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Importance of Irrigated Agriculture to the Ethiopian Economy: Capturing the Direct Net Benefits of Irrigation

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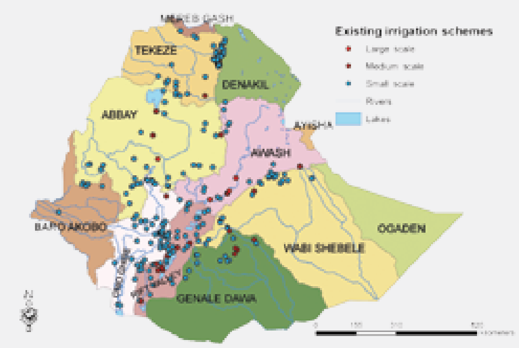

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Cover photographs (clockwise from top left):

(a) Existing irrigation schemes classified by typology (*source:* Awulachew et al. 2007b)
(b) Wenji Irrigation Canal (*Photo credit:* Seleshi Bekele Awulachew)
(c) Methara Irrigation Channel used by livestock (*photo credit:* Seleshi Bekele Awulachew)
(d) Methara Irrigation Distribution Canal control point used for multiple purposes (*photo credit:* Seleshi Bekele Awulachew)

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Partners

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International Water Management Institute (IWMI), Colombo, Sri Lanka

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Contents

Summary

Irrigation development has been identified as an important tool to stimulate economic growth and rural development, and is considered as a cornerstone of food security and poverty reduction in Ethiopia. While a lot of effort is being exerted towards irrigation development, little attempt is being made to quantify the contribution of irrigation to national income. This study is an attempt in that direction by quantifying the actual and expected contribution of irrigation to the Ethiopian national economy for the 2005/2006 and 2009/2010 cropping seasons using the adjusted net gross margin analysis.

Our results show that irrigation generates an average income of approximately US$323/hectare (ha) under smallholder-managed irrigation systems compared to an average income of US$147/ha for rainfed systems. This indicates that, after accounting for annual investment replacement cost, the adjusted gross margin from irrigation is 219.7% higher than the gross margin from rainfed agriculture. The gross margin from medium- and large-scale systems was calculated to be US$400/ha and US$1,308/ha, respectively. Based on our calculations, irrigation contributed approximately 5.7 and 2.5% to agricultural Gross Domestic Product (GDP) and the overall GDP, respectively, during the 2005/2006 cropping season. By the year 2009/2010, the contribution of irrigation to agricultural GDP and overall GDP is estimated to be approximately 9 and 3.7%, respectively.

After relaxing some of the underlying assumptions, the future contribution of irrigation to agricultural GDP rises to approximately 12% while the contribution to overall GDP will be approximately 4%. To realize these outcomes, besides the obvious task of developing the planned irrigation infrastructure, there is a need to: i) improve the provision of agricultural inputs including high-value crops, ii) improve the performance of the agricultural extension system to support irrigation to enhance efficiency and productivity, iii) improve market access conditions and marketing infrastructure, and iv) improve the management of schemes to increase efficiency at all levels. Additional policy implications for cost recovery and sustainability of irrigation investment are drawn.

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Introduction

Heavy reliance on rainfed agriculture, during conditions of very variable rainfall and recurrent droughts, affects agriculture and, hence, has adverse effects on the economy of Ethiopia. In fact, the World Bank (2006) estimated that hydrological variability currently costs the economy over one-third of its growth potential and has led to a 25% increase in poverty rates. Enhancing public and private investment in irrigation development has been identified as one of the core strategies to de-link economic performance from rainfall and to enable sustainable growth and development (World Bank 2006; MoWR 2002; MoFED 2006). In government policy documents, irrigation development has already been identified as an important tool to stimulate sustainable economic growth and rural development, and is considered as a cornerstone of food security and poverty reduction (MoWR 2002; MoFED 2006). This policy has led to concerted efforts to expand irrigation development in the country during the last decade or so, especially since 2005/2006.

Ethiopia has an estimated irrigation potential of 3.5 million hectares (Awulachew et al. 2007b). During 2005/2006 the total estimated area of irrigated agriculture in the country was 625,819 ha, which, in total, constitutes about 18% of the potential (MoWR 2006). It is planned to expand irrigation development in the country by an additional 528,686 ha by the year 2010 (Atnafu 2007; MoWR 2006; MoFED 2006), which will constitute about 33% of the potential.

Notwithstanding these developments, there has been little systematic analysis to estimate the aggregate benefits[1] of irrigation development. This study aims to partly fill this gap by quantifying the current and future direct benefits of irrigation to the national economy. It also addresses the issue of the economic viability of irrigation investment. Studies of this kind, in comparing the actual and expected direct benefits of irrigation with the actual and expected costs of irrigation expansion, can guide policymakers in irrigation development.

Irrigation contributes to the national economy in several ways. At the micro level, irrigation leads to an increase in yield per hectare and subsequent increases in income, consumption and food security (Bhattarai and Pandy 1997; Vaidyanathan et al. 1994; Ahmed and Sampath 1992; Lipton et al. 2003; Hussain and Hanjra 2004). Irrigation enables smallholders to diversify cropping patterns, and to switch from low-value subsistence production to high-value market-oriented production (Hagos et al. Forthcoming). Irrigation can benefit the poor specifically through higher production, higher yields, lower risks of crop failure, and higher and all year round farm and non-farm employment (Hussain and Hanjra 2004).

[1] There are various studies that examine the poverty and food security impacts of irrigation at a scheme or at local level using household level data (see Awulachew et al. 2007a).

Macro level impacts manifest themselves through agricultural impacts on economic growth. At the aggregate level, irrigation investments act as production and supply shifters, as they push the production frontier to a higher level and render production possible which is, otherwise, risky, if not impossible, because of a shortage of moisture and thereby have a positive effect on economic growth. Studies in Asia show that agricultural growth served as an "engine" of overall economic growth (van Koppen et al. 2005; Francks et al. 1999), and irrigation-led technological changes were identified as the key drivers behind productivity growth in the agricultural sector (Hussain and Hanjra 2004; Alagh 2001; Dhawan 1988).

Irrigation development, however, not only has direct and indirect positive impacts on the economy, but it also generates negative direct and indirect impacts (see Hanjra 2007; Bhattarai et al. 2007). Numerous studies have discussed the importance and difficulties of evaluating a number of these impacts (Hanjra 2007; Bhattarai et al. 2007; WCD 2000; Bell and Hazel 1980). For instance, WCD (2000) underlines the need to extend consideration to the indirect benefits and costs when assessing impacts of dam projects. Hanjra (2007) and Bhattarai et al. (2007), on the other hand, report that the indirect benefits of irrigation could be larger than the direct benefits through the multiplier effects.

Various methods were proposed to capture the diverse impacts of irrigation on the economy, be they direct or indirect. The methodological approaches applied included linear programming; regression models; partial equilibrium models; and economy–wide models such as input-output models, Social Accounting Matrices (SAM) and Computable General Equilibrium (CGE) models. For instance, Bhattarai and Pandy (1997) used a linear programming technique to isolate the impact of irrigation from other factors (such as roads and markets) on crop production and productivity in Nepal. Vaidyanathan et al. (1994) used regression analysis at the aggregate level to assess the difference in land productivity between irrigated and un-irrigated lands in India. Ahmed and Sampath (1992) used a partial equilibrium model that incorporated shifts in demand and supply to assess the impact of irrigation on efficiency and equity in Bangladesh. Makombe (2000) used a similar partial equilibrium model to estimate the impact of irrigation-induced technological change in Zimbabwe. Bell and Hazel (1980) used SAM and a semi-input-output model to measure the magnitude and incidence of regional downstream effects of the Muda irrigation project in Malaysia. Bhatia et al. (2003) used SAM for a detailed analysis of the multiplier effects of dams in India, Brazil and Egypt. Many of these studies focused on Asia with few studies focusing on Africa. This study is the first of its kind in the region trying to capture the direct contribution of irrigation to the national economy.

In this paper, the focus is only on quantifying the direct benefits of irrigation on the national economy. Quantifying the indirect effects of irrigation using the methods described above requires more data than that are currently readily available. In doing so, we adopt a simple methodological framework that draws on the method of adjusted gross margin analysis, which accords with the recommendations of the System of Integrated Environmental and Economic Accounting (SEEA) (UN 2003) and provides a "best estimate" of the change in GDP generated by irrigation at the farm gate (Doak 2005). We believe our approach provides the 'best' approach in data-limited environments. However, it should be noted that a large number of estimates and assumptions are required to estimate the impact on GDP, and the results should be interpreted with caution. The sensitivity of our results to some of the assumptions is tested in our scenario analyses. Finally, as the increased output from irrigated farms will have different multiplier effects in the wider economy, the total impact of irrigation on GDP is likely to be higher than the impact at the farm gate.

We relied on data collected during the 2005/2006 season from eight representative small- and medium-scale irrigation schemes in four regional states in Ethiopia, and secondary data gathered from selected large-scale commercial farms in the Awash and Blue Nile basins.

This report is organized as follows: The section, *Background*, presents the background to the study and is followed by the section, *Methodology*, which provides an outline of the methodology used to value the contribution of irrigation to the national economy. The section, *Data Sources*, provides a description of the data used. The section, *Valuing Irrigation's Contribution to the National Economy*, presents the results of the valuation of the current contribution of irrigation while the next section, *Projecting the Future Contribution of Irrigation*, looks into the future contribution of irrigation. In the section, *Sensitivity Analysis*, we conduct sensitivity analyses to take account of possible changes in cropping patterns and crop cover, in input and output prices and improvements in efficiency levels. The final section, *Conclusion and Recommendations*, discusses the results and draws some policy recommendations.

