Cost-benefit analysis of investments on water spreading wires for sustainable land management in flood prone areas of Afar

By Mesfin Tilahun (PhD)

Associate professor in Economics at Department of Economics, Mekelle University, P.O.Box 451, Mekelle, Ethiopia, E-mails: mesfintilahungelaye@gmail.com

Research associate professor at School of Economics and Business, Norwegian University of Life Sciences (NMBU), Box 5003 *Ås, Norway, E-mail:* mesfin.tilahun.gelaye@nmbu.no

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Contents

1. Introduction

1.1. Background

The Afar region is one of the drought prone areas in Ethiopia where rainfall is low, evapotranspiration is high (Fazzini et al., 2015) and the capacity to produce food and feed crops is extremely weak (Brown et al., 2017; Getnet et al., 2020). Recurrent drought and flash floods coming from upstream highlands that generate sudden and excessive runoff in the rainy seasons are affecting livelihoods of the pastoral and agropastoral systems in the region (Getnet et al., 2020; Belay et al., 2005). Although for many years in the past the flood waters were reported to have spread across the low-lying grazing lands of Afar (Hailu et al., 2018), benefiting the rangelands which supported the livelihoods of pastoralists and agro-pastoralist, the growing livestock population and year-round grazing, the pastoral (agr-pastoral) landscapes of Afar have degraded and the flood channels have become deep gullies (Van Steenbergen et al., 2011) with less chance for the waters to spread and irrigate natural pastures (Gumma et al., 2020). A recent study of four years flood monitoring (2015-2018) in the Afar region indicated that a minimum of 142 and 172 thousand of ha of land were flooded in the minor and main rainy seasons, respectively (Gumma et al., 2020).

Unlike the land and soil degradation effects of sudden flash floods coming from the upstream highlands and the damages they cause on the pastural and agro-pastural livelihoods, the fact that the region is hydrologically connected with a series of mountainous terrains of adjacent highlands of the upstream neighbouring regions, which generate a large amount of flood, also provided opportunities that could be transformed to productive use of the flood waters through introducing spate irrigation systems (Steenbergen et al., 2011). Gumma et al., (2020) reported that Afar has a potential of more than 550,000 ha of land that could be developed using seasonal flood water coming from the upstream highlands of the Amhara and Tigray regions. However, this requires among other things, investment on sustainable land management options that could reduce the damaging effects of the flash floods on downstream soil erosion and land degradation. The effects of strong runoff and sporadic flash floods could be reversed by a holistic approach using water spreading weirs (WSW) (Elisabeth et al., 2015). Getnet et al. (2020) reported that WSWs have positive impact in created differing farming zone following soil moisture regime, affecting grain and biomass yield, and the system has a positive and visible impact on the recovery of degraded rangelands.

For a better-informed policy decision and intervention, it is important to assess the costs of intervention against the economic, environmental and social benefits of investment on sustainable land management interventions aimed as harnessing the potential of land that could be developed using flood waters in the region.

1.2. Brief information on the project

Agricultural is the most important economic sector in Ethiopia. In the Ethiopian lowlands, pastoral (agro pastoral) systems are the basic form of livelihood. Increasing climate variability and extreme weather events such as droughts, floods or unseasonal rainfall, are threatening the pastoral(agro pastoral) production systems. The Ethiopian government has recognized the need to promote sustainable natural resource management in fragile dryland ecosystems and to support marginalized pastoral- and agro-pastoral communities in Afar and Somali regions.

The ‘Afar Soil Rehabilitation Project (ASRP)’ makes part of the programme "Strengthening Drought Resilience" (SDR) and supports in coordination with the other technical cooperation projects the holistic and integrated approach development for Dry Valley Rehabilitation and Productive Use (DVRPU), intended to offer new livelihood opportunities to local communities.

In cooperation with the other TC modules under the umbrella of the SDR programme, a landscape and eco-system-based approach is applied including the use of water-spreading weirs (WSWs) and a range of other bio-physical soil and water-conservation measures, suitable to make productive use of seasonal floods for sustainable natural resource management in dry valleys.

The activities of ASRP focus on the following districts (Woreda) of Afar: Chifra, Gulina, Yalo, Awra, Ewa, Korri and Teru. The lead executing agency of the project at national level is the Ministry of Agriculture and Natural Resources (MoANR) with its Natural Resources Management (NRM) directorate. At regional level, the respective agricultural office in the capital of Semera and its line authorities at district and village level are partners in the implementation.

ASRP strengthens the self-help capacities of local communities, which improve their basis for production through improved natural resource management and planning, erosion control and productive use of flood water and rehabilitated land. Activities are jointly implemented based on participatory land-use planning with the local communities while safeguarding their access to land.

1.3. Context

A key technological innovation within ASRP is the introduction of water-spreading weirs (WSWs). WSWs are low retention walls commonly built in the foot slopes of mountainous landscapes, designed to regulate seasonal floodwaters, reduce runoff and minimize erosion (Haile and Fetene, 2012). WSWs are made of natural stone and cement and consist of a spillway in the dry riverbed itself, lateral abutments for stabilization and wing walls that span the width of the valley perpendicular to the dry river on both sides of the spillway (GIZ, 2012; Akker et al., 2015). WSWs may alter flood course and the distribution of fertile sediments and nutrients. Sedimentation could improve the physical and chemical properties of soils; builds up soil depth, increases crop production and keeps production costs low as no cost of fertilizer is involved (Tesfai and Stroosnijder, 2001; Tesfai and Sterk, 2002; Mesbah et al., 2016). This would create spatial difference in soil moisture and soil fertility that could determine the area of land to be cultivated and crop productivity and production (Schöning et al., 2012).

The rationale of introducing WSWs in the intervention woredas of Afar is that communities will be benefiting from rehabilitated lands through improved crop and / or fodder production and regeneration of the natural vegetation. However, this technology has some significant initial and recurrent investment costs. These technical solutions need to be embedded in a framework of business models that secure the sustained operation.

For the assessment of rentability it is not only necessary to look into potential revenue from crops produced, based on productive potential. The project assumes weirs to be part of a public goods approach with shared public and private contribution to secure societal welfare in the form of ecosystem services.

Added to this cost-benefit assessment needs to be an analysis of opportunity costs, resulting from non-intervention. Cost factors here to be considered should be (societal , environmental) costs of land degradation and costs associated with food aid for the highly food insecure region of Afar.

1.4. Objectives of the study

The main objective of this study is to assess the economic, environmental, and societal benefits of the investment on water spreading wires and compare these benefits against the costs using a cost-benefit analysis. The specific objectives include:

- ✓ Assessing the present values of the establishment and maintenance costs of water spreading wires

- ✓ Assessing the present values of the benefits of water spreading wires that can be derived from the positive impacts of the water spreading wires in land rehabilitation. Specifically, the study aims at assessing the economic benefits from crop production, the environmental benefits (reducing soil nutrient loss, water retained for productive use), and the social benefits in terms of rural employment, food security, and avoiding/reducing the reliance on food aid.
- ✓ Assess the net present value of investment in water spreading wires as a sustainable land management technology in the flood prone study sites.
- ✓ Assess the sensitivity of the results of the cost benefit analysis to changes in discount rate and prices of inputs and outputs.

2. Materials and methods

2.1. Study sites and data

The study was conducted in seven woredas of the Afar region (Chifra, Ewa, Awura, Gulina, Yalo, Teru and Kori) where the Afar Soil Rehabilitation Project (ASRP) has been introducing the WSW technology and constructed a total of 17 WSW cascades over the period 2015 to 2020. Table 1 below provides the WSW cascades in the seven woredas and rehabilitated land area around the WSWs.

Table 1. Area of rehabilitated land around WSW

Woreda	Local name	WSW Cascade	Year of establishment	Rehabilitated land in ha
Chifra	Shekayboru	CH1W	2014	222.83
	Tawalie	CH2W	2015	2480.08
	Geriro	CH3W	2016	4669.94
Ewa	Duba	EW1W	2017	53.97
Awura	Kalkalsa	AW1W	2014	1.86
	Lekaro	AW2W	2016	4793.48
	Udeladulu	AW3W	2014	7.19
	Gafonelie	AW5W	2014	9.78
Gulina	Tibiadora	GU1W	2016	232.99
Yalo	Muhurgolo	YA1W	2017	3166.66
	Eliligolo	YA2W	2016	2136.92
	Wokriedie	YA4W	2018	2231.47
	Wahalieali	YA5W	2018	13.04
Teru	Debaho	TE1W	2018	2349.37
Kori		KO1W	2018	2419.60
	Musile	KO2W	2018	3130.11
Total				27919.29*

Source: SDR Programme at GIZ and the estimation was based on a method using Landsat 8 data with a resolution of 30m x 30m from 2013-2019 for the month September (after the big rainy season) to indicate a positive development of the quality of vegetation by using the Normalized Difference Vegetation Index (NDVI). Note: * refers that 7996.42 ha of the rehabilitated area is within the protected areas.

The main data sources for this study are data provided by the project, which include establishment and maintenance costs of the WSWs, crop production potential in treated (around the WSW cascades) and control sites, and rehabilitated land areas around the WSW cascades that could be converted to productive use (Table 1). These data from the project are supplemented with other relevant data from the literature and other sources and used in the study. Tables 2-5 below summarize all the input and output data and data on prices used in the study.

Table 2. Maintenance and establishment costs of WSWs and cultivable land area around WSWs

Woreda	**WSW Cascade**	**Actual costs of WSWs (2015-2020) in Birr**			**Assumed annual maintenance costs for the period 2021-2032**	**Total cultivable land in ha around the WSW**
		Establishment	Maintenance	Total		
Chifra	CH1W	1540209	1373569	2913777	274714	159.01
	CH2W	1325238	400298	1725535	80060	1769.75
	CH3W	2062276	616200	2678476	123240	3332.41
Ewa	EW1W	5159354	1243040	6402394	248608	38.51
Awura	AW1W	1929448†	53820	1983268	10764	1.33
	AW2W	4194581	937260	5131841	187452	3420.57
	AW3W	1929448†	15000	1944448	3000	5.13
	AW5W	1929448†	22680	1952128	4536	6.98
Gulina	GU1W	4738861	1315005	6053867	263001	166.26
Yalo	YW1W	549249†	0	549249	191036	2259.69
	YW2W	549249	0	549249	229415	1524.88
	YW4W	3968822	1147076	5115898	229415	1592.35
	YW5W	2628957	594600	3223557	118920	9.30
Teru	TE1W	1950555	948600	2899155	189720	1676.48
Kori	KO1W	1062911†	125880†	1188791	25176	1726.59
	KO2W†	1006968†	231600†	1238568	46320	2233.61
	KO3W	2069879	357480	2427359	71496	NA
Total		38595453	9382108	47977561	2296873	**19922.85*** **
Total -†		30187981	9024628	39212609		

Source: *Accounts section of the project, ** data is based on Table 1 and the cultivable land is assumed to be the rehabilitated land area in Table 1 minus the area of rehabilitated land around the WSWs that is int the protected areas (27919.29 ha – 7996.42 ha= 19922.85 ha), annual maintenance costs for the period 2021-2030 are assumed to be one-fifth of the actual maintenance costs incurred over the period 2015-2020. Note: †refers the WSWs were not reported in the accounts because of the fact that they were established by other partners and we assumed actual cost incurred in establishing and maintaining similar cascades. The total actual establishment cost incurred by the project for the other 11 cascades was 30.19 million Birr whereas the maintenance cost was 9.025 million Birr. On average 21.73% of the establishment cost was incurred one year after the establishment of the cascades whereas the remaining close to 78% was incurred in the fourth year after establishment of the cascades.

Table 3. Crop yields and crop to biomass in ton/ha

Output	2015		2016		2017		2018		2019		2020		2021-2030	
	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
Grain														
Maize	2.42†	2.42†	2.62	0.79	3.54	1.85	3.95	1.44	4.20	2.10	0.00	0.00	3.58	1.72
Sorghum	3.95	1.26	1.26	3.95	6.20	1.26	1.35	1.26	4.30	0.96	0.00	0.00	3.95	1.20
Millet	3.80	1.50†	3.80	1.50	3.80	1.50	3.80	1.50	3.80	1.50	0.00	0.00	3.80	1.50
Cow pea	1.67	1.01*	1.67	1.01	2.30	1.01	1.34	1.01	1.36	1.01	0.00	0.00	1.67	1.01
Mung bean	1.20	0.41†	1.20	0.41	1.91	0.41	1.12	0.41	1.33	0.41	0.00	0.00	1.35	0.41
Crop residue														
Maize	3.63	3.63	3.92	1.19	5.31	2.77	5.93	2.16	6.30	3.15	7.10	7.10	5.36	2.58
Sorghum	7.90	2.52	2.52	7.90	12.40	2.52	2.70	2.52	8.60	1.91	6.10	6.10	7.90	2.40
Millet	7.60	2.99	7.60	2.99	7.60	2.99	7.60	2.99	7.60	2.99	3.60	3.60	7.60	2.99
Cow pea	1.67	1.01	1.67	1.01	2.30	1.01	1.34	1.01	1.36	1.01	4.50	4.50	1.67	1.01
Mung bean	1.20	0.41	1.20	0.41	1.91	0.41	1.12	0.41	1.33	0.41	4.50	4.50	1.35	0.41

Note: Except for 2020, crop biomass was estimated using grain to biomass conversion factors (Maize = 1.5, Sorghum = 2, Millet =2, Cow pea =1, Mung bean =1). All values of grain yield except for those with † and * are based on the data from the project on crop cut and measurements in treated and control sites. † refers average data from CSA Agricultural Sample survey data for the period 2003/04 to 2015/16 for Afar region), * refers data from Yosef (2014).

