Integrating agriculture in National Adaptation Plans Programme (NAP-Ag)

Safeguarding livelihoods and promoting resilience through National Adaptation Plans

Conservation agriculture for climate change adaptation in Zambia: A cost-benefit analysis

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Contents

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Acronyms

AI	Asset index
BMU	Federal Ministry for the Environment, Nature Conservation and Nuclear Safety, Government of Germany
CA	Conservation agriculture
CBA	Cost-benefit analysis
CO_2eq	Carbon dioxide equivalent
EDF	European Development Fund
EIRR	Economic Internal Rate of Return
FAO	Food and Agricultural Organization of the United Nations
Ha	Hectares
HH	Household
IRR	Internal Rate of Return
MAL	Ministry of Agriculture and Livestock
MCA	Multiple Correspondence Analysis
NAP-Ag	Integrating Agricultural Sectors into National Adaptation Plans programme
NIB	Net incremental benefits
NPV	Net present value
SERF	Standard Exchange Rate Factor
UNZA	University of Zambia
ZMW	Zambian Kwacha (local currency, 1 USD = 9.17 ZMW; 1 EUR = 12 ZMW at time of study)

Highlights

- This study was carried out under the Integrating Agricultural Sectors into National Adaptation Plans programme (NAP-Ag) with the aim of generating empirical evidence about adaptation options in agriculture and to inform adaptation policy dialogues in Zambia.
- The study uses a cost-benefit analysis to analyse the financial and economic worthiness of conservation agriculture (CA) practices using primary data from a survey of a sample of 18 183 households (HH) targeted by the Conservation Agriculture Scaling-up (CASU) Project in Zambia.
- Results suggest that if a farmer switches from conventional farming to CA, annual net income from agricultural production would increase from USD 217 to 351, a 62 percent increase.
- In the first three years of switching from conventional to CA implementation, there are negative incremental net benefits. This is due to the transition period needed for CA benefits on crop yields to become effective. While farmers begin to see benefits in the fourth year, they will incur investment costs in the beginning. This causes a low proportion of farmers to adopt CA.
- Negative income recorded in the first years of CA implementation is an adoption barrier, even with the provision of input packages and vouchers. The econometric analysis confirms that low asset (including land and income) levels, limited family size, and opportunity cost of labour present barriers to the adoption of CA technology.
- Ad-hoc policy measures beyond the voucher system should be introduced to facilitate the transition from conventional farming and promote adaptation to increased climate change.

Introduction

Conservation agriculture (CA) is among the most widely-promoted approaches to climate change adaptation in agriculture in Zambia. While the biophysical and land productivity benefits of CA have been extensively investigated, little empirical evidence exists on the costs and overall profitability of investing in CA practices. The aims of this study were: (i) to estimate the on-farm costs and benefits of CA practices and, ultimately, their viability in the context of more sustainable, climate-adapted smallholder farming; and (ii) to analyse the barriers to CA adoption at the farm level.

This case study reports the results of a cost-benefit analysis (CBA) that was applied to the Conservation Agriculture Scaling-up Project (CASU), which promoted CA for climate change adaptation in Zambia.[1] The study also reports an econometric analysis conducted to determine the barriers to adoption of the promoted sustainable farm management practices and to estimate the impact of factors which may facilitate adoption.

These findings can inform policy makers and development practitioners working to promote CA measures for climate change adaptation in the context of national adaptation planning processes.

The National Adaptation Plan (NAP) process, established as a decision[2] by the United Nations Framework Convention on Climate Change (UNFCCC), facilitates effective medium- to long-term adaptation planning in developing countries. This process is underway in Zambia, which is mobilizing resources to formulate a National Adaptation Plan. With support from the NAP-Ag programme, Zambia's agriculture sectors developed a draft roadmap in 2018 to ensure that agriculture priorities are integrated into the NAP process. Applying cost-benefit analysis to assess and appraise adaptation practices in agriculture is one of the key preparatory steps of the NAP process (FAO, 2017).

Conservation agriculture

Conservation agriculture aims to produce high crop yields while reducing production costs and maintaining soil fertility. Its basic principles are to minimize disturbance of the soil, maximize soil cover and rotate crops.