Background

Agriculture is the mainstay of the Ethiopian economy in terms of income, employment and generation of export revenue. Its contribution to GDP, although showing a slight decline over the years, has remained very high, at approximately 44% (see Table 1). From among the sub-sectors of agriculture, crop production is a major contributor to GDP accounting for approximately 28% in 2005/2006. The most important crops grown and their area are described below.

Ethiopia has an estimated irrigation potential of 3.5 million hectares (Awulachew et al. 2007b)[2].

TABLE 1. Contribution of Agriculture to GDP (in '000 Ethiopian Birr (ETB)) (1995/1996-2005/2006).

Year	GDP at current market prices (in million ETB)	Agricultural GDP (in million ETB)	Crop GDP (in million ETB)	Contribution of agriculture to GDP (%)	Contribution of crop production to GDP (%)
1995/1996	53.6	28.6	17.3	53	32
1996/1997	55.5	28.7	16.7	52	30
1997/1998	53.4	25.2	14.5	47	27
1998/1999	57.4	25.4	15.5	44	27
1999/2000	64.4	28.4	17.7	44	28
2000/2001	65.7	27.7	16.3	42	25
2001/2002	63.5	24.4	13.1	39	21
2002/2003	68.9	26.2	14.9	38	22
2003/2004	81.7	32.2	19.9	39	24
2004/2005	98.4	42.2	27.3	43	28
2005/2006	115.6	50.9	32.2	44	28

Source: FDRE (2006)

Note: US$1 was equivalent to ETB 8.67 in 2005/2006 prices.

[2] Other estimates put it in the order of 3.7 million hectares (MoWR 2002; World Bank 2006).

Irrigation schemes in Ethiopia are classified in three ways: (a) size, (b) technology use, and (c) management. The first classification is by the size of the command area of the scheme. Schemes are classified as small (less than 200 ha), medium (200 to 3,000 ha) and large-scale (over 3,000 ha) schemes (MoWR 2002; Awulachew et al. 2005). The small-scale irrigation schemes, in turn, are further classified into two major categories; namely, modern schemes and traditional schemes. Modern schemes usually have fixed or improved water control/diversion structures. These schemes are generally constructed by the government or NGOs, which have mostly been constructed since the mid-eighties. Traditional schemes, on the other hand, are different from the modern schemes because their diversion weirs are usually made from local materials, and are usually reconstructed every year. Many are constructed by local communities and have been functional for relatively longer periods of time, some extending close to a century. Werfring (2004) and Awulachew et al. (2005) describe the typology of small-scale irrigation in Ethiopia, the former describing it in more detail. The second classification is by the differences in the technology used to control and divert water, which have implications on water availability, water loss and establishment, and for operation & maintenance (O&M) costs. The third classification is by management system, namely traditional, modern, public and private (Werfring 2004). The management systems of the two small-scale irrigation schemes are similar, usually involving local leadership and a water users' association or irrigation cooperatives with the government providing extension support, while the medium- and large-scale schemes are usually managed by the government (Werfring 2004). There are studies, however, that show that local water management institutions are stronger in traditional schemes (Alamirew et al. 2007) compared to modern irrigation, as a result of which the performance of traditional schemes could be higher. In this paper, we have used a combination of the first three classification systems, without significant consideration of pubic versus private management because we did not have any schemes falling under private ownership and management. Thus, modern medium-scale schemes are those in which the size is between 200 and 3,000 ha, with fixed or improved water control/diversion structures (see Table 2).

In 2005/2006, the total reported area of irrigated agriculture in the country was about 626,116 ha, out of which 483,472 ha is from traditional irrigation, 56,032 ha is from modern small-scale irrigation, and 86,612 ha is from modern medium- and large-scale irrigation schemes. Out of the total irrigated area, 197,250 ha are covered by the so-called modern schemes while the remaining area is covered by traditional schemes (MoWR 2002). The total irrigated area and the modern irrigated area account for about 18% and 5%, respectively, of the reported potential. In 2005/2006, the total cultivated land area, including the rainfed area, was about 12.28 million hectares (MoFED 2006). Hence, the total current irrigated land area accounts for approximately 5% of the total cultivated land. When the traditional

TABLE 2. Summary of typologies of irrigation schemes in Ethiopia.

Typology	Size of scheme (ha)	Infrastructure	Water management scheme (ha)
Small-scale modern	<200	Fixed or improved water control and diversion structures	Water users' association or irrigation cooperatives
Small-scale traditional	200	Made of local materials and not permanent	Local water users' association
Medium-scale	200-3,000	Fixed or improved water control and diversion structures	Water users' association/irrigation cooperatives or state
Large-scale	>3,000	Fixed or improved water control and diversion structures	Mostly state enterprises

schemes are not considered, the irrigated land area covers a minimum of approximately 1.6% of the total cultivated area.

There is a high spatial variability in water resources endowment and development in the country. Hence, 90% of the country's water resources development hitherto occurred in four river basins (World Bank 2006). Much of the formal irrigation developments are located in the Awash Basin, where about 50 medium- and large-scale irrigated farms are located (Figure 1).

with little or no supplementary irrigation, under rainfed conditions. During the dry season farmers grow cereals and a variety of vegetables including onions, tomatoes, and leafy green vegetables like lettuce under full irrigation. Farmers also grow perennial crops like mango, banana, sugarcane which are sometimes intercropped with seasonal crops. For ease of presentation, we clustered crops into different categories; namely, cereals, pulses, oilseeds, spices, fruits, vegetables and others, and calculated area cover (as a percentage

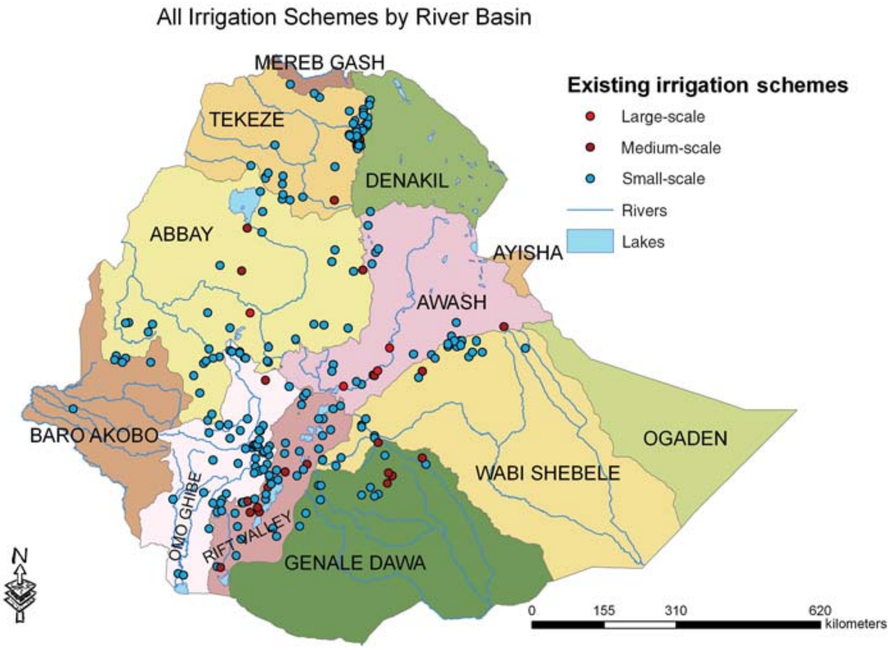

FIGURE 1. Existing irrigation schemes in various river basins in Ethiopia (*Source:* Awulachew et al. 2007b).

In terms of regional distribution, Afar and Oromia have the bulk of the share in irrigated agriculture accounting for 45 and 31%, respectively, of the total irrigated area. Amhara, Southern Nations, Nationalities and People's Region (SNNPR) and Tigray account for 8, 7 and 5%, respectively, of the total irrigated area (Awulachew et al. 2007b).

We looked into cropping patterns of the different schemes to see if there are differences between rainfed and irrigated schemes, and traditional and modern schemes. During the main rainy season most of the small-scale irrigation schemes grow cereals like teff, maize and barley, with little or no supplementary irrigation, under rainfed conditions.

of the total area) for these different crop categories in the different irrigation systems.

From our survey data, we present below the composition of crops under irrigated and rainfed conditions. The dominant crop categories under the traditional irrigation system, in terms of the percentage area covered, are: cereals (55%), vegetables (11%), fruits (11%), pulses (10%), spices (8%), oilseeds (5%), and others (0.2%) (Figure 2a). The dominant crop categories under the modern irrigation system are: cereals (67%), pulses (3%), vegetables (21%), fruits (4%), oilseeds (0%), spices (0.4%), and others (5%) (Figure 2b).

The dominant crop categories under the rainfed system, in order of importance, are: cereals (78%), vegetables (1%), fruits (1%), pulses (16%), spices (0.2%), oilseeds (1%), and others (3%) (Figure 2c).

