Community Markets for Conservation (COMACO) links biodiversity conservation with sustainable improvements in livelihoods and food production

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In the Luangwa Valley, Zambia, persistent poverty and hunger present linked challenges to rural development and biodiversity conservation. Both household coping strategies and larger-scale economic development efforts have caused severe natural resource degradation that limits future economic opportunities and endangers ecosystem services. A model based on a business infrastructure has been developed to promote and maintain sustainable agricultural and natural resource management practices, leading to direct and indirect conservation outcomes. The Community Markets for Conservation (COMACO) model operates primarily with communities surrounding national parks, strengthening conservation benefits produced by these protected areas. COMACO first identifies the least food-secure households and trains them in sustainable agricultural practices that minimize threats to natural resources while meeting household needs. In addition, COMACO identifies people responsible for severe natural resource depletion and trains them to generate alternative income sources. In an effort to maintain compliance with these practices, COMACO provides extension support and access to high-value markets that would otherwise be inaccessible to participants. Because the model is continually evolving via adaptive management, success or failure of the model as a whole is difficult to quantify at this early stage. We therefore test specific hypotheses and present data documenting the stabilization of previously declining wildlife populations; the meeting of thresholds of productivity that give COMACO access to stable, high-value markets and progress toward economic self-sufficiency; and the adoption of sustainable agricultural practices by participants and other community members. Together, these findings describe a unique, business-oriented model for poverty alleviation, food production, and biodiversity conservation.

conservation farming | food security | poaching | carbon | sustainability

The Luangwa Valley exhibits many characteristic linkages between poverty traps and risks to biodiversity. There is heavy reliance of households (HHs) on limited natural resources, shared vulnerability to yearly climatic variability, an absence of strong social/economic institutions, and unintended negative consequences of economic development efforts. The situation has been heading toward a new equilibrium impoverished in both human condition and biodiversity. Positive feedback stemming from trophic disruptions to wildlife populations and habitat, relatively recent shocks such as HIV/AIDS or fluctuations in cotton markets, and the continual shock of variations in rainfall all serve to hasten this change. Given the severity of these interrelated problems, a unique approach has been implemented to preserve biodiversity by focusing on improving livelihoods and food security. The Community Markets for Conservation (COMACO) model uses markets and an adaptive business approach to promote sustainable agricultural practices, rather than base development on natural resources. We begin with a brief local history and then describe the mechanisms of the COMACO model. The expected outcomes provide quantifiable metrics by which we evaluate COMACO's early progress in meeting its biodiversity, economic, and social objectives.

Local Challenges. The Luangwa Valley is home to several of Zambia's most prominent national parks (NPs), and wildlife-based tourism provides critical foreign income. Although human activities have long impacted Valley wildlife (1), the remoteness and poor roads allowed the ecosystem to survive relatively intact, with the exception of the black rhinoceros, which was extirpated in the 1980s. However, this ecosystem is facing new challenges from an expanding human population that suffers from severe and chronic poverty and food insecurity (*SI Appendix*, Fig. S1). Inconsistent rains and suboptimal farming practices limit crop production, and high crop-yield variability suggests that soil and crop management have significant potential to influence crop productivity (*SI Appendix*, Fig. S2). Lack of access to large markets limits income and nonfarm economy. Limited education and skills, as well as the threat of diseases such as HIV/AIDS, tuberculosis, and malaria, contribute to the poverty trap. Accordingly, food aid is needed on a routine basis (*SI Appendix*, Fig. S1).

On the Valley floor, farming is concentrated in alluvial soils along tributaries of the Luangwa River. Maize is the staple crop, although a variety of grains, vegetables, and fruits are grown (2). Trypanosomiasis precludes the keeping of cattle, and reliance on hand tillage, along with HH labor constraints, largely restricts plot size to smallholder status. Traditional agricultural practices include variations of *chitemene* (clearing and tree coppicing with burning of the wood), with fallowing historically occurring at 4- to 10-y intervals (3). To spur development, large-scale outgrower schemes have promoted HH planting of cotton and tobacco. Although successful at introducing capital, these efforts have contributed substantially to Zambia's high deforestation rate as they spread from the plateau into the Valley. In the absence of

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chemical fertilizers, farmers now typically change plots every 2–3 y, significantly increasing the amount of cleared land. Despite its small size, Zambia is second in Africa and fifth in the world in terms of highest absolute annual loss of forest area (4). Over-reliance on nonfood crops also leaves farmers susceptible to commodity market fluctuations. When suboptimal rainfall reduces yield, the resultant reduction in income is compounded by reduced area dedicated to HH food crop production.

