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Ecosocial effects of community participatory tsetse (*Glossina* spp.) (Diptera Glossinidae) and bovine trypanosomiasis management at Luke, Southwestern Ethiopia

Abstract - Suppression of tsetse (*Glossina* spp.) populations and trypanosomiasis infection of infected cattle using mass trapping and trypanocidal drug treatment were carried out in the area of Luke in Southwestern Ethiopia. Adaptive management of the ecosocial system was conducted during the course of the programme to enhance sustainability. The results obtained during 2006 were combined with previously analyzed data from the period of 1995-2005 and interpreted with respects to ecological, economic and social dimensions. Tsetse fly populations and trypanosomias prevalence were greatly reduced, initial indications of potential overstocking of cattle were alleviated slightly, while cattle productivity (calving rates and milk production) improved and oxen for ploughing land increased. Improved animal husbandry and crop production increased income that allowed greater investments in improved housing, a school and the continuation of the tsetse control operations. The latter two factors suggest the development of an evolving social organization not evident in 1995. The increased school attendance also reflects ongoing social change in the community. On the negative side, the continued high stocking rate of cattle threatens the ecological capital of the grazing land. In addition, the entry of an external investor in agricultural lands in 2006 added further complexity to the system. To avoid negative effects on economic and social capital, the Luke community has to find an agreement with the external investor who leased land for crop production. The human population increased by 44% since 1995 making a reproductive health program an increasingly important component in maintaining sustaining rural development. This will require on-going adaptive management of the system for the public good.

Riassunto - *Effetti eco-sociali in un intervento di gestione della Mosca tsétsé (*Glossina *spp.) (Diptera Glossinidae) e della tripanosomiasi bovina a Luke, Etiopia sud-occidentale.*

Nell'area di Luke, Etiopia sud-occidentale, sono state condotte attività di controllo delle popolazioni di Mosca tsétsé (*Glossina* spp.), per mezzo di trappole, e di riduzione della prevalenza della tripanosomiasi bovina tramite trattamento con tripanocidi. La gestione adattativa del sistema eco-sociale, condotta con il metodo partecipativo, è stata realizzata coinvolgendo la comunità rurale locale in un programma volto al miglioramento della sostenibilità del sistema stesso. Nella presente nota, i risultati ottenuti durante il 2006 sono stati combinati con i dati rilevati nel periodo 1995-2005 e interpretati facendo riferimento alle dimensioni ecologiche, economiche e sociali che caratterizzano il sistema preso in esame. Da quanto osservato, l'abbondanza delle popolazioni di Mosca tsétsé e la prevalenza della tripanosomiasi bovina si sono attenuate, inoltre sono emerse indicazioni circa una leggera diminuzione dell'indice di pascolamento, mentre è migliorata la produttività zootecnica (valutata tramite il tasso di natalità animale e la produttività in latte), come pure si è avuto un aumento del numero di buoi destinati alla lavorazione della terra. Il miglioramento delle condizioni generali di allevamento del bestiame e della produttività agricola, ha consentito di investire maggiori risorse nelle abitazioni, nella costruzione di una scuola e nelle operazioni di controllo della Mosca tsétsé. Gli ultimi due aspetti citati suggeriscono una dinamica evolutiva del sistema sociale che non era evidente nel 1995, in particolare l'incremento della frequenza scolastica risulta essere un importante indicatore del cambiamento in atto in seno alla comunità rurale di Luke. Al contrario, l'elevato indice di pascolamento del bestiame deve considerarsi una minaccia per il capitale ecologico dei pascoli; particolare attenzione merita l'intervento di un operatore economico esterno al sistema che ha investito nella produzione agricola locale, utilizzando terreni della Comunità presi in affitto dal Governo Regionale; tali eventi aumentano la complessità del sistema che può manifestare conseguenze non facilmente prevedibili. Dal 1995 la popolazione umana residente a Luke è aumentata del 44%, questo fenomeno rende molto importante la programmazione di adeguati interventi di "salute riproduttiva" che sono il presupposto per il mantenimento di uno sviluppo sostenibile della comunità rurale. Il complesso delle attività richiede un preciso progetto di management adattativo del sistema, indirizzato soprattutto al miglioramento dello stato di salute globale.

