

RESEARCH ARTICLE

Agricultural extension approach: evidence from an Integrated Soil Fertility Management Project in Ethiopia

Gerba LETA (✉)¹, Steffen SCHULZ¹, Girum GETACHEW ALEMU²

¹ Integrated Soil Fertility Management Project, Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Sustainable Use of Rehabilitated Land for Economic Development (SURED), Addis Ababa 100009, Ethiopia
² TMG-Thinktank for sustainability, 53474 Bad Neuenahr-Ahrweiler, Hauptstrasse 27B, Germany

Abstract Agricultural extension is an approach to rural development and agricultural transformation in which training, demonstration and technology transfer are key to reducing rural poverty, ensuring food security, and sustainably managing natural resources. During recent decades, different extension approaches have been tested and validated by the Ethiopian government and non-governmental organizations to stimulate *participation* in the agricultural extension system (AES). The most recent was a German-funded project entitled “Integrated Soil Fertility Management Project” (ISFM⁺), which employed a novel approach to piloting and upscaling proven technology and best practice. The purpose of this study was to analyze and document the modalities of ISFM⁺ and illustrate its effects on technology uptake and dissemination. The study used a mixed methods approach to collect data. ATLAS.ti and SPSS were used for data management and analysis. Farmer Research and Extension Groups and Farmer Field Schools were found to be central to the participation process. Also, the ISFM⁺ was found to aid technology transfer and helped to increase grain and residue yields as well as farmer livelihoods. Based on these empirical findings, it is argued that the ISFM⁺ approach and technology should be integrated and institutionalized in the mainstream AES in order to promote their extensive application.

Keywords Ethiopia, Farmer Field School, Farmer Research and Extension Group, governance, institutionalization, ISFM⁺ ambassador, participation

1 Introduction

Agriculture is the mainstay of the Ethiopian economy,

accounting for the livelihoods of 85% of the population^[1]. However, the sector is riddled with problems that result in chronically poor food and nutritional security in the nation. These include unsustainable agricultural practice, soil erosion, increasing soil acidity, excessive removal and use of crop residues that exacerbate the risk of land degradation, and declining production and productivity^[2,3]. These problems are compounded by inconsistent distribution of rainfall and its erosive nature. Shortage of agricultural inputs and the lack of effective technology and practice add to these problems.

Over the years, rapid population growth and loss of arable land have added to the burden on farmlands^[4,5]. To feed livestock, build thatched roofs and similar activities, farmers are forced to exhaustively mine soil nutrients through practices such as complete removal of crop residues^[6]. Poor adoption of organic fertilizers because of their labor-intensive production, and fear of biomass shortage have increased farmer reliance on chemical fertilizers that are, in fact, affordable only to a relatively small proportion of better-off farmers. While farmers seek yield increments, repeated use of inorganic (chemical) fertilizers contributes to increased soil acidity. However, the adverse effects of the continuous use of chemical fertilizers on soil properties remain largely unknown to many farmers.

Stakeholder interaction and collective action are needed to identify the root causes of the problems faced by smallholder farmers. Capacity building, combined use of organic and inorganic fertilizers, demonstration of new technology, collective learning through Farmer Field Schools (FFSs) and Farmer Research and Extension Groups (FREGs), field visits and exchange of farmer experiences can change the mindset of smallholder farmers and encourage the adoption and dissemination of productive, environmentally friendly and sustainable technology/practice. These can be achieved by introducing an inclusive agricultural extension approach

In Ethiopia, agriculture extension is a publicly run

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Correspondence: letagerba@gmail.com

program that focuses on crops, natural resource management (NRM) and livestock, in that order. Crop-related objectives are to increase production and productivity through the introduction of improved seed and promoting judicious use of chemical fertilizers. NRM mainly targets the arresting of soil erosion and physical land degradation. However, it does not address biological or chemical degradation, which are also a concern for Ethiopian farmers. Also, soil acidity, which is a widespread threat to the livelihoods of smallholder farmers in the western highlands and high rainfall areas of the country, has only recently received some limited attention.

An agricultural approach that has yielded remarkable outcomes, even though it has not been well documented, is the German-funded project entitled “Integrated Soil Fertility Management Project” (ISFM⁺), which has been in operation in Ethiopia since 2015. It was introduced as a quick-win solution to increasing both crop and biomass production through varied but complementary technology packages. The project is predicated on the contention that high biomass production can help in the production of organic fertilizers and retention of crop residues, which in turn can minimize excessive mining of soil nutrients.

High input price and knowledge gaps are among the main reasons Ethiopian farmers are reluctant to adopt new technology. To change this mindset the project trains and exposes farmers to organic fertilizer use, compost production with effective microorganisms (EMOs), vermicompost and bioslurry, use of technology/practice such as biofertilizer, intercropping of large cereal crops with legumes, and small-scale mechanization for minimum tillage. The production of organic fertilizers is labor-intensive but requires less financial investment. The project encourages farmers, especially those with limited means, to use these fertilizers in order to increase both soil fertility and crop productivity. In addition to drastically reducing input costs, the ISFM⁺ extension approach offers farmers diverse income sources such as the production and sale of organic fertilizers, worms for vermicompost, green manure seed, and poultry farming (for which worms can serve as supplementary protein feed). The project has been implemented in close collaboration with the national and regional research and extension system, and all field activities are conducted by national partners.

