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Broad bed maker technology package innovations in Ethiopian farming systems: An *ex post* impact assessment

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Table of Contents

List of Tables

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Prior to using the broad bed maker plough (BBM), Vertisol farmers in the North Gondar zone forum reported being considered to be 'poor farmers'. Without the possibility of having a second crop, many farmers used to plant sorghum in April and wait 10 months to harvest it—a relatively long time. The women and children had to watch the crop to guard it against bird damage. As a result children had to miss school. Other farmers were restricted to only having a single crop—usually chickpea. Now with the BBM the same farmers can choose to have two crops per season, e.g. improved wheat and chickpea. Compared to sorghum, they have a shorter time from planting to harvest, and because the crops do not need protection from birds, the children can attend school. The farmers also have more straw from wheat and chickpea for animal feed. They have reduced their risk of total crop failure because even if the wheat crop fails they have a second crop. The extra income from using the BBM package is spent improving their children's schooling, buying farm inputs, increasing the quality and variety of their diet and increasing their family's food security. Some farmers even buy a house in the local town and rent it out. Other farmers have started a flourmill for the community.

Executive summary

Even the simplest farming systems are complex. Consequently, the paths between system interventions and impacts on the welfare of the system are complex. In Ethiopia, over 80% of the country's rapidly growing population of 80 million people is classified as rural and most live in the country's highlands. Traditional crop–livestock farming systems still predominate—exemplified by the oxen-drawn ploughs used to cultivate the land. Improving the welfare of households and agricultural sector actors that depend on these integrated crop–livestock systems in the Ethiopian highlands remains a challenge for Ethiopia's government, the emerging private sector, and research and development communities.

This report is the latest of two separate *ex post* impact assessments conducted by ILRI 10 years apart. It provides timely insights into the welfare impacts of a technology package introduced in the early 1990s into the crop–livestock farming system of the Ethiopian highlands rich Vertisol soils. Both studies were conducted using an economic surplus methodology, gross margin analysis and qualitative and quantitative assessments of adoption and the economic risks associated with uptake of this technology. The majority of data used in this assessment was obtained from surveying farmers. Other primary information was obtained from forum discussions with farmers and government personnel. Secondary data was collected from government personnel and non-governmental organizations (NGOs).

The Joint Vertisol Project (JVP) developed the Broad Bed Maker (BBM) technology package (TP) in the late 1980s. ILRI (formerly known as ILCA in Ethiopia) was one of five collaborating institutions on this project. The aim of the JVP was to improve the productivity of 7.6 million hectares of Vertisol soils in the Ethiopian highlands. Although fertile, less than 20% of the highland Vertisol area is cultivated as Vertisol soils can be difficult to work—cracking when dry and becoming sticky and waterlogged when wet.

The BBM itself is a type of a plough that was developed from the traditional dual oxen-drawn plough, the *maresha,* in order to more efficiently make raised seedbeds and furrows at the time of seed covering—thus reducing water logging and encouraging early planting of improved cereals which could then be followed by a second pulse crop in the same growing season. Early planting also enhances natural resource conservation. The traditional practice involves ploughing the land before the rainy season, but not planting until after the rains have stopped and the land has drained, which leads to serious soil erosion problems.

The elements of the BBM TP include the BBM, improved seeds, fertilizer, herbicides and pesticides, credit and training. The design of the BBM evolved in the period between the two studies but its function in the technology package of making raised seedbeds and furrows for early planting of improved seeds and soil conservation has not changed. Similarly, new

improved seed varieties have replaced earlier improved seed varieties and this has allowed slightly earlier planting. The BBM is almost exclusively used in conjunction with the other elements of the technology package in the highlands. In drier areas, it has been reportedly been used as a 'stand alone' intervention for water conservation rather than water drainage.

On a national scale, BBM TP adoption and impact on welfare remain relatively low, with approximately 100,000 farmers now using the TP on 63,000 hectares. With estimated total real research and extension expenditures of USD 63.6 million since 1986, the change in net economic surplus generated was calculated to be USD 47 million, with a benefit–cost ratio of 3.3:1 for the research and dissemination efforts and a positive internal rate of return of 0.1. For the farmers who have used the BBM TP, the net economic impact on their households welfare has usually been positive—particularly for those who previously were restricted to having only a single crop in any one season. Recent innovations in the package's elements (including the BBM plough and improved seed varieties) and association of the BBM TP with water harvesting strategies have further enhanced adoption and improved the livelihoods of those households engaged in water harvesting. Further research to better understand these linkages and the impacts of water harvesting innovations is needed.

In order to reach their food production targets, the Ethiopian government has recently been actively promoting the adoption and use of the BBM TP once again via BBM price subsidies, increased access to credit, and increased training. There appeared to be very little spontaneous adoption of the BBM TP between the government's two BBM TP 'promotional bursts' in 1994–1998 and 2004–08. Therefore, under current economic and market conditions, widespread adoption and sustained use of the BBM TP will likely remain reliant on government support.

The most important lesson learned from both *ex post* impact assessments for the Ethiopian government and research institutions like ILRI is that key factors continue to constrain adoption and impact of the BBM TP—particularly lack of savings, access to longer-term credit, sufficient training and information on the BBM TP, and supplies of improved seeds.

For sustainable adoption and widespread realization of welfare-enhancing impacts of the BBM TP interventions, each of these constraints need to be alleviated without reliance on long-term financial assistance from the government. The complex challenges associated with alleviating each of these constraints are best faced by encouraging more effective communication between, and actions of, farming households and groups, the government, non-governmental organizations like ILRI, and the commercial sector (including private seed companies).

1 Introduction

The Broad Bed Maker (BBM) was developed in the late 1980s from the traditional dual oxen drawn plough, the *maresha* by the Joint Vertisol Project (JVP). ILRI (formerly known as ILCA in Ethiopia) was one of five collaborating institutions on this project. The aim of the JVP was to improve the productivity of 7.6 million hectares of Vertisol soils in the Ethiopian highlands—60% of Ethiopia's total Vertisols. Although fertile, less than 20% of the highland Vertisol area is cultivated as Vertisol soils can be difficult to work—cracking when dry and becoming sticky and waterlogged when wet. The role of the BBM was to make raised seedbeds and furrows more efficiently and effectively, thus reducing water logging and encouraging early planting of a cereal crop of an improved cereal variety which could then be followed by a second crop of pulses in the same growing season.

As highland crops rely on retained soil moisture, traditional land preparation normally begins with the short rains (March/April) for one to two months and resumes with cultivation and planting when the main rains begin (June/July). While traditional moisture tolerant crops such as teff were planted in flat beds without man-made improved drainage, traditional improved drainage methods for other crops included hand-made broad beds and furrows (*zekosh*), drainage furrows, and ridges and furrows (*shurube*). There is a small window of opportunity between when the soil is too dry and too wet to work. This period occurs after the main rains begin when bed and furrow making is less arduous—particularly for women and children who have traditionally engineered the hand-made broad beds and furrows. This window can be quite narrow for the BBM—especially for farmers sharing the implement and when a lot of rain is received at the start of the season.

Three early prototypes of the BBM were developed and tested by the JVP before the final BBM design was selected. The first version had a wooden-wing mouldboard shape replacing the traditional flat wings (*digir*) of the *maresha* (Alemayehu and Hailemariam 2008) (see diagrams in Annex 1). However, farmers found it to be too time-consuming and limited in terms of its reduction of water logging. In the second version, the *maresha* had shorter beams and larger mouldboard shaped wings. Although it was technically effective, it was too heavy (35 kg) and bulky to transport to the field.

The 'then' final version was made out of two *mareshas* connected in a triangle structure. The oxen ends of the *maresha* beams were tied together and connected to the yoke and a steel wing of the mouldboard shape was attached to each inner wing of the *maresha*—with the two metal wings joined by a chain for seed covering (Amede et al. 2004) (see photographs in Annex 1). This 1993/94 double-beamed BBM was also drawn by two oxen but required an additional human 'driver' to operate compared to the *maresha*. Land preparation was still conducted the same way (i.e. two or three passes with the *maresha*) but broad bed and furrow construction and seed coverage were achieved using one pass of the BBM—the extra width of the implement actually reducing the labour requirements during seed coverage/planting compared to the *maresha* despite having an additional operator.

The BBM became the centre piece of a technology package that evolved to contain seven key elements—namely a plough to improve the effectiveness and efficiency of traditional drainage practices and resource conservation, improved (higher yielding but less water-tolerant) seeds, fertilizer, herbicides and pesticides, credit for the plough and/or inputs, and training on how to use the package. Widespread distribution of the BBM technology package (TP) by the Ethiopian Ministry of Agriculture began in 1993/94. To date, the elements of this technology package have not changed in number or function. Some elements have evolved in form (i.e. the improved seed varieties and the design of the broad bed and furrow maker as explained below).

ILRI's first *ex post* impact assessment (EPIA) of the BBM TP was undertaken in 1998 (Rutherford et al. 2001). This study quantitatively assessed the returns to the research investment in the Broad Bed Maker technology package using the economic surplus methodology. In terms of improving the welfare of farmers and consumers, the study found that the overall impacts were disappointing. However, some key lessons were learned in terms of constraints to the realization of the potentially significant welfare benefits this technology package offered. The first key lesson in relation to the BBM TP was that adopting and using the package exposed the farm households welfare to considerable risk. This welfare risk arose because of the very high cost of adopting the technology package relative to the farming households income and savings (see Rutherford et al. 2001). Furthermore, in suboptimal conditions of adoption and impact, this risk is magnified. For example, if the BBM TP is purchased and not used correctly as a result of inappropriate/insufficient training, missing the window of opportunity, and/or not having timely supplies of improved seeds, the farm households welfare would be adversely affected. In addition, in below average seasonal conditions, improved crop yields and net returns were reported to be significantly lower than those of traditional crops. All of these scenarios would either erode the farm households savings or, if they obtained short-term rather than longer-term credit, place them in a debt which they may not be able to escape.

The second important lesson from the earlier assessment was that the type and quality of training received by farmers and MoA staff was often insufficient. Third, the human labour requirements and the oxen draught power were usually underestimated. Fourth, the BBM was too heavy if not used at the optimal time—particularly for oxen weakened by lack of feed and disease. Fifth, in the absence of a watershed approach to drainage, increased drainage on one plot often exacerbated water logging and erosion in neighbouring plots.

Ten years on, this *ex post* impact assessment was commissioned by ILRI to assess the current role of the same BBM TP in the sustainable utilization of Vertisol soils in Ethiopia. One major finding of the current study was that the BBM that has been extended to farmers by the MoA for the last four years is a single-beam BBM—most similar to a prototype of the double-beam BBM that was developed in the 1980s. No evidence was found of the use of the 1993/94 double-beam BBM that was the focus of the earlier *ex post* impact assessment so from this point forward, the term BBM refers to the single-beam BBM unless otherwise stated (see photographs in Annex 1). While the BBM itself has evolved, the purpose for which it is used (i.e. making beds and furrows to allow early planting) has not changed between the two studies.

2 Methodology

The economic surplus methodology used in the 1998/99 impact assessment was also used in this impact assessment. Due to time constraints, the latest study was conducted on a smaller scale with respect to field work and the number of farmers surveyed.

In Ethiopia, the country is administratively divided into eight regions that are subsequently divided into zones. These zones are further divided into *woredas* and finally peasant associations (*kebeles*) that represent the least aggregated of the administrative classes. This 2008 study began in August and relied on primary data collected from government Development Agents (DAs) and farmers from the two major Vertisol regions (i.e. Amhara and Oromia) and secondary data from the Ministry of Agriculture (MoA) personnel at the regional, zonal, *woreda* and peasant associations/*kebeles* levels as well as from the Ministry of Agriculture and Rural Development (MoARD) and the Central Statistical Authority (CSA).

Primary data was collected in two formats—one-on-one surveys of farmers (see Annex 2 for the full survey form) and group discussions with a 'forum' covering broad topics with interested farmers (some also having been formally surveyed for this study and some not) and DAs as an interactive group (see Annex 3 for the forum discussion outline). The forums proved invaluable for gathering more in-depth insights into BBM TP related innovations, adoption and impact.

Two national scientists from ILRI coordinated the primary and secondary data collection in each region. Primary data collection from farmers was conducted by a team of five enumerators in the Amhara region (where travelling distances and conditions are more challenging) and three in the Oromia region after initial pre-testing of the survey in the Oromia region. The four weeks of fieldwork were conducted in October/November 2008.

Within each of the two regions, four zones and one *woreda* from each zone were originally selected for surveying on the basis of advice about BBM distribution from the MoA to provide as broad coverage as possible in the time available. Some adjustments had to be made to the *woredas* selected as further information on BBM TP use became available. From each *woreda*, peasant associations were purposely selected based on reported use of the BBM TP and taking travel times into consideration. Farmers who had used the BBM TP some time in the last 2 years were randomly selected from each peasant association to obtain a sample of 15 farmers per *woreda*. An effort was made to select some female-headed farm households for the survey and forum discussion.

The fieldwork yielded 121 completed farmer surveys (including 7 female-headed farm household responses), from 13 peasant associations and 8 *woredas*. The number of zones covered in the Oromia region was reduced to three (with two *woredas* selected from the same zone) due to difficulties experienced in the field including unseasonably heavy rain (Table 1).

Table 1. *Farmer survey coverage, 2008*

Region	Zone	*Woreda*	Peasant Association
Amhara	West Gojam	Semen Achefer	Denbola Quengarie
	South Wello	Jamma	Shelafafe
	East Gojam	Debaytelagn	Assendabo
	North Gondar	Gondar Zuria	Tsehion segach
Oromia	West Shewa	Dendi	Chelka Bobie Kela Embortu
	Southwest Shewa	Becho	Awash Buni Kobo
	East Shewa	Lume	Deka Bora Tulu Rae
		Ada	Denkaka Ketaba

3 Results and discussion

Two factors in particular are renewing interests in productivity improving technologies, including the BBM TP, in Ethiopia. The first is population pressure. Ethiopia's population was estimated at 60 million in 1999. The latest census revealed an increase to 80 million people in 2008. Examining population policies was beyond the scope of this study but it is a significant policy issue. The second and related factor is the most recent regional food shortages—exacerbated by insufficient short and long rains. This section examines the use and impact of the BBM TP at the national and regional levels and is followed in Section 3.2 with an examination of the important policy environment surrounding the BBM TPs use and impact. Section 3.3 examines the quantitative impacts of the package at the regional, zonal and *woreda* level in detail.

3.1 National and regional impacts

This section provides an overview of the national and regional impacts of the BBM TP and was obtained from various sources including informal interviews with senior MoA staff. More detailed information collected from the Amhara region is provided in Annex 5.

Total BBM TP area

In the 2007/08 crop season, there were approximately 63,600 hectares utilizing the BBM TP in Ethiopia (Table 2). In 1998 when the earlier assessment was carried out, there were 625 hectares under BBM TP and the forecast for the area of land to be drained using the BBM TP by 2005 was around 63,000 hectares. Thus the BBM TP area predicted in the earlier analysis was accurate although it took two to three more years to reach than projected.

Table 2. *National BBM TP usage 2007/08*

Region	BBM TP drained land (ha)
Oromia	35,805
Amhara	24,736
Tigray	5000
Southern Region	52
Total	63,566

Source: MoARD, W Ayalneh (2008).

The current season's area using the BBM TP represents approximately one per cent of the estimated 7.6 million hectares of Vertisol soil (not all cultivated) in the Ethiopian highlands. The government has ambitious plans for expansion of the BBM TP usage. The government's plan for the Oromia region in 2008/09 is to increase the cultivated area in the region to 551,000 hectares with one million farmers participating. The plan includes having 85% of the cultivated area planted using the BBM TP. However, the actual BBM TP prepared land has often been significantly less than planned—as indicated by the statistics for the Oromia region where the area under the BBM TP reportedly increasing sixfold over the previous year (Table 3) (see Annex 5 for more detail on the Amhara region). The area of land drained using the BBM TP as a proportion of the total cultivated land in the 2007/08 cropping season was 37% in the Oromia region and 18% in the Amhara region.

Table 3. *Oromia zone cultivated land by practice—planned and actual 2007/08*

Oromia zones	Cultivated land (ha)					
	Planned			Actual		
	BBM TP	Traditional	Total	BBM TP	Traditional	Total
Southwest Shewa	84,212	9357	93,569	8959	2483	11,442
West Shewa	72,863	8096	80,959	13,168	3552	16,720
North Shewa	68,023	7558	75,581	3991	17,549	21,540
East Shewa	35,337	3926	39,263	4261	–	4261
Arsi	72,983	8109	81,092	4285	–	3316
Bale	86,782	9642	96,424	887	33,105	33,992
West Arsi	29,800	3311	33,111	254	4987	5241
Total	450,000	50,000	500,000	35,805	61,676	96,512

Source: Oromia MoA, BBM TP conference October 2008; W Ayalneh (2008).

First and second BBM technology package crops

The MoARD reported that improved wheat was the exclusive crop grown using the BBM TP in almost all regions. The exception was the Amhara region where barley/horse bean and lentils were also reported on BBM TP land (at 10% and 5% respectively).

As mentioned, one of the advantages of additional soil drainage and early planting is the possibility of growing a second crop in suitable areas. The dominant second crop in the Oromia region in 2007/08 was chickpea—predominantly in West Shewa and Southwest Shewa zones (Table 4). The area planted to second crops represents approximately one-third of the area under the BBM TP in these zones in 2007/08.

Table 4. *Second crops in the Oromia region by zone in 2007/08.*

Oromia zones	Second crop by type and area (ha)			
	Chickpea	Lentils	Rough pea	Total
Southwest Shewa	2385	130	1844	4359
West Shewa	5189	855	1518	7562
North Shewa	–	–	–	–
East Shewa	295	–	7	302
Total	7869	985	3369	12,223

Source: Oromia MoA, BBM TP conference October 2008; W Ayalneh (2008).

