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The potential of integrated soil fertility management for closing the yield gap in Ethiopia

JULIA DOLDT[1], KIDIST YILMA[1], JIM ELLIS-JONES[2], STEFFEN SCHULZ[1]

[1]*Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Integrated Soil Fertility Management Project (ISFM+), Ethiopia*
[2]*Agriculture-4-Development, United Kingdom*

Abstract

The dominant farming systems across the Ethiopian highlands includes cereals, notably wheat, maize, teff, sorghum and barley with faba bean being a widely grown legume. Key constraints limiting yields are soil degradation and low soil fertility. The Integrated Soil Fertility Management (ISFM+) Project has collected and analysed data from hundreds of farmer-managed demonstration plots over a 5-year period. These compare farmers' practices (control) with demonstrations that use at least three ISFM practices. These include the use of agricultural lime on acidic soils, improved seed, organic fertiliser, rhizobia on legumes, green manure as well as some inorganic fertiliser. Yields from 1,878 short-term demonstrations, maintained for one season and 103 long-term demonstrations, maintained for five years were measured. The results were used to evaluate the effects of ISFM on grain yields. The mean yield across the short-term control plots was 2.88 tonnes ha^{-1} while the ISFM plots yielded 4.81 tonnes ha^{-1}, a yield increase of 67%, while continuous use of ISFM over five consecutive years increased yields by 154 %. Low soil acidity had a significant negative impact on control yields, while lime used on the demonstration plots alleviated these effects. It was found that almost all plots would benefit from liming especially in the long-term as acidification increased across the control plots. A comparison of control yields with national averages showed no marked discrepancies while ISFM yields were 69% higher. With increasing mineral fertiliser prices and a need for more sustainable farming systems, ISFM can play a major role in agroecological transformation, in improving food insecurity, increasing farmers' incomes and reducing food imports. Scaling up will however require significant private and public investment to ensure access to lime, fertiliser, rhizobia and improved seed. A system of private agrodealers supplying inputs to farmers seems the most likely option to achieve this. Hence the environment for private sector sales of agricultural inputs needs to be improved.

Keywords: Ethiopian Highlands, integrated soil fertility management, lime, soil acidity, yields

Introduction

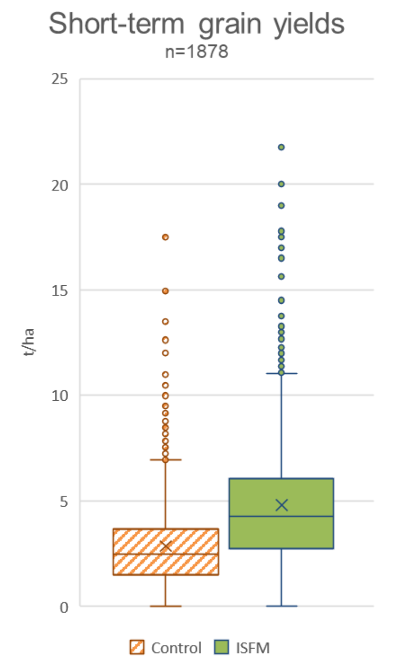
The livelihoods of Ethiopian farmers is increasingly endangered by soil degradation and ensuing fertility loss. Farmers' practices are characterized by traditional approaches and technologies. Ploughing repeatably using an oxen and broadcasting inputs such as seed and fertilizer is common. At the same time access to many farm inputs is limited. (Diriba, 2018) This low input – low output agriculture causes huge yield gaps (difference between actual yield and potential water-limited yield) in Ethiopia. Estimates vary across crops, regions, soil types and other factors but authors agree that production could be doubled if constrains are addressed (Getnet et al., 2022; Silva et al., 2021; van Dijk et al., 2020). Integrated soil fertility management (ISFM) has the potential to do so. ISFM technologies like improved seed, lime on acidic soils, line seeding, blended fertilizers, urea top dressing, compost, vermicompost, (green) manure and rhizobia on legumes can meet farmers' short-term needs for increased production while also contributing to efficient and sustainable use of resources.

