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Medium term impacts of alternative livelihoods on unsustainable use of wildmeat in Yangambi (Democratic Republic of Congo)

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ABSTRACT Wildmeat is an important source of animal protein and micronutrients for many low-income households. Hunting and trading wildmeat are the main livelihood activities for around 850 people across the Yangambi landscape in the Democratic Republic of Congo (DRC). Hunting in this region has been associated with loss of larger target species and a shift towards 'post-depletion' animal communities characterized by smaller resilient species. Sustainable wildlife use in the region is likely to require a reduction in hunting pressure. This paper describes an ongoing livelihood diversification project focused on livestock husbandry and cultivation of cash crops. It assesses the impacts of these potential alternatives on household income and as substitutes for the unsustainable use of wildmeat around Yangambi. The results show that pig breeding may have the most potential for providing a reliable protein source, increasing income and providing an alternative to wildmeat hunting. A quarter of the hunters engaged in the project no longer rely on hunting for their primary income, while a third of wildmeat traders no longer focus on selling as their main activity. This outcome suggests that benefits for wildlife conservation can be generated when suitable alternative livelihoods are available.

KEY WORDS Indigenous; Turumbu; Hunting; Diversification; Rural households.

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INTRODUCTION

Wildmeat plays a substantial role in national food systems, reducing risks of protein shortfalls in some of the most food-insecure countries (Chausson et al., 2019; Booth et al., 2021; Ingram et al., 2021). Wildmeat is also rich in fat and critical micronutrients (Neumann et al., 2003; Siren and Ma-

choa, 2008; Hoffman, 2013; Sarti et al., 2015; Rowland et al., 2017) that are necessary to lessen the micronutrient malnutrition suffered by a third of the world's population (Tontisirin et al., 2002). In Central Africa, hunting provides 30% - 90% of the animal protein intake among rural households (Arnold et al., 2011; Coad et al., 2018). It is consumed as an available and cheaper meat, but also because of its taste and as a festive food with ethnic or traditional values (Van Vliet & Mbazza, 2011).

Wildmeat is not only a subsistence food, but also a multimillion-dollar industry in Central Africa and an important component of local economies. It provides income at different levels of the market chain, particularly for hunters and traders (Wilkie & Carpenter, 1999; Wilkie et al., 2016; Fa et al., 2019). Recent estimates suggest that 1.6 to 4.6 million tons of wildmeat are traded annually in the sub-region (Ingram et al., 2021). Wildmeat trade comprises part of peoples' livelihood portfolios, with the income often used to purchase other food items and necessities and to pay for school fees or medical care (Van Vliet et al., 2019). Depending on local context, wildmeat may serve as a primary source of income or provide a fall-back during periods of hardship. In some regions, wildmeat trade peaks outside the farming season, indicating that wildmeat hunting and trading are parts of a diversified livelihood strategy and may serve as safety nets (Sackey et al., 2023). In other areas, people - and particularly youth - may be shifting away from relying on wild meat for income, as alternative employment opportunities become more available (Coad et al., 2013). Regardless of these contextual differences and changing trends, the contribution of wildmeat to global household cash income remains significant (Nielsen et al., 2018).

Unfortunately, unsustainable trade in wildmeat seriously threatens the conservation of tropical biodiversity (Nasi et al., 2011), contributing to wildlife declines, inducing cascading effects on ecosystem functioning and services (Effiom et al., 2014; Ripple et al., 2016), and causing threats to public health (Fa et al., 2019). The transition from subsistence hunting to large-scale commercial harvesting, coupled with a growing human population, increased accessibility to new technologies and easier access to remote forests, all contribute to increasing demand from growing urban centres and the unsustainable trade that now supplies large markets across tropical Africa (Coad et al., 2019). In response, the past twenty years have seen numerous initiatives in Central Africa to reduce dependence on wildmeat, while guaranteeing food security and sources of income for rural communities. Wicander & Coad (2018) identified 155 projects within the region, with the largest number in Ghana, the Democratic Republic of Congo (DRC), Cameroon, and the Republic of Congo (ROC). Projects included the development of alternative livelihood activities including beekeeping, cane rat farming, livestock rearing, and fish farming. The aim of these projects is typically to introduce or strengthen existing low-cost, easily implementable, low-environmental-impact activities, supplying communities with an alternative source of meat protein and/or alternative income, thus decreasing dependency on wildmeat and reducing pressures on wildlife (Wright et al., 2016). However, many of these alternative livelihoods projects lack monitoring and evaluation after implementation, and there has been limited analysis of common characteristics, successes and failures, little synthesis of the lessons learned and no overall assessment of the effectiveness of these measures (Wicander & Coad, 2018).

We share practical lessons learned from the implementation of a program to support the development of alternatives to wildmeat trade, implemented in the Yangambi landscape in the DRC. This study first presents the project approach and activities, based on the descriptors of interventions proposed by Wicander & Coad (2018). It focuses on the objectives, duration and funding, typology and number of beneficiaries, volumes produced, and income generated with the tested alternatives. The study then presents the results of an evaluation conducted three years after implementation, based on impacts observed at the level of beneficiaries, with a particular focus on the level of overall satisfaction with the alternative activity, the capacity of the alternative to compete with hunting or trade in terms of income generated, and the capacity of the alternative to generate wages at the community level. We also measured the contribution of the project to the wider diversification picture of the wildmeat sector and potential multiplying effects. Furthermore, we evaluated whether the alternatives contributed to reducing time involved in hunting or wildmeat trade with the assumption that, reduction of time spent in hunting or trade may help reduce the unsustainable use of wildmeat. Finally, we discuss recommendations that may be applicable to similar initiatives in Central Africa.

