BENEFITS AND COSTS OF GROUNDNUT AND SOYBEAN PRODUCTION: A FARM LEVEL ANALYSIS FOR MALAWI

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and
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FINAL REPORT

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ACRONYMS

SSA	Sub-Saharan Africa
AgDiv	Malawi Agricultural Diversification Activity
GM	Gross Margin
GM/ha	Gross Margin per hectare
TV	Treated Villages
T	Treated farmers
T1	Ingrower farmers
T2	Outgrower farmers
CV	Control Villages
C1	Neighbor Control farmers
C2	Non-Neighbor Control farmers
MWK	Malawian Kwacha
S1	Cost Scenario 1
S2	Cost Scenario 2
S3	Cost Scenario 3
S4	Cost Scenario 4
IC1	Innovation Combination 1
IC2	Innovation Combination 2
IC3	Innovation Combination 3
IC4	Innovation Combination 4
TVC	Total Variable Cost

1. INTRODUCTION

Agricultural productivity growth is widely viewed as a necessary strategy for overall economic growth and development in Sub-Saharan Africa (SSA). In recent decades, the region's moderate productivity growth, while received with optimism, has been flagged as needing more rapid gains (Fuglie and Rada 2012; Nin-Pratt 2015). Expediting productivity gains requires sustained improvements in technological progress and technical efficiency. The former corresponds to an outward shift in the production frontier stemming from the adoption of innovations, while the latter is a proxy for managerial performance reflected as movements closer to the frontier given input levels, the production environment and the technology (Bravo-Ureta, 2014; Njuki, Bravo-Ureta, & O'Donnell, 2018). Considering that productivity growth is closely tied to farm-level innovations and how well they are managed, measuring productivity and profitability is an essential step in generating the evidence and designing strategies required for the successful scaling of promising technological options.

In Malawi, private agricultural extension services to smallholder farmers that complement government extension delivery has been picking up momentum. Over the past decade, the Country has witnessed the rise of a privately driven farm business model known as anchor farming (e.g. Tukula Farms and Horizon Farms). In this model, a large commercial farm serves as a hub of innovative farming practices and extends knowledge to its network of village-based farmer clubs, comprised of outgrowers and ingrowers[1]. The ultimate objective of such an anchor farm is usually to increase farmer productivity and incomes, and improve livelihoods (Alliance for Green Revolution in Africa, 2015; Clinton Development Initiative, 2018).

The USAID-funded Malawi Agricultural Diversification Activity (AgDiv) has partnered with the Feed the Future Innovation Lab for Peanut (Peanut Innovation Lab), and other private organizations to transfer research-based innovations to their networks of smallholder farmers. Developing rigorous evidence of anchor farms as channels for promoting adoption and scaling technologies buttresses the basis on which such farms could be strategic entry points for agricultural development initiatives.

The available literature reveals a dearth of rigorous research on the contribution of anchor farms to smallholder outcomes. The few studies (e.g. Alliance for Green Revolution in Africa 2015; Maertens and Michelson 2017) suggest a positive role for anchor farms on diffusion of technologies, multiplication of seeds, investment in infrastructure, development of local capacity, and gains in yields and revenues. Considerable additional work is needed to carefully document the changes in production outcomes associated with innovations and with anchor farm participation.

[1] Outgrower farmers are members of village-based farmer clubs or organizations who receive extension services from an anchor farm and cultivate their own plots, mostly in their villages. Ingrowers, are similar to outgrowers, but in addition to their own plots they cultivate plots allocated to them within the anchor farm.

The general objective of this report is to examine the variability of various indicators based on baseline data for a sample of groundnut and soybean farmers in Malawi. The specific objectives are:

1. To analyze yield and gross margin (GM) differentials across farmer types and District;
2. To analyze yield and GM differentials across gender and Districts;
3. To analyze yield and GM differentials for several on-farm innovations across gender and farm size.

The report is organized into four additional sections: In section 2 we discuss the sampling design, data collection, the choice and calculation of outcome indicators, output price, and the structure of production costs. In Section 3, we present results of socio-demographic and production characteristics of farm managers and their households; and analysis of heterogeneity in yield and GM/ha by farmer type and District; gender and District; individual on-farm innovations by gender and farm size; and combinations of innovations. In Section 4 we summarize the main findings and conclude.

2. METHODOLOGY

In this section we present the sampling design, data collection method, and calculation of outcome indicators – yield and GM. We also discuss the procedures and assumptions underlying the calculation of cost of production, and the construction of different cost scenarios as the basis for generating alternative GM estimates. Finally, we discuss the categorization of on-farm innovations and farm size, which are used in a heterogeneity analysis.

2.1 Study Design and Sampling

The study was conducted in three Districts within the Central Region of Malawi, namely, Lilongwe, Mchinji, and Salima. These Districts were of initial interest to the Project[2] and represent three of four sites in the Central Region, where Exagris and/or Horizon Farms have operated. We defined the study population as all farmers who cultivate groundnut and/or soybean within and outside the anchor farms' sphere of influence. Two categories of villages and four categories of farmers were defined as follows:

1) Treated Villages (TV) – villages where farmers affiliated with Exagris/Horizon Farms live and farm.
    - Ingrowers (T1) – farmers that operate plots assigned by Exagris/Horizon Farms in addition to their own plots.
    - Outgrowers (T2) – farmers that do not have plots assigned by Exagris/Horizon Farms and operate only their own plots
    - Neighbor Control (C1) – farmers that live in treated villages but do not work with anchor farms and operate only their own plots

2) Control Villages (CV) – villages similar to the treated ones but outside the area of influence of Exagris/Horizon Farms.
    - Non-Neighbor Control (C2) – farmers that live in control villages and operate only their own plots

We carried out a power analysis (see Bravo-Ureta and Owusu 2019 for details) to determine the minimum sample size required for detection of anchor farm effects (if present). The survey involved one-on-one interviews with individuals that managed their groundnut and/or soybean plots or, if that individual was not available, an alternative household (HH) member with knowledge about the HH's farm operations (*viz*. spouse or adult HH member).

2.2 Data Collection

Data collection relied on two survey instruments: an individual farmer questionnaire; and a village head questionnaire. The farmer questionnaire focused on household structure; farming activities (e.g. input use, cost of production, farming techniques/methods, output produced and utilization, market integration, farm and non-farm income flows, irrigation

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[2] "The Project" implies the AgDiv-PMIL/Peanut Innovation Lab-Anchor farms collaborative platform.

technology adoption); institutional support to the farm (e.g. credit, extension); and resilience-related questions.

The village head questionnaire sought information on village demographics, agricultural practices and challenges, and availability of key resources and amenities. The questions were broadly adapted from the World Bank's Living Standard Measurement Survey for Malawi and tailored to the objectives of this project. Draft questionnaires were prepared by the P.I. and R.A. and were then reviewed by the key Project stakeholders. Electronic versions of both questionnaires were developed using the World Bank's Computer-Assisted Personal Interviewing (CAPI) Platform (Survey Solutions).

Enumerators were recruited by advertising the positions in the city of Lilongwe. Interested individuals submitted CVs that were screened by the PI and other members of the survey management team. Shortlisted individuals had at least a bachelor's degree in agricultural-related programs and had prior experience in large-scale farm data collection in Malawi. The candidates were trained at the *Kumudzi* Eco Center (near the Lilongwe University of Agriculture and Natural Resources or LUANAR) over the period August 9–23, 2017. The group was introduced to the Project stakeholders, the objectives of the study and the structure of the field work. A presentation and discussion focusing on ethical standards of data collection involving human subjects was an important component of the training. Then, the contents of the questionnaires were reviewed in detail (in the English language) to make sure individual enumerators understood the logic of every question, and to verify if the wording was appropriate for the local context. In collaboration with our local partners on the ground, the team was taken through one-on-one mock sessions to practice on the appropriate way to pose the questions in the local language – *Chichewa*. Five rounds of field-testing of the farmer questionnaire were carried out. The first two rounds used the paper-based or hardcopy format and the subsequent three rounds were done with the tablet – electronic format. A debriefing session to gather feedback, incorporate questionnaire changes, and address any bugs in the survey codes followed each round of field-testing.

The target respondent was the farm manager. If not available, an alternative household member with knowledge about the household's farm operations (*viz*. spouse or adult household representative) was interviewed. For the village-level interview, the target respondent was the village head. In his absence, any village elder with deep information about the village could respond. If selected farmers would not be available for the interview for any reason throughout the day(s) the team was in the village, a pre-specified replacement was provided. Usually, prior to the team's visit to a given village, the regional extension agent or Exagris/Horizon Farms officers would contact the village leader and farmers to let them know the day the enumerators would be visiting the village to conduct the interviews. On the day of the visit, the extension officers would also assist in identifying the selected farmers or replacements as needed.

Data collection began on September 14, 2017 and ended on January 31, 2018 with intermittent delays during this period. From February 1 to the beginning of April extensive work was undertaken to verify farmer treatment status and associated issues. Additional general data cleaning and consultations with the field team continued through the beginning of July 2018.

A total of 179 villages were visited. The dataset is composed of interviews with 178 village-heads and 2,600 farmers. The sample is comprised of 1,331 treated (T1+T2), and 1,269 control (622 C1 and 647 C2) farmers (Figure 1).

In this report, we focus on the groundnut and soybean samples. The total number of farmers that cultivated groundnut in the 2016/17 major production season is 1,802, and the number that cultivated soybean is 1,248 (Figure 2). A total of 929 farmers cultivated both groundnut and soybean.

2.3 Outcome Variables

We selected yield and GM as the outcome indicators because they allow us to capture both technical and economic outcomes associated with the production process. These indicators are defined as follows:

Yield (Y): Is the ratio of total output (Q) in kilograms (kg) to total area cultivated (A) in hectares (ha). The yield (kg/ha) of crop j (groundnut or soybean) for farm i is expressed as:

$$Y_{ji} = \frac{Q_{ji}}{A_{ji}} \qquad (1)$$

Total output was converted from units used locally into kgs. The conversion factors are presented in Table A-1 in the *Appendix*.

Gross Margin: Is the difference between the total value of production and total variable cost, all in Malawian Kwacha (MWK)[3]. Denoting the price of output by P_j, variable input by z_j with a price of w_j, the GM of crop j for farm i is expressed as,

$$\text{GM}_{ji} = P_{ji}Q_{ji} - \sum_k w_{jik}z_{jik} \qquad (2)$$

where, $P_{ji}Q_{ji}$ is the total value of output and $\sum_k w_{jik}z_{jik}$ is the total variable cost of production calculated by summing over k inputs.