Key words: Tsetse, mass trapping, bovine trypanosomiasis, adaptive management, animal health, sustainability, ecological, economic and social capital.

INTRODUCTION

A key constraint for development in many East African agro-pastoral communities is animal trypanosomiasis or nagana caused by *Trypanosoma* spp. and vectored by species of tsetse flies (*Glossina* spp.). There are numerous studies on vector population dynamics (e.g. Hargrove, 2006), and substantial efforts have been made to develop and implement vector/disease control systems (e.g. Torr *et al.*, 2002) including resistance management in drug utilization (FAO, 1998). In Ethiopia, animal health improvement is considered a key component of integrated community-based human health and poverty alleviation schemes (Aseffa *et al.*, 2003), and the alleviation or removal of human and livestock health constraints are prerequisite for sustainable development (Gilioli & Baumgärtner, 2006). To improve livestock health in Ethiopia, specialists of the International Centre of

Insect Physiology and Ecology (ICIPE) recommend suppression of tsetse vectors using odor baited traps (Kuzoe & Schofield, 2004) and the administration of trypanocidal drugs to infected cattle. This strategy has been effective for improving cattle health at several Ethiopian sites (Getachew *et al.*, 2003). At the request by the agro-pastoral community of Luke in Southwestern Ethiopia, a mass trapping/trypanosome treatment scheme was implemented and monitored in the area they husband starting in 1995 until the present time. The approaches and technologies for the program were introduced in a four phase implementation procedure with the responsibility of the ICIPE team decreasing as the Luke community assuming control of the tsetse control and drug administration responsibilities (Gilioli & Baumgärtner 2006). This occurred by training the community by veterinarians of the agricultural office and facilitators and ecologists of the ICIPE team to examine cattle for trypanosomiasis infection, drug administration, and the election and training of tsetse control committees to be responsible for servicing and maintaining the traps.

Data on tsetse trap catches and disease prevalence for 1995 to 2005 were analyzed in the context of ecosocial dynamics in the Luke community (Baumgärtner *et al.*, 2006). From 1995 to 2005, trap catches show that tsetse populations were reduced to very low levels, while the disease prevalence decreased to about 10%. On one hand, this led to a substantial increase in cattle including oxen populations, increased calving rates, increased milk production, and increased the *per capita* income. The availability of oxen allowed a substantial increase in cultivated land. In addition, other sources of income were also found. The increased revenue stream allowed the purchase of more cattle and the establishment of a school for educating village children.

On the negative side, tsetse control appears to encourage overstocking and environmental degradation, and to intensify land use in agriculture that will require land use planning if sustainability is to be achieved (Rogers & Randolph, 1988; Barrett, 1989; Reinhardt, 2006). To emphasize the interactions between ecological and social components of the system, Berkes *et al.* (2003) and Waltner-Toews *et al.* (2003) suggest that increasing complexity of social-ecological or ecosocial systems requires the application of *adaptive management*. Adaptive management is an iterative process of "optimal" decision-making in the face of uncertainty that seeks to reduce uncertainty over time through continuous monitoring (i.e. data collection) of the system (Anonymous 2006a). In this way, decision-making based on monitoring simultaneously improves one or more resource management rules and, in the process either passively or actively, accrues information needed to improve future management decisions. The data on the Luke agro-pastoral system for the 1995 – 2005 period were reported in Baumgärtner *et al.*, 2006) and those for 2006 are presented here and used for the dual purposes of improving knowledge on the ecosocial system dynamics and of providing decision support to stakeholders (Baumgärtner *et al.,* 2003; Sciarretta *et al.*, 2005; Gilioli & Baumgärtner, 2006). The goal of adaptive management of the Luke ecosocial system is the enhancement of ecological, economic and social capitals (Goodland, 1995; Gilioli & Baumgärtner, 2006) based on the monitoring information. In this paper, the bioeconomic model of Regev *et al.*, (1998) and Gutierrez & Regev (2005) are used to interpret the monitoring data and to provide guide-lines.