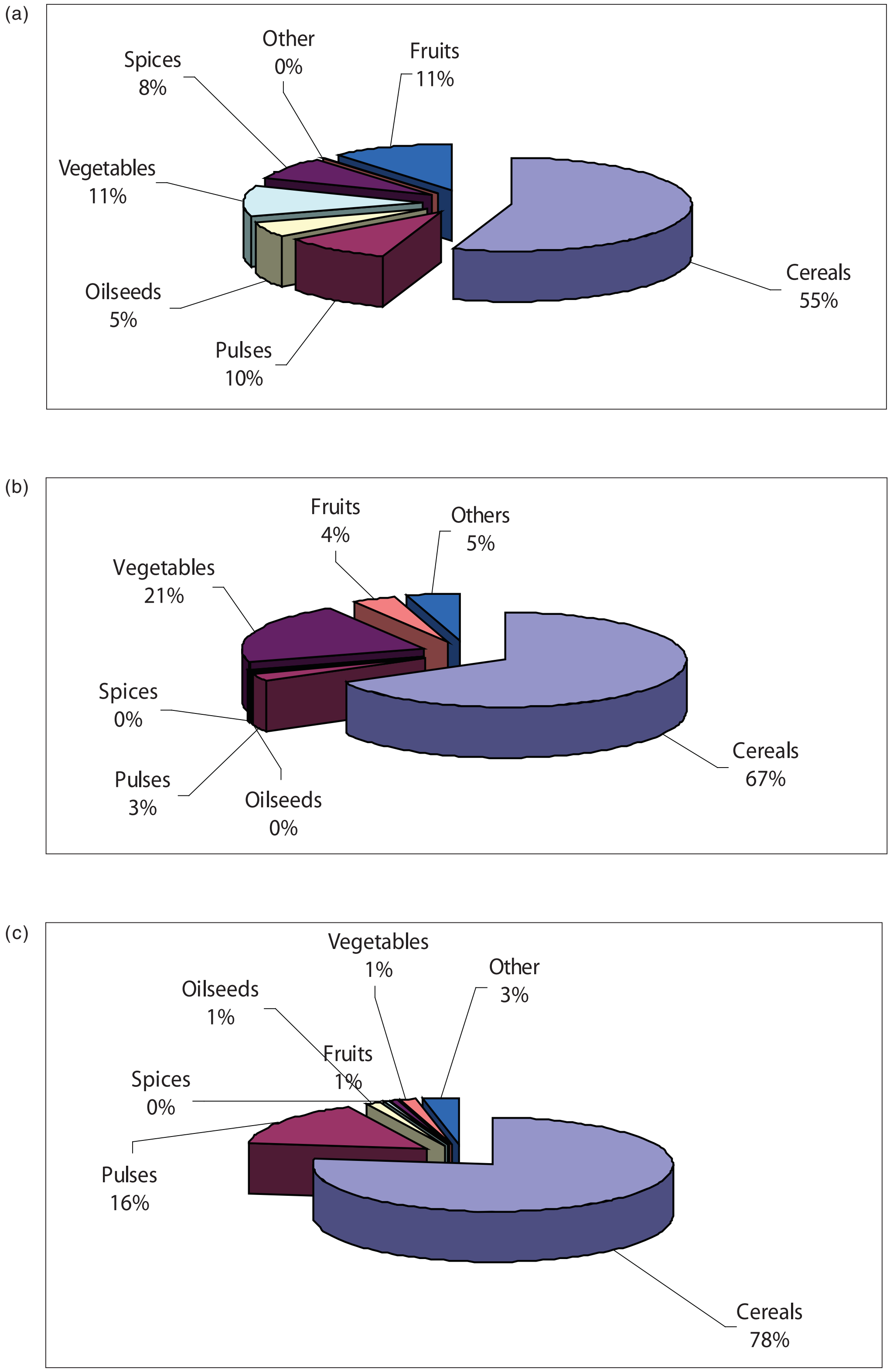

FIGURE 2. (a) Dominant crops under the traditional irrigation system (n=1,240); (b) dominant crops under the modern irrigation system (n=1,533); and (c) dominant crops under the rainfed system (n=2,092).

The above figures show that there is an emerging difference in the relative importance of the crop categories under different systems. Cereals and pulses are dominant under the rainfed system while fruits and vegetables cover approximately 2% of the land area. While cereals still remain dominant under the irrigation systems, covering approximately 61% of the land area, fruits and vegetables become important under both the traditional and modern systems. There is also a noticeable difference in the share of land taken by fruits and vegetables between the modern and traditional irrigation systems. Vegetables take more land area under the modern systems compared to that of traditional systems while more land area is covered with fruit trees under the traditional system, likely reflecting the length of time since the establishment of the traditional schemes.

Medium- and large-scale irrigation schemes, on the other hand, grow mainly sugarcane, cotton, fruits and vegetables. The Wonji/Shoa, Metehara and Finchaa schemes grow sugarcane while the Amibara and Upper Awash schemes grow cotton, and fruits and vegetables, respectively (see Table 3).

irrigation schemes to be developed by the regional governments in Ethiopia (Atnafu 2007). Accordingly, 39 significant irrigation projects are planned to be implemented during the PASDEP period. To just mention a few of the major projects, these include the World Bank projects around Tana (100,000 ha); Anger Negesso Project in Oromia (49,563 ha); Humera project in Tigray (42,965 ha); Kessem Tendaho in Afar (90,000 ha); Upper Beles in Benishangul Gumz (53,000 ha); and Ilo-Uen Buldoho (32,000 ha) in Somali (MOFED 2006; MoWR 2006). Most of these irrigation schemes will be large-scale community-managed schemes to be used by smallholder farmers. Exceptions to these are the schemes to be developed in the Awash and Abay basins, which will mainly involve the expansion of the already existing large-scale schemes or the development of new schemes (see Table 4). About 90,000 ha of irrigation land will be developed in Kesem and Tendaho to grow sugarcane while there are planned expansions in the already existing sugar plantations. By the year 2010 there will be an additional 122,000 ha of irrigated land developed to grow sugarcane (ESDA 2007). Overall, the total extension to irrigated area by the year 2009/2010 compared to 2005/2006 will be in the range of 528,686 ha. This implies that further development will extend the irrigated area to cover approximately 33% of the irrigated potential area and approximately 9% of the total cultivated land area. These plans are used as indicative targets for future irrigation development and for valuing the future contribution of irrigation to the national economy.

TABLE 3. Large-scale schemes under irrigation and the type of cropping.

Region	Name of scheme	Major crop	Area 2005/2006 (ha)
Afar	Amibara (Middle Awash)	Cotton	6,448
Oromia	Finchaa sugar plantation	Sugarcane	7,185
Oromia	Metehara sugar plantation	Sugarcane	10,145.9
Oromia	Upper Awash	Fruits and vegetables	6,017.34
Oromia	Wonji/Shoa sugar plantation	Sugarcane	4,094

Source: ESDA (2007); MOFED (2006)

The Irrigation Development Program (IDP), as set out in the government's Plan for Accelerated and Sustained Development to End Poverty (PASDEP) document (2005/2006-2009/2010), envisages the expansion of irrigation in the country by an additional 528,686 ha by the year 2010 (MoWR 2006; MOFED 2006). Of this 430,061 ha will consist mainly of medium- and large-scale schemes while 98,625 ha will involve small-scale

TABLE 4. Future development plans of large-scale schemes.

Region	Name of scheme	Basin	Main crop	Future expansion/development until 2010 (ha)
Oromia	Finchaa	Abay	Sugarcane	12,000
Afar	Kesem	Awash	Sugarcane	40,000
Oromia	Metehara	Awash	Sugarcane	10,000
Afar	Tendaho	Awash	Sugarcane	50,000
Oromia	Wonji/Shoa	Awash	Sugarcane	10,000

Source: ESDA (2007)

Methodology

The methodology calculates the contribution of existing irrigation to the gross domestic product (GDP) by taking into account the contribution from the alternative rainfed production from the same area of land. The method adopted follows, a "with minus without" irrigation approach, adjusted for changes in farm type and scale.

Following Doak (2005) the formula is:

Farmgate GDP due to irrigation = GDP with irrigation – GDP without irrigation (1)

where: GDP with irrigation is calculated as irrigated land use mix in hectares * (irrigated Gross Margin – fixed costs/ha), and GDP without irrigation is calculated as rainfed land use mix in hectares * (rainfed Gross Margin – fixed costs/ha).

A gross margin (GM) is the total revenue associated with a particular production (income) less the costs that clearly vary in direct proportion to the level of production - the direct or variable costs associated with the enterprise. Gross margin analysis is an accepted tool commonly used in the evaluation of farming enterprises (Barnard and Nix 1979) and is also used in the evaluation of the costs and benefits of irrigation (Gittinger 1984). Assessing the change to the gross margin per unit area as a result of irrigation and then scaling this appropriately by the total affected area provides an initial estimate of the change in the GDP (at the farm gate) that is likely to occur as a result of irrigation, i.e., the average net gross margin (NGM) from a given area (in hectares) from a specific scheme *j*, is given as:

$$NGM_j = NGM_j / ha * SchemeArea_j \text{ (in hectares)} \quad (2)$$

where: j = 1,2.......k represents the different schemes in the country and NGM_j is the average value of the net gross margin expressed in per hectare terms from a specific scheme and is obtained as the difference given in Equation (1).