In the case of farms cultivating more than one groundnut and/or soybean plot, we summed the cultivated area, output and input quantities over those plots. For plots with intercrops or mixed stands (e.g. maize & soybean, groundnut & soybean, gnut & pumpkin, etc.), we adjusted the costs related to land preparation (clearing, plowing, ridging) and weed control (herbicide, herbicide application, hand weeding) using the proportion of the value of output for the relevant crop in total value of output of all crops in a mixed stand. Data for all other

[3] MWK is Malawian Kwacha. In 2018 MWK 714 = US $1

inputs was captured specifically for the relevant crop. We observe that fewer number of farms, about 15% for groundnut and 19% for soybean, operate some type of mixed stand.

2.4 Output Price, Cost Components and Cost Scenarios

Output Price

We collected output price data for May, June & July, August & September, and October & November. However, we used the average June & July price for both crops, which are the months following harvest in which most farmers sell their output. The average price for groundnut is MWK 232.5 per kg, and MWK 138.2 per kg for soybean.

Cost Components

The main cost items associated with groundnut and soybean production systems are:

Land: Farmers cultivate on both owned and rented plots. Major sources of land, beyond what is owned, include renting, and allocation by family and by local village leaders. The data indicates that 25% of groundnut farmers and 22% of soybean farmers rented plots. In this study, the land cost comprises the cash paid for rented plots and the value of owned land. The average rental rates calculated from the data are MWK 13,067/acre in Lilongwe, MWK 15,000/acre in Mchinji, and MWK 10,750/acre in Salima.

Labor: Both family and hired labor are utilized in production. The data shows that 40% of groundnut farms supplemented family labor with hired workers, compared to 23% of soybean farms. Thus, labor cost comprises cash cost for hired labor and the value of family labor.

Family labor used in all agronomic practices - *land preparation (clearing, plowing, ridging), planting, weed control, pest control, fertility management, and harvesting* - is measured in worker equivalents (w.eq). The weights used are: 1 for an adult male; 0.8 for an adult female; and 0.5 for children ages 12 and below (Burke, Hichaambwa, Banda, & Jayne, 2011). We use District-level average daily wages generated from the data to impute the opportunity cost of family labor.

Seed: Various seed varieties are planted by farmers in our sample. These can be grouped into improved and traditional landrace varieties.

Improved groundnut varieties include *CG7, Chitala, Nsinjiro, JL24/Kakoma, Baka, Gambia, Spanish, "CADECOM", "ICRISAT"*, and *"NASFAM"*. Traditional landrace groundnut varieties consist of *Chalimbana, Nambwindi, Chitembana, Manipintar, Mawanga, Malimba, Kamlomo/Kanlomo, Mkhalatsonga, Kandiya, Kalisere, Katelela, Katerera, Kamunjute*, and *"Local"*.[4] Improved varieties of soybean are *Makwacha, Tikolore, Nasoko, Serenade, Squire, and "Chitedze"*. Traditional landrace soybean varieties are only identified as *"Local"*.

[4] Farmer only knows groundnut planted as a local variety.

In terms of the seed source, about 42% of groundnut and 36% of soybean farmers used recycled seeds. The rest purchased seeds mainly from local, District, and regional input dealers. The cash cost of purchased seed and value of own seeds constitute the cost of seed. We valued own seeds using District-level average prices in the data.

Agrochemicals: Use of agrochemicals *viz*. fertilizer, weedicide/herbicide, pesticide/fungicide, and inoculant, is minimal in groundnut and soybean production. In our data, only 2% of groundnut and 5% of soybean farmers applied some type of fertilizer (organic or inorganic) while just about 5% of groundnut and 3% of soybean farmers applied herbicides. Similarly, a low proportion of farmers, 3% and 6% respectively, applied pesticides/fungicides. Inoculant use is even lower with 0.2% for groundnut and 3.2% for soybean producers. We included the total purchase value as reported by farmers for these inputs in our cost calculations.

Cost Scenarios

To gain insights into returns under different cost configurations, we define four cost scenarios:

Scenario 1 (S1): Composed of only *cash costs* of production, i.e. expenditures on hired labor, seeds and agrochemicals, and rent paid on land.

Scenario 2 (S2): Comprised of *cash costs* (S1), plus the value of own seeds and the value of non-purchased agrochemicals.

Scenario 3 (S3): Includes S2 plus the opportunity cost of family labor.

Scenario 4 (S4): Is equal to S3 plus the value of own land.

2.5 On-farm Innovations and farm size categories

On-farm Innovations

On-farm innovations are defined in this study as alternative management techniques or improved inputs used in the production process (from land preparation to harvesting). We identified four innovations related to seed quality and planting that are generally promoted in groundnut and soybean farming. These innovations are:

Use of treated seeds: Pertains to the use of inoculant- and/or fungicide-treated seeds. This is a dichotomous variable assigned a value of 1 when “treated seed is used” and 0 otherwise.

Seed type: Refers to whether the seed variety planted is improved or traditional landrace. This variable is also dichotomous with 1 for “improved” varieties and 0 for “traditional”.

Rows per ridge: Defines the number of rows planted per ridge. It is dichotomous with 1 for “double row” and 0 for “single row”.

Planting date: Measured as a categorical variable based on whether planting was done *before*, *during* or *after* December in the 2016/17 production season. The categories are coded as: 0 for planting in December (common practice); 1 for planting before December (early); and 2 for planting after December (late).

Beyond analyzing heterogeneity in yield and GM associated with individual innovations, we also examine heterogeneity for four different combinations of individual innovations defined as follows:

IC1= Innovation Combination 1: Improved variety and early planting

IC2 = Innovation Combination 2: Improved variety and double row planting

IC3 = Innovation Combination 3: Improved variety, double row, and early planting

IC4 = Innovation Combination 4: Improved variety, double row, early planting, and treated seed

Farm Size

We categorize farm size into large and small based on the median value (1.01 ha) of total plot area of the household, independent of the cropping pattern. It is noteworthy that 33% of the total land was cultivated to groundnut and 31% to soybean. Large farms are those greater than or equal to the median size and small farms are those below the median size.