When they are food insecure, more than half of Valley farmers in surveyed communities set wire snares for wildlife (5). A small percentage of residents are "professional poachers," using locally made guns to hunt a variety of species (5). Although currently less common, poaching targeting elephants and rhinos was often a commercial activity committed by organized groups from outside the Valley (6). Today, other natural resources, such as fish and timber for charcoal, are increasingly relied on either as coping mechanisms or as routine food/income sources.

COMACO Model. Building upon the lessons from previous integrated conservation and development projects (ICDPs) in the area (*SI Appendix*, Fig. S3), new activities of the Wildlife Conservation Society began informally in 2001 in game management areas (GMAs) east of the North and South Luangwa NPs. Poachers were trained in alternative livelihood skills (e.g., carpentry, bee-keeping, village scouts), and poor, food-insecure families were trained in sustainable agriculture practices [referred to as "conservation farming" (CF)]. These activities remain as core components of the model. Crops are chosen based on their ability to be grown organically in the Valley, impact food security, increase resilience to climate variation, and have marketability as commodities and/or as value-added processed products. Participants choose the crops they grow and are encouraged to diversify their income sources. All participants are required to turn in guns and/or wire snares to show their commitment to sustainable practices (metal is locally scarce, limiting replacement). The COMACO model described here (*SI Appendix*, Fig. S4) began on a small scale in 2003 with the development of a producer group organization and the application of market incentives. COMACO is currently restructuring into a stand-alone business entity and continues to evolve through an iterative, adaptive process. For example, food relief from the World Food Program initially assisted the transition of food-insecure HHs to the use of CF. However, cessation of this temporary aid resulted in marked attrition of approximately one-third of participating HHs because farmers conflated the aid with the cooperative agribusiness-based model. Although food aid is no longer associated with the model, numbers of participating HHs have risen steadily as COMACO has expanded its farmer training and organization and has grown into a reliable purchaser of large volumes of farm products.

COMACO relies heavily on its relations with communities and traditional rulers in the various chiefdoms. When entering an area, extension officers seek assistance from the village headman to identify those HHs in greatest need and those most responsible for resource degradation (e.g., professional poachers or charcoal makers). These assessments are verified via survey, and then selected HHs are encouraged to participate. In practice, more HHs in a new area typically request participation than can be trained in a single season. The model's goal is that, within 3–4 y, participants will be able to support HH food needs independently through increased yields from CF and increased income through market access.

In 6 y, COMACO's 60 extension staff have used community field days and farm visits to train more than 40,000 farmers, 19,000 of whom are registered as having completed training and being compliant with CF practices, which include dry-season land preparation using no/minimal tillage; repeated use of small basins for planting and for soil amendments such as compost; no burning of crop residues but rather using them to suppress weed growth, return nutrients to the soil, and help retain moisture; and rotating and/or interplanting with nitrogen-fixing crops. This sustainable intensification improves yields and reduces land requirements, thus limiting agricultural drivers of deforestation. To facilitate knowledge transfer, COMACO has adopted a tiered lead-farmer extension system (*SI Appendix*, Fig. S4).

Incentives for compliance were initially provided through higher prices for CF-certified farmers versus noncertified farmers. Using this pricing structure as the sole mechanism to maintain compliance was found to be inadequate. During its early growth, COMACO often lacked the capital needed for purchases at the higher prices at the precise time when the farmers needed to sell, resulting in farmer frustration, reduced compliance, and increased sales to alternative buyers. COMACO has now incorporated a "conservation dividend" (CD) mechanism to reward *all* producer groups that are certified as compliant, whether they sell to COMACO or another buyer. This CD is not a subsidy but rather a true dividend—an incentive returned to members that will vary among years. The CD is disbursed just before the beginning of the wet season ("hungry season") when HH food and financial reserves are typically low and new crops are about to be planted. In 2010, the CD included one or more of the following, depending on local conditions: treadle pumps, beehives, and/or hoes. The CD mechanism is meant to promote CF compliance and the use of new technologies and, to a small extent, to smooth HH food availability. From a business perspective, the CD allows this incentive to be given after the production and sale of value-added products as opposed to at the time of purchase of raw materials. This CD approach represents a second major adaptive management adjustment.