In the Ethiopian agricultural extension system (AES), farmers without monetary means, particularly the disadvantaged groups of society such as women, have limited access to benefits and services. However, ISFM⁺, through its extension approach, engages about one-third of the women in the target regions as both farmer leaders and followers. This has increased participation in terms of gender and social category. In addition, the overall participation in agricultural extension is growing gradually as a number of farmers in the pilot *woreda* (third level administrative division in Ethiopia) are involving themselves in technology demonstration and upscaling. Insti-

tutionalizing this technology and approach in the mainstream through the AES can boost real farmer participation, which is based on demand, unlike the politically oriented and enforced participation typically employed in agricultural extension^[7]. Improving participation through FREGs and FFSs as well as the implementation of technology packages with technical support from project staff and partners can make agricultural extension services more effective and sustainable. However, the extension approach used, and the technology packages implemented by the ISFM⁺ have not been investigated or documented for use at different levels. Therefore, the objectives of this study were to (1) analyze and illustrate the methodological approach employed by the ISFM⁺ and its partners to promote farmer participation, and (2) enhance documentation of proven ISFM technology and best practice and allow their upscaling for wider adoption and use.

2 Concept and theory

In this study, we adopted the evolutionary governance theory (EGT) as a framework to examine the governance of the ISFM⁺ intervention^[8–10]. In EGT, *governance* is conceived as coordinated and collectively binding decision-making within a community by governmental and other actors^[7,8]. According to van Assche and Hornidge, development approaches are heavily influenced by the *governance path*^[10]. *Governance paths* are specific evolution patterns characterized by the interaction of *dependencies* (*path dependency*, *goal dependency* and *interdependency*). In a given context they are dependent on material, external factors, governance at other levels, and factors outside the governance environment. Evolving institutions, actors, their roles, how processes are organized, and how they interact are key factors of governance^[8]. It is important to note that how a process progresses, for example, toward *participatory approaches* in agricultural extension cannot be considered a linear process.

Van Assche and colleagues emphasize that new development strategies such as participatory extension do not follow a smooth process from inception to implementation^[8]. They are conceived by a few actors, modified by others with different views, reformulated by some others, and even ignored and distorted in a web of *dependencies* which ultimately mold *governance*^[1,11]. In the Ethiopian AES the introduction of new technology, knowledge and approaches has been adopted as the means to ensure food and nutritional security. Experience has shown that extension services that accommodate varying interests, needs and capacities of farmers to increase agricultural production and thus improve food security^[7]. In principle, Ethiopia has adopted an extension system that is rooted in farmer participation. However, the term *participation* is

often just rhetoric used by the state and public agricultural organizations responsible for agricultural extension and rural development. Needless to say, positioning development within the participation context enables the state to attract and cater to the needs of many development partners^[1].

Van Assche and colleagues argue that the outcome of a development strategy is shaped by ideas about past successes and failures, the needs of the present and the future, and the conflicting desires of a community and its circles of *governance*^[8]. For example, the agency and the position of those responsible for implementing the participatory policy have influenced both the practice and interpretation of *participation* in Ethiopia^[12]. Given these diverse influences, changes in the *governance* of *participation* are often unpredictable and uncontrollable.

The state enforces *participation* in some activities which are communal in nature. However, because only certain groups are interested in participation, this eventually leads to a complete lack of participation and failure to achieve the intended objectives. *Participation* in public activities is considered a benefit only by a few. Loaded with many predefined state development goals, *participation* is implemented in a practical and useful way but not to empower the community^[1].

For non-government organizations (NGOs), *participation* is a tool to empower the poor and marginalized and to equally distribute the benefits of the development intervention^[13]. In Ethiopia the overall aim of NGOs in agricultural extension is to address the issues of smallholder farmers and to liberate marginalized farmers from being treated as passive recipients of benefits^[1]. The participants themselves are considered to be responsible for controlling the development process^[14]. The goal of NGOs in the case of ISFM⁺ is to improve the extension approach and promote its adoption by introducing technology and best practice tailored to the problems of farmers. The ISFM⁺ helps smallholder farmers to adopt and internalize the concept and principles of *participation* through FREGs and FFSs.

Unlike the short life span of most NGOs operating in agricultural extension and rural development, ISFM⁺ has been a stable project. In fact, the prolonged project duration has facilitated the cycle of participatory extension and allowed for its short- and long-term effects to be analyzed on farmer mindset, soil properties and the socioeconomic conditions of farmers. The project cycle has offered important insights into the incremental design changes and measures needed to ensure the sustainability of the piloted and validated technology, and to promote their adoption and incorporation into the mainstream public AES. Sustainable financial support from the German Society for International Cooperation, particularly the German Ministry of Cooperation and Economic Development, has been instrumental in driving this project, apart from innovative and insightful leadership. This is in

stark contrast to the short-term implementation phase of many other NGOs, which tend to curb engagement from users, their uptake of environmentally-friendly technology, and the ability of the project to make inroads into the *governance path* and AES.

3 Materials and methods

A mixed methods design, with qualitative and quantitative data collection tools, was used^[15–17]. The fieldwork was conducted in three regional states of Ethiopia (Tigray, Amhara, and Oromia) between 2018 and 2019. Data were collected through a household survey, participant observation, key informant interviews with (1) experts from the regional Bureau/*Woreda* Office of Agriculture, and (2) development agents (DAs), and focus group discussions (FGDs) with (a) ISFM⁺ target farmers, who were members of an FREG, and (b) resident farmers of a *kebele* (fourth and lowest level administrative division in Ethiopia) who were not members of any FREG.

