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An area-wide control campaign against bovine trypanosomosis in Southeast Uganda and its impact

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Abstract
As tsetse invaded new areas in Uganda during the 20th Century, several control campaigns were launched. Amongst them was the EU-funded Farming in Tsetse-Controlled Areas (FITCA) project. The control campaign, implemented in an area-wide manner, covered 12 districts in Southeast Uganda, an area of 25,883 Km^2 with an estimated cattle population of 904,075. It combined insecticide-impregnated tsetse traps with pour-on application and block-treatment of cattle with Isometadium chloride and Diminazene aceturate. In a bid to assess its impact, two cross-sectional surveys were conducted in Busia, Tororo, Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge districts in Southeast Uganda. The closing survey was conducted four years after the baseline survey. Village sampling points for cattle were identified using Geographical information systems (GIS) grid sampling strategy. Cattle blood samples were examined for trypanosome infection using Haematocrit Centrifugation Technique (HCT) combined with the Buffy Coat Technique (BCT). The surveys revealed that the area-wide campaign achieved a decline of 36.8% in the prevalence of bovine trypanosomosis over the four-years period. Out of the 9,627 cattle sampled during the baseline survey, the prevalence of bovine trypanosomosis of 633 (6.8%), *Trypanosoma brucei* infection of 90 (0.9%), *Trypanosoma vivax* infection of 366 (3.8%), *Trypanosoma congolense* infection of 113 (1.2%) and mixed infection of 64 (0.6%) were registered. Of the 10,414 cattle sampled during the closing survey, the prevalence of bovine trypanosomosis of 449 (4.3%), *T. brucei* infection of 14 (0.1%), *T. vivax* infection of 327 (3.1%), *T. congolense* infection of 69 (0.6%) and mixed infection of 39 (0.3%) were recorded. Indicating that 88.9%, 18.4%, 50.0% and 50.0% decline in the prevalence of *T. brucei* infection, *T. vivax* infection, *T. congolense* infection and mixed infection in cattle, respectively, were achieved. At district level, the area-wide campaign achieved decline in the prevalence of bovine trypanosomosis of 42.1%, 8.5%, 28.9%, 40.4%, 70.0%, 43.8% and 57.4% in the districts of Busia, Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge, respectively. However, an increment of 17.9% in the prevalence of bovine trypanosomosis in Tororo district was observed, despite efforts of the control campaign. During the baseline survey, a total of 1000, 1400, 687, 1795, 1692, 1156 and 897 cattle were sampled in Busia, Tororo, Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge districts, respectively. The prevalence of bovine trypanosomosis of 7.6%, 8.4%, 7.1%, 7.6%, 10.4%, 3.0%, 1.6% and 10.1% were registered in Busia, Tororo, Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge districts, respectively. Meanwhile during the closing survey, a total of 907, 1400, 939, 1000, 1768, 2100, and 1100 cattle were sampled in Busia, Tororo, Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge districts, respectively. The prevalence of bovine trypanosomosis of 4.4%, 9.5%, 6.5%, 5.4%, 6.2%, 0.9%, 0.9% and 4.3% were registered in Busia, Tororo, Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge districts, respectively. In conclusion, the area-wide control campaign implemented in Southeast Uganda achieved the desired impact of reduction in the prevalence of bovine trypanosomosis, despite challenges of financial sustainability and community commitment experienced.

Keywords: Area-wide, control, campaign, bovine trypanosomosis, southeast Uganda, impact

1. Introduction
An estimated 106,400 km^2 of the entire landmass of Uganda has been reported to be tsetse infested (Chizyuka, 1998; Magona and Mayende, 2002; Magona *et al.*, 2017) [1, 2, 3]. Human African Trypanosomosis (HAT) outbreaks with resultant 50,000 cases and over one million people dead were reported in Uganda during the periods: 1976-82 and 1984-93 (Abaru, 1985) [4]. A prevalence of African Animal Trypanosomosis (AAT) of 11.9% in the intensive dairy system and 25% under communal grazing in Uganda has been reported (Magona and Mayende, 2002; Magona *et al*., 2017) [2, 3]. Likewise, a prevalence of 12.2% of haemorrhagic *T. vivax* has been reported in Uganda (Magona *et al*., 2008) [5].