MATERIAL AND METHODS

Study area

The Yangambi region

Our study focuses on the wild meat trade chain in the Yangambi landscape, where our research team has been conducting research on wildmeat since 2009 (Shephard et al., 2023, 2024; Van Vliet et al., 2012, 2018, 2019, 2022, 2023). Yangambi town is located about 100 km west of the city of Kisangani (Tshopo province, DRC). It originated in the 1930s as a research campus, but eventually attracted workers from neighbouring areas and evolved to become a secondary regional town. The surrounding landscape is characterized by a superposition of land tenures combining the Yangambi Man and Biosphere Reserve (YBR), the legally contested Ngazi Forest Reserve and logging concession. Turumbu is the main tribe and the principal traditional land ower in Yangambi landscape. In the town of Yangambi, multiple tribes (Turumbu, Topoke, Lokele, Mbole, Bangelema, etc.) coexist (Fig. 1). Due to lack of human and financial resources, the YBR has no official management plan, its limits are contested, and it is not under any specific form of management. Deforestation in the reserve may not differ from bordering areas (Kipute et al., 2023).

Food security in Yangambi

The human population living in the landscape was estimated in 2016 at 141,643 inhabitants, based on data from the Yangambi Registry Office. Two thirds of households experience insufficient food availability to meet the recommended 2,000 calories per day (Nowak & Aevermann, 2019). Wildmeat significantly contributes to animal protein needs, and is eaten more than once a week by >60% of households (Van Vliet et al., 2017). A 24-hour recall survey implemented across the whole Yangambi landscape found that a significant pro-

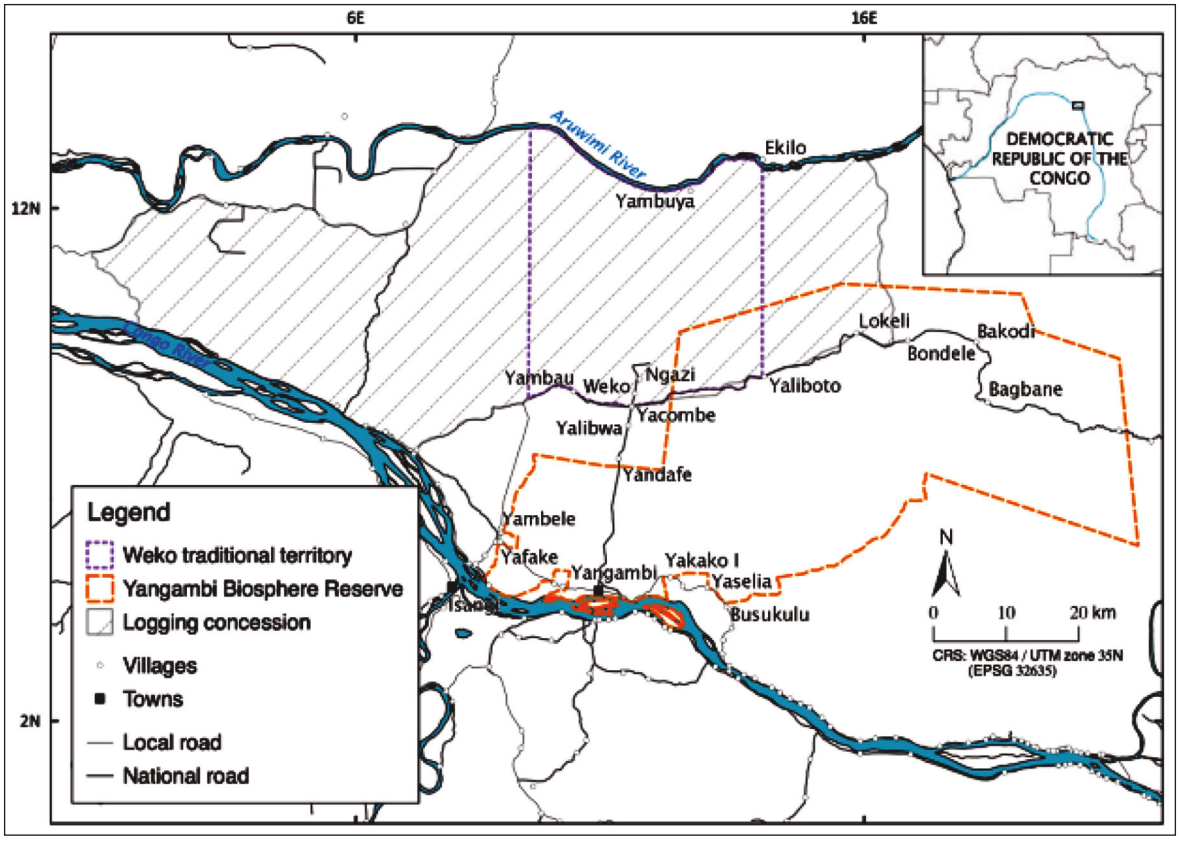

Figure 1. Map of the study area in the Yangambi region, Democratic Republic of Congo.

portion (27%) of rural households had not consumed any animal products the previous day, while 32% of households had consumed wildmeat, 18% fish and 10% caterpillars. Wildmeat was listed among the preferred meats, followed by fish. However, if wildmeat was to become scarce, consumers would welcome pork or chicken (Van Vliet et al., 2017). Most Turumbu households reported hunting wildmeat themselves, and therefore seasonality and resource availability in the wild were identified as the main factors affecting access. Wildmeat demand from Yangambi town is high because fish is expensive in the market, and no other source of meat is available for the growing population (Van Vliet et al., 2017).