3.1 Data collection

A semi-structured interview guide was used for FGDs and key informant interviews and a structured questionnaire for the household survey. Data collection also involved observation of farmers who implemented the integrated soil fertility management packages of technology and practice in Tigray and Oromia regions. In addition, data were obtained on types of organic fertilizers, their preparation and uses; other agronomic practices such as intercropping; and minimum tillage practices using small-scale mechanization. Overall, six FGDs were conducted with male and female farmer groups (Fig. 1) in the intervention *kebeles* and FREGs in three *woredas* of Oromia region. A household survey was conducted with 290 randomly selected household heads in five micro-catchments of the Amhara region in the ISFM⁺ intervention district (*woreda*) and *kebeles*. Interviews with key informants across the regions, review of literature including project reports and unpublished adoption studies, and secondary data were obtained to gather information about the extension approach deployed by the ISFM⁺.

3.2 Data analysis

The Statistical Package for Social Sciences was used for quantitative data management and analysis^[18]. A simple descriptive statistic such as frequency distribution table was used to analyze the data obtained from the household survey and long-term technology demonstration. Specifically, mean separations and percentiles were used to complement qualitative data. Primary and secondary qualitative data were measured and analyzed with ATLAS.ti 7, which was used for coding and subsequent



Fig. 1 A farmer focus group discussion in the Darbas-Gerado *kebele* of Gudeya-Bila *woreda* (© Gerba Leta, 8:38 A.M., June 20, 2019).

thematic analysis and interpretation of various ISFM⁺ activities^[19].

4 Results and discussion

4.1 Landscape approach and integration of ISFM⁺ with sustainable land management

As outlined by Scherr et al., *landscape* is a socio-ecological system that consists of multiple natural and/or human-modified ecosystems^[20]. They add that the spatial arrangements of different land use and land cover types, along with characteristics of their governance, contribute to a landscape. Depending on the objectives of the stakeholders, distinct watershed boundaries are created, constituting a hydrologic unit for implementing a management intervention. The sustainable land management program (SLMP) and the ISFM⁺ intervention complement one another in terms of watershed selection along the landscape (Fig. 2). Landscapes may constitute different areas of land, ranging from micro-sized holdings to extensive catchments or the basin system. Divided into upper, middle and lower zones, the landscape in the intervention regions calls for management practices that are relevant to the prevailing issues such as area closure, physical and biological soil and water conservation, and other integrated soil fertility management and rural development activities. The ISFM⁺ has complemented

SLMP in this regard in four regions and 60 *woredas*.

Such alignment between interventional projects has helped address the multifaceted issues of natural resources affecting everything from broad landscape to smaller units, as well as from common to private land. The ISFM⁺ mainly focuses on the latter as it directly affects the livelihoods of smallholders. Participants in an FGD in the Digaja-Ogda *kebele* of Bedelle *woreda* described the combined intervention of SLMP and ISFM⁺ as an integrated unit which functions in unison. The majority described the integrated intervention as inseparable and complementary.

4.2 Structure and approach of ISFM⁺ extension

The ISFM⁺ intervention pursues a participatory extension approach. FREGs and FFSs are employed as the main participatory extension and learning units to test and validate introduced technology for adoption and scaling (Fig. 3).

In ISFM⁺, the FREG constitutes a strategy to promote agricultural extension and rural development. This approach stimulates the adoption of new technology by engaging farmers at the community level in participatory planning, joint learning and evaluation. The process of involving farmers in participatory extension has substantial impact on building human and social capital. Farmer-led FREGs encourage collective action at different points during the project intervention.



Fig. 2 Integrated sustainable land management program (SLMP) and Integrated Soil Fertility Management Project (ISFM⁺) intervention along the landscape (area closure in the upper, and stone bunds and integrated soil fertility management in the middle and lower catchment areas) in Tigray region (© Gerba Leta, 11:35 A.M., April 19, 2019).

In participatory extension, farmers tend to support each other; that is, a group of 15–20 farmers collectively investigate, learn and act together. Such collective action not only facilitates learning but also enhances knowledge transfer and scaling of the tested technology. FREGs often conduct new technology trials for wider adoption and upscaling. Proper and practical application of technology boosts its rate of adoption. The ISFM⁺ experiences have shown that successful outcomes of pilot activities and strong groups have encouraged more farmers to join the FREG. For instance, the FREG membership for watershed activities has increased from 50 to 60 farmers in 1 to 2 years in the Seglame *kebele* of Lay-Lay Machew *woreda* in Tigray region and in the Ale-Buya *kebele* in Mattu *woreda* in Oromia region.

As described earlier, under the ISFM⁺ intervention the landscape along the catchment is divided into upper, middle and lower zones for better identification of problems and appropriate solutions that integrate SLMP and ISFM⁺ practices. Such synthesized efforts between the interventional program and project have increased resident farmer understanding and value for participatory extension and collective action. The ISFM⁺ approach of investigating problems at the grassroots level and identifying constraints such as erosion, soil degradation, increased soil acidity, and reduced organic matter has allowed the intervention to address real problems of farmers. This in turn has motivated farmers to actively engage in the practice of collective learning and in the adoption and dissemination of proven technology tested and validated through FREGs and FFSs.