Several attempts have been made to control tsetse and trypanosomosis on large-scale in Uganda. Previously, an EU-funded control campaign was implemented in Southeast Uganda from 1990-97 against both HAT and AAT using insecticide-impregnated pyramidal traps, integrated with pour-on and chemotherapy, achieving 95-99.5% decline in tsetse apparent density and 79-94% decline in prevalence of AAT (Lancien *et al*., 1990; Magona *et al*., 1998; Magona *et al*., 2017) [6, 7, 3]. Unfortunately, in the aftermath of the control campaign, there was re-invasion of *Glossina f. fuscipes* and *G. pallidipes* (Magona *et al*., 2008) [5] and an upsurge of both HAT and AAT in Southeast Uganda. The EU-funded FITCA project was therefore launched to contain the tsetse re-invasion and the upsurge in HAT and AAT. The control campaign was intended to reduce the prevalence of AAT in high-risk villages in Southeast Uganda to below 5% (Magona *et al*., 2017) [3]. During the FITCA campaign, attempts were made to control tsetse through tsetse-trapping and pour-on application, and trypanosomosis by means of block treatment of cattle in high-risk sub-counties with Isometamidium chloride and Diminazene aceturate in 12 districts (Meyer *et al*., 2016; Magona *et al.*, 2017) [8, 3]. An area of 25,883 Km^2 in Southeast Uganda that had an estimated cattle population of 904,075 was covered. Despite the resources, operations and efforts involved, little has been documented on the impact of such a large-scale FITCA control campaign implemented in Southeast Uganda. We therefore report on the findings of Year 1-baseline survey and Year 4-closing survey conducted in Busia, Tororo, Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge districts of Southeast Uganda, intended to demonstrate the impact of the control campaign.

2. Materials and Methods

2.1 Study area

The cross-sectional studies were conducted in Southeast Uganda, an area largely infested with *Glossina f. fuscipes* and a limited extent with *G. pallidipes* (Magona *et al*., 2008) [5]. Southeast Uganda has savannah grassland as the main vegetation with a bimodally distributed rainfall of 1,200-1500 mm. The area received two wet seasons (March to June and September to November) and two dry seasons (December to February and July to August). The daily mean minimum and mean maximum temperatures are 15 °C and 27 °C, respectively.

2.2 Sampling strategy

Busia, Tororo, Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge districts had land surface area of 732, 1849, 1387, 682, 2525, 3737, 1931 and 1104 Km^2, respectively. This accordingly translated into proportional total area of 0.028, 0.071, 0.054, 0.026, 0.098, 0.144, 0.075 and 0.043 for Busia, Tororo, Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge districts, respectively, as per the total land surface area for Southeast Uganda. A total of 180 GIS grid points of 10 x 10 km were derived by dividing up the entire land surface area for Southeast Uganda of 25,883 km^2. This translates grid points into proportional sampling villages for Busia, Tororo, Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge districts of 10, 13, 10, 10, 18, 21, 13 and 10, respectively. In each village, 100 cattle were selected through the systematic sampling method (Thrusfield, 1995) [9]. In case farmers brought less than 100 cattle at the village sampling point, all cattle were selected. Blood samples were collected from the jugular vein of each animal and examined for trypanosomes using the Haematocrit Centrifugation Technique (HCT) (Woo, 1969) [10] performed in parallel with the Buffy Coat Technique (BCT) (Murray *et al.*, 1977) [11].

2.3 Cross-sectional surveys

The afore-mentioned GIS grid sampling strategy and identified sampling villages in respective districts were maintained during both the baseline survey and the closing survey four years later. A total of 9,627 and 10,414 cattle were sampled and tested for trypanosome infections in Busia, Tororo, Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge districts of Southeast Uganda during the baseline and closing surveys, respectively.

2.4 Control approach

Control interventions included deployment of insecticide-impregnated tsetse traps at a rate of 5 traps per an area of 1 km^2. Traps were replaced every six months but were monitored by district entomology staff continuously. The selected districts had an estimated total cattle population of 655,452, consisting of Busia (14,000), Tororo (163,688), Mbale (100,272), Jinja (16,338), Iganga (83,350), Kamuli (159,052), Pallisa (102,918) and Mayuge (15,834). Pour-on was applied twice per month on 10% of the cattle population (65,540) in the project districts by the veterinary staff for the first six months. This routine was sustained using communal crush spraying in high-risk villages (with a prevalence of 5% or above). The community in such villages were organized into spraying groups with a committee of elders and their chairperson. The project team together with the community in high-risk villages erected a crush. The project provided Decatix® twice per month until the project funds expired. The community chairperson organized routine maintenance of the crushes and the spraying schedule. This routine was maintained until either the community ran out of morale or until project funds expired. In addition, 10% of the cattle population in the project area (65,540) were blocked-treated against trypanosome infection using Diminazene aceturate. Later at a time deemed appropriate by the district veterinary teams, the same proportion of cattle was block-treated with Isometamidium chloride. The control interventions were maintained during the four-year control campaign until project funds expired.

2.5 Statistical analysis

Statistical analysis was performed using GENSTAT (GENSTAT®, Version 13). P-values < 0.05 were considered significant.

3. Results

Out of the 9,627 cattle sampled during the baseline survey, the prevalence of bovine trypanosomosis of 633 (6.8%), *T. brucei* infection of 90 (0.9%), *T. vivax* infection of 366 (3.8%), *T. congolense* infection of 113 (1.2%) and mixed infection of 64 (0.6%) were registered. Of the 10,414 cattle sampled during the closing survey, the prevalence of bovine trypanosomosis of 449 (4.3%), *T. brucei* infection of 14 (0.1%), *T. vivax* infection of 327 (3.1%), *T. congolense* infection of 69 (0.6%) and mixed infection of 39 (0.3%) were recorded. Indicating that 88.9%, 18.4%, 50.0% and 50.0% decline in the prevalence of *T. brucei* infection, *T. vivax* infection, *T. congolense* infection and mixed infection in cattle, respectively, were achieved. In addition, the surveys revealed that the area-wide campaign achieved a decline of 36.8% in the prevalence of bovine trypanosomosis over the four-years period.