BBM technology package inputs

The price of inputs for the BBM package varied significantly between regions and between *woredas* within the Oromia region in particular. This is often a key factor constraining adoption and use in particular areas. Some prices also vary significantly between years (Table 5).

Table 5. *Price of BBM package inputs in Oromia region* woreda *and Amhara region in 2008*

Region/*woreda*/zone	BBM (ETB)	DAP (ETB/quintal)	Urea (ETB/quintal)	Herbicides (ETB/litre)	Pesticides (ETB/litre)
Oromia					
Becho—Southwest Shewa	119	789	524	48	75
Dendi—West Shewa	197	787	603	60	
Lume—East Shewa	180	916	562		
Average	165	831	563	54	75
Amhara region	45	756–843	604–635	115–140	75

Source: MoA—W Ayalneh, S Gebresalassie (2008).

The nominal price of the BBM itself has halved since 1988 when the price was USD 36 (Ethiopian birr, ETB[1] 251) in 1998. However, the price of the BBM varied and has increased recently—in Lume and Ada it cost ETB 96 and 92 in 2007, respectively, almost doubling to ETB 180 in 2008.

Training

To date, the *woreda* experts, peasant association experts, and farmers who had received training on the BBM package in the region were approximately 490, 1790, and 139,800 respectively. This indicates that approximately only one-third of the farmers who had been trained on the BBM package actually used the BBM in the region in 2007/08 (based on an estimate of average BBM land per farmer).

There is a significant difference between distribution to government offices vs. distribution and actual use by farmers. While the region currently has approximately 80,000 BBMs, only 50% of them had been distributed to farmers—ranging from 10 to 80% depending on the zone. A similar situation exists in the Amhara region where only 15% of the BBMs supplied to the zonal and *woreda* offices have been distributed to farmers (Table 6) (for more details see Annex 5).

1. Ethiopian birr, ETB. In December 2008, USD 1 = ETB 9.9724.

Table 6. *Distribution of BBMs to government offices and farmers in the Amhara region to date, 2008*

Zone	BBMs remaining in government store	BBMs distributed to farmers
West Gojam	4901	501
North Gondar	21,331	3055
East Gojam	19,730	4643
South Wello	13,813	6783
Awi	1117	23
North Wello	12,245	3265
South Gondar	9465	1204
Oromia (zone not region)	262	0
North Shewa	34,230	1129
Wag Hemra	0	0
Total	117,094	20,603

Source: MoA—W Ayalneh (2008).

Similar statistics revealing relatively low adoption of and impact from, the BBM TP were found throughout the country and have led the government to question the best way to extend the BBM TP.

3.2 The policy environment

This section provides an overview of the policies affecting adoption and use of the BBM TP and was obtained from various sources including informal interviews with senior MoA staff. The goal is to provide a broader picture of the various policies and policy instruments the government of Ethiopia is using at the national, regional and subregional levels to achieve their policy objectives. All of the issues raised below are arguably worthy of further study and were beyond the scope of this study.

Ethiopia's Federal Ministry of Agriculture has renewed its interests in the BBM TP since 2006/07—providing political support aimed at increasing its adoption and impact. This was also the case from 1993/94 to 1998. One of the policies used by the government to encourage use of the BBM TP is to set target quotas for each region, zone and *woreda* with respect to the number of people receiving training (government personnel and farmers), the quantity of package inputs distributed, and as seen in the previous section, the area of land drained using the BBM TP. However, in most cases these targets are not met for various reasons. For example, in Fogera *woreda* (South Gondar, Amhara region) rice growing is preferred by farmers and appears to be more suited to the land gradient, soils, and rainfall than BBM TP crops. In Ada *woreda* (East Shewa, Oromia region), only 50% of the land identified as suitable for the BBM TP by the Office of Agriculture and Rural Development (OARD) was subsequently identified as suitable by the local government staff. Another problem with target policy instruments (as discussed in detail in the previous report) is that even when some targets are met, they do not achieve the governments overall policy objective, i.e. actual adoption and use by farmers to improve welfare. For example, BBMs may reach their quotas in terms of being distributed to *woreda* offices, but that is where they often remain rather than being used by a farmer (see Annex 5).

The forum discussions held in West Gojam zone (Amhara region) revealed that there are some cultural constraints to adoption and use of the BBM TP for female-headed farm households and poorer households (see Annex 3). Firstly, female-headed farm households do not usually plough themselves—they either rent out their land or hire male labour in. When they hire in labour, the men are sometimes unwilling to 'do extra work' associated with the BBM (i.e. spending time attaching the BBM wings). Secondly, some women are too shy to register under their own name with the PA—using their son's or their deceased husband's name if they do register. Thirdly, women find it difficult to attend training and demonstrations due to difficulties finding someone to mind their children. The government is training female DAs to try and help reach women. BBM TP-related policies in the Amhara region currently do not disadvantage poorer households from using the BBM. The major constraint for poorer families appeared to be convincing risk averse members of the household of the benefits the BBM TP can offer.

Unlike the situation in 1993/94, in 2008 there is relatively little traditional non-governmental agency (NGO) support for extension of the BBM TP apart from some localized activity of Sasakawa-Global 2000 (Sasakawa-Global 2000 2007). The Rural Capacity Building Project funded by the World Bank and CIDA has also recently supported the distribution of the BBM TP in its operational areas. Yet in the intervening period, when there was little or no government or NGO support for extension, there appears to have been minimal use of the BBM TP let alone 'spontaneous' adoption. This is supported by the survey finding that of the farmers surveyed, only a very small number had used the BBM prior to 2006, i.e. one farmer in the Amhara region (in 2004) and four farmers in the Oromia region (1 in 1995, 1 in 1996, 1 in 1998, and 2 in 2005). This finding has serious policy implications as it suggests that under current economic and market conditions, widespread adoption and sustained use of the BBM TP will not occur without government support.

Supplies and prices of inputs and outputs

Current input markets related to the BBM TP are characterized by severe shortages of, and subsequently record prices for, seeds and fertilizer—compounded by high fuel prices. These high prices present significant challenges to the government's foreign capital reserves. For example, the price of diammonium phosphate (DAP) fertilizer increased from USD 252/tonne in January 2007 to USD 752/tonne in January 2008 and to more than USD 1000/tonne in March 2008. The government is looking at initiatives, other than subsidies, to reduce the fertilizer price for farmers on the basis that 'fertilizer price subsidies do not work'. Sasakawa-Global 2000 has been encouraging the use of compost-derived fertilizer at its BBM TP study sites. Trials on the use of biofertilzers are also being conducted.

To relieve food shortages to consumers, the Ethiopian government recently imported 150 thousand tonnes of wheat from South Africa for ETB 520/qt. This wheat was then sold to local flour mills with a 30% price subsidy (ETB 320/qt) on the basis that this subsidized price is passed on to consumers. Using federal reserves, the flour price was subsidized further (to ETB 175/qt) for the poorer households.

The timeliness of the supply of inputs, particularly seed, is another constraining factor—sometimes arriving too late for farmers to feasibly use in that season. Only 42% of the total quantity of improved wheat seed (164 thousand tonnes) demanded in 2008 was supplied due to there being insufficient private companies and/or farmers in Ethiopia involved in commercial seed production (personal communication, Dr Tesfaye Tessema, Deputy Director, Bisrat Aretu, Finance Manager, Sasakawa-Global 2000, September 2008). The seed supply shortage has resulted in the creation of various other growing/marketing arrangements. For example, in South Wello zone (Amhara region), the farmers' seed purchase price for many crops is lower than the grain selling price. This is due to the seed being supplied by a farmers union at a subsidized price under a contract to sell the product to the union for the market price at harvest. Around Ginchi in Dendi *woreda* (West Shewa zone, Oromia region) farmers were growing improved wheat for seed multiplication purposes under contract for the government who was buying the grain at 15% above the market price. In Semen Achefer *woreda* (West Gojam, Amhara region), farmers were contract-growing improved chickpeas for the Ethiopian Seed Company.

In an effort to reduce input price constraints, regional governments are providing financial support for utilization of the BBM TP using two different strategies depending on the region. The Amhara regional government is subsidizing the price of the BBM (and other farming equipment such as pedal pumps)—reducing its price by 50% due to a surplus of supplies. However, this policy instrument will probably be removed in 2009. In Semen Achefer *woreda* (West Gojam, Amhara region), the price of the BBM to farmers is ETB 45 (50% of the actual price) and is provided to the farmers on credit for one year without charging interest). Within the Amhara region, *woredas* were divided into 'more' or 'less' self-sufficient *woreda* with the latter having access to more government support (e.g. credit for fertilizer and subsidies for pond liners). Some DAs felt that this was disadvantageous to the more productive *woredas*. It was also reported that the lack of access to credit for inputs in this region was disadvantaging women and poorer households (on the basis that they were more risk averse). As a result, the women often resorted to renting out their land or planting sorghum. One female-headed farm household in the North Gondar zone forum (Amhara region) reported using the BBM TP when she had access to credit. However, when the credit stopped in 2007 she was forced to sell her oxen to buy the BBM TP inputs because she had seen the benefits of the package and wanted to continue using it.

The Oromia regional government is subsidizing credit for all BBM TP inputs (offered on short-term credit of nine months) and the BBM (offered on intermediate-term credit of three to five years) (personal communication, Dr Wonderad Mandefro, Ministry of Agriculture, Head of Extension, September 2008). In addition, in 2008 in an effort to encourage the use of the BBM TP, the Oromia regional government withdrew access to credit for farmers not using the BBM TP (with the exception of poorer farmers). This policy may be counter-productive—particularly where the other elements of the package are not available/sufficient such as training. Also the length of the short-term credit for inputs may be a constraint—particularly in a season when insufficient rains lead to crop failure.

Manufacture, distribution and quality of BBMs

The BBMs in the Amhara region were being built by local Technical and Vocational Education and Training Centre (TVET) graduates who formed metal workshop groups using financial assistance from the government. The specification of the wings is that they have a 7 cm long tip, a 63 cm long, 20 cm wide, blade curved at an angle of 150 degrees, and a 46 cm rod extension at the back of the blade. The rod is for seed covering and essentially replaces the role of the metal chain in the double-beam BBM. The metal used in the wings is recommended to be 4 mm thick (2.8 mm at a minimum) or it will bend and break (see Annex 1). The BBM's are being distributed by farmer cooperatives (personal communication, Aynalem Haille, Head of Extension, Regional Bureau of Agriculture, Amhara region, September 2008).

Other BBMs were being supplied by a private supplier who also manufactured and sold the majority of the original BBMs to the government in the 1990s. This supplier's BBMs came in two qualities—one with wings made of metal that was too thin and subsequently often bent backwards or broke. If the oxen were not well trained, the wings would easily become detached and sometimes harm their legs. Another problem with the private supplier's design was that the metal rods welded to the vertical back edge of the wings were welded in the middle rather than at the bottom of the wing and this was not optimal for seed coverage. Quality control in the Amhara region is the responsibility of a committee formed from zonal MoA and the Rural Technology Development Department—the latter has two centres at Kombolcha and Bahir Dar.

Farmers at the forum discussion in Semen Achefer (West Gojam zone, Amhara region) said that the BBMs would be more durable if the wings were supported by a cross bar (Alemayehu and Hailemariam 2008) (see Annex 1). Preventing the wings from moving too much also facilitated the creation of uniform broad beds of the most effective width. The DA confirmed that quality of the BBM was a problem, revealing that the metal tip broke sometimes when they were demonstrating. When the implements break in the farmers' fields, they bring them back to the DA and ask for a replacement that they often do not have.

The forum discussion in Gondar Zuria *woreda* (North Gondar zone, Amhara region) revealed that the DA here, Derese Andargea, was particularly active in innovative re-engineering of the BBM—often to try and correct poor quality manufacturing. He had sent reports on his designs to the *woreda* office but received no feedback. He was the only person the field team had met during this study that knew about the 1993/94 BBM. Similarly at this forum, the farmers generally agreed that the BBM should be of better quality, i.e. the metal in the wing blades was too thin and compromised the BBMs operation despite having the extra stability of a cross bar welded between the two wings by the DA. The other modifications the DA had made in consultation with the farmers included the following (see Annex 1):

- bending the narrow tip of the wing to help keep it attached to the *maresha* (and discarding those that broke when they were bent at the *woreda* office);
- welding a metal ring near the tip of each wing to facilitate tying the wings to the *maresha* with one rope;
- Designing a BBM with an adjustable metal cross bar between the two wings. This is to assist with fitting the wings to different size wooden yokes. For example, if the yoke is 120 cm wide it is perfect for the 2 by 40 cm beds and 2 by 20 cm furrows and the oxen do not trample the beds. However, if the yoke size is not a uniform 120 cm, the bar can be adjusted to change the width of the seed covering wings and prevent the oxen from trampling the beds; and
- Modifying the metal rods coming out from the wing by welding two more rods to make a triangle thereby maximizing seed coverage on uneven ground.

While double-beam BBM breakages were reported in the 2001 assessment, they were not as significant an issue as reported for the single-beam BBM in the current assessment. The single-beam BBM is also arguably not as efficient or effective as the double-beam BBM in making even beds leading to yield losses as a result of insufficient seed covering. The weight of the double-beam BBM is also reported as not being a significant problem for the operators or oxen when it is used in the correct planting 'window'. The weight becomes an issue when the Vertisol soil is too wet and sticks to the surfaces of the BBM and creates significant friction and drag (personal communication, Wagnew Ayalneh, December 2008). One possible explanation for not capturing the window of opportunity is insufficient training. The emergence and promotion of the single-beam BBM appears to be a trade-off between having a wider window of opportunity afforded by a lighter implement and higher yields (and lower rates of implement failure). This trade-off assumes that increased competition in supplying the BBM of both types would make their prices more comparable and removing this as a trade-off factor. A farmer at this forum also mentioned that having access to other accessories such as metal threshing forks rather than wooden ones, would also help to work with the increased grain yields obtained from the improved seeds.

In the Oromia region, the government is focusing its efforts on micro-enterprises (i.e. Urban Youth groups) to supply and distribute the BBM. These groups are contracted by the government to make the BBMs according to their specifications and quality control. The BBM has been modified in the last few years by changing the angle of the metal wings and reducing the thickness of the metal (below 2.8 mm) and the thickness of the wooden beams in an attempt to make it lighter and easier to pull. However, there have been some issues related to the quality of the BBMs including the wings breaking due to the metal being of insufficient thickness.

Contrasting the situation in the Amhara region, there were no reported farmer modifications to the BBM as in the Oromia region in 2008. However, reports of farmer adaptations of the BBM have been around since the double-beam BBM. For example, the drainage practice, locally called *menose*, was growing in Oromia's Northwest Shewa zone in 1998 following farmers' seeing the double-beam BBM. *Menose* is a practice in which a wooden stick/shrub is tied across a local *maresha* to help cover broadcast seeds and to level the soil after creation of the furrows by the *maresha* (at intervals of 60–80 cm wide). It technically performed the same function as the BBM in the area but is lighter, more 'durable' and less expensive.

In Becho (Southwest Shewa, Oromia region), Sasakawa-Global 2000 found that in 2007, 3233 farm households (2924 male-headed and 309 female-headed) were using a *chaga* (or *shaga*) (Aredo and Tsegaye 2007). This implement is a farmer-modified version of the BBM being made entirely from wood (Amede et al. 2004). Although the yield disadvantage from using the *chaga* vs. the BBM was reportedly 500 kg/hectare, the major advantage was that, being lighter and easier to pull than the BBM, it widened the window of opportunity for planting. In a joint project, Sasakawa-Global 2000 and CIMMYT plan to monitor BBM adoption and impact in this *woreda* over the next two years—beginning in December 2008.

Training

Amede et al. (2004) commented that despite a considerable investment in disseminating the original BBM TP beyond individual targeted farmers, dissemination and adoption of the technology proved to be very slow. This was attributed to two key factors: firstly, the initial individualistic approach that provided limited opportunities for farmers to take collective action; and secondly, an inappropriate phase-out strategy that did not fully consider farmers' needs—including their training requirements. The slow rate of adoption was compounded by the farmers not encouraging neighbouring farmers or communities to use the BBM TP due to the reservations they had about it.

The government is using new training methods whereby graduates who have specialized in use of the BBM TP are going out into the field. Also, in the last two years there have been field days that promoted exchanges of practices, *woreda* to *woreda*, where farmers saw new farming practices for themselves and talked to a farmer or relative that they trusted. In another example of this type of 'training', a farmer who was the chairman of his farmer association was reported to have encouraged 28 other farmers in his cooperative to try his BBM (personal communication, Dr Wonderad Mandefro, Ministry of Agriculture, Head of Extension, September 2008).

Previously in the Amhara region, only zonal staff received training on the BBM TPs use and potential impact. The current training methods include training zonal, *woreda* (DAs) and NGO staff. During the three day training sessions (including a practical component), the participants present their views of the BBM TP and specialists address their queries. The DAs then give the BBMs and one day of theoretical and practical training—including how to assemble the BBM—to interested farmers (see Annex 1). The farmers then train their oxen to drawing the BBM by walking them along the same furrow two to three times. The major constraint to adoption in the Amhara region was reportedly improper introduction of the technology to the farmers—possibly because some DAs did not believe or trust in the technology. Conversely, adoption of the BBM TP in Arsi zone in Oromia region was encouraged via a farmer who showed other farmers in the *woreda* how the BBM TP worked. The other farmers subsequently asked the DAs to supply them with the BBM TP.