FFS, a participatory approach to extension, is a season-long training activity that takes place in the field^[21]. In line with Khisa remarks^[21], the ISFM⁺ activity brings together

farmer group members at least six times in a season for land preparation, liming, planting, and different cycles of crop harvesting and post-harvesting. The training process is always learner centered, wherein a model farmer facilitates the experiential learning process. Learning from peers instead of other actors is simpler and more engaging for the farmers^[22]. FFSs are farmer-monitored units where management decisions are taken during meetings and discussions. Under ISFM⁺, intervention packages consist of lime application to acidic soil, use of blended fertilizers and improved seed, line seeding, the use of organic fertilizers (such as improved compost or compost produced by EMOs and vermicompost), green manuring and the use of biofertilizers are collectively known as quick-win technologies. Minimum tillage, intercropping of large cereal crops with legumes are also a part of ISFM technology and practice. These packages are simultaneously implemented to increase grain and residue yield and restore the physical, chemical, and biological properties of the soil. These quick-win technologies and other such incrementally tested practices bridge the gaps in agricultural extension and make the ISFM⁺ a comprehensive and strong intervention. Additional ISFM technology/practice includes the production and use of bioslurry, agroforestry, conservation agriculture, crop residue management, and collection and use of livestock urine and waste.

In FFS, farmers learn in a group, and their learning is ascertained by comparing the results of quick-win technologies with those of the standard practices of farmers. Long-term technology demonstration implemented since 2015 has facilitated the application of quick-win technologies on the target farmlands. This approach is in line with the integrated soil-crop management system in

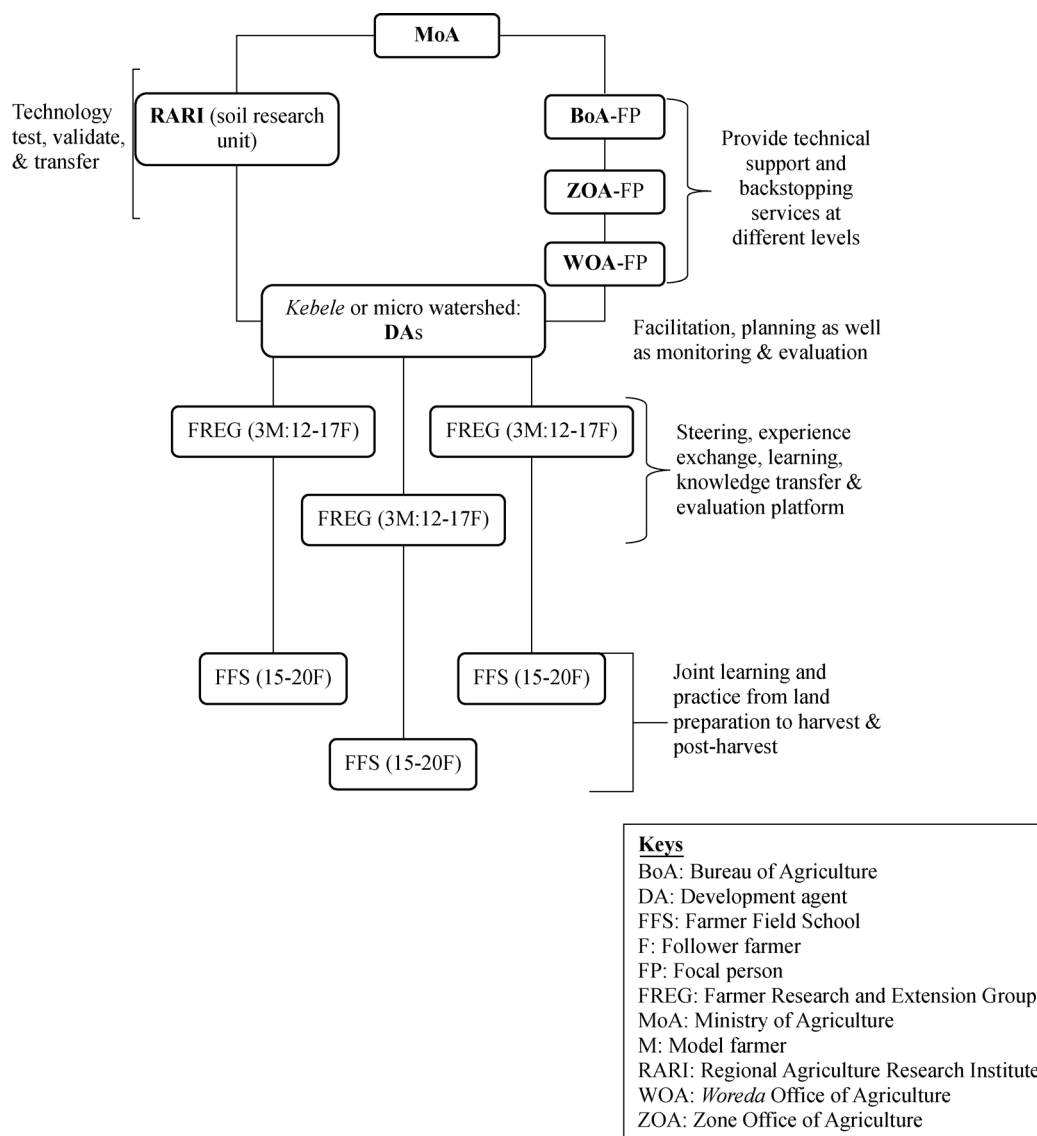


Fig. 3 Implementation framework of the Integrated Soil Fertility Management Project (ISFM⁺).