Farmers bring crops in excess of anticipated HH food needs to community trading depots for grading, weighing, and selling to COMACO, whose trucks transport them to a regional trading center [also known as a Conservation Trading Center (CTC)]. There they are processed into value-added products or, in some cases, bulked for trade on commodity markets. In this way, the CTCs provide HHs in remote areas with reliable access to higher-value urban and export markets. Inability to reach these markets, often caused by lack of transportation, is recognized as a key economic constraint facing rural smallholders in Sub-Saharan Africa. Because COMACO operates across the entire value chain, the higher sales prices available in those markets can be returned to farmers through higher crop prices and the CD.

To increase its conservation benefits, lower transaction costs, and increase the size of reliable contracts for value-added products, COMACO has expanded to operate multiple CTCs, each with its own circumscribed area of operation (Fig. 1). The CTCs operate as separate profit/cost centers but function collectively as a single company. A head office in Lusaka makes trade deals, directs product distribution and marketing, and performs commercial financial management and business planning. Internal and external audits monitor business operations.

Through promoting sustainable practices that increase productivity, COMACO is similar to an ICDP in seeking to limit practices that degrade resources. However, COMACO differs in several ways. (*i*) It does not rely on wildlife to support development objectives. (*ii*) It provides a business infrastructure to link rural HHs with more profitable markets. (*iii*) It prioritizes production of food crops to meet HH needs, promoting sales of surplus. (*iv*) It does not mix its activities with punitive anti-poaching efforts. (*v*) COMACO works on an extremely large scale (>35,000 km^2) so that it can impact the entire watershed ecosystem. (*vi*) The model allows HHs to choose their crops, giving it flexibility to operate across culturally diverse chiefdoms as well as three different agroecozones. Regional variations are such that the CTCs have different product lines and machinery, further diversifying the business. (*vii*) The goals are specified: it uses markets to encourage sustainable practices that should in turn lead to biodiversity conservation.

However, COMACO also differs from a traditional business in several ways. (*i*) It does not restrict its activities to areas having low transportation costs or high productivity but rather seeks to provide market access throughout a geographically disadvantaged area, thereby increasing operating expenses. (*ii*) It pro-

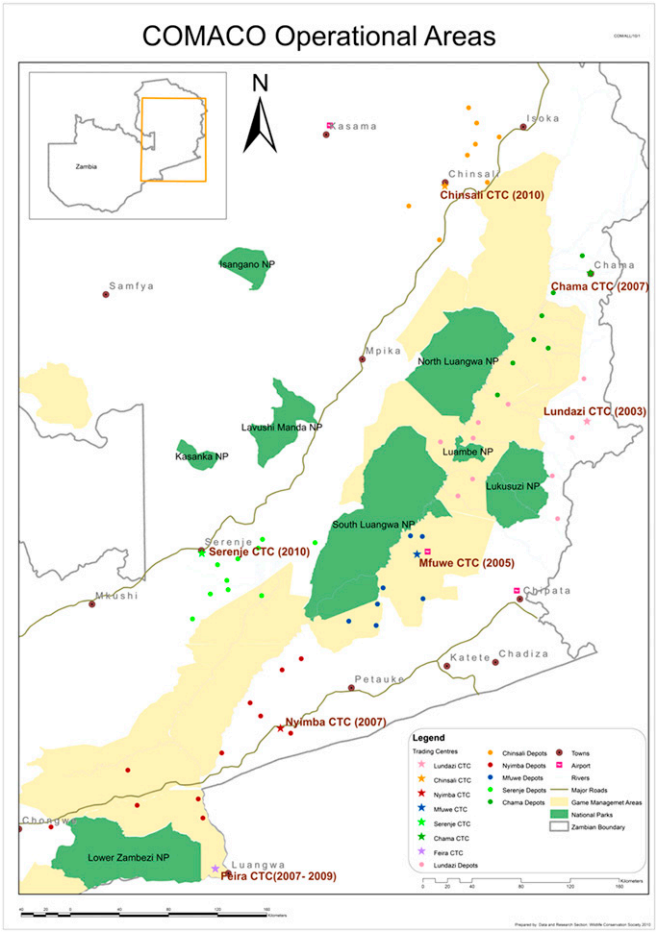


Fig. 1. Spatial distribution of CTCs and years of first operation. New CTCs in Chama, Serenje, and Chinsali will allow COMACO to ring the Valley's NPs, in an attempt to reduce unsustainable behaviors, provide ecological corridors between protected areas, and increase the scale of commercial operations.

vides social services such as training on HH nutrition. (*iii*) It monitors and evaluates social and conservation outcomes. Research is sponsored by foundations as well as by partnerships with academic institutions, and results are integrated as part of an adaptive management framework (7).