Another important innovation that has recently occurred in government planning in the Amhara region and affects the BBM TP use is that the PAs make the plan (in terms of the number of BBM distributed etc.) and send it to the *woreda* officials who make any minor modifications before approving it. Previously, the *woreda* used to make the plan and hand it to the PAs with little consultation or coordination.

A DA in West Gojam (Amhara region) reported that he had received no training on the BBM TP so he had to resort to reading a manual about it. The *woreda* staff he reports to also indicated that he had not received any training in relation to the BBM TP. This situation often arises in the government for two reasons—firstly, the frequent transfer of trained staff to other areas results in a shortage of trained staff in Vertisol areas and secondly, there is a lack of funding at the *woreda* office to train new staff. In addition, the DA wanted to organize a BBM TP field day on a farmers' field but was having difficulty getting it financed by the *woreda* office. The government's plan of conducting BBM TP training every three months at all administrative levels and with farmers is often constrained by funds. In the North Gondar zone forum (Amhara region) the DA said that the farmers needed more training—especially on the theoretical aspects of the BBM TP as they have only received practical training. This theoretical training is particularly needed if the farmer wants to try planting a different type of crop. He attributed the lack of theoretical training to the *woreda* not having funds for the per diem of *woreda* staff who conduct theoretical training.

3.3 Farmer survey results

The results from each section of the farmer survey are presented and discussed below in relation to their significance to adoption and impact of the BBM TP.

Land resources

Crop production in the Ethiopian highlands is still characterized by relatively small, fragmented areas of land held by farmers, i.e. averaging 3 ha per farmer with landholdings being larger in the Oromia region (Table 7) (see Annex 1). These areas are larger than expected possibly due to the presence of some large farms in the sample as indicated by the range of farm sizes. Only one farmer using the BBM TP reported having no Vertisol soil but he, and others, reported using the BBM TP on red soils.

Table 7. *Land resources*

Responses	All	Amhara	Oromia
Cultivated area (ha)			
Average	3.12	2.61	3.64
Range		0.38–7.50	0.75–23.00
n	121	61	60
Vertisol area/cultivated area (%)			
Average	67	53	75
Range		0–100	0–100
n	121	61	60
Water logging area/Vertisol area (%)			
Average	45	53	37
Range		0–100	0–120
n	121	60	60

The average land holding was approximately two-thirds Vertisol soil (more in Oromia) with just under half of the Vertisol area having major water logging problems (less in Oromia). In absolute terms, the amount of Vertisol soil affected by serious water logging is slightly higher in Oromia than in Amhara—encouraging BBM TP adoption in the former, particularly as risks associated with adoption are spread over a larger land resource base.

BBM utilization

Access to credit for the BBM in both regions, as well as the subsidized price of the BBM in the Amhara region has encouraged sole ownership of the BBM (Table 8). Despite the price subsidies and access to credit, financial constraints in the Amhara region still result in some sharing of the BBM and its expense with others—particularly in Gondar Zuria (i.e. 11/15 sharers).

Table 8. *BBM utilization*

BBM utilization	All	Amhara	Oromia
Sole owner	104	46	58
Shared ownership	15	15	0
Borrow (Becho, Kobo PA)	2	0	2
n	121	61	60

The number of farmers sharing a BBM averaged 5 with the notable exception of 10 farmers sharing it in a farmer group arrangement in Gondar Zuria. The fact that most farmers are willing to pay for the BBM indicates their willingness to adopt the BBM TP. The current situation compares to the situation 10 years ago where the price of the BBM was significantly higher—resulting in the unsustainable situation where the MoA tried to encourage adoption by letting the majority of farmers borrow the BBM at no cost.

The test in terms of willingness to adopt the BBM TP will be adoption and use when the price subsidies are removed in the Amhara region, as expected in 2009, and if access to credit for the BBM and inputs is offered once again to all farmers, not just the BBM TP farmers, in the Oromia region.

Draught animal usage with the BBM

Draught animal availability for use with the BBM did not appear to be as constraining as it was 10 years ago when approximately a quarter of farmers had less than 2 suitable animals and had to borrow, share, or lease in draught animals. This may be as a result of the single-beam BBM being significantly lighter than the double-beam BBM and the farmers being more willing to use their animals. Most of the borrowing/sharing of draught animals occurred in the Oromia region. In the Amhara region, all of the farmers who borrowed and rented were in Jamma.

Table 9. *Draught animal usage*

Draught animals used with BBM (per household)	All	Amhara	Oromia
Owned			
Average	2.8	2.5	3.1
Range		0–6	1–10
n	120	60	60
Borrowed/shared			
Average	3.2	1	3.7
Range		1	1–12
n	18	3	15
Rented in			
Average	1.5	2	1
Range		2	1
n	2	1	1
Rental price (ETB/head)			
Average	130	60	200
Range		60	200
n	2	1	1

Farmers' sources of information about the BBM TP

As an indication of the 'spontaneity' and sustainability of BBM TP adoption, it was hoped that more farmers would have learnt about the BBM TP from sources other than the MoA. However, only 2 out of 121 farmers had heard about the BBM TP from a neighbour and not the MoA—both in the Oromia region. In the past, the more spontaneous adaptation and adoption appeared to occur as a result of farmers seeing a BBM and making a *chaga* or using *menose* practice. Based on this adaptive evidence, it could be argued that the origin of the new BBM was a farmer who originally modified his/her original BBM and the MoA personnel copied them.

BBM first crop parameters

Area. In the Amhara region, the average total area per farmer of all crops grown with the BBM TP has averaged around 0.6 ha over the last four years—reflecting the gradual recovery following the poor growing season experienced by many farmers in 2007. The average area per farmer increased by approximately 25% from 2005/06 to 2007/08 to 0.75 ha in the Oromia region (Table 10). The average area of all first crops grown with the BBM TP was lower in 1998/99 at 0.5 ha.

Table 10. *Average total BBM TP crop area by region, 2008–2005*

Region	2008	2007	2006	2005
Amhara	0.60	0.48	0.69	0.58
n	60	42	11	3
Oromia	0.75	0.74	0.58	0.52
n	60	30	12	7

Crop type. Five different first crops were grown using the BBM TP. As an indication of the differences in the crop–livestock systems within and between the two regions, further analysis revealed that only three farmers in the Oromia region grew more than one crop in the 2008 season on BBM TP land (i.e. 2 farmers grew improved lentil with improved wheat, while one grew barley with improved wheat). This contrasts with farmers in East Gojam and North Gondar zones in the Amhara region where 18 farmers grew 2 different crops and 2 grew 3 different crops on BBM TP land in 2008. Farmers from the other two zones in Amhara almost exclusively grew only one crop on BBM TP land in 2008.

Seed variety, sowing time and rate. As improved wheat was the most common BBM TP crop, farmers were asked for the wheat variety name and wheat crop parameters in the 2008 season (Table 11). The predominant improved wheat variety identified was HR1685 while six respondents identified the improved wheat variety used as HR1522. This contrasts with the predominant wheat variety ET13 used 10 years ago that has been replaced. Three-quarters of farmers planted improved wheat from early June to early July—approximately 10 days earlier than 10 years ago. This reflects farmers being more amenable to earlier planting and the increased opportunity to grow a second crop. The average improved wheat seed sowing rate was slightly higher than expected (i.e. 150 kg/ha) but the wide variation in responses suggest more significant issues, i.e. lack of knowledge of the recommended rates and/or lack of availability to obtain the recommended rates as a result of financial or supply constraints. A number of farmers mentioned that they were using improved wheat seed from last season's crop—providing them with a hedge against rising seed prices and lack of supplies.

Fertilizer. There was also a wide variation in urea and DAP usage even though the average for DAP is close to the recommended rates of 100 kg/ha, the rate of urea application is double the recommended rate—this was also the finding 10 years ago and is surprising given the cost of fertilizer.

Herbicides and pesticides. The use of herbicides and pesticides was limited to one farmer in the Amhara region (ETB 60/ha) with a number of farmers commenting that they used hand weeding—reflecting the lack of availability of credit for BBM TP inputs in this region. Within the Amhara region, only farmers in Jamma reported using credit at an average rate of ETB 300/ha.

Table 11. *BBM TP first crop parameters in 2008—improved wheat*

Parameter	All	Amhara	Oromia
BBM TP wheat crop (else other)			
Improved wheat	95	39	66
Barley	16	16	0
Horse bean	6	6	0
Improved lentil (including 1 red)	4	0	4
Haricot bean	1	1	0
n	122	62	70
2008 Wheat crop planting time			
June	66	29	37
July	41	19	22
Other	14	13	1
n	121	61	60
2008 Wheat sowing rate (kg/ha)			
Average	173	166	178
Range		32–300	50–400
n	88	32	56
2008 Urea used (kg/ha)			
Average	110	110	111
Range		0–260	25–300
Frequency of application		16x1, 13x2, 2x3	17x1, 38x2, 1x3
n	88	32	56
2008 DAP used (kg/ha)			
Average	126	106	139
Range		0–200	10–400
Frequency of application		31x1, 1x2	54x1, 2x2
n	88	32	56
2008 Herbicides/pesticides used (ETB/ha)			
Average	–	–	53
Range	–	–	0–280
n	–	–	56
2008 Credit for BBM (ETB/ha)			
Average	–	(45 ETB/BBM)	202
Range	–	–	0–784
n	–	–	56
2008 Average credit for inputs (ETB/ha)			
Average	969	300 (Jamma *woreda*)	1304
Range		0–2800	0–4028
n	88	32	56

This contrasts with farmers in the Oromia region who have access to credit for BBM TP inputs and where a large proportion used herbicides/pesticides and accessed credit for inputs at an average cost of ETB 53/ha and an average rate of ETB 1300/ha respectively—consistently across all zones, *woreda* and PAs in the region.

Credit. Credit for BBM TP inputs in 2008 was approximately double of that used 10 years ago, i.e. ETB 570/ha. The impact of the different credit arrangements between the regions (and sometimes *woredas*) discussed previously is evident in the results related to credit for the BBM TP. In the Amhara region, 14 farmers reported borrowing ETB 45 at no interest for 1 year from the MoA. These farmers were spread consistently across all zones with the exception of Gondar Zuria where farmers reported having no credit. This supports the earlier finding of a large proportion of farmers in this *woreda* sharing the BBM as a solution to a lack of credit, to make it more affordable for each farmer. In Oromia, where credit for the BBM was available, a large proportion of farmers utilized it with the credit per BBM ranging from ETB 96 to 180.

BBM TP first crops by area, yield and prices of grain and residues

The average area per farmer of improved wheat grown with the BBM TP in 2008 was 0.62 ha, with an average grain yield of 2500 kg/ha fetching a price of ETB 5.7/kg. All of these figures represent four-year highs and follow an upward trend over this time period (Table 12). The estimates of grain yield for improved wheat, while still a lot lower than those reported to occur under favourable experimental conditions, are higher than the 1720 kg/ha seen in 1998/99. The upward trends in areas, yields and prices are also evident in the barley and horse bean estimates. Estimates of residue yields are notoriously difficult to estimate—as they are not usually sold but rather used for animal feed in the Oromia region and for animal feed and housing construction in the Amhara region. The average improved wheat residue yields were estimated at 2720 kg/ha in 2008—significantly higher than the 970 kg/ha recorded in 1998/99. The gross margin analysis in this report uses the survey findings and is comparable to the 1998/99 analysis.

BBM TP second crops by area, yield and prices of grain and residues

The second crops grown on BBM TP plots were predominantly chickpea and rough pea with some lentils and improved chickpea (Table 13). An upward trend in the area, yields and prices of chickpea is also evident (with the exception of 2007). The average area per farmer of chickpea grown on a BBM TP plot in 2008 was 0.59 ha, with an average grain yield of 1600 kg/ha fetching a price of ETB 5.5/kg. The yield and price obtained for improved chickpea were higher at 1930 kg/ha and ETB 6.7/kg, respectively. Improved chickpea was included in the gross margin estimates as it is a potentially important future crop in the BBM TP.

Future plans for BBM TP usage

All farmers who were surveyed with the exception of one had used the BBM TP each year since the first year they had adopted it. In addition, all farmers planned to use the BBM TP in 2009. One farmer was forced to interrupt his BBM TP usage as he was not able to obtain improved seed in time to plant in the 2008 season—despite having obtained credit and purchased the BBM in that season. This adoption and usage pattern is far more consistent than it was in the five years up to 1998. The major crops the farmers intended to use with the BBM TP included improved wheat (98 responses), barley (30 responses), horse bean (14 responses) and lentil (6 responses).

Comparing the planned change in the average area per farmer prepared using the BBM TP from 2008–09 indicated an increase of 0.4 ha per farmer (ranging from –1 to + 7 ha) in absolute terms, an increase of 82%. Of the 121 responses, 33 farmers indicated they would make no change in the BBM TP crop area from 2008 to 2009, 9 indicated they would decrease this area, and 65 indicated they would increase the BBM TP crop area. The BBM TP was relatively new to most farmers as indicated by their responses as to when they first used the BBM TP (i.e. 49 in 2008, 44 in 2007, 19 in 2006, 4 in 2005 and 1 in 2004). However, four farmers had obviously used the original BBM in the TP (2 in 1995, 1 in 1996 and 1 in 1998). As these farmers had indicated using a BBM for the last four years of this survey, it suggests they might have been using a BBM almost continually since they first started—albeit a BBM of at least two different types.

Crops the BBM TP crops replaced

As found in 1998/99, the 2008 assessment indicated that BBM TP crops replaced 13 other crops. Over a third of respondents indicated teff would be replaced with a BBM TP crop (particularly in Oromia) and almost a fifth of respondents reported replacing local wheat (Table 14). The traditional method of land preparation for both these crops is the use of drainage furrows. One-quarter of those surveyed indicated that chickpea (using flat-bed planting) would be grown if the BBM TP had not been used and a tenth indicated that rough pea would have been grown. This follows as some areas only receive sufficient rainfall for a single crop planted in July when the soils have drained a little—particularly around Jamma in South Wello and Ada in East Shewa. In these instances, even though the BBM TP allows earlier planting of the first crop, the climatic conditions still do not permit a second crop to be grown in the same growing season as it does in most of the other Vertisol areas.

Table 12. *First crops grown with BBM TP, area of land covered under BBM TP, crop output and prices of grains and residues, 2008-2005*

Type of crops	Area of land, crop yield and prices											
	2008			2007			2006			2005		
	Land area	Crop yield	Price	Land area	Crop yield	Price	Land area	Crop yield	Price	Land area	Crop yield	Price
	(ha)	(kg/ha)	(ETB/kg)	(ha)	(kg/ha)	(ETB/kg)	(ha)	(kg/ha)	(ETB/kg)	(ha)	(kg/ha)	(ETB/kg)
Improved wheat (all)	0.62	2500	5.7	0.56	1700	4.8	0.51	1840	3.3	0.49	2300	2.6
n	94			48			15			8		
Amhara	0.34	2350	6									
n	38											
Oromia	0.78	2600	5.6									
n	56											
Barley	0.58	2700	4.3	0.58	2600	3.7	0.75	2600	2.5	0.63	2100	1.2
n	16			18			6			2		
Horse bean	0.36	2600	6.3	0.33	2200	6.3						
n	9			3								
Improved wheat (all)	2720	0.4	1	2370	0.4	1	2810	0.3	1	1700	0.3	1
Amhara			1,2			1,2						
Oromia			1			1						
Barley	2160	0.2	1,2									
Horse bean	1100	0.3	1									

*Use: 1 = Animal feed, 2 = Construction, 3 = Fuel, 4 = Sales, 5 = compost (soil fertility), 6 = No use

Table 13. *Types of second crops grown on BBM TP plots, grain and residue yields and prices, 2008-2005*

Type of crops	Area of land, crop yield and prices											
	2008			2007			2006			2005		
	Land area (ha)	Crop yield (kg/ha)	Price (ETB/kg)	Land area (ha)	Crop yield (kg/ha)	Price (ETB/kg)	Land area (ha)	Crop yield (kg/ha)	Price (ETB/kg)	Land area (ha)	Crop yield (kg/ha)	Price (ETB/kg)
Chickpea	0.59	1600	5.5	0.48	1070	4.9	0.55	1120	3.3	0.3	1260	3
n	71			37			15			5		
Amhara	0.41	1730	5.7									
n	31											
Oromia	0.72	1510	5.3									
n	40											
Rough pea	0.48	2090	3.2	0.5	1830	2.8						
n	25			5								
Amhara	0.53	2330	3.1									
n	17											
Oromia	0.38	1330	3.5									
n	8											
I. Chickpea	0.41	1930	6.7									
n	4											
Lentil	0.25	1300	9	0.35	1410	6.6						
n	2			3								
Chickpea—Amhara	680	0.4	1	680	0.3	1	490	0.2	1	900	0.3	
Chickpea—Amhara	680	0.4	1	680	0.3	1	490	0.2	1	900	0.3	
n	27											
				15								
Rough pea—Amhara	1060	0.3	1									
n	14											

*Use: 1 = Animal feed, 2 = Construction, 3 = Fuel, 4 = Sales, 5 = compost (soil fertility), 6 = No use

Table 14. T*ype and area of crops that would have been grown on BBM TP plots if BBM TP had not been used, grain and residue output and prices (2008–2005*)

Type of crops grown	Area of land, method of cultivation, crop yield and prices of crops planted															
	2008				2007				2006				2005			
	Land area (ha)	Method*	Crop yield kg/ha	Price ETB/kg	Land area ha	Method*	Crop yield kg/ha	Price ETB/kg	Land area ha	Method*	Crop yield kg/ha	Price ETB/kg	Land area ha	Method*	Crop yield kg/ha	Price ETB/kg
Local wheat	0.56	3	1600	5.9	0.36	2,3	1520	5.1								
n	24	18			8	4										
Teff	0.64	3	1190	8.9	0.47	3	1130	6.6	0.50	3	1080	5.1	0.56	2,3	1250	3.6
n	47	35			21	16			6	4			4	2		
Chickpea	0.58	2	1710	5.6	0.68	2	1800	4.3	0.60	3	1600	4.3	0.5	2	1400	4.2
n	37	5			21	14			7	4			1	1		

*Method: 1 = hand-made BBF, 2 = flat-bed planting, 3 = drainage furrows, 4 = ridges and furrows (*shurube*)

Type of crops residues	Crop-residue yields, prices and uses of crop residues											
	2008			2007			2006			2005		
	Yield (kg/ha)	Price (ETB/kg)	Use of residues *	Yield (kg/ha)	Price (ETB/kg)	Use of residues *	Yield (kg/ha)	Price (ETB/kg)	Use of residues *	Yield (kg/ha)	Price (ETB/kg)	Use of residues*
Local wheat	1780	0.3	1 (2,4)	1090	0.4	1 (2)						
n	24			7								
Teff	2520	0.5	1 (2)	1980	0.6	1 (2)	2480	0.4	1 (2)	1350	0.3	1 (2)
n	47			21			7			4		
Chickpea	830	0.4	1	920	0.3	1	1740	0.3	1	900	0.2	1
n	37			21			6			1		

*Use: 1 = Animal feed, 2 = Construction, 3 = Fuel, 4 = Sales, 5 = compost (soil fertility), 6 = No use

Major factor(s) affecting use of the BBM TP

Of the 233 perceived factors influencing how farmers use the BBM TP, almost half the respondents cited 'evidence of the benefits' from the package compared to traditional practices as pertinent, including higher yields, better drainage and the opportunity to grow a second crop. The other major factors (each equivalent to 10% of responses) included the following: the subsidized price of the BBM; the availability of training; access to credit for the BBM and BBM TP inputs; time saved during planting; and higher returns from using improved seeds. The availability of the BBM and BBM TP inputs, reduction in the amount of seed and fertilizer being washed away, the increased ease of weeding/having less weeds, having more straw/residue for animals and improvements in the design of the BBM were also given as important factors.