China^[23]. The yield difference between quick-win technologies and standard farmer practices in acidic and less acidic or neutral soil has been substantial. This has motivated farmers to engage in and adopt them (Fig. 4). Overall, participation in group learning enhances farmer skills and the desire for self-investigation and implementation. The approach builds their confidence and sense of ownership toward the acquired lessons, technology and practice. Thus, the ISFM technology and approach are instrumental in the sustainability of the project beyond its pilot phase and domain.

4.3 Establishment and promotion of agro-dealers for input supply

Agro-dealers are private actors who supply and deliver inputs and services based on farmer demands. New

development projects typically supply free inputs to the farmers to promote technology-piloting. However, this inevitably has negative effects on the adoption and sustaining of the technology and best practice. Recognizing these pitfalls, the ISFM⁺ introduced an innovative cost-sharing mechanism for important agricultural supplies such as lime, biofertilizers and green manure seeds. By collaborating with other development partners such as SNV Ethiopia, the ISFM⁺ extended financial support to agro-dealers in Tigray region. The project has also backed lime suppliers in Amhara region whose experience is currently extended to Oromia region. By identifying capable and proactive dealers who can supply inputs on a subsidized basis, in addition to material and technical support, the ISFM⁺ has included agro-dealers in the process.

To ensure the sustainability of technology and practice

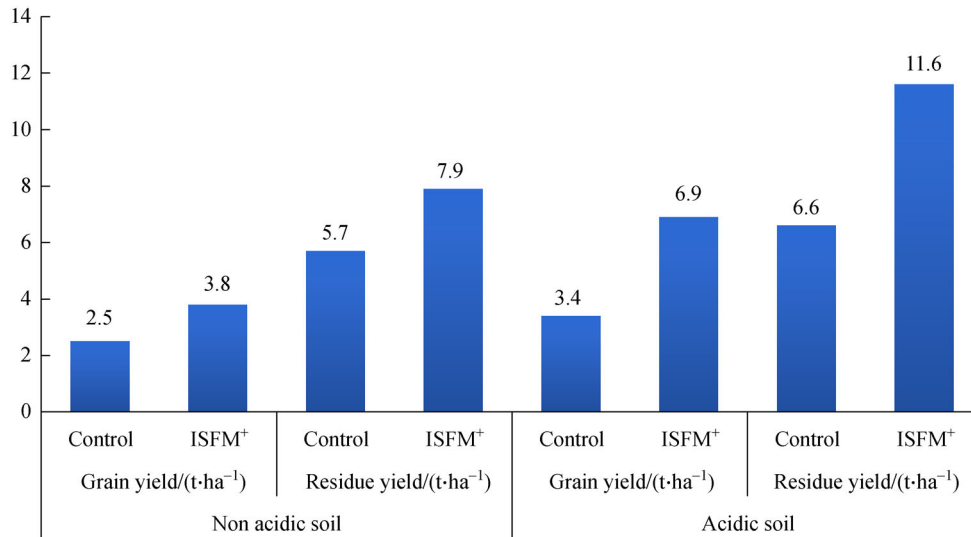


Fig. 4 Effects of long-term demonstration of ISFM quick-win technologies (in neutral soils) and quick-win + lime (in acid soils) on crop grain and residue yield. Source: ISFM⁺ progress report, 2019^[24].

after the intervention is phased out, the ISFM⁺ has introduced a revolving fund for lime suppliers in Amhara region. In this way, 20% of the premium stays with the suppliers in order to make the system sustainable and an independent business model. This measure has been realized through strong partnerships between the ISFM⁺ and private actors on the one side, and the government extension system on the other. Such actions can lead to the development of a pluralistic AES in which the private sector and community-based organizations (CBOs) have key roles^[25,26].

4.4 Motivation of farmers and development actors

Herath notes that motivation, or reasons, for engagement are vital to technology adoption by farmers^[27]. In the ISFM⁺ context, different incentives have been designed to motivate farmers. Supplying of agricultural inputs such as lime, seeds, fertilizers, worms and EMOs for compost production; capacity building through training; and field days and experience exchange visits are some of the basic incentives for smallholder farmers. Training opportunities motivate farmers to become more empowered and thus develop a sense of ownership toward the introduced technology and practice.

In addition to technology and agricultural inputs, the project recognizes the contribution of development agents (DAs) and focal persons (FPs) at different levels. Certificates of appreciation and letters of recommendation are given in recognition of their contributions. These improve their commitment to the project intervention. More importantly, tangible outcomes of the ISFM⁺ intervention, implemented with the help of partner organizations such as bureaus and offices of agriculture,

are a source of motivation for the DAs and FPs. Their achievements reflect favorably on their performance evaluations which are conducted every year and are vital for DA career development and biennial salary increments^[1].

5 Adoption and dissemination of ISFM technology and approach

Adoption of agricultural practice through social learning is part of the mainstream activities of farmers. The effects of a social network are captured in the network analysis of social learning^[28]. As noted by Leta et al., adoption refers to the choices that individuals make about accepting or rejecting an innovation^[22]. The diffusion theory describes how an innovation spreads through a population^[29]. Social learning can facilitate the adoption of innovations by promoting social networking through formal and informal institutions. The ISFM⁺ employs farmer-to-farmer extension through FREGs, FFSs, and the organization of field days and experience exchange visits.

Inspired by the steering of the ISFM quick-win technology through familiarization training and awareness created by project staff and partners, the tendency of farmer responses to technology adoption in long-term demonstration is high from the beginning of project intervention except for vermiculture/vermicompost production associated with early resistance. However, the resistance gradually shifted to hailing with increasing smallholder perception about the accruable benefits from earthworm produce, the vermicompost, and its direct sale (Table 1).

