritional security in the study area [3–5, 8, 34]. Indeed, proteins, carbohydrates, dietary fibres, potassium, calcium, magnesium, phosphorus, Vitamin A, Vitamin C and Vitamin E have been shown to be significantly higher in indigenous vegetables than their exotic counterparts [35]. Our findings that women cultivated mainly traditional vegetables in comparison with men corroborates previous results by Ndenga et al. [36] that indicated women vegetable producers in the Rift Valley and Central provinces in Kenya allocated more land for the production of traditional vegetables than men.

Challenges to vegetable production around agro-pastoral dams

Some of the key challenges faced by vegetable producers around APDs, namely, lack of equipment, access to inputs and credit or capital, and access to and fluctuation of market opportunities are not specific to working around agro-pastoral dams. These constraints have been reported previously in vegetable production systems in Benin, Cameroon, Nigeria, Senegal and South Africa [8, 9, 26, 30, 37]. Although we did not assess how gender affects the perception of the constraints (e.g. Ngome and Foeken [26] and Alao et al. [30]), we found a strong and significant agreement on the ranking of the most important constraints among the respondents, indicating that gender did not considerably affect the perception of the constraints in our study. In addition, contrary to previous investigations in southern Benin and elsewhere in West Africa that reported access to land as a major constraint for vegetable production, especially in urban areas [9, 11, 12, 37, 38], we found that land access is not a major challenge for vegetable producers around APDs, even in the more urbanized study area. Indeed, challenges related to land access have been ranked as second to last (out of ten) around almost all the three APDs (see Table 2). This is inconsistent with results by Ogunjimi and Adekalu [37] and Cissé et al. [39], which reported strong competition over lands around the major perennial streams in Nigeria and around APDs in Ouagadougou, Burkina Faso, respectively.

However, conflicts with livestock keepers (due to recurrent destruction of vegetable plots and seedlings by livestock) were challenges specific to vegetable production around APDs, especially in the rural study areas. It is very likely to be the case around other APDs in northern Benin where vegetable production occurs. Indeed, the APDs were constructed initially to provide additional drinking water for livestock production after the severe drought experienced in Benin in the 1970s, which had seriously affected the national livestock population [14]. Consequently, up to now, some livestock herders believe that the APDs are for them and they have more use-rights than other stakeholder groups, though there is a dam management committee (CoGes) for each APD [16, 17].

Another key challenge for producers around the APDs is access to water, especially at the peak of the dry season. This constraint has also been reported by small-scale irrigation farmers along major rivers in Nigeria [37]. Unfortunately, since the majority of the producers are located upstream of the dams, the strategies they have developed to cope with this challenge, which include digging wells and boreholes in the dams' watercourse, potentially contribute to dam siltation. In addition, with frequent tillage, soils become more vulnerable to erosion and easily transported into the waterholes by runoff [40]. Some of the producers are perfectly aware of this since they have identified farming and vegetable production around the dams as causes of dam siltation in the study areas. However, very few respondents ranked vegetable production as the first cause of dam siltation, while more experienced producers around APDs and those with high vegetable species richness were more likely to rank farming as the first cause of dam siltation.

Although pest and disease management was reported to be a very key challenge for vegetable farmers in southern Benin and in other regions of Africa [41, 42], it was not perceived as a major constraint around APDs. It was only in urban Nikki that pest and disease pressures emerged as a serious constraint. This can be explained by the fact that urbanization process modifies farmer practices in response to increased food demand, changes dietary patterns towards fruits and vegetable consumption, and increases competitiveness of fruits and vegetable production in the urban and peri-urban areas over staple crops [41]. Pest and disease pressures combined with the challenge of limited access to pesticides have led men producers in Nikki to have recourse to non-recommended pesticides (namely, those intended for cotton cultivation). This practice is not specific to vegetable production around APDs and has actually been reported in the fruit and vegetable production systems of small farmers in sub-Saharan Africa [41]. This raises the issues of the quality of vegetables produced and the health risks not only for consumers and producers but also living organisms in the dams such as crocodiles and fishes [38, 41, 42]. Moreover, utilization of APD water can also represent significant health risks due to bacteriological and microbial contaminations [39, 43]. As explained by respondents, livestock defecate and urinate directly into the dams when drinking water, contributing to water contamination. In addition, given the inappropriate waste disposal and poor waste water management system, especially in the town of Nikki [17], it is very likely that runoffs, streams and effluents that feed the dams carry pathogens contaminating dam water [43].