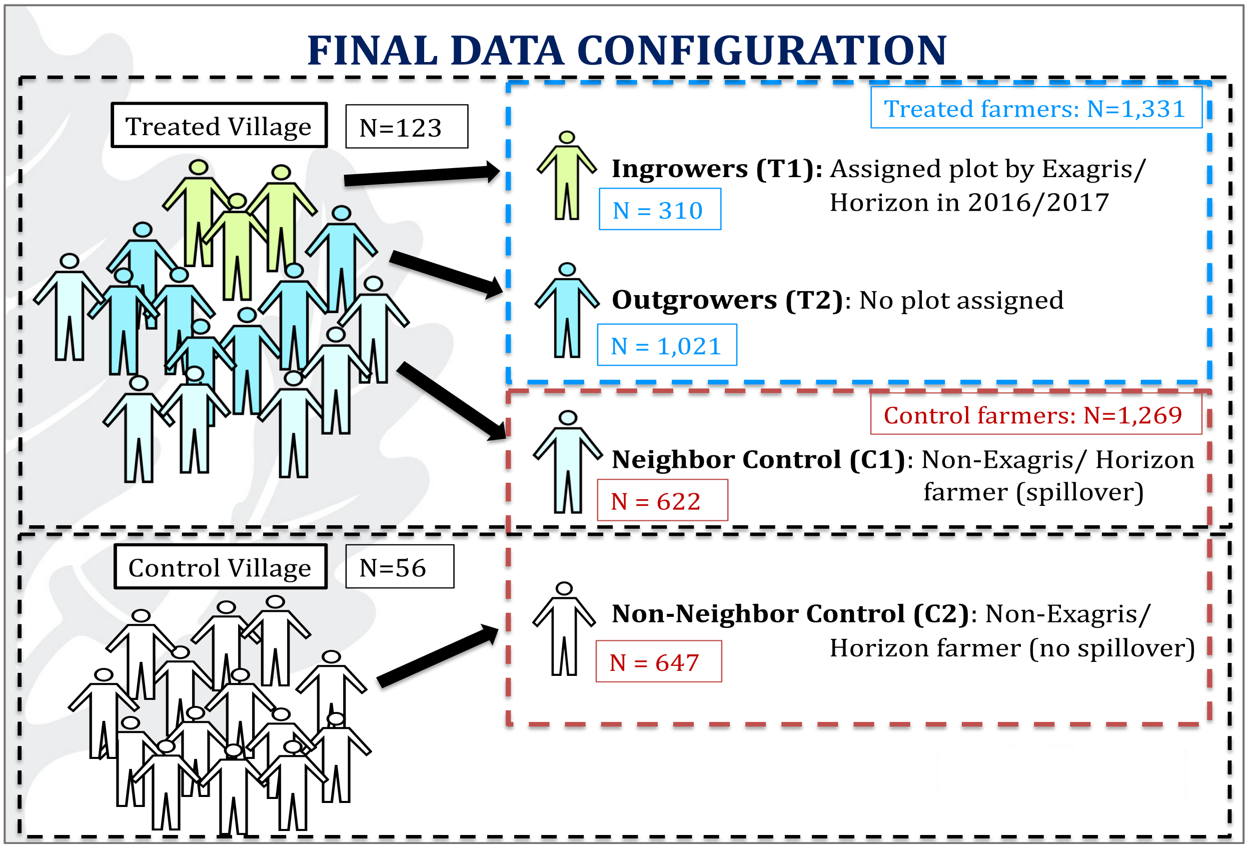


Figure 1: Final sub-samples by village type and farmer category

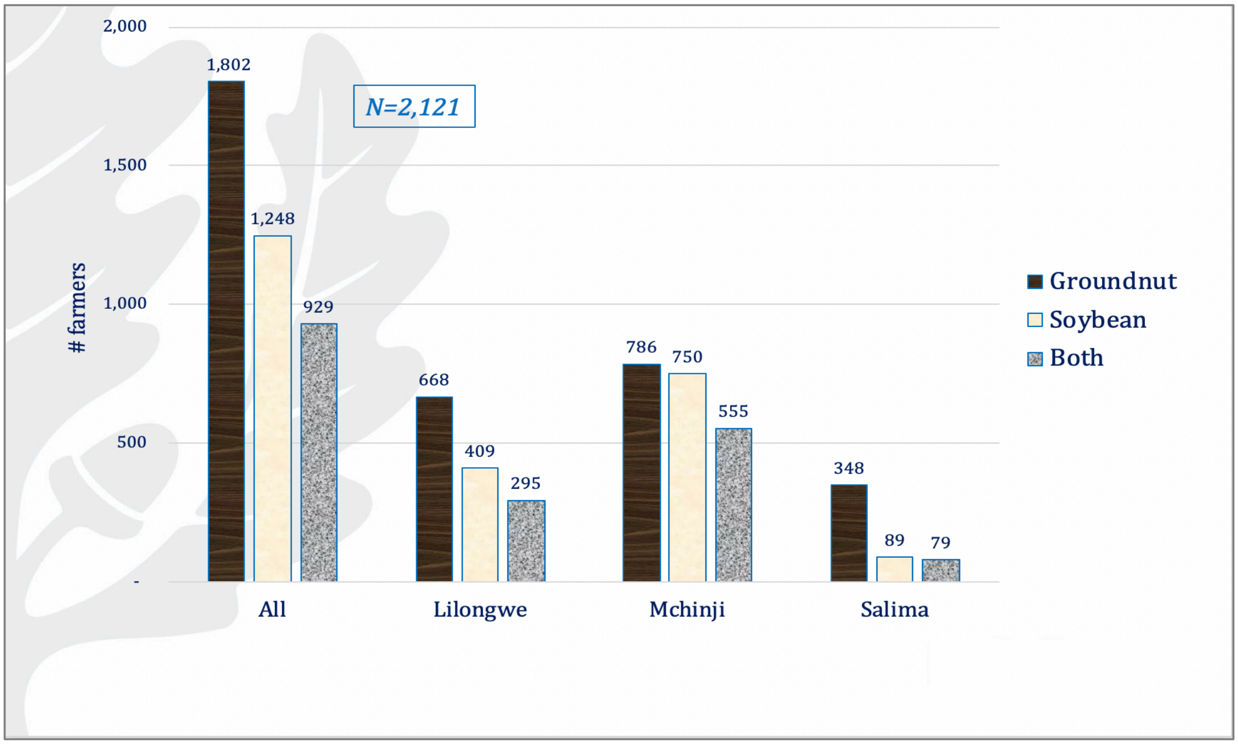


Figure 2: The sample of groundnut and/or soybean farmers: Total and by District

3. RESULTS

In this section we present the main findings of our analysis separated into five sub-sections. Sub-section 3.1 gives a synoptic account of socio-demographic and production characteristics pertaining to groundnut and/or soybean farming. Sub-section 3.2 presents summaries of cost, value of output, GM/ha and Benefit-Cost ratio (B/C); Sub-section 3.3 examines yield and GM associated with farmer type (T, C1, and C2) and District (Lilongwe, Mchinji, and Salima). Sub-section 3.4. contains a discussion of the association between yields and GMs, and gender and farm size across various innovations (e.g. improved seeds, early planting, etc.). Sub-section 3.5 examines the connection between the bundling of innovations, and yield and GM. In Sub-sections 3.3, 3.4, and 3.5, we use GM/ha obtained from cost scenario 2 (S2). Statistical tests are conducted using the *Student t* and significance at the 5% level.

3.1 Socio-demographic and Production Characteristics

The key socio-demographic attributes are summarized in Table 1, and they include: age, years of schooling, and gender of the farm manager; HH size, dependency ratio, and gender of the HH head. For the entire sample, the mean age is about 42 yrs, with a slightly above average age (43 years) in Salima District. On average, farm managers have 6 years of formal education, ranging from a low of 5 years in Lilongwe to a high of 6 yrs in Mchinji. For the full sample, the majority of managers is male (53%), which is driven by Mchinji District where female managers predominate (61%) compared to the other two Districts, Lilongwe (52%) and Salima (59%).

A typical HH has about 5 members, with Mchinji exhibiting the highest number (close to 6 members) and Lilongwe the lowest (around 5) (Table 1). The average dependency ratio is 1.1, which is defined as the total number of HH members younger than 15 and older than 64 (economically dependent) divided by the number aged 15 to 64 years (independent). Most HHs (84%) have male heads and this is consistent across Districts.

Table 1 also shows summaries of total land held by HHs, total cultivated area and crop-specific cultivated area. Average land held by HHs is 1.19 ha, of which 1.17 ha (98%) was cultivated. On average, HHs put 0.39 ha into groundnut and 0.37 ha into soybean. Geographically, HHs in Mchinji cultivated 0.43 ha for both crops while in Salima groundnut producers cultivated 0.42 ha.

Figure 3 shows average yields for groundnut and soybean, for the pooled sample and by District. On the basis of the pooled sample, the average yield for groundnut is 855 kg/ha and 882 kg/ha for soybean. Mean yield by District for groundnut ranges from 766 kg/ha in Salima to 934 kg/ha in Mchinji and for soybean ranges from 704 kg/ha in Lilongwe to 987 kg/ha in Mchinji. Mchinji, thus, is associated with the highest mean yields (934 kg/ha and 987 kg/ha) for both crops.

Minimal mechanization is observed in Malawi, as is the case for most African farms (Kirui & von Braun, 2018), which places a heavy burden on workers. We analyze labor requirement (in worker equivalents) of various agronomic practices by computing the respective shares in total labor. On average, the total labor days involved in production is 66.3 worker equivalents (w.eq) for groundnut (26.4% hired; 73.6% family), and 42.2 w.eq for soybean (16.1% hired; 83.9% family).

Labor shares by agronomic practice for groundnut and soybean are shown in Figure 4. Land preparation accounts for 40% of total labor in groundnut and 47% in soybean; thus, this activity constitutes the major labor-using practice. The data also show that the bulk (>85%) of farm labor needs in both crops comes from land preparation, harvesting, and weed control.

3.2 Variable Costs, Value of Output, Gross Margin and Benefit-Cost Ratio

Table 2 summarizes the variable costs, value of output, GM/ha and B/C for each crop. Considering only cash cost of production (column (1)), the average total variable cost (TVC) per ha is MWK 49,767 for groundnut and MWK 33,216 for soybean. Average TVC increases respectively by 22% and 18% when the value of non-purchased seeds and organic fertilizer are added, the case of column (2); and by 337% and 394% when family labor is also considered (column (3)). Accounting for all indirect variable costs of production (column (4)) leads to 388% and 470% increases in TVC for groundnut and soybean, respectively.

Cost shares of the various inputs are shown in Figure 5. Among inputs, labor accounts for the largest share of TVC under all cost scenarios, ranging from 51% in S1 to 75% in S4 for groundnut, and from 40% in S1 to 73% in S4 for soybean (Figure 5). Considering only cash costs (S1), seed is the second most costly item and makes up about a third of total cost. However, when all inputs are valued (S4), land becomes the second most prominent cost item, and accounts for about 14-17% of total cost. The cost share of agro-chemicals is the lowest (<9%), reflecting their minimal use in both production systems.

The average value of output per ha is MWK 198,763 for groundnut and MWK 121,951 for soybean (Table 2).

GM/ha averages are also shown in Table 2. We find that these averages are positive under S1 and S2 but negative under S3 and S4. Thus, when only cash costs are considered, average returns to non-purchased inputs (GMs/ha in S1) are MWK 148,996 for groundnuts and MWK 88,734 for soybean. Similarly, the average returns to family labor and owned land (GM/ha in S2) are MWK 138,043 for groundnut and 82,767 for soybean. However, costs grow over three-fold in S3 and S4; hence, all positive returns are erased leading to negative GM/ha. Computed B/C for both crops are well above the breakeven point for S1 (4.8 and 5.3) and S2 (4.6 and 5.0), and below breakeven for S3 (0.9 and 0.8) and S4 (0.8 and 0.7).

3.3 Yield and Gross Margin by Farmer Type and District

Table 3 presents descriptive summaries and statistical comparisons for yield and GM/ha across farmer types (T *versus* C1 and T *versus* C2) for the pooled sample and by Districts.

For the entire sample, the average groundnut yield is 861 kg/ha for T, 856 kg/ha for C1 and 841 kg/ha for C2. The values range from a low of 669 kg/ha for C2 in Salima to a high of 1,005 kg/ha for C1 in Mchinji. The difference (Diff) in yields between T and C1 is not significant for the pooled sample across Districts. The difference between T and C2, although not significant for the pooled sample and in Lilongwe and Mchinji Districts, is estimated to be 173 kg/ha higher for the T group in Salima.

For soybean, the pooled mean yield is 843 kg/ha for T, 963 kg/ha for C1, and 899 kg/ha for C2 (Table 3). Geographically, mean values range from a low of 594 kg/ha for T in Lilongwe to a high of 1,007 kg/ha for C1 in Mchinji. The pooled difference is 120 kg/ha lower for T compared to C1. For the same groups, the difference is 255 kg/ha lower for T in Lilongwe but is not significantly different from zero in the other Districts. Comparing T *versus* C2, the observed difference is only significant in Lilongwe, where, again, the T group attains 256 kg/ha less than the C2 group.

Average GM/ha for the pooled sample and by District are shown in Table 4. For groundnut, the mean GM/ha in the overall sample is MWK 137,400 for T, MWK 140,700 for C1, and MWK 136,900 for C2, with some variation across Districts. District-level means range from MWK 96,500 for C2 in Salima to MWK 174,100 for C1 in Mchinji. The mean difference in GM/ha for T *versus* C1 and T *versus* C2 is not significant in the pooled sample or within Districts.

For the pooled soybean sample, average GM/ha is MWK 78,300 for the T group compared to MWK 86,900 for C1 and 88,000 for C2 (Table 4). District-level means range from MWK 31,100 for C1 in Salima to MWK 96,700 for C1 in Mchinji. The difference in means is only significant for T *versus* C2 in Lilongwe, where the T group makes MWK 21,500 less than the C2.

3.4 Yield and Gross Margin by Gender and District

A number of studies have been published on gender disparities in agricultural productivity. The gap is often attributed to differential access to productive resources, which when accounted for reduces, and in some cases eliminates, the gap (Aguilar, Carranza, Goldstein, Kilic, & Oseni, 2015; Campos, Covarrubias, & Patron, 2016; Kilic, Palacios-López, & Goldstein, 2015). We discuss results based on descriptive analysis of the gender differences in average yield and GM/ha for the pooled data and separately for each District. The results are summarized in Table 5.