A positive interplay between the configuration of actors

and institutions is key to project implementation. ISFM⁺ ambassadors serve as models for upscaling integrated ISFM technology packages. Based on empirical analysis, we discuss opportunities and challenges for the adoption and dissemination of ISFM technology/practice and how the project stimulates this process through network building that positively influences the livelihoods of smallholder farmers.

5.1 Opportunities for adoption of technology and approach

Central to the demonstration and upscaling of ISFM technology is a people-centered participatory approach which is bottom-up by nature and engages the target community in learning and local development. Farmer-to-farmer extension has been employed to promote the adoption and dissemination of ISFM technology introduced and demonstrated at pilot micro catchments. Model farmers working with DAs are encouraged to share their acquired knowledge and skills with other farmers within as well as outside the FREG. As noted earlier, FREGs offer a monthly learning and experience exchange platform. Led by innovative farmers, the FREG promotes peer-to-peer learning and building of trust. Apart from learning, FREGs conduct an evaluation session during which information about developments is shared with member farmers. FREGs and FFSs are the two most important participatory approaches employed to encourage technology adoption and upscaling. Community participation promoted through FREGs and learning-by-doing encouraged by FFSs actively engage the farmers instead of making them passive recipients of project benefits. In addition, the participatory approach and participation in ISFM⁺ increase farmer self-reliance.

Apart from engaging farmers in co-designing, implementation, participatory monitoring and evaluation, the ISFM⁺ intervention adopts a highly tailored solution-oriented approach from the outset, which inspires farmers to trust, adopt and ingrain the technology. The project targets soil problems such as low fertility, acidity buildup and other related issues. Most soil-related problems in Ethiopia stem from improper practice of agriculture over generations; small and fragmented lands that are prone to overuse; erratic and erosive rainfall, undulating topography; and the underlying parent materials. Quick-win packages have evolved during the adoption of the second

and third phases of ISFM technology/practice. The addition of new technology/practice into the existing quick-win solutions and their customization to farmer needs has transformed the quick-win packages in terms of scope and coverage. Reliable experiential findings, observations and the desires of farmers to progress through the project have become another impetus triggering adoption and upscaling.

The problem-solving approach of the project has been instrumental in convincing resource-poor farmers. In some regions the intervention approach has also catered to local interests and the national AES agenda by adopting cluster formation to demonstrate the proven technology and best practice, such as bioslurry production from biogas and vermiculture/vermicompost production and use in the Lay-Lay and Tay-Tay Machew *woredas* in Tigray region, and green manuring and improved seed multiplication in Amhara region. FFSs have inspired collective learning and action among the target groups and beyond the project domains.

In Tigray and Oromia intervention *woredas*, organic fertilizer sale at local level has been promoted through setting and controlling price. In Tigray, controlled grazing is a potential source of inputs for production of organic fertilizers largely practiced. As learned during participant observation, application of ISFM technology packages enhanced reclaiming the degraded land and improved soil properties in terms of increased fertility and moisture retention capacity. Equally, application of dry forms of bioslurry reduces the negative effects of excess moisture on crops produced in waterlogged environments.

The transdisciplinary approach of the ISFM⁺ intervention involves different research and development partners and farmers who support each other through on-ground research and sharing of new knowledge and skills. More importantly, the project has helped the target farmers understand the causes and effects of declining soil fertility and increasing soil acidity. It has also taught them practical measures to mitigate the prevailing threats of degradation. Notably, the farmers validated the methods proposed by the ISFM⁺ to identify soil-related problems, which was a unique experience for all those involved. In an FGD, farmers described the ISFM⁺ approach as novel: a new solution to engaging farmers in technology and practice for reversing the harmful effects of acidity and preventing loss of soil productivity. In general, through transdisciplinary

Table 1 Farmer adoption trends of ISFM technology/practice

Year	Quick-win technology/practice (%)							
	Improved seed	Blended fertilizer	Line seeding	Green manuring	Biofertilizer	Liming acid soil	Improved compost	Vermi-compost
2015	64.7	61.2	59.5	50.0	47.2	71.5	63.6	10.5
2016	31.0	33.0	34.3	28.9	20.8	21.9	32.5	5.3
2017	3.5	2.9	5.4	12.5	13.9	3.6	2.9	21.1
2018	0.8	2.9	0.8	8.6	18.1	2.9	1.0	63.2

Note: Source from household survey data.

thinking and action, the project intervention managed to link science and practice to ensure the sustainability of the initiatives.

Training of partners and farmers, technical support, and follow-up by project staff and partners are other factors that have enabled implementers to actively monitor the intervention and beneficiaries to take up and adapt the technology and practice to their own needs. Also, the income earned by model farmers from the sale of worms, vermicompost and bioslurry has incentivized follower farmers to embrace the innovative strategies.

Customized technologies such as the development and addition of second and third steps to quick-win have increased the environmental friendliness of the ISFM⁺. The project supports organic agriculture by promoting the production and use of organic fertilizers, which pose little or no risk to human health and are cheaper than chemical alternatives. A key change that ISFM⁺ advocates is the adoption of organic fertilizers and the use of low-cost organic products that can complement inorganic fertilizers^[30]. Our data show that over 60% of the target farmers engage in the production and use of organic fertilizers. Such evidence is promising for the scaling of technology and practice, and this shift in farmer practice has important implications for soil health and sustainable improvement of soil properties.