Wildmeat trade in Yangambi

Wildmeat trade in the Yangambi landscape involves about 845 people who participate in the supply chain among them 250 traders and brokers and 538 hunters (Van Vliet et al., 2019). Local forests supply about 145 tonnes of smoked wildmeat per year to consumers in Yangambi town (Van Vliet et al., 2019). Most of the meat consumed in Yangambi town originates from the Turumbu sector and particularly from Weko, a village located about 30 km north. As sales are very attractive, hunters from Weko sell more than 80% of what they hunt, sometimes neglecting family needs (Van Vliet et al., 2019). Hunting is a readily available source of income that requires little or no investment and the assurance that it will be sold immediately. In fact, the traders literally grab the products from the hands of the hunters when coming out from the forest, at what is called the Mipila market located at the exit route of several hunting trails 2 km north of Weko. This informal wildmeat market takes place every weekend and traders travel to Weko to purchase all the wildmeat coming out from the forest (Van Vliet et al., 2019). Traders make a profit of USD 29.3 per month whereas hunters can make a net profit of about USD 40 per month (double the 2017 official minimum income in the DRC) (Van Vliet et al., 2019.

Until the early 2000s, wildmeat from the Yangambi landscape travelled as far as Kisangani. However, due to increased local demand from the town of Yangambi (and potentially a decrease in supply, Shephard et al., 2024), the amount of wildmeat that reaches Kisangani from the Yangambi landscape has considerably decreased over the years. The town of Yangambi can now be considered the further end of the trade chain.

Status of wildlife populations in Yangambi

Forests in the Yangambi landscape present a post-depletion profile, characterized by the local extinction of *Loxodonta africana* (Blumenbach, 1797), the depletion of vulnerable species - e.g. *Orycteropus afer* (Pallas, 1766) and *Pan troglodytes* (Blumenbach, 1775) - population declines of medium-sized ungulates - e.g. *Potamochoerus porcus* (Linnaeus, 1758), *Hyemoschus aquaticus* Ogilby, 1841, etc. - and stable populations of fast-reproducing or small-sized species - e.g., *Cricetomys emini* Wroughton, 1910, *Atherurus africanus* J.E. Gray, 1842, *Protoxerus stangeri* (Waterhouse, 1842), *Dendrohyrax* sp., and *Philantomba monticola* (Thunberg, 1789) (Van Vliet et al., 2018; Shephard et al., 2024). Over 88% of hunters consider hunting to have become more difficult over the last 10 years. The collapse of local governance systems, the disruption of the economic vitality of the region, and immigration from neighbouring conflict hotspots are all factors that have triggered increased hunting pressure. Independently from conflict, innovations in hunting practices (either local such as manufacture of firearms and cartridges, or external such as the head lamps used to hunt at night) also explain increased pressure particularly on nocturnal and arboreal species (Van Vliet et al., 2018; Shephard et al., 2024).

Description of the Livelihoods Intervention

To structure our intervention, we used the components proposed in Wicander & Coad (2018) for projects implemented as alternatives to the unsustainable use of wildmeat. Each of these components has an associated set of questions, which we try to answer here as follows.

The project aimed at supporting stakeholders involved in the trade chain to reduce their dependence on wildmeat as a source of income. This remained the primary aim throughout the project. This activity was part of a larger wildlife management initiative, which was informed by a two-year

baseline assessment process to understand the hunting and wildmeat trade system (Van Vliet et al., 2018, 2019, 2023). Besides the development of alternatives, the project also supported hunters in establishing wildlife committees, carry out wildlife and hunting monitoring systems, develop and implement a behaviour change campaign for rural and urban populations and children, and support the Provincial Ministry of Environment in the development of a landscape level wildlife management plan.

This project was funded by USAID and the European Union, without interruption from 2017 to date and implemented by CIFOR.

The project was implemented by CIFOR, in close collaboration with a local NGO (SO WILD), village leaders, INERA, MAB, the University of Kisangani, and the Provincial Ministry of Environment.

Community members were involved in the initiation, design and implementation of the project following an FPIC approach. Village leaders participated in decisions around the criteria to choose beneficiaries, in the validation of project proposals and in monitoring of implementation.

In order to identify opportunities for the development of alternatives to wildmeat trade in Yangambi, we used information gathered during the two-year baseline study of the hunting and wildmeat system carried out in 2017-2018 and on a survey carried out among 154 hunters from the Yangambi landscape and 63 local wildmeat traders. The objectives of the baseline assessment included understanding the role of hunting and wildmeat trade in the household economy, the entrepreneurial profile of hunters and wildmeat traders, and other economic activities present in the landscape.

Project Theory of Change (ToC). The baseline assessment was used to formulate the hypothesis on which the project intervention was based, i.e., that the development of alternative micro-projects could be considered an alternative to hunting and wildmeat trade if these effectively reduced hunting pressure to more sustainable levels. The underlying assumption was that hunters and traders would invest their time in a more stable and lucrative activity and abandon hunting and wildmeat trade if other sources of income were readily available. The range of eligible income-generating activities was extremely wide, including the development of other small-scale production systems, agriculture, livestock production, crafts, commerce etc. In order to increase the probability of substitution, these alternative activities had to target actors who are actually involved in hunting and the wildmeat trade, to consider the traditional gender distribution of income-generating activities, be based on a business plan, guarantee equal or greater income from hunting and wildmeat trade and have characteristics compatible with household economies and the socio-economic context in which they apply.

Project participant selection. In order to give an equal opportunity to all commercial hunters and all wildmeat traders, a call for projects was launched during July 2020. The call was firstly distributed in the villages of Weko and Ngazi, where most of the wildmeat is sourced according to baseline results. The call was explained at community general meetings in the local language. Secondly, at the market level, the project team organized a workshop with wildmeat traders to explain the purpose of the call and potential modes of participation. The project team supported candidates in putting their project into a simple concept note, which provided general information about the candidate, the importance of hunting or wildmeat trade in their household economy, the rationale behind which the alternative activity would reduce their hunting or wildmeat trade activity, the objectives, desired clients, potential markets, human resource needs, existing capacities and necessary capacities, and investments already available or needed to develop the alternative. A list of selection criteria for beneficiaries and projects was established (Table 1) to carry out a first screening and pre-selection. We promoted household or individual projects (as opposed to community level projects), those that could both contribute to food security and income and those for which a clear local market was available (Brittain et al., 2022).