Table 4. Input quantities and prices

	Values	References
Seed quantity in kg/ha		
Maize	25	Georgis and Beshir (2010)
Sorghum	20	
Millet	10	Simon et al. (2020)
Cow pea	40	Georgis and Beshir (2010)
Mung bean	35	
Labor in days/ha/season†		
Maize	90	Based on FAO corp calander for Ethiopia
Sorghum	90	https://cropcalendar.apps.fao.org/#/home
Millet	70	and Qu and Hoa (2018)
Cow pea	75	
Mung bean	85	
Oxen power in numbers/ha/season	2	
Productive lifetime of oxen in years	5	Tilahun et al. (2007)
Crop prices in Birr/ton		
Maize	5640.00	FAOSTAT, Producers prices of crops
Sorghum	7640.00	
Millet	7610.00	
Cow pea	18410.00	
Mung bean	13930.00	
Prices of crop residues		
Maize	650.00	Dejene et al. (2014)
Sorghum	650.00	
Millet	800.00	
Cow pea	800.00	
Mung bean	800.00	
Wage	85.13	CSA (2016)
Ox	12675.00	FAOSTAT, Prices of live animals
Depreciation cost of 2 oxen in Birr/year*	2535.00	Tilahun et al. (2007)
Irrigation water price in Birr/1000s m3	4.75	Ayana et al. (2015)
Nutrient prices in Birr/ton**		
N (Nitrogen)	10175.54	Tilahun (2020)
P2O5 (Phosphorous)	26004.46	
K2O (Potasium)	10675.86	

Note: † refers that we considered 100% of the working days during land preparation and planting, about 18% of the working days during mid-season (growing season), and 33% of the working days during the harvesting season to calculate the effective number of working days for each crop type per season following the crop calendars. Following Tilahun et al. (2007), depreciation of oxen is calculated by assuming half of the live animal price for ox as book value after 5 years (Depreciation per year/ox = (Price of ox – Book value)/productive lifetime. * *refers in Tilahun et al (2020), prices of N, P2O5, and K2O nutrients were reported USD 337.41, USD 862.28 and USD 354.00 per ton of each nutrient respectively for the year 2012. In this study, GDP deflator of 2015/16 fiscal year (which equals 0,74276 (NBE, 2019)) and average exchange rate of 1USD=22.4 in 2016 (NBE, 2019), are used to calculate the nutrient prices for 2016.

Table 5. Conversion factors of environmental services (nutrients and water)

	Conversion factors	Source
Soil nutrients		
Ecosystem service trade off index= avoided NPK loss in kg /change in yield in kg due to SLM	0.016	Tilahun (2020)
Ratio of N to NPK from for Afar	0.278	
Ratio of P_2O_5 to NPK from for Afar	0.132	
Ratio of K_2O to NPK from for Afar	0.590	
Water footprint in m3/ton		
Maize	1222	Mekonnen and Hoekstra (2010)
Sorghum	3048	
Millet	4478	
Cow pea	6906	
Mung bean	6561	

2.2. Method of data analysis

The study used the net present value (NPV) as a main decision criterion to evaluate the economic returns from the scenario of investment in water spreading wires (WSW), which is considered as a sustainable land management for harnessing upstream flood water in Afar region, and the business as usual (BAU) scenario. NPV sums up the discounted annual flows of net benefits, which in turn is the difference of discounted benefits and discounted costs of land under WSWs and BAU over the life of the project. The NPV of a project is the amount by which it increases net worth in present value terms. Therefore, the decision rule is to accept a project, in this case a WSW project aimed at converting upstream flood water into productive use in the lowlands of Afar, with non-negative NPV and reject otherwise:

$$NPV_{ijk} = \sum_{t=0}^{T} \sum_{i=1}^{16} \left[\frac{B_{ijkt} - C_{ijkt}}{1 + r} \right] \quad (1)$$

Type equation here.

Where,

NPV_{ijk} is Net Present Value (in Birr) of cultivable land around WSW cascade i in woreda j under scenario k, where i ={1,2,3, ….16}, j = {1, 2, 3, …7}, and k= 1 for WSWs scenario and K=0 for the business-as-usual scenario.

B_{ijkt} is total benefit (in Birr) of cultivable land around the WSW cascade i in woreda j under scenario k at time t.

C_{ijkt} is total cost (in Birr) of cultivable land around the WSW cascade i in woreda j under scenario k at time t.

r is country level average real discount rate

t is time in years (t = 0, 1, 2, …T) where t=0 in year 2015, t=1 in year 2016, …, and T= 15 in year 2030.

Calculating NPV requires decision on three important parameters that may necessitate making some plausible and policy relevant assumptions. These are the discounting period, the flows of costs and benefits over the discount period, and the discount rate.

Discounting period: The first is to determine a reasonable period over which a country or the decision maker makes proper planning, implantation, and monitoring and evaluation of investments in the technology of WSWs.

In the determination of the discount period, taking national and global scale development goals and the time set to achieve such goals is also an important factor to consider so that the results of the study can be integrated to national and global scale development goals. In this regard, we have selected a period of 16 years (2015 to 2030), which is also the remaining time for the world and countries who have agreed to achieve the post-2015 sustainable Development Goals.

Rate of discount: In the evaluation of public projects in the framework of cost-benefit analysis, the choice of discount rate has been a focus of continuous debate in the economics literature. One of such a debate is whether to use the market interest rate, which is based on individual time preference, and others argue that we need to take into account intergenerational equity in which market rates of interest may be too high and inappropriate. So far there is no a one-fit-for all method or way of choosing the discount rate. Therefore, real interest rate data for Ethiopia as reported in the World Bank Database for the period 1991-2017is used for the analysis in this study. The geometric mean of this data was calculated to get the real discount rate of 0.59% that is used in the study.

Flow of costs and benefits: Once the project period is determined, the next step is to estimate the flows of costs and benefits for each year of the discounting period. Based on cost and benefit data (Tables 1 to 5), we determined the flows of costs and benefits over the discounting period.

Benefit cost ratios and annuity: As a second decision criterion, we also calculated the benefit cost ratio.

Sensitivity analysis: We conducted sensitivity analysis to observe the sensitivity of NPVs and BCR to changes in important parameters used in the cost benefit analysis. These include changes in the discount rates, cost of crop production including prices of crops, establishment and maintenance costs of the WSWs.

3. Results

3.1. Physical quantities of ecosystem services

Table 6 bellow shows the annual flows of ecosystem services from total cultivable land area of 19923 ha by land use (crop types) under adopting water spreading wires and a business as usual (BAU) scenarios for the period 2015-2030. The ecosystem services include grain, biomass (crop residues), soil nutrients, and water.

Grains of food crops and biomass of crop residues: The study indicated that equal allocation of the 19923 ha of cultivable land that has been rehabilitated because of the WSWs (see Table 2) to the production of the five crop types (Maize, Sorghum, Millet, Cow pean, and Mung bean) could yield 47260 tons of grains and 84810 tons of biomass of crop residues per year over the period 2015-2030 (Table 6). The average annual grain yield under the WSW scenario is 25460 tons (116.81%) higher than the yield under BAU scenario. The biomass of crop residues under the WSW scenario is 43160(103.63%) higher than the biomass under BAU scenario. The differences in grain yield as well as biomass of crop residues from land under WSW and BAU also varies by crop types. The highest difference was observed in the case of sorghum for which the cultivating all the cultivable land area under WSW scenario with Sorghum could yield 40012 tons (178.36%) higher grains and 80023 tons (152.54%) higher biomass of crop residues than the BAU scenario.

Soil nutrients: The study also indicated that WSWs could avoid the loss of about 402 tons of NPK (Nitrogen, Phosphorous, and Potassium) soil nutrients that could be lost through erosion, leaching and gaseous exchanges. The amount varies from 165 tons/year in the case of allocating all the land for cow pea production to 632 tons/year for all land cultivated with Sorghum (Table

6). Whereas in the case of BAU scenario, cultivating the land with the different crop types indicated could result the loss of the corresponding amounts of soil NPK nutrients.

Water footprint: The average annual water footprint of cultivating all the cultivable land (See Table 2) with the five crops is 177.22 million m3 for land under the WSW scenario whereas it is 82.58 million m3 under the BAU scenario. This indicate that WSWs could harness 177.22 million m3 of flood water to the production of 47260 tons of grains and 84810 tons of crop residues whereas under the BAU scenario it is only possible to harness less than half (or 82.58 million m3) of water that could produce less tons of grain and biomass of crop residues. Water footprint varies with the type of crop and is the highest for Millet and lowest for Mung bean (Table 6).

Further details on quantities of grain, biomass of crop residues, soil nutrients, and water footprint from cultivable land of the rehabilitated land around the 16 cascades of WSWs in the 7 woredas that can be cultivated with the five crops indicated can be consulted from Tables A1 to A7 of Annex 1.

Table 6. Annual flows of ecosystem services from total cultivable land area (19922.85ha) by land use under WSW and business as usual (BAU) scenarios for the period 2015-2030

Ecosystem service	**Scenario**	**Land use**					
		Maize	Sorghum	Millet	Cow pea	Mung bean	Average of the 5 corps
Grain in 1000s ton/year	WSW	61.03	62.45	61.98	29.20	21.64	47.26
	BAU	32.14	22.43	27.94	18.77	7.70	21.80
Biomass in 1000s ton/year	WSW	100.39	132.48	128.45	35.48	27.25	84.81
	BAU	57.05	52.46	60.37	25.05	13.31	41.65
N in ton/year	WSW	126.91	175.59	149.37	45.77	61.23	111.77
P2O5 in ton/year	WSW	60.25	83.27	70.84	21.70	29.07	53.03
K2O in ton/year	WSW	269.39	372.78	317.21	97.10	129.72	237.24
NPK in ton/year	WSW	456.54	631.64	537.41	164.57	220.02	402.04
Water in millions of m3/year	WSW	74.58	190.33	277.56	201.63	141.99	177.22
	BAU	39.28	68.38	125.14	129.59	50.54	82.58

3.2. Net present values, present values of costs and benefits

Net Present Values: The results of the cost-benefit analyses indicate that that equal allocation of the 19923 ha of cultivable land that has been rehabilitated because of the WSWs (see Table 2) to the production of the five crop types (Maize, Sorghum, Millet, Cow pean, and Mung bean) could generate 3.607 billion Birr (181064 Birr/ha) in net present value for the period 2015-2030. Whereas, in the case of the BAU scenario with no investment in WSW, the same land could generate a negative NPV of 2.28 billion (-11431 Birr/ha) considering all benefits and costs (See NPV 3 in Tables 7 and 8) over the same period (2015-2030). Under the BUA scenario, cultivating the land could provide positive NPV only if we consider zero cost of labor, which may be a case in rural areas of developing countries with imperfect labor market and zero opportunity cost of labor because of lack of access to off-farm employment opportunities. Under such a condition and the BAU scenario, the total land will generate 1.909 billion Birr (95816 Birr/ha) in net present value (see NPV 4 in Tables 7 and 8). The NPV varies with the type of crop and is the highest for Millet (5.118 billion or 255887 Birr/ha) and the lowest for Mung bean (0.999 billion or 50164 Birr/ha) (see NPV3 in Tables 7 and 8).

Present value of costs: The total cost of the 19923 ha of cultivable land that has been rehabilitated because of the WSWs (see Table 2) to the production of the five crop types (Maize, Sorghum, Millet, Cow pean, and Mung bean) is 3.840 billion Birr (192756 Birr/ha) in present

value for the period 2015-2030 (Tables 7 and 8). Of this present value of the total cost, the total establishment cost of the 16 WSW in the 7 woredas account only 0.94% of the present value of the total cost whereas the sum of the present values of maintenance costs that had been incurred over the last years (2016-2020) and the maintenance costs that will be incurred annually over the next years until 2030 account only 0.77% of the present value of the total cost. The remaining 98.29% of the present value of the total cost is accounted by the present value of the cost of crop production, which include cost for seed (2.53%), oxen power (40.28%), and labor (55.48%). Whereas in the BAU scenario while there are no costs for establishment and maintenance cost of WSWs, the crop production costs are same for both scenarios.

Present value of benefits: The total benefits from the 19923 ha of cultivable land that has been rehabilitated because of the WSWs (see Table 2) if used for the production of the five crop types (Maize, Sorghum, Millet, Cow pean, and Mung bean) is 7.448 billion Birr (373820 Birr/ha) in present value for the period 2015-2030 (Tables 7 and 8). Of this present value of the total benefits, benefits from crop production as direct use value (benefits) account 98.8% with revenues of 6.489 billion in present value from grains accounting 87.13% and revenues of 0.869 billion in present value from biomass of crop residues accounting 11.67% of the present values of total benefits. The remaining 0.089 million in present value or 1.2% of the present value of the total benefits is accounted by the value of avoided soil NPK loss (1.03% of the present value of total benefits) and the monetary value of the water footprint (0.17% of the present value of total benefits). The present value of total benefits varies with the type of crop and is the highest for Millet (8.571 billion or 430217 Birr/ha) and the lowest for Mung bean (4.969 billion or 249402 Birr/ha) (see Tables 7 and 8). In the case of the BAU scenarios, the present value of total benefits is 3.547 billion Birr (178033 Birr/ha), which is less by 3.901 billion Birr (195787 Birr/ha) compared to the present value of total benefits under the WSW scenario. While there no benefit in terms of avoided soil NPK nutrient loss under the BAU scenario, the benefits from crop production account 99.83% and the remaining 0.17% of the benefits is the monetary value of the water footprint.

The study also indicated that the benefit cost ratios 1.94 and 0.94 for the WSW and BAU scenarios respectively if we consider the opportunity cos of labor indicating that benefits of investing in WSWs outweighs the costs of the sum of the WSW investment costs and crop production costs whereas the benefits of the BAU scenario even could not cover the full cost of crop production. Benefit cost ratio varies with the type of crops and is the highest for millet and lowest for Mung bean (Table 7).