Minimum tillage (planting basins and ripping) is a common entry point of CA (see Figure 1). The biggest impediment of the minimum tillage approach is weed growth, which favours conditions with minimum soil disturbance. Ripping, which involves creating a small furrow without turning the soil, is more popular than using planting basins; small pockets of soil, which are hoed and filled with seed and fertilizer. Basins are typically applied to smaller pieces of land compared to ripping, and are more labour intensive.

Figure 1. Conservation agriculture as applied in Zambia: Planting basins (left) and ripping (right)

Source: Unknown

[1] The CASU Project was implemented by the Zambian Ministry of Agriculture and the Food and Agriculture Organization of the United Nations (FAO), and financed by the European Union, via the 10th European Development Fund (EDF) over the period June 2013 - December 2017.

[2] Decision 5/CP.17

Figure 2. Conservation agriculture in maize production in Zambia: mulching (left) and intercropping with legumes

Source: Unknown

CA also involves maintaining crop residues in fields using methods like mulching. As a result of the CASU project, farmers reported increased retention of residues in fields with levels of soil cover ranging from 25 percent to 50 percent, whereas burning was more commonly practiced in the past.

Finally, crop rotation in the CASU project is accomplished using legumes. Researchers found that the area dedicated to legume production has increased, partly due to farmers' access to input packages.

Data and methods

The data used in this study comes from a sample of 18 183 households targeted by CASU. The dataset includes information on agriculture and farm management practices (such as the demographics of lead farmers), total land available for cultivation, type of farming systems and land management in place, crops grown, livestock owned, material inputs provided through the electronic voucher system[3] and their cost, and the type of interventions undertaken by the project. Estimates of crop yields per hectare, both for farmers under the project and those practicing conventional farming, were obtained from the CASU *Post-Harvest and Marketing Survey* from the 2015/16 farming season. **Table 1** shows the descriptive statistics computed for the main variables in the household sample while **Table 2** reports the main analytical assumptions.

The average land size of sampled households is about 4 hectares (ha), of which less than 1 ha on average applies CA principles. Almost all farmers grow cereals (maize being the main staple crop) and most of them grow legumes and tubers in addition. Most farmers (89 percent) also use tillage as a land preparation method. Only a small percentage (7.2 percent) adopted CA in full (that is, the combination of the three principles of minimum tillage, crop rotation, and residue management). Amongst these, crop rotation is widely adopted (84 percent), even if it is not clear whether cereal-legume rotation is practised in all cases as recommended by the CA approach. The adoption of the other two CA practices (minimum tillage and residue management-mulching) is far more limited. The implementation of other adaptation practices, such as contour farming, terracing and agroforestry with fertilizer trees, is also limited (less than 5 percent of farmers).

Researchers used a comparison of net benefits under two scenarios as the analytical method for the cost-benefit analysis discussed herein. Those scenarios compared were groups '**with**' and '**without**' adaptation measures. Researchers computed the incremental benefits accruing in the implementation of climate adaptation measures as the difference between base income (i.e. the value of income 'without adaptation measures') and 'with adaptation' income. Adapting to

[3] Lead farmers are issued with electronic vouchers, which provide for input packages containing materials such as legumes and cereal seeds, basal and top-dressing fertilizer, herbicides, agricultural lime, masks and gloves. The vouchers were paid for by the CASU project.

climate change involves resources re-allocation. Since most farmers will only adopt adaptation measures if they are profitable, the analysis estimates the on-farm profitability of the selected measures.

As climate change impacts affect not only individual farmers but also society in general, there is a societal interest in adaptation measures, which goes beyond the farm gate. Furthermore, the national government intervenes in the agriculture sector (through input subsidies, price support, etc.) with the goal of achieving certain welfare objectives. The CBA is implemented from both farmers' perspective and overall society's perspective through financial (farmers') and economic (society) analyses. The analysis included the following steps: (i) the computation of costs and benefits of the selected adaptation measures at farm level; (ii) financial analysis; (iii) economic analysis; and (iv) sensitivity analysis.