Based on pre-selection, the project team coordinated with village authorities to analyze the proposals and visited each of the pre-selected candidates to complete information where needed. During these visits, the project team was also responsible for understanding the feasibility of the project in terms of the beneficiary's investment capacity, cap-

ital already acquired (e.g., equipment and tools), and current know-how. Based on these visits, a first selection of projects was then conducted. With support from the project team, beneficiaries finalized their business plans, identifying needs in terms of training, investment, marketing, etc. and potential support that the project could provide. The business model was used to make a final selection based on expected income generated, return on investment and capacity for reimbursement of the micro-credit. The project team and final beneficiaries negotiated and formalized support in the form of a contract agreement specifying the amount provided by the project and the plan for reimbursement.

Project conditionality and sanctions. Support was provided by the project based on a contractual agreement with each beneficiary, with a detailed description of the reimbursement schedule where applicable. No condition on reduced hunting was imposed. No sanctions were provided for beneficiaries that did not reimburse the full amount, but those that did were encouraged with further support to enhance their alternative activity.

Project monitoring. The wildlife team monitored the execution of the business plan monthly and carried out monthly visits to write execution reports with supporting photographic evidence. A mid-term evaluation and a final year evaluation was carried out for all projects on a yearly basis. The team built the capacities of each beneficiary to keep a monitoring book note with information on production, costs and sales, which was compiled on a monthly basis.

Project sustainability. Business plans were developed for each individual project to assess sustainability and decide on the selection of the project. Substantial support was provided during the first two years of the projects to provide technical advice and training, as well as to support the

Target group	Criteria for selection of projects
Wildmeat traders	- The income-generating activity should be adapted to the female gender since most sellers are women. - The activity should highlight the strengths of their current occupation: business skills, network and customers. - The activity should be economically competitive with the wildmeat trade but compatible with other activities such as agriculture. - The project should target people who are under 30 years old, who express a real interest in changing careers, with great organizational skills and experience in managing loans/repayments. - Small-scale peri-urban livestock farming could be a promising sector given that the beneficiaries could manage the entire sector from production to marketing to the consumer, and thus capitalize on their experience and their clientele.
Wildmeat hunters	- The income-generating activity should be adapted to the male gender since most hunters are men. In particular, the activity should allow them to maintain a certain mobility. - The activity should be economically competitive with the game trade but compatible with other economic activities including agriculture. - The project should target people under 25 years if age, who are still able to capitalize on new skills. - Candidates should express a real interest in changing careers, with great organizational skills and experience in managing loans/repayments. - Activities linked to crafts (carpentry, sewing, etc.) or services (health, photography, printing, etc.) with a local clientele could be favoured.

Table 1. Criteria for selection of projects targeted at wildmeat hunters and traders in Yangambi.

	Pig farming		Chicken farming		Plant cultivation		Photography
Year	Trader	Hunter	Trader	Hunter	Trader	Hunter	Hunter
2021	2	2	0	0	2	13	1
2022	0	0	1	2	2	19	0
2023	1	0	0	0	1	5	0
2024	0	0	0	0	0	0	0
Total	**3**	**2**	**1**	**2**	**5**	**37**	**1**

Table 2. Number of beneficiaries (wildmeat hunters and traders) that participated in each of the main livelihood alternatives.

beneficiaries throughout the processing and marketing process where needed. The project is ongoing (2024).

Project Implementation and Monitoring

The project has supported 51 wildmeat stakeholders since 2021, comprising 41 hunters and 10 traders (Table 2). Stakeholders received financial support for only one type of activity. Agriculture production projects involved the cultivation and processing of rice, African pistachio and soya. The project provided support in the form of a microcredit to purchase equipment (e.g., tarpaulins, bags, boots, tools and seeds) and to pay for labour (cultivation, harvesting and packaging). Technical support was provided by an agronomist (field assessment, seed proposal and technical advice). In relation to livestock production, during the initial year, the project provided support for the construction of five pig production units and three chicken coops (covering the procurement of roofing sheets, planks, nails, and cement) as well as the acquisition of breeding pigs or chickens, the provision of feed, veterinary supplies, and veterinary technical assistance. The project also facilitated capacity building through training in pig and poultry husbandry. The project also supported establishment of a photography business for one hunter passionate about photography. Support included training, as well as construction of the photography studio, a camera, a portable printer, a solar panel, an energy converter and a battery.

Data on number of beneficiaries, main occupation and role in the trade chain as well as gender were reported in the beneficiary database. To monitor project implementation, all beneficiaries were trained to collect data on quantities produced, costs for production and income generated in monitoring book notes specifically designed for each beneficiary based on the activity chosen as an alternative. In addition, the project team visited all beneficiaries at least once per month to provide technical advice, verify and compile monitoring data.

Methods for Impact Evaluation

We developed a semi-structured questionnaire (Supplementary Material) to evaluate the impacts of the intervention based on perceptions of project beneficiaries. Among 51 beneficiaries of the project (41 hunters and 10 traders), 27 hunters and 9 traders were interviewed. The Interviews were prepared by the project team but implemented by students hired and trained for that purpose to avoid conflict of interest and bias in responses. The semi-structured interviews aimed (1) to assess the level of satisfaction of beneficiaries with respect to the new alternative activities, and to compare the income from alternative activities with selling wildmeat, (2) to assess the contribution of activities to the wider economy and to diversification within the wildmeat sector, and (3) to better understand the capacity of the alternatives to replace hunting and wildmeat trade, including whether beneficiaries became less involved in hunting. The questionnaire explored socio-eco-

nomic variables (residence, gender, ethnic background), level of involvement in wildmeat trade (role in the trade chain five years ago and now, time since last hunt/last wildmeat trade), alternative activity (type of alternative, years involved, monthly income, number of full time, part time and seasonal labour involved, perceived changes in wildmeat volumes traded) and effectiveness and productivity (level of satisfaction in the activity, number of other persons that were inspired by the activity, trends in income and food security in last five years).