MATERIAL AND METHODS

Background information and monitoring program

Detailed background information and a description of the monitoring program were reported in Baumgärtner *et al.* (2006). Briefly, Luke is an agro-pastoral community with 254 households in the Gurage zone of Southwestern Ethiopia (Table 1). The community is an administrative and political unit ('woreda') of the zone.

At the beginning of the project in 1995, the villagers lived in extreme poverty earning an average *per capita* income far less than one USD per day (UNSTATS, 2006). Note, however, that the income reported in Table1 may be underestimated since it only represents the monies derived from the sale of farm products and off-farm labour. The livelihood of the villagers was seriously affected by the reduced health and productivity of livestock due to tsetse/trypanosomiasis. In addition, crop pests and diseases, unbalanced and insecure food supplies, high levels of malaria, and limited opportunities for income generation were further limitations. To help solve these problems, the Luke community, through their elected community project committees, invited the Nairobi-based International Centre of Insect Physiology and Ecology (ICIPE) to assist Ethiopian institutions involved in poverty reduction work (Aseffa *et al.*, 2003). In 1995, ICIPE initiated a community based tsetse/trypanosomiasis control project that had, as its operational goal, the training of the villagers to assume full responsibility for the future execution of the programme. The management system relies primarily on drug administration to *Trypanosoma* spp. infected animals (FAO, 1998) and tsetse vector control using an odour baited trapping technology (Kuzoe & Schofield, 2004). Monoconical traps were used to sample and suppress adult tsetse fly populations that vector trypanosomiasis (Sciarretta *et al.*, 2005). The savannah tsetse *Glossina morsitans submorsitans* Newstead was the main target, but *Glossina fuscipes* Newstead and *Glossina pallidipes* Austen were also trapped. For the purpose of this work, the data are reported as total tsetse caught. As an aside, the areas near the rivers bordering the Luke area in the north and the west are inhabited by different tsetse species that are disregarded in the here presented project. Here, unreported data collected during 2006 are combined with the data on tsetse and trypanosomiasis management activities for the period 1995-2005.

The assessment of the impact of tsetse and trypanosomiasis control on ecological, economic and social factors requires the monitoring of additional variables on cattle husbandry, crop management and community socioeconomics (Table 1). The acquisition and sharing of the data proved to be difficult mainly because the collaborators, albeit experienced in traditional experimental methodology, have limited knowledge on the requirements of adaptive management as used in the work at Luke during the period 1995-2006.

Prior to 2000, several institutions including the International Livestock Research Institute (ILRI) undertook chemical tsetse ('the pour-on approach') and trypanosomiasis control operations in the Gurage zone (Rowlands *et al.*, 1999, 2000). In a neighbouring area, tsetse control operations were carried out in 1997 by the Ethiopian Gurage Zone Administration that examined 574 cattle for trypanosomiasis infection and made the data available to us. The influence of these control activities on the Luke ecosocial system cannot be excluded from our data sets.

After 2000, the monitoring and control operations of the project were conducted solely by the Luke community/ICIPE team. From 2000 to 2003, the Food and Agriculture Organization of the United Nations recommendation of deploying 4 traps per km^2 (i.e. a total of 242 traps) was followed (FAO, 2006). The traps were serviced and the trapped tsetse adults counted at biweekly intervals. Using adaptive management, an analysis of the data showed that the deployment of 107 monitoring traps and biweekly tsetse counting was an accurate and cost-effective monitoring system (Baumgärtner *et al.* 2003; Sciarretta *et al.* 2005). This allowed the establishment of precision deployment of control traps to areas of relatively high tsetse occurrence in space and time. (Readers are referred to Sciarretta *et al.* (2005) for a detailed description of trap type and the trap deployment strategy.) Trapping results were reported as total tsetse of all species per traps (Fig. 1).