Village-level changes in the prevalence of bovine trypanosomosis in Busia district between Year 1-baseline survey and Year 4-closing survey are presented in Table 1. Cattle in five villages experienced decline of 54.5% to 90.0%, while cattle in four villages experienced increment in the prevalence of trypanosomosis of 42.5% to 500.0% during the control campaign. Otherwise, cattle in one village did not experience any change in the prevalence of trypanosomosis. Fortunately, a district-level decline in the prevalence of bovine trypanosomosis of 42.1% was registered in Busia district between Year 1-baseline survey and Year 4-closing survey.

Table 1: Village-level changes in the prevalence of bovine trypanosomosis in Busia district between Year 1-baseline survey and Year 4-closing survey

Subcounty	Parish	Villages	Year 1-Baseline survey*		Year 4-Closing survey*		Percentage change
			Sample size (n)	Prevalence (%)	Sample size (n)	Prevalence (%)	
Bulumbi	Bukhubalo	Bubolwa	100	0.0	100	0.0	0.0
Masaba	Mbehenyi	Mbehenyi (& Bumela)	100	1.0	100	5.0	+500
Lunyo	Nalwire	Bulegei B (& Buwanga)	100	4.0	100	8.0	+400
Lunyo	Busiime	Dhaha A (& Dhaha B)	100	0.0	61	4.9	+490
Busitema	Chawo	Bulamba (& Busire)	100	22.0	100	3.0	-86.4
Bulumbi	Bulumbi	Buwero	100	11.0	100	5.0	-54.5
Masafu	Mawanga	Mawanga	100	2.0	89	0.1	-90.0
Lumino	Hasyule	Hasyule-Nebolola B	100	4.0	70	5.7	+42.5
Buteba	Buteba	Kayoro	100	8.0	100	1.0	-87.5
Buteba	Mawero	Amagoro (& Okame-amagoro)	100	24.0	87	4.6	-80.8
Total			1000	7.6	907	4.4	-42.1

*****Year 1-Baseline survey-2001 and Year 4-Closing survey-2004.

Village-level changes in the prevalence of bovine trypanosomosis in Tororo district between Year 1-baseline survey and Year-4-closing survey are shown in Table 2. Cattle in six villages experienced decline of 29.4% to 300.0%, while cattle in six villages experienced increment of 20.0% to 233.3% in the prevalence of trypanosomosis. Cattle in two villages did not experience any change in the prevalence of trypanosomosis. Unfortunately, a district-level increment in the prevalence of trypanosomosis of 13.0% was registered in Tororo district between Year 1-baseline survey and Year 4-closing survey.

Table 2: Village-level changes in the prevalence of bovine trypanosomosis in Tororo district between Year 1-baseline survey and Year 4-closing survey

Subcounty	Parish	Villages	Year 1-Baseline survey		Year 4-Closing survey		Percentage change
			Sample size (n)	Prevalence (%)	Sample size (n)	Prevalence (%)	
Busaba	Busaba	Bugwera	100	8.0	100	5.0	-37.5
Buddumba	Banawale	Gombe	100	9.0	100	20.0	+122.2
Iyolwa	Poyemi	Bumanda	100	19.0	100	3.0	-84.2
Kirewa	Mifumi	Winyaka-Iyopoki	100	5.0	100	18.0	+260
Busolwe	Busolwe	Kisiro	100	1.0	100	2.0	+200
Kachonga	Nabiganda	Nampologoma	100	17.0	100	12.0	-29.4
Paya	Nawire	Pasule Zone	100	3.0	100	10.0	+233.3
Iyolwa	Magola	Pabasi	100	12.0	100	37.0	+208.3
Mulanda	Mwelo	Amori zone	100	12.0	100	6.0	-100.0
Molo	Merikit	Paragang South (& Paragang North)	100	0.0	100	0.0	0.0
Kisoko	Kisoko	Koyi	100	2.0	100	2.0	0.0
Osukuru	Kayoro	Kayoro A	100	10.0	100	12.0	+20.0
Kwapa	Mella	Amoni A	100	3.0	100	0.0	-300.0
Kwapa	Apocarp	Asinge A (& B)	100	15.0	100	6.0	-60.0
Total			1400	8.4	1400	9.5	+13.0

Village-level changes in the prevalence of bovine trypanosomosis in Mbale district between Year 1-baseline survey and Year 4-closing survey is presented in Table 3. Cattle in four villages experienced decline of 50.0% to 100.0%, while cattle in four villages experienced increment of 40.0% to 200.0% in the prevalence of trypanosomosis during the control campaign. Cattle from two villages did not experience any change in the prevalence of trypanosomosis. A small district-level decline in the prevalence of trypanosomosis of 8.5% was registered in Mbale district between Year 1-baseline survey and Year 4-closing survey.