Average groundnut yield for males is 912 kg/ha in the pooled sample, 886 kg/ha in Lilongwe, 969 kg/ha in Mchinji, and 790 kg/ha in Salima. Mean yield for females is 795, 734, 887, and

750 kg/ha in the respective samples/locations. The pooled averages translate into 118 kg/ha in higher yield for males relative to females and is significant. By District, males still attain a significantly better yield in Lilongwe (152 kg/ha) and Mchinji (82 kg/ha).

The bottom half of Table 5 contains analogous yield summaries for soybean. The pooled average is 958 kg/ha for males and 778 kg/ha for females. The male average varies geographically, ranging from 759 kg/ha in Salima to 1,054 kg/ha in Mchinji. The female average goes from a low of 638 kg/ha in Lilongwe to a high of 879 kg/ha in Salima. The gender yield gap is also observed for soybean where the mean difference shows a significant male advantage of 180 kg/ha in the pooled sample, 136 kg/ha in Lilongwe and 185 kg/ha in Mchinji.

GM/ha estimates for groundnut and soybean disaggregated by gender and District are shown in Table 6. For the whole sample, the average GM/ha for male groundnut managers is MWK 145,400 and MWK 130,400 for females. The difference of MWK 15,000 is significant. Geographically, only the mean difference in Lilongwe (MWK 20,100) in favor of males is significant (and thus drives the overall trend for the pooled data).

For the pooled soybean sample, males on average exhibit MWK 21,400 more than females (MWK 70,400) (Table 6). The male advantage in GM/ha is persistent in both Lilongwe and Mchinji, with differences of MWK 135,500 and MWK 184,600, respectively.

3.5 Yield and Gross Margin by Individual Innovations, Gender, and Farm Size

In this subsection, we first discuss comparisons of mean yield and GM/ha based on S2, disaggregated by innovations. The innovations analyzed include *use of treated seed*, *seed type*, *number of rows per ridge*, and *planting date*. The data used in this part of the analysis pools all observations that incorporate the innovations just cited without consideration given to type of farmer (treated or control) or location (District). The results are presented in Table 7. We then focus on comparisons by innovations and gender, with results for yield and GM/ha shown in Tables 8 and 9, respectively. Lastly, we compare results obtained when the sample is categorized by innovation and farm size, shown in Tables 10 for yield and 11 for GM/ha.

Comparisons by Innovation

<u>Use of treated seed</u>: The average yield for users of treated groundnut seed is 807 kg/ha and that for users of untreated seed is 859 kg/ha (Table 7). The mean yield difference of 52 is not statistically different from zero. GM/ha estimates are respectively, MWK 123,000 and MWK 139,000, and the difference is also not significant.

In the case of soybean, the average yield is 1,037 kg/ha for users of treated seeds and 848 kg/ha for users of untreated seeds. Here, the mean difference of 189 kg/ha is significant. For

the associated GM/ha, users of treated seeds report MWK 102,000 as opposed to MWK 94,000 for untreated seeds. The mean difference of MWK 8,000 is not significant.
Seed type: The quality of seed is expected to have an important effect on yields. We compare the average yields of improved varieties with those of traditional landrace varieties. The results show that, on average, the yield from improved groundnut varieties is 861 kg/ha and that of traditional varieties is 837 kg/ha. The difference is not significant. The benefit from using improved seed is also not evident in estimated GM/ha, where averages show MWK 136,000 for improved and MWK 140,000 for traditional.

For soybean, the average yield for improved is 932 kg/ha, which is 59 kg/ha higher than that of traditional (871 kg/ha) but not significant. GM/ha estimates, however, display a significantly higher average for improved varieties (MWK 102,000) relative to traditional (MWK 88,000).

The lack of a statistically significant difference in mean yields for both crops may be explained by the considerable reliance on recycled seeds (42% for groundnut and 36% for soybean) with potentially compromised efficacy or vigor (Jelliffe, Bravo-Ureta, Deom, & Okello, 2018).

Rows planted per ridge: Here we compare planting in double row against single row. It is expected that double row planting generates higher yields and possibly GM/ha because of increased plant population (Balkcom, Arriaga, Balkcom, & Boykin, 2010; Chikowo, Snapp, & Hoeschle-Zeledon, 2015; Mukanga et al., 2019). A large number of groundnut farmers (79%) and about 50% of soybean farmers plant in single row, suggesting that the double row innovation, promoted by extension services, is not that popular.

Planting in double row for groundnut leads to an average yield of 883 kg/ha and GM/ha of MWK 123,000 compared to 848 kg/ha and MWK 142,000 for single row (Table 7). While the mean yield difference (35 kg/ha) is not significant, the difference in GM/ha (MWK 19,000) is. Thus, double row planting is associated with a significantly lower GM/ha, contrary to our expectation. Further examination shows that statistically both groups of farms have the same mean value of output but differ systematically on mean variable cost of production (*Appendix* Table A-2). These systematic differences are observed in the cost of labor, seed, and agro-chemicals. In all three factors, double row planting is associated with significantly higher average costs. The results also highlight low groundnut productivity for double row plots.

For soybean, double row planting is associated with an average yield of 1,027 kg/ha and GM/ha of MWK 110,000, while single row planting results in 740 kg/ha and MWK 82,000 (Table 7). Both mean differences - 287 kg/ha and MWK 28,000 - are statistically significant and confirm the expectation of higher yield and GM associated with a larger plant population.

Planting date: The bottom of Table 7 compares early (before December) against common practice (during December) planting, and late (after December) against common practice.

The average yields of groundnut are 954 kg/ha for early, 819 kg/ha for common practice and 671 kg/h for late. The mean difference of 135 kg/ha between early and common practice is significant. Early compared to December (common practice) planting also results in a significantly higher GM/ha with a difference of MWK 32,000. The results indicate an average yield of 671 kg/ha for late and 819 kg/ha for common practice, and the difference of 148 kg/ha in favor of common practice is significant. This difference also translates into MWK 30,000 GM/ha shortfall for late planting.

Early planting of soybean results in an average yield of 946 kg/ha compared to 858 kg/ha for December planting date, for which the difference is statistically significant. However, for soybean the yield benefit of early planting does not translate into a GM/ha advantage. Also, the average yield for late planting of soybean is 851 kg/ha and is not significantly different from that for common practice, which is also true for GM/ha.

Comparisons by Innovation and Gender

In the previous sections, we unearthed some systematic yield and GM benefits favoring male managers and early planting. In this section, we contrast innovation and gender, and examine variability in the indicators. Summaries for groundnut are given in Table 8 and those for soybean in Table 9. Again, GM are those obtained from Scenario 2 (S2).

Groundnut

<u>Use of treated seed</u>: We note that in Tables 8 to 11 we make both horizontal as well as vertical comparisons, which should become clear in the discussion.

The data at the top of Table 8 shows that male users of treated seeds, on average, attain 843 kg/ha versus 774 for females, and the 69 kg difference is not significant (horizontal comparison). The corresponding averages for users of untreated seed are 918 kg/ha and 797 kg/ha. The mean difference of 121 kg/ha in favor of males is significant and provides additional evidence of a gender gap in yield.

A vertical comparison of males using treated *versus* those using untreated seed shows a non-significant difference of 75 kg in favor of untreated. The same comparison for females reveals a similar outcome. Thus, just like in the pooled sample, neither the male nor the female sub-samples show evidence of yield benefits attached to treated seed.

Also, in the same panel of Table 8, the mean difference in GM/ha between males and females (horizontal comparison) is significant only for users of untreated seeds (MWK 16,000). Just like yields, mean difference in GM/ha between users of treated and untreated seeds, given gender (vertical comparison), is not statistically significant.

<u>Seed type</u>: The average yield for males who plant improved varieties is 921 kg/ha and that for females is 805 kg/ha (Table 8). For traditional varieties, the average yield is 899 kg/ha for males *versus* 761 kg/ha for females. The mean differences between males and females

are 115 kg/ha for improved and 138 kg/ha for traditional varieties, and both are significant at the 5% level. Regarding GM/ha, the only group that benefited (MWK 19,000) is males who plant traditional varieties. Furthermore, the data reveals that no yield or GM/ha advantages exist for use of improved seed varieties, which is true for both male and female managers. The results point to greater rewards for males relative to females regardless of whether improved or traditional varieties of groundnut are planted.

<u>Rows planted per ridge</u>: The average yield for male managers using double row is 946 kg/ha and that for females is 822 kg/ha (Table 8). For single row users, males get 904 kg/ha versus 787 kg/ha for females. The respective mean differences of 124 and 117 kg/ha are significant. However, no systematic yield benefit is found for double row versus single row according to gender.

Estimates of GM/ha for groundnut show that on average, single row males make MWK 150,000 and females make MWK 134,000, and the MWK 16,000 differential is significant at the 5% level (Table 8). Thus, male farmers receive more returns from single row than female farmers. For females, while no significant differences in average GM/ha exists between double and single row, contrary to expectations, double row is associated with significantly less GM/ha (MWK 126,000) compared to single row (MWK 150,000).

<u>Planting date</u>: The average yield for males who plant early is 1,007 kg/ha as against 887 kg/ha for females (Table 8). For farmers planting at the usual time in December, the average yield is 884 for males and 757 kg/ha for females. Average yields associated with late planting are 623 kg/ha for males and 715 kg/ha for females. The mean difference for both males and females is significant for early (120 kg/ha) versus common practice (127 kg/ha). Also, planting early relative to common practice is associated with positive yield differences of 123 kg/ha for males and 130 kg/ha for females. Planting late relative to common practice results in a significantly lower yield (261 kg/ha) for male managers. The difference for females is not significant.

For GM/ha, the differential is only evident for December planting, where male managers receive MWK 17,000 more than female managers (Table 8 bottom). Early planting relative to common practice results in MWK 30,000 more GM/ha for males and MWK 32,000 more for females. Also, males who plant late compared to common practice receive MWK 53,000 in lower returns.

Soybean

<u>Use of treated seed</u>: Yield and GM/ha summaries for soybean are presented in Table 9. The average yield for male users of treated seeds is 1,118 kg/ha and 931 kg/ha for female users (Table 9 top). The difference of 187 kg/ha is significant at the 5% level. Similarly, for users of untreated seeds, males on average attain 924 kg/ha, which is 181 kg/ha higher than that of females (743 kg/ha). Also, within each gender group, use of treated seed is associated with significantly higher yields at 194 kg/ha for males and 187 kg/ha for females.