Table 1

Conservation Agriculture Scaling-up Project (CASU) household sample: Descriptive statistics

VARIABLES	Mean	St. Dev.
Cropping patterns and farmaland management (%)		
Cereals	0.983	0.130
Legumes	0.693	0.461
Nuts	0.903	0.296
Tubers	0.676	0.468
Conservation agriculture	0.072	0.258
Crop rotation + no tillage	0.088	0.283
Crop rotation	0.844	0.363
No tillage	0.099	0.298
Crop residues	0.587	0.492
Fertilizer trees + agroforestry	0.024	0.152
Contour	0.045	0.207
Terrace	0.008	0.091
Tillage	0.891	0.312
Socio-economic characteristics of the HHs		
HH head male (%)	0.598	0.490
HH head age (years)	49.688	11.379
HH head: no formal education (%)	0.036	0.187
HH head: primary education (%)	0.512	0.500
HH head: secondary/tertiary education (%)	0.424	0.494
HH head marital status: monogamous (%)	0.813	0.390
HH composition: number of adults, male	2.008	1.525
HH composition: number of adults, female	2.006	1.454
HH composition: number of children, male	2.032	1.637
HH composition: number of children, female	1.864	1.577
Participation to cooperatives (%)	0.811	0.392
Income ($)	514.766	773.289
Phisical assets per HH		
Cultivated Land (ha)	3.998	3.844
Cultivated Land under CA	0.933	0.015
Livestock rearing (TLU)	4.866	7.313
Asset Index	0.005	1.005

Source: Author's elaborations

Table 2

Cost-benefit analysis analytical assumptions

	Conventional Technology (Counterfactual)	Conservation Agriculture
Description	- Conventional farming practices	- Conservation farming mainly; minimum tillage, crop rotation and increased land under legumes
Key Assumptions	- Total land cultivated: 4 ha; 1 ha per crop - Maize selling price: ZMW70 per 50kg - Average selling prices for beans, soya beans and groundnuts: ZMW 250 per 50kg - Person-days/year: 50 - Labour cost at ZMW12 per person-day (family labour) - Transport cost: ZMW2/ton/km - Average distance of target group population from the market: 75km	- Total land cultivated: 4 ha; 1 ha per crop - Increase in yields starting as of year two - Crop yields in years one to three are unchanged with respect to the 'without project' scenario and assuming full development and realization of project interventions occurring in year four - Maize yields from fourth year onwards remain unchanged at 2 600kg per ha - Maize selling price: ZMW70 per 50kg - Average selling prices for beans, soya beans and groundnuts: ZMW250 per 50kg - Person-days/year: 40 - Labour cost at ZMW12 per person-day (family labour) - Lime applied once every 3 years - Transport cost: ZMW2/ton/km - Average distance of target group population from the market: 75km
Benefits	- Yield: 2,000kg/ha - Gross Income: ZMW,800/ha	- CA skills improved - CA farmer input and output supply chain improved - Land management improved - Yield: 2 000kg/ha first to third year and 2 600kg/ha in subsequent years - Annual income: ZMW3,640 per ha
Breakdown of costs	- Maize seed:ZMW4 per kg - Bean seed:ZMW10 per kg - Soy bean seed: ZMW7.25 per kg - Groundnut seed: ZMW7.25 per kg - Fertilizer: ZMW720 - 50kg bags: ZMW120 - Person-days: 40*ZMW12=ZMW600 - Transport: ZMW300	- Maize seed: ZMW4 per kg - Bean seed: ZMW10 per kg - Soy bean seed: ZMW7.25 per kg - Groundnut seed: ZMW7.25 per kg - Fertilizer: ZMW360 - ADP (Ag. Dev. Prog.) hire: ZMW281 - 50kg bags: ZMW156 - Transport: ZMW450 - Lime: ZMW200

Source: Author's elaborations

Researchers conducted an econometric analysis to identify the drivers of CA adoption at the household level and highlight possible barriers to the adoption of innovations like CA. The analysis uses a logistic model (Hilbe, 2009), which estimates the expected effect of selected variables on the probability of adopting a specific practice (or a combination of practices). In the model specification, it is assumed that the adoption probability (dummy variable) is on the left-hand side of the regression equation, while a combination of demographic variables (e.g. age, educational level, number of family members, social capital and participation in cooperatives, land, income, and assets including livestock) is on the right-hand side of the equation.

