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Ex-post economic analysis of push-pull technology in Eastern Uganda

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ABSTRACT

Push–pull technology (PPT) simultaneously reduces the impact of three major production constraints, pests, weeds and poor soil, to cereal–livestock farming in Africa. In order to ascertain the social value of the technology and to make decisions about the trade-offs in the allocation of scarce resources in research, gross margin analysis and the Dynamic Research for Evaluation Management economic surplus model were applied to calculate and analyze the benefits of PPT for 568 households located in four districts in eastern Uganda. The results showed that with PPT the economy of these districts would derive an overall net gain of 3.8 million USD. At a discount rate of 12% for a period of 20 years (2015–2035), Net Present Value was about 1.6 million USD, the internal rate of return 51%, and the Benefit to Cost Ratio 1.54. This implies that PPT is economically viable and profitable. Hence the technology should be further up-scaled and disseminated to other regions to reduce poverty and increase household food security.

1. Introduction

Low agricultural productivity is linked to human, technical and socio-economic factors, and in the dominant smallholder sector in sub-Saharan African (SSA), to a virtual absence of improved varieties of crops and breeds of livestock, agronomic and post-harvest technologies, and inputs of fertilizers, pesticides and irrigation (Nkamleu et al., 2003; Republic, 2011). In SSA, smallholder farmers are faced with three constraints that result in low maize yields, poor soils, stemborers and parasitic weeds (Menkir et al., 2012; Rubiales and Fernández-Aparicio, 2012). As part of addressing these issues, this paper evaluates the economic benefits that have emerged from the introduction of farm-based push-pull technology (PPT) systems into eastern Uganda.

Control methods for parasitic *Striga* weeds and stemborers in maize production have been widely researched in Africa (Berner et al., 1994; Mullen et al., 2003; Labrada, 2007; Rubiales and Fernández-Aparicio, 2012). Methods that embrace the application of herbicides, insecticides and inorganic fertilizers are environmentally unfriendly and unaffordable to most farmers, as is the use of Imazapyr Resistant (IR) maize-StrigAway, whereas crop rotation, uprooting *Striga* weeds, organic fertilizers and natural enemies, although affordable, often result in insufficient levels of control (Berner et al., 1994; Woomer, 2004). Additionally, control of stemborers using insecticides is often ineffective as the chemicals fail to reach deep inside the plant stems where the larvae reside; similarly use of herbicides against *Striga* can be ineffective (http://www.push-pull.net/2.shtml).

Push-pull technology (PPT) is a habitat strategy developed for the integrated management of stemborers, *Striga* weeds and poor soil fertility in SSA. It involves intercropping maize (and other cereal crops) and desmodium (e.g. *Desmodium uncinatum*), with Napier (*Pennisetum purpureum* Schumach) or Brachiaria (*Brachiaria cv mulato II*) grass planted as a border crop (Khan et al., 2008b; Midega et al., 2010). The desmodium repels stemborer moths ('push'), while the surrounding grass attracts them ('pull') (Khan et al., 2001). The desmodium also suppresses *Striga* weeds, mainly through allelopathy i.e. root-to-root interference (Khan et al., 2001). Farmers practising this technology have benefited from increased maize and fodder yields, as well as improved milk production and soil fertility (Khan et al., 2008a; Midega et al., 2015). To date, this technology has been adopted by > 155,000 smallholder farmers in Kenya, Uganda, Tanzania, and Ethiopia (http://www.push-pull.net/adoption.shtml).

The economic benefits of PPT for maize cropping have been demonstrated previously. Khan et al. (2001) evaluated the benefit-cost ratio of introducing PPT compared to maize monoculture with or without the use of pesticides, and Khan et al. (2008c) the returns on investment for the basic factors of production under PPT compared with other cropping methods. Both studies showed that PPT was more profitable. However, these studies only focused on incomes generated

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from increased maize yield; the other benefits of PPT, increased fodder from Napier or Brachiaria grasses and desmodium, and increased milk production, were not quantified. They were also conducted in selected districts in the western part of Kenya where PPT had been widely disseminated since 1998 (http://www.push-pull.net/Climate-smart_Push-Pull.pdf). In contrast, PPT technologies were first introduced into Uganda in 2001 into more diverse farm typologies and socio-economic conditions (Gatsby Charitable Foundation, 2005). The broader approach of this new study can potentially strengthen the relevance of PPT in other parts of SSA where the production of cereals is hugely constrained by the same suite of problems as in Uganda.

Around 30% of the total population in Africa live with chronic hunger and malnutrition; this number could probably increase given its projected rate of population growth (FAO, 2009). Hence there is a need to increase food security in the continent; one solution is through increased agricultural productivity that delivers increased food availability and rural income (Godfray et al., 2010; Asenso-Okyere and Jemaneh, 2012). Maize yield losses caused by stemborers can reach as high as 80% and by *Striga* weeds between 30 and 100%, and both are aggravated by low soil fertility (Khan et al., 2014a). Where both pests occur simultaneously, farmers often lose their entire crop (Khan et al., 2008b; Oerke, 2006). These losses, which amount to approximately USD 7000M annually in SSA, mostly affect subsistence farmers resulting in high levels of food insecurity, malnutrition and poverty (Kfir et al., 2002; Khan et al., 2014a; Ngesa et al., 2015; http://www.push-pull.net/2.shtml).