Material and Methods

The ISFM+ project with its partners has collated data over five years from farmer-led demonstrations across five regions covering various crops (mainly wheat, maize, teff, barley, sorghum and faba bean). The 103 long-term demonstrations were established five years ago in order to record accumulating effects over time while the short-term demonstrations were established by different model farmers for one season only. Farmers implement three or more ISFM technologies of their choosing simultaneously to deploy their full synergistic potential. ISFM technologies are then compared to traditional farmers' practices on adjoining plots of 600m² of which 20m² were randomly selected and sampled to determine yields after drying. Lime was applied when the pH of the plot was <5.5. Yield analysis was undertaken using MS Excel Pivot tables. Yield increases were calculated based on the mean yields of both plots. Short-term data for specific crops has the dispersion indicated and for significances two-sided t-tests with equal variances were conducted. Additionally, specific crop yields were compared with five years of data from the Ethiopian Central Statistics Agency (CSA) in order to validate the dataset.

Results and Discussion

Within a year, a yield increment of 67% was observed across all crops (n=1878). The mean yield of the control was 2.9 tonnes ha-1 while plots under ISFM yielded 4.8 t ha-1 (p=8.6E-125). Long-term yields in the first year were comparable (2.8 t ha-1 and ISFM 4.9 t ha-1) while after five years the control declined to 2.2 t ha-1 and the ISFM yield increased to 5.6 t ha-1, an increase of 154% (p= 5.08E-48). ISFM reduces the incidents of extremely low yields of less than 2 t ha-1 not only increasing yields but also resilience and yield stability, thereby contributing to food security. Additionally, the longer ISFM is applied, the higher the observed yield differences due to declining control yields and increasing ISFM yields over time.



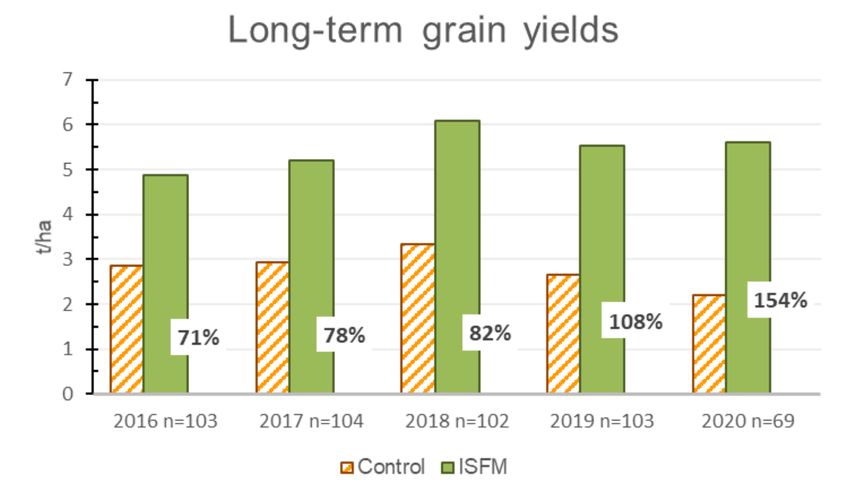
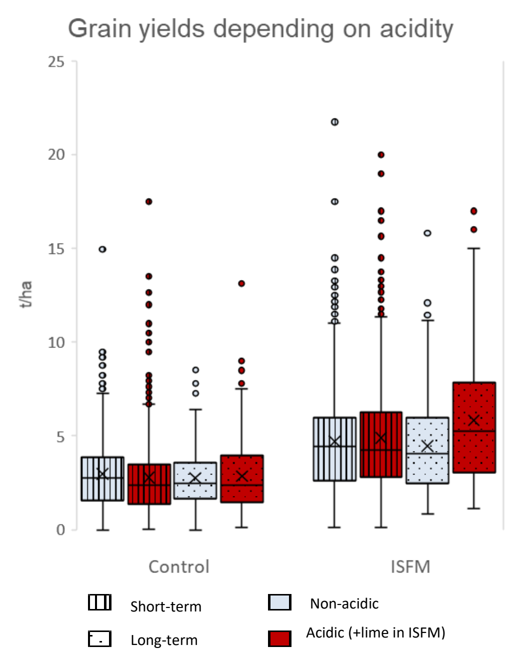