Table 7: Present values of costs, benefits, and net present values from total cultivable land area (19922.85 ha) by land use under WSW and BAU scenarios for the period 2015-2030 and real discount rate of 0.59%

S.No	Ecosystem service	Land use											
		Maize		Sorghum		Millet		Cow pea		Mung bean		Average of the 5 corps	
		WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
I	**PV of Costs in millions of Birr**												
1	WSWs establishment	36.01		36.01		36.01		36.01		36.01		36.01	
2	WSW maintenance	29.73		29.73		29.73		29.73		29.73		29.73	
3	**Total1**	**65.74**		**65.74**		**65.74**		**65.74**		**65.74**		**65.74**	
	Seed	43.01	43.72	46.60	46.60	23.21	23.21	224.57	224.57	148.71	148.71	97.22	97.36
	Oxen power	1547.01	1547.01	1546.54	1546.54	1546.54	1546.54	1546.54	1546.54	1547.01	1547.01	1546.73	1546.73
	Labor	2337.81	2337.81	2337.11	2337.11	1817.75	1817.75	1952.24	1952.24	2207.93	2207.93	2130.57	2130.57
4	**Crop production cost**	**3927.83**	**3928.55**	**3930.24**	**3930.24**	**3387.50**	**3387.50**	**3789.09**	**3723.35**	**3903.66**	**3903.66**	**3774.52**	**3774.66**
5	Crop production cost*	1590.02	1590.73	1593.14	1593.14	1569.75	1569.75	1836.85	1771.11	1695.72	1695.72	1643.95	1644.09
6	**Total cost (1+4)**	**3993.57**	**3928.55**	**3995.99**	**3930.24**	**3453.24**	**3387.50**	**3783.45**	**3723.35**	**3969.40**	**3903.66**	**3840.26**	**3774.66**
7	**Total cost * (1+5)**	**1655.76**	**1590.73**	**1658.88**	**1593.14**	**1635.49**	**1569.75**	**1831.21**	**1771.11**	**1761.46**	**1695.72**	**1709.69**	**1644.09**
II	**PV of Benefits in millions of Birr**												
8	Grain	5244.02	2743.97	7250.82	2623.00	7177.50	3253.83	8190.71	5285.99	4583.76	1641.82	6489.36	3109.72
9	Biomass	995.83	559.72	1310.46	523.01	1271.37	601.10	434.04	307.82	332.90	163.95	868.92	431.12
10	**Direct use values (8+9)**	**6239.85**	**3303.70**	**8561.28**	**3146.01**	**8448.87**	**3854.93**	**8624.75**	**5593.81**	**4916.66**	**1805.77**	**7358.28**	**3540.84**
11	N	19.58		27.05		23.02		7.04		9.44		17.23	
12	P2O5	23.75		32.78		27.90		8.54		11.46		20.89	
13	K2O	43.60		60.25		51.30		15.68		20.98		38.36	
14	NPK (11+12+13)	86.93		120.08		102.22		31.26		41.88		76.47	
15	Water footprint	5.40	3.28	13.74	4.97	20.07	9.10	14.60	9.42	10.26	3.67	12.81	6.09
16	**Indirect use values (14+15)**	**92.33**	**3.28**	**133.83**	**4.97**	**122.29**	**9.10**	**45.86**	**9.42**	**52.14**	**3.67**	**89.29**	**6.09**
17	Direct and indirect benefits (10+14+15)	**6332.18**	**3306.97**	**8695.10**	**3150.98**	**8571.15**	**3864.03**	**8670.61**	**5603.23**	**4968.80**	**1809.44**	**7447.57**	**3546.93**
III.	**Net present value in millions of Birr**												
18	NPV1	2246.28	-624.85	4565.29	-784.24	4995.63	467.44	4835.65	1870.46	947.26	-2097.89	3518.02	-233.82
19	NPV2	4584.09	1712.97	6902.40	1552.87	6813.38	2285.19	6787.89	3822.70	3155.20	110.05	5648.59	1896.75
20	NPV3	**2338.61**	**-621.57**	**4699.12**	**-779.26**	**5117.92**	**476.53**	**4881.51**	**1879.88**	**999.40**	**-2094.21**	**3607.31**	**-227.73**
21	NPV4	4768.75	1719.52	7170.05	1562.81	7057.95	2303.38	6879.61	3841.54	3259.47	117.39	5827.17	1908.93
V.	**BCR**	**1.59**	**0.85**	**2.18**	**0.80**	**2.48**	**1.14**	**2.29**	**1.50**	**1.25**	**0.46**	**1.94**	**0.94**

NPV1 = NPV that includes only direct use values (10-6), NPV2 = NPV that includes only benefits from direct use values but with zero opportunity cost of labor (10-7), NPV3= NPV includes indirect benefits (10-6+14+15), NPV4 = NPV including indirect benefits but with zero opportunity cost of labor (10-7+14+15), *Refers labor cost is not included

Table 8: Present values of costs, benefits, and net present values (**in Birr/ha)** from total cultivable land area (19922.85 ha) by land use under WSW and BAU scenarios for the period 2015-2030 and real discount rate of 0.59%

S.No	Ecosystem service	Land use											
		Maize		Sorghum		Millet		Cow pea		Mung bean		Average of the 5 corps	
		WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
I	**PV of Costs**												
1	WSWs establishment	1808		1808		1808		1808		1808		1808	
2	WSW maintenance	1492		1492		1492		1492		1492		1492	
3	**Total1**	3300		3300		3300		3300		3300		3300	
	Seed	2159	2195	2339	2339	1165	1165	11272	11272	7464	7464	4880	4887
	Oxen power	77650	77650	77626	77626	77626	77626	77626	77626	77650	77650	77636	77636
	Labor	117343	117343	117308	117308	91239	91239	97990	97990	110824	110824	106941	106941
4	**Crop production cost**	197152	197188	197273	197273	170031	170031	186889	186889	195939	195939	189457	189464
5	Crop production cost*	79809	79845	79965	79965	78791	78791	88899	88899	85114	85114	82516	82523
6	**Total cost (1+4)**	**200452**	**197188**	**200573**	**197273**	**173331**	**170031**	**190188**	**186889**	**199238**	**195939**	**192756**	**189464**
7	**Total cost * (1+5)**	83108	79845	83265	79965	82091	78791	92198	88899	88414	85114	85815	82523
II	PV of Benefits												
8	Grain	263216	137730	363945	131658	360265	163322	411121	265323	230075	82409	325724	156088
9	Biomass	49984	28095	65777	26252	63815	30171	21786	15450	16710	8229	43614	21639
10	**Direct use values (8+9)**	313201	165825	429722	157910	424079	193493	432907	280773	246785	90638	369339	177728
11	N	983		1358		1156		354		474		865	
12	P2O5	1192		1646		1400		428		575		1048	
13	K2O	2189		3024		2575		787		1053		1926	
14	NPK (11+12+13)	4363		6027		5131		1569		2102		3839	
15	Water footprint	271	164	690	250	1007	457	733	473	515	184	643	306
16	**Indirect use values (14+15)**	4634	164	6717	250	6138	457	2302	473	2617	184	4482	306
17	Direct and indirect benefits (10+14+15)	**317835**	**165989**	**436439**	**158159**	**430217**	**193950**	**435209**	**281246**	**249402**	**90822**	**373820**	**178033**
III.	**Net present value**												
18	NPV1	112749	-31363	229149	-39364	250749	23462	242719	93885	47547	-105301	176582	-11736
19	NPV2	230092	85980	346456	77944	341988	114702	340709	191875	158371	5524	283523	95205
20	NPV3	**117383**	**-31199**	**235866**	**-39114**	**255887**	**23919**	**245021**	**94358**	**50164**	**-105116**	**181064**	**-11431**
21	NPV4	239361	86309	359891	78443	354264	115615	345313	192821	163605	5892	292487	95816

NPV1 = NPV that includes only direct use values (10-6), NPV2 = NPV that includes only benefits from direct use values but with zero opportunity cost of labor (10-7), NPV3= NPV includes indirect benefits (10-6+14+15), NPV4 = NPV including indirect benefits but with zero opportunity cost of labor (10-7+14+15), *Refers labor cost is not included

3.3. Annuities

Annuity of Net Present Value: The study shows that equal allocation of the 19923 ha of cultivable land that has been rehabilitated because of the WSWs (see Table 2) to the production of the five crop types (Maize, Sorghum, Millet, Cow pean, and Mung bean) could generate 236.92 million Birr/year (11892 Birr/ha/year) in net present value each year over the period 2015-2030. Whereas, in the case of the BAU scenario with no investment in WSW, the same land could cause a loss of 14.96 million Birr/year (or net loss of 751Birr/ha/year) considering all benefits and costs (See NPV 3 in Tables 9 and 10) over the same period (2015-2030).

Annuity of the present value of costs: The annuity of total cost, which includes 2.37 million Birr/year establishment cost and 1.95 million Birr/year as maintenance costs of WSWs and crop production costs, is 252.22 million Birr/year (12660 Birr/ha/year) in present value for the period 2015-2030 (Tables 9 and 10). Whereas in the BAU scenario while there are no costs for establishment and maintenance cost of WSWs, the annuity of the present value of the crop production costs is 247.91 million Birr/year (12444 Birr/ha/year).

Annuity of present value of benefits: The annuity of the present value of benefits is 489.14 million Birr/year of which 483.28 million Birr/year is revenue from grain and biomass of crop residues and the remaining 5.86 million Birr/year is the sum of the values of avoided soil nutrient loss and value of the water footprint of the crops (Tables 9 and 10).

Table 9: Annuities of costs, benefits, and net present values from total cultivable land area (19922.85 ha) by land use under WSW and BAU scenarios for the period 2015-2030 and real discount rate of 0.59%

S.No	Ecosystem service	Land use											
		Maize		Sorghum		Millet		Cow pea		Mung bean		Average of the 5 corps	
		WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
I	**Annuity of costs in millions of Birr/year**												
1	WSWs establishment	2.37		2.37		2.37		2.37		2.37		2.37	
2	WSW maintenance	1.95		1.95		1.95		1.95		1.95		1.95	
3	**Total1**	4.32		4.32		4.32		4.32		4.32		4.32	
	Seed	2.82	2.87	3.06	3.06	1.52	1.52	14.75	14.75	9.77	9.77	6.39	6.39
	Oxen power	101.60	101.60	101.57	101.57	101.57	101.57	101.57	101.57	101.60	101.60	101.59	101.59
	Labor	153.54	153.54	153.50	153.50	119.39	119.39	128.22	128.22	145.01	145.01	139.93	139.93
4	**Crop production cost**	257.97	258.02	258.13	258.13	222.48	222.48	244.54	244.54	256.38	256.38	247.90	247.91
5	Crop production cost*	104.43	104.48	104.63	104.63	103.10	103.10	116.32	116.32	111.37	111.37	107.97	107.98
6	**Total cost (1+4)**	**262.29**	**258.02**	**262.45**	**258.13**	**226.80**	**222.48**	**248.86**	**244.54**	**260.70**	**256.38**	**252.22**	**247.91**
7	**Total cost * (1+5)**	108.75	104.48	108.95	104.63	107.42	103.10	120.64	116.32	115.69	111.37	112.29	107.98
II	**Annuity of benefits in millions of Birr/year**												
8	Grain	344.42	180.22	476.22	172.27	471.40	213.71	537.95	347.17	301.05	107.83	426.21	204.24
9	Biomass	65.40	36.76	86.07	34.35	83.50	39.48	28.51	20.22	21.86	10.77	57.07	28.31
10	**Direct use values (8+9)**	409.82	216.98	562.29	206.62	554.90	253.18	566.46	367.39	322.92	118.60	483.28	232.56
11	N	1.29		1.78		1.51		0.46		0.62		1.13	
12	P2O5	1.56		2.15		1.83		0.56		0.75		1.37	
13	K2O	2.86		3.96		3.37		1.03		1.38		2.52	
14	NPK (11+12+13)	5.71		7.89		6.71		2.05		2.75		5.02	
15	Water footprint	0.35	0.22	0.90	0.33	1.32	0.60	0.96	0.62	0.67	0.24	0.84	0.40
16	**Indirect use values (14+15)**	6.06	0.22	8.79	0.33	8.03	0.60	3.01	0.62	3.42	0.24	5.86	0.40
17	Direct and indirect benefits (10+14+15)	**415.88**	**217.20**	**571.08**	**206.95**	**562.94**	**253.78**	**569.47**	**368.01**	**326.34**	**118.84**	**489.14**	**232.96**
III.	**Annuity of net present value in millions of Birr/year**												
18	NPV1	147.53	-41.04	299.84	-51.51	328.10	30.70	317.60	122.85	62.21	-137.79	231.06	-15.36
19	NPV2	301.07	112.50	453.34	101.99	447.49	150.09	445.82	251.07	207.23	7.23	370.99	124.57
20	NPV3	**153.59**	**-40.82**	**308.63**	**-51.18**	**336.13**	**31.30**	**320.61**	**123.47**	**65.64**	**-137.54**	**236.92**	**-14.96**
21	NPV4	313.20	112.93	470.91	102.64	463.55	151.28	451.84	252.30	214.08	7.71	382.72	125.37

NPV1 = NPV that includes only direct use values (10-6), NPV2 = NPV that includes only benefits from direct use values but with zero opportunity cost of labor (10-7), NPV3= NPV includes indirect benefits (10-6+14+15), NPV4 = NPV including indirect benefits but with zero opportunity cost of labor (10-7+14+15), *Refers labor cost is not included

Table 10: Annuities of costs, benefits, and net present values **(in Birr/ha/year)** from total cultivable land area (19922.85 ha) by land use under WSW and BAU scenarios for the period 2015-2030 and real discount rate of 0.59%

S.No	Ecosystem service	Land use											
		Maize		Sorghum		Millet		Cow pea		Mung bean		Average of the 5 corps	
		WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
I	**Annuity of costs**												
1	WSWs establishment	119	0	119	0	119	0	119	0	119	0	119	0
2	WSW maintenance	98	0	98	0	98	0	98	0	98	0	98	0
3	**Total1**	**217**	**0**	**217**	**0**	**217**	**0**	**217**	**0**	**217**	**0**	**217**	**0**
	Seed	142	144	154	154	77	77	740	740	490	490	320	321
	Oxen power	5100	5100	5098	5098	5098	5098	5098	5098	5100	5100	5099	5099
	Labor	7707	7707	7705	7705	5992	5992	6436	6436	7279	7279	7024	7024
4	**Crop production cost**	12949	12951	12956	12956	11167	11167	12274	12274	12869	12869	12443	12444
5	Crop production cost*	5242	5244	5252	5252	5175	5175	5839	5839	5590	5590	5419	5420
6	**Total cost (1+4)**	**13165**	**12951**	**13173**	**12956**	**11384**	**11167**	**12491**	**12274**	**13086**	**12869**	**12660**	**12444**
7	**Total cost * (1+5)**	5458	5244	5469	5252	5392	5175	6055	5839	5807	5590	5636	5420
II	**Annuity of benefits**												
8	Grain	17288	9046	23903	8647	23661	10727	27002	17426	15111	5412	21393	10252
9	Biomass	3283	1845	4320	1724	4191	1982	1431	1015	1097	540	2864	1421
10	**Direct use values (8+9)**	20570	10891	28223	10371	27853	12708	28432	18441	16208	5953	24257	11673
11	N	65	0	89	0	76	0	23	0	31	0	57	0
12	P2O5	78	0	108	0	92	0	28	0	38	0	69	0
13	K2O	144	0	199	0	169	0	52	0	69	0	126	0
14	NPK (11+12+13)	287	0	396	0	337	0	103	0	138	0	252	0
15	Water footprint	18	11	45	16	66	30	48	31	34	12	42	20
16	**Indirect use values (14+15)**	304	11	441	16	403	30	151	31	172	12	294	20
17	Direct and indirect benefits (10+14+15)	**20875**	**10902**	**28664**	**10388**	**28256**	**12738**	**28584**	**18472**	**16380**	**5965**	**24552**	**11693**
III.	**Annuity of net present values**												
18	NPV1	7405	-2060	15050	-2585	16469	1541	15941	6166	3123	-6916	11598	-771
19	NPV2	15112	5647	22755	5119	22461	7533	22377	12602	10401	363	18621	6253
20	NPV3	**7709**	**-2049**	**15491**	**-2569**	**16872**	**1571**	**16092**	**6197**	**3295**	**-6904**	**11892**	**-751**
21	NPV4	15721	5669	23637	5152	23267	7593	22679	12664	10745	387	19210	6293

NPV1 = NPV that includes only direct use values (10-6), NPV2 = NPV that includes only benefits from direct use values but with zero opportunity cost of labor (10-7), NPV3= NPV includes indirect benefits (10-6+14+15), NPV4 = NPV including indirect benefits but with zero opportunity cost of labor (10-7+14+15), *Refers labor cost is not included

3.4. Sensitivity

The results of the sensitivity analysis to changes in the main parameters that affect NPV and BCR are summarized in Annex C in Tables C1 to C5. The results indicate that NPV and BCR are less sensitive to changes in the real discount rate (Table C1 in Annex C) and changes in establishment and maintenance costs of WSWs (Table C2 in Annex C). Whereas NPV and BCR are highly sensitive to changes in prices of inputs for crop production (seed, oxen power, and labor) (Table C3), prices of outputs (prices of grains, crop residues, soil nutrients, and water) (Table C4), and changes in productivity (Table C5).