To synthesize information and to avoid including too many asset categories (e.g. ripper, plough, tractor, sheller, planter, harrow, hoe, sprayer, cultivator, ox-cart) in the regressions, researchers built an asset index using a Multi Correspondence Analysis (MCA), which is a descriptive technique designed to analyse multi-way tables that contain measures of correspondence between rows and columns. This method produces results that allow exploration of the structure of the categorical variables included in a table (Greenacre and Blasius, 2006). In this work, the function of asset index (AI) obtained through MCA can be described as:

$$AI = \frac{1}{K} \sum_{k=1}^{K} \sum_{jk=1}^{jk} W_{jk}^{k} I_{jki}^{k}$$

In this equation *k* is the number of dimensions (variables), *j* is the number of modalities of each dimension, *I* is the binary indicator of each modality, *W* is the weight determined with MCA and *i* is the index number indicating households. This asset index has been included among the variables in the right-hand side of the logistic regression equations.

Results

Table 3 shows on-farm financial results from the crop models. Annual net benefits for farmers under conventional agriculture ('without project') amount to ZMW 1 987 and ZMW (-413) before and after labour costs, respectively. After switching from conventional crop management to CA, farmers' net income reaches ZMW 3 223 and ZMW 1 723 before and after labour costs, respectively, at the full-development stage. A comparison of scenarios indicates that farmers can expect greater net benefits from engaging in CA farming than from maintaining current conventional practices. The incremental net benefits are negative in the beginning, since CA benefits are only realized in the third year and the farmer incurs initial investment costs. However, in the following years the incremental net benefits are positive, indicating that the net benefits in the 'with project' scenario (CA management) would be higher than in the 'without project' scenario (conventional management).

Table 3

Financial results for crop production areas over 4 hectares

Financial budget (in ZMW)	Market Price	WITHOUT PROJECT	WITH PROJECT									
		1 to 10	1	2	3	4	5	6	7	8	9	10
Gross value of production												
Maize	1 400	2 800	2 800	2 800	2 800	3 640	3 640	3 640	3 640	3 640	3 640	3 640
Beans	5 000	700	700	700	700	4 450	4 450	4 450	4 450	4 450	4 450	4 450
Groundnuts	5 000	2 650	2 650	2 650	2 650	4 500	4 500	4 500	4 500	4 500	4 500	4 500
Soya beans	5 000	1 750	1 750	1 750	1 750	2 750	2 750	2 750	2 750	2 750	2 750	2 750
Total revenue		*3 500*	*3 500*	*3 500*	*3 500*	*8 090*	*8 090*	*8 090*	*8 090*	*8 090*	*8 090*	*8 090*
Investment costs												
Electronic voucher	1 000	0	1,000	755	0	0	0	0	0	0	0	0
Sub-total investment costs		*0*	*1,000*	*755*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Operating input costs												
Maize seeds	4.00	40	0	0	80	80	80	80	80	80	80	80
Hybrid bean seeds	10.00	0	0	0	600	600	600	600	600	600	600	600
Hybrid nuts seeds	7.25	0	0	0	435	435	435	435	435	435	435	435
Hybrid soya bean seeds	7.25	0	0	0	435	435	435	435	435	435	435	435
Fertilizer	1.80	720	0	0	540	540	540	540	540	540	540	540
Chemicals	90.00	0	1 260	1 260	1 260	1 260	1 260	1 260	1 260	1 260	1 260	1 260
ADP hire	250.00	0	281	281	281	281	281	281	281	281	281	281

Table 3

continued

Bags (50 kg)	3.00	300	300	300	300	336	336	336	336	336	336	336
Transport cost	150.00	453	750	900	900	900	900	900	900	900	900	900
Lime	50.00	0	200	0	0	200	0	0	200	0	0	200
Water charges	0.00	0	0	0	0	0	0	0	0	0	0	0
Sub-total operating cost		*1 513*	*0*	*4 831*	*4 831*	*5 067*	*4 867*	*4 867*	*5 067*	*4 867*	*4 867*	*5 067*
Labour costs												
Hired labour	13.00	0	0	0	0	0	0	0	0	0	0	0
Family labour	10.00	2 400	1 500	1 500	1 500	1 500	1 500	1 500	1 500	1 500	1 500	1 500
Sub-total labour cost		*2 400*	*1 500*	*1 500*	*1 500*	*1 500*	*1 500*	*1 500*	*1 500*	*1 500*	*1 500*	*1 500*
Sub-total production costs		**3 913**	**2 500**	**7 086**	**6 331**	**6 567**	**6 367**	**6 367**	**6 567**	**6 367**	**6 367**	**6 567**
Net income (after labour costs)		**-413**	**1,000**	**-3 586**	**-2 831**	**1 523**	**1 723**	**1 723**	**1 523**	**1 723**	**1 723**	**1 523**
Net income (before labour costs)		**1 987**	**2 500**	**-2 086**	**-1 331**	**3 023**	**3 223**	**3 223**	**3 023**	**3 223**	**3 223**	**3 023**