In terms of GM/ha, the average for males who plant treated seeds is MWK 99,000 and that for females is MWK 61,000. For untreated seeds, the respective averages are MWK 90,000 and MWK 72,000. The significantly higher mean differences of MWK 37,000 and MWK 18,000 reveal a male advantage in yields and GM/ha regardless of the seed treatment category.

Seed type: The average yield for males who plant improved seeds is 1,007 kg/ha and that for females is 827 kg/ha (Table 9). Male managers who plant traditional varieties achieve yields of 984 kg/ha as opposed to 688 kg/ha for female managers. For both seed types, males realize significantly higher yields: 180 kg/ha for improved and 296 kg/ha for traditional. The benefit to planting improved seeds is significant only when we compare yields for female farm managers with a mean increase of 139 kg/ha.

The GM/ha summaries show that the higher yield among male managers also translates into greater GM/ha: MWK 22,000 from improved seed and MWK 32,000 from traditional seed (Table 9). There is no evidence of extra GM/ha for improved varieties in either the male or female sub-samples. Therefore, male managers are observed to be systematically more productive relative to females irrespective of seed type.

Rows planted per ridge: Male managers attain 1,088 and 808 kg/ha for double and single row planting, while female managers achieve 926 and 664 kg/ha, respectively.

These reflect on GM/ha as follows: Males receive MWK 103,000 and MWK 79,000 for double and single row, and females MWK 81,000 and MWK 62,000, respectively. All four-way mean differences for both yield and GM are significant. The results confirm that males do better regardless of the number of rows planted; and planting in double row is more beneficial regardless of the manager's gender.

Planting date: The average yield from early planting is 1,027 kg/ha for males and 814 kg/ha for females (Table 9). For males and females, the corresponding averages for common practice are 939 kg/ha and 758 kg/ha, and for late planting, 874 kg/ha and 816 kg/ha. Respective yield differences between males and females are significant only for early and common practice. These differences further translate into GM/ha benefits of MWK 27,000 for early planting and MWK 23,000 for common practice. For early *versus* common practice and late *versus* common practice, yield and GM/ha differences (vertical comparison) are neither significant for males nor females.

Comparisons by Innovation and Farm Size

We explore yield and GM/ha by innovation and farm size, large *versus* small, to ascertain any systematic link between these variables. We present results for groundnut in Table 10, and for soybean in Table 11.

Groundnut

Use of treated Seed: The average yield for large farm users of treated seeds is 884 kg/ha and 697 kg/ha for small farms (Table 10). The mean difference of 187 kg/ha is significant at the 5% level. Among farms that use untreated seeds, large ones attain significantly higher average yield (927 kg/ha) compared to small ones (803 kg/ha). However, there is no difference in yields between treated and untreated seed users within a given farm size. Mean differences in GM/ha are not significant except for small farm users of treated and untreated seeds where the latter make MWK 33,000 less than the former.

Seed type: Use of improved seeds is associated with yields of 911 kg/ha for large farms and 812 kg/ha for small farms (Table 10). Similarly, for traditional seeds, large farms attain 921 kg/ha and small farms 783 kg/ha. The differences in mean yields between large and small farms are significant for both improved seeds (99 kg/ha) and traditional seeds (138 kg/ha). The results, however, show no yield benefits associated with improved seeds irrespective of farm size and none of the mean differences in GM/ha are statistically significant.

Rows planted per ridge: On average, planting in double row yields 956 kg/ha for large farms and 812 kg/ha for small farms (Table 10). Single row results in 915 and 793 kg/ha for large and small farms, respectively. Both of these differences are significant and provide additional evidence for the yield effect associated with farm size, although we find no farm size effect for GM/ha. We do, however, find that double row is associated with MWK 22,000 lower GM/ha for large farms and MWK 16,000 less for small farms.

Planting date: The average groundnut yield associated with early planting is 1,045 kg/ha for large farms and 862 kg/ha for small farms (Table 10). For common practice, the corresponding yields are 878 and 774 kg/ha. Late planting is associated with yields of 653 kg/ha for large farms and 690 kg/ha for small farms. The difference in mean yields between large and small farms is significantly different from zero for early (183 kg/ha) and common practice (104 kg/ha), but not for late planting. The results also show that for large farms, planting late relative to common practice leads to a drop of 225 kg/ha.

Summaries for GM/ha indicate that on average, planting early is associated with MWK 171,000 for large farms and MWK 151,000 for small farms (Table 10). Similarly, for common practice, large farms on average make MWK 128,000 and small farms MWK 130,000. For large farms, the extra yield benefit translates into a significant GM/ha advantage (MWK 20,000) only when planting is done early. It is also evident that for both large and small farms, early planting results in MWK 43,000 and MWK 21,000 higher GM/ha, respectively. In contrast, late planting leads to a decline of MWK 31,000 in GM/ha for large farms. The results do confirm benefits in yield and GM for early planting and for large farms, but losses for late planting, especially on large farms.

Soybean

Use of treated Seed: The top of Table 11 reveals average yield for large farms that use treated seed at 1,067 kg/ha and 1,007 kg/ha for small farms. The corresponding average yields for users of untreated seeds are 907 kg/ha and 795 kg/ha. The yield difference between large and small farms is, however, significant only for untreated seed users (i.e. 112 kg/ha). Also, use of treated seeds results in yield gains of 160 kg/ha and 212 kg/ha for large and small farms, respectively. For GM/ha, all four-way mean differences are not significant.

Seed type: Large farm users of improved seeds yield 987 kg/ha compared to 880 kg/ha for small farms, and the difference, 107 kg/ha, is significant at the 5% level (Table 11). For traditional varieties, the average yield of 875 kg/ha for large farms is not significantly different from that of small farms (867 kg/ha). Across each group, large and small farms, we detect no significant differences in average yields between improved and traditional varieties. The only significant difference in average GM/ha is a MWK 21,000 increase for improved over traditional varieties in large farms.

Rows planted per ridge: The average yield associated with double row is 1,047 kg/ha for large farms and 1,007 kg/ha for small farms (Table 11). Similarly, for single row, the average is 818 kg/ha for large farms and 680 kg/ha for small ones. The mean difference across large and small farms is significant only for single row planting. The results also show that planting in double row is associated with a significant rise equal to 229 kg/ha and 327 kg/ha for large and small farms, respectively.

The average GMs/ha associated with double row are MWK 89,000 for large farms and MWK 101,000 for small farms. The difference of MWK 12,000 is significant in favor of small farms. Consistent with expectations, we do find that within both the large and small farm groups double row leads to a MWK 14,000 and a MWK 33,000 increase in GM/ha, respectively.

Planting date: For farms that plant early, the average yield is 955 kg/ha for large and 935 kg/ha for small (Table 11). For common practice data, large farms achieve 953 kg/ha and small farms, 785 kg/ha. Late planting results in 810 kg/ha for large farms and 896 kg/ha for small. The difference in mean yields between large and small farms is only significant for common practice (168 kg/ha). The yield benefit of early planting is only significant for small farms where the computed difference of 150 kg/ha. Further, we find no significant yield difference between late and common practice regardless of farm size.

Regarding GM/ha, we find no systematic differences between the averages for large (MWK 88,000) and small farms (MWK 94,000) with early planting, and between corresponding averages - MWK 85,000 and MWK 78,000 - when planting is common practice. For late planting, however, the average GM/ha is significantly lower for large farms (MWK 51,000) relative to small (MWK 96,000). The results further show that for large farms, planting late relative to common practice is associated with a MWK 34,000 loss in GM/ha.

3.6 Yield and Gross Margin by Combinations of Innovations for Groundnut and Soybean

In this section, we examine heterogeneity in yields and GM/ha for groundnut and soybean according to the following combinations of innovations: improved variety and early planting

(IC1); improved variety and double row (IC2); improved variety, double row, and early planting (IC3); and improved variety, double row, early planting, and treated seed (IC4). For each combination, we compare the average yield and GM/ha for "users" with those for "non-users". The results are presented in Table 12.

Improved variety and early planting (IC1): The average groundnut yield for users is 988 kg/ha and that for non-users is 780 kg/ha (Table 12). Also, the average GM/ha is significantly higher for users (MWK 164,000) compared with non-users (MWK 126,000).

Average yield and GM/ha in the case of soybean are also significantly different between use and non-use of IC1 (Table 12). Users, on average, achieve yields of 960 kg/ha, which is 146 kg/ha more than that for non-users (814 kg/ha). The difference in mean yield also translates into a GM/ha benefit of MWK 21,000.

For both crops, therefore, early planting of improved seeds is beneficial in both yield and GM.

Improved variety and double row (IC2): Groundnut farmers attain an average yield of 862 and non-users 822 kg/ha (Table 12) but this difference is not statistically significant. Average GM/ha, however, is MWK 23,000 lower for users compared to non-users indicating that the additional cost incurred when double row is used is not fully covered by the higher yields.

In contrast, the average soybean yield and GM/ha are 1,077 kg/ha and MWK 101,000 for IC2 users and 836 kg/ha and MWK 76,000 for non-users. The respective mean differences of 241 kg/ha and MWK 25,000 are both significant at the 5% level, confirming the agronomic and economic advantages of planting improved soybean varieties in double rows.

Improved variety, double row, and early planting (IC3): The average groundnut yield of 1,036 for users is significantly higher than that for non-users (778 kg/ha). The difference, however, does not reflect on GM/ha as corresponding averages for users (MWK 151,000) and non-users (MWK 128,000) are not significantly different from each other.

For soybean, we find that the average yield is 1,118 kg/ha for users of IC3 compared to 809 kg/ha for non-users, which results in a significant difference of 309 kg/ha. In addition, IC3 is associated with a significantly higher GM/ha for users (MWK 98,000) relative to non-users (MWK 71,000).

Improved variety, double row, early planting, and treated seed (IC4): The average values of yields and GM/ha of groundnut show that, users achieve 686 kg/ha and MWK 88,000, and non-users obtain 779 kg/ha and MWK 128,000, respectively. These mean differences are not significantly different from zero.

Users of IC4 in soybeans achieve an average yield of 1,143 and non-users attain 815 kg/ha. The mean difference (328 kg/ha), is significant and confirms the yield-enhancing role of IC4. Nevertheless, the average difference in GM/ha between users (MWK 87,000) and non-users (MWK 73,000) of MWK 14,000 is not significantly different.

