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Evolution and impacts of groundnut research and development in Malawi: An ex-post analysis

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Groundnut is currently the second income earner for smallholder farmers in Malawi, and an inexpensive source of balanced protein. Owing to the continued crop improvement research and extension efforts, production has risen by more than 15 times in the past two decades. Despite the dramatic growth, no impact assessment has ever been conducted to date. This study aims to assess the economic impacts of investments in groundnut research and development (R&D) in Malawi, covering the period 1982-2013. Relevant information on investments and changes in outputs was gathered from a range of sources including a smallholder household survey and secondary data provided by international and national agricultural research programmes, and non-governmental organisations. The economic surplus approach (the PEDPIS method and the Akino-Hayami method) was employed to compute the internal rate of return (IRR) and the net present value (NPV). It was found that the IRR for the base scenario was 22%, higher than the opportunity cost of capital being 11%, indicating that the investment was competitive as well as profitable. The NPV ranged from USD 204 million to USD 206 million, depending on the calculation method. With sensitivity analyses, the NPV remained positive and the IRR stayed above 11% in all scenarios except when the research and extension costs were raised by 50%. The IRR compares well among impacts of crop research in sub-Saharan Africa. The result implies the need for policy formulation towards long term commitment to developing improved seeds, reinforcement of the seed systems, and enhancement of extension services to smallholders.

Key words: Groundnut, economic surplus, Akino-Hayami, internal rate of return, net present value, Malawi.

INTRODUCTION

Malawi ranks among the world's least developed countries. The country's economy is predominantly agrarian, in which agriculture accounts for 27% of gross domestic product and 85% of export revenues. About 90% of the population reside in rural areas, and are engaged in small-scale farming activities (World Bank, 2014). Despite the economy's heavy dependence on agriculture, the government has been allocating less and

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less resources in real terms to agricultural research programmes (Pardey et al., 2006). The funding has also been irregular and inconsistent over the years, rendering it difficult for researchers to rely on the government support. Nonetheless, public financial supports from the government and international donors have led to visible improvement in seed performance such as higher yields, drought tolerance, and pest and disease resistance (Alene and Coulibaly, 2009).

Organised agricultural research in Malawi began a century ago. The main focus of research during that time was variety-screening trials on experimental farms. In 1948, the Chitedze Agricultural Research Station was established, followed by the launch of the Mbawa Station in 1950 and the Chitala Station in 1955 (Beye, 2002; Department of Agricultural Research Services - DARS, 2011). DARS, formerly known as DARTS (Department of Agricultural Research and Technical Services), has been the largest research institution in the country in terms of staffing (Ministry of Economic Planning and Development, 2011).

The major legume crops in Malawi are groundnut, pigeonpea, common bean, cowpea, and soybean, among which groundnut is the most widely grown, with nearly 27% of the total land under legume production sown to the crop. In 2009, area under groundnut was about 14% compared with area planted to maize, the dominant staple crop (Simtowe et al., 2009a, b). Around 93% of groundnut production in Malawi is realised by smallholder farmers as the crop provides considerable benefits to smallholders. First, it is valuable for improving food security through its low-cost provision of balanced protein, unsaturated fatty acids, vitamins, and minerals, added to the predominantly maize-based Malawian diet. In agro-pastoral communities, groundnut is used as feed, which enhances livestock productivity as the haulm and seed cake are rich in digestible crude protein. Second, it is the second income earner for smallholders in Malawi after tobacco. Approximately 40% of total groundnut production is marketed, generating about 25% of household’s agricultural income (Diop et al., 2003; Derlagen and Phiri, 2012). The export channel represents 10% of total production. Third, it fixes atmospheric nitrogen into the soils and thus improves soil fertility, saving fertiliser costs for subsequent crops (Derlagen and Phiri, 2012).

Sporadic research activities on groundnut started in the 1950’s. However, the first organised research initiatives on groundnut improvement kicked off in 1982 under the auspices of the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), which was termed Groundnut Improvement Programme (GIP). Since its inception, sizable resources from donors and the government have been invested in GIP. A simple and effective field screening technique was developed to evaluate germplasm and breeding lines for desirable traits. Several high-yielding breeding lines with stress resistance were developed for evaluation and utilisation by the National Agricultural Research System (NARS).

Crop improvement efforts materialised in the release of six improved varieties during the period. Those varieties are equipped with favourable traits such as pest resistance, high yields, and drought tolerance. The dissemination of these improved varieties was a major driver of the dramatic increase in national groundnut production from 18 000 tons in 1990 to 280 000 tons in 2010.

Without doubt, the groundnut technologies have improved the status of production over the decades. Yet, there has been no attempt of impact assessment of groundnut R&D to date. Since public spending on agricultural R&D has been declining all these decades, the need for efficient resource allocation and the justification of resource utilisation necessitated the assessment of economic impacts of GIP. Without the evidence of economic impact, it would be difficult to recognise the social value of technologies and to make judgments as to the trade-offs in the allocation of scarce resources for research (Alston et al., 1998). Given the importance of the crop to the country, the outcomes of such assessment would inform policy makers for the food and agricultural sector, and would also serve as inputs for evidence-based policy dialogue at country or regional level.

The objective of this study is to assess the socioeconomic impacts of groundnut research and complementary services during the period 1982 to 2013. The rest of the paper is organised as follows: details of the groundnut subsector; a description of the evolution of groundnut research initiatives; an introduction of the methodology for assessing the impacts; discussion of the results; and concluding remarks.

Groundnut subsector in Malawi

Area and production

In the past two decades, area sown to groundnut has steadily expanded and the productivity per area has also significantly increased, which resulted in a dramatic boost in production over the years. The groundnut area grew from nearly 50 000 ha in 1990 to 270 000 ha in 2010, while the yield rose from almost 400 kg/ha in 1990 to 1026 kg/ha in 2010. As a result, the production in 2010 was close to 300 000 tons, which was almost ten times the level in the early 1990s (Figure 1).

Much of the yield improvement is attributed to the adoption of improved varieties that are higher yielding, drought tolerant, and pest and disease resistant. The traditional groundnut variety in Malawi is Chalimbana, a Virginia-type large size cultivar with relatively high levels

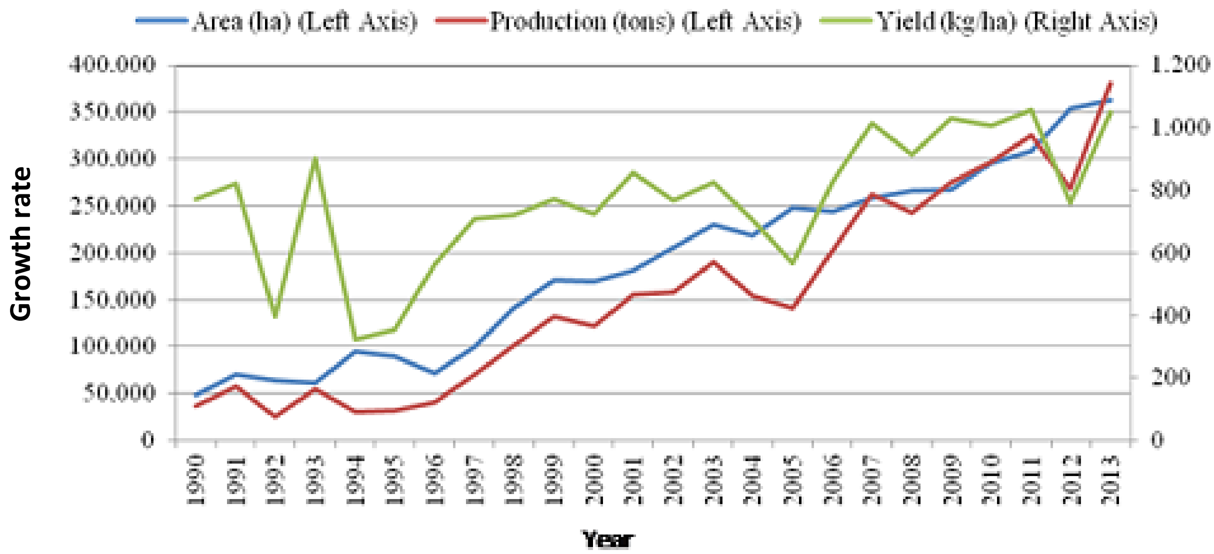

Figure 1. Growth of groundnut production, area, and yield in Malawi, 1990-2013. Source: Authors' creation from Ministry of Agriculture and Food Security (2012a) and FAOSTAT (2015).

of protein.[1] In 1990, ICRISAT introduced an improved Chalimbana-type variety named CG7, characterised by drought tolerance and yield potential 60% higher than that of Chalimbana. CG7 has become popular in markets due to its rich oil content and preferred colour of red. Other improved varieties released and promoted for commercial production since 1982 are Chitala, Chalimbana 2005, ICGV-SM 90704 (Nsinjiro), JL 24 (Kakoma), and IGC 12991 (Baka). Farmers' awareness and preferences determine the extent to which these varieties would be adopted.

While the production and yield have increased to a great extent, the yield potential has yet to be fully attained due to a number of constraints on production (ICRISAT and DARS, 2007; MoAFS, 2008). Groundnut is predominantly grown by smallholder farmers operating on an average of 1.2 ha of land (CYE Consult, 2009), and the average area allocated to groundnut is 0.5 ha per grower (Msere et al., 2015). In general, smallholders in Malawi focus fertiliser use on maize production and do not apply it to groundnut, which is added to by poor crop management. They also resort to use of recycled seeds because improved seeds tend to be either unavailable or unaffordable, which affects the yield performance. Furthermore, the yield kept fluctuating over the decades due to unpredictable drought events as smallholder agriculture in the country is based on rainfed conditions without access to irrigation. Stakeholders, especially in the processing sector, consider the unstable yields and supply of groundnut as an impediment to both domestic marketing and exports. The labour intensiveness is also a disincentive to increase production of groundnut (Minde et al., 2008).