Financial budget (in ZMW)	INCREMENTS									
	1	2	3	4	5	6	7	8	9	10
Gross value of production										
Maize	0	0	0	840	840	840	840	840	840	840
Beans	0	0	0	3 750	3 750	3 750	3 750	3 750	3 750	3 750
Groundnuts	0	0	0	1 850	1 850	1 850	1 850	1 850	1 850	1 850
Soya beans	0	0	0	1 000	1 000	1 000	1 000	1 000	1 000	1 000
Total revenue	*0*	*0*	*0*	*4 590*	*4 590*	*4 590*	*4 590*	*4 590*	*4 590*	*4 590*
Investment costs										
Electronic voucher	1 000	755	0	0	0	0	0	0	0	0
Sub-total investment costs	*1 000*	*755*	*0*	*0*	*0*	*0*	*0*	*0*	*0*	*0*
Operating input costs										
Maize seeds	40	40	40	40	40	40	40	40	40	40
Hybrid bean seeds	600	600	600	600	600	600	600	600	600	600
Hybrid nuts seeds	435	435	435	435	435	435	435	435	435	435
Hybrid soya bean seeds	435	435	435	435	435	435	435	435	435	435
Fertilizer	-180	-180	-180	-180	-180	-180	-180	-180	-180	-180
Chemicals	1 260	1 260	1 260	1 260	1 260	1 260	1 260	1 260	1 260	1 260
ADP hire	281	281	281	281	281	281	281	281	281	281
Bags (50 kg)	0	0	0	36	36	36	36	36	36	36
Transport cost	297	447	447	447	447	447	447	447	447	447
Lime	200	0	0	200	0	0	200	0	0	200
Water charges	0	0	0	0	0	0	0	0	0	0
Sub-total operating cost	*-1 513*	*1 228*	*3 318*	*3 554*	*3 354*	*3 354*	*3 554*	*3 354*	*3 354*	*3 554*
Labour costs										
Hired labour	0	0	0	0	0	0	0	0	0	0
Family labour	-900	-900	-900	-900	-900	-900	-900	-900	-900	-900
Sub-total labour cost	*-900*	*-900*	*-900*	*-900*	*-900*	*-900*	*-900*	*-900*	*-900*	*-900*
Sub-total production costs	**-1 413**	**3 173**	**2 418**	**2 654**	**2 454**	**2 454**	**2 654**	**2 454**	**2 454**	**2 654**
Net income (after labour costs)	**1 413**	**-3 173**	**-2 418**	**1 936**	**2 136**	**2 136**	**1 936**	**2 136**	**2 136**	**1 936**
Net income (before labour costs)	**513**	**-4 073**	**-3 318**	**1 036**	**1 236**	**1 236**	**1 036**	**1 236**	**1 236**	**1 036**

Source: Author's elaborations

Researchers converted financial values into economic values by means of specific conversion factors after deducting taxes, duties and transfer payments. The economic IRR associated with CA adoption is 39 percent, which is above the assumed opportunity cost of capital of 7 percent. The net present value (NPV) generated per beneficiary is ZMW 25 151. Investing in CA implementation is regarded as economically profitable overall at the farm level.

The incremental net benefits computed above indicate the monetary incentive for farmers to engage in proposed CA-related activities. When researchers convert accounts in the farm budget to economic values and aggregated for all participants, the incremental net benefits represent the project's contribution to society. The study aggregated on farm benefits while considering the 268 137 farmers directly benefitting from the CASU project in various Agro Ecological Regions (regions I, IIa, IIb and III), provinces (Eastern, Central, Southern, Muchinga, Western), and districts (mainly Monze, Mazabuka, Kalomo, Choma, Chongwe, Petauke, Katete, Chipata, Mumbwa, Chibombo) during the 5-years of project implementation (see **Table 4**).

Stakeholders use project activities to implement CA promotion and knowledge dissemination among farmers. CASU investment costs are reported in **Table 4**).