During an FGD, target farmers lauded the intercropping practices of the intervention in maize-growing areas and minimum tillage using small-scale mechanization (Fig. 5). The integration of these technologies/practices has resulted

in multiple short- and long-term benefits for the target community. Piloting of technology/practice via the ISFM⁺ extension approach, local and national field days, and experience exchange visits has enhanced the dissemination of ISFM technology and practice on a larger scale.

Informants explained that minimum tillage through line seeding, intercropping, and retention and management of crop residues have yielded the following benefits:

(1) reduced tillage frequency and mitigated risks of soil loss to flash erosions in the monsoon before the land is covered by crop;

(2) enhanced efficient utilization of land for growing early maturing beans;

(3) addressed food shortage issues toward the end of the monsoon when farmer food reserves are on the decline;

(4) introduced protein-rich legumes into the household diets;

(5) generated additional income through the sale of companion crops; and

(6) sustainably increased the fertility status of degrading soils by promoting the accumulation of rhizobia in root nodules.

5.2 Challenges to adoption and sustainability

Given that ISFM⁺ integrates diverse technologies and practices, the availability of resources for investment is essential. However, high initial cost can dissuade resource-poor farmers from adopting the technology/practice, even though a cost-benefit analysis may confirm the benefits of



Fig. 5 Line seeding of maize using small-scale mechanization on a smallholder farm in Agalo-Gidami *kebele* (© Gerba Leta, 8:38 A.M., June 10, 2019).

adopting ISFM technology^[32]. Other obstacles anticipated by participants at an FGD included limited access to sustainable supplies or inputs such as lime, improved seeds of farmer choice, biofertilizers, and initial/starter kits for vermicomposting. In addition, limited access to EMOs and the high cost of small-scale mechanization can result in farmers losing interest and limiting their adoption and dissemination of ISFM technology. Problems associated with compost production and use mainly consist of competing uses for crop residues and animal manure.

The fragmented land tenure system in Ethiopia and the distance between farmer homes and fields make it difficult for farmers to carry organic fertilizers from the sites of production to the sites of application (Table 2). In an FGD, farmers noted that compost preparation was undertaken even as part of the mainstream AES, but often the compost remained unused. This highlights the importance of follow-up in agricultural interventions. Lack of availability of labor for compost production, line seeding, lime application, or combined use of organic and inorganic fertilizers as well as limited access to inputs were the main constraints to the adoption of ISFM technologies (Table 2). However, better access to lightweight vermicompost and bioslurry can be positioned as alternatives to inorganic fertilizer use.

High turnover of technical personnel trained by project staff is another impediment to project implementation. Inconsistent staff retention by partner organizations increases the work burden on the staff engaged in support services, which in turn promotes the likelihood of losing trained focal persons and introduces uncertainties into the pilot phase. The situation can be addressed by simultaneously training main and backup personnel, though it will

add to project costs. Losing experienced personnel and the associated drawbacks are common during project implementation. Thus, despite best intentions, variation in the implementation of ISFM⁺ across sites has been unavoidable.

5.3 Patterns of technology dissemination

The farmer-to-farmer extension approach, facilitated by FREGs and FFSs, is fundamental to the dissemination of ISFM technology and best agronomic practice. The three ISFM⁺ ambassadors, appointed in each *kebele*, further strengthen the diffusion of technologies to the marginalized social groups. Informal institutions such as CBOs, especially a self-help association (*iddir*) and collective labor groups (*dado*), complement the formal setups in collective action, learning, and technology transfer for rural development and agricultural extension^[22].

Strategic partnerships and the involvement of research and development actors help in piloting and validating the technology for adoption and dissemination. At the local level, *woreda* FPs and DAs are important for the provision of technical support and following up on operational activities. Short- and long-term demonstration activities by model farmers as well as organized field days and experience exchange visits promote the uptake of ISFM technology at different levels.

5.4 Implications of the ISFM⁺ intervention on farmer livelihoods

Target farmers considered the ISFM⁺ to be a surprising and an innovative solution to soil problems. They fully

Table 2 Barriers to adoption of ISFM technologies/%

Determinant	Improved seed	Combined organic and inorganic fertilizers	Line seeding	Green manure	Bio-fertilizer	Lime	Vermi-compost	Preparation of improved compost
Limited availability of technology	42.6	33.8	8.8	24.3	21.1	13.0	19.4	9.2
Limited knowledge of the source of the technology	19.0	22.2	11.6	22.9	37.0	27.5	43.3	14.4
Limited knowledge of technology management	20.8	24.6	22.9	28.5	34.5	29.2	41.5	21.5
Limited knowledge of the technology benefits	4.9	8.8	7.4	14.1	22.9	16.5	33.5	11.3
High cost of production	64.4	62.0	23.6	29.2	16.9	32.4	18.0	18.3
Lack of profitability	1.1	1.4	2.8	3.2	7.0	4.6	7.4	2.1
Limited access to finance	49.6	46.8	5.3	15.5	13.4	16.9	7.0	2.5
Land tenure security issues	8.5	19.4	5.6	15.1	14.4	22.5	16.5	19.7
Small landholding	12.7	8.1	8.8	9.5	6.0	7.4	4.9	5.6
Long distance to farmland	9.9	35.9	22.9	9.9	6.7	49.6	19.7	61.6
Limited labor availability	15.8	37.7	63.4	9.5	7.0	46.5	21.5	64.4
Limited availability of livestock	11.6	34.9	20.8	5.6	3.5	48.9	19.4	60.2

Note: High figures show the effect of the determinants on production, transportation, and uses of ISFM technologies/practices. Source from household survey data.

recognized the substantial economic and ecological benefits introduced by the intervention, including increased incomes and improvement in soil quality. During an FGD, the target farmers revealed that the knowledge and skills acquired from the ISFM⁺ intervention exceeded the direct returns from the investment. Proper implementation of the quick-win technologies has helped farmers witness the transformation of acid soils and degraded land. Thus, the ISFM⁺ intervention has unequivocally contributed positively to the livelihoods of target farmers, providing ample justification for upscaling the project.