[1] There are four major cultivar groups of groundnut in the world: Spanish, Runner, Virginia, and Valencia. Certain cultivar groups are preferred for particular uses because of differences in flavor, oil content, size, shape, and disease resistance. Most of the marketed groundnut is of the Virginia type, along with some Valencias selected for large size and the attractive appearance. The large seeded Virginia group groundnut is grown in the US states of Virginia, North Carolina, and others. They are gaining popularity due to demand for large peanuts for salting, confections, and roasting in the shells.

Consumption

33% of groundnut production is consumed by farm households (Msere et al., 2015). Although the higher yielding CG7 is not as preferred for local consumption as Chalimbana, it has spread as a cash crop through seed loans and seed bank projects operated by non-governmental organisations (NGOs) and international institutions. On the other hand, the lower yielding Chalimbana has remained as the choice for home consumption and for snacks in local markets (Goyder and Mang'anya, 2009).

Due to its nutritional significance, Malawi's Agricultural Sector Wide Approach (ASWAp) specifies groundnut among the crops whose production and consumption should be vigorously promoted. The total domestic human consumption of groundnut rose from 11 000 tons in 1990 to 68 000 tons in 2007 (Figure 2). The per capita consumption also showed a similar trend rising from 1.5 kg in 1990 to 4.7 kg in 2007, and further to 7.3 kg in 2013 (Derlagen and Phiri, 2012; Tsusaka et al., 2015a, b).

Marketing and export

Many smallholder groundnut growers sell part of their groundnut production to markets. It is estimated that

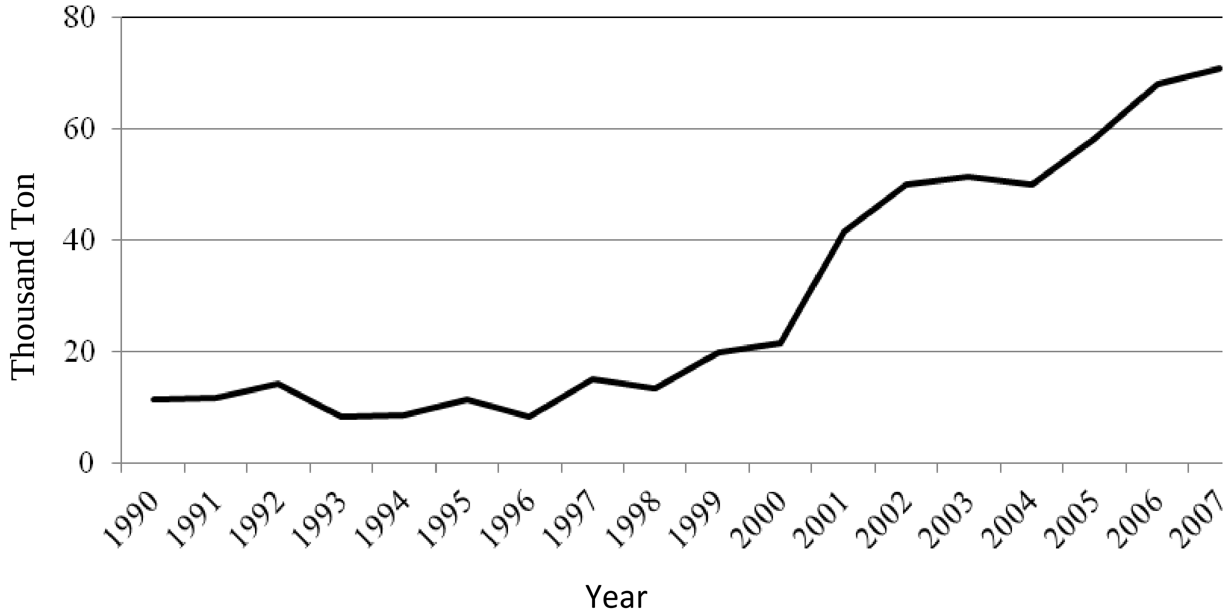

Figure 2. Groundnut consumption in Malawi, 1990-2007. Source: Adapted from Derlagen and Phiri (2012).

about 35% of the production is used as an input to the agro-processing industry for production of peanut snacks, cake, oil, and butter, and about 10% is exported (Derlagen and Phiri, 2012).

Back in the 1960s to 1980s, all other major export crops were grown only by estates, under the Special Crops Act. During that period, groundnut was the only viable export alternative for smallholder farmers, and Malawi was a major exporter of confectionery Chalimbana variety. The farmers sold groundnuts via the Agricultural Development and Marketing Corporation (ADMARC), a parastatal that was the only trader of groundnut until 1987. Government policies were in effect to control prices of inputs (both seed and fertiliser) and outputs, and to subsidise credit.

However, the export prospects for groundnut declined for several reasons. First, the kernel shape was less suitable for processing compared with varieties from China. Importers were against the bigger size 'Malawi nuts' (e.g. Chalimbana). Second, with the liberalisation of tobacco production, smallholder farmers started obtaining licenses to grow tobacco. Growers, particularly in central Malawi, shifted from groundnut to burley tobacco as their main cash crop. At the same time, the role of ADMARC as the main buyer was taken over by private traders in an inefficient way. Third, producers faced strict aflatoxin standards imposed by Europe. The aflatoxin issue undermined production and export capabilities of Malawi groundnut, resulting in losing overseas markets (Sangole et al., 2010). As a consequence of all these, groundnut exports stayed minimal in the early 1990s (Figure 3). From the mid-1990s, production and export began recovering slowly, and 2007 saw 9.3% of production being exported (Derlagen and Phiri, 2012). This experience in Malawi suggests how massive markets can be lost easily by not keeping up with the competitive trade environments. It was also learned that there would be potential in proactive innovations for the aflatoxin control, which would require sustainable incentives for farmers to achieve and maintain quality standards (Goyder and Mang'anya, 2009).

While in the 1970s and 1980s groundnut was predominantly exported to Europe, recently the main export destinations are regional markets in Africa. The shares of individual export destinations vary from year to year. In 2005, the key destinations were South Africa (56%) and Zimbabwe (20%), and in 2010, Tanzania (49%) and Kenya (28%) were the main importers of groundnut from Malawi (Ministry of Economic Planning and Development, 2011).

Extension system

Government extension agents are the main agricultural extension service providers in Malawi.[2] The government extension service is housed in the Department of Agricultural Extension and Services (DAES) within the Ministry of Agriculture, Irrigation and Water Development (MoAIW). While CGIAR (the Consultative Group for International Agricultural Research) institutions as well as NGOs also provide extension advice to farmers, MoAIW, through DAES, remains the largest agricultural extension

[2] The most prevalent type of extension service provider in the least developed countries is the government extension services (Arnon 1989).

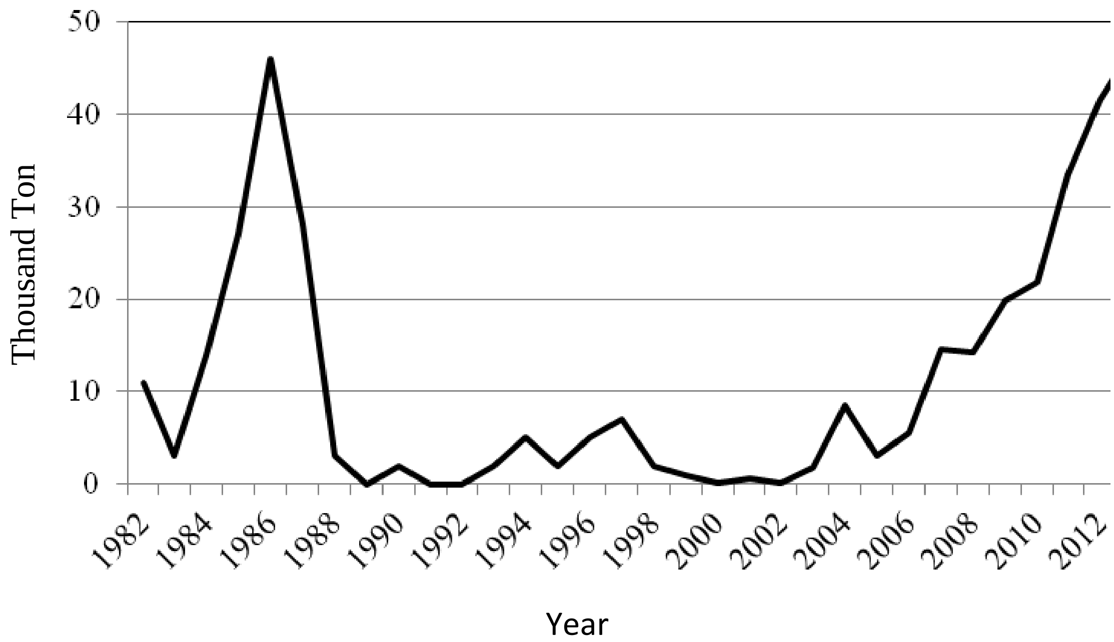

Figure 3. Groundnut export volume from Malawi, 1961-2009. Source: Authors' creation from Derlagen and Phiri (2012) and data provided by Ministry of Industry and Trade.

service provider in the country (Masangano and Mthinda, 2012). Members of the extension staff offer services to seed and grain producers an average of three times a year. The frequency increases when farmers face problems.

For groundnut, the efforts of extension staff are complemented by ICRISAT's field activities, especially for seed production. ICRISAT engages with NGOs such as Concern Universal and Plan International through a number of seed production projects. The government's Farm Input Subsidy Programme (FISP) largely contributed to scaling up the seed production by these NGOs over the years, while ICRISAT has been the supplier of certified seeds to the FISP via different seed companies.