In the Ethiopian context, farmers use full irrigation to grow crops during the dry season when crop production from rainfall is not possible. This implies that households get an additional income from irrigation, which is in addition to what farmers get during the main cropping season. Under the small-scale irrigation system, irrigation does not replace rainfed agriculture but complements it. Large-scale schemes, however, are under full irrigation throughout the year. In this case, to obtain the value of irrigation under large-scale schemes, we deducted the rainfed income that could have been achieved without irrigation during the wet season. Hence, for a given farmer, the total income for a specific year includes both the income from rainfed and irrigation. Once these adjustments were made, we aggregated the income to calculate GDP at the farm gate. In other words, the gross margins (GMs) were determined for farm types in each of the schemes and aggregated to a scheme-scale throughout Ethiopia using the data obtained from the household surveys and secondary sources. The formula we used is as follows:

$$\text{Farmgate GDP} = \sum_{j=1}^{K} \sum_{i=1}^{N} NGM_j * \underset{\text{(in hectares)}}{SchemeArea_j} \quad (3)$$

where: $i = 1,2....,N$ represent crop types grown in the different schemes and $j = 1,2....,K$ represent the different schemes under the smallholder and large-scale irrigation systems.

The gross margins are those for the 2005/2006 season and are defined as the revenue generated from the activity less the direct costs of producing the revenue. The Gross Margins were also adjusted to account for the differences in overheads (fixed costs)[3] of land uses with and without irrigation, and for differences in shadow prices of labor and oxen in irrigated and rainfed systems (for the small-scale schemes). Shadow prices of labor and oxen were estimated from the production data by first estimating elasticities, which were used to estimate the marginal values of labor and oxen[4], in a production function framework (for details see Jacoby 1993).

The "without irrigation" land use is what would now exist if irrigation had not been developed, rather than if irrigation was no longer available for that particular land. This was estimated based on the GM of rainfed agriculture from similar plots around the scheme or the average GM value for all rainfed, if data for adjacent rainfed plots were not available. The value of irrigated production and the value of production from rainfed use, that would be most likely if there was no irrigation, were derived from the survey data for each scheme. For the large-scale schemes, we explored the dominant rainfed production type and estimated average gross margins per hectare from the household survey.

The assumption here is that all the land that is under irrigation now would have been under some sort of rainfed farming had it not been converted to irrigation plots. However, there are also some other possible scenarios. It is possible that some of the land currently under irrigation is hitherto uncultivated land or new openings[5]. If this is true, the methodology we adopted may underestimate the true contribution of irrigation development without considering the environmental costs of such changes. It may also be that the current irrigated land may have been used for grazing livestock[6]. The direction of bias on our estimation depends on whether the gross margin per unit area from livestock husbandry is greater or less than the gross margin per unit area for cropping under rainfed. While a meaningful analysis should take account of these diverse scenarios, the lack of data on livestock productivity under pastoral production in Ethiopia and environmental costs of land use change made it impossible to carryout such an analysis. Hence, the approach described above (in equations 1 and 3) was used to assess the current and future contribution of irrigation to the national economy.

In estimating the future contribution of irrigation to the national economy, we used information about the expected growth of the irrigation sector during 2005/2006 and 2009/2010

[3] For the fixed cost, we calculated an annual replacement cost on a per hectare basis. Annual replacement cost was computed as initial investment divided by project lifetime (25 years), and the O&M cost was assumed to be 10% of annual replacement cost for small-scale schemes, and 50 years and 5% for medium- and large-scale schemes, respectively (Inocencio et al. 2007).

[4] The shadow price of labor/oxen can be computed, by first estimating the elasticity of labor or oxen from a production function, as a product of elasticity and the ratio of the predicted quantity of output to the quantity of labor/oxen input used.

[5] The development of the Finchaa Sugar Estate is a case in point where forestland is being transformed for sugarcane plantation.

[6] The development of irrigation in the Middle and Lower Awash Basin is a case in point.

based on the country's IDP (Atnafu 2007; MoWR 2006; World Bank 2006; MoFED 2006). These policy documents outline how irrigation is expected to develop over the planning period. The details were provided in the section, *Background*, of this report.

A complex issue related to the calculation of the future contribution of irrigation to the national economy is how to address the impact of increased output on prices. Gross margin calculations generally assume that a change in output has no effect on prices. While this might well approximate reality[7] for small-scale changes at the individual farm level, the large-scale land use changes generated by irrigation on the national scale are believed to be sufficient to have some measurable effect on output prices. Lipton et al. (2003) state that if irrigation leads to increases in staples or non-staple food output then this may result in lower prices for staples and food in imperfectly open economies. This effect is more vivid if there are significant transport costs from food-surplus areas to towns or food deficit areas. For crops that are largely dependent on the local markets and for which there is little opportunity to develop large-scale export markets, increases in production tend to have a dramatic effect on price (Doak et al. 2004). A complicating factor in assessing the impact of future irrigation-driven increases in output on prices is also that growers of annual crops are very flexible in the combinations of crops that they choose to grow (Doak et al. 2004). If, for example, tomatoes are in over-supply, growers would switch to another crop that proves to be more profitable. The farmer is, therefore, able to choose the most profitable crop to produce, and to increase the value of the product, e.g., by producing at a time of the year when price is the highest, or by increasing the quality of the product. There is also the possibility that as irrigation expands, it tends to get more government support (e.g., better extension services) and, hence, intensification can increase. This upside potential has by and large been included in the analysis. We suggested possible scenarios in changes in cropping patterns. However, it is difficult to forecast the exact possible future changes in cropping patterns. The crop combinations and gross margins used in the analysis are, therefore, only indicative of a range of possible crops and their outcomes.

To quantify the effect of irrigation development on prices, we assumed different price scenarios based on certain assumptions about demand growth and output growth. In light of all these considerations, we assumed different price changes in the price of the major produce when assessing the impact of future irrigation-driven increases in output. This is described in detail in the section, *Sensitivity Analysis*, of this report. It is important to note that, we assumed that there is limited impact of world prices on local prices or irrigation's expansion in Ethiopia on global prices or vice versa.

Finally, there are a host of multiplier effects expected to manifest themselves with irrigation development, including the expansion of the off-farm sector, provision of inputs to industry and better nutrition for rural households. These effects are not captured in this study. Our calculated GDP represents, at best, the return to labor and capital of producers (including capital tied up in land). It is also worth noting that the high income sector of irrigation (emerging flower farming and capital-intensive commercial farms) is not included in our assessment. Our method, therefore, probably underestimates the true contribution of irrigation to GDP; at best, it provides the lower margin of the contribution of irrigation to GDP.

[7] Even at the small-scale, we observe increases in crop output of tomato and onion leading to crashes in prices.

Data Sources

This study made use of both primary data on smallholder production, both rainfed and irrigated data collected from household surveys and data from various secondary sources. The household survey was part of a comprehensive nationwide study on the Impact of Irrigation on Poverty and Environment (IIPE) carried out in Ethiopia between 2004 and 2007 by the International Water Management Institute (IWMI) with support from the Austrian Government. The major components of the project included: assessment of the performance of irrigated agriculture; assessment of the importance of irrigated agriculture to the national economy; assessment of the institutional frameworks and support services of irrigated agriculture; and assessment of the generic environmental and health issues (see Awulachew et al. 2007b). This study focuses only on the importance of irrigated agriculture to the national economy.

The component, which investigated into irrigation's contribution to the national economy, addressed a total sample size of 1,024 households from eight irrigation sites in four regional states involving traditional and modern irrigation systems, and rainfed systems. The total sample comprised 397 households practicing purely rainfed agriculture and 627 households (382 modern and 245 traditional) practicing irrigated agriculture. These households operate a total of 4,953 plots (a household operates five plots on average). The data collected include demographics, asset holdings, access to services, plot level production and sale and input use data (distinguished between irrigated and rainfed agriculture), constraints to agricultural production and household perceptions about the impact of irrigation on poverty, environment and health, and other household and site specific data. The data were collected for the 2005/2006 cropping season. All data were collected in local areal units (in timad) and local currency (in Ethiopian Birr (ETB)) and converted into hectares (4 timad ≈ 1 ha) and US$ (US$1 ≈ ETB 8.67). We used part of this comprehensive dataset for the analysis here. Summaries of data used and their source are given in Table 5 below.

We also used secondary data from various sources. From the large-scale schemes we gathered data on investment cost/initial capital outlays, cost of production, output, and revenue

TABLE 5. List of variables used in the study and their source.

Variable name	Description	Source
Crop cover	Type of crops grown with average land area under all kinds of irrigation typologies and rainfed (in hectares)	Household survey
Irrigated area	Land under irrigation (in hectares)	IWMI database and MoWR data sources
Investment cost	Capital costs (in ETB)/initial capital outlays of projects	Project documents and feasibility studies
Input use and expenditure	Quantity of labor, seed/seedling, fertilizer, chemicals, etc., and their prices	Household survey
Output prices	Price of farm outputs for small-scale systems	Household survey
O&M costs	Annual operation and maintenance costs (in ETB) for small- and large-scale systems	Calculated by authors
Cost of production	Inputs and other costs of production from large-scale schemes	Annual reports of schemes
Output	Yield ha-1 or aggregate output per scheme	From household survey and annual reports
Revenue	Quantity sold and price per unit of output or reported sales	From household survey and annual reports
Future expansion plans	Envisaged expansion plans for small-, medium- and large-scale schemes	MoWR and other documents

among others. From official documents, such as the policy documents of the government (MoWR 2006; World Bank 2006; MoFED 2006), we gathered information on developed and projected irrigation development plans. Furthermore, for specific data on future expansion and new development plans on sugar estates we used the revised master plan of the Ethiopian Sugar Development Agency (ESDA 2007). The plans for the development of small-scale irrigation are prepared by the regional governments and are compiled by the Ministry of Agriculture and Rural Development that oversees the development of the sub-sector.