A change in the real discount rate, for example 50% increase in the real discount rate, causes only a 2.77% decrease in the NPV from cultivating the 5 crops on the cultivable land under the WSWs scenario and BCR remains higher than one and only decreases from 1.94 to 1.93. A change in the cost of establishment and maintenance cost of the WSW, say a 50% increase in these costs, could only decrease the NPV by 0.91% and BCR by only 0.85%, indicating that both NPV and BCR are less sensitive to changes in the cost of WSWs.

Changes in the prices of all the three inputs for crop production (seed, oxen power, and labor) cause a relatively smaller changes in NPV and BCR for land under the WSW scenario and cultivated with crops other than Maize and Mung bean. For example, a 50% increase in the prices of all the three inputs would cause a relatively lower percentage decreases in NPVs from Sorghum (decrease by 41.82%), Millet (decrease by 33.09%) or Cow pea (decrease by 38.14%) production on cultivable land under the WSW scenario (Table C3 in Annex C).

Changes in either prices of outputs (grains of crops, crop residues, soil nutrients and water) or changes in crop productivity have significant effect on NPV and BCRs. While NPV is highly sensitive to changes in these parameters, BCR is also highly sensitive and changes almost proportionally to the changes in these parameters. For example, while a 50% increase in the prices of all the outputs increase NPV by 103.23% for land under the WSW scenario and cultivated with the 5 crops, BCR increases to 2.91, which is a 50% increase from the base case (Table C4). Similarly, while a 50% decrease in crop productivity decreases NPV by 102.23%, BCR decreases to 0.98, which is a 49.52% decrease (Table C5).

The results of the sensitivity analyses indicate that NPV and BCR are highly robust and less sensitive to changes in real discount rate and cost of establishment and maintenance costs of WSWs. Prices of inputs, prices of outputs and crop productivity are the major factors whose change cause NPV and BCRs to change by significant amounts.

4. Conclusions and policy implications

4.1. Conclusions

The main objective of this study is to assess the economic, environmental, and societal benefits of the investment on water spreading wires and compare these benefits against the costs using a cost-benefit analysis. The study is based on data provided by the project other relevant data from the literature and other sources.

The study showed that equal allocation of the 19923 ha of cultivable land that has been rehabilitated because of the WSWs to the production of the five crop types (Maize, Sorghum, Millet, Cow pean, and Mung bean) could provide the following benefits per year over the period 2015-2030.

- **47260** tons of grains (116.81%) higher than the yield under BAU scenario

- **84810** tons of biomass of crop residues (103.63% higher than the biomass under BAU scenario).
- Avoid the loss of **402** tons of NPK (Nitrogen, Phosphorous, and Potassium) soil nutrients that could be lost through erosion, leaching and gaseous exchanges.
- Harness **177.22 million m3** of flood water (114.60% higher than the water footprint of crop production under the BAU scenario) to the production of the 47260 tons of grains and 84810 tons of crop residues.

The monetary value of these benefits is 7.448 billion Birr (373820 Birr/ha) in present values, which is 109.98% higher than the present value of the benefits of the land under the BAU scenario. The annuity of the present value of benefits under the WSW scenario is 489.14 million Birr/year of which 483.28 million Birr/year is revenue from grain and biomass of crop residues and the remaining 5.86 million Birr/year is the sum of the values of avoided soil nutrient loss and value of the water footprint of the crops.

The study also indicated that present value of the cost the 19923 ha of cultivable land that has been rehabilitated because of the WSWs to the production of the five crop types is 3.840 billion Birr (192756 Birr/ha) in present value. The total establishment cost of the 16 WSW in the 7 woredas account only 0.94% of the present value of the 3.84 billion total cost whereas the sum of the present values of maintenance costs that had been incurred over the last years (2016-2020) and the maintenance costs that will be incurred annually over the next years until 2030 account only 0.77% of the present value of the total cost. The remaining 98.29% of the present value of the total cost is accounted by the present value of the cost of crop production.

Thus, investment in WSWs and the cultivation of the rehabilitated land around the WSWs could worth 3.607 billion Birr (181064 Birr/ha) in net present value over the indicated period (2015-2030) whereas cultivating the same land under the BAU could generate a negative NPV of 2.28 billion (-11431 Birr/ha) considering all benefits and costs. Under the BUA scenario, cultivating the land could provide positive NPV only if we consider zero cost of labor, which may be a case in rural areas of developing countries with imperfect labor market and zero opportunity cost of labor because of lack of access to off-farm employment opportunities. The annuity of the NPV under the WSW scenario is 236.92 million Birr/year (11892 Birr/ha/year) over the period 2015-2030. Whereas, in the case of the BAU scenario with no investment in WSW, the same land could cause a loss of 14.96 million Birr/year (or net loss of 751Birr/ha/year) considering all benefits and costs. The study also indicated that the benefit cost ratios 1.94 and 0.94 for the WSW and BAU scenarios respectively.

The results of the sensitivity analyses indicate that NPV and BCR are highly robust and less sensitive to changes in real discount rate and cost of establishment and maintenance costs of WSWs. Prices of inputs, prices of outputs and crop productivity are the major factors whose change cause NPV and BCRs to change by significant amounts.

4.2. Policy implications

Based on the results of this study and a previous study by Gumma et al. (2020) that reported that Afar has a potential of more than 550,000 ha of land that could be developed for agricultural production using seasonal flood water coming from the upstream highlands, this study has made further analyses on the costs and benefits of developing the 550,000 with water spreading wires. Installing water spreading wires on average costs 3300 Birr/ha in present values or about 217 Birr/ha/year in annuity terms of which about 119 Birr/ha/ year is as establishment cost and the remaining 98 Birr/ha/ year is for maintenance cost. Thus, developing the 550,000 ha would require close to 1.82 billion Birr in present value over the period until 2030. In other words, it requires close to 1 billion Birr over the first 5 years for establishing the structures of WSWs and

another 0.82 billion Birr (or 53.9 million birr per year) for maintenance cost. Such an investment coupled with full cultivation of the land with crops that require 6.844 billion Birr/year (or 12433 Birr/ha/year) as input costs could enable the region to produce 1.3 million tons of grains and 2.34 million tons of crop residues annually through avoiding 11.10 thousand tons of soil NPK nutrients and harnessing 4.89 billion m^3 of flood water as water footprint of the crop produce. The value of these benefits amounts 13.5 billion Birr/year in present value of which 11.78 billion Birr/year is the value of the 1.3 million tons of grains that could be produced from the 0.55 million ha of land.

Thus, the above analyses have important policy implication to employment, food security and reduction of the country's dependence on food aid. Both the establishment and maintenance of WSW structures as well as production of crops in the developed land could generate rural employment opportunities, food security, and reduction of the country's dependence on food aid. For example, assuming 0.3 tons of grains as the average annual requirement for food security per person, the 1.3 million tons of grains from the 0.55 million ha of land that could be developed to harness the flood water for agricultural production would feed close to 4.35 million people in the country. In addition, the 2.34 million tons of crop residues would serve as important source of animal feed, which is a critical constraint in the region whose livelihood very much depends on livestock production. In the case of food aid, Ethiopia is one of the poorest country's affected by recurrent drought and sever effects of climate change that for many years left the country to rely on humanitarian food aid. One of the ways out to such reliance on food aid is conserving the natural resources of the country and using water spreading wires as a means to reduce land degradation in the low land areas of Afar could create an important opportunity for harnessing the flood water to boost agricultural production as a pathway out of the country's reliance on food aid.

References

Akker EVD, Berdel W and Murele JN (2015) Reversing natural degradation into resilience: The Afar case Conference on International Research on Food Security, Natural Resource Management and Rural Development Tropentag 2015, Berlin, Germany.

Ayana M, Teklay G, Abate M, Eshetu F and Mada M (2015). Irrigation water pricing in Awash River Basin of Ethiopia: Evaluation of its impact on scheme-level irrigation performances and willingness to pay. African Journal of Agricultural Research 10(6): 554-565.

Belay K, Beyene F and Manig W (2005) Coping with drought among pastoral and agro-pastoral communities in eastern Ethiopia. Journal of Rural Development 28, 185–210.

Brown ME, Funk C, Pedreros D, Korecha D, Lemma M, Rowland J, Williams E and Verdin J (2017) A climate trend analysis of Ethiopia: examining subseasonal climate impacts on crops and pasture conditions. Climate Change 142, 169–182.

Central Statistical Agency of the Federal Democratic Republic of Ethiopia (CSA) (2016). Statistical Abstract: Average Retail Price of Goods and Services by Region and Selected Market Places. www.csa.gov.et.

Dejene M, Bediye S, Alemu D, Kitaw G, Kehaliw A, Assefa G and Tadesse G (2014) Livestock Feed Marketing in Ethiopia: Challenges and Opportunities for Livestock Development. Journal of Agricultural Science and Technology A 4 (2014) 155-168 Earlier title: Journal of Agricultural Science and Technology, ISSN 1939-1250.

Elisabeth V, Wolf B and Jemal NM (2015) Reversing natural degradation into resilience: the afar case. In Tielke E (ed.), Management of Land use Systems for Enhanced Food Security: Conflicts, Controversies and Resolutions. Berlin and Müncheberg: Cuvillier Verlag, p. 1. Available at www.tropentag.de/2015/proceedings/pro ceedings.pdf.

Fazzini M, Bisci C and Billi P (2015) The climate of Ethiopia, In Billi P (ed.) Landscapes and Landforms of Ethiopia. World Geomorphological Landscapes. Springer, Dordrecht, pp. 65–87. Food and Agricultural Organization of the United Nations (2021). FAOSTAT: Producer Prices. http://www.fao.org/faostat/en/#data/PP.

Georgis K, Beshir B (2010) Cereals and grain legumes for semi-arid areas of Ethiopia. Research Report 85, Ethiopian Institute of Agricultural Research, Addis Ababa, ISBN: 978-99944-53-54-2.

Getnet M, Amede T, Tilahun G, Legesse G, Gumma MK, Abebe H, Gashaw T, Ketter C, Akker EV (2020). Water spreading weirs altering flood, nutrient distribution and crop productivity in upstream–downstream settings in dry lowlands of Afar, Ethiopia. Renewable Agriculture and Food Systems 1–11. https://doi.org/10.1017/S1742170519000474.

GIZ (2012). Water-spreading Weirs for the Development of Degraded dry River Valleys: Experience from the Sahel. GIZ, Bonn and Eschborn, Germany. Available at https://www.Giz.De/fachexpertise/downloads/giz2013-en-waterspreading-weirs.Pdf.

Gumma MK, Amede T, Getnet M, Pinjarla B, Panjala P, Legesse G, Tilahun G, Van den Akker E, Berdel W, Keller C, Moses Siambi M and Whitbread AM (2020). Assessing potential locations for flood-based farming using satellite imagery: a case study of Afar region, Ethiopia. Renewable Agriculture and Food Systems 1–15. https://doi.org/10.1017/S1742170519000516.

Haile G and Fetene M (2012) Assessment of soil erosion hazard in Kilie catchment, East Shoa, Ethiopia. Land Degradation & Development 23, 293–306.

Hailu R, Tolossa D and Alemu G (2018) Water institutions in the Awash basin of Ethiopia: the discrepancies between rhetoric and realities. International journal of river basin management 16, 107–121.

Mekonnen MM and Hoekstra AY (2010) The Green, Blue and Grey Water Footprint of Crops and Derived Crop Products. UNESCO-Institute for Water Education (IHE). VALUE OF WATER RESEARCH REPORT SERIES NO. 47.

Mesbah SH, Mohammadnia M and Kowsar SA (2016) Long-term improvement of agricultural vegetation by floodwater spreading in the Gareh Bygone plain, Iran. In the pursuit of human security, is artificial recharge of groundwater more lucrative than selling oil? Hydrogeology Journal 24, 303–317.

National Bank of Ethiopia (NBE) (2019) Annual Report (2018/19). https://nbebank.com/wp-content/uploads/pdf/annualbulletin/report-2018-2019.pdf.

Qu C and Hao X (2018) Agriculture Drought and Food Security Monitoring over the Horn of Africa (HOA) from Space. DOI: 10.1109/Agro-Geoinformatics.2018.8476128.

Schöning A, Akker EVD, Wegner M and Ackermann K (2012) Water-spreading weirs: Improving resilience in dry areas. Available at http://www.tropentag.de/2012/abstracts/posters/714.pdf.

Simion T, Markos S and & Samuel T (2020) Evaluation of finger millet (Eleusine coracana (L). Gaertn.) varieties for grain yield in lowland areas of southern Ethiopia. Cogent Food & Agriculture, 6:1, https://doi.org/10.1080/23311932.2020.1788895.

Steenbergen FV, Haile AM, Alemehayu T, Alamirew T and Geleta Y (2011) Status and potential of spate irrigation in Ethiopia. Water Resour Management 25, 1899–1913.

Tesfai M and Sterk G (2002) Sedimentation rate on spate irrigated fields in Sheeb area, Eastern Eritrea. Journal of Arid Environments 50, 191–203.

Tesfai M and Stroosnijder L (2001) The Eritrean spate irrigation system. Agricultural Water Management 48, 51–60.

Tilahun M (2020) The Economics of Land Degradation Neutrality in Ethiopia: Empirical analyses and policy implications for the Sustainable Development Goals. Report for the Economics of Land Degradation Initiative in the framework of the "Reversing Land Degradation in Africa by Scaling-up Evergreen Agriculture" project. Available from: www.eld-initiave.org.