Women in Agribusiness in Sub-Sahara Africa Alliance (WASAA) is an NGO that promotes female traders to steer economic independence of women. It was formed in 2010 and registered in each country in Eastern and Southern Africa. The basic role is to secure big contracts and share information. In Malawi, WASAA has more than 3600 members. The main activities are (1) seed multiplication for legumes, (2) commodity trading both locally and internationally, and (3) agro-dealership. WASAA borrows money from FDH Bank Limited, with collateral being the groups of traders and the warehouse crop.

The Rural Market Development Trust (RUMARK) is a non-state actor aiming to develop the agro-dealers network to expand access to smallholder farmers. The agro-dealers are trained in subjects of business management, demand creation, and linkage to input suppliers in rural areas. The agro-dealers' input package is tailored to each farmer's requirement (e.g., 5 kg of fertiliser). When farmers achieve production beyond subsistence level, they sell to the agro-dealers. Agro-dealers assist in collecting outputs for further marketing. RUMARK offers agro-dealers competitive and profitable prices in rural areas. The agro-dealers provide RUMARK with statistics on their monthly operation.

Seedco's Malawi Office deals with products associated with legumes value chains, and supplies 845 to 1000 tons of groundnut seeds per year, which is larger than any other company in Malawi. Prior to the enforcement of FISP, Seedco marketed groundnut seeds through supermarket chains. When the supermarkets pulled out of rural areas, it started using Farmers World's network to distribute seeds in rural areas. Seedco now uses agro-dealers accounting for 70% of sales, while supermarkets account for 30%. These agro-dealers have been successful in delivering inputs into remote areas. Seedco's groundnut seed production is based on contractual arrangements with commercial farmers through Mbadzi Estate, Press Agriculture, Mc Ferson, and Exagris. Seedco currently has 145 agro-dealers for legumes, each with a minimum of five shops.

With all the aforementioned extension forces, it is worth noting that a considerable proportion of smallholder groundnut farmers receive no extension advice at all. The government extension service faces such serious resource constraints that the workforce has an estimated vacancy rate of 40 to 60%. The current farmer-to-extension worker ratio stands at 3000:1 compared with the recommended level of 1000:1.

Policies

Malawi's post-independence policies focused on attaining national food self-sufficiency through the enhancement of smallholder agriculture and rapid economic growth. Almost all agricultural programmes were guided by the food security agenda, which promoted the staple maize production at the expense of other crops. Consequently, close to all households (97%) engaging in farming grow maize. Maize is grown on over 50% (almost 1.5 million hectares) of the available arable land (MoAIW, 2012).

From the mid-1980s, restrictions on production of some strategic commodities such as burley tobacco by smallholder farmers were lifted to allow for enhanced income by smallholders. Other important policy reforms included the price decontrols, the commercialisation of parastatals, and the removal of controls over agricultural input and output marketing.

In 1995, the government developed the Agriculture and Livestock Development Strategy and Action Plan (ALDSAP), though the implementation registered limited success because, among other factors, the sector's policies and strategies were so numerous and overlapping that no visible impact was obtained. In 1999, the government undertook a comprehensive review of agricultural policies under the Malawi Agricultural Sector Investment Programme (MASIP). Nonetheless, the review did not yield a coherent policy, which resulted in many sub-sector policy documents. To tackle the situation, Ministry of Agriculture and Food Security (MoAFS, one of the institutional precursors to MoAIW), in cooperation with MASIP, developed the Agricultural Development Plan (ADP) in 2006. The ADP sought to enhance coordination among the sector priority programmes by working with stakeholders. In 2007 to 2009, MoAFS, guided by a Cabinet directive, focused on developing ASWAp, to harmonise investment and support programmes in agriculture based on the assessment of potential contribution to food security and agricultural growth. In combination with the National Agricultural Policy (NAP), the ASWAp serves as the policy administration guideline.

Regarding agricultural inputs, fertiliser and seed subsidies for smallholders have been the major policy instruments in Malawi. The government reintroduced subsidies in 1998 through the Starter Pack Initiative Scheme (SPIS), distributing fertiliser and improved seeds to all smallholder farmers for free. The SPIS intended to reverse the negative effects of liberalisation and abolition of subsidies. Each starter pack contained 5 kg of basal fertiliser, 5 kg of top dressing fertiliser, 2 kg of maize seed, and 1 kg of legume seed. In 1999, the programme covered all smallholder households, providing a total of 2.86 million packs. In 2000, the SPIS was scaled down and renamed Targeted Input Programme (TIP), distributing complimentary agricultural inputs to 1.5 million targeted households in its first year. To curtail administrative and operational costs, TIP was further scaled down to target around 1 million households in 2001. The prioritised households were those with elderly, disabled, widows, widowers, and other vulnerable members of society. TIP registered production surpluses and yield gains. The extended TIP was undertaken in 2002 to mitigate the adverse effect of food insecurity following the poor harvest. The evaluation showed TIP's contribution of 13% to total maize production in 1999 and 10% in 2002.

Attention to legume seeds increased when FISP was introduced in 2005 in response to the severe food shortage in 2004. The programme gave resource poor smallholders access to fertiliser and quality legume seeds in addition to maize. FISP contributed to the output growth of 7% per annum on average for the 5 years, after 25 years of stagnation. The programme also led to lower food prices, higher rural casual wage rate, and enhanced household resilience. Use of drought tolerant varieties had a positive impact on crop productivity and resilience to harsh weather events (MoAFS, 2011). A downside was that as farmers hinged heavily on FISP for groundnut and other legume seeds, commercial entities felt reluctant to rely on growers, in fear of an unexpected demise of FISP. In the long-run, the government plans to reduce free distribution and promote the adoption of improved technologies without subsidies.

Groundnut research in Malawi

Evolution of agricultural research systems

As in many other countries, Malawi continued reorganizing its NARS. The Department of Agriculture (DAR) was the main organisation mandated to conduct research on broad range of agricultural themes. DAR was reorganised in 1985 into seven research groups: (1) Cereals, (2) Horticulture, (3) Grain Legumes, Fibers, and Oilseeds, (4) Livestock and Pastures, (5) Soils and Agricultural Engineering, (6) Technical Services, and (7) Adaptive Research. Each group was led by a national research coordinator responsible for research without administrative responsibilities. The research groups operated at three major research stations: Chitedze in the Central Region; Bvumbwe in the Southern Region; and Lunyangwa in the Northern Region. These are supplemented by four experimental stations and eight sub-stations located across the nation.

In November 1985, Agricultural Research Council (ARC) was established as a high level policy body to determine research priorities. The council consisted of 15 selected members from relevant departments, institutions, and private sector entities. ARC was authorised to orient the direction of research and approve research programmes, budgets, and funding levels. In 1988, DAR was restructured into DARTS (Beye, 2002; Beintema et al., 2004; Ministry of Economic Planning and Development, 2011). Bunda College of Agriculture and Chancellor College were the two main academic institutions to carry out research on agriculture in close collaboration with DARTS. DARTS transformed over the years as a professional institution. As of 1998, it had 87 researchers of which 17 held Ph.D and 46 held MSc. degrees.

In 2002, DARTS was transformed into DARS (Beintema et al., 2004). By 2011, DARS had 70 Malawian scientists and a network of 16 research stations, experimental stations, and sub-stations (MoAFS, 2012b). The major research thrusts for DARS include the followings:

1) High yielding and early maturing crop varieties that are tolerant to drought, pests and diseases and the evaluation of animal breeds suitable for various production systems;
2) Integrated pest management strategies for crops and, disease and parasite control measures for livestock;
3) Evaluation of feeding technologies for increased livestock production;
4) Improved soil fertility techniques, appropriate land husbandry and improved soil and water conservation practices;
5) Appropriate farm machinery, irrigation, storage, processing and post-harvest technologies.

Research is conducted both on station and on farm throughout the country. A major requirement is that field trials must be conducted for at least three seasons before technologies are accepted for release by the Agricultural Technologies Clearing Committee.

Apart from DARS, the followings are regarded as part of NARS: higher education institutions whose mandate is research and teaching of agriculture; technical departments of some ministries; development agencies that undertake research programmes on agriculture and natural resources; and NGOs and the private sector entities engaged in agricultural research activities.

The international agricultural research centers of the CGIAR consortium are not considered as part of NARS, because these centers are committed to regional and global agenda where the national interest is implicit. However, their research results are extremely important as they represent a broader group of international and regional research coalition.

Evolution of groundnut research

DARS in collaboration with ICRISAT is tasked to conduct research on groundnut in Malawi. The focus of groundnut research is on cultivar development and identification of appropriate crop management techniques. Nearly all the varieties that are traditionally grown are landraces well adapted to the climate but with low yields. Such varieties have yields as low as 400 to 800 kg/ha, whereas yields as high as 3,000 kg/ha have been recorded on research stations using improved technologies. On-farm yields are low because of such factors as use of low-yielding varieties, continued cultivation on marginal land, and outbreaks of pest infestations and diseases, unreliable rains in non-irrigated cultures, traditional small-scale farming with minimal mechanisation.

International collaboration on groundnut research (that is, GIP) began, following the establishment of the ICRISAT office in Malawi in 1982. ICRISAT complements the activities of NARS especially in the area of varietal development and breeder/foundation/certified seed multiplication. The original involvement of ICRISAT was production of foundation seeds for distribution to farmers for further multiplication. Over time, ICRISAT engaged into forward integration by undertaking certified seed production for distribution to farmers for commercial production. Contract growers started seed multiplication in 2000. In 2005, the government introduced the FISP, which has led to the expansion of ICRISAT seed production programme. ICRISAT is currently the main supplier of groundnut and pigeonpea foundation seeds in the country, supplying to nearly all stakeholders engaged in seed production programmes.