Expected Outcomes of the Model. The objective of the COMACO model is to effect change at an ecosystem scale by using business activities to promote HH-level behavioral changes. Expected benefits or outcomes represent specific, testable hypotheses with quantifiable metrics (*SI Appendix*, Fig. S5). In this article, we address the following hypotheses: (*i*) COMACO will stabilize wildlife populations in the Luangwa Valley GMA; (*ii*) COMACO will show economic growth approaching financial self-sufficiency; (*iii*) through COMACO, participating HHs will gain access to high-value markets; (*iv*) COMACO's training of HHs in sustainable farming practices will improve soil quality; and (*v*) participants will achieve increased crop yields and higher incomes.

Results

Wildlife/Ecosystem. In addition to reducing habitat loss, COMACO attempts to conserve wildlife by reducing illegal snaring and poaching with guns. To date, more than 61,000 wire snares and 1,467 guns have been turned in by participants. Training of poachers in alternative careers began as a pilot program in 2001 before implementation of the model's market components. We compared data from "pre-COMACO" aerial wildlife surveys in 1999 and 2002 against results from surveys performed on the same flight transects in 2006 and 2008 (*SI Appendix*, Figs. S6 and S7; note that severe flooding in 2007 resulted in atypical distributions that precluded use of those data). Results showed that populations of most species were stable or increasing. Increase in hartebeest was statistically significant (Fig. 2*A*). The degree of the positive change suggests that reduced hunting pressure likely contributed to redistribution of animals back into the GMAs.

These populations were already in a dynamic state before our surveys. Previous reports suggested that several large-bodied ungulates were in decline from 1979 to 1996 (8). Because these species are desirable targets for poaching and are particularly sensitive to it, the stability of eland, hartebeest, kudu, roan, waterbuck, wildebeest, and zebra populations is noteworthy. Stability of the elephant population is of special importance, given the recent local history and focus for regional tourism.

The relative impacts of COMACO's poacher transformation program (more than 760 individuals have completed the program), snare removal, improvements in the efficacy of the Zambia Wildlife Authority (ZAWA), and other anti-poaching efforts are unclear. Social surveys of professional poachers indicate that multiple arrests and convictions are insufficient to deter most from returning to poaching (5). To investigate whether COMACO's snare removal program was successful or whether snares were simply being replaced, we sought independent evidence from ZAWA's patrol reports. These data showed seasonal and yearly fluctuations, but a downward trend in snares recovered from NPs as well as GMAs was observed despite consistent patrol effort over time (Fig. 2*B*). These findings suggest that COMACO's snare removal provided benefits to wildlife in the NPs as well as in the GMAs in which its participants live.

Business. To sustain its activities over time, COMACO would ideally become financially self-supporting. The tactical plan has been to increase the scale of operations, so it can reliably meet required thresholds for contracts of value-added products and commodities in larger urban and export markets. To evaluate the success of these efforts, we have analyzed its sales and costs figures. Early accounting methods were inadequate for a rigorous analysis but can fairly be characterized as "start up" investment in facilities, extension staff, and HH training, with low volumes of sales. Growth necessitated rigorous accounting, including internal and external audits. Improved accounting practices produced sales and costs data adequate for analysis beginning in the 2007–2008 financial year, and individual market contract data were adequately recorded beginning in 2008–2009.

Data for the CTCs that are generating value-added products (and which include costs of the administrative and distribution center) show progress toward a break-even point with the percentage of sales revenue to total operating expenses increasing from 31% to 79% over the past 3 y (Fig. 3*A*). Importantly, contract data show that COMACO is providing rural HHs with access to high-value urban and international markets (Fig. 3*B*). Proof of the counterfactual—that such access would not exist without COMACO—is difficult to demonstrate with rigor. However, the Luangwa Integrated Resource Development Project (8) did not provide that access, the lack of road/rail infrastructure makes such access difficult, and no other large-scale food-processing equipment exists in the Valley area to provide a comparable value chain.