Table 4

Target beneficiaries and project costs

Project target group (number of HHs)	Y1	Y2	Y3	Y4	Y5	Total
Improved Agric. Practces-Lead farmers	20 396	20 396	20 396	20 396	0	81 584
Total number of beneficiaries (includes follower farmers)	67 034	67 034	67 034	67 034	0	26 8137
Project Costs (in ZMW)						
C1 - Improved Ag. Practces-Lead farmers	15 398 980	15 398 980	15 398 980	15 398 980	-	61 595 920
C3 - Programme Management Unit	8 436 878	8 436 878	8 436 878	8 436 878	8 436 878	42 184 392
C4 - Other costs and services	3 724 826	3 724 826	3 724 826	3 724 826	3 724 826	18 624 132
Total Project Costs (including contingencies)	**27 560 685**	**27 560 685**	**27 560 685**	**27 560 685**	**12 161 705**	**122 404 444**
Price and physical contingencies	109 900	109 900	109 900	109 900	109 900	549 500
Project Base Costs	**27 450 785**	**27 450 785**	**27 450 785**	**27 450 785**	**12 051 805**	**121 854 944**
Administrative costs (taxes and transfers)	1 721 354	1 721 354	1 721 354	1 721 354	1 721 354	8 606 772
Deduction of transfers	-	-	-	-	-	-
Base Costs net from taxes and transfers	**25 729 430**	**25 729 430**	**25 729 430**	**25 729 430**	**10 330 450**	**113 248 172**
Economic Base costs (SERF)	**30 233 945**	**30 233 945**	**30 233 945**	**30 233 945**	**12 139 028**	**133 074 807**

Source: Author's elaborations based on CASU project data

Recent literature has seen some debate over CA adoption in Zambia (for example, see Arslan *et al.* 2014). From a private individual's viewpoint, CA and other climate-smart agricultural practices such as reduced tillage, crop rotations and associations, manure application, and nutrient management can yield tangible (financial) benefits at the farm level by increasing productivity and profitability. CA practices also offer some potential for reducing input costs, especially labour, as in the case of conservation agriculture (ripping). Conversely, the intangible benefits from GHG mitigation can generate significant economic (social) benefits for society (positive externalities) by reducing GHG emissions from agriculture by sequestering carbon in biomass and soils. Such social benefits can be valued in monetary terms using a "social price of carbon" and incorporated into the economic analysis for IRR/NPV calculation.

Researchers factored the economic benefits of GHG mitigation into the annual economic cash flows of the project as shown in **Table 5**. This was done using the following assumptions:

(i) Carbon sequestrated per hectare was 1.2 metric tons of CO_2 equivalent, estimated using the Ex-Ante Carbon-balance Tool (EX-ACT) and developed largely using the *Guidelines for National Greenhouse Gas Inventories* (IPCC 2006) and a review of default coefficients for the mitigation option as a base. Most calculations in EX-ACT use a Tier 1 approach[4] (see Bernoux *et al*, 2010 for details).

(ii) Carbon price per metric ton of CO_2 equivalent used in this analysis is ZMW 4 (corresponding to \$0.40/tCO_2eq). It must be specified that actual prices range from under \$0.10 /tCO_2eq to just over \$70/tCO_2eq in March 2018 (Hamrick and Gallant, 2018). The World Bank suggests a social price of carbon ranging between \$38-77/tCO_2eq for the year 2018 (World Bank, 2017). However, most GHG emissions are recorded as being traded at a price lower than \$1/tCO_2eq (Hamrick and Gallant, 2018). Therefore, researchers adopted a considerably conservative approach in order to avoid overestimating mitigation benefits. Therefore a carbon price of only \$0.40/ tCO_2eq is used.

The total area under the project was 1 340 685 ha, which potentially results in total positive externalities of ZMW 6 435 288. Researchers incorporated these externalities in the economic analysis to give the project net incremental benefits as shown in the next section.