Table 1: Socio-demographic attributes: Pooled sample and by District

	Pooled	Lilongwe	Mchinji	Salima
Farm manager				
Age (yrs)	42.1	41.9	41.9	43.4
Schooling (yrs)	5.6	5.1	5.9	5.6
Gender (%)				
Male	52.9	48.3	60.9	41.1
Female	47.1	51.7	39.1	58.9
Household (HH)				
Size	5.4	4.9	5.7	5.5
Dependency ratio	1.1	1.0	1.1	1.2
Gender: HH head (%)				
Male	84.3	84.1	85.9	80.2
Female	15.7	15.9	14.1	19.8
Farm				
Total land area (ha)	1.19	0.86	1.33	1.53
Total cult. area (ha)	1.17	0.85	1.31	1.46
Cult. area (ha): Groundnut[1]	0.39	0.32	0.43	0.42
Cult. area (ha): Soybean[2]	0.37	0.27	0.43	0.27

Note: [1] N=1,802; [2]N=1,248; N=2,121 for all other variables (Source: Survey, 2018).

Table 2: Estimates of gross margins and benefit-cost ratios under four cost scenarios: Groundnut and soybean farming

	(1)	(2)	(3)	(4)
	Cash cost	(1) + own seed & organic fert.	(2) + family labor	(3) + own land
Groundnut				
Land	7,590	7,590	7,590	32,799
Labor	25,272	25,272	181,972	181,972
Seed	13,868	24,612	24,612	24,612
Agro-chemical	3,037	3,247	3,247	3,247
TVC	49,767	60,720	217,420	242,630
Value Prod.	198,763	198,763	198,763	198,763
GM/ha	148,996 *127,575*	138,043 *126,742*	-18,657 *153,053*	-43,867 *152,205*
B/C	4.8	4.6	0.9	0.8
N	1,802	1,802	1,802	1,802
Soybean				
Land	6,716	6,716	6,716	32,044
Labor	13,131	13,131	138,001	138,001
Seed	10,563	16,258	16,258	16,258
Agro-chemical	2,807	3,080	3,080	3,080
TVC	33,216	39,184	164,054	189,383
Value Prod.	121,951	121,951	121,951	121,951
GM/ha	88,734 *81,789*	82,767 *80,549*	-42,103 *107,474*	-67,432 *106,817*
B/C	5.3	5.0	0.8	0.7
N	1,248	1,248	1,248	1,248

Note: Standard deviations in italics; B/C ratios summarized for cases with modified z-scores between ±3.5 sd; US $1 = MWK 714 in 2018 (Source: Survey, 2018).

Table 3: Average yield of groundnut and soybean by farmer type and District

Farmer type	Pooled		Lilongwe		Mchinji		Salima	
	Mean (N)	Diff	Mean (N)	Diff	Mean (N)	Diff	Mean (N)	Diff
Groundnut								
T	861 (952)	5	777 (360)	18	943 (410)	-62	842 (182)	143
C1	856 (398)		759 (146)		1,005 (176)		699 (76)	
T	861 (952)	20	777 (360)	-142	943 (410)	88	842 (182)	173**
C2	841 (452)		919 (162)		855 (200)		669 (90)	
Soybean								
T	843 (643)	-120**	594 (233)	-255**	1,004 (373)	-3	783 (37)	-149
C1	963 (242)		848 (58)		1,007 (164)		932 (20)	
T	843 (643)	-56	594 (233)	-256**	1,004 (373)	64	783 (37)	-13
C2	899 (363)		852 (118)		940 (213)		796 (32)	

Note: Yield in kg/ha; Sig. ** *p<0.05*; Number of observations (N) in parenthesis.

Table 4: Average gross margin per hectare by farmer type and District: Groundnut and soybean farming

Farmer type	Pooled		Lilongwe		Mchinji		Salima	
	Mean (N)	Diff	Mean (N)	Diff	Mean (N)	Diff	Mean (N)	Diff
Groundnut								
T	137.4 (952)	-3.3	123.7 (360)	11.1	154.7 (410)	-19.4	125.7 (182)	8.3
C1	140.7 (398)		112.6 (146)		174.1 (176)		117.4 (76)	
T	137.4 (952)	0.5	123.7 (360)	-24.5	154.7 (410)	8.7	125.7 (182)	29.2
C2	136.9 (452)		148.2 (162)		146.0 (200)		96.5 (90)	
Soybean								
T	78.3 (643)	-8.6	60.0 (233)	-18.4	91.9 (373)	-4.8	56.2 (37)	25.1
C1	86.9 (242)		78.4 (58)		96.7 (164)		31.1 (20)	
T	78.3 (643)	-9.7	60.0 (233)	-21.5**	91.9 (373)	-3.3	56.2 (37)	-7.2
C2	88.0 (363)		81.5 (118)		95.2 (213)		63.4 (32)	

Note: GM in '000 MWK; Sig. ** *p<0.05*; Number of observations (N) in parenthesis.

Table 5: Average yield of groundnut and soybean by gender and District

Gender	Pooled		Lilongwe		Mchinji		Salima	
	Mean (N)	Diff	Mean (N)	Diff	Mean (N)	Diff	Mean (N)	Diff
Groundnut								
Male	912 (921)	118**	886 (322)	152**	969 (457)	82**	790 (142)	40
Female	795 (881)		734 (346)		887 (329)		750 (206)	
Soybean								
Male	958 (721)	180**	774 (200)	136**	1,054 (478)	185**	759 (43)	-120
Female	778 (527)		638 (209)		869 (272)		879 (46)	

Note: Yield in kg/ha; Sig. ** *p<0.05;* Number of observations (N) in parenthesis.

Table 6: Average gross margin per hectare by gender and District: Groundnut and soybean farming

Gender	Pooled		Lilongwe		Mchinji		Salima	
	Mean (N)	Diff	Mean (N)	Diff	Mean (N)	Diff	Mean (N)	Diff
Groundnut								
Male	145.4 (921)	15.0**	137.6 (322)	20.1**	161.8 (457)	11.9	109.8 (142)	-10.9
Female	130.4 (881)		117.6 (346)		149.9 (329)		120.8 (206)	
Soybean								
Male	91.8 (721)	21.4**	773.5 (200)	135.5**	1,053.5 (478)	184.6**	758.9 (43)	25.1
Female	70.4 (527)		638.1 (209)		868.9 (272)		878.7 (46)	

Note: GM in '000 MWK; Sig. ** *p<0.05*; Number of observations (N) in parenthesis.

Table 7: Average yield and gross margin per hectare by individual innovations: Groundnut and soybean farming

Innovation	Groundnut				Soybean			
	Yield		GM/ha		Yield		GM/ha	
	Pooled (N)	Diff	Pooled (N)	Diff	Pooled (N)	Diff	Pooled (N)	Diff
Use of treated seed:								
Treated	807 (153)	52	123 (153)	-17	1,037 (227)	189**	102 (227)	8
Untreated	859 (1649)		139 (1649)		848 (1021)		94 (1021)	
Seed type:								
Improved	861 (879)	24	136 (879)	-4	932 (863)	59	102 (863)	14**
Traditional	837 (779)		140 (779)		871 (126)		88 (126)	
Rows per ridge:								
Double	883 (364)	35	123 (364)	-19**	1,027 (621)	287**	110 (621)	28**
Single	848 (1418)		142 (1418)		740 (618)		82 (618)	
Planting date:								
Early	954 (615)	135**	161 (615)	32**	946 (361)	88**	103 (361)	9
Common practice	819 (1054)		129 (1054)		858 (757)		94 (757)	
Late	671 (126)	-148**	97 (126)	-30**	851 (126)	-7	85 (126)	-9
Common practice	819 (1054)		129 (1054)		858 (757)		94 (757)	

Note: Yield in kg/ha; GM in '000 MWK; Sig. ** *p<0.05*; Number of observations (N) in parenthesis.

Table 8: Average yield and gross margin per hectare by individual innovations and gender: Groundnut farming

Innovation	Yield			GM/ha		
	Male (N)	Female (N)	Diff	Male (N)	Female (N)	Diff
Use of treated seed:						
Treated	843 (74)	774 (79)	69	124 (74)	121 (79)	2
Untreated	918 (847)	797 (802)	121**	147 (847)	131 (802)	16**
Diff	-75	-23		-23	-10	
Seed type:						
Improved	921 (422)	805 (457)	115**	142 (422)	130 (457)	12
Traditional	899 (430)	761 (349)	138**	148 (430)	129 (349)	19**
Diff	22	45		-6	1	
# Rows per ridge:						
Double	946 (179)	822 (185)	124**	126 (179)	121 (185)	5
Single	904 (732)	787 (686)	117**	150 (732)	134 (686)	16**
Diff	42	34		-24**	-13	
Planting date:						
Early	1,007 (343)	887 (272)	120**	168 (343)	153 (272)	14
Common practice	884 (514)	757 (540)	127**	138 (514)	121 (540)	17**
Diff	123**	130**		30**	32**	
Late	623 (60)	715 (66)	-92	85 (60)	113 (66)	-27
Common practice	884 (514)	757 (540)	-	138 (514)	121 (540)	-
Diff	-261**	-42		-53**	-8	

Note: Yield in kg/ha; GM in '000 MWK; Sig. ** $p<0.05$; Number of observations (N) in parenthesis.

Table 9: Average yield and gross margin per hectare by individual innovations and gender: Soybean farming

Innovation	Yield			GM/ha		
	Male (N)	Female (N)	Diff	Male (N)	Female (N)	Diff
Use of treated seed:						
Treated	1,118 (129)	931 (98)	187**	99 (129)	61 (98)	37**
Untreated	924 (592)	743 (429)	181**	90 (592)	72 (429)	18**
Diff	194**	187**		9	-11	
Seed type:						
Improved	1,007 (505)	827 (358)	180**	98 (505)	75 (358)	22**
Traditional	984 (78)	688 (48)	296**	90 (78)	58 (48)	32**
Diff	24	139**		8	18	
# Rows per ridge:						
Double	1,088 (390)	926 (231)	161**	103 (390)	81 (231)	21**
Single	808 (325)	664 (293)	144**	79 (325)	62 (293)	17**
Diff	280**	262**		23**	19**	
Planting date:						
Early	1,027 (224)	814 (137)	212**	101 (224)	74 (137)	27**
Common practice	939 (418)	758 (339)	181**	91 (418)	68 (339)	23**
Diff	88	55		10	6	
Late	874 (76)	816 (50)	58	71 (76)	75 (50)	-4
Common practice	939 (418)	758 (339)	-	91 (418)	68 (339)	-
Diff	-65	57		-20	6	

Note: Yield in kg/ha; GM in '000 MWK; Sig. ** *p<0.05*; Number of observations (N) in parenthesis.