From 2000 to 2006, blood samples were taken at infrequent intervals from randomly

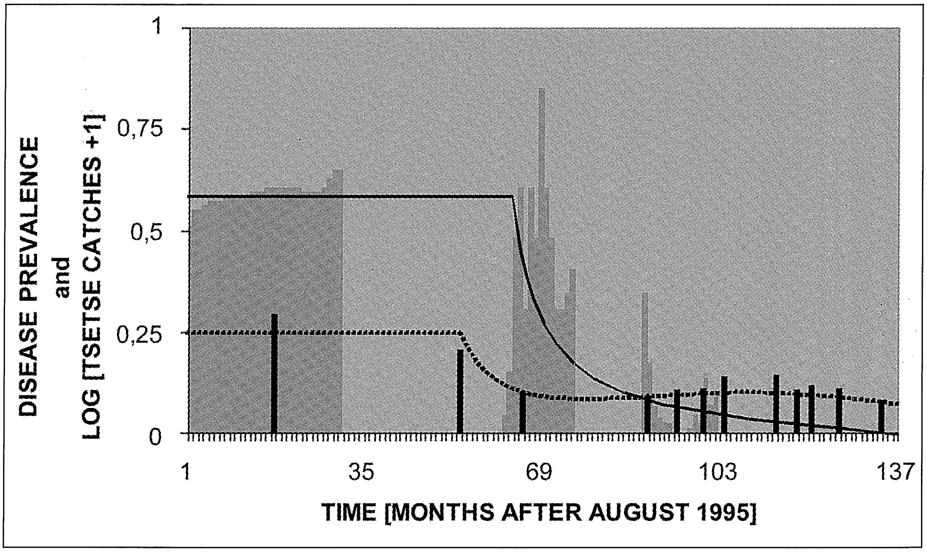

Fig. 1 - Trends in biweekly tsetse trap catches in odor baited monitoring traps (dashed line, expressed in log [catches per trap and day + 1], marked with light color) and in occasional recordings of trypanosomiasis prevalence (dotted line, expressed as proportion of examined cattle, marked with dark color) at and near Luke in Southwestern Ethiopia (from month 1 to month 30, we present tsetse catches of Rowlands *et al.* (2000) working in the Ghibe valley, near Luke, and a disease prevalence value obtained from the Gurage zonal administration; from month 30 to month 80, we report the Luke data obtained in ICIPE's 'BioVillage project' (Herren *et al.*, 2004); after month 80, we present the Luke data obtained in ICIPE's adaptive management project (Baumgärtner *et al.*, 2003, Sciarretta *et al.*, 2005); ILRI = International Livestock Research Institute, Nairobi; ICIPE = International Centre of Insect Physiology and Ecology, Nairobi).

selected individuals and analyzed for *Trypanosoma* spp. infection. Infected cattle were treated with trypanocidal drugs. The number of cows sampled and the dates are as follows: 240 animals were examined in January 2000 and January 2001; 89 in July, 2003; 214 in December, 2003; 155 in April, 2004; 58 in February, 2005; 98 in July 2005; 52 during March and August of 2006.

Other data collected yearly included a census of animals, estimates of land area used for agriculture, income per household, and school numbers and school attendance. The list of the monitoring data and the year of acquisition, the source of the data and variable values are given in Table 1.

Table 1 - The response to tsetse and trypanosomiasis control operations at and near Luke, Southwestern Ethiopia, reflected by the change in values of monitoring variables obtained in 1995, 2005 and 2006. The data from 1995 and 2005 have been presented and analyzed by Baumgärtner et al. (2006). For overview purposes, some values obtained after 1995 have been combined with the 1995 data set (Birr = Ethiopian currency transformed at the rate of 0.12 to the USD on June 8, 2006; values for variables characterized by (a) have been recorded in 2000 and 2005 in door-to-door surveys, (b) have been obtained from the Gurage zonal administration (1995) and in a random sample (2000), while (c) and (d) have kindly been made available by the Agricultural Office of the Gurage zone and the Ministry of Agriculture, respectively). (The income reported in the table represents the monies derived from the sale of farm products and off-farm labor).