BBM modifications

Given the difficulties experienced with the BBM, farmers were asked if they had modified it themselves in any way. None of the farmers in the Oromia region had made any modifications. This result contrasts with the modifications that had been made by a number of farmers and MoA personnel in the Amhara region. These modifications included bending the tip of the wing, adding a joining bar and changing the angle of the wing to make it more stable and comfortable to use.

BBM TP associated innovations in farming practices

A major innovation related to the BBM TP has been the construction of ponds for collecting and storing the water drained from the fields using the BBM TP. The ponds are built with only human labour and are 10 m^2 at the top, 2.5 m deep and 4 m^2 at the base. Sesbania (*Sesbania sesban*) sourced from the government is popular for growing on the pond walls and used as cattle fodder. The water is also used to grow irrigated vegetable crops and herbs such as onions, cabbage, garlic, and fenugreek. The major impacts from having ponds are improved incomes, improved family diets and health, risk reduction from crop diversification, spring improvement via seepage, and reduction of erosion and flooding of neighbours fields from BBM TP plot run-off.

In some areas black plastic is used to line the ponds. The current price of the plastic is ETB 1053/pond and the government has subsidized it to ETB 150 in 'less self-sufficient' *woredas* (i.e. not North Gondar in the Amhara region). In other places, plastic is not needed as the walls do not crack and leak—especially if the walls are reinforced with straw. The government is introducing pedal-pumps to help get the water up and out of the ponds while some motor pumps have also been used.

The government is also encouraging pond formation and utilization by selecting farmers and using community labour to construct the ponds and then 'model' the pond's advantages. Model farmers often choose to expand the number of ponds they have while other farmers have started building ponds now that they have seen evidence of the benefits. Pond formation was particularly evident in the Amhara region—with the numbers growing rapidly. For example, in East Gojam zone, 2800 ponds were reported (Annex 5).

The farmers in this study reported harvesting the run-off from the BBM TP plots in ponds and using it for growing timber, animal fodder, and herbs and vegetables. The impacts from water harvesting and use they reported included: improvements in the households diet; increased feed supplies for animals; and increased cash income. One farmer said that having the pond saved his family labour for water collection and saved his animals having to walk in search of water. Another farmer commented that he could reduce the risk of second crop failure by using the water to irrigate their second crop if necessary. Fodder crops were also viewed as having a role in conserving and improving the soil fertility. Five farmers in the survey had ponds and they were all from the Amhara region. Three farmers in West Gojam (Amhara region) forum were planning to build ponds next season.

All of the information gathered from the farmer surveys were used in estimating the gross margins (partial budgets) for different cropping scenarios, and subsequently the economic surplus modelling, to estimate the welfare changes with and without the use of the BBM TP. Both of these analyses are summarized in the following two sections and full details are provided in Annexes 6 and 7.

3.4 Crop yields and prices with and without the BBM TP: Gross margins (GM)

Summary of the yield and price information obtained from the farmer survey and used in the calculation of gross margins is given in Table 15. A full version of the gross margins used in the economic surplus model is provided in Annex 6. Comparison of the changes in gross margin estimates for different cropping systems indicates that the greatest gains for a first crop were realized in changing from local wheat to improved wheat with a BBM TP—even assuming the BBM was purchased at full price (Table 16). The change was even more significant when the cropping system changed from a single crop per growing season to having a second crop—as has occurred in certain areas of Ethiopia as discussed earlier.

Table 15. *Yield and price summary information, 2008*

Crop	Crop yield (kg/ha)	Price (ETB/kg)	Residue yield (kg/ha)	Price (ETB/kg)
Local wheat	1600	5.9	1780	0.3
Improved wheat	2500	5.7	2720	0.4
Teff	1190	8.9	2520	0.5
Chickpea	1600	5.5	830	0.4
Rough pea	2090	3.2	1060	0.3
Improved chickpea	1930	6.7	1600	0.4
Barley	2700	4.3	2160	0.2
Horse bean	2600	6.3	1100	0.3

Table 16. *Gross margin estimates by cropping system, 2008*

Cropping system	Gross margin increase (USD/ha)	Gross margin increase (%)
Improved wheat vs. local wheat	253	27
Improved wheat vs. teff	88	8
Improved wheat + chickpea vs. local wheat	1136	120
Improved wheat + chickpea vs. teff	970	87

BBM TP adoption and use in the future is likely to be encouraged as more improved varieties of other crops such as improved chickpea, barley and maize, become available.

3.5 Welfare with and without the BBM TP: Economic surplus (ES)

The time period for this *ex post* analysis was 23 years from 1986 to 2008 inclusive—including the 13 *ex post* years up to 1998 (and the eight *ex ante* years) from the previous study. The same economic surplus methodology used in the first study was followed here. A full description of the assumptions (including those related to elasticity estimates), considerations leading to under- and overestimates (including having multiple products related in consumption and production markets and domestic price policies) can be found in the previous report and are not repeated here (Alston et al. 1995, Rutherford et al. 2001).

The economic surplus model assumed improved wheat replaced local wheat and teff as this was the predominant situation. The small area of land that switched from chickpea to improved wheat was not included in the ES estimation for the sake of simplicity.

As in the previous study, no prior estimate of the BBM TP adoption rate for Ethiopia was available. The 2008 adoption rate was estimated from the area under the BBM

TP as a proportion of the total area of wheat and teff from MoA statistics (t = 1.3% in 2008, t = 0.02% in 1998). The current adoption rate translates to approximately 98,000 farmers using the implement (based on the average BBM TP area/farmer). The adoption rate estimated in 2008 was forecast to occur between 2004/05 in the previous study. However, given that the constraints associated with adoption of the BBM TP were not alleviated on a broad scale until the last three to four years, the current adoption rate is to be expected.

In order to estimate net economic surplus, an estimate of the costs associated with both research and extension on the BBM TP (adjusted for inflation) was required. These costs were estimated based on information provided by MoA personnel in individual zones and regions. Sensitivity analysis was conducted with different estimates of research and expenditure due to the difficulty in estimating these costs. As in 1998, the results in 2008 were not particularly sensitive to either a 50% increase or decrease in these costs.

The results of the ES model in 2008 were more favourable than they were in the previous study (Table 17). The full ES model is presented in Annex 7, showing how the net economic surplus over the 23-year period is calculated.

Table 17. *Results of the 2008 vs. 1998 study* ex post *time period*

	1998	2008
Adoption rate (%)	0.02	1.3
Total area under BBM TP (ha)	625	63,566
Average BBM TP area per farmer (ha)	0.5	0.65
Number of BBM TP farmers	1250	97,800
Change in net economic surplus (ETB × 10^6)	–139.4	709.4
Net present value (10%)	–12.6	–1.1
Benefit–cost ratio	0.01:1	3.3:1
Internal rate of return	–	0.1
Real research and extension expenditure (ETB × 10^6)	140.7	308.4

The net economic surplus generated by the BBM TP by 2008 was found to be ETB 709.4 million (USD 47 million). Estimated real research and extension costs since 1986 totalled ETB 308 million (USD 63.6 million), giving a benefit–cost ratio of 3.3:1. The rate of return to this investment was small but positive by 2008, at 0.1.

The following changes have had a positive effect on net economic surplus since 1998:

- the area of BBM TP prepared land per farmer has increased over time—improving the per hectare productivity per farmer by reducing the cost of the BBM TP per hectare per farmer;

- the productivity of the BBM TP has also increased as a result of an increase in output per farmer as they have developed greater proficiency with the 'modified' technology (i.e. yields of improved wheat up from 1720 to 2500 kg/ha); and
- the productivity of the BBM TP has increased as a result of a reduction of the cost of the BBM TP via a reduction in the cost of the BBM itself (USD 36 down to USD 18).

4 Conclusions and recommendations

This study was the second *ex post* impact assessment of the BBM technology package. Both studies were commissioned by ILRI and were undertaken 10 years apart. This afforded some unique insights into both adoption and impact—particularly as the overall assessment period covered 23 years. The 1998/99 study included an *ex post* component (from 1986 to 1998) and an *ex ante* component—forecasting from 1999 to 2006. The findings of the *ex ante* component proved to be extremely robust in terms of the area under the new technology and the predictions as to what factors had to change and what lessons needed to be learned in order to increase adoption and impact in the future.

We found that more widespread access to credit, and at a reduced cost, has reduced the financial risks faced by farmers using the BBM technology package and encouraged adoption and continued use. Further work is recommended to look more deeply into the conditions under which credit is offered (such as the length of the repayment period). The financial risks faced by farmers using the package have been significantly reduced by a reduction in the cost of the BBM itself.

While some progress has been made in terms of improving the quantity and quality of extension activities, further efforts towards more effectively and efficiently providing training and information is particularly recommended as it still appears to be a major constraint to future BBM technology package adoption and impact.

Household labour and BBM draught power constraints (and the cost constraint mentioned above) have largely been addressed by modifications to the BBM design and subsequently its weight and cost. The re-engineering of the BBM by farmers, as well as by individual MoA personnel working closely with farmers, has significantly alleviated major adoption constraints that had persisted for many years.

Finally, innovative farming practices associated with the BBM technology package, such as pond formation to collect the excess water run-off, have proven to be very successful in reducing erosion and water logging of neighbouring plots caused by the BBM. The ponds are also providing water to irrigate high-value vegetable, herb and fodder crops. Such innovations are encouraging continued adoption and use of the BBM technology package and as such are significantly contributing to improved welfare.

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Annex 1 Drawings and photographs

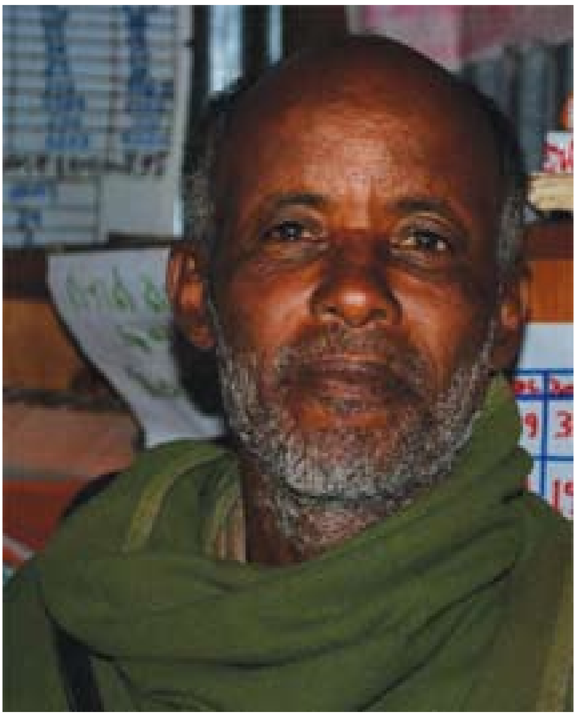
Ethiopian Highlands, Amhara region, November 2008 (Photo: A Rutherford).

Teff (Photo: A Rutherford).

Field work transport, Amhara region, November 2008 (Photo: A Rutherford).

Informal meeting, Amhara, November 2008 (Photo: W Ayalneh).

Farmer survey, Semen Achefer, November 2008 (Photo: A Rutherford).



(Photo: A Rutheford).


BBM wings (Photo: A Rutherford).


Pond, West Gojam, November 2008 (Photo: A Rutherford).

Threshing (Photo: W Ayalneh).

Harvest (Photo: A Rutherford).


Market day (Photo: A Rutherford).


Farmer survey, Semen Achefer, November, 2008 (Photo: W Ayalneh).

Forum discussion, Semen Achefer, November, 2008 (Photo: J Alemayehu).

'New' BBM, Oromia (Photo: S Gebreselassie).

BBM field, Oromia (Photo: S Gebreselassie).

Dry Vertisol (Photo: S Gebreselassie).

Waterlogged Vertisol (Photo: source unknown).

Irregular BBFs (Photo: S Gebreselassie).

BBM wheat, Oromia (Photo: S Gebreselassie).

Harvesting, Oromia (Photo: S Gebreselassie).

Highlands cropping (Photo: S Gebreselassie).

New BBM modifications (Photo: A Rutherford).


New BBM modifications (Photo: A Rutherford).


(Photo: A Rutherford).

(Photo: A Rutherford).

Constructing the *maresha* and BBM (Photo: A Rutherford).

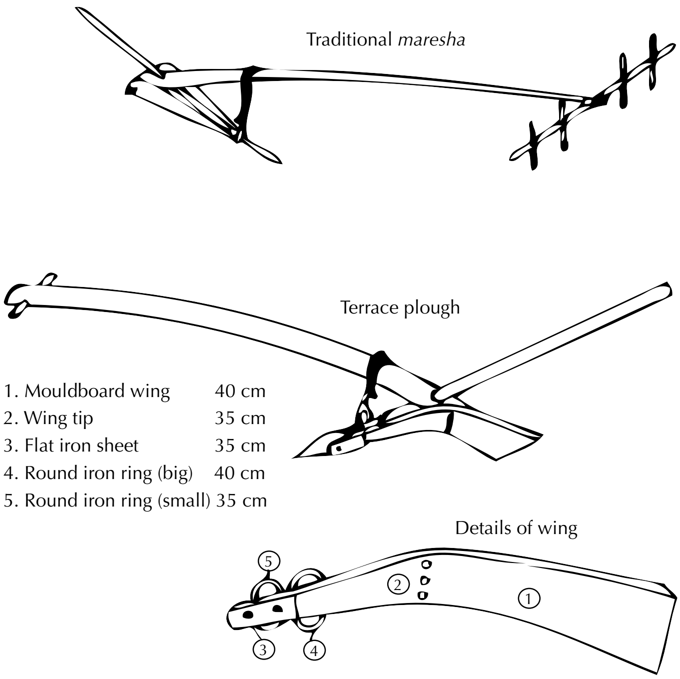
(Photo: A Rutherford).

(Photo: A Rutherford).

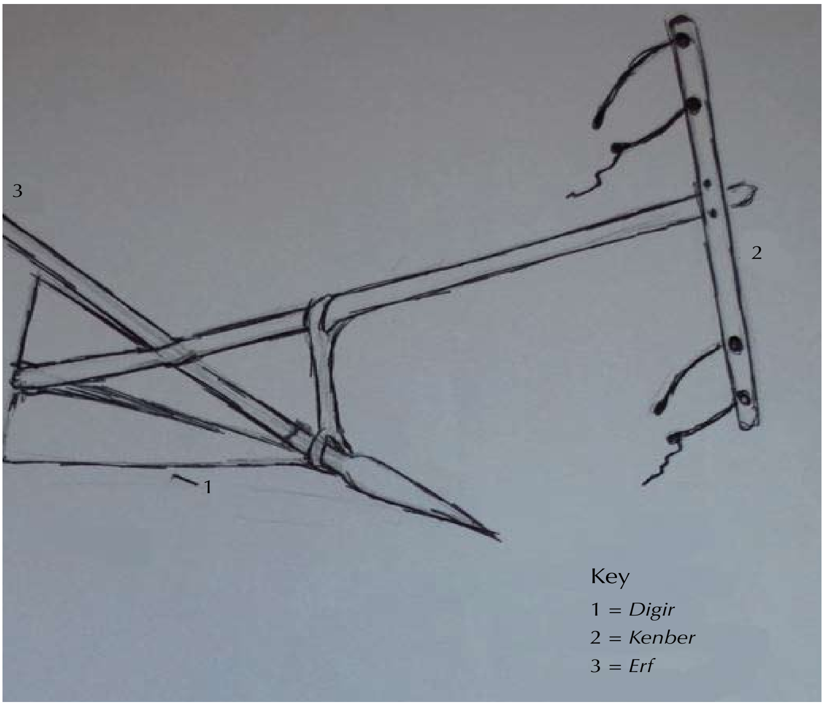
(Photo: A Rutherford).