There is also capacity within ICRISAT to test for aflatoxin contamination in groundnuts. Export markets require that nuts be produced from certified seeds with low levels of aflatoxin contamination. To reduce the contamination, ICRISAT has intensified trainings of farmers in post-harvest seed handling. The training is held once a year and is mounted jointly with DAES extension staff, NASFAM, and field staff of other collaborating partners, where participants learn how to harvest and store at the right level of moisture content.

On the whole, the development and release of six improved varieties has been a major milestone marked by GIP.[3] These varieties have contributed to alleviating some of the constraints on production. Tremendous progress was made on introgression of desirable yield attributes into Chalimbana, Malimba, and other released groundnut varieties.

Emerging issues such as aflatoxin and biotechnology are being addressed and incorporated into the research agenda. To maintain or increase marketing, breeders need to adapt the seed traits to buyer and consumer requirements. Table 1 summarises the production of basic seeds and certified seeds by ICRISAT for the period 2007-2010.

Bilateral funding

USAID is a key player for groundnut R&D activities and

[3] Seven new varieties were released in 2015. This study does not incorporate the impacts of these varieties as they are not yet disseminated to a significant extent.

Table 1. ICRISAT's Groundnut seed production in Malawi, 2007- 2010.

Season	Area (ha)		Average Yield (Ton/ha)		Production (Ton)	
	Basic seeds	Certified seeds	Basic seeds	Certified seeds	Basic seeds	Certified seeds
2007/08	20	167	1.5	0.8	30	133
2008/09	149	344	1.0	0.8	149	275
2009/10	195	459	1.0	0.8	195	367

Source: Data from ICRISAT.

has been operating the Feed the Future programme in seven districts of Malawi. The programme aims to integrate nutrition in the value chains through partners such as NASFAM, Catholic Development Commission in Malawi (CADECOM), Agrishare, RUMARK, Afri-Save, and IITA. The programme also works with banks such as FDH, EcoBank, FMB, OIMB, and Standard Bank on credit related issues.

Irish Aid has recently made a significant commitment to supporting the Malawi Seed Industry Development Project. This initiative was launched in 2009, and has been contributing to seed availability of groundnut and pigeonpea for the FISP. In 2010, smallholder farmers accessed about 500 tons of improved seed of the two legumes through the project. Together, Irish Aid, ICRISAT, NASFAM, and STAM (the Seed Trade Association of Malawi) launched MASA (the Malawi Seed Alliance), an umbrella brand that could be used by small-scale seed producers to promote certified seed.

McKnight Foundation is another key contributor to groundnut R&D in Malawi. Its Collaborative Crops Research Programme (CCRP) has made significant impacts on the livelihoods of Malawian farmers, particularly in Mchinji District. Initiated in 2006 in partnership with NASFAM, the project successfully developed community seed banks and involved farmers in participatory variety selection. Majority of the farmers in the target area currently plant a minimum of 0.5 ha of Nsinjiro variety through the programme, compared to 0.1 to 0.2 ha before the project started.

GIZ (Deutsche Gesellschaft für Internationale Zusammenarbeit) was a significant donor between 1987 and 2003. The funding schedule was DM 2.34 million for the first phase (1987-1988), DM 5.0 million for the second phase (1989-1992), DM 4.5 million for the third phase (1992-1994), DM 2.7 million for the fourth phase (1995-2000), and DM 2.7 million for the final phase (2001-2003) (Maredia et al., 2000). The Malawi NARS participated in regional evaluations while selecting elite materials for adaptation to local conditions through incorporation of the pre-bred materials into national yield testing.

METHODOLOGY FOR IMPACT ASSESSMENT

Defining 'impact' in this study

The 'impact' of R&D encompasses (1) people level impact, (2) direct product (effectiveness) of research, and (3) intermediate/institutional impact (Anderson and Herdt, 1990; Anandajayasekeram et al., 1996; Moshi et al., 1998; IAASTD, 2009). The people level impact consists of economic impact (efficiency analysis), socio-cultural impact, and environmental impact (Anandajayasekeram et al., 1996). The main focus of this study is the economic impact. Thus, the economic impact assessment undergoes quantitative analysis, whilst other types of impacts are described in a qualitative manner.

Our analysis examines the 'aggregate' impacts of groundnut R&D. In other words, disaggregation of the analytical outcome at different levels is not presented. More specifically, the term 'aggregate' refers to the following six dimensions:

(1) NARS and ICRISAT: Since it is almost impossible to separate the R&D activities by the government and by ICRISAT as they were very closely linked and interconnected, this study in effect investigates the impact of the joint investment by the ICRISAT projects and the NARS programmes (that is, GIP). Although minor, there are some actors indirectly involved in groundnut R&D. It is not possible to accurately incorporate their investment in our analysis.
(2) Research and Extension: It is difficult to separate the effect of research from that of extension and other support services needed to generate the developmental impacts. Thus, the estimated rates of return (ROR) and net present value (NPV) are with respect to the entire investment on research and extension, as well as marketing.
(3) 5 varieties or 6 varieties: Although six varieties were released by GIP since 1982, the five most successful ones are incorporated in the analysis. That is, the success case method is used (Brinkerhoft, 2003) on the premise that if the five varieties can generate a positive net benefit from the investment, then the entire range of outputs should generate a greater cumulative benefit to the society.
(4) Varieties: It is difficult to track down the costs for individual varieties and recommendations. Hence, our analysis employs the costs for all the varieties under consideration instead of costs for individual varieties.
(5) Seeds and Agronomy: The yield gains are assumed to be due to both the adopted improved varieties and the recommended crop management practices. That is, the impacts of technology packages are estimated.
(6) Purity of Seeds: Another important note is that farmers' practice of recycling improved seeds makes it difficult to clearly separate pure improved varieties from contaminated improved varieties.

To account for all these data constraints, sensitivity analysis is performed to examine the potential effects of missing data on benefits and costs.

Another important consideration in impact analysis is comparison between the 'with' and 'without' situations, where 'with' refers to the actual case with the intervention while 'without' corresponds to the counterfactual scenario. In our study, the 'without' scenario is the situation that would have prevailed if the R&D investments had been missing. The point is that there may have been endogenous changes taking place in any society even without research intervention, and thus some improvement in productivity. In our study, however, the assessment incorporates a whole range of technologies generated since 1982, and all the changes in productivity are assumed to have resulted from the intervention and its spillover. In this regard, the situation prior to 1982 is regarded as an adequate proxy for the 'without' scenario. The five year moving average yields for 1977-1981 (that is, the baseline) is taken to represent the yields in the 'without' case, for which estimates of farm-level yields regularly recorded by MoAIW are used. The yield gain is then computed from the difference between the 'with' and 'without' cases for the relevant years.

Economic impact (efficiency analysis)

Economic impact assessment examines effects of a given set of R&D activities by systematically comparing the streams of costs (including adoption and transfer costs) with the stream of project benefits. The premise is that research is an investment which is expected to generate some benefits, for which ROR can be defined and computed. The ROR is used as a summary indicator of benefits from and costs of the investment, which can be readily compared with ROR from alternative investment options.

The common approaches to estimating the ROR belong to three main categories: the partial equilibrium economic surplus approach, the econometric approach, and the programming approach (Masters et al., 1996).

The economic surplus approach measures the aggregated social benefits of a project by considering benefits and costs to calculate the average rate of return (ARR). The whole expenditure regime is regarded as given, so that the ROR to the global set of expenditures can be computed. This approach incorporates changes in consumer and producer surplus caused by a technological change due to R&D. The ARR provides for a measure of whether the entire investment package is worthwhile, though it does not indicate whether the allocation of resources across investment components is optimal (Oehmke, 1992). The economic surplus together with the research costs is utilised to calculate the net present value (NPV) and the internal rate of return (IRR) (Maredia et al., 2000). The advantage of the economic surplus method is that the model requires less information than do the other models.

In contrast, the econometric approach entails estimation of the production function, the cost function, or the total factor productivity by regression analysis, to derive marginal rates of return (MRR) of R&D during a long period. The MRR is the return associated with the last dollar invested in each component of research. The difficulty is that a reasonable estimate of the MRR requires high quality time series data for all relevant variables, which is usually not easy to obtain in developing countries.

The programming approach aims to identify one or more optimal technologies or research activities from a set of options. In other words, the approach attempts to maximise one objective, that is, farmers' profit subjected to constraints such as availability of land, labour and other inputs (Wander et al., 2004).

Given the data quality and availability in Malawi, our study adopts the economic surplus approach to estimate the ARR for investments in groundnut R&D programmes. To obtain the ARR, the net benefits for each year need to be computed by netting out R&D expenditures from the gross benefits for the year under consideration.

Gross benefits

The economic surplus approach presumes that new technologies lead to increased productivity, causing the aggregate supply curve to shift outward. Assuming market equilibrium and linear demand and supply curves, the gross benefits from the supply shift are captured by the area ABCD in Figure 4. The area represents the gross benefits resulting from research and related investments in the given technology. The gross benefits are shared between consumers and producers. Price elasticities of demand and supply determine the relative gain by producers and consumers. An export parity price, adjusted for distortions, is used in the analysis since Malawi has been a net exporter of groundnut during the study period.

There are different versions of calculation of the gross benefits in empirical work, corresponding to varying assumptions on the nature of demand and supply curves and the expected type of supply shift. The most concise means of obtaining the gross benefit is the Perfectly Elastic Demand - Perfectly Inelastic Supply (PEDPIS) method as we dub it, which is also simply referred to as the benefit-cost method (Anandajayasekeram et al., 1996; Fleischer and Felsenstein, 2002; Wander et al., 2004). The PEDPIS method does not explicitly incorporate the price elasticities of demand and supply, assuming the simple case of a perfectly inelastic supply curve and a perfectly elastic demand curve. The perfectly elastic demand curve represents the case where the country in question is a price taker and the intervention does not change the status of the country from a net importer to a net exporter of the commodity or vice versa. The perfectly inelastic supply curve is possible when inputs such as land and labour resources are fixed and fully utilised, and the commodity under evaluation is the main user of these resources. The change in supply is represented by a parallel shift. In the PEDPIS method, welfare gains from R&D investments are expressed by the area abcd in Figure 5. This rectangular area is computed as the increase in outputs (Q_1 - Q_0) multiplied by the price (P*) which is constant. The great advantage of this method is that elasticity estimates are not required, which makes the computation terse.