Data analysis consisted in assessing level of satisfaction with the alternative activity and measuring relationships between satisfaction and type of alternative using Correspondence Analysis. Another Correspondence Analysis was computed between level of satisfaction and type of project beneficiary (trader or hunter). We calculated the average monthly income generated by alternative activities and compared it with the monthly income generated from wildmeat as assessed by van Vliet et al. (2019) in the Yangambi landscape. Furthermore, we computed an ANOVA to assess significant differences in monthly income generated depending on the alternative activity, and computed a Multiple Correspondence Analysis to assess the relationship between alternative activity type, perception of improved food security and perception of improved income. Finally, we computed an ANOVA to assess differences in job creation by activity, and differences in the number of persons that replicated project-driven activities without support.

To assess whether the alternatives proposed by the project significantly contributed to the wider diversification process of the wildmeat sector, we additionally interviewed 36 traders from Yangambi and 41 hunters from Weko and Ngazi that did not receive project support, using the same questionnaire as for project beneficiaries but adding a question about whether they had diversified their income in the absence of support. For respondents that confirmed diversification, we further asked since when and into which type of alternatives. We then graphically represented the diversification time series showing the number of hunters and traders that diversified activities over time and compared this series with diversification among project beneficiaries.

To evaluate whether the alternative projects significantly reduced pressure on wildlife, we assessed the number of beneficiary hunters and traders that no longer considered wildmeat trade as their primary activity. Furthermore, we calculated time since last hunt or wildmeat trade as an indication of the time not spent in the wildmeat business as a proxy for pressure on wildlife, based on the assumption that if people spend less time hunting or trading, they will put less pressure on wildlife if all other variables remain stable. We computed ANOVAs to assess differences in time since last hunt depending first on stakeholder type (trader or hunter) and secondly on alternative activity type.

RESULTS

The project has supported 51 wildmeat stakeholders (41 hunters and 10 traders) to engage in alternative activities to hunting and bushmeat sales. The first activity was the agriculture production projects that involved the cultivation and processing of rice, African pistachio and soya (Fig. 2). The second was livestock production which consisted of five pig production units and three chicken coop (Figs. 3, 4). The last one was the establishment of a photography business.

	Metric	Rice	Pistachio	Soya
Year 1	Area (ha)	14.5	15	-
	Cost ($/ha)	269	220	-
	Production (kg/ha)	290	77	-
	Income ($/ha)	186	167	-
	Jobs	7	7	-
Year 2	Area (ha)	19	14	1.6
	Cost ($/ha)	212	122	132.3
	Production (kg/ha)	379	87	217
	Income ($/ha)	264	139	185
	Jobs	12	11	-

Table 3. Summary costs, production and outcomes for the cultivation-based alternative activities.

Figure 2. African cultivation.

Figure 3. Pig farming

Figure 4. Chicken farming.

The crop production was high in 2022, 379 Kg per ha compared 290 Kg per ha in 2021 for rice. About the African pistachio, the production was 87 Kg per ha in 2022 and 77 Kg per ha in 2021. The production of soya was 217 Kg per Kg in 2022 (Table 3). Pig production units showed average production of live pig biomass was 6,570 Kg in 2021, 5,760 Kg in 2022 and 5,760 Kg in 2023. The average laying rate for chickens was 18.5% in 2022 and 23.4% in 2023.

1. Level of satisfaction with alternatives and impacts on income and food security

According to beneficiaries, revenue generated from new livelihood activities has covered schooling costs, clothing, health costs, house construction and investment in agriculture or small business. Our results show that the overall level of satisfaction by traders and hunters was very mixed, with about 44% of the beneficiaries being very satisfied or satisfied with the new alternative, 51% being unsatisfied or very unsatisfied, and the rest having no opinion (Fig. 5). We found that level of satisfaction was significantly correlated (Correspondence Analysis, $p=0.016$) with the given alternative, with beneficiaries of pork production activities being significantly more likely to be very satisfied, while the beneficiaries of crop cultivation activities were mostly unsatisfied or very unsatisfied (Fig. 5). No significant relationship was found for beneficiaries that chose poultry production, while the beneficiary of the photography project expressed satisfaction.

We did not find a significant relationship ($p=0.381$) between level of satisfaction and beneficiary type, i.e., trader or a hunter (Fig. 6). Monthly income generated varied significantly (ANOVA, $p<0.0001$) with type of alternative activities, with photography (90 USD) and pork production (74.4 USD) providing significantly more income than soya production (53 USD), rice cultivation (24.5 USD), African pistachio (4.5 USD) or egg production (10.8 USD). Only photography, pork production and soya production provided a higher monthly income than the average income for a hunter in Yangambi (USD 40.0) and the average monthly income of a wildmeat trader (USD 29.3) calculated in van Vliet et al. (2019).

Perceptions of improved income and improved food security were significantly correlated with pork production beneficiaries (Multiple Correspondence Analysis, $p<0.05$). On the contrary, hunters participating in cultivation projects (rice and African pistachio) were significantly more likely to express reduced income and food security. Nevertheless, while cultivation activities generated the least monthly income per beneficiary, these activities generated significantly more jobs within the communities (ANOVA, $p<0.0001$) as they require much more labour than other tested alternative activities. Cultivation activities generated wages, i.e., job creation, for 53 to 66 persons per project, including full time, part time or seasonal workers, as opposed to pork production activities which only generated about eight jobs per project (Fig. 7). The difference in number of jobs created was not significant because of high variability (ANOVA, $p=0.153$).