6 Institutionalization of ISFM technology and approach for sustainable intensification

In the interventional *woredas* of the three regional states, the farmers were impressed by the packages of technology and practice that not only improved soil health but also promoted food security and sustainability by increasing the productivity of their land. The intervention allowed them to view their own land as a resource to be inherited by the future generations. Centuries of environmentally unsustainable farming practice have exhausted soil nutrients and burdened resource-poor farmers. However, alternative farming practices such as minimum tillage, intercropping, preparation and use of organic fertilizers, line seeding, and combined application of inorganic and organic fertilizers introduced by the ISFM⁺ helped salvage the land from inefficient use and abuse.

The positive response from farmers toward the technology and best practice has encouraged project donors and development partners to replicate the intervention on a larger scale. As *governance* efforts involve dynamic configurations of actors/institutions and power/knowledge, incorporating the ISFM technology and extension approach into the existing government AES at different levels can trigger coevolution and complementarity effects. *Institutionalization* of the ISFM technology into the mainstream extension system is essential to harness its full potential for the betterment of agricultural and rural development in Ethiopia.

Evolution in EGT is incremental; any change in structures and elements builds on the previous ones^[8,31]. Infusing reliable technology and best practice of the ISFM into the AES is a novel approach to preempting failure in up/out-scaling. Doing so can help extend the beneficial outcomes of the pilot project to the existing government extension system. The concept of *path creation* in EGT emphasizes the positive interplay between actors/institutions and between institutions themselves as a route to introduce reforms, providing an opportunity to transform the AES and rural development^[1].

Along with efforts to mainstream ISFM technology, locating sustainable sources of inputs such as lime and strengthening its supply chain from producers to end users

is vital. The agro-dealers in the study represent a key link in the project. As with other agricultural inputs such as inorganic fertilizers and improved seed, securing the distribution and use of lime is essential. Currently, the purchase and distribution of lime is funded by the government and other developmental actors. To overcome the dependency that free distribution tends to create, the government should explore other strategies such as the cost-sharing method piloted by the ISFM⁺ for lime distribution. Nonetheless, subsidies and economic incentives are needed to make farmers more self-reliant in accessing the necessary inputs. Apart from generating awareness, farmers should be practically shown how applying lime to acid soil can sustainably increase its production and productivity.

7 Conclusions

A salient feature of this study is that it traces the evolution of the extension services system by integrating science and practice, and by mainstreaming the ISFM technology and approach into the public AES. Innovative measures such as leveraging the supply of lime through agro-dealers, reducing farmer dependency on free supply of inputs, introducing a revolving fund into the lime supply chain to agro-dealers and watershed users have enabled target farmers to develop a sense of ownership toward the ISFM⁺ approach.

The sale of worms for vermiculture is a valuable source of short-term income for farmers. Also, the application of vermicompost boosts the yield of the farmland. Easy to produce and transport, vermicompost increases the fertility and moisture retention capacity of the soil, similar to other component technologies such as the application of lime and other organic fertilizers. Residual moisture is favorable for crop growth during dry periods. Such visible benefits have motivated farmers across regions to embrace and upscale the ISFM technology. Similarly, the positive experiences of farmers using bioslurry in liquid and solid forms have persuaded many in the regions to adopt its use.

In Tigray region, the Bureau of Agriculture has introduced initiatives in ISFM⁺ *woredas* to control the price and quality of organic fertilizers in order to promote their production, distribution and use. Organic fertilizers not only benefit the soil but also support the livelihoods of model farmers. Farmer confidence in the project intervention has been strengthened by both the public agriculture extension and stakeholders. In summary, the ISFM technology and approach are well suited to wider application. By treating soil acidity and restoring productive potential, these measures minimize smallholder vulnerability to the threat of reduced food and nutritional security.

Since the launch of long-term technology demonstration in 2015, grain and residue yield in the intervention regions

have increased significantly. Also, high biomass production has led to the retention of crop residues, which is used to feed livestock and produce improved compost, vermicompost and bioslurry. In Tigray region, controlled grazing systems have yielded promising results which can be scaled and sustained. Thus, the ISFM⁺ approach, backed by technical training and demonstration, promotes balanced interactions between crops and livestock, which is vital to sustainable growth and development.

Overall, the steering of diverse technologies and best practices by ISFM⁺ signals the evolution of the impact of NGOs/bilateral cooperation *governance* on rural development and agricultural extension. The *institutionalization* of the intervention into the AES can serve as a prototype for other development partners pursuing related interventions. Such efforts can help consolidate the influence of weaker extension approaches on promoting technology adoption and upscaling.

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Compliance with ethics guidelines Gerba Leta, Steffen Schulz, and Girum Getachew Alemu declare that they have no conflicts of interest or financial conflicts to disclose.

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