One of the most widely adopted approaches in ex-post assessment of gross benefits from R&D is the Akino-Hayami (AH) method (Akino and Hayami, 1975). The precursor to this model was developed by Schultz (1953) and Griliches (1958), which was later modified and adapted by Akino and Hayami and has been used in hundreds of agricultural research impact assessments and became well established within the discipline of agricultural economics as the main analytical approach in assessing the gross benefits of agricultural R&D investments, as illustrated by Norton and Davis (1981), Masters et al. (1996), Walker et al. (2008), Maredia et al. (2014), and so forth. The high IRRs emanating from studies based on the AH method demonstrated the large economic benefits generated by public investments in agricultural R&D (Evenson, 2001; Alston et al., 2000). The AH method allows for non-linear demand and supply curves (with constant elasticities), and a pivotal (that is, conservative) shift of the supply curve in response to the technological change. Since this method explicitly incorporates demand and supply elasticities, it is more data demanding than the PEDPIS method. Still, the data requirements are modest as the elasticities are assumed constant. Therefore, the method is widely adopted in empirical studies in countries where quality data are limited. The AH method employs a formula for estimation of the welfare gains expressed as area ABO in Figure 6.

The surplus area ABO is the sum of area AOC and area ABC. Area AOC is computed as follows:

$$Area\ AOC = K\ Factor\ \times Total\ Production\ Value$$

Where

$$K\ Factor = \begin{bmatrix} Proportion\ of\ Area \\ Planted\ to\ MVs \end{bmatrix} \times \frac{Yield\ Gains\ from\ MVs}{Yield\ for\ MVs}$$

$$= \begin{bmatrix} Proportion\ of\ Area \\ Planted\ to\ MVs \end{bmatrix} \times \frac{(Yield\ for\ MVs) - (Yield\ for\ TVs)}{Yield\ for\ MVs}$$

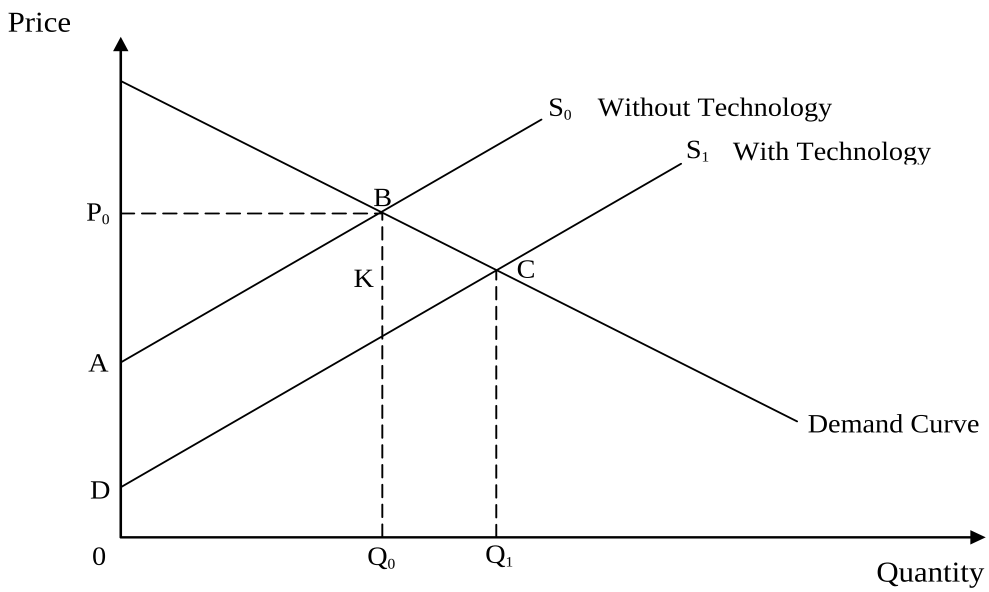

Figure 4. Producer surplus and consumer surplus with and without new technology. Source: Anandajayesekeram et al. (1996).

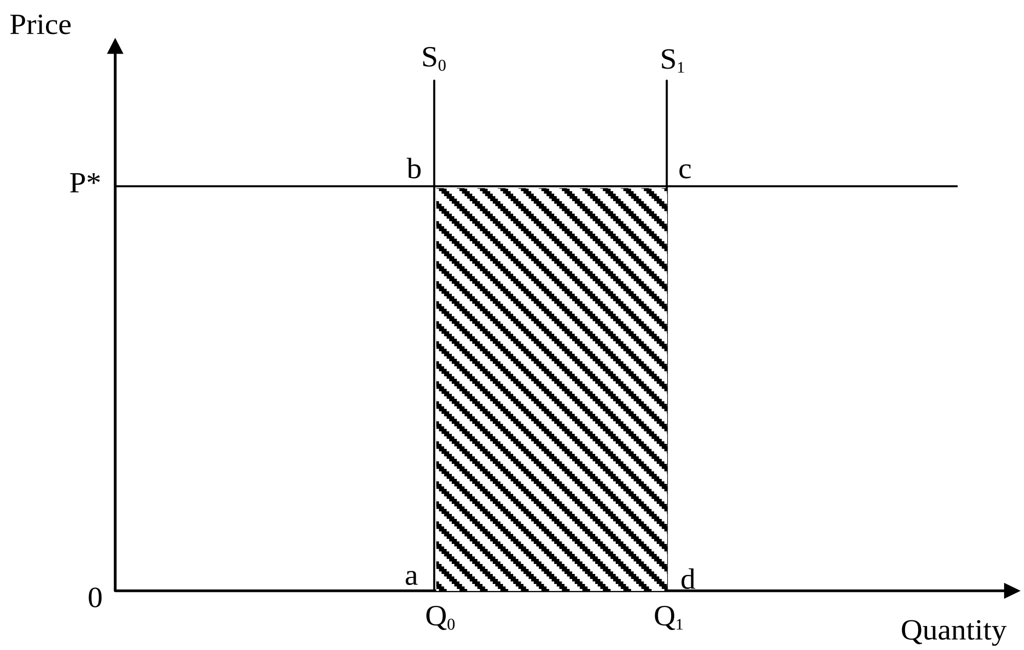

Figure 5. Perfectly inelastic supply curve and perfectly elastic demand curve. Source: Anandajayesekeram et al. (1996).

with MV and TV standing for modern variety and traditional variety, respectively.

Area ABC is calculated as follows:

$$Area\ ABC = 0.5 \times Area\ AOC + K\ Factor \times \frac{(1 + Price\ Elasticity\ of\ Supply)^2}{\begin{pmatrix} Price\ Elasticity \\ of\ Supply \end{pmatrix} + \begin{pmatrix} Price\ Elasticity \\ of\ Demand \end{pmatrix}}$$

The yields in the above formulae are weighted when there are multiple varieties.

The most notable alternative model is the Alston-Norton-Pardey (ANP) method developed by Alston et al. (1998) as a modification of the AH method. The ANP constructs the K shift in a sophisticated way, incorporating the supply elasticity at a particularly crucial point in the calculation. The sensitivity of the result to supply elasticity estimates implies that the ANP method is advantageous when

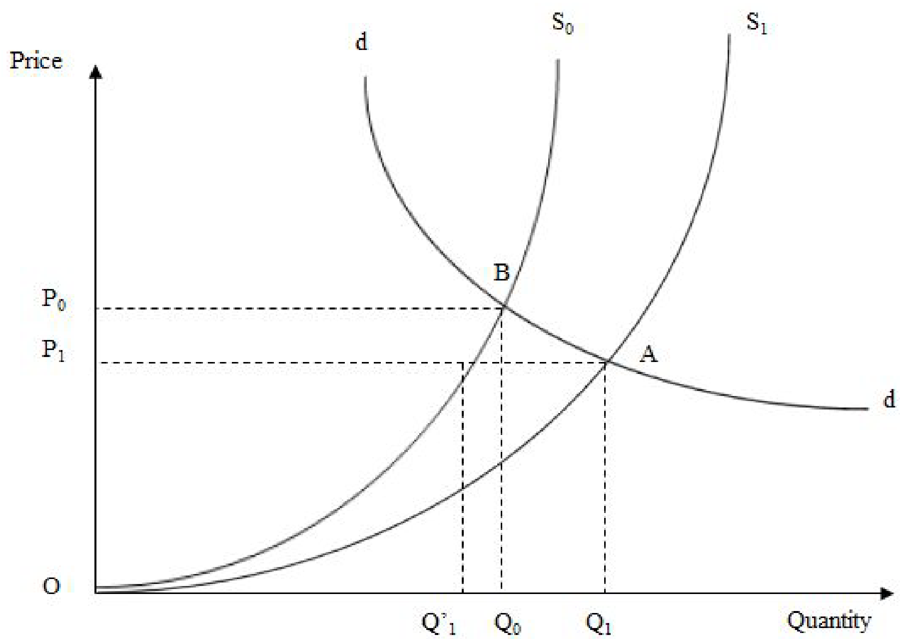

Figure 6. Demand and supply curves in Akino and Hayami method. Source: Adapted from Anandajayesekeram et al. (1996).

highly reliable elasticity estimates are available (Oehmke and Crawford, 2002). Since precise estimates of supply elasticities are difficult to obtain in least developed countries, the AH method still maintains certain popularity for studies in developing countries; for instance, as used by Hasan and Islam (2014) and Miah et al. (2015).