Analysis (Fig. 3*A*) shows the large contributions to total sales of items requiring relatively little processing, such as rice and mealie-meal (ground maize flour used to make the staple dish, nshima). Honey has the highest profit margin and bee-keeping is heavily promoted for this reason as well as for ecosystem benefits (retention of forest flowering trees). In 2005, facility improvements and intensive staff training in hygiene, safety, and quality control allowed COMACO to obtain Hazard Analysis and Critical Control Points (HACCP) certification. The products consistently pass quality and safety testing at the University of Zambia's food laboratory. These steps were essential in COMACO's cer-

A

	Pre-COMACO		COMACO		
	estimate	SE	estimate	SE	t-test
Buffalo	5,111	2,654	1,608	876	-1.25
Eland	73	41	91	55	0.26
Elephant	1,028	346	1,635	501	1.00
Hartebeest	13	10	283	103	2.60*
Kudu	86	43	137	68	0.64
Puku	1,104	445	1,539	493	0.65
Roan	16	11	162	104	1.39
Waterbuck	152	62	149	78	-0.03
Wildebeest	1,149	542	1,840	678	0.80
Zebra	568	220	946	444	0.76

B

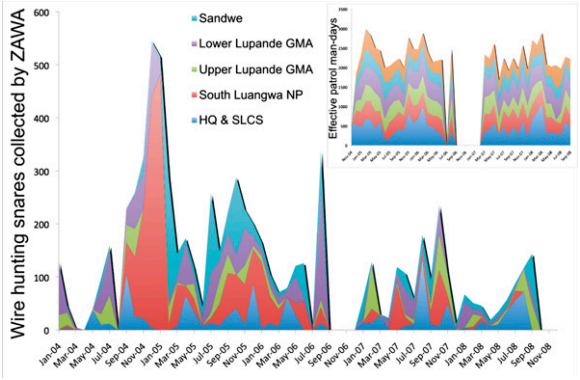
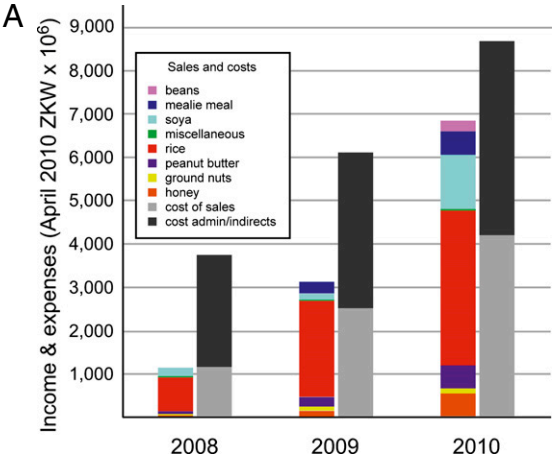


Fig. 2. Temporal changes in wildlife populations and in wire snare collections by ZAWA patrols. (*A*) Comparison of wildlife populations from aerial surveys performed in 1999 and 2002 (pre-COMACO) versus 2006 and 2008 (COMACO). Variance weighted averages are listed. *Significance of the *t* test at $P < 0.05$. Bushbuck, impala, and warthogs were omitted because they were not assessed during the 1999 survey. (*B*) Total wire snares collected by ZAWA plotted by month (colors indicate sectors). Between 2004 and 2008, an overall decline in snares was observed. Although COMACO's activities are focused in the GMAs, snares recovered from the adjacent South Luangwa NP also declined. *Inset* shows a relatively consistent effort in terms of effective patrol "man-days" during the period for which ZAWA data were available.

A



B

Market type and number of contracts	Time period[1]	Value of Sales (April 2010 ZKW)
Retail (2-3 national chains, ~265 individual stores)	4/2008-3/2009	2,146,555,269
	4/2009-3/2010	2,520,929,618
	4/2010-7/2010[1]	2,333,029,809[1]
Wholesale (35)	4/2008-3/2009	157,552,522
	4/2009-3/2010	510,302,971
	4/2010-7/2010[1]	328,975,033[1]
Commodities and Exports[2] (27)	4/2008-3/2009	N/A
	4/2009-3/2010	392,216,388
	4/2010-7/2010[1]	1, 114,281,687[1,3]

[1] Time period for the current business year includes only April-July, 2010.
[2] Commodities (number of contracts) include beans (8), groundnuts (5), HEPS (3), maize (1), peanut butter (1), and soya (9). Exports to South Africa, Botswana, and the Democratic Republic of the Congo included peanut butter, as well as beans, groundnuts, and soya.
[3] Approximate value in USD using the currency exchange rate on July 31, 2010 is $232,680.