(Photo: A Rutherford).

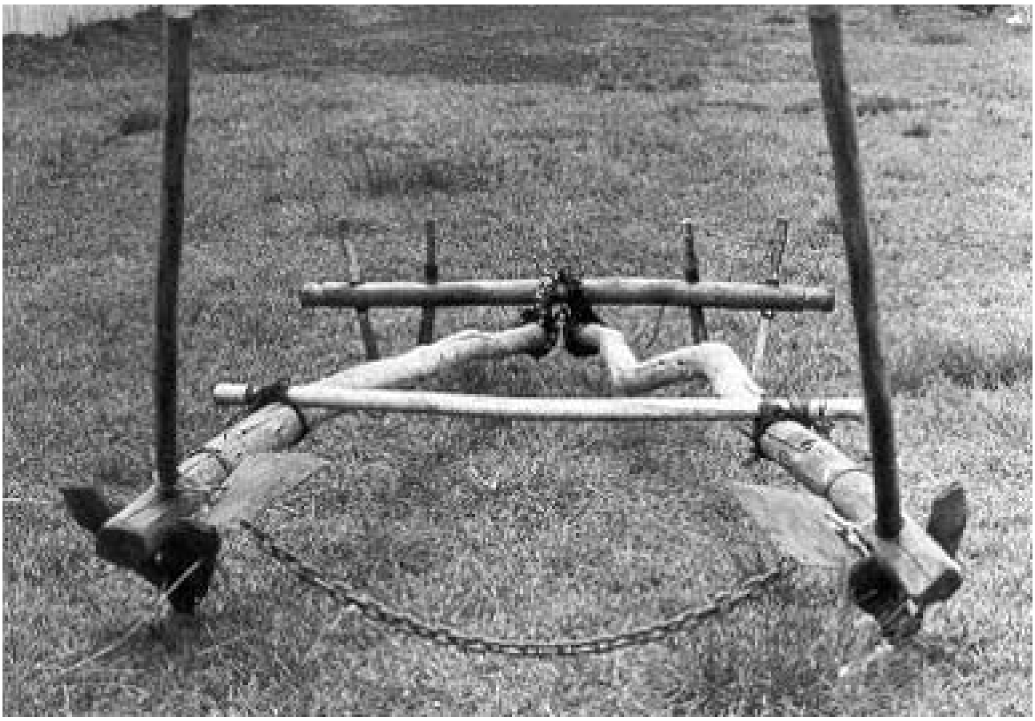
(Photo: A Rutherford).



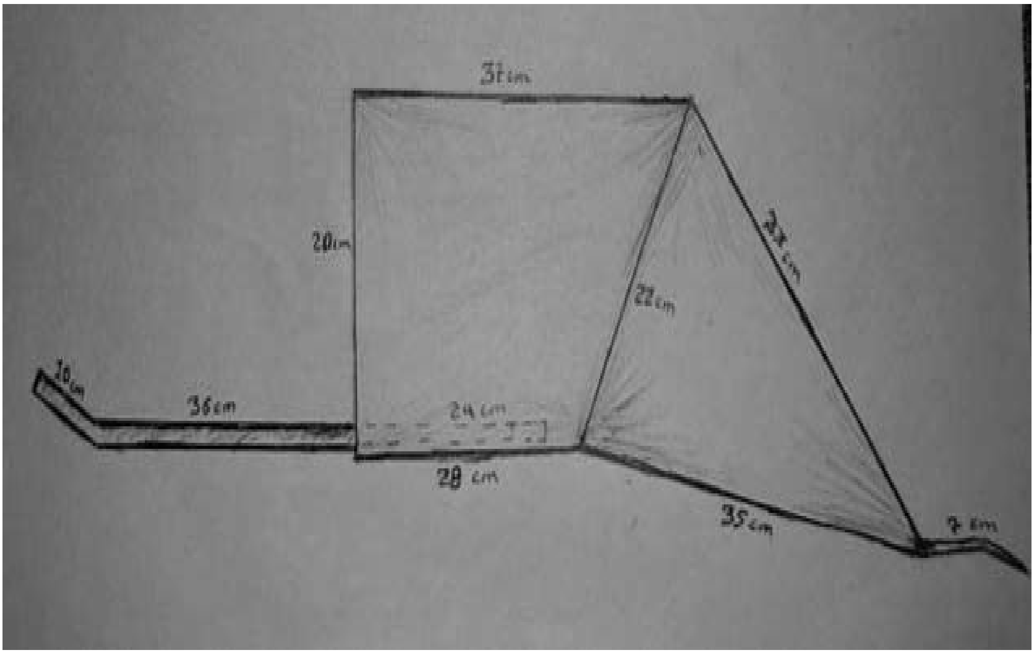
Origins of the BBM (Source: ILRI).



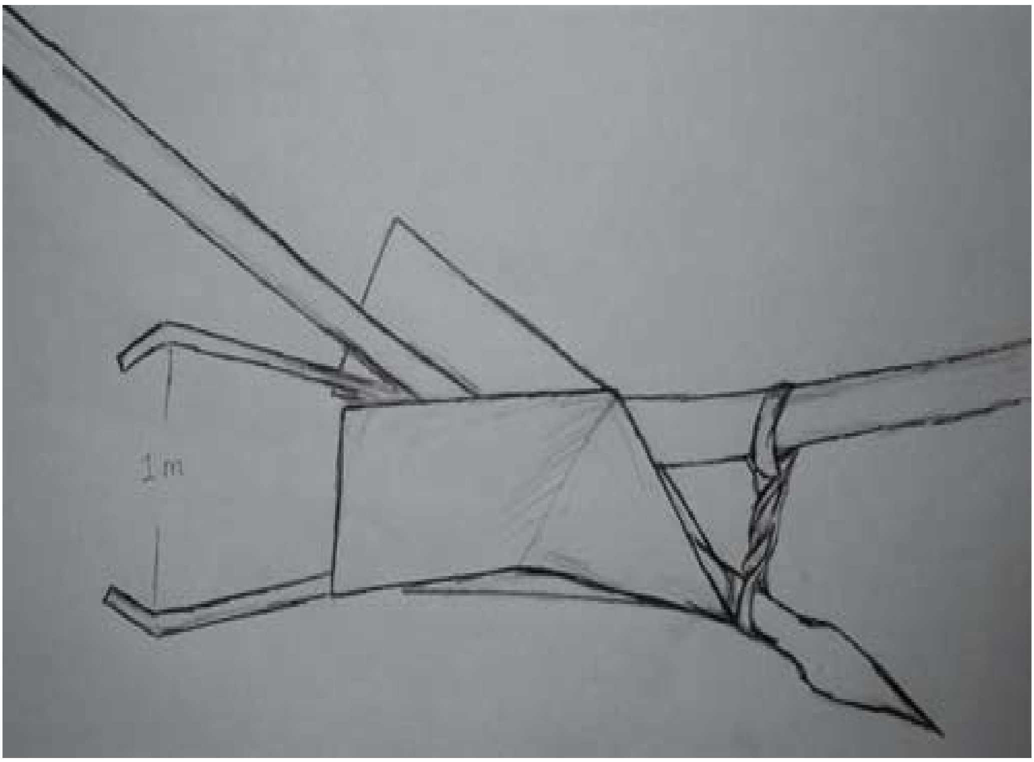
Maresha components (Source: F Hailemariam).



Original BBM (Source: ILRI).



BBM wing dimensions (Source: F Hilemaryam).



New BBM (Source: F Hilemaryam).

(Source: F Hilemaryam).

Farmer being surveyed (Source: F Hilemaryam).

Annex 2 Farmer survey

ILRI broad bed maker *ex post* impact assessment: Survey 2008

Section A. Location information

1 Region ____________________
2 Zone _____________________
3 *Woreda* _____________________
4 Peasant association _________________

Section B. Household resources and use

5 Land use (current season) (‘*kert/timad/kada*’)
a. Total cultivated area (owned/shared/rented) ________
b. Area of crop land with vertisol soils ________
c. Area of Vertisol soil with major waterlogging problem ________

6 Under what arrangements is the broad bed maker utilized? ________
(1 = sole owner, 2 = shared owner, 3 = rented in, 4 = borrowed)
a. If 2 above, how many others is the BBM shared with? ________
b. If 3 above, at what price is the BBM rented in (ETB)? _________

7 Indicate the source and prices (where relevant) of draught animals used with the BBM?

a. Own (head) _________
b. Borrowed/shared (head) _________
c. Rented in (head, ETB/head) _________ __________

8 When the BBM technology is used, which of the following elements of the package are also used?
a. Improved wheat varieties (name_________, quantity_____, units_____)
b. Early planting (month ________, early (1), mid (2), late (3) _____)
c. Urea fertilizer (quantity_______, units _____, frequency____)
d. DAP fertilizer (quantity _______, units _____, frequency___)
e. Herbicide/pesticide/insecticide (total cost for season_____ ETB)
f. Credit for BBM (ETB ________)
g. Credit for BBM inputs (ETB ________)

9 Where did you learn about the BBM package?

(1 = Ministry of Agriculture, 2 = NGO, 3 = neighbour, 4 = relative, 5 = others, specify)

10 Types of crops grown with BBM TP, area of land covered under BBM TP, crop output and prices of grains from BBM TP plots (2008–2005)

Type of crops grown with BBM TP prepared land	Area of land, crop yield and prices prepared with BBM TP during 2008–2005											
	2008			2007			2006			2005		
	Land area (*kert/timad*)	Crop yield (quintal)	Price (ETB/qt)	Land area (*kert/timad*)	Crop yield (quintal)	Price (ETB/qt)	Land area (*kert/timad*)	Crop yield (quintal)	Price (ETB/qt)	Land area (*kert/timad*)	Crop yield (quintal)	Price (ETB/qt)
Improved wheat												
Barley												
Horse bean												
Others (specify)												

11 Crop-residue yields, prices and use of crop residues from crops plated using BBM TP (2008–2005)

Residues from crops grown with BBM TP prepared land	Crop-residue yields, prices and use from crops BBM TP-prepared land 2008–2005											
	2008			2007			2006			2005		
	Yield (local unit)	Total value (ETB)	Use*	Yield (local unit)	Total value (ETB)	Use*	Yield (local unit)	Total value (ETB)	Use *	Yield (local unit)	Total value (ETB)	Use*
Improved wheat												
Barley												
Horse bean												
Others (specify)												

* Use: 1 = Animal feed, 2 = Construction, 3 = Fuel, 4 = Sales, 5 = Compost (soil fertility), 6 = No use.

12 Type and area of second crops grown on BBM TP plots, their grain output and prices (2008–2005)

Type of second crops	Area of land, method of cultivation, crop yield and prices of second crops											
	2008			2007			2006			2005		
	Land area (*kert/timad*)	Crop yield (quintal)	Price (ETB/qt)	Land area (*kert/timad*)	Crop yield (quintal)	Price (ETB/qt)	Land area (*kert/timad*)	Crop yield (quintal)	Price (ETB/qt)	Land area (*kert/timad*)	Crop yield (quintal)	Price (ETB/qt)
Chickpea												
Rough pea												
Others (specify)												

12A Crop-residue yields, prices and use of crop residues from second crops on BBM TP plots (2008–2005)

Type of second crop residues (straw)	Crop-residue yields, prices and uses from second crops											
	2008			2007			2006			2005		
	Yield (local unit)	Total value (ETB)	Use of residues *	Yield (local unit)	Total value (ETB)	Use of residues*	Yield (local unit)	Total value (ETB)	Use of residues*	Yield (local unit)	Total value (ETB)	Use of residues*
Chickpea												
Rough pea												
Others (specify)												

* Use: 1 = Animal feed, 2 = Construction, 3 = Fuel, 4 = Sales, 5 = compost (soil fertility), 6 = No use.

13 Do you plan to use the BBM TP in 2009? (1 = yes, 2 = no) _______________

14 If yes to question 13, what crop will you plant on BBM TP prepared land? _________

15 What area will you plant the crops (from question 14)? _______________

16 In what year did you first use the BBM TP? __________________

17 Type and area of crops that would have been grown on BBM plots if BBM TP had not been used, grain output and prices (2008–2005)

Type of crops grown	Area of land, method of cultivation, crop yield and prices of crops planted															
	2008				2007				2006				2005			
	Land area (*kert/timad*)	Meth-od*	Crop yield (quintal)	Price (ETB/qt)	Land area (*kert/timad*)	Meth-od*	Crop yield (quintal)	Price (ETB/qt)	Land area (*kert/timad*)	Meth-od*	Crop yield (quintal)	Price (ETB/qt)	Land area (*kert/timad*)	Meth-od*	Crop yield (quintal)	Price (ETB/qt)
Local wheat																
Teff																
Others (specify)																

* Method: 1 = Hand-made BBF, 2 = Flat-bed planting, 3 = Drainage furrows, 4 = Ridges and furrows (*shurube*).

18 Crop-residue yields, prices and use of crop residues from crops that would have been planted on BBM TP plots if BBM TP had not been used (2008–2005)

Type of crops	Crop-residue yields, prices and uses of crop residues											
	2008			2007			2006			2005		
	Yield (local unit)	Total value (ETB)	Use of residues*	Yield (local unit)	Total value (ETB)	Use of residues*	Yield (local unit)	Total value (ETB)	Use of residues*	Yield (local unit)	Total value (ETB)	Use of residues*
Local wheat												
Teff												
Others (specify)												

* Use: 1 = Animal feed, 2 = Construction, 3 = Fuel, 4 = Sales, 5 = Compost (soil fertility), 6 = No use.

19. What was the most important factor in your decision to use the BBM technology package? ____________ (Use code sheet and additional pages if necessary)

20. Have you modified the BBM itself in any way? ____________

a) How? ____________________ b) What has been the result? __________________________
c) What/who led you to make these modifications? ___________________________________

21. Have you incorporated any other farming practices with the BBM TP? _______________

a) What are they? ____________________ b) What is their scope/scale? __________________
c) What are they used for?_____________ d) What is their impact on your household's well being? ____

Annex 3 Forum discussion outline

ILRI broad bed maker *ex post* impact assessment:

Group forum discussion 2008

Region ___________________
Zone ___________________
Woreda ___________________
Peasant association ___________________

1 What factor would most facilitate increased and sustained use and impact of the BBM TP? ______________________________________ ________________________________

____
____
____
____
____

2 What other factors have affected the use and impact of the BBM TP? _____________

____
____
____
____
____

3 Identify organizational and/or institutional ('rules of the game') arrangements that have contributed to changes in the use and impact of the BBM TP? ______________________

____
____
____
____
____

4 How enabling has the policy environment been in relation to the use and impact of the BBM TP? ____

____
____
____
____

Annex 4 Contacts

Rutherford's BBM TP contacts in Addis Ababa and Nairobi

- ILRI-Nairobi:
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- ILRI-Ethiopia—IPMS:
  - Dirk Hoekstra
  - Ranjitha Puskur
  - Noah Kebede (GIS)
  - Yigzaw Dessalegn (RDO, Amhara, West Gojam, Bure)
  - Nigatu Alemayehu (RDO, Oromiyo, East Shewa, Ada)
  - Tilahun Gebey, (RDO, Amhara, South Gondar, Fogera)
- Federal Ministry of Agriculture (MoA), Dr Wonderad Mandefro (Head of Extension)
- Regional MoA, Regional Office of Agriculture and Rural Development (OARD) (Extension):
  - Aynalem Haile (Amhara)
  - Abebe Diriba (Oromiyo)
  - Ex-ILRI staff: Abiye Astatke
  - CIMMYT: Roberto la Rovere
- Sasakawa-Global (SG) 2000:
  - Dr Tesfaye Tessema (Deputy Director)
  - Bisrat Aretu (Finance Manager)
  - Wondwossen Tsegaye (Economist) CIMMYT/SG2000

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Tefera Seifu	Agricultural input extension expert, Amhara Regional BOA	Bahir Dar 0918-704904
Lanteyideru Tesfaye	West Gojam Zone BOA Head	Bahir Dar
Melese Alemayehu	West Gojam Zone BOA Technology transfer expert	Bahir Dar
Honelegne Alene	Semen Achefer *Woreda* BOA Head	Semen Achefer
Yenealem Delnesaw	Semen Achefer *Woreda* BOA Assistant Head	Semen Achefer
Mesenbet Alemu	Semen Achefer *Woreda* BOA crop production and protection expert	Semen Achefer
Aemro Degu	Semen Achefer *Woreda* BOA, Denbola PA, development agent	Semen Achefer, Denbola
Mulu Tsega	Semen Achefer *Woreda* BOA, Denbola PA, development agent	Semen Achefer, Denbola
Atena Ayesew	Semen Achefer *Woreda* BOA, Konger PA, development agent	Semen Achefer, Konger 0918-788702
Tekeba Tebabel	North Gondar Zone, Extension Department Head	Gondar, 0918-778513
Hagos W/Gebreal	North Gondar Zone, Market Study Expert	Gondar
Yohannes Beruk	Gondar Zuria *Woreda* BOA Head	Makesegnet
Melaku Alebel	Gondar Zuria *Woreda* BOA Extension Department Head	Makesegnet
Terngo Yilak	Gondar Zuria *Woreda* BOA Crop Production Expert	Makesegnet
Derese Andargea	Gondar Zuria *Woreda* BOA Supervisor	Makesegnet
Abebe Dessie	East Gojam Zone BOA Extension Department Head	Debre Markos
Mulugeta Mekuria	East Gojam Zone BOA Extension Department Head	Debre Markos
Zelalem	Debaytelagn *Woreda* BOA Head	Debaytelagn
Zewdu Kassa	Debaytelagn *Woreda* BOA Crop Production Expert	Debaytelagn
Menawgaw Tegod	Debaytelagn *Woreda,* Asendabo PA development agent	Debaytelagn
Mulualem Gezachew	Debaytelagn *Woreda*, Asendabo PA development agent	Debaytelagn
Tesfaye Dargea	South Wello Zone BOA Head	Dessie, 0331-116020
Birru Amede	South Wello Zone BOA input supply and distribution coordinator	Dessie
Fekere Temtem	Jamma *Woreda* BOA assistant Head	Jamma, 0332-260005
Getachew Tadese	Jamma *Woreda* BOA Supervisor	Jamma
Ali Jemal	Jamma *Woreda*, Shelafaf PA development agent	Shelafaf
Tadesse Girma	Jamma *Woreda*, Shelafaf PA development agent	Shelafaf

Annex 5 Amhara zone, *woreda* and peasant association information

South Wello zone, Amhara region, November 2008, Wagnew Ayalneh

The last zone visited by the survey group was South Wello. After gathering information from the zonal office in Dessie town, we were advised to go to Jamma *woreda* where one of ILRI's predecessors, ILCA, used to have experimental site. The *woreda* is 120 km from Dessie town on 2nd grade gravel roads and it took us a day to reach.