Based on this discussion, our study applies the PEDPIS and AH methods and juxtapose the outcomes to examine the robustness of the result.

Costs of R&D

The R&D costs consist of three key components: (1) research (technology development) costs, (2) extension (technology transfer) costs, and (3) adoption costs incurred by farmers and other service providers. These cost components emanates from the major cost items as listed below.

(1) *Research Costs*:

i) Personnel costs (staff salaries and benefits);
ii) Recurrent expenditures;
iii) Overheads and administration expenditures; and
iv) Depreciation of capital assets.

(2) *Extension Costs*:

i) On-farm research and demonstration trials;
ii) Costs of running the Commodity Training Center;
iii) Expenditures by public extension institutions on extension activities for a particular commodity (estimates);
iv) Expenditures by chemical and other input companies on extension and promotion activities;
v) Expenditures by public and private product marketing firms on extension;
vi) Expenditures by farmer organisations (commodity associations and farmers' unions) on extension; and
vii) Expenditures of NGOs on research and extension.

(3) *Adoption Costs*:

i) Difference in the cost of seeds between MVs and TVs;
ii) Difference in the cost of chemicals between new and old pest and disease control methods;
iii) Difference in the use of labour and equipment between the new and old production practices;
iv) Difference in fertiliser usage between the MVs and TVs; and
v) Difference in the costs of harvesting, shelling, and other processes.

The personnel costs (that is, salaries and benefits) for the government and ICRISAT were summed up to obtain the figure for personnel costs incorporated in the analysis. The costs of salaries and benefits for ICRISAT staff associated with groundnut research were collected from human resources records and progress reports. The salaries and benefits for government staff working on groundnut were estimated and supplied by Chitedze Agricultural Research Station. The estimates are derived from the annual allocation of DARS budget to groundnut research by taking into account the number of staff working on groundnut and the proportion of their time spent on groundnut.

The figures for annual recurrent expenditures and depreciation costs allocated to groundnut were obtained from the annual reports compiled by researchers working on GIP. ICRISAT provided its annual recurrent figures associated with groundnut, which were combined with the figures from NARS.

Overhead and administration costs figures were derived from the accounting records provided by ICRISAT. These figures were given as percentages of the total costs of individual projects in which ICRISAT was involved. The percentage varied from 10 to 20% depending on the project.

For the adoption of new technologies, the major cost items were seeds, labour, and other farm inputs that went with the recommendations. These costs were estimated by NGOs such as Concern Universal engaged in GIP.

A considerable number of stakeholders were involved in the diffusion of groundnut technologies. The major ones were the government department of extension, seed companies, NGOs, and community based development groups. However, it was not possible to obtain technology transfer costs from the DAES. In consultation with researchers and extension staff, it was agreed that the estimates from Concern Universal would provide a reasonable guide for the government spending on groundnut extension. Their estimate was therefore taken and adjusted for the zones of the country to present the national average for each year. Some donor projects were also involved in extension programmes, whose costs were incorporated under research costs.

NPV and IRR

The benefits and costs of research, which is a long-term investment, are realised over time, and are measured in a common unit at any given point in time to facilitate comparison. This means that the analyst needs to convert the entire flow of benefits and costs into a single number. Discounting is considered to estimate the present value of flows of benefits and costs at any particular point in time. The most commonly adopted measures of a project's net worth are NPV and IRR.[4]

The NPV of a project is the sum of the discounted incremental net benefits, expressed as follows:

$$NPV = \sum_{i=0}^{T} \frac{B_i}{(1+r)^i} - \sum_{i=0}^{T} \frac{C_i}{(1+r)^i} = \sum_{i=0}^{T} R(B_i - C_i)$$

where r is the discount rate, T is the number of years, i is the year in which the costs and benefits occur, B_i is the benefit in year i, C_i is the cost in year i, and $R = \frac{1}{(1+r)^i}$ is a discount factor. The IRR is defined as the threshold discount rate that renders the NPV equal to zero. In other words, at r = IRR, the discounted incremental benefit is equal to the discounted incremental cost.

Other types of impacts

Although this study focuses on the economic impact, other types of impacts are discussed to a certain extent in a qualitative manner. This subsection outlines those other types of impacts, namely, spill-over effects, direct product (effectiveness) of research, intermediate/institutional impact, socio-cultural impact, and environmental impact.

Spill-over effects

Research results are often utilised over a range of agricultural production conditions or environments that can span across commodities, sectors, geographical and national boundaries.

Direct products of research (Effectiveness analysis)

Direct products of research include improved technology and specialised information. Effectiveness analysis assesses the performance of a project by focusing on the degree to which the project achieved its desired objectives. The emphasis is on evaluating the results against clearly defined goals, which requires measurable indicators, and some standard for measurement of success.

Sociocultural impact

Sociocultural impact is the final effects of research outputs on the attitude, beliefs, resource utilisation patterns, status of women and minorities, income distribution, nutrition status, empowerment of the target group, and so forth. The common method for assessing sociocultural impacts is to conduct socioeconomic surveys. In our study, an adoption survey is used to explore the sociocultural impacts of groundnut R&D investments.

Environmental impact

From time to time, the adoption of technologies leads to positive or negative externalities through impacting the surrounding environment. For instance, while chemicals such as pesticides and insecticides are used to reduce crop damage, some chemicals may harm biodiversity and/or cause pollution of water sources.

Data sources

Both published and unpublished sources were used to collect quantitative and qualitative information. The base scenario in the economic impact analysis is based on the data from the following sources: MoAFS (2010, 2011, 2012a, b), MoEPD (2011, 2012), NSO (2012), FAOSTAT (2015), ICRISAT's unpublished records and documentations, and unpublished reports by other researchers. These documents and records provide information on acreage, production, CPI, interest rates, export parity prices, price elasticities, costs of research and transfer, input and output prices, and other relevant indicators.

In addition to these, primary data are collected to feed into the sensitivity analysis as well as to provide insights in understanding the different types of impacts. The sources of the primary data are focus group discussions (FGDs), key informant interviews, and a household survey with groundnut farmers. The survey was conducted immediately after the 2012/2013 crop season, covering 1129 households.[5]

RESULTS AND DISCUSSION

Yield gains

Figure 7 shows proportions of yield gains from new technologies over the years, where the yields prior to 1982 are taken to be due to old technologies. Until 1995, the yield gain fluctuated largely and registered a negative gain in four of these years. The fluctuation was largely due to the unstable weather conditions. Since 1995,

[4] One other measure is benefit-cost ratio (BCR) which represents the relation between the present value of the benefits and the present value of the costs. The investment is considered profitable if the BCR is higher than 1.

[5] To keep the paper focused and succinct, most of the findings from the survey are not presented in this paper but are summarized in Appendix B of Tsusaka et al. (2015b).

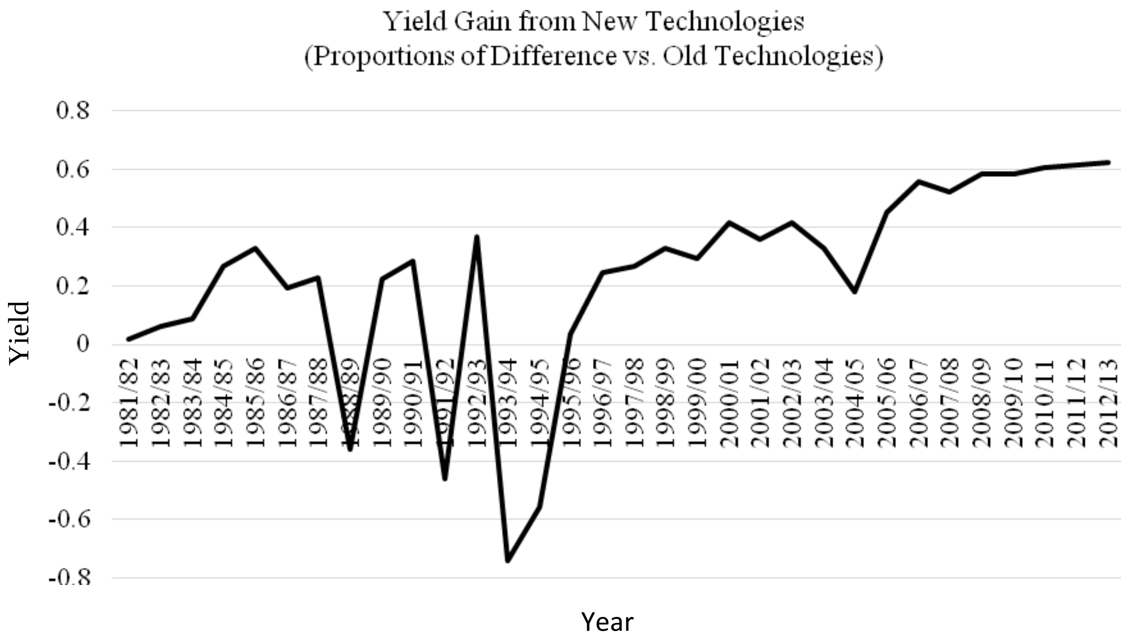

Figure 7. Yield advantage of improved groundnut varieties in Malawi, 1982-2013. Source: Authors' creation with data from MoAIW.

Table 2. Mean labor allocation to groundnut (person days, adult equivalent) by activity and area, 2012/13.