Tilahun M, Olschewski R, Kleinn C and Gebrehiwot K (2007) Economic analysis of closing degraded Boswellia papyrifera dry forest from human intervention: A study from Tigray, Northern Ethiopia. Forest Policy and Economics 9: 996–1005.

Van Steenbergen F, Haile AM, Alemehayu T, Alamirew T and Geleta Y (2011) Status and potential of spate irrigation in Ethiopia. Water Resources Management 25, 1899–1913.

Yoseph T (2014) Performance Evaluation of Cowpea (Vigna unguiculata L.) Varieties Under Moisture Conservation Practices for Yield and Yield Components at Alduba, Southern Ethiopia. Journal of Natural Sciences Research www.iiste.org ISSN 2224-3186 (Paper) ISSN 2225-092, Vol.4, No.7.

Appendices

Annex 1: Quantities of ecosystem services from cultivable land under WSW and BAU Scenarios

Table A1. Crop output in tons/year from cultivable land under WSW and business as usual (BAU) scenarios for the period 2015-2030

		Land area in ha	**Maize**		**Sorghum**		**Millet**		**Cow pea**		**Mung bean**		**Average of the five corps**	
			WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
Chifra	CH1W	159.01	518.06	256.54	556.77	179.10	539.00	223.10	240.51	149.82	192.00	61.48	409.27	174.01
	CH2W	1769.75	5643.13	2855.22	5925.54	1993.40	5837.65	2483.06	2607.21	1667.44	2055.62	684.26	4413.83	1936.68
	CH3W	3332.41	10217.47	5376.33	10587.33	3753.54	10512.45	4675.56	4771.59	3139.76	3680.44	1288.45	7953.86	3646.73
Kori	KO1W	1726.59	5014.58	2785.59	5271.22	1944.79	5156.73	2422.51	2378.63	1626.78	1779.43	667.57	3920.12	1889.45
	KO2W	2233.61	6487.11	3603.58	6819.11	2515.88	6671.01	3133.88	3077.12	2104.48	2301.97	863.60	5071.26	2444.28
Ewa	EW1W	38.51	109.72	62.13	113.13	43.38	112.56	54.04	52.67	36.29	38.65	14.89	85.35	42.15
Gulina	GU1W	166.26	514.68	268.23	540.06	187.27	530.75	233.27	241.12	156.65	187.36	64.28	402.79	181.94
Teru	TE1W	1676.48	5132.02	2704.74	5078.44	1888.34	5174.79	2352.19	2322.58	1579.56	1841.38	648.20	3909.84	1834.60
Awura	AW1W	1.33	4.35	2.14	4.69	1.49	4.53	1.86	2.02	1.25	1.61	0.51	3.44	1.45
	AW2W	3420.57	11165.84	5518.55	11070.26	3852.83	10831.58	4799.25	4954.76	3222.82	3828.98	1322.53	8370.28	3743.20
	AW3W	5.13	16.83	8.27	18.13	5.78	17.53	7.20	7.80	4.83	6.24	1.98	13.31	5.61
	AW5W	6.98	22.90	11.26	18.13	5.78	17.53	7.20	7.80	4.83	8.50	2.70	14.97	6.35
Yalo	YW1W	2259.69	6917.34	3645.65	6911.18	2545.25	7074.20	3170.47	3160.36	2129.05	2428.07	873.69	5298.23	2472.82
	YW2W	1524.88	4721.74	2460.15	4820.67	1717.58	4846.98	2139.49	2173.81	1436.72	1686.08	589.58	3649.86	1668.71
	YW4W	1592.35	4520.18	2569.00	4695.16	1793.58	4641.16	2234.15	3191.17	1500.29	1595.42	615.67	3728.62	1742.54
	YW5W	9.30	27.02	15.01	15.66	5.78	15.32	7.20	7.07	4.83	9.59	3.60	14.93	7.28
Total		**19922.85**	**61032.97**	**32142.40**	**62445.49**	**22433.76**	**61983.76**	**27944.43**	**29196.21**	**18765.38**	**21641.36**	**7702.99**	**47259.96**	**21797.79**

Table A2. Biomass of crop residue in tons/year from cultivable land under WSW and business as usual (BAU) scenarios for the period 2015-2030

		Land area in ha	**Maize**		**Sorghum**		**Millet**		**Cow pea**		**Mung bean**		**Average of the five corps**	
			WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
Chifra	CH1W	159.01	847.66	455.37	1174.17	418.83	1113.78	481.97	290.69	199.99	236.73	106.21	732.61	332.47
	CH2W	1769.75	9250.02	5068.16	12525.80	4661.52	12073.49	5364.32	3165.67	2225.89	2553.45	1182.09	7913.69	3700.40
	CH3W	3332.41	16804.97	9543.25	22445.14	8777.56	21774.69	10100.92	5823.15	4191.32	4617.86	2225.86	14293.16	6967.78
Kori	KO1W	1726.59	8288.04	4944.56	11200.70	4547.84	10701.94	5233.50	2923.47	2171.61	2265.13	1153.27	7075.86	3610.16
	KO2W	2233.61	10721.83	6396.53	14489.79	5883.32	13844.57	6770.32	3781.95	2809.31	2930.29	1491.92	9153.69	4670.28
Ewa	EW1W	38.51	181.66	110.29	240.95	101.44	233.78	116.74	64.83	48.44	49.49	25.72	154.14	80.53
Gulina	GU1W	166.26	845.80	476.13	1143.51	437.93	1098.91	503.95	293.58	209.11	234.13	111.05	723.19	347.63
Teru	TE1W	1676.48	8441.97	4801.04	10796.03	4415.84	10726.78	5081.60	2851.61	2108.58	2312.98	1119.79	7025.87	3505.37
Awura	AW1W	1.33	7.11	3.80	9.88	3.49	9.36	4.02	2.43	1.67	1.99	0.89	6.15	2.77
	AW2W	3420.57	18266.63	9795.71	23444.61	9009.76	22432.79	10368.13	6034.14	4302.20	4791.20	2284.75	14993.87	7152.11
	AW3W	5.13	27.51	14.69	38.21	13.51	36.22	15.54	9.42	6.45	7.69	3.43	23.81	10.72
	AW5W	6.98	37.45	19.99	38.21	13.51	36.22	15.54	9.42	6.45	10.46	4.66	26.35	12.03
Yalo	YW1W	2259.69	11378.74	6471.21	14683.87	5952.00	14656.83	6849.37	3873.41	2842.11	3063.72	1509.34	9531.32	4724.81
	YW2W	1524.88	7759.28	4366.90	10222.70	4016.52	10037.05	4622.08	2654.99	1917.91	2115.03	1018.53	6557.81	3188.39
	YW4W	1592.35	7486.88	4560.11	9997.41	4194.23	9640.60	4826.58	3693.64	2002.76	2043.35	1063.60	6572.38	3329.46
	YW5W	9.30	44.66	26.64	33.27	13.51	31.79	15.54	8.68	6.45	12.21	6.21	26.12	13.67
Total		**19922.85**	**100390.21**	**57054.37**	**132484.26**	**52460.81**	**128448.81**	**60370.15**	**35481.07**	**25050.24**	**27245.70**	**13307.33**	**84810.01**	**41648.58**

Table A3. Avoided nitrogen (N) nutrient loss in kg/year from cultivable land under WSW scenario for the period 2015-2030

Woreda	Casecade	Land area in ha	Land use					
			Maize	Sorghum	Millet	Cow pea	Mung bean	All the 5 crops
Chifra	CH1W	159.01	1145.42	1654.09	1383.57	397.24	571.66	1030.40
	CH2W	1769.75	12210.34	17221.77	14692.23	4115.96	6006.19	10849.30
	CH3W	3332.41	21202.99	29930.27	25564.06	7147.02	10476.34	18864.14
Kori	KO1W	1726.59	9762.40	14568.92	11975.19	3292.94	4869.68	8893.82
	KO2W	2233.61	12629.13	18847.09	15491.71	4259.91	6299.66	11505.50
Ewa	EW1W	38.51	208.40	305.51	256.32	71.77	104.07	189.21
Gulina	GU1W	166.26	1079.36	1545.15	1302.89	369.95	539.04	967.28
Teru	TE1W	1676.48	10630.90	13971.82	12362.23	3254.26	5225.87	9089.02
Awura	AW1W	1.33	9.68	13.98	11.70	3.36	4.82	8.71
	AW2W	3420.57	24733.66	31610.49	26420.07	7585.46	10977.62	20265.46
	AW3W	5.13	37.45	54.10	45.27	13.00	18.66	33.70
	AW5W	6.98	234.17	248.52	207.95	59.70	116.66	173.40
Yalo	YW1W	2259.69	14329.15	19121.67	17097.36	4516.86	6807.80	12374.57
	YW2W	1524.88	9905.18	13590.74	11858.10	3228.25	4802.40	8676.93
	YW4W	1592.35	8545.67	12708.23	10542.08	7405.63	4291.07	8698.54
	YW5W	9.30	241.64	198.78	163.39	44.93	120.53	153.85
Total		**19922.85**	**126905.56**	**175591.12**	**149374.11**	**45766.24**	**61232.07**	**111773.82**

Table A4. Avoided phosphorous (P_2O^5) nutrient loss in kg/year from cultivable land under WSW scenario for the period 2015-2030

Woreda	Casecade	Land area in ha	Land use					
			Maize	Sorghum	Millet	Cow pea	Mung bean	All the 5 crops
Chifra	CH1W	159.01	542.00	782.70	654.69	187.97	270.50	487.57
	CH2W	1769.75	5777.81	8149.17	6952.22	1947.63	2842.07	5133.78
	CH3W	3332.41	10033.04	14162.70	12096.66	3381.90	4957.30	8926.32
Kori	KO1W	1726.59	4619.47	6893.87	5666.54	1558.19	2304.28	4208.47
	KO2W	2233.61	5975.98	8918.25	7330.52	2015.75	2980.94	5444.29
Ewa	EW1W	38.51	98.61	144.56	121.29	33.96	49.24	89.53
Gulina	GU1W	166.26	510.74	731.15	616.51	175.06	255.07	457.71
Teru	TE1W	1676.48	5030.44	6611.32	5849.68	1539.89	2472.83	4300.83
Awura	AW1W	1.33	4.58	6.62	5.54	1.59	2.28	4.12
	AW2W	3420.57	11703.72	14957.77	12501.71	3589.36	5194.50	9589.41
	AW3W	5.13	17.72	25.60	21.42	6.15	8.83	15.95
	AW5W	6.98	207.31	220.02	184.10	52.86	103.28	153.51
Yalo	YW1W	2259.69	6780.41	9048.18	8090.30	2137.33	3221.38	5855.52
	YW2W	1524.88	4687.03	6431.00	5611.14	1527.57	2272.45	4105.84
	YW4W	1592.35	4043.73	6013.41	4988.41	3504.27	2030.49	4116.06
	YW5W	9.30	213.92	175.98	144.65	39.78	106.71	136.21
Total		**19922.85**	**60246.53**	**83272.30**	**70835.37**	**21699.25**	**29072.15**	**53025.12**

Table A5. Avoided potassium (K_2O) nutrient loss in kg/year from cultivable land under WSW scenario for the period 2015-2030

Woreda	Casecade	Land area in ha	Land use					
			Maize	Sorghum	Millet	Cow pea	Mung bean	All the 5 crops
Chifra	CH1W	159.01	2428.45	3506.90	2933.35	842.19	1211.99	2184.58
	CH2W	1769.75	25887.56	36512.47	31149.51	8726.39	12733.94	23001.98
	CH3W	3332.41	44953.19	63456.20	54199.26	15152.64	22211.26	39994.51
Kori	KO1W	1726.59	20697.60	30888.07	25389.01	6981.47	10324.37	18856.10
	KO2W	2233.61	26775.47	39958.37	32844.51	9031.59	13356.13	24393.21
Ewa	EW1W	38.51	441.83	647.72	543.43	152.16	220.64	401.16
Gulina	GU1W	166.26	2288.39	3275.92	2762.30	784.35	1142.84	2050.76
Teru	TE1W	1676.48	22538.95	29622.14	26209.59	6899.48	11079.54	19269.94
Awura	AW1W	1.33	20.52	29.64	24.80	7.12	10.22	18.46
	AW2W	3420.57	52438.69	67018.50	56014.10	16082.20	23274.04	42965.51
	AW3W	5.13	79.41	114.71	95.98	27.56	39.56	71.44
	AW5W	6.98	642.10	801.61	714.25	114.76	194.24	493.39
Yalo	YW1W	2259.69	30379.73	40540.52	36248.70	9576.36	14433.45	26235.75
	YW2W	1524.88	21000.32	28814.21	25140.78	6844.32	10181.73	18396.27
	YW4W	1592.35	18117.98	26943.15	22350.63	15700.94	9097.65	18442.07
	YW5W	9.30	701.42	651.07	584.92	176.77	208.74	464.58
Total		**19922.85**	**269391.63**	**372781.19**	**317205.13**	**97100.30**	**129720.35**	**237239.72**

Table A6. Avoided NPK nutrient loss in kg/year from cultivable land under WSW scenario for the period 2015-2030

Woreda	Casecade	Land area in ha	Land use					
			Maize	Sorghum	Millet	Cow pea	Mung bean	All the 5 crops
Chifra	CH1W	159.01	4115.88	5943.70	4971.61	1427.40	2054.15	3702.55
	CH2W	1769.75	43875.71	61883.41	52793.96	14789.98	21582.20	38985.05
	CH3W	3332.41	76189.22	107549.17	91859.98	25681.56	37644.90	67784.96
Kori	KO1W	1726.59	35079.47	52350.85	43030.73	11832.60	17498.33	31958.40
	KO2W	2233.61	45380.58	67723.71	55666.74	15307.25	22636.73	41343.00
Ewa	EW1W	38.51	748.84	1097.79	921.04	257.89	373.96	679.90
Gulina	GU1W	166.26	3878.50	5552.21	4681.71	1329.36	1936.96	3475.75
Teru	TE1W	1676.48	38200.29	50205.28	44421.50	11693.63	18778.24	32659.79
Awura	AW1W	1.33	34.78	50.24	42.04	12.07	17.33	31.29
	AW2W	3420.57	88876.07	113586.76	94935.88	27257.03	39446.17	72820.38
	AW3W	5.13	134.59	194.41	162.67	46.70	67.05	121.08
	AW5W	6.98	1083.59	1270.16	1106.29	227.32	414.17	820.31
Yalo	YW1W	2259.69	51489.30	68710.37	61436.36	16230.56	24462.63	44465.84
	YW2W	1524.88	35592.54	48835.95	42610.02	11600.14	17256.57	31179.04
	YW4W	1592.35	30707.38	45664.78	37881.12	26610.84	15419.21	31256.66
	YW5W	9.30	1156.98	1025.82	892.95	261.48	435.99	754.64
Total		**19922.85**	**456543.72**	**631644.61**	**537414.61**	**164565.80**	**220024.58**	**402038.66**