2. Contribution of the project to wider diversification in the wildmeat sector

Beneficiary projects inspired many other people to engage in similar alternative activities (Fig. 8). Inspired individuals did not receive project support, but turned to beneficiaries for practical information, guidance on starting their own activity, or for other support. In total, the 51 projects that received direct support from the project potentially benefited 261 people with advice, technical support and training. The number of inspired persons varied with project type. Pork producers inspired on average 15 other people, while the photographer inspired only one. Beneficiaries mentioned sharing their experience in the form of advice on medication, ration and care for animal production, and seed choice, planting and pest control for cultivation projects.

Despite the fact that hunters and traders have been diversifying their income source for decades (mostly since the 2000s), the project seemed to accelerate this trend, particularly among hunters (Fig. 9). In the last three years, 4 out of the 41 recorded hunters and four out of the 36 traders around Yangambi diversified their income *without* the project, while 27 hunters and 9 traders engaged in alternatives *with* project support. Of those that are no longer primarily hunters or traders, but were five years ago, 35% and 16% respectively are beneficiaries of the project. Traders have diversified into schoolteachers (n=4), farmers (n=3), pork producer (n=1), soap producer (n=1) or fish trader (n=1), while hunters have mostly diversified into agriculture, but also various activities such as photography, school teaching, health worker, carpenter, fisherman, taxi driving, construction of boats, fuel trade or mini-livestock production.

3. Reduction of pressure on wildlife

While hunting and trade have decreased as a primary activity for beneficiaries of the project

over the past three years, none of them have completely given up hunting or trade. Of the 27 hunters that received support, 10 are no longer primarily hunting (37%) and two of the nine traders (22%) that received support are no longer primarily engaging in wildmeat trade. Hunters that received project support for alternatives have spent significantly more time without hunting since the date of the interview than those that did not receive support (ANOVA, p=0.022), suggesting reduced hunting pressure. Most hunters (73%) that received support perceive that their hunting pressure has decreased, while the rest perceive that it has either not decreased or slightly decreased. The reasons given to explain reduction in hunting include awareness given by the project, lack of time available for hunting and the scarcity of game in the forest. Only one hunter mentioned that he did not reduce hunting because he was disappointed by the alternative revenue.

Wildmeat traders receiving support from the project did not significantly change their frequency of attendance at the market (ANOVA, p=0.101), but the majority of traders (six of seven) perceived that the amount of wildmeat traded has significantly decreased and that they now combine this product with trade in smoked fish and other meats. As such, while they continue to be engaged in trade, they rely

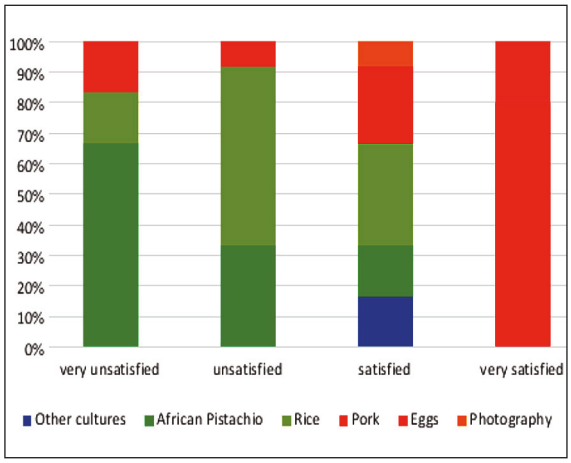

Figure 5. Level of beneficiary satisfaction for each alternative activity promoted in the project.

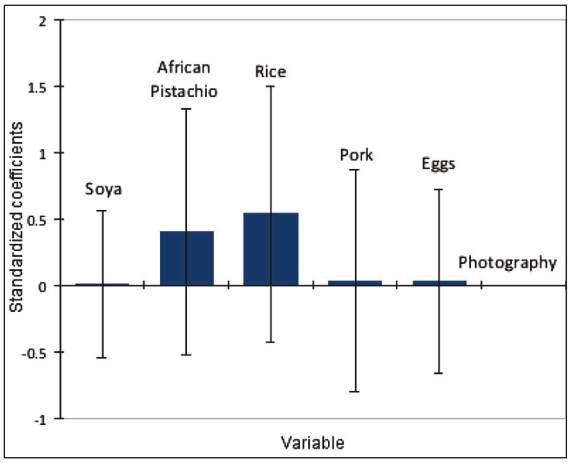

Figure 7. Estimate of overall job creation with each alternative activity. Standardized coefficients with 95% ci.

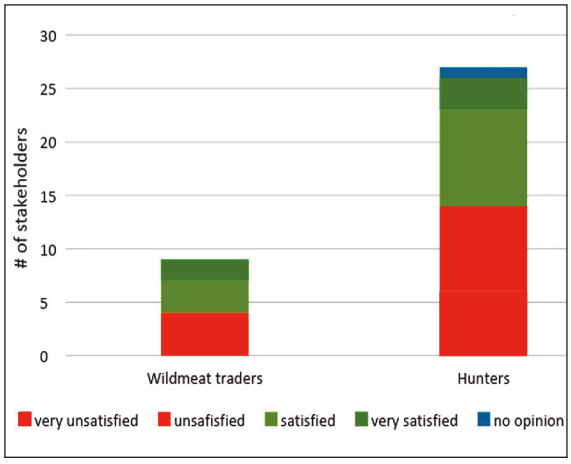

Figure 6. Level of beneficiary satisfaction with alternative activities among wildmeat traders and hunters.