Labor type	Activity	Lakeshore				Central				Mzimba	Overall mean
		MH	KK	SA	Mean	KU	MC	LL	Mean	MZ	
Family	Ploughing	23	22	17	21	24	33	21	26	24	23
	Planting	3	4	3	4	4	4	4	4	5	4
	Weeding	17	19	13	16	20	27	17	21	22	19
	Harvesting (Lifting)	15	15	12	14	17	19	13	16	16	15
	Stripping and Shelling	12	18	12	14	21	21	14	19	26	18
Hired		14	21	24	19	30	24	36	31	41	26
Total		84	99	81	87	116	129	104	116	135	105

Source: Authors' calculation with the adoption survey 2013 data.

however, the gain has been constantly positive and growing at a steady pace, while stress-tolerant technologies disseminated.[6]

Reduction in opportunity cost

According to the adoption survey, the sampled farmers allocated a total of 105 (adult equivalent) days to cultivate the improved varieties (Table 2), which was considerably smaller than the 135 days typical for traditional varieties. Adoption of improved varieties therefore led to saving 30 person days of labour, and this saving was considered as an additional benefit to adoption. To convert the labour saving into monetary terms, US$ 0.90/day was used as the opportunity cost of labour.

Economic impacts

Base scenario

Figures 8 and 9 present the calculated net benefits for the period 1982 to 2013 by the AH method and the PEDPIS method, respectively. In both methods, the net benefits were negative in the first 10 years during the study period, and later turned positive. In addition to the adoption factor, land allocation to groundnut is another

[6] This observation is consistent with Tsusaka et al. (2015a)'s finding that it can take about one decade for popular improved varieties to adequately disseminate after their launch.

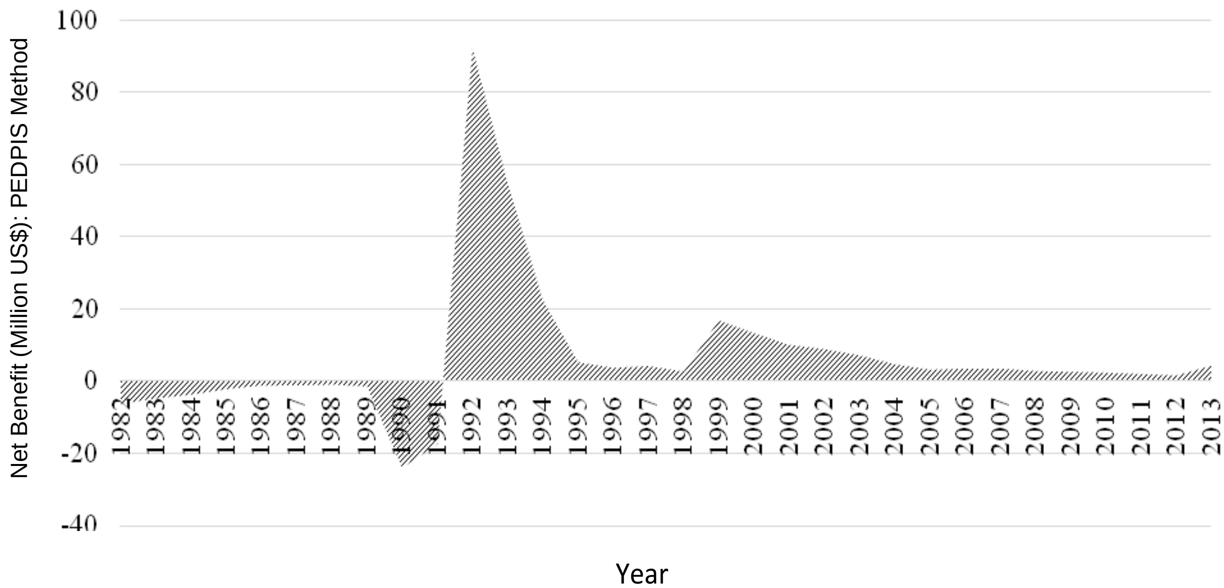

Figure 8. Estimated net benefits for groundnut R&D in Malawi, under the PEDPIS method, 1982-2013.

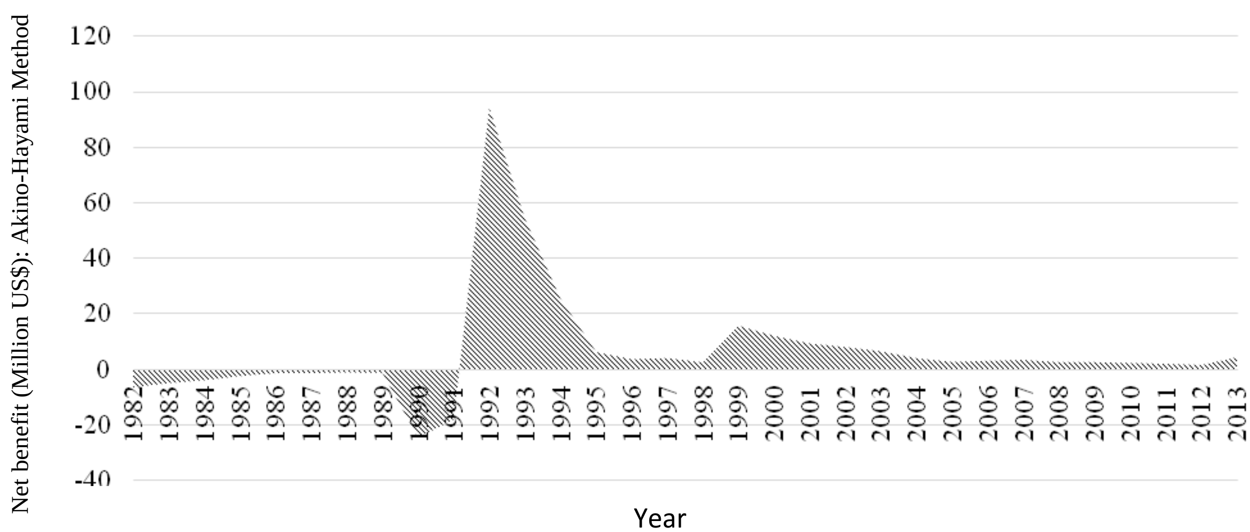

Figure 9. Estimated net benefits of groundnut R&D in Malawi, under the Akino-Hayami method, 1982-2013

factor affecting the benefits. When tobacco prices are relatively high, farmers allocate more land to tobacco at the expense of groundnut, and vice-versa.

As for the price elasticities of demand and supply for groundnut required in the AH method, reliable data were not available in Malawi, and we thus decided to find proxies. For the elasticity of demand, the case of groundnut in South Africa was adopted, which was -0.72 as estimated by van Schalkwyk (2003). For the elasticity of supply, Schiff and Montenegro (1995) and Chhibber (1989) argue that elasticities of supply in developing countries where farming rely on traditional tools such as hoes range from 0.3 to 0.5. Our study took the middle point (that is, 0.4) between the borders. Nonetheless, according to Masters et al. (1996) and Akino and Hayami, social benefits defined as the change in economic surplus in this method are not highly sensitive to the choice of elasticity parameters, which is also implied by the small difference in results between the two methods presented here.

Based on the stream of benefits and costs accruing over the years, the overall NPV and IRR of the groundnut R&D investment were calculated. The nominal long-term bond rate (social time preference) in Malawi was 36.5%

Table 3. Estimated net present value and internal rate of return for groundnut R&D investment in Malawi, 1982-2013: Base scenario.

Discount rate (%)	Net present value (Million US$)		Internal rate of return (%)	
	AH	PEDPIS	AH	PEDPIS
10.53	203.8	205.9	22	22
12.00	164.0	165.4	20	20
15.00	106.3	106.8	17	17

Source: Authors' calculation.

Table 4. Estimated net present value and internal rate of return for groundnut R&D investment in Malawi, 1982-2013: With increased research and extension costs.

Discount rate (%)	Net present value (Million US$)				Internal rate of return (%)			
	AH		PEDPIS		AH		PEDPIS	
	20% increase	50% increase	20% increase	50% increase	20% increase	50% increase	20% increase	50% increase
10.53	185.1	157.0	187.2	159.1	18	14	18	14
12.00	147.1	121.7	148.5	123.1	17	12	17	12
14.00	92.2	71.2	92.8	71.8	13	9	14	9

Source: Authors' calculation.

while the annual inflation rate was 23.5%.[7] From these, the computed real interest rate (opportunity cost of capital) was 10.53%. Table 3 presents the NPV and the associated IRR, calculated at 10.53, 12.00, and 15.00% real discount rates.

At the 10.53% discount rate, the IRR for both methods was found to be 22%, indicating that the investment in groundnut R&D in Malawi was not only profitable but also competitive against other investment options. The NPV at the same discount rate was estimated to be US$ 204 million with the Akino-Hayami method and US$ 206 million with the PEDPIS method, where the difference between the two methods was within 1%. As expected, the NPV decreased as the discount rate was raised. Nonetheless, the value remained positive at all considered discount rates, suggesting that the investment in GIP was profitable even at the higher end of discount rate assumption.

Sensitivity analysis

As previously mentioned, both the yields and costs data used in the analysis generally involved some assumptions on missing information. Taking this into account, a sensitivity analysis was conducted to examine the influence of modifying the assumptions for yields and costs on the economic impact estimates.

[7] According to Standard Bank Malawi in 2013.

Modifying research costs

The sensitivity to altering research costs (that is, personnel, recurrent expenditures, depreciation, adoption, and extension) was examined by increasing the research costs by 20 and 50%. As Table 4 shows, the increases in research costs led to decreases in NVP and IRR from the base scenario. Even so, the investments in groundnut research remained more or less profitable in view of the opportunity cost of capital in Malawi. However, as the discount rate was set at 14% and the research costs were raised by 50%, the IRR became 9%, indicating that the investment under this assumption was still profitable but lost its competitive edge over other investment options.

Modifying overheads and administration costs

Another sensitivity test was performed by doubling the overheads and administration costs (Table 5). Both the NPV and IRR exhibited sensitivity to this alteration. The NPV dropped to US$ 104 million and US$ 105 million for the respective methods. The IRR also decreased but remained higher than the opportunity cost of capital.