Table 10: Average yield and gross margin per hectare by individual innovations and farm size: Groundnut farming

Innovation	Yield			GM/ha		
	Large (N)	Small (N)	Diff	Large (N)	Small (N)	Diff
Use of treated seed:						
Treated	884 (90)	697 (63)	187**	135 (90)	104 (63)	31
Untreated	927 (746)	803 (903)	124**	142 (746)	137 (903)	5
Diff	-43	-106		-7	-33**	
Seed type:						
Improved	911 (435)	812 (444)	99**	138 (435)	134 (444)	4
Traditional	921 (305)	783 (474)	138**	144 (305)	137 (474)	7
Diff	-10	29		-6	-3	
# Rows per ridge:						
Double	956 (180)	812 (184)	144**	125 (180)	122 (184)	4
Single	915 (639)	793 (779)	122**	147 (639)	138 (779)	9
Diff	41	19		-22**	-16**	
Planting date:						
Early	1,045 (308)	862 (307)	183**	171 (308)	151 (307)	20**
Common practice	878 (457)	774 (597)	104**	128 (457)	130 (597)	-2
Diff	167**	88**		43**	21**	
Late	653 (64)	690 (62)	-37	98 (64)	102 (62)	-4
Common practice	878 (457)	774 (597)	-	128 (457)	130 (597)	-
Diff	-225**	-83		-31**	-28	

Note: Yield in kg/ha; GM in '000 MWK; Sig. ** $p<0.05$; Number of observations (N) in parenthesis.

Table 11: Average yield and gross margin per hectare by individual innovations and farm size: Soybean farming

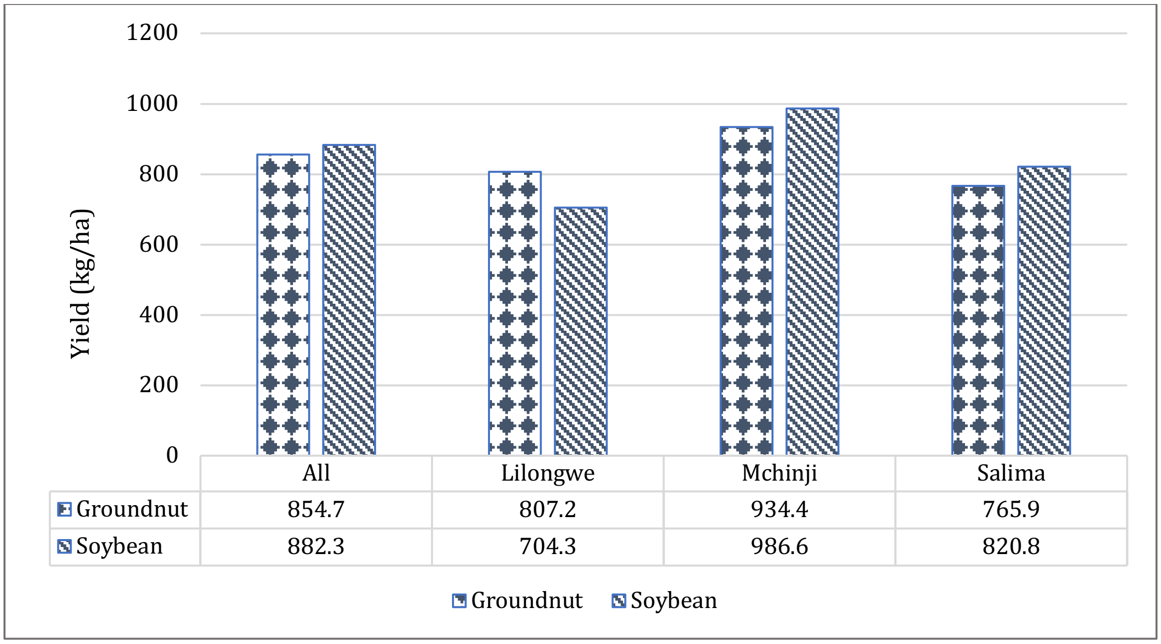
Innovation	Yield			GM/ha		
	Large (N)	Small (N)	Diff	Large (N)	Small (N)	Diff
Use of treated seed:						
Treated	1,067 (113)	1,007 (114)	60	75 (113)	90 (114)	16
Untreated	907 (483)	795 (538)	112**	84 (483)	82 (538)	2
Diff	160**	212**		-9	9	
Seed type:						
Improved	987 (423)	880 (440)	107**	89 (423)	87 (440)	2
Traditional	875 (67)	867 (59)	8	68 (67)	88 (59)	20
Diff	112	14		21**	0.7	
# Rows per ridge:						
Double	1,047 (318)	1,007 (303)	40	89 (318)	101 (303)	-12**
Single	818 (269)	680 (349)	137**	75 (269)	68 (349)	7
Diff	229**	327**		14**	33**	
Planting date:						
Early	955 (199)	935 (162)	20	88 (199)	94 (162)	-6
Common practice	953 (329)	785 (428)	168**	85 (329)	78 (428)	7
Diff	1	150**		3	15	
Late	810 (66)	896 (60)	-86	51 (66)	96 (60)	-45**
Common practice	953 (329)	785 (428)	-	85 (329)	78 (428)	-
Diff	-144	111		-34**	18	

Note: Yield in kg/ha; GM in '000 MWK; Sig. ** *p<0.05*; Number of observations (N) in parenthesis.

Table 12: Average yield and gross margin per hectare by combinations of innovations: Groundnut and soybean farming

Innovation	Yield			GM/ha		
	Users (N)	Non-users (N)	Diff	Users (N)	Non-users (N)	Diff
Groundnut						
Improved variety & early planting	988 (265)	780 (476)	209**	164 (265)	126 (476)	38**
Improved variety & double row	862 (245)	822 (688)	40	115 (245)	139 (688)	-23**
Improved variety, double row & early planting	1,036 (77)	778 (426)	258**	151 (77)	128 (426)	23
Improved variety, double row, early planting & treated seeds	686 (13)	779 (423)	-93	88 (13)	128 (423)	-40
Soybean						
Improved variety & early planting	960 (260)	814 (87)	146**	91 (260)	71 (87)	21**
Improved variety & double row	1,077 (450)	836 (64)	241**	101 (450)	76 (64)	25**
Improved variety, double row & early planting	1,118 (138)	809 (52)	309**	98 (138)	71 (52)	28**
Improved variety, double row, early planting & treated seeds	1,143 (36)	815 (51)	328**	87 (36)	73 (51)	14

Note: Yield in kg/ha; GM in '000 MWK; Sig. ** $p<0.05$; Number of observations (N) in parenthesis.



	All	Lilongwe	Mchinji	Salima
Groundnut	854.7	807.2	934.4	765.9
Soybean	882.3	704.3	986.6	820.8