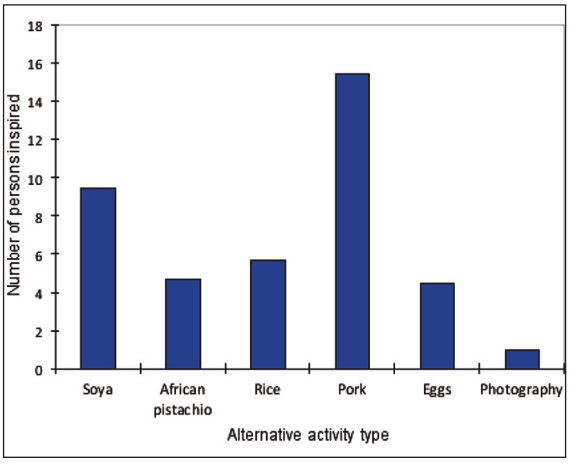

Figure 8. Mean number of persons inspired by project type (per beneficiary).

on wildmeat much less. The reasons given for reduction in wildmeat volumes traded include scarcity of wildmeat and the lack of time to secure sufficient product from hunters. Traders usually have to walk to neighbouring villages up to 30 km away in search of game because motorbike fuel is too expensive.

DISCUSSION

Many studies have demonstrated that wildmeat represents an important protein source in many food-insecure countries (Chausson et al., 2019; Ingram et al., 2021), as well as serving cultural and medicinal purposes (Ingram, 2020). However, wildmeat hunting is associated with declining populations of target species in many tropical systems (Nasi et al., 2011), including the Yangambi region (Shephard et al., 2024). Law enforcement is often insufficient to control illegal hunting (Holmern et al., 2007), but participation in hunting tends to decline as people acquire protein and wealth from other sources (Loibooki et al., 2002). This shift in livelihoods can emerge naturally from resource depletion or urbanisation (Gils et al., 2019), but wildlife conservation and human wellbeing can also benefit from programs that actively develop alternative livelihoods (van Velden et al., 2020). The current study represents one of the first in-depth quantitative analyses of the medium-term impacts of a diverse range of alternative projects in the context of unsustainable wildlife trade.

We evaluated our project with regard to (1) the satisfaction of the local participants, including their encouragement and support of other local people, (2) aspects of production and income, and (3) whether tested alternatives actually reduced time spent hunting wildmeat. There was evidence that some activities had potential for sustainable shifts in livelihoods and benefits for conservation of wildlife. Pork production projects generated monthly income greater than that from wildmeat hunting, and correspondingly the highest level of satisfaction among beneficiaries. This income is acquired only a few times a year, when piglets are available for sale, but represents a savings account that can be used to invest in assets, e.g., small businesses or building materials. In DRC, pork production is generally a male activity, but educated farmers and women may invest more in the sector (Thutwa et al., 2020).

The availability of financial resources for initial investment and education are crucial in livelihood decision making, providing farmers with the ability to perceive and process information in a changing environment and constituting one of the key drivers of resource allocation and technology adoption (Thutwa et al., 2020). Our results show that continued external investment in the form of micro-credit and capacity-building are critical to maintain and upscale local efforts in Yangambi. While pork production is suitable as an alternative for men involved in hunting, further support is required to encourage wildmeat traders (typically women) to engage in this sector. Demand for pork is likely to increase by more than 150% by 2050 in Sub-Saharan Africa (Erdaw, 2023), with evidence for a rapid increase in production and consumption in some countries, including the DRC (Nantima et al., 2015). Pork demand currently remains significantly higher than supply, suggesting potential for growth (Steinfeld et al., 2006).

Cultivation of crops provided job opportunities beyond the beneficiary households and therefore contributed more widely to local economies than pork. However, the income generated did not compete with that available in wildmeat trade, except for soya production, for which beneficiaries found a local market as feed for livestock. For rice and African pistachio, the local market did not offer good prices and beneficiaries had to invest in processing, stocking and transportation solutions to target the larger market in Kisangani. Processing reduced volume and increased value, while stocking allowed producers to target periods of higher prices. Nevertheless, the volatility of rice prices, together with losses associated with variable rainfall and pests rendered these activities risky for producers and less lucrative than hunting. Uptake of rice production might be enhanced by policies that support local farmers (Tran et al., 2021). Egg production generated the lowest monthly income, and these projects did not generate long standing enthusiasm among beneficiaries. Eggs typically generate a small but steady income, which makes it an activity more compatible with women, who generally manage their income at this scale, in particular to meet childhood nutritional needs (Njuki & Sanginga, 2013).

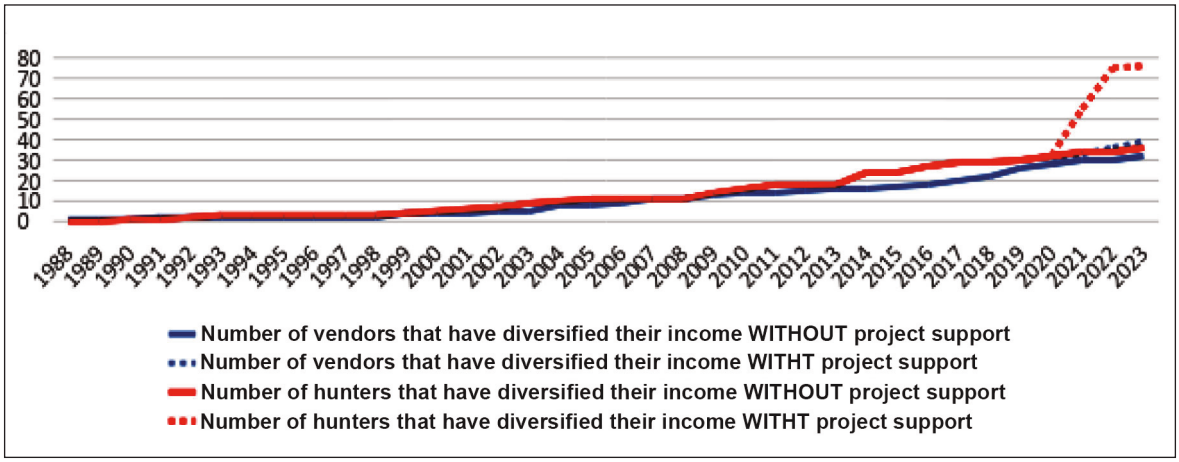

Figure 9. Time series of livelihood diversification by wildmeat hunters and traders in Yangambi, showing the project period starting in 2020.