The objective of the current study was to evaluate the economic benefits of push-pull technology (PPT) in the context of maize cropping and the associated production of fodder and milk in eastern Uganda. This was done by assessing the social gains, and calculating gross margins with and without PPT and three investment parameters: present value (NPV), internal rate of return (IRR) and benefit cost ratio (BCR). The relevance of the results for accountability and planning purposes, and the further adoption of PPT in Uganda are discussed.

2. Methodology

2.1. Study area

The study covered four districts in eastern Uganda, namely Bugiri, Busia, Pallisa and Tororo (Fig. 1). In these districts, *Striga* weed, stemborers, poor soil fertility, and unreliable rainfall are the major constraints to maize production (Odendo et al., 2001; Khan et al., 2006). The districts are subject to the same tropical climatic conditions and land use, which is mainly arable. All are rain fed with annual rainfall between 1000 and 2000 mm, with short rains in April to May and long rains in September to November (http://psipse.org/about-uganda/). Agriculture is a core sector of Uganda's economy and the largest employer, and maize one of four major subsistence crops; the others are cassava, plantain and sweet potato (Karyeija et al., 1998; Mukwaya et al., 2011).

2.2. Sampling procedure and data types

Primary and secondary data were collected, the latter obtained from *icipe* offices in Mbita, Kenya and Mbale, Uganda. Data collected were both quantitative and qualitative. Quantitative data were collected during the November to December 2014 growing season and growing seasons between January and October 2015 from smallholder households, the sampling unit, through one-on-one interviewing with the household head, or if absent, their spouse. Qualitative data were collected from farmer groups and key informants and based on focus group discussion (FGD) and key informant interview (KII) guidelines respectively.

The sampling frame comprised smallholder farmers participating in PPT and those not participating. A multi-stage sampling procedure was applied. In the first stage, purposive sampling was used to select the region, Eastern Uganda and four districts with a predominant use of PPT relative to other districts. To obtain a sample of households from the four districts in the second stage, systematic random sampling was employed to identify sub-counties, parishes and villages. To ensure that different units in the population had equal probabilities of being chosen, selection of the sample was based on probability proportionate to size sampling, and sample size, n was computed from Kothari's (2004) formula:

$$n = \frac{Z.^2\ p.\ q.\ N}{e^2(N-1) + Z^2.\ p.\ q} \tag{1}$$

where p = population proportion with the characteristic of interest, q = (1-p), N = size of the population, e = margin of error, Z = critical value at the desired confidence interval. Given a population of approximately 1300 farmers in the study area who had the characteristics of interest, and assuming that the sample mean should be ± 3% of the population mean at 95% level of confidence, the sample size was calculated as follows:

$$n = \frac{(1.96)^2 * (0.5) * (0.5) * 1300}{(0.03)^2(1300-1) + (1.96)^2 * (0.5) * (0.5)} = 586 \tag{2}$$

Thus a sample of approximately 586 respondents was required in which, for every district, smallholders both with and without PPT were sampled equally. Because of incomplete and/or poor responses, the final sample size of 568 households was achieved, 148 in Tororo and 140 each in Bugiri, Busia, and Pallisa. Of these, approximately half the households in each district had adopted PPT. This study was done simultaneously with an impact assessment of push-pull pest management in the same districts (Chepchirchir et al., 2017) which targeted early adopters of the technology. The earlier dissemination of PPT in Tororo than the other districts may explain the higher number of useable questionnaires from Tororo.

Experienced enumerators were trained to collect household data. The interview schedule focused on farmers' socio-economic characteristics, farm and institutional factors, household incomes, food and non-food expenditure, and consumption. FGDs were held with groups of farmers and KII's with founder farmers, opinion leaders, agronomists and agribusiness officers in the Ministry of Agriculture Animal Industry and Fisheries (MAAIF), and PPT project officers. Information collected from FGD's and KII's were quantities and prices per unit of maize, fodder and milk. A data validation exercise was conducted after the survey in Busia and Tororo from January to October 2015 whereby 30% of the previously interviewed farmers (both PPT and non-PPT participants) were interviewed.

2.3. Theoretical framework

Performance was evaluated using the DREAM economic surplus model (Alston et al., 2000). This model is based on the assumption that technology adoption leads to an outward shift in the product's supply curve which triggers a process of market-clearing adjustments in one or multiple markets, thereby affecting the flow of final benefits to producers and consumers. Through appropriate parameterization, the model was used to assess annual changes in producer and consumer economic surpluses as a consequence of the adoption of PPT. Thus:

$$\Delta PS_{it} = (K_{it} + PP_{it}^{R} - PP_{it})[Q_{it} + 0.5(Q_{it}^{R} - Q_{it})] \tag{3}$$

$$\Delta CS_{it} = (PC_{it} - PC_{it}^{R})[C_{it} + 0.5(C_{it}^{R} - C_{it})] \tag{4}$$

where, holding back the subscripts for region i in time t, ΔPS and ΔCS are the producer and consumer benefits, K is the realized supply curve shift or reduction in the per unit cost of production, and PP_{it}^{R} and PP_{it} are the producer prices with and without PPT, Q^R and Q the annual production totals with and without PPT, PC^R and PC the consumer prices with and without PPT, and C^R and C the market costs with and