The Ministry of Agriculture office in Jamma *woreda* selected Shelafafe PA for surveying out of the 14 PA where they have distributed the BBM TP. The Shelafafe PA was selected based on its accessibility, farmer settlement arrangements, and availability, as the farmers were very busy harvesting wheat and teff. Even though the *woreda* was originally one of the first to receive BBM TPs in the 1990s, this PA had only received BBM TPs in the last four years. Upon reaching the PA, we found that the DA had been transferred to another area and the office was closed. We were forced to select farmers without an appointment (usually arranged by the DA) from those we saw harvesting in the field.

After 15 household heads were interviewed, we conducted a group discussion with *woreda* DAs and farmers. During the discussion farmers and DAs raised the following points:

1. Average crop areas varied from 0.25 to 1.5 hectares per farmer and average yields were 3200 kg/ha for improved wheat, 1600 kg/ha for local wheat and teff and 2000 kg/ha for horse beans.
2. The most dominant crop in the area is wheat. Planting dates ranged from July 20 up to August 12. Local wheat is planted using traditional drainage system called *zekosh*. This involves opening up a furrow about every 80 cm across the field using a local plough and a pair of oxen. Then the soil is moved up to form a bed by human labour, especially women and children's labour. Improved wheat variety HAR1685 is planted using the BBM TP in July.
3. The contract-growing price of improved wheat was ETB 750/quintal at planting time as the farmers union was buying the wheat at 15% above the market price.
4. The farmers mostly have only one crop per growing season due to the rainy season ending early in September. In some good years when the rain comes early in June and continues through to September, they have a second crop such as chickpea or rough pea.
5. The major advantage of the BBM TP in this area is soil conservation and human labour reduction—freeing it for other agricultural activities.

6. The only problem of the new BBM is the weakness of the tip—breaking during assembly when the tip is bent. An increased availability of welding resources in each *woreda* would facilitate greater use of the implement.

7. Training and convincing farmers to use the BBM TP were identified as a very important factor in the BBM TPs use. The area is very remote and farmers' acceptance of new technologies is relatively low. Intensive practical training as well as technical training for farmers and DAs is necessary.

8. Within the PA, 300 farmers were given training on BBM TP use—out of which 69 farmers had used the BBM TP in the current cropping season. In order to motivate the farmers to use the BBM TP, prizes were awarded for the farmers who used the BBM TP successfully. Approximately 200 farmers were registered to use BBM TP in the coming 2009 crop season.

9. Three farmers in the PA had constructed ponds even though the area is not that suitable for pond constructing—being stony and towards the edge of the plateau.

South Wello Zone BBM distribution and use

Woreda	BBM distributed 2003–07	BBM distributed 2008	BBM Used (2008)
Wereillu	2592	417	
Kelala	2621	1142	
Sayint	800	615	
Jamma	4016	2278	
Wegedi	1550	925	
Tenta	364	170	
Werebabo	50	50	
Legambo	1020	458	
Legehida	898	142	
Ambasel	49	44	
Mekedela	195	195	
Debresina (Borena)	695	575	
Mahelsayint	66	66	
Albuko	19	11	
Dessie Zuria	52	34	
Kala	10	8	
Total	14,997	7130	3894

% of total 22,000 distributed =18

Planned and actual area and farmers using BBM TP

2007/08 crop season	Planned	Actual	Actual % of planned
BBM TP used (ha)	18,200	6110	34
No. of farmers used BBM TP	38,608	19,593	51

Male	32,756	17,824	54
Female	5852	1769	30

Traditional drained land (ha)	54,917	46,855	85
No. of farmers	54,192	67,183	124
Male	46,613	57,720	124
Female	7579	9463	125
Total crop land (ha)	73,117	52,965	

BBM TP land % of total land (BBM TP + traditional) =12

Ponds constructed

2007/2008 crop season	Planned	Actual	Actual % of planned
Total	2000	836	42
Male		760	
Female		76	

Input prices and use, 2008

Input	Input prices ETB/quintal	Amount used on Vertisols (qt)
DAP (Range 760–802)	781	20,855
Urea	549	20,415
Wheat	470	
Barley	485	
Chickpea	700	
Maize—hybrid	820	
Maize—other	400	
Teff	700	
Finger millet	400	
Horse bean	600	
Haricot bean	700	
Improved seed		4336

Selected crop prices in Dessie town on 06 December 2008 (ETB/qt)

Crop	Producer/farmer	Wholesaler	Retailer
Teff—white	960	965	975
Teff—mixed	940	950	970
Teff—red	930	940	955
Wheat white	730	740	780
Wheat—mixed	650	660	680
Barley—white	750	765	775
Barley mixed	730	740	750
Maize—white	570	590	610
Maize—mixed	570	570	590
Sorghum—white	650	660	670
Sorghum—mixed	600	610	620

Horse bean	530	540	560
Field pea	630	640	660
Chickpea	520	530	540
Lentils	920	930	945
Noug	820	830	890
Fenugreek	800	810	820
Sesame	830	840	850
Pepper	4000	4300	4500
Onion	500	510	550

East Gojam zone, Amhara region, November 2008, Wagnew Ayalneh

The team went to East Gojam zone on 07 November 2008. The zonal office had distributed BBM to all *woredas* in the zone and the team was advised to go to Debaytelagn *woreda* based on the BBM distribution and number of farmers using the BBM TP. The *woreda* is about 60 km from Debre Markos on gravel road. The area is about 2500 to 2600 metres above sea level with high rainfall distributed from June up to the end of September.

The number of BBMs distributed up to 2007 was 1740 and after 2007 was 2969—making a total to date of 4709. The demand for BBMs is very high and farmers have already paid ETB 10 in advance as a down payment. To alleviate the BBM shortage problem, the *woreda* borrowed 2000 pair from the adjacent Dejen *woreda*.

Table 1. *Debaytelagn* woreda *crop production using BBM TP and traditional drainage systems (2007/2008 crop season)*

Crop type	Using BBM TP (ha)	Using traditional drainage (ha)
Barley	514	3208
Horse bean	1278	1879
Wheat	272	437
Field pea	217	470
Lentils	4	–
Maize	1	652
Noug	13	–
Total	2327	6648

Author's note: in this *woreda*, BBM TP land as a percentage of the total cropped land of 8962 hectares is 26%—this is relatively high but it is a relatively small *woreda*.

As part of the BBM TP farmers were also constructing ponds to store the drained water from the field and use it later in the dry season to grow vegetables. The number of ponds during the time of our visit was 266.

The *woreda* DA selected Asendabo PA (out of 15 PAs) based on accessibility and the number of farmers who had used the BBM TP. In the group discussion the following points were raised both by farmers and development agents who participated in the discussion:

1 The BBM TP was introduced in the *woreda* four years ago and the number of farmers using it is increasing every year after seeing the benefits other farmers experienced. The number of BBMs distributed in the PA were 50, 126 and 748 in 2005, 2006 and 2007 crop season, respectively.

2 Twelve farmers from the PA had constructed ponds and were growing vegetables—both for home consumption and generating income.

3 The government policy is to support about 30% of the farmers in the use of new technology and participation in extension programs.

4 The BBM is supplied from Bahir Dar and some of the implements are not up to an acceptable standard. Implement quality control is very necessary. The tip of the BBM breaks easily when they bend it. To solve this problem the DAs began bending it in the office and gave out ones that had not broken.

5 The yokes the farmers used with their oxen were shorter than recommended with the BBM—consequently they found it difficult to keep the beds 80 cm wide and one ox had to walk on the bed. The traditional two side struts directly behind, and supporting, the metal spear are too narrow to offer much support to the BBM wings that sit on top of them once they are tied on and need to be wider.

6 Traditionally, the major crops grown in the PA were barley (3500 kg/ha), wheat (2000 kg/ha) and horse bean (2400 kg/ha). Most of the crops were grown in September without any fertilizer.

7 Using the BBM TP, the farmers have started growing a second crop (i.e. chickpea and lentils) that has doubled their income.

8 In addition to double cropping, the yield from the first crop has also increased. The average yields of barley, wheat, and horse bean has increased to 4000, 3000, and 4000 kg/ha, respectively. The improved wheat used in the area is only of one variety and more varieties were required in the *woreda*. *Noug* is a new crop they are planting on the Vertisol soils during the rainy season.

9 Increases of input supply prices and reliability of supply were mentioned as major constraints to using the BBM TP—particularly in 2008 when the planting date for some crops passed before seed was available.

10 Practical training on the BBM TP for the farmers and DAs is very necessary.

11 The BBM TP does not exclude the poor or women farmers as such as the advance payment for the BBM is only ETB 5. It is only lack of awareness and the tendency to avert risk that constrains use.

Planned and actual drained land using the BBM TP and traditional methods, 2007/08

Woreda	Planned drained land (ha)			Actual drained land (ha)			BBM TP %
	BBM TP	Traditional	Total	BBM TP	Traditional	Total	Actual/planned
Huletegunese	7037	890	7927	469	1328	1797	7
Gonecha	1826	2450	4276	71	365	436	4
Enbesea	3576	4802	8378	2483	297	2780	69
Enarge	7406	939	8345	760	1249	2009	10
Enemay	14,812	1877	16,689	454	4891	5345	3
Shebel	4321	5802	10,123	193	1273	1466	4
Debaytelagn	14,457	1833	16,290	2327	6648	8975	16
Dejen	7362	933	8295	167	1676	1843	2
Awabel	9215	1168	10,383	412	2064	2476	4
Aneded	6300	799	7099	60	327	387	1
Basoliben	302	39	341	53	152	205	18
Gozamen	495	63	558	185	250	435	37
Total	77,109	21,595	98,704	7634	20,520	28,154	10
				BBM TP land % of total land =27			

Woreda	Ponds completed
Huletegunese	490
Gonecha	213
Enbesea	409
Enarge	458
Enemay	114
Shebel	212
Debaytelagn	194
Dejen	124
Awabel	351
Aneded	150
Basoliben	83
Gozamen	28
Total	2,826

2008	Input price	Market price
Teff	737	780
Wheat	564	683
DAP	783	
Urea	560	

North Gondar zone, Amhara region, November 2008

BBM distribution

Woreda	BBM distribution to farmers July 2007/08	BBM distribution to farmers 1997–08	BBM still in *woreda* storage
Alefa		330	2234
Chilga		347	2395
Dembia		662	2113
Gondar town	–	–	1026
Gondar Zuria	80	342	3283
Lay Armachiho		–	–
Metema		273	3638
Quara		324	2282
Tach Armachiho		93	312
Takusa		911	–
Tegede	23	97	1708
West Armachiho		20	180
Adiarkay		–	–
Beyeda		–	–
Dabat		519	63
Debark		90	365
East Belesa		–	–
Janamora		–	100
Wogera		377	302
Telemet		–	–
West Belesa		–	–
Total	103	4385	20,001

% distribution =22

Input prices

Input	2006 (ETB/qt)	2007 (ETB/qt)	2008 (ETB/qt)
DAP	387	425	858
Urea	330	378	604
Wheat	260	325	470
Barley	271	335	470
Teff	370	575	700
Horse bean	320	425	425
Chickpea	385	525	700
Lentil	600	600	800
BBM (ETB)		90	45
Adjustable BBM (ETB)			71
Interest (%)	12.5	12.5	13.5

MoA and Wagnew Ayalneh.

West Gojam zone, Amhara region, November 2008

Total land and yield using BBM TP in 2007/08 crop season

Woreda	Wheat area (ha)	Yield (qt)	Barley area (ha)	Yield (qt)	Horse beans area (ha)	Yield (qt)	Maize area (ha)	Lentils area (ha)	Teff area (ha)
Yelmana	37	1494	4	91	0	3			
Gonge	18								
Bahir Dar Zuria	219								
Mecha	84	1690			1	10			29
Debub Achefer	3		168		12		5	58	
Semen Achefer	72		348		14				
Bure Zuria	71								
Jabitehenan	50		13		2				
Fenote Selam	4								
Kerit	10								
Denbecha	82		1						
Dega Damot	2		6						
Weberma	62								
Total	714		538		29		5	58	29
% of total crop area	40		16		7		0	51	1

Total land and yield using traditional drainage in 2007/08 crop season

Woreda	Wheat area (ha)	Yield (qt)	Barley area (ha)	Yield (qt)	Horse beans area (ha)	Yield (qt)	Maize area (ha)	Lentils area (ha)	Teff area (ha)
Yelmana	108	3875	116	2560	15	277			419
Gonge	47		108		53				833
Bahir Dar Zuria	82		198						900
Mecha	710	1420			8	80		4	309
Debub Achefer	1		129		16		41	39	148
Semen Achefer	3		1624		144			12	220
Bure Zuria	73		45				314		
Jabitehenan	49		264		36		467		108
Fenote Selam							34		37
Kerit	3		206		76				409
Denbecha			83		23		727		40
Dega Damot			150						20
Weberma							61		
Total	1076		2923		372		1644	55	3443
Total crop land (ha)	1790		3461		400		1648	113	3473

Source: MoA and Wagnew Ayalneh.

Total land and yield of second crop in 2007/08 crop season

Woreda	Chick-pea area (ha)	Rough pea area (ha)	Lentils area (ha)	Barley area (ha)	*Noug* area (ha)	
Yelmana	121	1320		2130	2	
Gonge	62	109			3	
Bahir Dar Zuria	282	569		160	58	
Mecha	134	1012		2080	895	
Debub Achefer	92	353	42	585		
Semen Achefer	709	2011				
Bure Zuria	622			156		
Jabitehenan	1229	764		2		
Fenote Selam				2770		
Kerit	12			1297	291	
Denbecha	1290					
Dega Damot	52	186				
Weberma	118					
Total	4723	6323	42	9179	1249	21,515

Farmers using BBM and number distributed, 2007/08 upto now

Woreda	No. of farmers (BBM + Traditional)			No. of farmers using BBM			BBM farmers (% of total)	No. of BBM distributed to *woreda*	No. of BBM used
	Male	Female	Total	Male	Female	Total			
Yelmana	1589	83	1672	195	7	202	12	949	165
Gonge	2150	367	2517	66	3	69	3	81	52
Bahir Dar Zuria	1975	43	2018	218	3	221	11	889	185
Mecha	1339	41	1380	537	24	561	41	192	107
Debub Achefer	1644	77	1721	542	22	564	33	664	55
Semen Achefer	8544	374	8918	897	91	988	11	206	137
Bure Zuria	1229	20	1249	209	8	217	17	155	162
Jabitehenan	1910	51	1961	235	4	239	12	671	89
Fenote Selam	118	21	139	14	0	14	10	83	6
Kerit	351	23	374	39	1	40	11	380	12
Denbecha	2027	118	2145	235	7	242	11	130	81
Dega Damot	407	13	420	47	1	48	11	50	9
Weberma	287	16	303	114	2	116	38	58	52
Total	23,570	1247	24,817	3348	173	3521		4508	1112
BBM farmers as % of total farmers =				14	14	14	Used % dist.=25		

Cultivated land planned and actual, BBM TP and traditional, 2007/08

Woreda	Planned cultivated area (ha)	Actual total (ha)	Actual % planned	Actual BBM TP land	Actual Traditional land	BBM TP % actual total land
Yelmana	3761	739	20	41	698	6
Gonge	3503	1134	32	19	1115	2
Bahir Dar Zuria	10,749	1399	13	219	1180	16
Mecha	3027	1146	38	115	1031	10
Debub Achefer	1480	636	43	245	391	39
Semen Achefer	5371	2441	45	438	2003	18
Bure Zuria	1091	705	65	71	634	10
Jabitehenan	3049	1118	37	64	1054	6
Fenote Selam	20	82	410	4	78	5
Kerit	2671	703	26	10	693	1
Denbecha	1986	1331	67	89	1242	7
Dega Damot	3053	186	6	8	178	4
Weberma	241	244	101	70	174	29
Total	40,002	11,864		1393	10,471	

Semen Achefer *woreda* input prices, 2008

Input	ETB/qt
BBM (ETB)	45
DAP	751
Urea	634
Improved maize (HB540)	909
Improved maize (HB3253)	1121
Teff	700
Wheat	470
Chickpea	700

Semen Achefer cultivated land by method and crop type, 2008

Crop	BBM TP	Traditional	Total
Wheat	72	3	75
Barley	351	1526	1877
Horse beans	15	144	158
Teff	0	318	318
Fenugreek	0	12	12