Fig. 3. (*A*) Income and expense data for Lundazi and Mfuwe CTCs as well as the Lusaka headquarters. Data are presented by fiscal years closing on March 31. Sales of high-energy protein supplement (HEPS) are included under soya and constitute approximately two-thirds of 2010 soya sales. (*B*) COMACO's major market contracts and their annual values current as of July 31, 2010. Data are presented in April 2010 ZKW (values fluctuated between ZKW 3,160 and 5,700 per $1 USD during this period). Values for 4/2010–7/2010 have not been adjusted because Consumer Price Index data are not yet available for this period.

tification as a vendor for large-volume contracts of high-energy protein supplement with the World Food Program and Catholic Relief Services as well as sales to regional hospitals, schools, and commercial markets.

Training of a food technologist and additional extrusion equipment donated by General Mills have enabled development of additional products (e.g., food bars and poultry feeds). However, diversification has proven difficult because of limitations in water and electrical infrastructure. Additional research has decreased breakage of rice as well as reduced phase separation and improved packaging of peanut butter to improve quality and shelf life. These changes have enhanced COMACO's ability to negotiate contracts with urban supermarkets. Retail sales are now complemented by sales on the Zambian Agriculture Commodities Exchange.

Despite these relatively positive indicators, expansion has not been uniformly successful. Although desirable from a conservation perspective because of its proximity to the Lower Zambezi NP, the CTC at Feira was unsuccessful because of high transportation costs, restricted varieties of local commodities, and lack of reliable water and electricity. CTC status was shifted to the facility at Nyimba in 2009 (opened as a regional depot in 2007). This site has more reliable utilities and direct access to the major paved highway running to Lusaka, but it required substantial investment in 2008–2009 to accommodate the new functions and scale. New CTCs in Serenje and Chinsali have just become operational with the 2010 harvest. In addition to increasing scale, the growth in number of CTCs has allowed specialization; for example, extrusion processing is performed at Lundazi.

The costs associated with expansion, including purchasing/leasing/remodeling the CTC facilities, building of local depots, etc., are sizeable investments. Per the COMACO balance sheet as of March 31, 2010, the capitalized capital expenditure grants totaled Zambian Kwacha (ZKW) 3,532,727,637 (approximately $740,000 USD at then-current exchange rates), an increase of ZKW 98,271,408 (approximately $21,000 USD) over the prior year. COMACO's expansion has been made possible by support from several sources, most notably, the Royal Norwegian Embassy.

Social/HH. A prerequisite to investigation of social impacts is analysis of potential selection bias in farmer recruitment into the model. Information on HH size and stores of food crops was collected as COMACO evaluated potential new participants. These surveys were performed in August/September, several months after harvest and before planting. Food stores at this time provide an indirect indicator of HH food security in the following hungry season, when reserves are dwindling and crops are planted but are not mature for harvest. Over several years, surveyed HHs that later joined COMACO had either similar or significantly lower maize stores than did HHs that did not later participate (*SI Appendix*, Fig. S8). Independent surveys of participants versus nonparticipants in the Lundazi area (2009) showed no differences in education or in HH size and composition (*SI Appendix*, Fig. S1), with trends toward slightly lower education and more individuals in participating HHs. Together,

these data suggest that COMACO has been generally effective in its goal of recruiting participants from less well-off HHs.

Registration as a producer group member is limited to one person per HH to avoid double-counting in assessments or distribution of benefits. An emphasis on women (52% of registered farmers are female) is a positive aspect of the model, given cultural gender differences and the growing number of HHs headed by single women [in 1992, 18.7% of rural HHs were female-headed versus 25.4% in 2007 (data from Zambia Demographic Health Survey, Central Statistical Office, Zambia)]. Comparison within a group (*SI Appendix*, Fig. S8) reflects that HHs headed by women tended to have lower normalized mean food stores than male-headed HHs, making their inclusion of particular importance. Such HHs face additional labor constraints, and COMACO extension officers are trained not only to look for HHs headed by single women when they enter a new area, but also to offer training in diversified crops of the farmers' choice, with recommendations tailored to the area and predicted market. There are some gender differences in these choices; for example, women farmers more frequently request training in groundnuts and honey. Since severe flooding in 2007, additional emphasis has been placed on crops able to withstand or mitigate effects of flooding/drought such as cassava and sweet potatoes. New legume crops have also been introduced to improve soil quality and further diversification, bringing the total number of crops promoted to 16. In this way, the model differs from outgrower schemes, which are highly focused on single crops.