Using the yields from the adoption survey

The preceding analysis used the historical data provided by MoAIW to generate the yield advantage of the new

Table 5. Estimated net present value and internal rate of return for groundnut R&D investment in Malawi, 1982-2013: With doubled overheads and administration costs.

Discount rate (%)	Net present value (Million US$)		Internal rate of return (%)	
	AH	PEDPIS	AH	PEDPIS
10.53	200.8	202.9	21	21
12.00	161.3	162.7	19	20
15.00	104.1	104.6	16	16

Source: Authors' calculation.

Table 6. Estimated net present value and internal rate of return for groundnut R&D investment in Malawi, 1982-2013: With the yield advantage based on the adoption survey.

Discount rate (%)	Net present value (Million US$)		Internal rate of return (%)	
	AH	PEDPIS	AH	PEDPIS
10.53	179.9	185.2	21	22
12.00	146.4	151.0	20	21
15.00	96.6	100.0	17	18

Source: Authors' calculation.

technologies over the old ones. This time, we take the yields computed from the survey data. According to the survey, the yield was 552 kg/ha for CG7, 619 kg/ha for Nsinjiro, 406 kg/ha for Kakoma, 533 kg/ha for Baka, 700 kg/ha for Chitala, and 509 kg/ha for traditional varieties. The weighted average yield for improved varieties was derived using the proportion of area planted to each variety: 54% of the total area devoted to improved varieties was sown to CG7, 31% to Nsinjiro, and 5% to each of the remaining three varieties. As a result, the weighted average yield for the five improved varieties turned out to be 572 kg/ha, which translated to the yield advantage of 63 kg/ha. Table 6 presents the result based on the yield gain from the survey data. The result was largely similar to that in Table 3. Therefore, the investment in groundnut R&D remained profitable and competitive, under this assumption.

Increasing the yield to 1500 kg/ha

Lastly, the sensitivity to a rosy assumption of the new yield achieving 1500 kg/ha was tested (Table 7). Achieving this yield level would further boost the profitability and competitiveness of investments in groundnut R&D. The IRR jumped to over 30% for both methods. The NPV increased by US$ 49 million (Akino-Hayami Method) and US$ 78 million (PEDPIS Method) from the base scenario, at the 10.53% discount rate.

Other types of impacts

Spill-over effects

Table 8 presents the groundnut varieties originally released in Malawi, along with the countries benefited from the spillover of each variety. In principle, cultivars that have been extensively tested and evaluated in one country can be considered for accelerated release in neighbouring countries. For example, it took almost seven years for CG7 to proceed from the initial varietal testing to final release. When it was introduced in other countries, however, this period was shortened to 2 to 3 years. The reduction in lead time greatly curtails the cost of varietal development and release in spillover countries.[8] As this type of spillover leads to resource savings enjoyed outside Malawi, the benefits from this effect were not incorporated in the economic impact in Malawi.

Another dimension of spillover occurs through capacity development. Under GIP, both short-term and long-term trainings have remarkably benefited farmers, scientists, and technicians. Over time, many of these scientists as well as technicians have worked on other commodities, especially legume crops.

Thus, it can safely be said that the knowledge gained from training on groundnut has rendered positive inter-commodity spillovers. Citation analysis is often used as a proxy for knowledge spillover through research publications. In our study, an attempt was made to compile the summary statistics of the publications cited by other publications during the 1994 to 2001 period.[9] There were 147 citations of the different publications, demonstrating the knowledge spillovers of groundnut R&D into other commodities.

[8] Note that technologies other than germplasm such as cultural practices and fertiliser management tend to be more site-specific and offer limited opportunities for spillover.

[9] The citation analysis is based on Google Scholar.

Table 7. Estimated net present value and internal rate of return for groundnut R&D investment in Malawi, 1982-2013: With the new yield of 1,500 kg/ha.

Discount rate (%)	Net present value (Million US$)		Internal rate return (%)	
	AH	PEDPIS	AH	PEDPIS
10.53	253.0	283.4	35	36
12.00	206.1	232.0	33	34
15.00	138.2	157.4	30	31

Source: Authors' calculation.

Table 8. Groundnut R&D technology spillovers.

Variety selected in Malawi	Spill-over country
Chipego	Zambia
ICGM 286	Rwanda
ICGMS 42	Zambia
ICGV-SM 86066	Rwanda
ICGV-SM 85038	Rwanda
ICGV-SM 86080	Rwanda
Stella	Mauritus
Veronica	Mauritius
CG7	Zambia (MGV4)
ICGV-SM 90704	Zambia (Chishango), Mozambique (Mamane)
JL 24	Zambia (Leuna)
ICG 12991	Mozambique (Nametil)

Local names are in parentheses. Source: Data from ICRISAT.

Direct product of research

Broad output categories that are common to most agricultural R&D programmes are (1) seed improvement, (2) crop management, (3) publications, (4) capacity development, and (5) dissemination schemes, among others (Peterson et al., 2003). This paper refrains from presenting the list of outputs of GIP as the list is extremely long.[10]

Socio-cultural impacts

Food and Nutritional Security: About 77% of the sampled farmers indicated that the adoption of improved groundnut varieties had improved the food security status. 82% of the farmers experienced an increase in groundnut consumption. 19% exchanged groundnut with other food. Almost 50% used income from groundnut to buy food, and 40% used it to purchase farm inputs. Farmers also used this additional income to purchase livestock. These findings demonstrate that the new technologies of groundnut have significantly contributed to improving the food and nutrition security in Malawi.

Gender: Much of the processes in groundnut production are handled by women (Orr et al., 2014), especially the labour intensive post-harvest processes. For instance, while the traditional groundnut varieties are of spreading type, involving considerable labour in harvesting, the improved varieties are of the 'bunch' type and easier to harvest. Thus, the adoption of new technologies is expected to have reduced women's drudgery at harvest. Besides, CG7 is also easy to strip (that is, separate pods from the harvested plant), which must have led to labour saving for women.

Environmental impacts

Many of the recommended groundnut management practices have positive impacts on the environment. As a common practice in Malawi, groundnut is grown on ridges formed across the slope of land. This helps control the flow of rain water and to prevent the soil erosion. Other common practices are intercropping, crop rotation, and ploughing beneath crop residues, which contribute to

[10] The list of direct outputs of groundnut R&D can be found in Appendix A of Tsusaka et al. (2015b).

improving soil structure, texture, and fertility. Screening and selection of early-maturing groundnut cultivars for production in areas prone to rust disease and late leaf spot as well as pests help reduce the need for chemicals that tend to pollute the natural environment.

One of the negative externalities of groundnut production is the effect of aflatoxin on human health. Aflatoxin is carcinogenic to human beings.

Concluding remarks

The study provides for the first impact assessment of groundnut R&D over the past three decades in Malawi, with a focus on economic impacts. Using the economic surplus approach, the NPV estimated at the discount rate equivalent to the opportunity cost of capital was more than US$ 200 million with the IRR being 22%, under the base scenario. The result is in line with the observed increase in groundnut production led by improved technologies developed and disseminated by the R&D activities. The NPV and IRR are somewhat sensitive to varying assumptions on discount rate, groundnut yield, and cost items. Yet, in most cases, the estimated IRR suggests that investment in groundnut R&D has been profitable and competitive, and thus benefited consumers and producers in Malawi. Our estimated IRR is slightly lower than the aggregate IRR to agricultural R&D in Africa (27 to 44%) as calculated by Alene (2010). Nonetheless, the majority of the investments were made for staple crops including star crops such as wheat and rice. As for long-term crop-specific R&D for legumes in sub-Saharan Africa, there are a couple of notable cases found for cowpea: the IRR was estimated to be 15% for the 20-year investment in Cameroon (Sterns and Bernsten, 1994) and 13% for the 38-year investment in Senegal (Boys et al., 2007), with which our result compares favourably. Furthermore, Maredia et al. (1998) argue that in many cases, the immediate benefit from agricultural R&D is negative while it turns positive in the long run. Figures 8 and 9 imply a similar story, and continued investment is therefore suggested.

The social and environmental impacts cannot be divorced from the economic impact to the society. This study showed that so many beneficiaries of groundnut technologies perceived improved food security and reduced poverty. From the gender perspective, the early maturing varieties with the shapes easier for lifting and stripping must have alleviated drudgery, particularly for women. The improved crop management practices helps in conserving the environment through better control over rain water flow, prevention of soil erosion, and retention of soil fertility. The crop resistance to diseases and pests contributes to reducing the need for applying chemicals that may pollute the environments.

Given the limited public funding, the following intervention areas are suggested based on the information gathered in this study: (1) Developing improved seeds remains to be an essential vehicle for generating impacts on society. It is however worth noting that it may take about a decade for released technologies to start benefiting the society. (2) Groundnut farmers heavily recycle seeds of improved varieties, limiting the crop performance. The ability of the seed markets to provide sufficient seeds is critical in promoting the adoption of available technologies among smallholders. (3) 70% of the farmers never received extension services on groundnut production since the government extension service faces serious resource constraints including the shortage of extension staff. Provision of extension services to smallholders should be given a high priority in the agricultural policy agenda.

The major limitation to precise assessment of the impact of R&D investments is the lack of reliable data and consistent record keeping, which is true of the entire research system in Malawi and many other developing countries. The dearth of classified data prevents the estimation of the benefits of individual technologies. Although external partners contributed to the R&D at different periods, there is no office where all the information is centralised and maintained. In addition, the unavailability of reliable supply elasticity estimates hampered the use of the ANP method in estimating the gross benefits of R&D. In this study, the data limitation was basically addressed by conducting a sensitivity analysis with varying assumptions on costs and benefits. In all likelihood, there is a need to establish an effective monitoring and evaluation system to assess the performance of technologies and improve the accountability of agricultural research programmes.

Conflict of Interests

The authors have not declared any conflict of interests.

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