Table 3: Village-level changes in the prevalence of bovine trypanosomosis in Mbale district between Year 1-baseline survey and Year 4-closing survey

Subcounty	Parish	Villages	Year 1-Baseline survey		Year 4-Closing survey		Percentage change
			Sample size (n)	Prevalence (%)	Sample size (n)	Prevalence (%)	
Nakaloke	Namabasa	Kolonyi 2	100	3.0	100	3.0	0.0
Bungokho	Bumageni	Sabanyanya	100	5.0	100	7.0	+40.0
Busiu	Bufukhula	Namache	100	4.0	100	14.0	+250.0
Bungokho	Wanale	Nashibiso	100	0.0	39	0.0	0.0
Bukhiende	Bunashimolo	Bumayena	100	6.0	100	15.0	+150.0
Bugobero	Butta	Bunatanga	100	34.0	100	12.0	-64.7
Bushika	Bunabutti	Bubungi	100	5.0	100	1.0	-80.0
Bwabwala	Bukhabusi	Buwunga	100	0.0	100	2.0	+200.0
Bubutu	Bumulika	Busiemba	100	12.0	100	6.0	-100.0
Bulucheke	Bumasata	Bumwalya	100	2.0	100	1.0	-50.0
Total			1000	7.1	939	6.5	-8.5

Village-level changes in the prevalence of bovine trypanosomosis in Jinja district between Year 1-baseline survey and Year 4-closing survey are shown in Table 4. Cattle in six villages experienced decline of 20.0% to 54.0%, while cattle in one village experienced an increment of 500.0% in the prevalence of trypanosomosis. Cattle in three villages did not experience any change in the prevalence of trypanosomosis. A district-level decline of 28.9% in the prevalence of bovine trypanosomosis was recorded in Jinja district between year 1-baseline survey and Year 4-closing survey.

Table 4: Village-level changes in the prevalence of bovine trypanosomosis in Jinja district between Year 1-baseline survey and Year 4-closing survey

Subcounty	Parish	Villages	Year 1-Baseline survey		Year 4-Closing survey		Percentage change
			Sample size (n)	Prevalence (%)	Sample size (n)	Prevalence (%)	
Butagaya	Budima	Buwuka	100	10.0	100	8.0	-20.0
Butagaya	Nawampanda	Nabukosi Bugaiso A	48	14.6	100	10.0	-31.5
Buwenge	Magamaga	Kyerinda South	53	7.5	100	6.0	-20.0
Budondo	Buwagi	Budondo	80	0.0	100	5.0	+500
Mafubira	Buwende	Kyomya	90	13.3	100	10.0	-24.8
Buyengo	Buwabuzi	Musisi	56	5.4	100	0.0	-54.0
Kakira	Kalongo	Mawoito	100	0.0	100	0.0	0.0
Mafubira	Bugembe	Nakanyonyi	53	0.0	100	0.0	0.0
Busedde	Nabitambala	Kisirira	60	26.7	100	15.0	-43.8
Busedde	Nalinaibi	Kiko	47	0.0	100	0.0	0.0
Total			687	7.6	1000	5.4	-28.9

Village-level changes in the prevalence of bovine trypanosomosis in Iganga district between Year 1-baseline survey and Year 4-closing survey are described in Table 5. Cattle in ten villages experienced decline of 20.0% to 100.0%, while cattle in seven villages experienced increment of 33.3% to 650.0% in the prevalence of trypanosomosis. One village registered no change in the prevalence of bovine trypanosomosis. Fortunately, Iganga registered a district level decline in the prevalence of bovine trypanosomosis of 40.4% between Year 1-baseline survey and Year 4-closing survey.

Table 5: Village-level changes in the prevalence of bovine trypanosomosis in Iganga district between Year 1-baseline survey and Year 4-closing survey

Subcounty	Parish	Villages	Year 1-Baseline survey		Year 4-Closing survey		Percentage change
			Sample size (n)	Prevalence (%)	Sample size (n)	Prevalence (%)	
Bulongo	Nakubugu	Buyunze	95	4.2	100	0.0	+420.0
Nawampiti	Nakiswige	Nakaseddere	100	3.0	100	4.0	+33.3
Ikumbya	Inula	Bdhuuba	100	18.0	100	6.0	-66.7
Nawandala	Bugongo	Nawandala	100	23.0	100	4.0	-82.6
Bukanga	Buwologoma	Buwologoma Central	100	14.0	100	2.0	-85.7
Waibuga	Butimbwa	Lwanika	100	10.0	100	2.0	-80.0
Nambale	Nabitende-Kidongo	Nabitende	100	15.0	100	4.0	-73.3
Namungalwe	Namungalwe	Kawete	100	2.0	86	3.5	+75.0
Nakalama	Bukaye	Buseyi	100	5.0	100	4.0	-20.0
Ivukula	Ivukula	Ivukula	100	7.0	100	26.0	+190.0
Kibaale	Kisega	Kasozi	100	2.0	100	15.0	+650.0
Namalembe	Namalembe	Butongole	100	3.0	82	15.0	+400.0
Ibulanku	Ibaako	Busesa	100	11.0	100	0.0	-100.0
Makuutu	Makuutu	Buswiriri	100	12.0	100	3.0	-75.0
Magadi	Mazuba	Nsoola	100	24.0	100	1.0	-95.8
Namutumba	Nakaloke	Nakaloke	100	4.0	100	4.0	0.0
Bulange	Bulange	Nawakofu	100	9.0	100	12.0	+33.3
Bulange	Bugoba	Kisiiro	100	21.0	100	5.0	-76.2
Total			1795	10.4	1768	6.2	-40.4