Table A7. Water footprint in millions of m^3/year by crop type from cultivable land under WSW and business as usual (BAU) scenarios for the period 2015-2030

		Land area in ha	**Maize**		**Sorghum**		**Millet**		**Cow pea**		**Mung bean**		**Average of the five corps**	
			WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
Chifra	CH1W	159.01	0.633	0.313	1.697	0.546	2.414	0.999	1.661	1.035	1.260	0.403	1.533	0.659
	CH2W	1769.75	6.896	3.489	18.061	6.076	26.141	11.119	18.005	11.515	13.487	4.489	16.518	7.338
	CH3W	3332.41	12.486	6.570	32.270	11.441	47.075	20.937	32.953	21.683	24.147	8.454	29.786	13.817
Kori	KO1W	1726.59	6.128	3.404	16.067	5.928	23.092	10.848	16.427	11.235	11.675	4.380	14.678	7.159
	KO2W	2233.61	7.927	4.404	20.785	7.668	29.873	14.034	21.251	14.534	15.103	5.666	18.988	9.261
Ewa	EW1W	38.51	0.134	0.076	0.345	0.132	0.504	0.242	0.364	0.251	0.254	0.098	0.320	0.160
Gulina	GU1W	166.26	0.629	0.328	1.646	0.571	2.377	1.045	1.665	1.082	1.229	0.422	1.509	0.689
Teru	TE1W	1676.48	6.271	3.305	15.479	5.756	23.173	10.533	16.040	10.908	12.081	4.253	14.609	6.951
Awura	AW1W	1.33	0.005	0.003	0.014	0.005	0.020	0.008	0.014	0.009	0.011	0.003	0.013	0.005
	AW2W	3420.57	13.645	6.744	33.742	11.743	48.504	21.491	34.218	22.257	25.122	8.677	31.046	14.182
	AW3W	5.13	0.021	0.010	0.055	0.018	0.079	0.032	0.054	0.033	0.041	0.013	0.050	0.021
	AW5W	6.98	0.028	0.014	0.055	0.018	0.079	0.032	0.054	0.033	0.056	0.018	0.054	0.023
Yalo	YW1W	2259.69	8.453	4.455	21.065	7.758	31.678	14.197	21.825	14.703	15.931	5.732	19.791	9.369
	YW2W	1524.88	5.770	3.006	14.693	5.235	21.705	9.581	15.012	9.922	11.062	3.868	13.649	6.322
	YW4W	1592.35	5.524	3.139	14.311	5.467	20.783	10.005	22.038	10.361	10.468	4.039	14.625	6.602
	YW5W	9.30	0.033	0.018	0.048	0.018	0.069	0.032	0.049	0.033	0.063	0.024	0.052	0.025
Total		**19922.85**	**74.582**	**39.278**	**190.334**	**68.378**	**277.563**	**125.135**	**201.629**	**129.594**	**141.989**	**50.539**	**177.219**	**82.585**

Annex B: Net present value, present values of costs and benefits, and annuities from cultivable land under WSW and BAU scenarios

Table B1. Net present value, present values of costs and benefits, and annuities from Maize cultivation on cultivable land under WSW and BAU scenarios for the period 2015-2030

Cascade	Scenario	Millions of Birr			Annuity in millions of Birr/year			1000s of Birr/ha			Annuity per ha in 1000s			BCR
		PVC	PVB	NPV	PVC	PVB	NPV	PVC	PVB	NPV	PVC	PVB	NPV	
CH1W	WSW	36.82	53.90	17.08	2.42	3.54	1.12	231.53	338.97	107.44	15.21	22.26	7.06	1.46
	BAU	31.35	26.70	-4.65	2.06	1.75	-0.31	0.19	167.92	167.73	0.01	11.03	11.02	0.85
CH2W	WSW	351.37	586.61	235.24	23.08	38.53	15.45	198.54	331.46	132.92	13.04	21.77	8.73	1.67
	BAU	348.91	297.18	-51.74	22.92	19.52	-3.40	2.46	167.92	165.46	0.16	11.03	10.87	0.85
CH3W	WSW	660.79	1060.56	399.78	43.40	69.66	26.26	198.29	318.26	119.97	13.02	20.90	7.88	1.60
	BAU	656.99	559.58	-97.42	43.15	36.75	-6.40	4.64	167.92	163.28	0.30	11.03	10.72	0.85
KO1W	WSW	341.81	519.48	177.67	22.45	34.12	11.67	197.97	300.87	102.90	13.00	19.76	6.76	1.52
	BAU	340.71	273.16	-67.56	22.38	17.94	-4.44	2.41	158.21	155.80	0.16	10.39	10.23	0.80
KO2W	WSW	442.01	672.02	230.01	29.03	44.14	15.11	197.89	300.87	102.98	13.00	19.76	6.76	1.52
	BAU	440.77	353.37	-87.39	28.95	23.21	-5.74	3.12	158.21	155.09	0.20	10.39	10.19	0.80
EW1W	WSW	16.20	11.36	-4.84	1.06	0.75	-0.32	420.55	294.97	-125.58	27.62	19.37	-8.25	0.70
	BAU	7.59	6.47	-1.13	0.50	0.42	-0.07	197.15	167.92	-29.23	12.95	11.03	-1.92	0.85
GU1W	WSW	41.20	53.44	12.24	2.71	3.51	0.80	247.83	321.43	73.61	16.28	21.11	4.83	1.30
	BAU	32.78	27.92	-4.86	2.15	1.83	-0.32	197.15	167.92	-29.23	12.95	11.03	-1.92	0.85
TE1W	WSW	335.16	532.59	197.44	22.01	34.98	12.97	199.92	317.68	117.77	13.13	20.86	7.73	1.59
	BAU	330.52	281.51	-49.01	21.71	18.49	-3.22	197.15	167.92	-29.23	12.95	11.03	-1.92	0.85
AW1W	WSW	2.34	0.45	-1.89	0.15	0.03	-0.12	1769.35	341.44	-1427.91	116.21	22.42	-93.78	0.19
	BAU	0.26	0.22	-0.04	0.02	0.01	0.00	197.15	167.92	-29.23	12.95	11.03	-1.92	0.85
AW2W	WSW	681.16	1158.39	477.23	44.74	76.08	31.34	199.14	338.65	139.52	13.08	22.24	9.16	1.70
	BAU	674.37	574.38	-99.99	44.29	37.72	-6.57	197.15	167.92	-29.23	12.95	11.03	-1.92	0.85
AW3W	WSW	2.98	1.75	-1.23	0.20	0.12	-0.08	581.78	341.44	-240.35	38.21	22.42	-15.79	0.59
	BAU	1.01	0.86	-0.15	0.07	0.06	-0.01	197.15	167.92	-29.23	12.95	11.03	-1.92	0.85
AW5W	WSW	3.37	2.57	-0.80	0.22	0.17	-0.05	482.85	368.42	-114.43	31.71	24.20	-7.52	0.76
	BAU	1.38	1.17	-0.20	0.09	0.08	-0.01	197.15	167.92	-29.23	12.95	11.03	-1.92	0.85
YW1W	WSW	447.84	717.87	270.02	29.41	47.15	17.73	198.19	317.68	119.50	13.02	20.86	7.85	1.60
	BAU	445.50	379.45	-66.06	29.26	24.92	-4.34	197.15	167.92	-29.23	12.95	11.03	-1.92	0.85
YW2W	WSW	303.33	490.23	186.90	19.92	32.20	12.27	198.92	321.49	122.56	13.06	21.11	8.05	1.62
	BAU	300.63	256.06	-44.58	19.75	16.82	-2.93	197.15	167.92	-29.23	12.95	11.03	-1.92	0.85
YW4W	WSW	321.09	467.95	146.86	21.09	30.73	9.65	201.65	293.88	92.23	13.24	19.30	6.06	1.46
	BAU	313.94	267.39	-46.55	20.62	17.56	-3.06	197.15	167.92	-29.23	12.95	11.03	-1.92	0.85
YW5W	WSW	6.11	3.00	-3.11	0.40	0.20	-0.20	657.03	322.26	-334.77	43.15	21.17	-21.99	0.49
	BAU	1.83	1.56	-0.27	0.12	0.10	-0.02	197.15	167.92	-29.23	12.95	11.03	-1.92	0.85
Total_WSW	Total_WSW	3993.59	6332.18	2338.59	262.29	415.88	153.59	200.45	317.83	117.38	13.17	20.87	7.71	1.59
Total_BAU	Total_BAU	3928.56	3306.97	-621.59	258.02	217.20	-40.82	197.19	165.99	-31.20	12.95	10.90	-2.05	0.84

Table B2. Net present value, present values of costs and benefits, and annuities from Sorghum cultivation on cultivable land under WSW and BAU scenarios for the period 2015-2030

Cascade	Scenario	Millions of Birr			Annuity in millions of Birr/yea			1000s of Birr/ha			Annuity per ha in 1000s			BCR
		PVC	PVB	NPV	PVC	PVB	NPV	PVC	PVB	NPV	PVC	PVB	NPV	
CH1W	WSW	36.84	77.85	41.01	2.42	5.11	2.69	231.71	489.62	257.91	15.22	32.16	16.94	2.11
	BAU	31.38	25.16	-6.22	2.06	1.65	-0.41	0.19	158.21	158.02	0.01	10.39	10.38	0.80
CH2W	WSW	351.69	827.16	475.47	23.10	54.33	31.23	198.72	467.39	268.67	13.05	30.70	17.65	2.35
	BAU	349.23	279.99	-69.24	22.94	18.39	-4.55	2.46	158.21	155.74	0.16	10.39	10.23	0.80
CH3W	WSW	661.39	1474.95	813.56	43.44	96.87	53.43	198.47	442.61	244.14	13.04	29.07	16.03	2.23
	BAU	657.60	527.21	-130.39	43.19	34.63	-8.56	4.64	158.21	153.56	0.30	10.39	10.09	0.80
KO1W	WSW	342.12	733.09	390.98	22.47	48.15	25.68	198.15	424.59	226.44	13.01	27.89	14.87	2.14
	BAU	340.71	273.16	-67.56	22.38	17.94	-4.44	2.41	158.21	155.80	0.16	10.39	10.23	0.80
KO2W	WSW	442.42	948.37	505.95	29.06	62.29	33.23	198.07	424.59	226.52	13.01	27.89	14.88	2.14
	BAU	440.77	353.37	-87.39	28.95	23.21	-5.74	3.12	158.21	155.09	0.20	10.39	10.19	0.80
EW1W	WSW	16.20	15.72	-0.49	1.06	1.03	-0.03	420.73	408.09	-12.64	27.63	26.80	-0.83	0.97
	BAU	7.60	6.09	-1.51	0.50	0.40	-0.10	197.33	158.21	-39.13	12.96	10.39	-2.57	0.80
GU1W	WSW	41.23	75.30	34.07	2.71	4.95	2.24	248.01	452.91	204.90	16.29	29.75	13.46	1.83
	BAU	32.81	26.30	-6.51	2.15	1.73	-0.43	197.33	158.21	-39.13	12.96	10.39	-2.57	0.80
TE1W	WSW	335.46	706.01	370.55	22.03	46.37	24.34	200.10	421.13	221.03	13.14	27.66	14.52	2.10
	BAU	330.83	265.23	-65.59	21.73	17.42	-4.31	197.33	158.21	-39.13	12.96	10.39	-2.57	0.80
AW1W	WSW	2.35	0.66	-1.69	0.15	0.04	-0.11	1769.53	494.51	-1275.02	116.22	32.48	-83.74	0.28
	BAU	0.26	0.21	-0.05	0.02	0.01	0.00	197.33	158.21	-39.13	12.96	10.39	-2.57	0.80
AW2W	WSW	681.78	1543.43	861.65	44.78	101.37	56.59	199.32	451.22	251.90	13.09	29.64	16.54	2.26
	BAU	674.99	541.16	-133.83	44.33	35.54	-8.79	197.33	158.21	-39.13	12.96	10.39	-2.57	0.80
AW3W	WSW	2.98	2.54	-0.45	0.20	0.17	-0.03	581.96	494.51	-87.46	38.22	32.48	-5.74	0.85
	BAU	1.01	0.81	-0.20	0.07	0.05	-0.01	197.33	158.21	-39.13	12.96	10.39	-2.57	0.80
AW5W	WSW	3.01	2.76	-0.25	0.20	0.18	-0.02	586.19	537.27	-48.92	38.50	35.29	-3.21	0.92
	BAU	1.01	0.81	-0.20	0.07	0.05	-0.01	197.33	158.21	-39.13	12.96	10.39	-2.57	0.80
YW1W	WSW	448.25	961.23	512.98	29.44	63.13	33.69	198.37	425.38	227.01	13.03	27.94	14.91	2.14
	BAU	445.91	357.50	-88.41	29.29	23.48	-5.81	197.33	158.21	-39.13	12.96	10.39	-2.57	0.80
YW2W	WSW	303.61	671.36	367.75	19.94	44.09	24.15	199.10	440.27	241.17	13.08	28.92	15.84	2.21
	BAU	300.91	241.25	-59.66	19.76	15.84	-3.92	197.33	158.21	-39.13	12.96	10.39	-2.57	0.80
YW4W	WSW	321.38	652.32	330.94	21.11	42.84	21.74	201.83	409.66	207.83	13.26	26.91	13.65	2.03
	BAU	314.22	251.92	-62.30	20.64	16.55	-4.09	197.33	158.21	-39.13	12.96	10.39	-2.57	0.80
YW5W	WSW	5.29	2.35	-2.94	0.35	0.15	-0.19	1031.61	458.81	-572.80	67.75	30.13	-37.62	0.44
	BAU	1.01	0.81	-0.20	0.07	0.05	-0.01	197.33	158.21	-39.13	12.96	10.39	-2.57	0.80
Total_WSW	Total_WSW	3996.00	8695.10	4699.11	262.45	571.08	308.63	200.57	436.44	235.87	13.17	28.66	15.49	2.18
Total_BAU	Total_BAU	3930.26	3150.98	-779.28	258.13	206.95	-51.18	197.27	158.16	-39.11	12.96	10.39	-2.57	0.80

Table B3. Net present value, present values of costs and benefits, and annuities from Millet cultivation on cultivable land under WSW and BAU scenarios for the period 2015-2030