Valuing Irrigation's Contribution to the National Economy

The contribution of agriculture to the national economy is estimated on the basis of the estimated production during the ***Meher*** (main rainy season) and the ***Belg*** (small rainy season) seasons (MoFED 2006). Although not explicitly stated in the official document, we assume that the contribution of irrigation is included in the production during the ***Belg season***. As already stated, farmers use full irrigation to grow crops during the dry season when it is not possible to produce crops using rainfall alone. Thus, households get additional income from irrigation in comparison to farmers who can only grow crops during the main rainy season. Under small-scale irrigation systems, irrigation does not replace rainfed agriculture but complements it. Large-scale schemes in Ethiopia, however, are under full irrigation throughout the year.

Based on the net gross margin calculations (see Table 6), irrigation in the study sites generates an average income of approximately US$323/ha compared to the calculated gross margin for rainfed which is approximately US$147/ha. This indicates that after accounting for annual investment replacement costs, the net gross margin from irrigation is more than double the gross margin from rainfed agriculture.

When we disaggregate net income by irrigation typology, we also see a strong difference between the typologies. Average income from small-scale but modern irrigation schemes is approximately US$355/ha while being approximately US$477/ha from small-scale traditional schemes. This may sound counterintuitive in the sense that schemes with permanent structures and well-lined canals should have better returns. There are three possible reasons for these differences in gross margins. First, higher margins for traditional schemes have to do with high average investment costs of modern schemes compared to the traditional schemes, as modern schemes have fixed or improved water control/diversion structures yielding higher annual investment replacement costs than traditional schemes, which is approximately US$165/ha and US$25/ha for modern and traditional schemes, respectively. Second, the relatively longer irrigation experience and, hence, the acquired improved irrigated crop management practices of farmers working under traditional systems may have also contributed to this difference. Third, a better institutional setting (as a result of stronger local water institutions) under traditional irrigation schemes is also expected to contribute to differences in performance. There is already evidence in support of the superior performance of traditional schemes compared to modern schemes in Ethiopia. Using the frontier technical efficiency analysis, Makombe et al. (2007b) showed that farmers in traditional irrigation schemes displayed lower inefficiency compared to modern irrigation schemes, although the latter were found to be on a higher frontier. Moreover, Alamirew et al. (2007) showed that traditional water institutions ensured the efficient distribution of water, and in enforcing their byelaws their penalty sanctioning mechanisms were stronger. Gashaye and Alamirew (2007) also reported the case of schemes that are performing poorly due to weak institutional arrangements. Hence, although not conclusive, there is a growing body of evidence that point to the superior performance of traditional schemes resulting from better water management institutions. There are also huge intra-scheme differences in income within the same typology which could be attributed to relative differences in cropping patterns and access to markets (see Table 6). On the role of irrigation to market-oriented production, Hagos et al. (Forthcoming) reported that irrigation has contributed significantly to increases in market participation, volume of marketed produce and, hence, household income by inducing shifts in the cropping mix of farmers.

When it comes to the valuation of the contribution of large-scale schemes, we followed the approach outlined in the section, *Methodology*. Hence, in calculating net income from large-scale schemes, we deducted the contribution of rainfed from the net income obtained under irrigation to account for the income foregone by not using the land under rainfed production. The rationale behind this is that irrigation in the large-scale schemes is a full-year enterprise without possibilities to practice rainfed agriculture. Before netting out the contribution coming from rainfed, the average income from large-scale schemes was US$1,456/ha. However, there are strong differences in the GM between the schemes. This difference in performance is strongly related to the type of crop grown in the schemes, and, perhaps, also to the differences in management and efficiency (see Table 7). Overall, schemes growing sugarcane have, on average, higher gross margin values compared with schemes growing other crops. In line with this, using scheme-level physical and economic performance indicators, Ayana and Awulachew (2007: 1) showed that schemes that grow sugarcane attained outputs per unit of land and water used compared to other crops, namely, cotton, and fruits and vegetables.

TABLE 6. Gross margin calculations from small- and medium-scale irrigation schemes (in US$).

Name of scheme	Scale of scheme	Typology	Area (ha)	O&M costs	GM/ha rainfed	GM/ha irrigated	GM minus fixed cost	Total income
Indris	Medium	Modern/traditional*	382	8.5	49.5	213.4	204.8	78,266.6
Gologota	Medium	Modern	850	34.9	123.2	876.1	841.2	715,016.5
WBS	Medium	Modern/Traditional*	685	23.1	171.3	300.2	277.1	189,810.4
Tikurit	Small	Traditional	102	10.5	156.1	300.2	467.1	47,644.9
Zengeny	Medium	Modern	270	25.6	227.3	389.3	363.5	98,173.0
Haiba	Medium	Modern	250	50.4	182.8	322.4	272	67,997.4
Golgol Raya	Micro-irrigation	Modern	104	158.2	197.2	258.4	100.1	10,412.9
Hare	Medium	Modern/traditional*	1,345	18.3	74.5	109.6	91.2	122,745.8

Source: Authors' calculations

* Within these schemes there are traditional and modern systems where some of them fall under the small-scale and some under the medium-scale and the indicated GM values represent average figures.

When it comes to medium-scale irrigation schemes, the average income from modern irrigation schemes was US$400/ha, which is higher than the gross margin from modern small-scale schemes but lower than the gross margin from the traditional small-scale schemes.

Taking these average margins from smallholder-managed small- and medium-scale irrigation schemes in the country and multiplying it by the total irrigated area under both typologies, we calculated the total income driven from irrigation to be approximately US$262.3 million. This accounts for about 4.5% of the agricultural GDP in 2005/2006 and 2% of the total GDP.

As we did not have data from rainfed in and around the large-scale schemes, we used rainfed data from other sites where we sampled the medium- and small-scale sites. The average gross margin per hectare calculated from rainfed agriculture, as indicated earlier, was US$147. Taking this value into account, the net income from a hectare of irrigation under large-scale schemes is US$1,308. When we differentiate the large-scale schemes into sugar plantation and other crop growing plantations (i.e., predominantly schemes growing fruits and vegetables, and cotton) the average net income is US$1,782.5 and US$998.9, respectively. Taking all large-scale schemes in the country, differentiated by their cropping pattern, and the average income from the selected learning sites, the total income earned from large-scale schemes amounted to approximately US$74.0 million. This accounts for about 1.26% of the agricultural GDP and 0.5% of the total GDP. Overall, the contribution of irrigation to agricultural GDP and total national GDP was about 5.7 and 2.5%, respectively, during the 2005/2006 cropping season. When only the modern system was considered, it contributed to about 1.3 and 0.5% of agricultural GDP and total national GDP, respectively.

TABLE 7. Gross margin calculations from large-scale irrigation schemes (in US$).

Name of scheme	Main crop	Area (ha)	Average investment cost/ha	Annual investment recovery cost/ha	Total GM (millions)	GM/ha	Net income	Total income
Amibara*	Cotton	5,358	1,316.3	26.3	1.59	139.79	113.49	607,882.69
Finchaa	Sugarcane	7,185	7,728.6	144.5	21.27	339.45	194.81	1,411,309.4
Metehara	Sugarcane	10,146	1,073.0	21.45	35.03	3,765.74	3,744.3	3,798,922.7
Upper Awash	Fruits and vegetables	6,017	437.5	8.8	7.25	1,913.95	1,905.19	11,464,462.4
Wonji/Shoa**	Sugarcane	4,094	4,150.8	83.1	5.68	1,408.30	1,325.26	5,425,664.3

* Based on 2004/2005 estimate

** Average investment cost for the Wonji scheme is taken as the average for Metehara and Finchaa schemes

Projecting the Future Contribution of Irrigation

In this section, we present the projected expansion of irrigated agriculture vis-à-vis rainfed agriculture and the contribution of the former to agricultural GDP. To estimate the future scenario, we used cropping patterns as observed in our empirical results and projected cropping patterns based on the projections of the PASDEP (2005/2006-2009/2010) document (see Table 8). In projecting the future scenario of irrigation development, small-, medium- and large-scale schemes are taken into account.

In projecting future scenarios, we assumed that the cropping pattern of the large-scale sugar plantations to be the same. In these sugar plantations, we ruled out the possibility of a reduction in irrigated land area due to salinity or other environmental problems, which was due to the lack of data that clearly shows the magnitude of the problem. However, there are indications of soil crusting and a rise in the groundwater table in two of the large-scale schemes (Ruffeis et al. 2007). On the other hand, we assumed that the cropping pattern in the smallholder-managed large-, medium- and small-scale irrigation schemes to be the same as depicted in Table 8. The land cover statistics of the irrigation, taking into consideration all typologies, and rainfed systems are also given in Table 9. We relaxed this assumption later in the sensitivity analysis as it is realistic that farmers will shift to high-paying crops as they gain experience and when the market situation is likely to improve.

The PASDEP document also outlines the projected development of the economy for the whole planning period. Accordingly, the Ethiopian economy is expected to grow at an average of 7.3% throughout the PASDEP period[8]. Agriculture, the major sector of the economy, is also expected to grow at an average rate of 6.2% (MOFED 2006: 55). A slight reduction will be shown in the share of agriculture in the economy from 46.2% in 2004/2005 to 43.9% at the end of the planning period. Taking the baseline situation (2005/2006), Ethiopia's GDP will grow to US$17.67 billion while agricultural GDP will grow to US$7.46 billion, both at 1999/2000 constant basic prices.