Implications and research avenues for sustainable vegetable production and integrated afro-pastoral dam management

Our results revealed a strong gender gap in vegetable production systems around agro-pastoral dams in northern Benin. A tailored and gender-specific training programme on sustainable production practices targeted to women will certainly contribute to filling this gap and improving vegetable production around APDs. Indeed, women's training on improved vegetable production practices can dramatically increase production of leafy vegetables, profitability and income, thus improving women's livelihoods [44, 45]. This capacity building programme should be supported by increased agricultural extension service support to vegetable farmers around APDs, which could improve technical efficiency of producers [46]. Environmentally friendly solutions and innovations developed by women producers to manage pests and diseases (e.g. botanical extracts) need to be strengthened to reduce health risks for consumers and ensure healthy ecosystems.

Our results also indicated that vegetable producers around APDs were organized into farmer groups or associations, and almost all the respondents belonged to one. However, facilitation to access external support was the main motivation behind group membership, with little concerns about cooperative activities such as mutual support for labour, group marketing strategies, and regular meetings. Promotion of vegetable production around APDs by addressing production bottlenecks and training on sustainable cropping practices could certainly be a driving force in the resurgence of vegetable farmer groups.

Currently, the management of APDs is subject to contestation, and the use of the dams results in recurrent conflicts not only among human stakeholders (e.g. between herders and vegetable producers) but also between humans and wildlife (e.g. human-crocodile conflicts) [17]. Indeed, prior to the 2005 decentralization reforms in Benin, APDs and their management were under the control of the *Centre Communal de Promotion Agricole* (the Communal Centre for Agriculture Promotion under the Ministry of Agriculture, Livestock production and Fisheries) and their maintenance by the *Direction Générale de l'Eau* (the General Directorate of Water at the Ministry of Environment, Housing and Urban Planning). Following the decentralization reforms, the control and management of water resources have been transferred to the local government (i.e. the Municipal Assembly or Council) [14, 16, 17, 47]. As a result, the 20 APDs in the Municipality of Nikki are now under the control of the Municipal Council of Nikki [17]. For each APD, a CoGes is put into place by the Municipal Council to ensure the monitoring and maintenance of the APD and to manage and control the access to and use of the APDs' water and surrounding land so as to prevent siltation and water pollution [14, 17]. However, the ability of CoGes to effectively and sustainably manage the APDs is debatable [14, 16, 17]. Many of the CoGes were inactive or have collapsed [14, 16]. The most recent inventory and assessment of the existing 250 geo-referenced APDs in Benin showed that many of the APDs were not regularly maintained and 44% of them needed urgent rehabilitation of their dyke [47]. Five of the 250 APDs are abandoned and no longer in use [47]. Furthermore, according to many stakeholder groups, in addition to the recurrent conflict between farmers and herders, the siltation and shrinking storage over time have become key impediments to the use of the APDs [17].

In this complex and conflicting context, developing scenarios for the future of this common resource may be helpful. Scenarios are a useful tool for grappling with the uncertainty and complexity of social-ecological challenges [48]. Rather than predicting what will happen in the future, scenarios are 'what if?' stories, which can assist in decision-making and strategic planning [49]. Scenarios can help identify a desired future state for APDs to which to work towards or help prepare for a range of possible futures [49]. We suggest the implementation of the Transformative Scenario Planning approach [48] to stimulate social learning by enabling all stakeholders and users of APDs, including the municipal council, to engage and discuss options for coping with uncertainty through collaborative actions. The process will help discuss and find a common solution for the recurrent destruction of the vegetable plots, for instance by defining corridors, accepted by all parties, for livestock. The conditions and prerequisites (e.g. availability of irrigation facilities, improved accessibility to the sites through creation of roads) for moving vegetable producers to the downstream sites will also be discussed for sustainable use of the common resource. Additionally, it would be interesting to conduct the transformative scenario planning process per gender to allow a comparative analysis of women and men perspectives for the future of APDs.