Cascade	Scenario	Millions of Birr			Annuity in millions of Birr/year			1000s of Birr/ha			Annuity per ha in 1000s			BCR
		PVC	PVB	NPV	PVC	PVB	NPV	PVC	PVB	NPV	PVC	PVB	NPV	
CH1W	WSW	32.51	74.80	42.29	2.14	4.91	2.78	204.46	470.43	265.97	13.43	30.90	17.47	2.30
	BAU	27.04	30.85	3.80	1.78	2.03	0.25	0.19	194.01	193.82	0.01	12.74	12.73	1.14
CH2W	WSW	303.46	809.19	505.72	19.93	53.15	33.21	171.47	457.23	285.76	11.26	30.03	18.77	2.67
	BAU	301.00	343.35	42.34	19.77	22.55	2.78	2.46	194.01	191.55	0.16	12.74	12.58	1.14
CH3W	WSW	570.58	1454.43	883.85	37.47	95.52	58.05	171.22	436.45	265.23	11.25	28.67	17.42	2.55
	BAU	566.79	646.52	79.73	37.23	42.46	5.24	4.64	194.01	189.37	0.30	12.74	12.44	1.14
KO1W	WSW	295.07	711.81	416.75	19.38	46.75	27.37	170.90	412.26	241.37	11.22	27.08	15.85	2.41
	BAU	293.66	334.97	41.31	19.29	22.00	2.71	2.41	194.01	191.60	0.16	12.74	12.58	1.14
KO2W	WSW	381.55	920.84	539.29	25.06	60.48	35.42	170.82	412.26	241.44	11.22	27.08	15.86	2.41
	BAU	379.90	433.34	53.44	24.95	28.46	3.51	3.12	194.01	190.89	0.20	12.74	12.54	1.14
EW1W	WSW	15.15	15.53	0.37	1.00	1.02	0.02	393.48	403.15	9.67	25.84	26.48	0.64	1.02
	BAU	6.55	7.47	0.92	0.43	0.49	0.06	170.08	194.01	23.93	11.17	12.74	1.57	1.14
GU1W	WSW	36.70	73.47	36.76	2.41	4.83	2.41	220.76	441.88	221.12	14.50	29.02	14.52	2.00
	BAU	28.28	32.26	3.98	1.86	2.12	0.26	170.08	194.01	23.93	11.17	12.74	1.57	1.14
TE1W	WSW	289.77	715.10	425.33	19.03	46.97	27.93	172.85	426.55	253.70	11.35	28.01	16.66	2.47
	BAU	285.14	325.25	40.11	18.73	21.36	2.63	170.08	194.01	23.93	11.17	12.74	1.57	1.14
AW1W	WSW	2.31	0.63	-1.68	0.15	0.04	-0.11	1742.28	474.61	-1267.67	114.43	31.17	-83.26	0.27
	BAU	0.23	0.26	0.03	0.01	0.02	0.00	170.08	194.01	23.93	11.17	12.74	1.57	1.14
AW2W	WSW	588.57	1498.93	910.36	38.66	98.45	59.79	172.07	438.21	266.14	11.30	28.78	17.48	2.55
	BAU	581.78	663.62	81.84	38.21	43.59	5.38	170.08	194.01	23.93	11.17	12.74	1.57	1.14
AW3W	WSW	2.84	2.43	-0.41	0.19	0.16	-0.03	554.71	474.61	-80.10	36.43	31.17	-5.26	0.86
	BAU	0.87	0.99	0.12	0.06	0.07	0.01	170.08	194.01	23.93	11.17	12.74	1.57	1.14
AW5W	WSW	2.87	2.62	-0.24	0.19	0.17	-0.02	558.94	511.76	-47.18	36.71	33.61	-3.10	0.92
	BAU	0.87	0.99	0.12	0.06	0.07	0.01	170.08	194.01	23.93	11.17	12.74	1.57	1.14
YW1W	WSW	386.67	978.27	591.60	25.40	64.25	38.86	171.12	432.92	261.81	11.24	28.43	17.19	2.53
	BAU	384.33	438.40	54.06	25.24	28.79	3.55	170.08	194.01	23.93	11.17	12.74	1.57	1.14
YW2W	WSW	262.06	670.72	408.67	17.21	44.05	26.84	171.85	439.85	268.00	11.29	28.89	17.60	2.56
	BAU	259.36	295.84	36.48	17.03	19.43	2.40	170.08	194.01	23.93	11.17	12.74	1.57	1.14
YW4W	WSW	277.99	640.12	362.13	18.26	42.04	23.78	174.58	402.00	227.42	11.47	26.40	14.94	2.30
	BAU	270.83	308.93	38.10	17.79	20.29	2.50	170.08	194.01	23.93	11.17	12.74	1.57	1.14
YW5W	WSW	5.15	2.27	-2.88	0.34	0.15	-0.19	1004.36	441.95	-562.41	65.96	29.03	-36.94	0.44
	BAU	0.87	0.99	0.12	0.06	0.07	0.01	170.08	194.01	23.93	11.17	12.74	1.57	1.14
Total_WSW	Total_WSW	3453.24	8571.15	5117.91	226.80	562.94	336.13	173.33	430.22	256.89	11.38	28.26	16.87	2.48
Total_BAU	Total_BAU	3387.50	3864.03	476.53	222.48	253.78	31.30	170.03	193.95	23.92	11.17	12.74	1.57	1.14

Table B4. Net present value, present values of costs and benefits, and annuities from Cow pea cultivation on cultivable land under WSW and BAU scenarios for the period 2015-2030

Cascade	Scenario	Millions of Birr			Annuity in millions of Birr/year			1000s of Birr/ha			Annuity per ha in 1000s			
		PVC	PVB	NPV	PVC	PVB	NPV	PVC	PVB	NPV	PVC	PVB	NPV	BCR
CH1W	WSW	35.19	71.62	36.43	2.31	4.70	2.39	221.33	450.45	229.12	14.54	29.58	15.05	2.04
	BAU	29.73	44.73	15.01	1.95	2.94	0.99	0.19	281.33	281.14	0.01	18.48	18.46	1.50
CH2W	WSW	333.31	775.71	442.40	21.89	50.95	29.06	188.34	438.32	249.98	12.37	28.79	16.42	2.33
	BAU	330.85	497.89	167.04	21.73	32.70	10.97	2.46	281.33	278.87	0.16	18.48	18.32	1.50
CH3W	WSW	626.78	1418.25	791.47	41.17	93.15	51.98	188.09	425.59	237.51	12.35	27.95	15.60	2.26
	BAU	622.99	937.51	314.52	40.92	61.57	20.66	4.64	281.33	276.69	0.30	18.48	18.17	1.50
KO1W	WSW	324.19	706.07	381.89	21.29	46.37	25.08	187.76	408.94	221.18	12.33	26.86	14.53	2.18
	BAU	322.78	485.75	162.96	21.20	31.90	10.70	2.41	281.33	278.92	0.16	18.48	18.32	1.50
KO2W	WSW	419.22	913.41	494.20	27.53	59.99	32.46	187.69	408.94	221.25	12.33	26.86	14.53	2.18
	BAU	417.57	628.38	210.82	27.43	41.27	13.85	3.12	281.33	278.21	0.20	18.48	18.27	1.50
EW1W	WSW	15.80	15.63	-0.17	1.04	1.03	-0.01	410.35	405.92	-4.43	26.95	26.66	-0.29	0.99
	BAU	7.20	10.83	3.63	0.47	0.71	0.24	186.95	281.33	94.38	12.28	18.48	6.20	1.50
GU1W	WSW	39.51	71.70	32.19	2.59	4.71	2.11	237.62	431.24	193.61	15.61	28.32	12.72	1.81
	BAU	31.08	46.77	15.69	2.04	3.07	1.03	186.95	281.33	94.38	12.28	18.48	6.20	1.50
TE1W	WSW	318.05	689.47	371.42	20.89	45.28	24.39	189.71	411.26	221.55	12.46	27.01	14.55	2.17
	BAU	313.41	471.65	158.23	20.58	30.98	10.39	186.95	281.33	94.38	12.28	18.48	6.20	1.50
AW1W	WSW	2.33	0.60	-1.73	0.15	0.04	-0.11	1759.14	453.00	-1306.14	115.54	29.75	-85.78	0.26
	BAU	0.25	0.37	0.13	0.02	0.02	0.01	186.95	281.33	94.38	12.28	18.48	6.20	1.50
AW2W	WSW	646.26	1473.31	827.05	42.44	96.76	54.32	188.93	430.72	241.79	12.41	28.29	15.88	2.28
	BAU	639.47	962.31	322.85	42.00	63.20	21.20	186.95	281.33	94.38	12.28	18.48	6.20	1.50
AW3W	WSW	2.93	2.32	-0.61	0.19	0.15	-0.04	571.58	453.00	-118.58	37.54	29.75	-7.79	0.79
	BAU	0.96	1.44	0.48	0.06	0.09	0.03	186.95	281.33	94.38	12.28	18.48	6.20	1.50
AW5W	WSW	2.95	2.36	-0.59	0.19	0.16	-0.04	575.81	460.82	-114.98	37.82	30.27	-7.55	0.80
	BAU	0.96	1.44	0.48	0.06	0.09	0.03	186.95	281.33	94.38	12.28	18.48	6.20	1.50
YW1W	WSW	424.78	938.54	513.75	27.90	61.64	33.74	187.98	415.34	227.36	12.35	27.28	14.93	2.21
	BAU	422.44	635.72	213.28	27.75	41.75	14.01	186.95	281.33	94.38	12.28	18.48	6.20	1.50
YW2W	WSW	287.77	645.99	358.22	18.90	42.43	23.53	188.72	423.63	234.91	12.39	27.82	15.43	2.24
	BAU	285.07	429.00	143.92	18.72	28.18	9.45	186.95	281.33	94.38	12.28	18.48	6.20	1.50
YW4W	WSW	304.84	943.46	638.62	20.02	61.96	41.94	191.44	592.50	401.06	12.57	38.91	26.34	3.09
	BAU	297.69	447.98	150.29	19.55	29.42	9.87	186.95	281.33	94.38	12.28	18.48	6.20	1.50
YW5W	WSW	5.24	2.14	-3.10	0.34	0.14	-0.20	1021.22	417.61	-603.61	67.07	27.43	-39.64	0.41
	BAU	0.96	1.44	0.48	0.06	0.09	0.03	186.95	281.33	94.38	12.28	18.48	6.20	1.50
Total_WSW	Total_WSW	3789.15	8670.61	4881.45	248.86	569.47	320.60	190.19	435.21	245.02	12.49	28.58	16.09	2.29
Total_BAU	Total_BAU	3723.41	5603.23	1879.82	244.55	368.01	123.46	186.89	281.25	94.35	12.27	18.47	6.20	1.50

Table B5. Net present value, present values of costs and benefits, and annuities from Mung bean cultivation on cultivable land under WSW and BAU scenarios for the period 2015-2030.

Cascade	Scenario	Millions of Birr			Annuity in millions of Birr/year			1000s of Birr/ha			Annuity per ha in 1000s			BCR
		PVC	PVB	NPV	PVC	PVB	NPV	PVC	PVB	NPV	PVC	PVB	NPV	
CH1W	WSW	36.62	44.22	7.59	2.41	2.90	0.50	230.32	278.08	47.76	15.13	18.26	3.14	1.21
	BAU	31.16	14.44	-16.71	2.05	0.95	-1.10	0.19	90.82	90.63	0.01	5.97	5.95	0.46
CH2W	WSW	349.23	472.86	123.63	22.94	31.06	8.12	197.33	267.19	69.86	12.96	17.55	4.59	1.35
	BAU	346.77	160.73	-186.03	22.77	10.56	-12.22	2.46	90.82	88.36	0.16	5.97	5.80	0.46
CH3W	WSW	656.75	845.39	188.64	43.13	55.52	12.39	197.08	253.69	56.61	12.94	16.66	3.72	1.29
	BAU	652.96	302.66	-350.30	42.88	19.88	-23.01	4.64	90.82	86.18	0.30	5.97	5.66	0.46
KO1W	WSW	339.71	407.90	68.18	22.31	26.79	4.48	196.75	236.25	39.49	12.92	15.52	2.59	1.20
	BAU	338.31	156.81	-181.50	22.22	10.30	-11.92	2.41	90.82	88.41	0.16	5.97	5.81	0.46
KO2W	WSW	439.31	527.68	88.37	28.85	34.66	5.80	196.68	236.25	39.57	12.92	15.52	2.60	1.20
	BAU	437.66	202.86	-234.79	28.74	13.32	-15.42	3.12	90.82	87.70	0.20	5.97	5.76	0.46
EW1W	WSW	16.15	8.86	-7.29	1.06	0.58	-0.48	419.34	229.94	-189.40	27.54	15.10	-12.44	0.55
	BAU	7.55	3.50	-4.05	0.50	0.23	-0.27	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46
GU1W	WSW	41.00	43.06	2.06	2.69	2.83	0.14	246.62	259.00	12.38	16.20	17.01	0.81	1.05
	BAU	32.58	15.10	-17.48	2.14	0.99	-1.15	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46
TE1W	WSW	333.12	422.88	89.76	21.88	27.77	5.90	198.70	252.25	53.54	13.05	16.57	3.52	1.27
	BAU	328.49	152.26	-176.23	21.57	10.00	-11.57	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46
AW1W	WSW	2.34	0.37	-1.97	0.15	0.02	-0.13	1768.14	280.42	-1487.71	116.13	18.42	-97.71	0.16
	BAU	0.26	0.12	-0.14	0.02	0.01	-0.01	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46
AW2W	WSW	677.02	879.92	202.90	44.47	57.79	13.33	197.93	257.24	59.32	13.00	16.90	3.90	1.30
	BAU	670.23	310.66	-359.57	44.02	20.40	-23.62	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46
AW3W	WSW	2.98	1.44	-1.54	0.20	0.09	-0.10	580.57	280.42	-300.15	38.13	18.42	-19.71	0.48
	BAU	1.00	0.47	-0.54	0.07	0.03	-0.04	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46
AW5W	WSW	3.36	2.03	-1.33	0.22	0.13	-0.09	481.64	290.94	-190.70	31.63	19.11	-12.52	0.60
	BAU	1.37	0.63	-0.73	0.09	0.04	-0.05	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46
YW1W	WSW	445.11	557.17	112.07	29.23	36.59	7.36	196.98	246.57	49.59	12.94	16.19	3.26	1.25
	BAU	442.77	205.23	-237.54	29.08	13.48	-15.60	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46
YW2W	WSW	301.49	387.24	85.76	19.80	25.43	5.63	197.71	253.95	56.24	12.99	16.68	3.69	1.28
	BAU	298.79	138.49	-160.29	19.62	9.10	-10.53	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46
YW4W	WSW	319.16	365.51	46.35	20.96	24.01	3.04	200.44	229.54	29.11	13.16	15.08	1.91	1.15
	BAU	312.01	144.62	-167.39	20.49	9.50	-10.99	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46
YW5W	WSW	6.10	2.27	-3.83	0.40	0.15	-0.25	655.81	244.46	-411.35	43.07	16.06	-27.02	0.37
	BAU	1.82	0.84	-0.98	0.12	0.06	-0.06	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46
Total_WSW	Total_WSW	3969.45	4968.80	999.35	260.71	326.34	65.64	199.24	249.40	50.16	13.09	16.38	3.29	1.25
Total_BAU	Total_BAU	3903.71	1809.44	-2094.27	256.39	118.84	-137.55	195.94	90.82	-105.12	12.87	5.97	-6.90	0.46