Figure 3: Yields of groundnut and soybean overall and by District

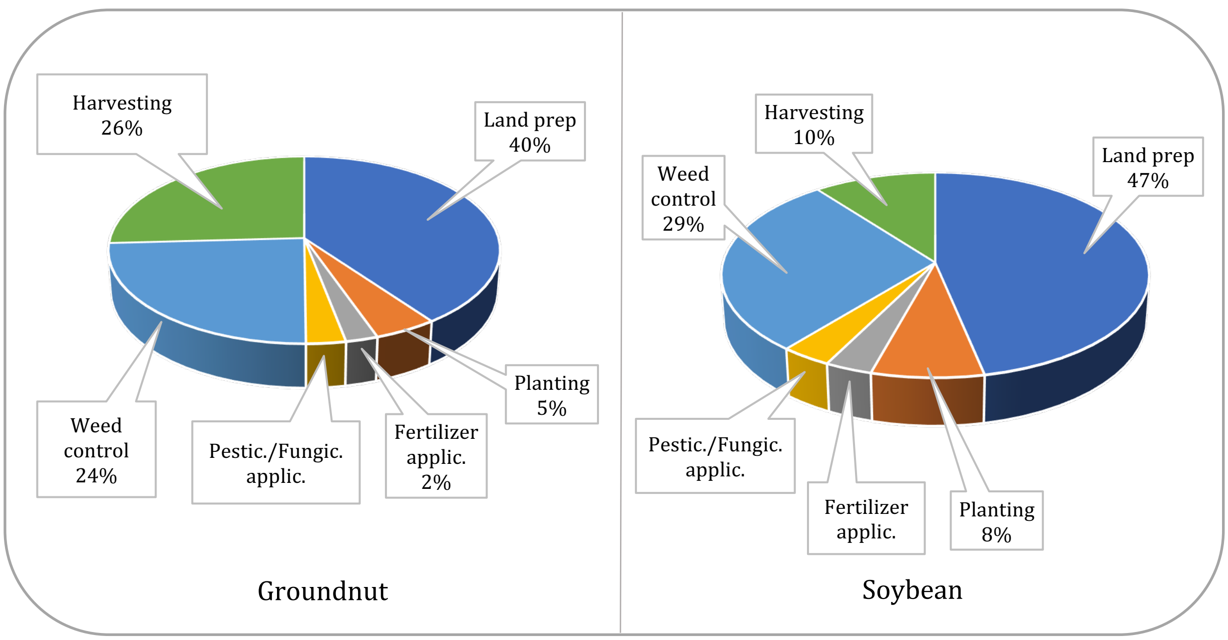


Figure 4: Labor shares of agronomic practices in groundnut and soybean farming

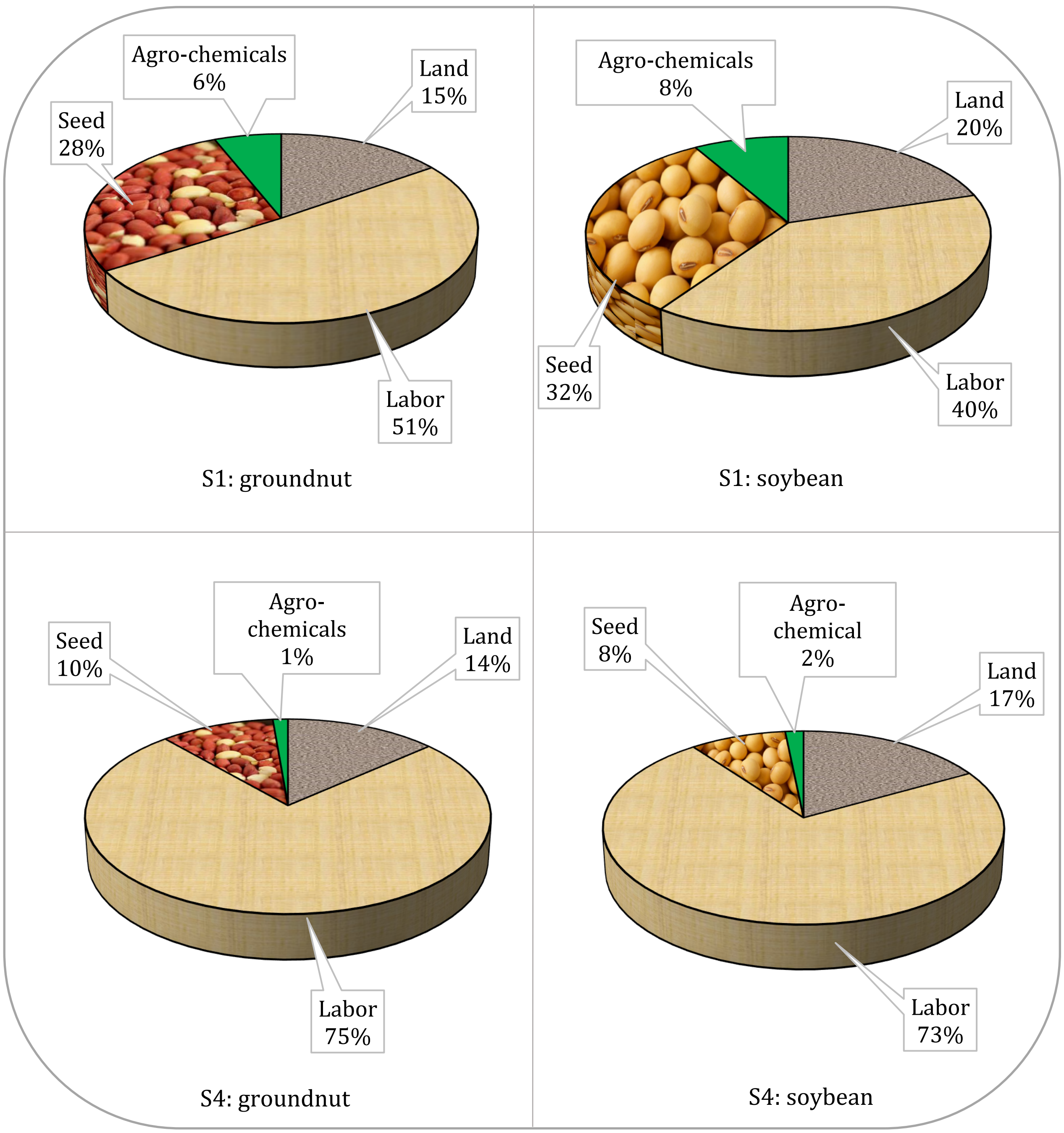


Figure 5: Cost shares of production inputs for groundnut and soybean under cost Scenarios 1 and 4

4. SUMMARY AND CONCLUSIONS

This report relied on baseline data for a sample of groundnut and soybean farmers in Malawi for the 2016/17 major production season. The specific objectives are: 1. To analyze yield and gross margin (GM) differentials across farmer types and District; 2. To analyze yield and GM differentials across gender and Districts; 3. To analyze yield and GM differentials for several on-farm innovations across gender and farm size. The indicators analyzed, yield and GM, capture both technical and economic outcomes associated with the production process.

The data was collected in three Districts within the Central Region of Malawi: Lilongwe, Mchinji, and Salima. These Districts represent three of four sites in the Central Region, where the anchor farms associated with Exagris and/or Horizon Farms have operated. The study population included all farmers who cultivated groundnut and/or soybean within and outside the sphere of influence of the anchor farms.

The villages selected randomly for data collection were classified into two: 1) Treated Village (TV) i.e., where farmers affiliated with the anchor farms lived; and 2) Control Village (CV) which were similar to the treated ones but outside the area of influence of the anchor farms. In turn, farmers in the TV group where classified into three groups: Ingrowers (T1) – farmers that operate plots assigned by Exagris/Horizon Farms in addition to their own plots; Outgrowers (T2) – farmers that do not have plots assigned by Exagris/Horizon Farms and operate only their own plots; and Neighbor Controls (C1) – farmers that live in TVs but do not work with anchor farms and operate only their own plots. All farmers in the CVs, referred to as Non-Neighbor Controls (C2) lived in control villages and are expected to have no exposure to anchor farm activities.

The data was collected using Survey Solutions, which is the World Bank's Computer-Assisted Personal Interviewing (CAPI) platform. The dataset is composed of interviews with 178 village-heads and 2,600 farmers. The sample is comprised of 1,331 treated (T1+T2), and 1,269 control (622 C1 and 647 C2) farmers. The analyses presented in this report, centered on the groundnut and soybean samples, includes 1,802 farmers that cultivated groundnut and 1,248 that cultivated soybean. A total of 929 farmers cultivated both crops.

The key results stemming from the analysis can be summarized as follows:

- Family labor represents the major share of all labor in groundnut and soybean farming. Hired labor represents 26.4% and 16.1% of total labor in groundnut and soybean production, respectively.

- Land preparation, hand weeding and harvesting make up the bulk of farm labor needs in both crops (88% in groundnut and 84% in soybean).

- Hired labor accounts for the highest share of cash costs for both crops.

- Considering only cash costs, GM for groundnut and soybean are highly positive, and the respective average benefit cost ratio (B/C) is well above 1.

- Considering all costs, i.e., cash expenses plus the opportunity costs of family labor and own land at market value, leads to negative GMs for both crops, a finding that is often reported in subsistence farm systems in Africa. It is important to stress that all costs include significant non-cash costs. Thus, considering cash costs, i.e. excluding market value of family labor and owned land, producers of both crops cover all other costs and realize positive revenues, which represent returns to family labor and land.

- Use of purchased inputs, especially agro-chemicals, is very low and accounting at most for 6% and 8% of all cash costs in groundnut and soybean production, respectively. In fact, substantial share of farmers does not purchase any inputs.

- The analysis focusing on gender reveals that males realize higher yields and GM than females. The estimated yield differences are 118 kg/ha for groundnut and 180 kg/ha for soybean in favor of male farmers. Gross Margin differences are MWK 15,000 and MWK 21,400, respectively.

- Treated groundnut seeds relative to untreated afford no significant pay off in general (i.e. when the comparison is made using all the pertinent data) and across gender. One exception is a better performance for larger farmers (>1.01 ha).

- In the case of soybean, seed treatment has a positive effect in general and across farm size.

- Improved seeds can play an important role in enhancing productivity. However, our data reveals no significant effect in both groundnut and soybean, in general. But, improved relative to traditional seeds do have a statistically significant and positive effect for males compared to females, and larger farms compared to smaller ones.

- Planting with double versus single rows has no effect in groundnut, generally, but does have a positive effect in soybean. More specifically, males and larger farmers achieve higher yields from planting double rows in groundnut while in soybean the large farm advantage dissipates.

- Planting before (early) or during December (common practice) is generally associated with higher yields relative to late planting (after December) in both groundnut and soybean. Again, males and larger farms exhibit yield advantages over their respective counterparts.

- The analysis also included comparisons of various combinations of innovations. First, planting improved varieties early revealed higher yield and GM for both crops.

- Planting improved varieties in double rows resulted in higher yield and GM for soybean.

- Combining improved varieties, double row and early planting generated higher yield and GM for both crops.

- Finally, combining improved varieties, double row, early planting and use of treated seed has a significant positive effect on soybean yield. However, the inferences made from this scenario are limited because of reduced number of observations.

The analysis and results summarized above lead to the following key conclusions:

- The low input use confirmed in this study implies potential for intensification i.e., getting more from the same land. Given that farms are small, bringing additional land to increase output on the extensive margin might sound like a good idea but this politically and administratively a challenging proposition and makes little sense.

- Several innovations analyzed offer opportunities to increase yields and every attempt should be made to promote their appropriate use.

- Available studies indicate low levels of managerial performance which is consistent with the low yields reported above (e.g. Julien, Bravo-Ureta and Rada, 2019). A key implication is that additional extension and farmer training could have a significant pay-off.

- Additional quantitative and qualitative work needed in various areas related to our findings including:
  - The evidence on the benefits to early planting suggests the need to understand barriers to further adoption (e.g. labor constraints; awareness, preference to other crops, etc.).
  - The overall lower performance by females compared to males requires more effort to understand why this appears to be the case.
  - Family labor is a major input and seemingly 'abundant'. However, the considerable reliance on hired labor indicates that it is important to better understand possible labor constraints for particular activities.
  - It is also important to understand the labor demand implications of the intensification implied by the adoption of the various innovations examined.
  - Seed quality is clearly an important issue and the continued underperformance of "improved seeds" requires more information. Seed recycling and degradation are the likely culprits. An implication is that breeding, generation and adoption of new improved fresh material is important and requires continued support.
  - Additional work using econometric procedures would be of value to quantify marginal effects of individual innovations and to measure managerial performance by focusing on technical efficiency analysis (e.g. Bravo-Ureta et al. 2007; Julien, Bravo-Ureta and Rada 2018).

Finally, the potential impact of anchor farms on farm productivity in Africa is an under-studied area and the authors argue that this is an important issue which deserves additional investigation.

APPENDIX

Table A-1: Kilogram equivalent scale for local

Local units	Shelled equivalent (kg)	
	Groundnut	Soybean
1 Maxi-bag	70	100
1 Mini-bag	40	50
1 Pail (small)	6	12
1 Pail (large)	14	17
1 Ox-cart/ Ngolo	500	-
1 Burundi bag	120	155
1 Bucket (5-litre type)	6	8
1 Plate (No. 12)	1	-
1 bag (50-kg type)	40	-
1 bag (70-kg type)	55	71
1 PICS bag	40	-
1 Ndowa	15	15

Table A-2: Mean comparisons of value of output and variable costs for double versus single row planting in groundnut

Variable	Double row	Single row	Diff
Value of production (MWK)	205,453	197,076	8,377
Total variable cost (MWK)	82,064	54,816	27,247**
Rent on land (cash) (MWK)	8,211	7,304	907
Labor cost (MWK)	32,694	23,128	9,567**
Seed cost (MWK)	31,773	22,699	9,074**
Agro-chemical cost (MWK)	9,386	1,687	7,699**
N	364	1,418	

Note: Sig. ** $p<0.05$.

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