Semen Achefer *woreda* average prices, 2008

Crop	Producer price (ETB/qt)	Retail price (ETB/qt)
Teff—white	750	775
Teff—mixed	690	810
Teff—red	645	840
Barley—white	365	380
Wheat	625	670
Maize	170	215
Sorghum	390	425
Horse bean	440	490
Chickpea	395	410
Rough pea	340	375

Annex 6 Ethiopia—Gross margin estimates, 2008

Analysis of cropping systems (USD/ha)	Cost increase	%	Return increase	%	GM increase	%
Improved wheat vs. local wheat	311	309	564	54	253	27
Improved wheat vs. teff	279	211	367	29	88	8
Improved wheat + chickpea vs. local wheat	389	387	1525	145	1136	120
Improved wheat + chickpea vs. teff	357	270	1327	106	970	87

Costs	Local wheat (USD/ha)	Improved wheat (USD/ ha)	Teff (USD/ ha)	Chick-pea (USD/ ha)	Rough pea (USD/ ha)	Improved chickpea (USD/ha)	Barley (USD/ ha)	Horse bean (USD/ha)
Inputs—see details below	101	407	132	78	41	119	110	99
BBM		4					4	4
Interest—BBM		1					1	1
Risk premium—BBM use		141					1	1
Subtotal (USD/ha)	101	411	132	78	41	119	114	104
Subtotal (ETB/ha)	956	3910	1257	740	390	1130	1087	985
Returns								
Grain—see details below	993	1499	1114	926	703	1,360	1221	1723
Residue—see details below	56	114	133	35	33	67	45	35
Subtotal (USD/ha)	1049	1613	1247	961	737	1428	1267	1758
Subtotal (ETB/ha)	9974	15,338	11,851	9132	7006	13,571	12,042	16,710
Gross margins (USD/ha)	949	1202	1114	883	696	1309	1152	1654
Gross margins (ETB/ha)	9019	11,428	10,594	8392	6616	12,441	10,955	15,725

Returns	Grain				Return		Residues			Return	
	(Source) 2008	Yield kg/ha	Price ETB/kg	ETB/ha	USD/ ha	USD/ T	Yield kg/ha	Price ETB/kg	ETB/ ha	USD/ ha	USD/ T
Local wheat	survey	1600	5.9	9440	993	621	1780	0.3	534	56	100
Improved wheat	survey	2500	5.7	14250	1499	600	2720	0.4	1088	114	311
Teff	survey	1190	8.9	10591	1114	936	2520	0.5	1260	133	334
Chickpea	survey	1600	5.5	8800	926	579	830	0.4	332	35	29
Rough pea	survey	2090	3.2	6688	703	337	1060	0.3	318	33	35
Improved chick-pea	survey	1930	6.7	12931	1360	705	1600	0.4	640	67	108
Barley	survey	2700	4.3	11610	1221	452	2160	0.2	432	45	98
Horse bean	survey	2600	6.3	16380	1723	663	1100	0.3	330	35	38

Cost of inputs

	Rate		Cost		ETB/ha	USD/ha
Local wheat						
Fertilizer	35	kg/ha	5.5	ETB/kg	193	20
(Fertilizer—not specified)						
Seed	150	kg/ha	4.7	ETB/kg	705	74
Herbicide						
Weeding labour	3	persondays	6.0	ETB/day	18	2
Harvesting labour	5	persondays	8.0	ETB/day	40	4
Interest—inputs					0	0
Total					956	101
Improved wheat						
Fertilizer—DAP	126	kg/ha	7.8	ETB/kg	983	103
Fertilizer—Urea	110	kg/ha	5.6	ETB/kg	616	65
Seed	173	kg/ha	4.7	ETB/kg	813	86
Herbicide	1	litre/ha	60.0	ETB/litre	60	6
Weeding labour	3	persondays	6.0	ETB/day	18	2
Harvesting labour	5	persondays	8.0	ETB/day	40	4
Interest—inputs	x 4 correction for survey average of ETB 1304/ha				1335	140
Total					3865	407
Teff						
Fertilizer—DAP	103	kg/ha	7.8	ETB/kg	803	85
Fertilizer—Urea						
Seed	50	kg/ha	7.0	ETB/kg	350	37
Herbicide						
Weeding labour	4	persondays	6.0	ETB/day	24	3
Harvesting labour	10	persondays	8.0	ETB/day	80	8
Interest—inputs					0	0
Total					1257	132
Chickpea						
Fertilizer—DAP		kg/ha	7.8	ETB/kg	0	0
Fertilizer—Urea		kg/ha	5.6	ETB/kg	0	0
Seed	100	kg/ha	7.0	ETB/kg	700	74
Weeding labour		persondays	6.0	ETB/day	0	0
Harvesting labour	5	persondays	8.0	ETB/day	40	4
Interest—inputs					0	0
Total					740	78

Rough pea						
Fertilizer—DAP		kg/ha	7.8	ETB/kg	0	0
Fertilizer—Urea		kg/ha	5.6	ETB/kg	0	0
Seed	100	kg/ha	3.5	ETB/kg	350	37
Weeding labour		persondays	6.0	ETB/day	0	0
Harvesting labour	5	persondays	8.0	ETB/day	40	4
Interest—inputs					0	0
Total					390	41
Improved chickpea						
Fertilizer—DAP (est.)	50	kg/ha	7.8	ETB/kg	390	41
Fertilizer—Urea		kg/ha	5.6	ETB/kg	0	0
Seed	100	kg/ha	7.0	ETB/kg	700	74
Weeding labour		persondays	6.0	ETB/day	0	0
Harvesting labour	5	persondays	8.0	ETB/day	40	4
Interest—inputs					0	0
Total					1130	119
Barley						
Fertilizer—DAP	30	kg/ha	7.8	ETB/kg	234	25
Fertilizer—Urea	30	kg/ha	5.6	ETB/kg	168	18
Seed	120	kg/ha	4.9	ETB/kg	582	61
Weeding labour	3	persondays	6.0	ETB/day	18	2
Harvesting labour	5	persondays	8.0	ETB/day	40	4
Interest—inputs					0	0
Total					1042	110
Horse bean						
Fertilizer—DAP	0	kg/ha	7.8	ETB/kg	0	0
Fertilizer—Urea	0	kg/ha	5.6	ETB/kg	0	0
Seed	150	kg/ha	6.0	ETB/kg	900	95
Weeding labour		persondays	6.0	ETB/day	0	0
Harvesting labour	5	persondays	8.0	ETB/day	40	4
Interest—inputs					0	0
Total					940	99

Converted residues

	Yield kg/ha	Price ETB/kg	ETB/ha	Return USD/ha
Local wheat	2400	0.3	720	76
Improved wheat	3750	0.4	1500	158
Teff	1785	0.5	893	94
Chickpea	2400	0.4	960	101
Rough pea	3135	0.3	941	99

Improved chickpea	2316	0.4	926	97
Barley	4050	0.2	810	85
Horse bean	3900	0.3	1170	123

Conversion factor		kg residue = kg grain x
	Teff, finger millet, wheat, barley, rice	1.5
	Maize	2.0
	Sorghum	2.5
	Pea, horse bean, lentil, rough pea, chickpea	1.2
	Noug	1.8

BBM credit cost of 202 birr/ha /5 years (not subsidised price)

	Other costs	ETB/ha	USD/ha
	BBM	40	4

Input and risk premium interest rate (%)	13.5
BBM input interest rate (%)	13.5

Exchange rate—2008	ETB	USD
	9.5068	1

BBM cost considers area/farmer, years used, no. farmers

Note: farmers may not borrow total cost of inputs

Note: farmers may borrow for the BBM but not other inputs

	Fertilizer	DAP	7.8 ETB/kg
		Urea	5.6 ETB/kg
		Not specified	5.5 ETB/kg
	Herbicide		60 ETB/litre

Improved seed yields Estimate		Yield (kg/ha)
	Improved chickpea	3000–4000
	Improved maize	4000–5000
	Improved barley	4000–5000

Note: Source W Ayalneh.

Annex 7 Broad bed maker technology

1. Improved vs. local wheat—Grain

1	2	3	5	6	7	8	9	10	11	13	14	15	16	17	18	19	20
Year	PeS	AbPeD	Tot wheat produced tonnes	All wheat nominal price ETB/tonne	CPI	Real price ETB/t	Av. yield new tech tonne/ha	Av. yield trad. tech tonne/ha	Yield increase tonne/ha	Tot. area under prod. both tech ha	Tot. area under prod new tech ha	Adop-tion rate (prop area)/t	Av. nat. yield tonne/ha	Prop. prod increase	Nominal adopt. cost per tot. area ETB/ha	Real adopt. cost per area ETB/ha	Real adopt. cost per output ETB/tonne
	E	e	Q		2008=1	P	Yn	Yt	dY	A			Ym=Q/A	j=dY*t/Ym		dC	I=dC*t/Ym
1986	0.8	0.4	856,000	1360	0.277	4907				661,860	0		1.29		–		
1987	0.8	0.4	813,000	1360	0.270	5029				680,000	0		1.20		–		
1988	0.8	0.4	836,000	1360	0.290	4696				700,000	0		1.19		–		
1989	0.8	0.4	845,000	1360	0.312	4355				680,000	0		1.24		–		
1990	0.8	0.4	867,000	1360	0.328	4142				680,000	0		1.28		–		
1991	0.8	0.4	890,000	1360	0.446	3052				690,000	0		1.29		–		
1992	0.8	0.4	930,000	1360	0.493	2761				625,000	0		1.49		–		
1993	0.8	0.4	897,000	1360	0.510	2667				743,000	0		1.21		–		
1994	0.8	0.4	1,023,914	1360	0.510	2668	1.72	1.052	0.668	769,340	101	0.0001	1.33	0.0001	786	1541	0.2
1995	0.8	0.4	1,118,179	1310	0.549	2388	1.72	1.052	0.668	890,800	130	0.0001	1.26	0.0001	786	1432	0.2
1996	0.8	0.4	996,829	1430	0.573	2495	1.72	1.052	0.668	807,480	131	0.0002	1.23	0.0001	786	1371	0.2
1997	0.8	0.4	1,106,785	1460	0.552	2645	1.72	1.052	0.668	787,720	142	0.0002	1.41	0.0001	786	1423	0.2
1998	0.8	0.4	1,142,686	1460	0.604	2416	1.72	1.052	0.668	831,770	208	0.0003	1.37	0.0001	786	1300	0.2
1999	0.8	0.4	1,149,618	1680	0.633	2654	1.72	1.052	0.668	1,031,140	310	0.0003	1.11	0.0002	786	1241	0.3
2000	0.8	0.4	1,235,224	1900	0.672	2827	1.72	1.052	0.668	1,062,010	383	0.0004	1.16	0.0002	786	1169	0.4
2001	0.8	0.4	1,596,012	2120	0.637	3328	1.72	1.052	0.668	1,203,720	520	0.0004	1.33	0.0002	786	1233	0.4
2002	0.8	0.4	1,447,621	2340	0.591	3959	1.72	1.052	0.668	1,006,271	522	0.0005	1.44	0.0002	786	1329	0.5
2003	0.8	0.4	1,618,037	2560	0.680	3765	1.72	1.052	0.668	1,166,237	726	0.0006	1.39	0.0003	786	1155	0.5
2004	0.8	0.4	2,176,603	2780	0.739	3764	1.72	1.052	0.668	1,398,215	1,306	0.0009	1.56	0.0004	786	1064	0.6
2005	0.8	0.4	2,219,075	3000	0.789	3802	2.50	1.600	0.900	1,459,540	2,181	0.0015	1.52	0.0009	2363	2995	2.9
2006	0.8	0.4	2,463,064	3200	0.874	3660	2.50	1.600	0.900	1,473,917	4,405	0.0030	1.67	0.0016	2363	2703	4.8
2007	0.8	0.4	2,709,370	4000	0.927	4316	2.50	1.600	0.900	1,714,791	15,374	0.0090	1.58	0.0051	2363	2550	14.5
2008	0.8	0.4	2,980,307	5800	1.000	5800	2.50	1.600	0.900	1,886,271	24,522	0.0130	1.58	0.0074	2363	2363	19.4

PeD e 0.4
PeS E 0.8

1. Improved vs. local wheat—Grain

1	21	22	23		24	25	26	27	28	29	30	31	32	33	34	Net change in economic surplus	
						All grain and residues values											
Year	Prop. cost in-crease	Net prop. cost redn from techn	Quantity increase tonnes	Proportion-ate decrease in price ETB × 10^6	Wheat grain Change in tot. economic surplus ETB × 10^6	Change in tot. economic surplus ETB × 10^6	Change in consumer surplus ETB × 10^6	Change in producer surplus ETB × 10^6	R&E ILRI Highlands USD × 0^6	R&E other USD × 10^6	R&E total USD × 10^6	US/ETB XR (ETB/ USD)	R&E total ETB × 10^6	Real R&E total ETB × 10^6	Real R&E total USD × 10^6	ETB × 10^6	USD × 10^6
	c=I/P	k=j/PeS-c	dQ=QeEk/(E+e)	Z=k(E/(E+e))	dTS= kPQ(1-.5Ze)	dTS	dCS= PZQ (1-(0.5Ze))	dPS=dTS-dCS									
1986					–	–	–	–	0.94	0.47	1.42	2.07	2.93	10.58	5.11	–11	–5.1
1987					–	–	–	–	0.97	0.48	1.45	2.07	3.00	11.08	5.35	–11	–5.4
1988					–	–	–	–	1.24	0.62	1.86	2.07	3.86	13.33	6.44	–13	–6.4
1989					–	–	–	–	1.15	0.58	1.73	2.07	3.58	11.46	5.54	–11	–5.5
1990					–	–	–	–	1.36	0.68	2.03	2.07	4.21	12.82	6.19	–13	–6.2
1991					–	–	–	–	1.08	0.54	1.62	2.07	3.35	7.51	3.63	–8	–3.6
1992					–	–	–	–	0.78	0.39	1.18	5.01	5.89	11.96	2.39	–12	–2.4
1993					–	–	–	–	0.56	0.28	0.83	5.47	4.55	8.93	1.63	–9	–1.6
1994	0.000	0.000	7	0.000	0.1	0.4	0.0	0.4	0.48	0.24	0.72	6.16	4.44	8.72	1.42	–8	–1.3
1995	0.000	0.000	8	0.000	0.1	0.5	0.0	0.4	0.65	0.32	0.97	6.28	6.09	11.11	1.77	–11	–1.7
1996	0.000	0.000	10	0.000	0.1	0.5	0.1	0.4	0.73	0.37	1.10	6.36	6.98	12.19	1.92	–12	–1.8
1997	0.000	0.000	11	0.000	0.1	0.6	0.1	0.5	0.62	0.31	0.92	6.69	6.18	11.20	1.67	–11	–1.6
1998	0.000	0.000	16	0.000	0.1	0.7	0.1	0.6	0.67	0.34	1.01	7.11	7.15	11.83	1.66	–11	–1.6
1999	0.000	0.000	30	0.000	0.3	1.4	0.2	1.2	0.67	0.34	1.01	7.95	7.99	12.62	1.59	–11	–1.4
2000	0.000	0.000	43	0.000	0.5	2.2	0.3	1.9	–	0.67	0.67	8.22	5.51	8.19	1.00	–6	–0.7
2001	0.000	0.000	64	0.000	0.8	3.7	0.5	3.2	–	0.67	0.67	8.47	5.67	8.91	1.05	–5	–0.6
2002	0.000	0.000	70	0.000	1.0	5.8	0.7	5.1	–	0.67	0.67	8.57	5.74	9.71	1.13	–4	–0.5
2003	0.000	0.000	102	0.000	1.4	7.4	1.0	6.5	–	1.00	1.00	8.60	8.60	12.65	1.47	–5	–0.6
2004	0.000	0.000	192	0.000	2.7	12.7	1.8	10.9	–	1.40	1.40	8.64	12.09	16.37	1.90	–4	–0.4
2005	0.001	0.000	196	0.000	2.8	35.7	1.9	33.9	–	1.80	1.80	8.67	15.60	19.77	2.28	16	1.8
2006	0.001	0.001	454	0.000	6.2	82.4	4.2	78.3	–	2.20	2.20	8.70	19.14	21.89	2.52	61	7.0
2007	0.003	0.003	2,190	0.002	35.4	296.4	23.6	272.8	–	2.40	2.40	8.97	21.52	23.22	2.59	273	30.5
2008	0.003	0.006	4,692	0.004	102.0	567.1	68.0	499.2	–	3.40	3.40	9.51	32.32	32.32	3.40	535	56.3
					154	1018		Totals	11.9	20.2	32.1		196.4	308.4	63.6	709	47.0

NPV (10%) -1.1
B/C 3.3
IRR 0.1

Assumptions

Small country case—comm. not traded, linear supply and demand curves, parallel technology induced supply shift

1. Year: annual benefits are estimated for current year—20 years after research commenced (t = 1, …,20).
2. PeS: price elasticity of supply—if information was available, it would be adjusted for time, changes in price and quantity and shifts.
3. AbPeD: absolute value of price elasticity of demand—see comment above.
5. Tot. wheat prod. 1994/95–1998/99 CSA and 1986/2003 FAO; CSA 2004–06, est of 2008 based on AGR 2004–06.
6. Nominal price for all wheat CSA 1994/95 to 1998/99—extrap. 2005 onwards based AGR local and imp. wheat price and 2008 survey price.
7. CPI, National Bank of Ethiopia Quarterly Bulletin to 1987, IMF 1998–2007, est. 2008 using AGR 2005–2007. Base year =2008.
9. Average yields for improved wheat taken from previous farm survey data to 1998, then current survey 2005–08.
10. As in 9 above.
13. As above in 5. Estimate for 2007–08 worked backwards using CSA 3 year average (2004–06) yield of 1580 kg/ha.
14. MoA est. 2008. <1999 from previous survey, >1998 estimated approx. sigmoidal adoption curve in column 15 and using column 13.
15. See comment in 14.
18. Nominal adopt cost/total area—GM estimate IW (borrow BBM) vs. LW to 2005, buy BBM at full price 2006–08; cost allocated at 80% to grain and 20% to residues below.
28. R&E costs—ILRI Highlands total operating costs and salaries—assumed to discontinue from 2000.
29. R&E costs—estimated based on increased MoA and SG2000 focus in last 4 years.
31. Exchange rate from National Bank of Ethiopia, Quarterly Bulletin, Vol 13. No. 4, 1999, website to 2008 (up to August Qtr for 2008).