Village-level changes in the prevalence of bovine trypanosomosis in Kamuli district between Year 1-baseline survey and Year 4-closing survey are presented in Table 6. Cattle in 16 villages experienced decline of 52.8% to 100.0%, while cattle in one village experienced an increment of 300.0% in the prevalence of trypanosomosis. Four villages registered no change in prevalence of bovine trypanosomosis. Kamuli registered a district level decline in the prevalence of bovine trypanosomosis of 70.0% between Year 1-baseline survey and Year 4-closing survey.

Table 6: Village-level changes in the prevalence of bovine trypanosomosis in Kamuli district between Year 1-baseline survey and Year 4-closing survey

Subcounty	Parish	Villages	Year 1-Baseline survey		Year 4-Closing survey		Percentage change
			Sample size (n)	Prevalence (%)	Sample size (n)	Prevalence (%)	
Kidera	Bukungu	Kiwantama	70	4.3	100	2.0	-53.5
Kidera	Ntala	Kisaikye	86	0.0	100	3.0	+300.0
Nkondo	Immeri	Kyabazala	100	1.0	100	0.0	-100.0
Balawoli	Kiige	Busiige	96	0.0	100	0.0	0.0
Namasagali	Kisaikye	Kisaikye A	64	1.6	100	0.0	-100.0
Butansi	Bugeywa	Busamo	47	10.6	100	5.0	-52.8
Buyende	Namusita	Kikaya	100	1.0	100	0.0	-100.0
Buyende	Buyende	Kisege	82	0.0	100	0.0	0.0
Nabwigula	Nabwigula	Bulondo	76	2.6	100	0.0	-100.0
Kitayungwa	Namisambya	Bukafika	67	11.9	100	5.0	-58.0
Bugulumya	Kasambira	Bukapere	96	2.0	100	0.0	-100.0
Kagulu	Bumugoli	Mairo	100	5.0	100	2.0	-60.0
Bugaya	Kitukiro	Kiryongo	64	1.6	100	0.0	-100.0
Bugaya	Wandogo	Bususwa-Bukosi	64	1.6	100	0.0	-100.0
Namwenda	Kidiki	Bulungo-Busakwa	100	4.0	100	0.0	-100.0
Nawaikoke	Bukamba	Buwulungoti	100	0.0	100	0.0	0.0
Nawaikoke	Buluya	Isooba	84	0.0	100	0.0	0.0
Namugongo	Namukoge	Nakabale	60	3.4	100	0.0	-100.0
Gadumire	Kisinda	Bukunya	100	2.0	100	0.0	-100.0
Namwiwa	Bukonde	Bukondo	100	4.0	100	0.0	-100.0
Namwiwa	Kasokwe	Kiboyo	100	7.0	100	2.0	-71.4
Total			1692	3.0	2100	0.9	-70.0

Village-level changes in the prevalence of bovine trypanosomosis in Pallisa district between Year 1-baseline survey and Year 4-closing survey are shown in Table 7. Cattle in seven villages experienced decline of 50.0% to 100.0%, while cattle in two villages experienced increment of 42.9% to 108.3% in the prevalence of trypanosomosis. However, three villages registered no change in the prevalence of bovine trypanosomosis. Pallisa registered a decline of 43.8% in the prevalence of bovine trypanosomosis at district level between Year 1-baseline survey and Year 4-closing survey.

Table 7: Village-level changes in the prevalence of trypanosomosis in Pallisa district between Year 1-baseline survey and Year 4-closing survey

Subcounty	Parish	Villages	Year 1-Baseline survey		Year 4-Closing survey		Percentage change
			Sample size (n)	Prevalence (%)	Sample size (n)	Prevalence (%)	
Gogonyo	Gogonyo	Gogonyo	100	2.0	100	0.0	-100.0
Agule	Akwamoru	Akwamoru	100	4.0	100	2.0	-50.0
Kasodo	Olok	Kaukura	100	0.0	100	0.0	0.0
Buseta	Kasasira	Kapyani	100	2.0	100	0.0	-100.0
Kameke	Okisiran	Okisiran	100	1.0	100	0.0	-100.0
Puti-puti	Kamuge	Kamuge	100	3.0	100	1.0	-66.7
Kibuku	Kibuku	Kobolwa	85	2.4	100	5.0	+108.3
Butebo	Butebo	Butebo	100	0.0	100	0.0	0.0
Kaderuna	Kachomo	Kinyolo	100	0.0	100	0.0	0.0
Lyama	Lyama	Bukolya	71	1.4	100	2.0	+42.9
Kakoro	Tekwana	Osogon	100	2.0	100	1.0	-50.0
Iki-iki	Kakoli	Kakoli	100	2.0	100	0.0	-100.0
Total			1156	1.6	1200	0.9	-43.8

Village-level changes in the prevalence of bovine trypanosomosis in Mayuge district between Year 1-baseline survey and Year 4-closing survey are shown in Table 8. Cattle in all eleven villages registered decline of 36.3% to 100.0% in the prevalence of trypanosomosis. Fortunately, Mayuge registered a decline in the prevalence of bovine trypanosomosis of 57.4% at district level between Year 1-baseline survey and Year 4-closing survey.