Annex C. Sensitivity of NPV and BCR to changes in important parameters

Table C1. Sensitivity of NPV (in millions of Birr) and BCR to changes in real discount rate (r)

Land use	Summary	Base case (r = 0.59%)		50% increase in r		50% decrease in r		100% increase in r		100% decrease in r	
		WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
Maize	NPV	2338.59	-582.41	2272.53	-570.90	2407.02	-594.27	2208.74	-559.73	2477.91	-606.49
	Change in %			-2.82	-1.98	2.93	2.04	-5.55	-3.89	5.96	4.14
	BCR	1.59	0.85	1.58	0.85	1.59	0.85	1.58	0.85	1.59	0.85
	Change in %			-0.27	-0.03	0.27	0.03	-0.54	-0.05	0.53	0.06
Sorghum	NPV	4699.11	-779.28	4566.46	-763.28	4836.51	-795.78	4438.38	-747.76	4978.86	-812.80
	Change in %			-2.82	-2.05	2.92	2.12	-5.55	-4.04	5.95	4.30
	BCR	2.18	0.80	2.17	0.80	2.18	0.80	2.16	0.80	2.19	0.80
	Change in %			-0.39	-0.02	0.39	0.02	-0.78	-0.04	0.78	0.04
Millet	NPV	5117.91	476.53	4981.51	464.96	5259.14	488.53	4849.76	453.81	5405.40	500.99
	Change in %			-2.67	-2.43	2.76	2.52	-5.24	-4.77	5.62	5.13
	BCR	2.48	1.14	2.47	1.14	2.49	1.14	2.47	1.14	2.50	1.14
	Change in %			-0.34	-0.04	0.34	0.04	-0.67	-0.08	0.67	0.08
Cow pea	NPV	4881.45	1879.82	4756.44	1837.86	5010.91	1923.25	4635.69	1797.32	5144.98	1968.22
	Change in %			-2.56	-2.23	2.65	2.31	-5.03	-4.39	5.40	4.70
	BCR	2.29	1.50	2.28	1.50	2.29	1.51	2.28	1.50	2.30	1.51
	Change in %			-0.26	-0.04	0.26	0.04	-0.51	-0.07	0.51	0.08
Mung bean	NPV	999.35	-2094.27	960.62	-2050.07	1039.53	-2139.94	923.29	-2007.28	1081.22	-2187.14
	Change in %			-3.88	-2.11	4.02	2.18	-7.61	-4.15	8.19	4.43
	BCR	1.25	0.46	1.25	0.46	1.26	0.46	1.24	0.46	1.26	0.46
	Change in %			-0.36	-0.02	0.36	0.02	-0.72	-0.04	0.72	0.04
Average of 5 crops	NPV	3607.31	-219.92	3507.51	-216.28	3710.62	-223.64	3411.17	-212.73	3817.67	-227.44
	Change in %			-2.77	-1.65	2.86	1.69	-5.44	-3.27	5.83	3.42
	BCR	1.94	0.94	1.93	0.94	1.95	0.94	1.93	0.94	1.95	0.94
	Change in %			-0.32	-0.03	0.32	0.03	-0.64	-0.06	0.64	0.06

Table C2. Sensitivity of NPV (in millions of Birr) and BCR to changes in the cost (establishment and maintenance costs) of WSWs

Land use	Summary	Base case		50% increase in cost of WSWs		50% decrease in cost of WSWs		100% increase in cost of WSWs	
		WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
Maize	NPV	2338.59	-582.41	2305.72	-582.41	2371.46	-582.41	2272.85	-582.41
	Change in %			-1.41	0.00	1.41	0.00	-2.81	0.00
	BCR	1.59	0.85	1.57	0.85	1.60	0.85	1.56	0.85
	Change in %			-0.82	0.00	0.83	0.00	-1.62	0.00
Sorghum	NPV	4699.11	-779.28	4666.24	-779.28	4731.98	-779.28	4633.36	-779.28
	Change in %			-0.70	0.00	0.70	0.00	-1.40	0.00
	BCR	2.18	0.80	2.16	0.80	2.19	0.80	2.14	0.80
	Change in %			-0.82	0.00	0.83	0.00	-1.62	0.00
Millet	NPV	5117.91	476.53	5085.04	476.53	5150.78	476.53	5052.17	476.53
	Change in %			-0.64	0.00	0.64	0.00	-1.28	0.00
	BCR	2.48	1.14	2.46	1.14	2.51	1.14	2.44	1.14
	Change in %			-0.94	0.00	0.96	0.00	-1.87	0.00
Cow pea	NPV	4881.45	1879.82	4848.58	1879.82	4914.33	1879.82	4815.71	1879.82
	Change in %			-0.67	0.00	0.67	0.00	-1.35	0.00
	BCR	2.29	1.50	2.27	1.50	2.31	1.50	2.25	1.50
	Change in %			-0.86	0.00	0.88	0.00	-1.71	0.00
Mung bean	NPV	999.35	-2094.27	966.48	-2094.27	1032.22	-2094.27	933.61	-2094.27
	Change in %			-3.29	0.00	3.29	0.00	-6.58	0.00
	BCR	1.25	0.46	1.24	0.46	1.26	0.46	1.23	0.46
	Change in %			-0.82	0.00	0.84	0.00	-1.63	0.00
Average of 5 crops	NPV	3607.28	-219.92	3574.41	-219.92	3640.15	-219.92	3541.54	-219.92
	Change in %			-0.91	0.00	0.91	0.00	-1.82	0.00
	BCR	1.94	0.94	1.92	0.94	1.96	0.94	1.91	0.94
	Change in %			-0.85	0.00	0.86	0.00	-1.68	0.00

Table C3. Sensitivity of NPV (in millions of Birr) and BCR to changes in the prices of inputs for crop production

Land use	Summary	Base case		50% increase in prices of input for crop production		50% decrease in prices of input for crop production		100% increase in prices of input for crop production	
		WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
Maize	NPV	2338.59	-582.41	374.67	-2546.33	4302.51	1381.52	-1589.25	-4510.25
	Change in %			-83.98	337.21	83.98	-337.21	-167.96	674.42
	BCR	1.59	0.85	1.06	0.57	3.12	1.70	0.80	0.43
	Change in %			-32.97	-33.33	96.76	100.00	-49.59	-50.00
Sorghum	NPV	4699.11	-779.28	2733.98	-2744.40	6664.23	1185.85	768.85	-4709.53
	Change in %			-41.82	252.17	41.82	-252.17	-83.64	504.35
	BCR	2.18	0.80	1.46	0.53	4.28	1.60	1.10	0.40
	Change in %			-32.97	-33.33	96.76	100.00	-49.59	-50.00
Millet	NPV	5117.91	476.53	3424.16	-1217.22	6811.66	2170.28	1730.41	-2910.98
	Change in %			-33.09	-355.44	33.09	355.44	-66.19	-710.87
	BCR	2.48	1.14	1.67	0.76	4.87	2.28	1.25	0.57
	Change in %			-32.91	-33.33	96.26	100.00	-49.52	-50.00
Cow pea	NPV	4881.45	1879.82	3019.75	18.11	6743.16	3741.52	1158.05	-1843.59
	Change in %			-38.14	-99.04	38.14	99.04	-76.28	-198.07
	BCR	2.29	1.50	1.53	1.00	4.50	3.01	1.15	0.75
	Change in %			-32.95	-33.33	96.59	100.00	-49.56	-50.00
Mung bean	NPV	999.35	-2094.27	-952.51	-4046.12	2951.20	-142.41	-2904.36	-5997.98
	Change in %			-195.31	93.20	195.31	-93.20	-390.63	186.40
	BCR	1.25	0.46	0.84	0.31	2.46	0.93	0.63	0.23
	Change in %			-32.96	-33.33	96.74	100.00	-49.58	-50.00
Average of 5 crops	NPV	3607.28	-219.92	2006.19	-1974.69	5780.74	1799.85	118.92	-3861.96
	Change in %			-44.38	797.91	60.25	-918.41	-96.70	1656.07
	BCR	1.94	0.94	1.35	0.65	3.96	1.95	1.02	0.49
	Change in %			-30.37	-30.85	104.19	107.46	-47.63	-48.14

Table C4. Sensitivity of NPV (in millions of Birr) and BCR to changes in the prices of outputs (crops, biomass, nutrients, and water)

Land use	Summary	Base case		50% increase in prices of outputs		50% decrease in prices of outputs		100% increase in prices of outputs	
		WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
Maize	NPV	2338.59	-582.41	5504.68	1090.31	-827.50	-2255.13	8670.77	2763.03
	Change in %			135.38	-287.21	-135.38	287.21	270.77	-574.42
	BCR	1.59	0.85	2.38	1.28	0.79	0.43	3.17	1.70
	Change in %			50.00	50.00	-50.00	-50.00	100.00	100.00
Sorghum	NPV	4699.11	-779.28	9046.66	796.21	351.55	-2354.77	13394.21	2371.70
	Change in %			92.52	-202.17	-92.52	202.17	185.04	-404.35
	BCR	2.18	0.80	3.26	1.20	1.09	0.40	4.35	1.60
	Change in %			50.00	50.00	-50.00	-50.00	100.00	100.00
Millet	NPV	5117.91	476.53	9403.49	2408.54	832.33	-1455.49	13689.06	4340.56
	Change in %			83.74	405.44	-83.74	-405.44	167.47	810.87
	BCR	2.48	1.14	3.72	1.71	1.24	0.57	4.96	2.28
	Change in %			50.00	50.00	-50.00	-50.00	100.00	100.00
Cow pea	NPV	4881.45	1879.82	9216.76	4681.43	546.15	-921.80	13552.06	7483.05
	Change in %			88.81	149.04	-88.81	-149.04	177.62	298.07
	BCR	2.29	1.50	3.43	2.26	1.14	0.75	4.58	3.01
	Change in %			50.00	50.00	-50.00	-50.00	100.00	100.00
Mung bean	NPV	999.35	-2094.27	3483.75	-1189.55	-1485.05	-2998.99	5968.15	-284.83
	Change in %			248.60	-43.20	-248.60	43.20	497.20	-86.40
	BCR	1.25	0.46	1.88	0.70	0.63	0.23	2.50	0.93
	Change in %			50.00	50.00	-50.00	-50.00	100.00	100.00
Average of 5 crops	NPV	3607.28	-219.92	7331.07	1557.39	-116.50	-1997.23	11054.85	3334.70
	Change in %			103.23	-808.16	-103.23	808.16	206.46	-1616.32
	BCR	1.94	0.94	2.91	1.41	0.97	0.47	3.88	1.88
	Change in %			50.00	50.00	-50.00	-50.00	100.00	100.00

Table C5. Sensitivity of NPV (in millions of Birr) and BCR to changes in productivity

Land use	Summary	Base case		25% increase in productivity		25% decrease in productivity		50% increase in productivity		50% decrease in productivity	
		WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU	WSW	BAU
Maize	NPV	2338.59	-582.41	3899.31	231.63	777.87	-1396.45	5460.02	1045.67	-782.84	-2210.49
	Change in %			66.74	-139.77	-66.74	139.77	133.47	-279.54	-133.47	279.54
	BCR	1.59	0.85	1.98	1.06	1.19	0.64	2.37	1.27	0.80	0.44
	Change in %			24.65	24.33	-24.65	-24.33	49.29	48.67	-49.29	-48.67
Sorghum	NPV	4699.11	-779.28	6853.71	-10.70	2544.51	-1547.85	9008.31	757.87	389.90	-2316.42
	Change in %			45.85	-98.63	-45.85	98.63	91.70	-197.25	-91.70	197.25
	BCR	2.18	0.80	2.72	1.00	1.64	0.61	3.25	1.19	1.10	0.41
	Change in %			24.78	24.39	-24.78	-24.39	49.56	48.78	-49.56	-48.78
Millet	NPV	5117.91	476.53	7249.38	1431.22	2986.44	-478.17	9380.85	2385.91	854.97	-1432.86
	Change in %			41.65	200.34	-41.65	-200.34	83.29	400.69	-83.29	-400.69
	BCR	2.48	1.14	3.10	1.42	1.86	0.86	3.72	1.70	1.25	0.58
	Change in %			24.87	24.71	-24.87	-24.71	49.74	49.41	-49.74	-49.41
Cow pea	NPV	4881.45	1879.82	7029.57	3261.10	2733.34	498.54	9177.69	4642.37	585.22	-882.74
	Change in %			44.01	73.48	-44.01	-73.48	88.01	146.96	-88.01	-146.96
	BCR	2.29	1.50	2.86	1.88	1.72	1.13	3.42	2.25	1.15	0.76
	Change in %			24.77	24.65	-24.77	-24.65	49.55	49.30	-49.55	-49.30
Mung bean	NPV	999.35	-2094.27	2224.13	-1659.32	-225.43	-2529.21	3448.91	-1224.38	-1450.21	-2964.16
	Change in %			122.56	-20.77	-122.56	20.77	245.12	-41.54	-245.12	41.54
	BCR	1.25	0.46	1.56	0.57	0.94	0.35	1.87	0.69	0.63	0.24
	Change in %			24.65	24.04	-24.65	-24.04	49.30	48.08	-49.30	-48.08
Average of 5 crops	NPV	3607.31	-219.92	5451.22	650.79	1763.34	-1090.63	7295.16	1521.49	-80.59	-1961.33
	Change in %			51.12	-395.92	-51.12	395.92	102.23	-791.84	-102.23	791.84
	BCR	1.94	0.94	2.42	1.17	1.46	0.71	2.90	1.40	0.98	0.48
	Change in %			24.76	24.50	-24.76	-24.50	49.52	48.99	-49.52	-48.99