For the assumptions made about the IDP, differentiated into small- to medium-scale and large-scale schemes, we used MOFED (2006) and MoWR (2006), as indicated in the section, *Methodology*. According to the national IDP, the country's irrigation coverage will increase from the current 625,819 ha to 1.15 million hectares by 2009/2010. Accordingly, there will be 638,129 ha of small-scale irrigation, both traditional and modern, 328,485.9 ha of smallholder-managed

TABLE 8. Cropping pattern under different systems (% area covered) by small- and medium-scale irrigation.

Crop category	Area under rainfed system (%)	Area under traditional irrigation (%)	Area under modern irrigation (%)	Average area cover under irrigation (%)
Cereals	77	55	67	61
Vegetables	1	11	21	16
Perennials/fruits	1	11	4	7
Pulses	16	10	3	6
Oilseeds	1	5	0.4	3
Spices	0.5	8	0.3	4
Others	3	0.2	5	2.5

Source: Authors' calculations

TABLE 9. Land use assumptions for future irrigated areas (2005/2006-2009/2010).

Land use	Area with irrigation (in '000 ha)	Area without irrigation (in '000 ha)
Cereals	809.2	9,200
Pulses		1,600
Oilseed crops	119.4	1,200
Vegetables	212.2	
Fruits	99.5	419
Cotton		43
Sugarcane	122.0	60
Coffee		734*
Floriculture	N/A	2*
Tea		3.8*
Other	86.2*	39*
Total	1,362.3	12,522

Source: MOFED (2006) and authors' calculations;
N/A = no data available
*not considered in the calculation

[8] Actual annual GDP growth rate between 2003/2004 and 2006/2007 was more than 11% (IMF 2008).

medium- and large-scale irrigation and 122,000 ha of large-scale schemes dedicated to sugar plantations, and 35,511 ha of large-scale commercial farms dedicated to growing fruits and vegetables, and cotton.

Taking all the envisaged areal expansions, crop cover assumptions as indicated in tables 8 and 9 and the average gross margin by crop category (Table 10), we calculated that the contribution of smallholder-managed irrigation to the national economy would increase from US$262.3 million in 2005/2006 to about US$414.2 million in 2009/2010, which accounts for about 5.5% of the agricultural GDP and 2.3 of the overall GDP for the same year. On the other hand, the contribution coming from the large-scale sugar growing estates is estimated to be US$217.5 million in 2009/2010, which accounts for 2.9 and 1.2% of the agricultural GDP and overall GDP, respectively. Similarly, the contribution coming from large-scale commercial farms growing crops other than sugarcane is expected to increase to US$35.8 million in 2009/2010 which accounts for 0.4 and 0.2% of the agricultural GDP and overall GDP, respectively. This implies that large-scale commercial farms will contribute about 3.3 and 1.4% to the agricultural GDP and overall GDP, respectively. This shows that the bulk of the contribution is expected to come from smallholder-managed irrigation systems. In summary, this indicates that, under conservative estimates, the future contribution of irrigation to agricultural GDP and overall GDP will be in the range of 8.8 and 3.7%, respectively (see Table 11). This estimation is based on the projected areal expansion, current cropping patterns and prices. These results are likely to change when some of the assumptions were allowed to change as shown in the section, *Sensitivity Analysis*.

TABLE 10. Estimated average gross margin for different crop categories.

Crop category	Rainfed (US$/ha)	Irrigated (US$/ha)
Cereals	147.9	198.5
Vegetables		394.6
Fruits		317.75
Pulses and oilseeds	170.87	179.7
Sugarcane		522.34
Cotton		81.85
Others (hops, chat, etc.)	144.73	333.54

Source: Authors' calculations

TABLE 11. Current and future contribution (%) of irrigation to agricultural GDP and GDP (by typology).

Typology	2005/2006		2009/2010	
	Agricultural GDP	GDP	Agricultural GDP	GDP
Smallholder-managed	4.5	2	5.5	2.3
Large-scale sugar plantations	1.26	0.5	2.9	1.2
Other large-scale plantations			0.4	0.2
Overall	5.76	2.5	8.8	3.7

Source: Authors' calculations based on the projections of MOFED (2006)

Sensitivity Analysis

In projecting the future contribution of irrigation to the national economy or to agricultural GDP, our assumptions were rigid: only a change in area expansion was assumed. However, it is realistic to assume that there will be various changes associated with irrigation expansion. For instance, given the significant difference in the gross margin between different crop categories, farmers will benefit economically by growing more fruits and vegetables than cereals. Hence, it is realistic to assume that farmers will gradually shift to high value crops. Prices of inputs and outputs cannot be taken to remain constant. It is realistic to assume that there could be either upward or downward movements in the prices of agricultural inputs and outputs. Furthermore, the efficiency of farmers is also expected to improve with time as they gain irrigation experience, experiment with various technologies and combinations, and when local water management institutions are strengthened. Already, there are attempts to strengthen water users' associations with the expectation that it will improve water management on a scheme level and have a bearing on the gains in terms of efficiency. Hence, it is important to relax these assumptions and see the effect of these changes on irrigation's contribution to national income. This section presents the results of the sensitivity analyses.

Simulating Changes in Cropping Patterns under Smallholder-managed Irrigation Schemes

To simulate the effect of changes in cropping pattern on the agricultural GDP, we set the following scenarios: Scenario 1 involves a 10% increase in area coverage of fruits and vegetables (10% decrease in area for cereals) while areas for pulses, oilseeds and other crops remain the same; Scenario 2 assumes a 10% increase in the area of vegetables and a 5% increase in the area of fruits (15% reduction in the area for cereals, *ceteris paribus*); Scenario 3 assumes a 10% increase in area for both fruits and vegetables (20% reduction in the area for cereals); and, finally, Scenario 4 assumes a 25% increase in the area of fruits and vegetables (i.e., a 25% reduction in the area for cereals, *ceteris paribus*). The outcomes of these scenarios were compared against the baseline scenario where we assumed that there will only be areal expansion (Table 12).

As shown in Table 10 (see also Annex, tables A1 and A2) there is a significant difference in the gross margin between different crop categories. On average, farmers get US$198.5 from growing cereals, US$394.6 from vegetables, US$317.7 from fruits, US$179.7 from pulses and oilseeds, and US$333.5 from growing other crops such as spices and stimulants, on a per hectare basis.

TABLE 12. The effects of a change in cropping pattern on the projected contribution of smallholder-managed irrigated agriculture to agricultural GDP (net gross margin in ETB).

Crop type	Total NGM (million US$)	Contribution to agricultural GDP in 2009/2010 (%)	Contribution to GDP in 2009/2010 (%)	Relative change (%)
Baseline	315.2	4.22	1.78	
Scenario 1	327.9	4.39	1.85	+17
Scenario 2	335.8	4.5	1.9	+28
Scenario 3	340.6	4.56	1.92	+34
Scenario 4	384.5	4.67	1.97	+45

Source: Authors' calculations

From the simulation results, it can be seen that the contribution of smallholder-managed irrigation schemes to agricultural GDP increases to about 4.5%, or even more, when these various changes in cropping pattern are assumed. An increase of approximately 10 and 15% in the areas of fruits and vegetables (25% reduction in the area of cereals) leads to an approximate increase of 45% in the contribution of smallholder-managed irrigation schemes to agricultural GDP when compared to the baseline scenario. This intuitively obvious result reflects that the direct monetary contribution of irrigation could be maximized if smallholder farmers shift their cropping pattern to high value crops.

Simulating Changes in Crop Prices

The factors that influence price changes could be related to overall demographic change and improved economic performance (through increased demand), and an increase in the supply of output. It is reasonable to assume that the population of Ethiopia will continue to grow in the foreseeable future while there could be differences in opinion about the prospects of and rate of economic growth in the country. As indicated earlier, the prospects point towards an improvement in economic performance, which is expected to stimulate demand. Hence, for this exercise, we assumed that factors that influence demand will play a more significant role in influencing the prices of outputs. To simulate the effect of these changes in the prices of outputs on the contribution of irrigation to the national economy, we set various scenarios: GM net of annual investment recovery costs (baseline scenario); 10% increase in the price of fruits and vegetables, *ceteris paribus* (scenario 1); 15% increase in the price of fruits and vegetables, *ceteris paribus* (scenario 2); 10 and 15% percent increase in the price of cereals, *ceteris paribus* (scenarios 3 and 4, respectively); 10 and 15% increase in the price of pulses and oilseeds, respectively, *ceteris paribus* (scenarios 5 and 6); and 10 and 15% increase in the price of other crops, *ceteris paribus* (scenario 7 and 8, respectively). The simulation results are reported in Table 13 below.

These simulation results show that a 10-15% increase in the price of fruits and vegetables leads to a 15-23% increase in the relative contribution of smallholder irrigation to agricultural GDP. An

TABLE 13. The effects of a change in output prices on the projected contribution of smallholder-managed irrigated agriculture to agricultural GDP.

Scenarios	Description	Contribution to agricultural GDP in 2009/2010 (%)	Contribution to GDP in 2009/2010 (%)	Relative change (%)
Baseline	GM net of investment recovery costs	4.22	1.8	
Scenario 1	10% increase in the price of fruits and vegetables	4.37	1.85	15
Scenario 2	15% increase in the price of fruits and vegetables	4.45	1.88	23
Scenario 3	10% increase in the price of cereals	4.44	1.87	22
Scenario 4	15% increase in the price of cereals	4.55	1.92	32
Scenario 5	10% increase in the price of pulses and oilseeds	4.25	1.79	3
Scenario 6	15% increase in the price of pulses and oilseeds	4.26	1.80	4
Scenario 7	10% increase in the price of other crops	4.25	1.79	3
Scenario 8	15% increase in the price of other crops	4.26	1.80	4

Source: Authors' calculations

equivalent increase in the price of cereals leads to a 22-32% increase in the relative contribution of the sub-sector. On the other hand, the same level of increase in the prices of pulses, oilseeds and other crops did not yield a significant change in their contribution. The relatively higher contribution of cereals is due to the fact that cereals have a bigger share of the land cover, claiming about 61% of the cultivated area under irrigation. Hence, fruits and vegetables are economically more attractive. This implies that an increase or decrease in the prices of fruits and vegetables will have a stronger relative impact on the contribution of irrigation to the national economy compared to a change in the price of cereals and pulses.