Table 8: Village-level changes in the prevalence of bovine trypanosomosis in Mayuge district between Year 1-baseline survey and Year 4-closing survey

Subcounty	Parish	Villages	Year 1-Baseline survey		Year 4-Closing survey		Percentage change
			Sample size (n)	Prevalence (%)	Sample size (n)	Prevalence (%)	
Baitambogwe	Wabulungu	Igulubi	55	9.0	100	3.0	-66.7
Baitambogwe	Lugolole	Waina	100	9.0	100	5.0	-44.4
Imanyiro	Nkombe	Nkombe	100	14.0	100	8.0	-42.9
Imanyiro	Lwanika	Ndhokero	100	7.0	100	4.0	-42.9
Buwaya	Nangabo	Busu	100	8.0	100	4.0	-50.0
Kityerere	Maumu	Wambete	76	15.7	100	10.0	-36.3
Malongo	Malongo	Nkolongo	86	4.7	100	0.0	-100.0
Kigandalo	Kyoga	Namisu	65	13.8	100	5.0	-62.3
Malongo	Bwodha	Bwodha A	100	7.0	100	4.0	-42.9
Malongo	Bwodha	Bwodha B	20	5.0	100	1.0	-80.0
Kigandalo	Isenda	Isenda	95	8.4	100	3.0	-64.3
Total			897	10.1	1100	4.3	-57.4

District-level changes in the prevalence of bovine trypanosomosis in entire Southeast Uganda between Year 1-baseline survey and Year 4-closing survey are shown in Table 9. Mbale, Jinja, Iganga, Kamuli, Pallisa and Mayuge districts registered decline of 8.5% to 70.0%, while Tororo district registered an increment of 17.9% in the prevalence of bovine trypanosomosis. Surprisingly, the entire project area of Southeast Uganda registered a decline of 36.8% in the prevalence of bovine trypanosomosis between Year 1-baseline survey and Year 4-closing survey. Control attained below threshold of 5% in Busia, Kamuli, Pallisa and Mayuge districts. Tororo district remained extremely high (9.5%), followed by Mbale (6.5%), Iganga (6.2%) and Jinja (5.4%) districts.

Table 9: District-level changes in the prevalence of bovine trypanosomosis in Southeast Uganda between Year 1-baseline survey and Year 4-closing survey

District	Year 1-Baseline survey		Year 4-Closing survey		Percentage change
	Sample size (n)	Prevalence (%)	Sample size (n)	Prevalence (%)	
Busia	1000	7.6	907	4.4	-42.1
Tororo	1400	8.4	1400	9.5	+17.9
Mbale	1000	7.1	939	6.5	-8.5
Jinja	687	7.6	1000	5.4	-28.9
Iganga	1795	10.4	1768	6.2	-40.4
Kamuli	1692	3.0	2100	0.9	-70.0
Pallisa	1156	1.6	1200	0.9	-43.8
Mayuge	897	10.1	1100	4.3	-57.4
Overall	9,627	6.8	10,414	4.3	-36.8

District-level changes in the prevalence of different trypanosome infections of cattle in the entire project area of Southeast Uganda between Year 1-baseline survey and Year 4-closing survey are presented in Table 10. Decline of 88.9%, 18.4%, 50.0% and 50.0% in the prevalence of *T. brucei* infection, *T. vivax* infection, *T. congolense* infection and mixed infection in cattle, respectively, were registered during the area-wide control campaign.

Table 10: District-level changes in the prevalence of different trypanosome infections of cattle in Southeast Uganda between Year 1-baseline survey and Year 4-closing survey

District	Trypanosome species	Year 1-Baseline survey	Year 4-Closing survey
		Prevalence (%)	
Busia		Sample size (n = 1000)	Sample size (n = 907)
	*T. brucei**	0.7	0.2
	*T. vivax**	4.1	2.5
	*T. congolense**	2.2	1.4
	Mixed infection*	0.6	0.2
Tororo		Sample size (n = 1400)	Sample size (n = 1400)
	T. brucei	1.7	0.0
	T. vivax	3.6	6.0
	T. congolense	2.8	2.3
	Mixed infection	0.7	0.9
Mbale		Sample size (n = 1000)	Sample size (n = 939)
	T. brucei	0.0	0.0
	T. vivax	5.0	4.7
	T. congolense	1.5	0.9
	Mixed infection	0.6	0.7
Jinja		Sample size (n = 687)	Sample size (n = 1000)
	T. brucei	2.0	0.3
	T. vivax	4.9	3.9
	T. congolense	0.0	0.0