Sector	**Categories**	**Variable**	**1995**	**2005**	**2006**
Cattle husbandry	cattle population	total population size (a) number of oxen (a)	574 3	2872 136	2634 201
	health	animals examined (b) Trypanosomiasis prevalence (b)	574 29%	98 10%	52 7.7%
	production	milk [l day^{-1} cow^{-1}] (a)	0.12	1.30	1.40
	reproduction	calving rate [$year^{-1}$ cow^{-1}] (a)	0.068	0.56	0.64
Crop management	human nutrition	area ploughed [ha] (a) and confirmed by (c)	12	506	546
	animal nutrition	area of pastures [ha] (c)	440	295	295
Community socio-economics	land use	total area [ha] (c) agricultural area [ha](c) managed area	1500 452 30%	1500 801 53%	1500 840 55.5%
	population	number of households (d) mean number of people per household	524 3.5	524 5	544 5.2
		number of Luke residents (d)	1834	2620	2645
	education	number of schools (d) school children per household (a) school attendance (a)	0 0.03 10%	1 0.42 92%	1 0.62 94%
	economics	income per household (a) per month (a) per capita income per day (a)	130 Birr 15.6 USD 0.15 USD	500 Birr 60 USD 0.40 USD	1235 Birr 148 USD 0.95USD

RESULTS AND COMMENTS

Fig. 1 depicts trap catches obtained from 1995 to 2006. The catch data during month 62 to 65 was plagued by initial organizational problems and variable trapping efficiency and hence the data are viewed as qualitatively reflecting relative tsetse abundance. A real decrease in tsetse numbers appears to have occurred during months 67 to 91. The data on disease incidence reported in Fig. 1 does not allow the specification of the period of disease prevalence reduction, but what is obvious is that it decreased from 29% to less than 10%. This reduction is similar to the 63% reduction reported by Rowlands *et al.* (1999). In 2006, the disease prevalence dropped to 7.7% although only monitoring traps but no control traps were deployed.

Cattle numbers increased from 574 to 3296 (a factor of 5.7) during 1995 to 2005 (Table 1), but decreased in 2006 to 2634. The calving rate increased from 0.068 per year in 1995 to over to 0.56 in 2005 and 0.64 in 2006. This exceeds the average rate of about 0.5 reported for indigenous cattle in the Ethiopian highlands (Ketema & Tsehay, 1995). During the 239 days lactation period, milk production per day increased from 0.1 liters per day in 1995 to over 1.3 liters per day in 2005, and 1.4 liters per day in 2006. For indigenous cattle in the Ethiopian highlands, Ketema & Tsehay (1995) recorded an average production of 2.2 liters per day. The number of oxen increased from 3 in 1995 to 134 in 2005 and 201 in 2006. The increase in oxen greatly augmented drafting power resulting to a substantial extension of the cultivated area from 12 ha in 1995 to over 500 ha in 2005 and 546 ha in 2006. As the land area remained constant, the pasture area decreased from 440 (1995) to 295 ha (2005 and 2006). The extension of agricultural land occurred largely at the expense of unmanaged land (Table 1). Remarkably, the total number of cattle decreased in 2006, but the number of oxen and the cultivated area increased. The productivity of the cattle as measured by milk production and calving rates also increased in 2006.