Some of the alternatives promoted by the project boosted the diversification of local livelihoods among hunters and wildmeat traders. This medium-term project impact seemed to be in addition to the slow but long-term trend in livelihood diversification in Yangambi. Income diversification is pursued by rural householders as it tends to lower their exposure to risk, vulnerability and precarity in areas predisposed to environmental degradation (Ellis, 2004). Salifu (2019) has summarized how rural households are known to use different income diversification activities and strategies, sometimes combining different activities across broad groups. These groups may be classified depending on objectives (Zoomers, 1999; Dedehouann & McPeak, 2020) as follows: (1) Accumulation, (2) Consolidation, (3) Compensatory, and (4) Security. Income diversification activities that are considered accumulative are intended to enhance the level of household capital while also contributing to future expansion plans (Dev et al., 2016). Consolidation implies an increase in the number of income-generating activities with a clear intention of income stabilisation over a definite period of time (Saha and Bahal, 2015). Households adopt compensatory income diversification strategies in the event of sudden income gaps due to shocks from crop failure or loss of livelihoods from natural disasters (Barrett et al., 2001). Security-based income diversification activities involve the adoption of livelihood activities that ensure enhanced protection against risks arising from environmental hazards (Shishay & Mulugeta, 2014). We argue that crop cultivation and egg production activities promoted by the project fall into the compensatory category as the income generated can only complement other sources of income to cover basic necessities. Pork production and photography fall in the consolidation category, as they generate income that may be invested in assets or other productive activities.

Few livelihoods projects have systematically monitored their impacts on wildmeat hunting (Wicander & Coad, 2018). We used the output metrics suggested by Wicander & Coad (2018) to evaluate outcomes, with the ultimate indicator of project success being whether the tested livelihood activities are actually reducing hunting effort in Yangambi. In 2024, 10 of the project beneficiaries were no longer primarily engaged in hunting, while two were no longer focused on wildmeat trade. This outcome suggests convincingly that where activities lead to a net gain in income along with beneficiary satisfaction, then there can be benefits for wildlife conservation. The activities that prove successful are likely to vary with local context, while decreasing price and diversifying domesticated alternatives may lead to a decrease in wildmeat consumption (Chaves et al., 2019). Wildmeat is sometimes preferred to meat from domestic livestock (Brittain et al., 2022), meaning that establishment of activities such as pig farming will depend on local demand. In practice, wildmeat may be an irreplaceable protein source in some systems (Nunes et al., 2019) and is potentially sustainable

in certain post-depletion animal communities (Nielsen et al., 2018).

It has been suggested that so-called 'livelihood-focused interventions' should differentiate between households in a community that have the greatest environmental impact and those most vulnerable to resource access restrictions (Wright et al., 2016). Our study selected hunters as the main category of beneficiaries, but also included wildmeat traders. This targeted approach was intended to maximise the *per capita* effect of the intervention on reducing hunting effort. However, the impact of alternative livelihood effects may also be extended where benefits are directly shared, or beneficiaries inspire and share new knowledge and skills with other local people (Praptiwi et al., 2021) as happened in the current study - especially for pig farming. The spread of new livelihood activities can be facilitated by ongoing extension activities, and especially peer collaboration and learning (Millar & Connell, 2010). An important aspect of this process is to inspire participation and share appropriate skills among young people based on their personal interests and aspirations (Dutta et al., 2023) which are likely to diverge from their elders in changing social circumstances (Das, 2024).

CONCLUSIONS

This study demonstrates that livelihoods diversification can reduce dependence on wildmeat and associated hunting pressure when alternatives are economically competitive, socially acceptable, and locally adapted. In the Yangambi landscape, pig production generated higher income and satisfaction than wildmeat hunting or trading, suggesting strong potential as a sustainable substitute for protein and cash income. However, sustaining such benefits requires technical support, market access, and financial inclusion, particularly for women and youth facing resource and knowledge barriers.

Crop-based alternatives such as rice, soya, and African pistachio cultivation provided modest household income but created substantial employment within communities, enhancing social equity and resilience. Combining higher-value livestock production with labor-intensive crop activities may therefore achieve both conservation and livelihood goals.

Participatory project design and adaptive monitoring fostered local ownership and knowledge sharing, while successful beneficiaries inspired peers to adopt similar practices—amplifying conservation outcomes beyond direct participants. This "peer learning" effect highlights the importance of social diffusion in scaling community-based conservation interventions.

Despite reduced reliance on hunting, some beneficiaries continued partial engagement in wildmeat activities, emphasizing that alternative livelihood programs alone are insufficient. Integrating such initiatives with improved wildlife governance, local market regulation, and targeted awareness campaigns will be essential to ensure long-term conservation gains.

The Yangambi experience illustrates that diversified, inclusive, and context-specific livelihood strategies can align biodiversity conservation with human wellbeing across Central Africa's post-depletion forest landscapes.

Declaration of Conflicting Interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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