	Mixed infection	0.3	0.4
Iganga		Sample size (n = 1795)	Sample size (n = 1768)
	T. brucei	0.05	0.6
	T. vivax	7.4	4.6
	T. congolense	2.0	0.5
	Mixed infection	0.9	0.6
Kamuli		Sample size (n = 1692)	Sample size (n = 2100)
	T. brucei	1.2	0.0
	T. vivax	0.5	0.9
	T. congolense	0.1	0.0
	Mixed infection	0.8	0.0
Pallisa		Sample size (n = 1156)	Sample size (n = 1200)
	T. brucei	0.4	0.0
	T. vivax	0.3	0.8
	T. congolense	0.0	0.0
	Mixed infection	1.0	0.08
Mayuge		Sample size (n = 897)	Sample size (n = 1100)
	T. brucei	2.5	0.0
	T. vivax	5.5	2.8
	T. congolense	0.2	0.9
	Mixed infection	0.2	0.5
Overall		Sample size (n = 9,627)	Sample size (n = 10,414)
	T. brucei	0.9	0.1
	T. vivax	3.8	3.1
	T. congolense	1.2	0.6
	Mixed infection	0.6	0.3

*T. brucei-*Trypanosoma brucei*; **T. vivax-Trypanosoma vivax*; * T. congolense-*Trypanosoma congolense*; *Mixed infection with either *T. brucei, T. vivax* and *T. congolense*

4. Discussion

The FITCA campaign against bovine trypanosomosis implemented in Southeast Uganda registered changes in the prevalence of bovine trypanosomosis at district-level, village-level and area-wide. Sizeable reduction in the prevalence of bovine trypanosomosis in Southeast Uganda (36.8%), and across several districts and their associated villages was achieved over a four-year period. As well, reduction in the prevalence of respective *T. brucei, T. vivax, T. congolense* and mixed infections in cattle was observed. A similar large-scale tsetse and trypanosomosis control campaign implemented in Southeast Uganda earlier equally achieved a decline of 95-99.5% in tsetse apparent density and 79-94% decline in prevalence of AAT (Lancien *et al.*, 1990; Magona *et al.*, 1998; Magona *et al.*, 2017) [6, 7, 3].

Five villages in Busia district, most of which were originally high risk, experienced substantial decline in the prevalence of bovine trypanosomosis. Suggesting that control measures implemented were effective. While four villages, most of which were originally low risk, experienced a remarkable rise in the prevalence of bovine trypanosomosis. Indicating that not much attention had been paid in terms of tsetse and trypanosomosis control, given that they were originally low risk. Indeed, low risk villages were never targeted for communal crushing spraying of cattle. This probably allowed tsetse to re-invade massively, allowing full-scale transmission of trypanosomosis. Uniquely, one village did not experience change in the prevalence of bovine trypanosomosis. Such areas have been reported not to have conducive habitat for tsetse infestation (Magona *et al.*, 2005) [12], probably due to ongoing land use pressure. Increasing anecdotal evidence indicates that continuous intensive rice farming along fringes of wetlands in Southeast Uganda, originally infested by *G. f. fuscipes*, a riverine tsetse species, has led to elimination of tsetse-infestation in such areas due to destruction of the tsetse habitat. Despite the afore-mentioned scenarios, implementation of combined tsetse-trapping with pour-on application, block-treatment of cattle and communal crushing spraying of cattle led to a sizeable district-level decline (42.1%) in the prevalence of bovine trypanosomosis in Busia district.

Six villages in Tororo district, most of which were originally high risk, experienced reasonable decline in the prevalence of bovine trypanosomosis. Indicating that control measures instituted in these villages were effective. However, six villages, some of which were originally high risk and some low risk, experienced remarkable increment in the prevalence of bovine trypanosomosis. Suggesting that control measured instituted in such villages had had a modest impact on tsetse and trypanosomosis. Massive tsetse infestation must have occurred, especially, in such villages that were originally low risk. Such a scenario has been previously attributed to re-invasion by *Glossina f. fuscipes* and *G. pallidipes* in some areas of Southeast Uganda (Magona *et al.*, 2008) [5]. Two villages in Tororo district, both of which were originally low risk, did not experience change in the prevalence of bovine trypanosomosis. Suggesting the environment in such villages was never a suitable habitat for tsetse infestation. Unfortunately, a small district-level increment (13.0%) in the prevalence of bovine trypanosomosis was observed in Tororo district, despite control measures applied over the four-year control campaign.

Four villages in Mbale district, most of which were originally high risk, experienced substantial decline in the prevalence of bovine trypanosomosis, signifying control measures were effective. Meanwhile another four villages, some of which were originally high risk and some low risk, experienced substantial increment in the prevalence of bovine trypanosomosis. Suggesting control measures had had little impact on tsetse and trypanosomosis in such villages. However, two villages did not experience any change in the prevalence of bovine trypanosomosis. Suggesting such villages were not conducive for tsetse infestation. Overall, Mbale district had a meagre district-level decline (8.5%) in the prevalence of bovine trypanosomosis, indicating the district did not receive sufficient intensity of control measures during the four-year control campaign.