These community activities and others were possible because of on increase in household income per month from 15.6 USD in 1995 to over 60 USD in 2005, and 148 USD in 2006. As stated above, the income may be underestimated because it is derived from the sale of farm products and off-farm labor. The interpretation of the income data is difficult because details on sources of income and home micro-economics in the Luke community are not available. Nevertheless, it is obvious that income is seen as a significant part of the overall economic capital. Relative to the 1995 census, both the number of households and the people per households increased, with the Luke population increasing 44% (811 persons) reaching 2645 by 2006. At the same time, the number of children per family and the percentage of children attending the school increased. In 1995, there was no school and few children went elsewhere for an education, but by 2005, a new school was constructed and attended by 220 children. Between 2005 and 2006, enrollment increased 2% and student numbers reached 337. The establishment of a school required changes in political and administrative structures that could not be documented but may pave the way for economic and social capital enhancement.

DISCUSSION

As previously shown (Baumgärtner *et al.*, 2006), control of tsetse and trypanosomiasis control has evolving consequences for agricultural development, eco-system dynamics and biodiversity, and ecosocial change.

Trapping of tsetse adults greatly decreased their abundance in the target area over the period 2000-2005 (Fig. 1). Field data shown in Fig. 1 confirmed the positive prior experience with the mass trapping technology for tsetse control in Ethiopia (Brightwell *et al.,* 2001; Getachew Tikubet *et al.*, 2003). The decrease in disease prevalence was also expected based on prior work by Getachew Tikubet *et al.* (2003), but the decline of prevalence of infected cattle from 29% in 2005 to only 7.7% in 2006 was unexpected. Also unexpected was the increase in economic benefit that accrued to Luke community during 2006.

The 1995-2005 Luke data were interpreted using a theoretic bio-economic model (see Regev *et al.,* 1998) that predicted increased cattle populations and their marginal values as the risk from trypanosomiasis decreased. The model also predicted increased revenue expenditure to factors that may not immediately contribute to growth of the economic unit (i.e. consumption). The field data (Table 1) support the models predictions of increased cattle numbers from 1995 to 2005, and suggest that overstocking would result. Hence, the observed decrease in cattle density in 2006 was unexpected and may have been in response to community perception of overstocking. The bio-economic model's prediction of higher cattle densities was due to farmer perception of reduced risk of trypanosomiasis infections. As occurred, the observed higher marginal value of cattle was due not only to higher per cow productivity (e.g. higher milk production and calving rate) but also to the increased value of healthy cows due to an improved animal husbandry system.

The plateau of 10% infection of cattle to 2005 after a much larger steep decline in tsetse numbers was likely due to the purchase of infected animals originating from areas without tsetse/trypanomiasis control operations (Baumgärtner *et al.*, 2006). The further small decline in infected animals to 7.7% in 2006 may not be significant, or may reflect the delayed effect of prior increased calving rates and reduced calf mortality that increased healthy cow numbers (Rowlands *et al.*, 1999) and/or a decline in cattle purchased from infected areas (Table 1). Reductions in the total number of infected animals (i.e. 287 in 1995 to 203 in 2006) also reduced the costs for anti-trypanosomal drugs and contributed to increased income from the livestock sector (Table 1).

The suppression of the tsetse challenge resulted in an increase in draught oxen and in an increase in land used for agricultural purposes (i.e. 12 ha in 1995, 506 ha in 2005 and 546 ha in 2006 (Table 1)). This suggests that the area ploughed per ox decreased from an average of 3.72 ha during (2005) to 2.7 ha (2006). This apparent anomaly may be due to a sampling problem because oxen numbers on the date of the census may have differed from that on the date of ploughing when the full complement of cattle used were on hand. In the neighbouring Debre Zeit area of the Ethiopian highlands, an ox on average provides traction for only 1.9 ha (Gryseels *et al.*, 1984). The cultivation of additional land appears to reflect a trend to mixed farming and a shift from subsistence to market oriented agriculture. Presumably, the crop sector contributed to the increased *per capita* income (Table 1). The renewal of the road to Addis Ababa also improved the access to big markets and may have contributed to increased income at Luke.