Implementation of farming practices and technology adoption were investigated in the Lundazi region in November 2009 by using a HH survey. Data revealed that, although COMACO participants were more likely to use most CF practices (*SI Appendix*, Fig. S9), ~20–60% of respondents *who had never participated* in COMACO also used these practices. For all practices, the vast majority of nonparticipating farmers learned CF technologies from neighbors as opposed to governmental, private sector, or nongovernmental organizations (*SI Appendix*, Fig. S9). In the surveyed villages, COMACO has a very high participation rate (to the point of necessitating purposive sampling of nonparticipants). This situation strongly suggests that the nonparticipants learned these methods from COMACO farmers, and it reflects their positive perceptions of value. The actual value of these practices should be measurable in terms of soil quality and crop yields. Compared with plots farmed with traditional methods (paired comparisons on single farms), CF plots showed a statistically significant increase in total soil carbon at 0- to 15-cm depths (*SI Appendix*, Fig. S10). This level is the depth at which the basins are planted but, because the composite samples included soil from outside basins, the improvement reflects the impacts of minimum tillage and lack of burning of crop residues rather than just local amendments.

Although these results suggest a strong benefit created from knowledge transfer from COMACO members to the broader population of the region, these findings confound the comparison of crop yields between COMACO and non-COMACO farmers because non-COMACO farmers were shown to be using many of the same methods. Ideally, a pre- and post-COMACO comparison would have been used to test the impacts of participation on yield, income, and food security. However, the model spread quickly, precluding longitudinal studies with a multiyear preparticipation baseline (year-to-year variations in rainfall influence yields significantly). Instead, a cross-sectional postharvest survey comparing participating and nonparticipating HHs was performed in 2008 in multiple villages across eight chiefdoms. Gender comparisons suggest that participation was associated with increases in yield per hectare of groundnuts, maize, and rice for women farmers (*SI Appendix*, Fig. S11).

Income comparisons in the 2008 survey (*SI Appendix*, Fig. S11) did not reveal differences associated with COMACO membership. However, data from the 2009 survey revealed the confounding factor that 40% of COMACO participants sell to buyers outside COMACO. Addressing whether there was improvement in HH income before versus after participation would require comparison of data from different survey methods and is not included here. One clear result of the 2009 survey was that food insecurity was experienced by the vast majority of HHs, irrespective of membership. Lines of questioning developed by the Food and Nutrition Technical Assistance Project (9, 10), and validated through international field studies (11, 12), were applied to determine the extent of food insecurity during the start of the hungry season. More than 90% of all HHs indicated that they reduced the number of times and/or the quantity of food they ate, experienced hunger, and/or lost weight because of food being unavailable (*SI Appendix*, Fig. S1). This finding underscores the severity of the food insecurity in the Luangwa Valley. It also indirectly highlights the need for more precise future survey and analytical approaches that could discern whether COMACO were in fact improving conditions but not yet achieving food security.

Discussion

Through its spatial-temporal scale, gender awareness, reliance on nonwildlife revenues, and adaptive management research, COMACO has sought to avoid the problems historically associated with ICDPs. There is no inherent reason why projects cannot be successful at both conservation and development objectives; indeed, a retrospective study showed that World Bank projects with biodiversity goals were as successful in development objectives as those focusing solely on development (13). The only predictor of biodiversity success was presence of market mechanisms and sustainable finance (13). COMACO's adoption of a local business-based approach is meant not only to decouple development from wildlife revenues but also to remove the time constraints that plague ICDPs funded by short-term grants.

In pursuit of its economic goals, COMACO continues to expand and will this year begin to offer market benefits to participants on the western plateau. Studies of traders in several African nations have shown that increasing scale does not always confer improved margins (14), so the next years will provide an important test of this tactic. Financial analysis to date shows that increasing scale has allowed the model to meet thresholds of production that have enabled them to enter stable, high-value urban markets as well as participate in export and commodity markets. This access has led to a trend of sales covering an increasing percentage of operating expenses. Whether provision of market access to even more rural HHs will enable COMACO to meet all its objectives will be determined with time, but COMACO is also pursuing new ways, such as sale of organic cotton and involvement in global carbon markets, to diversify revenue streams while controlling costs.