2. Improved vs. local wheat residue

1	2	3	5	6	7	8	9	10	11	13	14
Year	PeS	AbPe	Tot residue produced tonnes	All residue nominal price ETB/tonne	CP	Real price ETB/t	Av. yield new tech tonne/ha	Av. yield trad tech tonne/ha	Yield increase tonne/ha	Tot. area under prod both tech ha	Tot. area under prod new tech ha
	E	e	Q		2008=1	P	Yn	Yt	dY	A	
1986	0.8	0.4	479,360	250	0.277	902				661,860	–
1987	0.8	0.4	455,280	250	0.270	924				680,000	–
1988	0.8	0.4	468,160	250	0.290	863				700,000	–
1989	0.8	0.4	473,200	250	0.312	801				680,000	–
1990	0.8	0.4	485,520	250	0.328	761				680,000	–
1991	0.8	0.4	498,400	250	0.446	561				690,000	–
1992	0.8	0.4	520,800	250	0.493	508				625,000	–
1993	0.8	0.4	502,320	250	0.510	490				743,000	–
1994	0.8	0.4	573,392	250	0.510	490	0.97	0.14	0.83	769,340	101
1995	0.8	0.4	626,180	250	0.549	456	0.97	0.14	0.83	890,800	130
1996	0.8	0.4	558,224	250	0.573	436	0.97	0.14	0.83	807,480	131
1997	0.8	0.4	619,800	250	0.552	453	0.97	0.14	0.83	787,720	142
1998	0.8	0.4	639,904	250	0.604	414	0.97	0.14	0.83	831,770	208
1999	0.8	0.4	643,786	250	0.633	395	0.97	0.14	0.83	1,031,140	310
2000	0.8	0.4	691,725	250	0.672	372	0.97	0.14	0.83	1,062,010	383
2001	0.8	0.4	893,767	250	0.637	392	0.97	0.14	0.83	1,203,720	520
2002	0.8	0.4	810,668	250	0.591	423	0.97	0.14	0.83	1,006,271	522
2003	0.8	0.4	906,101	250	0.680	368	0.97	0.14	0.83	1,166,237	726
2004	0.8	0.4	1,218,898	250	0.739	338	0.97	0.14	0.83	1,398,215	1306
2005	0.8	0.4	2,440,983	350	0.789	444	2.72	1.78	0.94	1,459,540	2181
2006	0.8	0.4	2,709,370	350	0.874	400	2.72	1.78	0.94	1,473,917	4405
2007	0.8	0.4	2,980,307	350	0.927	378	2.72	1.78	0.94	1,714,791	15,374
2008	0.8	0.4	3,278,338	350	1.000	350	2.72	1.78	0.94	1,886,271	24,522

PeDe 0.4
PeSE 0.8

1	15	16	17	18	19	20	21	22	23		24
Year	Adoption rate (prop. area)	Av. nat. yield tonne/ha	Prop. Prod increase	Nominal adopt. cost per tot. area ETB/ha	Real adopt. cost per area ETB/ha	Real adopt. cost per output ETB/tonne	Prop. cost increase	Net prop. cost redn. from techn	Quantity increase tonnes	Proportionate decrease in price ETB × 10^6	Change in tot. economic surplus ETB × 10^6
	t	Ym=Q/AA	j=dY*t/Ym		dC	I=dC*t/Ym	c=I/P	k=j/PeS-c	dQ= QeEk/(E+e)	Z=k(E/(E+e))	dTS = kPQ(1-.5Ze)
1986		0.72		–							–
1987		0.67		–							–
1988		0.67		–							–
1989		0.70		–							–
1990		0.71		–							–
1991		0.72		–							–
1992		0.83		–							–
1993		0.68		–							–
1994	0.0001	0.75	0.0001	196	384	0.1	0.000	0.000	7	0.000	0.0
1995	0.0001	0.70	0.0002	196	357	0.1	0.000	0.000	9	0.000	0.0
1996	0.0002	0.69	0.0002	196	342	0.1	0.000	0.000	9	0.000	0.0
1997	0.0002	0.79	0.0002	196	355	0.1	0.000	0.000	10	0.000	0.0
1998	0.0003	0.77	0.0003	196	324	0.1	0.000	0.000	14	0.000	0.0
1999	0.0003	0.62	0.0004	196	310	0.1	0.000	0.000	21	0.000	0.0
2000	0.0004	0.65	0.0005	196	292	0.2	0.000	0.000	26	0.000	0.0
2001	0.0004	0.74	0.0005	196	308	0.2	0.000	0.000	35	0.000	0.1
2002	0.0005	0.81	0.0005	196	332	0.2	0.001	0.000	35	0.000	0.1
2003	0.0006	0.78	0.0007	196	288	0.2	0.001	0.000	49	0.000	0.1
2004	0.0009	0.87	0.0009	196	265	0.3	0.001	0.000	88	0.000	0.1
2005	0.0015	1.67	0.0008	590	748	0.7	0.002	0.000	– 297	–0.000	–0.5
2006	0.0030	1.84	0.0015	590	675	1.1	0.003	–0.001	–600	–0.001	–0.9
2007	0.0090	1.74	0.0048	590	637	3.3	0.009	–0.003	–2,094	–0.002	–3.0
2008	0.0130	1.74	0.0070	590	590	4.4	0.013	–0.004	–3,340	–0.003	–4.4
										Total	–8.3

Assumptions

5	Estimate from previous study to 2004 based on survey information, after 2004 based on average of local and improved wheat residue yield from current survey.
6	As in 5 above.
9	As in 5 above.
10	As n 5 above.
13	From grain spreadsheet.
14	From grain spreadsheet.
18	See comment 18 from grain spreadsheet—allocating 20% of cost to residue.

3. Improved wheat vs. teff—Grain

1	2	3	5	6	7	8	9	10	11	13	14
Year	PeS	Ab-PeD	Tot. teff and I. wheat produced tonnes	Teff nominal price ETB/tonne	CPI	Real price ETB/t	Av. yield new tech IW tonne/ha	Av. yield trad tech teff tonne/ha	Yield increase tonne/ha	Total area under prod both tech ha	Total area under prod new tech ha
	E	e	Q		2008=1	P	Yn	Yt	dY	A	
1986	0.8	0.4	511,289	1600	0.277	5773				1,363,016	–
1987	0.8	0.4	574,482	1600	0.270	5916				1,418,331	–
1988	0.8	0.4	645,485	1600	0.290	5525				1,475,891	–
1989	0.8	0.4	725,264	1600	0.312	5124				1,535,787	–
1990	0.8	0.4	814,904	1600	0.328	4873				1,598,113	–
1991	0.8	0.4	915,622	1600	0.446	3590				1,662,969	–
1992	0.8	0.4	1,028,789	1600	0.493	3248				1,730,457	–
1993	0.8	0.4	1,155,943	1600	0.510	3137				1,800,683	–
1994	0.8	0.4	1,298,812	1600	0.510	3139	1.72	1.13	0.59	1,873,760	246
1995	0.8	0.4	1,713,646	1540	0.549	2807	1.72	1.13	0.59	2,131,780	311
1996	0.8	0.4	2,086,446	1460	0.573	2548	1.72	1.13	0.59	2,210,255	358
1997	0.8	0.4	1,307,889	1690	0.552	3062	1.72	1.13	0.59	1,747,190	314
1998	0.8	0.4	1,669,601	1690	0.604	2797	1.72	1.13	0.59	2,083,190	417
1999	0.8	0.4	1,719,689	2340	0.633	3696	1.72	1.13	0.59	1,810,199	544
2000	0.8	0.4	1,771,279	2990	0.672	4449	1.72	1.13	0.59	1,864,505	672
2001	0.8	0.4	1,824,418	3640	0.637	5714	1.72	1.13	0.59	1,920,440	830
2002	0.8	0.4	1,879,150	4290	0.591	7259	1.72	1.13	0.59	1,978,053	1026
2003	0.8	0.4	1,935,525	4940	0.680	7265	1.72	1.13	0.59	2,037,394	1269
2004	0.8	0.4	2,027,767	5590	0.739	7569	1.72	1.13	0.59	2,134,492	1993
2005	0.8	0.4	2,181,050	6240	0.789	7908	2.50	1.19	1.31	2,295,843	3431
2006	0.8	0.4	2,448,762	6890	0.874	7880	2.50	1.19	1.31	2,577,645	7704
2007	0.8	0.4	2,644,663	7540	0.927	8136	2.50	1.19	1.31	2,783,856	24,959
2008	0.8	0.4	2,856,236	8900	1.000	8900	2.50	1.19	1.31	3,006,565	39,085

PeD e 0.4
PeS E 0.8

1	15	16	17	18	19	20	21	22	23		24
Year	Adoption rate (prop. area)	Av. nat yield tonne/ha	Prop. prod increase	Nominal adopt. cost per tot. area ETB/ha	Real adopt. cost per area ETB/ha	Real adopt. cost per output ETB/tonne	Prop. cost increase	Net prop. cost redn. from techn	Quantity increase tonnes	Proportionate decrease in price ETB × 10^6	Change in tot. economic surplus ETB × 10^6
	t	Ym=Q/A	j=dY*t/Ym		dC	I=dC*t/Ym	c=I/P	k=j/PeS-c	dQ= QeEk/(E+e)	Z=k(E/(E+e))	dTS= kPQ(1-.5Ze)
1986		0.38		–							–
1987		0.41		–							–
1988		0.44		–							–
1989		0.47		–							–
1990		0.51		–							–
1991		0.55		–							–
1992		0.59		–							–
1993		0.64		–							–
1994	0.0001	0.69	0.0001	598	1,173	0.2	0.000	0.000	24	0.000	0.3
1995	0.0001	0.80	0.0001	598	1,090	0.2	0.000	0.000	29	0.000	0.3
1996	0.0002	0.94	0.0001	598	1,043	0.2	0.000	0.000	31	0.000	0.3
1997	0.0002	0.75	0.0001	598	1,084	0.3	0.000	0.000	32	0.000	0.4
1998	0.0002	0.80	0.0001	598	990	0.2	0.000	0.000	43	0.000	0.4
1999	0.0003	0.95	0.0002	598	945	0.3	0.000	0.000	70	0.000	1.0
2000	0.0004	0.95	0.0002	598	890	0.3	0.000	0.000	96	0.000	1.6
2001	0.0004	0.95	0.0003	598	939	0.4	0.000	0.000	127	0.000	2.7
2002	0.0005	0.95	0.0003	598	1012	0.6	0.000	0.000	164	0.000	4.5
2003	0.0006	0.95	0.0004	598	879	0.6	0.000	0.000	209	0.000	5.7
2004	0.0009	0.95	0.0006	598	810	0.8	0.000	0.001	335	0.000	9.5
2005	0.0015	0.95	0.0021	2122	2689	4.2	0.001	0.002	1187	0.001	35.2
2006	0.0030	0.95	0.0041	2122	2427	7.6	0.001	0.004	2731	0.003	80.7
2007	0.0090	0.95	0.0124	2122	2290	21.6	0.003	0.013	9026	0.009	274.9
2008	0.0130	0.95	0.0179	2122	2122	29.0	0.003	0.019	14,582	0.013	485.4
										Total	903

Assumptions: 5 Based on IW area and yield from Table 1 and teff yield from CSA 2004–06 extrap. forward and back to 1999, using previous estimates <1999.
13 As in 5 above. 18 See comment 18 for Table 2.

4.Improved wheat vs. teff straw

1	2	3	5	6	7	8	9	10	11	13	14
Year	PeS	Ab PeD	Tot. teff and I. wheat res. prod. tonnes	Teff nominal price ETB/tonne	CPI	Real price ETB/t	Av. yield new tech IW tonne/ha	Av. yield trad tech teff tonne/ha	Yield increase tonne/ha	Tot. area under prod both tech ha	Tot. area under prod new tech ha
	E	e	Q		2008=1	P	Yn	Yt	dY	A	
1986	0.8	0.4	511,289	300	0.277	1,082				1,363,016	–
1987	0.8	0.4	574,482	300	0.270	1,109				1,418,331	–
1988	0.8	0.4	645,485	300	0.290	1,036				1,475,891	–
1989	0.8	0.4	725,264	300	0.312	961				1,535,787	–
1990	0.8	0.4	814,904	300	0.328	914				1,598,113	–
1991	0.8	0.4	915,622	300	0.446	673				1,662,969	–
1992	0.8	0.4	1,028,789	300	0.493	609				1,730,457	–
1993	0.8	0.4	1,155,943	300	0.510	588				1,800,683	–
1994	0.8	0.4	1,298,812	300	0.510	588	0.97	0.225	0.745	1,873,760	246
1995	0.8	0.4	1,713,646	300	0.549	547	0.97	0.225	0.745	2,131,780	311
1996	0.8	0.4	2,086,446	300	0.573	523	0.97	0.225	0.745	2,210,255	358
1997	0.8	0.4	1,307,889	300	0.552	544	0.97	0.225	0.745	1,747,190	314
1998	0.8	0.4	1,669,601	300	0.604	497	0.97	0.225	0.745	2,083,190	417
1999	0.8	0.4	1,891,657	300	0.633	474	0.97	0.225	0.745	1,810,199	544
2000	0.8	0.4	1,948,407	300	0.672	446	0.97	0.225	0.745	1,864,505	672
2001	0.8	0.4	2,006,859	300	0.637	471	0.97	0.225	0.745	1,920,440	830
2002	0.8	0.4	2,067,065	300	0.591	508	0.97	0.225	0.745	1,978,053	1026
2003	0.8	0.4	2,129,077	300	0.680	441	0.97	0.225	0.745	2,037,394	1269
2004	0.8	0.4	2,230,544	300	0.739	406	0.97	0.225	0.745	2,134,492	1993
2005	0.8	0.4	2,399,155	500	0.789	634	2.72	2.520	0.200	2,295,843	3431
2006	0.8	0.4	2,693,639	500	0.874	572	2.72	2.520	0.200	2,577,645	7704
2007	0.8	0.4	2,909,130	500	0.927	539	2.72	2.520	0.200	2,783,856	24,959
2008	0.8	0.4	3,141,860	500	1.000	500	2.72	2.520	0.200	3,006,565	39,085

PeD e 0.4
PeS E 0.8

1	15	16	17	18	19	20	21	22	23		24
Year	Adoption rate (prop. area)	Av. nat. yield tonne/ha	Prop. prod increase	Nominal adopt. cost per tot. area ETB/ha	Real adopt. cost per area ETB/ha	Real adopt. cost per output ETB/tonne	Prop. Cost increase	Net prop. cost redn. from techn.	Quantity increase tonnes	Proportionate decrease in price ETB × 10^6	Change in tot. economic surplus ETB × 10^6
	t	Ym=Q/A	j=dY*t/Ym		dC	I=dC*t/Ym	c=I/P	k=j/PeS-c	dQ=QeEk/(E+e)	Z=k(E/(E+e))	dTS=kPQ(1-.5Ze)
1986		0.38		–							–
1987		0.41		–							–
1988		0.44		–							–
1989		0.47	`	–							–
1990		0.51		–							–
1991		0.55		–							–
1992		0.59		–							–
1993		0.64		–							–
1994	0.0001	0.69	0.0001	149	292	0.1	0.000	0.000	29	0.000	0.1
1995	0.0001	0.80	0.0001	149	272	0.0	0.000	0.000	36	0.000	0.1
1996	0.0002	0.94	0.0001	149	260	0.0	0.000	0.000	41	0.000	0.1
1997	0.0002	0.75	0.0002	149	270	0.1	0.000	0.000	36	0.000	0.1
1998	0.0002	0.80	0.0002	149	247	0.1	0.000	0.000	48	0.000	0.1
1999	0.0003	1.05	0.0002	149	235	0.1	0.000	0.000	63	0.000	0.1
2000	0.0004	1.05	0.0003	149	222	0.1	0.000	0.000	78	0.000	0.1
2001	0.0004	1.05	0.0003	149	234	0.1	0.000	0.000	96	0.000	0.2
2002	0.0005	1.05	0.0004	149	252	0.1	0.000	0.000	119	0.000	0.2
2003	0.0006	1.05	0.0004	149	219	0.1	0.000	0.000	147	0.000	0.2
2004	0.0009	1.05	0.0007	149	202	0.2	0.000	0.000	231	0.000	0.4
2005	0.0015	1.05	0.0003	531	673	1.0	0.002	–0.001	–743	–0.001	–1.8
2006	0.0030	1.05	0.0006	531	607	1.7	0.003	–0.002	–1,668	–0.002	–3.6
2007	0.0090	1.05	0.0017	531	573	4.9	0.009	–0.007	–5,405	–0.005	–10.9
2008	0.0130	1.05	0.0025	531	531	6.6	0.013	–0.010	–8,463	–0.007	–15.9
										Total	–31

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