Simulating Changes in Input Prices

Fertilizer is the most important input for smallholder farmers working under irrigation. The average cost of fertilizer varies depending on the type of crop category. Cereals and vegetables are major consumers of fertilizer with average expenditure of US$33.10 and US$46.5, respectively, per hectare. Pulses and oilseeds, other crops, and fruits reported expenditure on fertilizer of US$27.5, US$18.6, and US$5.4, respectively, per hectare. In projecting the impact of irrigation on the national economy, one needs to consider the effects of changes in input prices on the gross margin. To simulate such an effect, we determined the impact of the following scenarios: 10, 15, 25 and 35% increase in the price of fertilizer against the baseline scenario of fertilizer prices during 2005/2006. Given the current trends in fertilizer prices, it seems realistic to assume that fertilizer prices will increase[9].

According to the simulation results (Table 14), the contribution of smallholder-managed irrigation schemes to agricultural GDP does fall significantly compared to the baseline scenario if there was an increase of 10% or higher in the price of fertilizer. A 35% increase in the price of fertilizer, while

TABLE 14. Effects of a change in fertilizer prices on the contribution of smallholder irrigation to agricultural GDP.

Crop category	Contribution to agricultural GDP	Contribution to GDP	Relative change
Baseline scenario	4.22	1.78	
Scenario 1	4.17	1.76	-5
Scenario 2	4.14	1.75	-8
Scenario 3	4.08	1.72	-14
Scenario 4	4.03	1.70	-19

Source: Authors' calculation

assuming that other things remained constant, for instance, leads to a 19% reduction in its relative contribution to agricultural GDP compared to the baseline scenario. This calls for policy measures to stabilize the price of important production inputs, particularly fertilizer, and not to retract the benefits expected from irrigation development.

Improvement in Efficiency of Smallholder-managed Schemes

Besides exogenous changes in prices and endogenous changes in cropping patterns, farmers are also expected to gain irrigation experience and improve their efficiency in using land and water. This is also expected to lead to increases in the gross margin. We, hence, explored the effects of an increase in the gross margin, of farmers in smallholder modern schemes compared to those in the traditional schemes, on the contribution of irrigation. The simulation results show that the contribution of smallholder-managed irrigation schemes will increase to about US$475.5 million, which accounts for 6.4 and 2.7% of agricultural GDP and overall GDP, respectively, in 2009/2010. This also has an important policy implication; government and extension support through education and training may contribute to improved efficiency and increase the contribution of irrigation

[9] Between the cropping years 2004/2005 and 2006/2007 the average price of 100 kilograms (kg) of DAP increased by 5% and that of Urea by 12%, annually. It is reported that the price of fertilizer has continued to increase in 2007/2008 (EEA 2008).

to the national economy. Strengthening local water management institutions in modern schemes, such as water users' associations, could also have efficiency enhancing effects.

In summary, taking these scenarios into account, the contribution of smallholder-managed irrigation to agricultural GDP and overall GDP will vary between 4 to 6% and 1.8 to 1.9%, respectively.

Projecting the Future Contribution of Large-scale Plantations

In projecting the future contribution of large-scale commercial plantations, we tested various scenarios. First, we need to differentiate between large-scale smallholder-managed schemes and large-scale commercial plantations. The former category was covered in the previous sections, as smallholder farmers are characteristically the same, while in this section the focus is on large-scale commercial productions. The major expansion in the state-owned commercial plantations predominantly involves the growing of sugarcane for sugar production. There is no information on the future expansion plans of large-scale commercial farms growing fruits and vegetables, and other crops. Hence, the focus in this section will be on sugar plantations. Worth noting is that, there is a huge difference in both annual investment recovery costs and net gross margin in the existing sugar plantations (see Table 7). These differences could be attributed to differences in the structure of investment and management performance and, hence, efficiency of the schemes. The lack of relevant information on initial investment costs for some of the schemes has also made the analysis difficult. In schemes where data could not be gathered on initial investment costs, we used data related to initial capital outlays. The huge differences in annual investment recovery costs and net gross margin could partly be attributed to the lack of reliable data, although there is more reason to believe that there are underlying causes that yield huge inter-scheme differences in physical productivity (see Ayana and Awulachew 2007).

In simulating the future contribution of large-scale schemes, certain assumptions were set based on the differences in net gross margins between the three major sugar growing schemes. Since there will be further schemes emerging, e.g., Kesem and Tendaho on 90,000 ha of land, in the production of sugarcane, we need to set certain assumptions about the performance of these schemes. The assumptions made were that; the net gross margin for Finchaa, Metehara and Wonji/Shoa applies to the new schemes (scenarios 1-3); the performance of Kesem and Tendaho was on an average of the three existing schemes (scenario 4); the performance of all the schemes, existing and emerging, is similar to that of Finchaa (scenario 5); the performance of all the schemes is similar to that of Metehara (scenario 6); the performance of all the schemes is similar to that of Wonji/Shoa (scenario 7); the performance of all the schemes is on an average of the three existing schemes (scenario 8); and a 10 and 15% increase in the price of sugar while the average gross margin works in all schemes (scenarios 9 and 10, respectively) (Table 15). Looking at these scenarios, it can be seen that the contribution of large-scale plantations to agricultural GDP ranges from less than 1% in scenario 5 (worst scenario) to approximately 6% in scenario 2 (best scenario). The intermediate outcomes lie somewhere in between, contributing about 3% to agricultural GDP. These results show that the structure of investment and the way these schemes are managed may have a significant bearing on their contribution to the national economy.

In summary, the contribution of large-scale irrigation to agricultural GDP and overall GDP will be in the range of approximately 1.5 to 6% and 1.2 to 2.5%, respectively. Overall, the future contribution of irrigation to agricultural GDP will be in the range of approximately 7 to 12% while the contribution to GDP will be in the range of approximately 4%.

Table 15. Projected contribution of large-scale sugar estates to agricultural GDP.

Scenarios	Assumption	Contribution to agricultural GDP	Contribution to GDP	% Change
Baseline scenario	average net GM for large-scale schemes assumed	2.9	1.2	
Scenario 1	Kesem and Tendaho - performance similar to Finchaa	1.5	0.65	- 140
Scenario 2	Kesem and Tendaho - performance similar to Metehara	5.8	2.46	290
Scenario 3	Kesem and Tendaho - performance similar to Wonji/Shoa	2.9	1.22	0
Scenario 4	Kesem and Tendaho achieves performance an average	3.4	1.4	50
Scenario 5	All schemes – performance similar to Finchaa	0.32	0.13	-258
Scenario 6	All schemes – performance similar to Metehara	6.1	2.5	320
Scenario 7	All schemes - performance similar to Wonji/Shoa	2.16	0.9	-74
Scenario 8	All schemes – performance on an average of all three existing schemes	2.87	1.2	-3
Scenario 9	10% increase in baseline NGM	2.87	1.2	-3
Scenario 10	15% increase in baseline NGM	2.87	1.2	-3

Source: Authors' calculations

Conclusions and Recommendations

Irrigation development is quite a recent phenomenon in Ethiopia. While the country has a huge potential for irrigation only about 18% of this potential is currently being utilized. Irrigation development has been identified as an important tool to stimulate economic growth and rural development, and is considered as a cornerstone of the food security and poverty reduction strategies in the country. To this effect, a comprehensive National Irrigation Development Strategy (2005/2006-2009/2010) has been developed and is being implemented with the aim of establishing small-, medium- and large-scale irrigation schemes, either for use under smallholder-managed systems or as large-scale commercial plantations. In spite of this, there has been little attempt to measure the actual and expected contribution of irrigation to the national economy. Hence, the objective of this study was to estimate the net contribution of irrigation to GDP at the farm gate using an adjusted gross margin analysis approach. Studies of this kind could be instrumental in comparing the actual and expected direct benefits of irrigation with the actual and expected costs of irrigation expansion to guide policymakers in irrigation development. One limitation of this study is that it does not attempt to capture the multiplier effects of irrigation as doing that would require more data than what is presently available. However, this first attempt can be extended to a more precise analysis of the economy-wide effects of the development of irrigated agriculture when more data is made available through future research.

To summarize some of the most important findings: our results show that irrigation in the study sites generates an average net gross margin about US$323/ha. This compares to the calculated average net gross margin for rainfed which is US$147/ha. This indicates that after accounting for annual investment replacement costs, the net gross margin from irrigation is 219.7% higher than the gross margin from rainfed agriculture. This result underlines the fact that investment in irrigation is viable as more value is added to the economy after netting out the investment costs. Whether investment in irrigation is worthwhile, compared to other investments in the sector or outside, is something we did not address in this study. This could be another area of future research in its own right. Nonetheless, besides underlining the financial viability of smallholder irrigation, the results of our study has important implications on cost recovery for sustainable irrigation development.