COMACO provides education in farming practices that improve soil quality and mitigate losses to drought and flooding. However, such improvements have not yet translated into discernable differences in food security. Determining whether benefits have in fact been conferred without attaining food security is difficult in the absence of pre- and post-COMACO controls. Analysis of registration data demonstrated that COMACO did select participants from HHs who had lower mean food stores than their neighbors. Thus, the observed parity in food security as well as the improvements in soil carbon and increases in yields per hectare for groundnuts, maize, and rice for women farmers associated with COMACO together suggest that HH benefits are associated with membership. Future evaluation of the model's impact on HH food security will best be determined by focused study throughout a year, in context of individual HHs' histories of food security.

Expansion is also intended to provide protection to the core NPs on all sides. Biodiversity conservation was the major underlying motivation for COMACO, and most species show stabilization of populations relative to the declines noted in the 1990s, with buffalo being an important exception. Although well known to pose difficulties in transect-based aerial surveys because of their patchy distribution, a consistent decline in num-

bers of this species was observed. The cause of this change is uncertain given the contrasting results for other large-bodied ungulates, and this species is in need of focused assessments.

To achieve the permanence needed to meet economic, social, and biodiversity conservation objectives, COMACO has the goal of being financially self-supporting. Lessons learned from this model might therefore be of broad interest to other interventions with similar objectives. However, it would be prudent first to determine whether COMACO can survive its expansion phase. As the business grows, could the linkages between development and conservation be lost if economic success trumps social and environmental goals? Alternatively, the developing agribusiness that is COMACO might fail because of risks inherent to any business or risks associated more specifically with operations in rural areas of developing nations. At this stage, the model relies completely on a guaranteed volume of commodity production for it to fulfill its contracts for the added-value products. Persistent high or low rainfall over consecutive years might remove the revenues that drive the model. Although essential for success, expansion creates opportunities for mismanagement and theft as well as liability. Reliance on value-added food products imparts business risks related to food safety and requires constant product monitoring and quality control.

New challenges might also arise if COMACO is *successful* in its biodiversity goals. These challenges might include (*i*) increased human–wildlife conflicts such as crop predation resulting from higher wildlife densities, (*ii*) increased wildlife consumption because of increased incomes, (*iii*) increased deforestation because of increased agricultural incomes fostering a desire to farm larger plots of land, and (*iv*) increased unsustainable consumption of natural resources because of a larger, healthier population.

Despite the risks inherent to this or any intervention, the future in the absence of some vehicle of change is grim: continued poverty with rampant deforestation and degradation of an important watershed ecosystem. COMACO represents a hybrid approach to these interrelated challenges, supporting its biodiversity and social objectives with a foundation similar to a complex agribusiness that operates across the value chain. Evaluation of the model with any single metric would therefore be inadequate. Although this unique model is showing promising early results, its ability to sustain market linkages between biodiversity conservation and development objectives will be critical for long-term success.

Materials and Methods

Wildlife Surveys. Aerial surveys were performed according to established methods (15). Consistent pilot and observer training and ground calibration were used across all years to enable comparisons. Briefly, surveys of the "COMACO core area" of the GMAs between the South and North Luangwa NPs and Lukusuzi NP were performed in 1999 and 2002 using ZAWA personnel as flight rear-seat observers. In 2006–2008, personnel of the Wildlife Conservation Society Flight Program flew the same transects over the core area as well as additional transects covering an area in Musalangu to the north and the Lukusuzi NP (*SI Appendix*, Fig. S6). Tallies for the three areas were kept separately (*SI Appendix*, Fig. S7), so that comparisons were made strictly from identical replicates. Expanded methods are provided in *SI Appendix*, Fig. S6.

Business Economic Data Collection. Financial data were obtained annually from audited COMACO financial reports, prepared in compliance with requirements of the Companies Act of Zambia. Annual interviews with COMACO accountants and management have occurred since 2005 to aid interpretation of the data.

Food Security and Technology Adoption Survey. Results regarding food security and technology adoption in Luangwa Valley are drawn from the HH food security and technology adoption survey of November 2009. This survey was conducted near the Lundazi CTC in villages served by three local depots (Chitungulu, Zokwe, and Mapamba) but within similar agroecological zones. The Lundazi CTC was chosen because it was the first CTC to deliver premium pricing and its participants have had more years to become proficient at CF methods. Purposive sampling identified COMACO HHs that received premium pricing for their use of CF. The high density of COMACO participation in the Valley necessitated use of nonrandom "snowball sampling" based on respondents' knowledge to identify non-COMACO HHs.

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