In this study, we assessed perception and knowledge of only vegetable producers. It would be interesting to investigate the perception of other users (fishermen, herders, domestic users, crop farmers, etc.) on APD siltation and water quality. This will provide holistic insights on the different stakeholders' knowledge and perception of the common resource, which will be crucial in the scenario planning process. Further investigation is also needed to empirically quantify the contribution of vegetable production to APD siltation, eutrophication and proliferation of aquatic invasive species, which are becoming a challenge to APDs [17]. This assessment will provide information to inform decision-making regarding whether to move farming activities to downstream sites.

A water quality assessment will also help ascertain dam water quality for the various uses (e.g. agricultural and domestic uses, suitability for crocodiles) and inform policy decision-making at the district level. Contamination level assessments (bacteriological, microbial, and heavy metals) of vegetables produced and fishes from the dams are also needed to evaluate risks for consumers.

Conclusions

In this study, we investigated vegetable production systems around agro-pastoral dams in Northern Benin to better understand the management practices and challenges faced by producers, with a focus on gender and how this activity may contribute to the degradation of the dams. The results indicated that vegetable production systems around the APDs are a typical example of traditional vegetable farming systems and characterized by a diversity of African indigenous species and a strong gender difference in cropping systems and farming practices. The study identified the main challenges to vegetable production around APDs and factors that contributed to APDs degradation as perceived by vegetable farmers. The findings illustrate how information on cropping and farming practices and producers' perception can provide insights and avenues for integrated dam management and sustainable vegetable production. We discussed the implications of our findings and suggested a number of research avenues for integrated dam management and sustainable vegetable production around APDs, including (1) a tailored and gender-specific training programme on sustainable production practices targeted to women; (2) applying the Transformative Scenario Planning approach to stimulate social learning among all stakeholders and identify a desired future state for APDs to work towards through collaborative actions; (3) investigating the perception of other users (fishermen, herders, domestic users, crop farmers, etc.) on APD siltation and water quality; and (4) empirically quantifying the contribution of vegetable production to APD siltation, eutrophication and proliferation of aquatic invasive species.

Additional file

Additional file 1. Table S1. Socio-demographic and biophysical characteristics of study participants. **Table S2.** Pesticides labelled for cotton used by some vegetable producers around the Nikki agro-pastoral dam. **Table S3.** Logistic regression testing the effect of age, gender, number of year in vegetable production, position related to the dams, vegetable species richness, and village on the probability that a vegetable producer perceived that his/her activity affected dam water quality and crocodiles and contributed to dam siltation. **Table S4.** Multinomial logistic regression testing the effect of age, gender, number of year in vegetable production, position related to the dams, vegetable species richness, and village on the probability that a vegetable producer ranked a given source of dam siltation as the first source that affected dam water quality and crocodiles and contributed to dam siltation.

Abbreviations

APDs: agro-pastoral dams; CoGes: dam management committee; PSAIA: Programme de Sécurité Alimentaire par l'Intensification Agricole; PUASA: Programme d'Urgence d'Appui à la Sécurité Alimentaire; PDAVV: Programme de Diversification Agricole par la Valorisation des Vallées.

Authors' contributions

GNK, AS and ACS contributed to the conception and design of the study. ACS collected and analysed the data, contributed to the interpretation of

the findings, prepared the first draft of the manuscript and improved it. GNK supervised the data collection, contributed to the interpretation of the findings and improved the manuscript. AS supervised the data collection and improved the manuscript. GAM, NA and AJvdZ supervised the study and provided conceptual advice. All authors read and approved the final manuscript.

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Competing interests

The authors declare that they have no competing interests.

Availability of data and materials

The datasets supporting the conclusions of this article are included within the article and its additional files.

Consent for publication

Not applicable.

Ethics approval and consent to participate

The aim of the study was clearly explained to the administrative authorities at district and village level. Permission was obtained from the chief of each village before conducting the focus group discussion and the survey. Participants were included in the survey after obtaining their verbal prior informed consent. Participants had the opportunity to stop participating in the research at any time of their choice.

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