Table 5

Externalities of conservation agriculture implementation: Carbon sequestration

	Y1	Y2	Y3	Y4	Y5	Total
Number of hectares under CA	286 137	286 137	286 137	286 137	0	1 340 685
Positive externalities under CA	**1 287 058**	**1 287 058**	**1 287 058**	**1 287 058**	**0**	**6 435 288**

Source: Author's elaborations

Table 6 shows the results of the analysis when all project beneficiaries; expected net incremental benefits (NIB) from the farm model, project economic costs, and externalities are aggregated. The indicators of project worth provide a valuation in today's money, following the premise that money spent today is more valuable than money spent in the future (Gittinger, 1982). This section reports the NPV and the Economic Internal Rate of Return (EIRR). The total project NIB show deficits in the first four years though from year five onwards, and the differences show surpluses. The Economic Internal Rate of Return (EIRR) is 32 percent, while the total economic NPV generated by the project was found to be ZMW 2 292 982 760 (equivalent to USD 250 million). Given the above indicators, the project can therefore be regarded as economically viable.

[4] IPCC Guidelines provide three methodological tiers varying in complexity and uncertainty level: Tier 1, simple first order approach which uses data from global datasets, simplified assumptions, IPCC default parameters (large uncertainty); Tier 2, a more accurate approach, using more disaggregated activity data, country specific parameter values (smaller uncertainty); and Tier 3, which makes reference to higher order methods, detailed modelling and/or inventory measurement systems driven by data at higher resolution and direct measurements (much lower uncertainty).

Table 6

Aggregated economic analysis results and profitability indicators

	Y1	Y2	Y3	Y4	Total					
Nr. of beneficiaries	67 034	67 034	67 034	67 034	**268 137**					
Cumulative Nr. of beneficiaries	67 034	134 069	201 103	268 137						
	Y1	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**	**Y9**	**Y10**
Expected NIB Farm model (C1)	(3 028)	(2 634)	(1 747)	4 343	4 625	4 625	4 343	4 625	4 625	4 343
Aggregation considering facing	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**	**Y9**	**Y10**
100% Adoption	(202 972 500)	(176 584 516)	(117 113 090)	291,096,848	310 001 672	310 001 672	291 096 848	310 001 672	310 001 672	291 096 848
		(202 972 500)	(176 584 516)	(117 113 090)	291 096 848	310 001 672	310 001 672	291 096 848	310 001 672	310 001 672
			(202 972 500)	(176 584 516)	(117 113 090)	291 096 848	310 001 672	310 001 672	291 096 848	310 001 672
				(202 972 500)	(176 584 516)	(117 113 090)	291 096 848	310 001 672	310 001 672	291 096 848
Project Aggregated NIB	(202 972 500)	(379 557 016)	(496 670 106)	(205 573 258)	307 400 914	793 987 102	1 202 197 040	1 221 101 864	1 221 101 864	1 202 197 040
Project economic costs	30 233 945	30 233 945	30 233 945	30 233 945	12 139 028					
Project recurrent costs					8 436 878	8 436 878	8 436 878	8 436 878	8 436 878	8 436 878
Positive externalities	1 287 058	2 574 115	3 861 173	5 148 230	5 148 230	5 148 230	5 148 230	5 148 230	5 148 230	5 148 230
Project Net incremental Benefits	**(231 919 387)**	**(407 216 846)**	**(523 042 878)**	**(230 658 973)**	**300 410 116**	**790 698 454**	**1 198 908 392**	**1 217 813 216**	**1 217 813 216**	**1 198 908 392**

IRR	NPV@ 7%
32%	2 292 982 760

Source: Author's elaborations

SENSITIVITY BOX	
BENEFITS	100%
INVESTMENT COSTS	100%
RECURRENT COSTS	100%

For this CBA, researchers focused sensitivity analysis scenarios most appropriate for climate change adaptation on the more frequent droughts and climatic weather changes that Zambia has been experiencing, as well as a varying social price of carbon. Therefore, researchers conducted the sensitivity analysis assuming: (i) reduction in benefits/yields, (ii) changing the social price of carbon from ZMW 4 to ZMW 2 per ton of CO_2 equivalent, and (iii) reducing the recurrent costs of the project. Researchers found that the project is most sensitive to reduction in benefits although it can withstand reduction of up to 17 percent and still remain viable.

A benefit reduction of 18 percent reduces the EIRR to 6 percent and causes the NPV to become negative. Similarly, the model shows positive NPV and EIRR for increases in recurrent costs of less than 27 percent. For example, increasing costs by 25 percent reduces the EIRR to 8 percent and the NPV to ZMW 113 757 580. Increasing costs by 27 percent renders the project economically inviable as EIRR decreases to 6 percent (lower than the discount rate of 7 percent) and results in negative NPV. However, results indicate that the project is insensitive to carbon price reduction; researchers found that the project would still be economically viable if the carbon price was set at zero.