Six villages in Jinja district, all of which were originally high risk, experienced substantial decline in the prevalence of bovine trypanosomosis. Implying that the control measures had been effective against tsetse and trypanosomosis. While one village, originally low risk, experienced a substantial increment in the prevalence of bovine trypanosomosis. However, three villages, all of which were originally free from trypanosomosis, remained so. Suggesting that they were not conducive for tsetse infestation. Despite the varying scenarios, Jinja district experienced a sizeable district-level decline (28.9%) in the prevalence of bovine trypanosomosis during the four-years control campaign.

Ten villages in Iganga district, most of which were originally high risk, experienced reasonable decline in the prevalence of bovine trypanosomosis. Suggesting control measures were effective. While seven villages, most of which were originally low risk, experienced a substantial increment in the prevalence of bovine trypanosomosis. Suggesting that control measures in such villages were not effective. However, one village originally low risk did not experience any change in the prevalence of bovine trypanosomosis, suggesting it was not conducive for tsetse infestation. Fortunately, Iganga registered a substantial district level decline (40.4%) in the prevalence of bovine trypanosomosis over the four-year control campaign.

Sixteen villages in Kamuli district, most of which were originally low risk and a few originally high risk, experienced a substantial decline in the prevalence of bovine trypanosomosis. Suggesting control measures applied were effective. While one village originally low risk, experienced a substantial increment in the prevalence of bovine trypanosomosis. However, four villages, originally low risk, experienced no change in prevalence of bovine trypanosomosis. Suggesting they were not conducive for tsetse infestation. Surprisingly, Kamuli district experienced a remarkable district-level decline (70.0%) in the prevalence of bovine trypanosomosis.

Seven villages in Pallisa district, all of which were originally low risk, experienced a substantial decline in the prevalence of bovine trypanosomosis. Suggesting the control measures were effective. While two villages, all of which were originally low risk, experienced substantial increment in the prevalence of bovine trypanosomosis. However, three villages originally free of trypanosomosis remained so, indicating that they were conducive for tsetse infestation. Fortunately, Pallisa district experienced a substantial district-level decline (43.8%) in the prevalence of bovine trypanosomosis over the four-year control campaign.

All eleven villages in Mayuge district experienced a substantial decline in the prevalence of bovine trypanosomosis. Suggesting control measures were effective. Notably, Mayuge district experienced a sizeable district-level decline (57.4%) in the prevalence of bovine trypanosomosis over the four-year control campaign.

The control campaign attained the target threshold prevalence of 5% and below in Busia, Kamuli, Pallisa and Mayuge districts. Suggesting that such districts i.e. Busia and Mayuge received adequate intensity of tsetse and trypanosomosis control measures, a function of high level of cooperation among district veterinary and entomology teams and high level of willingness by local communities involved in the communal crush spraying of cattle. However, it should be noted that Kamuli and Pallisa districts were generally low-risk districts right from the onset of the control campaign. Surprisingly, Tororo, Mbale, Iganga and Jinja districts remained high-risk, failing to meet the target threshold of 5% and below. Suggesting that tsetse re-invasion especially with *G. f. fuscipes* and *G. pallidipes* and upsurge of AAT occurred in Tororo, Mbale, Iganga and Jinja as reported previously (Magona *et al.*, 2005)[12].

Despite achieving a sizeable decline in the prevalence of bovine trypanosomosis in Southeast Uganda, the control campaign was faced with several challenges, including (1) The control campaign solely depended on the project regarding funding, operations and project staff, hence control measures could not be sustained beyond the end of the project; (2) Decisions, actions, strategies and target points originated from top and were directed to bottom field operations, without room for contributions from either district local governments or individual farmers or local communities. This in-turn curtailed sustainability of control measures beyond the end of the project; (3) Willingness of the communities to fully participate in the implementation of control measures such as communal crush spraying hugely depended on the strength of community coordination within a given district or village, thus limiting the effectiveness and opportunities to replicate such control measures from village to villages; (4) The strategy of labelling villages high risk or low risk merely depended on the 5% threshold prevalence of bovine trypanosomosis at a given point in time. This did not take into consideration variation in tsetse infestation from area to area and changes in the prevalence of trypanosomosis over time during the four-year control campaign; and (5) Technical control measures alone could not eliminate the problem in Southeast Uganda over the four years, despite reduction in the prevalence of bovine trypanosomosis because presence of tsetse and trypanosomosis in Southeast Uganda depended on several factors, including socio-economic and political. Such community-based projects have been reported to face management and sustainability limitations (Meyer *et al.*, 2016) [8].

5. Conclusion
In conclusion, the area-wide control campaign implemented in Southeast Uganda achieved the desired impact of reduction in the prevalence of bovine trypanosomosis, despite challenges of financial sustainability and community commitment experienced.

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