The increased productivity of cattle husbandry and crop production increased food security and leads, from an economic standpoint, to a favourable assessment of the tsetse/trypanosomiasis control system in the short run. The effects of intensification of agriculture at Luke on species diversity are unknown, but the associated increasing pressure on land use may be disadvantageous for ecological sustainability in the long run. Negative consequences of tsetse control including overstocking rates and environmental degradation due to intensified land use have been reported in the literature for some time and careful planning has been recommended (Rogers & Randolph, 1988; Barrett, 1989; Reinhardt, 2006). While our data on cattle are not sufficient to calculate precise stocking rates in Tropical Livestock Units (TLU) (Anonymous, 2006b), the 2005 stocking rate of 9.7 cows per ha at Luke is considerably higher than the recommended 2-5 TLU per ha for the Southern Ethiopian Highlands (Hawando Tamirie, 2006). The Luke stocking rate of 8.9 in 2006 indicates a small downward adjustment of herd size relative to resource base. Hence, unless additional pastures can be obtained from the large unmanaged area (Table 1), intensified cattle husbandry threatens the ecological sustainability of the Luke area. This threat is aggravated by increased land cultivation without soil fertility conservation. It would appear that the current use pattern of land for pastures and cultivation may already have exceeded the biophysical limits of the Luke ecosystem beginning a decrease in ecological capital and reduced ecological sustainability. This process makes the role of ecologists in land management issues increasingly more important (Rogers & Randolph, 1988).

The opening up of arable land and the availability of manpower led in 2006 to an external investor leasing land for crop production and to the employment of Luke villagers for clearing new unmanaged areas. Such activity may have increasing effects on biodiversity and the ecological capital of the region and, unless an agreements is reached between villagers and external investors on the sharing and joint management of natural resources, severe permanent decreases in economic and social capital may result.

Income data on Luke villager indicate they continue to live in extreme poverty despite continuous increases in household income during 1995-2005 and a more than two-fold increase in 2006 (Table 1). The investments in housing, school and in tsetse control activities relied on increased revenues as well as on the development of additional social organizations than were not evident in 1995 when the first survey was taken. But the pace of change is increasing as external investments enter the Luke zone and this may require additional adaptations to the social system. For example, the establishment of tsetse control teams, school board and institutions dealing with external investors enhance institutional diversity and could contribute to sustainability enhancement (Becker & Ostrom, 1995). The higher level of school attendance reflects a preparedness of the Luke population to accept and adapt to change and to invest into the future. The willingness to accept change is an important prerequisite for sustainable development

(Gilioli & Baumgärtner, 2006), and among the most important of these changes was the initial bottom up request for assistance from the Luke community.

However, there are looming problems. The bio-economic model predicts the observed increases in human populations with reduced tsetse/trypanosomiasis pressure (Table 1), that combined with increased demands could, if not controlled, lead to a loss of ecological capital (i.e. degradation of agro-pastoral lands) and to a reversal of current ecosocial development. The model shows that the balance between positive uses of surplus revenues for economic consumption (e.g. schools, etc) and the negative side effects of potential environmental degradation must be managed. These changes as well as a possible problem of sharing the benefits of agricultural activities with external investors will continue to threaten system sustainability if not marshalled by appropriate sustainable social institutions working for the public good, solutions at the nexus of ecological, social and economic sustainability (Goodland 1995). Specifically, the Luke community not only maintain the tsetse/trypanosomiasis suppression program but also seek solutions to other disease issues (malaria). They must establish and maintain ecologically sound stocking rates for cattle, they must establish method for sharing the benefits resulting from joint agricultural activities by villagers and external investors and they must develop and implement human reproductive health programs so as not to overshoot the environmental carrying capacity as has happened in many other part of the world. Failure to develop adaptive management strategies now may represent lost opportunity resulting in a larger population at Luke that lives below the poverty level. As previously stated (Baumgärtner *et al.*, 2006), societal solutions must break from the past perceptions of high risk and give way to notions of risk levels commensurate with sustainable development.

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