Researchers conducted econometric analysis was conducted to identify the drivers of innovation adoption at the household level. Several logistical regressions were run, considering the following practices and their combinations: crop rotations, no tillage, and mulching, in combination (full CA) or separately; terracing; contour farming; and agroforestry (use of fertilizer trees in the fields). The results related to CA are reported in **Table 7**.

The estimated coefficients quantify the effect of a unit change in the variables on the CA adoption probability. For example, the probability of adopting CA is 1.1 percent higher for male-headed households and 2.6 percent higher for households that are members of a cooperative. This increases by 0.2 percent as farm size increases by one hectare and by 0.9 percent as household assets (through the asset index) increase by one. This probability decreases by 0.2 percent with every one-unit increase in livestock.

Table 7

Logistic regression results: Marginal effects for adoption of conservation agriculture

	Coeff	St. Err	dy/dx
HH head male (Ref. Female)	0.163**	0.067	0.011
Age	0.007***	0.003	0.001
HH head Primary education (Ref. No formal edu)	-0.047	0.132	-0.003
HH head Secondary education (Ref. No formal edu)	-0.093	0.134	-0.006
HH head married (Ref. Not married)	0.190**	0.089	0.013
N adults male	-0.004	0.022	0.000
N adults female	0.013	0.022	0.001
N children male	-0.023	0.019	-0.002
N children female	0.015	0.020	0.001
Participation to cooperatives (Ref. No participation)	0.399***	0.085	0.026
Land (ha)	0.035***	0.006	0.002
Crop diversification (Ref. No participation)	0.994***	0.340	0.065
TLU	-0.029	0.006	-0.002
Asset Index	0.131***	0.037	0.009
Income (USD)	0.000***	0.000	5.52e-06
Constant	-4.487	0.393	
* Statistically significant at 10%, ** Statistically significant at 5%, *** Statistically significant at 1%			

Source: Author's elaborations

Discussion and recommendations

The results of the financial analysis suggest that if a farmer switches from conventional farming to CA, the farmer will gain an increase in annual income from crop production once at full-development stage. However, for farmers adopting CA practices, the net income after labour shows deficits in the first three years of adoption. This is due to the transition period needed for the benefits of CA on crop yields to become effective; while the benefits become apparent from the fourth year, farmers incur initial investment costs.

The data shows that CA adoption is currently limited to a low percentage of farmers. Results of the econometric analysis indicate that negative income recorded in the first years of CA management implementation represents an adoption barrier, even with the provision of input vouchers. This is especially true for low-income and low-asset households. Increases in land size, household income and asset index positively influence the adoption of CA. This means that the ownership of farm equipment allows farmers to maximize labour effectiveness and cope with the risk commonly associated with innovations.

A second barrier is the opportunity cost of labour. Family size could limit the adoption of labour-intensive technologies (such as planting basins) and off-farm opportunities may be especially attractive for younger household members. Livestock rearing competes for the use of crop residues, therefore reducing households' willingness to adopt mulching and other residue management practices. Elements of social capital such as participation in a cooperative could help overcome some barriers (see also FAO and UNDP, 2019), through the cooperative sharing of knowledge and assets.

Gender and marital status also affect adoption. Researchers found that the marital status of the household head significantly influences the adoption of CA. Married householders, usually synonymous with large families and associated with labour availability, are more likely to adopt new practices, especially those that are more time-consuming (e.g. planting basins under the minimum-till CA approach). Female-headed households tend to adopt CA at a lower rate than men. Indeed, women often face constraints in terms of access to resources (Doss and Morris, 2000; Pender and Gebremedhin, 2007), suffer from social and cultural discrimination, and receive lower levels of education, all of which hinder adoption of CA.

Those introducing CA and other adaptation practices must consider the above barriers to adoption. It is clear that such technologies cannot be uniformly implemented by all types of farmers without some ad-hoc measures to facilitate the transition from conventional farming. Further, no single package of adaptation actions should be solely promoted over other possible methods of climate-smart agriculture and climate-resilient options. Farmers can implement various combinations of existing improved farm management to ease the transition from conventional farming to CA.

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