Figure 2: Mean yield development of ISFM and Control from 2016 until 2020 also displaying the mean increase in percent

Figure 1: Comparison of short-term ISFM and Control yield for 2016-2020



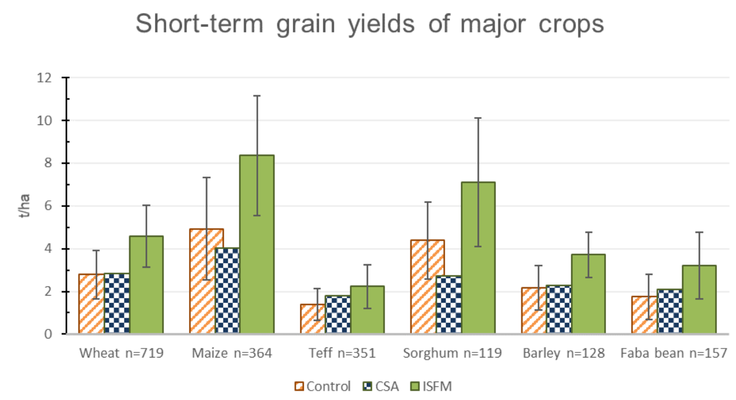


Figure 4: Comparison of control and ISFM yields with CSA (Ethiopian Central Statistics Agency) reported yield between 2016 and 2020 split by major crops in the dataset.

Figure 3: Comparison different control and ISFM yields depending on soil acidity levels. All acidic ISFM plots receieved lime (boxplot 6 and 8). Short-term non-acidic (lined, light blue n=902), Short-term acidic (lined, red n=976), Long-term non-acidic (dotted, light blue n=138), Long-term acidic (dotted, red n=343)

Comparing the control yields on acidic (2.8 t ha^{-1}) and non-acidic soils (3 t ha^{-1}) in the short-term trials (boxplot 1+2) showed a significant difference (p=0.0286). At the same time the ISFM yields were higher on the acidic soils where lime was applied (4.9 t ha^{-1}) than on the non-acidic soils (4.7 t ha^{-1}) (boxplot 5+6) even though the difference was not significant (p=0.112). In the long-term trials the data behaves differently, there being no difference between the acidic and non-acidic control yields (boxplot 3+4) (2.8 vs 2.9 t ha^{-1}), while the yields of the two respective ISFM yields (boxplot 7+8) (4.5 vs 5.8 t ha^{-1}) were different ($p=2.42E^{-05}$). This could be explained by the last soil sample being taken in 2015 and by 2021 acidification had probably increased explaining the significant difference caused by the application of lime in conjunction with ISFM. The ISFM yields on unlimed soils didn't increase over time (boxplot 5 and 7), hence lime can be regarded as prerequisite for building up soil fertility over time.

The crop yields of the six most common crops in the short-term demonstrations compared with CSA data (CSA, 2017-2021) showed a weighted mean difference (based on sample size) between CSA and control yields of 2% due to negative and positive yield differences (-22% to +62%). ISFM yields were 69% higher though (+25% to +162%). This comparison indicates that the control yields are comparable to the national averages. Higher C_4-plant yields are explained by their cultivation also in the lower-yielding lowlands where ISFM+ is not active and hence has no data.

Conclusions and Outlook

These farmer-managed trials have their short-comings with the yield measurements being prone to errors due to varying dry matter content, human bias and mistakes. However, the sample size and the comparable CSA yields indicate reliable data quality which will receive in-depth statistical analysis. It can be postulated though that ISFM and especially lime are of paramount importance for closing yield gaps in the Ethiopian highlands. Doubling the yield would ensure improved food security, substitution of expensive wheat imports while increasing mineral fertilizer use efficiency by ensuring an adequate pH. Hence the public sector and its development partners should further scale-up ISFM across the Highlands and ensure timely and consistent access to lime and other required inputs. Since 4-6 million ha are acidic this will require considerable effort and cooperation, which can only be achieved at scale by strengthening the private sector to supply these inputs.

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