When disaggregated by irrigation typology, the average income from small-scale modern systems is about US$355/ha while that of small-scale traditional systems is about US$477/ha. These differences in net income between the traditional and modern systems are attributed to differences in the structure of investment, cropping patterns and institutional settings, among others. We also found huge inter-scheme differences in average income within the same typology, where differences in cropping pattern, access to markets and relative irrigation experience are the major factors behind these differences. The average income from medium-scale irrigation schemes was US$400/ha. The average income net of annual investment recovery costs from a hectare of irrigation under large-scale schemes is US$1,308, because they primarily produce higher value sugarcane.

Taking the average adjusted gross margins from all typologies under the smallholder-managed systems and the total land area within the system in the whole country, we calculated the total income driven from irrigation to be about US$262.3 million. This accounts for approximately 4.5% of the agricultural GDP and 2% of the overall GDP in 2005/2006. Similarly, all the large-scale schemes in the country, differentiated by their cropping pattern, and based on the average net income from the selected learning sites, generate an estimated of US$74.0 million. This accounts for approximately 1.26% of the agricultural GDP and 0.5% of the total GDP. Overall, the contribution of irrigation to agricultural GDP and the total national GDP in the 2005/2006 cropping season was approximately 5.7 and 2.5%, respectively. Our results, therefore, show that the bulk of the contribution to the national economy comes from the smallholder-managed irrigation schemes, and, most importantly, from the traditional schemes, while only approximately 1.3 and 0.5% to the agricultural GDP and total GDP is contributed by the so-called modern system. The results also show that the contribution of irrigation to the national income is negligible compared to the overall contribution coming from crop production accounting for 28% of the national income. This is in stark contrast to the role of irrigation in the national economies of some countries in the region such as the Sudan and Egypt. In Sudan, irrigation contributes about 50% of the crop production while almost all agriculture in Egypt is irrigated (FAO 1997; FAO 2007).

Future projections by considering all the planned expansions, existing cropping patterns, and the average adjusted gross margin values for different crop categories, the expected contribution of smallholder-managed irrigation is expected to increase from US$262.3 million in 2005/2006 to about US$414.2 million in 2009/2010, which will account for approximately 5.5% of the agricultural GDP and 2.3% of the overall GDP for the same period. On the other hand, the contribution from the large-scale sugar growing estates in 2009/2010 is estimated to be US$217.5 million which amounts to 2.9 and 1.2% of the agricultural GDP and overall GDP, respectively. Similarly, the contribution from large-scale non-sugarcane growing farms is expected to increase to US$35.8 million in 2009/2010, which amounts to 0.4 and 0.2% of the agricultural GDP and overall GDP, respectively. This implies that large-scale commercial farms will contribute approximately 3.3 and 1.4% to the agricultural GDP and overall GDP, respectively. To conclude, our results indicate that under conservative estimates the future contribution of irrigation to agricultural GDP and overall GDP will be in the range of 8.8 and 3.7%, respectively.

After relaxing some of these underlining assumptions, i.e., allow changes in cropping patterns and input/output prices and improvements in levels of efficiency, the contribution of irrigation to the national income increases somewhat substantially. A 10 and 15% increase in the area of fruits and vegetables, respectively, leads to an approximate increase of 45% in the relative contribution of smallholder irrigation to agricultural GDP compared to the baseline scenario of no change. A 10-15% increase in the price of fruits and vegetables leads to a 15-23% increase in the relative contribution of smallholder irrigation to agricultural GDP. An equivalent increase in the price of cereals leads to a 22-32% increase in the relative contribution of the sub-sector. The relatively higher contribution from cereals is attributed to the bigger share that cereals have on the land area, claiming about 61% of the cultivated area under irrigation. This implies that an increase or decrease in the prices of fruits and vegetables will have a stronger relative impact on the contribution of irrigation to the national economy compared to that of cereals and pulses. Hence, fruits and vegetables are economically more attractive and could yield more value to the economy, if more and more land is shifted from cereal production to the cultivation of fruits and vegetables. This may have implications on the staple crop production, which should be considered.

On the other hand, a 35% increase in the price of fertilizer (a very realistic assumption given the current trends in fertilizer prices), while assuming that other things remain constant, leads to a 19% reduction in the contribution of smallholder irrigation to agricultural GDP compared to the baseline scenario.

Improvements in irrigation efficiency have been found to increase the contribution of irrigation to the national economy. Our simulation results show that the contribution of smallholder-managed irrigation will increase to about US$475.5 million, which is 6.4 and 2.7% of the agricultural GDP and overall GDP, respectively, in 2009/2010, when all smallholder irrigation farmers perform to the level of traditional irrigators. This has an important policy implication: there is a need for increased government and extension support through education and training, and the strengthening of local water institutions to improve efficiency at the scheme level and, thereby, their contribution to the national economy. Furthermore, changes in efficiency levels of existing and emerging large-scale sugar plantations and changes in the price of sugar, assuming a move from worst to best scenarios, will increase the contribution of large-scale plantations to agricultural GDP to approximately 6% in scenario 2. The intermediate outcome lies somewhere in between contributing approximately 3% to the agricultural GDP. These results show that the structure of investment and the way these schemes are managed (e.g., viable crop choice) may have a significant bearing on their contribution to the national economy.

In summary, taking these scenarios into account, the contribution of smallholder-managed irrigation to agricultural GDP and overall GDP will vary between approximately 4 to 6% and 1.8 to 1.9%, respectively. Similarly, the contribution of large-scale irrigation to agricultural GDP and overall GDP will be in the range of approximately 3 to 6% and 1.2 to 2.5%, respectively. Overall, the future contribution of irrigation to agricultural GDP will be in the range of 7 to 12% while the contribution to overall GDP will be in the range of approximately 3 to 4%. To realize these outcomes, there is a need to implement the planned irrigation developments as envisaged in the National Irrigation Development Plan. To enhance the contribution of irrigation to the national economy, however, there is also a need to: i) improve the provision of agricultural inputs including high value crops; ii) improve the performance of the agricultural extension system to support irrigation; iii) improve market access conditions and marketing infrastructure; and iv) improve the management of the schemes to increase the efficiency of small- and large-scale schemes.

Our results have important implications on cost recovery and on the sustainability of irrigation investment, with far reaching policy implications for irrigation development. A relatively higher financial return to irrigation investment implies that such investments could be made in a sustainable a manner if the government were to introduce irrigation cost recovery schemes. If policymakers were to introduce irrigation cost recovery schemes in Ethiopia, then farmers will be able to pay, including investment cost recovery. This study reinforces the findings of Makombe et al. (2007a), which also concluded that small-scale irrigation systems are financially viable considering O&M requirements, investment cost recovery, and the ability to replicate investments. This could ensure the sustainability of irrigation development in Ethiopia.

Annex

Table A1. Gross margin of rainfed crops.

Crop type	Mean area (in timad)	Gross value of output/mean area	GM - rainfed	GM - rainfed (per hectare)
Wheat	1.3	857	366.7	1,089.6
Teff	1.8	806	437.8	956.9
Barley	1.2	507.7	429.2	1493
Maize	1.7	609.2	341	816.7
Finger millet	1.3	717	652.6	2,055.4
Sorghum	2.4	754.7	644.6	1,053.8
Chickpea	1.3	498.4	337.9	1,031.7
Lathyrus	1.2	654.8	592.2	1,970.8
Bean	1.2	725	334.3	1,078.5
Lentil	0.6	309.4	250.4	1,584.8
Nug	2.2	1,132.3	939.6	1,709.9
Grass pea	1.6	568.2	237.9	599.2
Eucalyptus	0.9	271.3	259.7	1,185.6
Hops	0.6	214.1	136.5	956
Other	1.1	495.4	407.8	1,553.6

Table A2. Gross margin of irrigated crops.

Crop type	Mean area (in timad)	Grossvalue of output	GM - irrigated	GM - irrigated (per hectare)
Wheat	1.4	1,291.2	745.3	2,077.7
Teff	1.5	904.7	514.2	1,418.4
Barley	1	687.2	513.1	2,052.3
Maize	1.6	864.7	610.4	1,575.1
Sorghum	1.7	720.4	610.8	1,480.7
Cotton	2	394.9	354.8	709.6
Chickpea	1.4	966.3	452.3	1,256.5
Lathyrus	1.3	390	252	800.1
Bean	1.1	641.1	265.8	1,012.6
Lentil	1	1,505	1,309.4	5,237.6
Nug	1.4	717	538.5	1,516.8
Grass pea	2.2	916.4	420.2	771.8
Pea	1.5	1,467	617.7	1,625.5
Linseed	2.1	445.2	252.7	493
Pepper	1	952.2	833.7	3,437.9
Potato	0.9	574.6	420	1,812.5
Sweet potato	2	498	397	814.3
Cabbage	0.8	821	662.3	3,230.8
Onion	1.5	3,112	2,699.4	7,415.8
Tomato	1.5	1,506.1	1,017.7	2,765.4
Shallot	0.9	1,873.5	1,016.2	4,471.7
Papaya	1	679.5	625.4	2,399.9
Banana	1.9	534.1	475.8	995.9
Mango	1.2	711	652.2	2211
Guava	0.7	1,038	933.7	5,412.8
Coffee	0.7	8,407.4	8,341.4	45,210.6
Sugarcane	0.8	1,001.3	869.52	4,528.77
Eucalyptus	0.8	5,191.9	5,113.7	26,808.3
Hops	0.9	441.4	340	1,456.1
Chat	0.6	1,221.9	1,098.5	7,323.7
Enset	1	400.5	258.3	1,051.2
Other	1	505.6	441.4	1,736.2

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