Engineering Science
2026, Vol. 11, No. 4, pp. 75–80
https://doi.org/10.11648/j.es.20261104.11

Research/Technical Note

Small Dam on the Dawe River for Irrigation and Fish Farming: An Ex-Ante Design and Economic Assessment

Gamachu Busa Meskele*

Institute of technology, Wollega University, Nekemte, Ethiopia

Abstract

A small earth-fill dam on the Dawe River, Oromia, Ethiopia, designed for irrigation plus fish farming, returns an indicative benefit–cost ratio of 1.54 (30 years, 10% discount rate) on a USD 3.54 million investment. Smallholders in the Dawe River area depend on rain-fed, single-season farming, while seasonal river flow goes unused in the dry months. This ex-ante assessment sets out a multipurpose scheme: a 12–15 m dam with 2–3 million m ³of live storage, about 300 ha of irrigated command area for roughly 600 households, and pond and reservoir-cage fish production of 27.5 t per year. Design parameters are planning assumptions to be confirmed by feasibility studies. At full development, gross incremental income is about USD 637,125 per year (USD 577,125 net of operation and maintenance), giving a present value of net benefits of USD 5.44 million and a simple payback of 6.1 years. Ramp-up years and benefits that are hard to price are excluded. The main risks are site hydrology and geology, cost overruns, weak operation and maintenance, and water-related disease. The paper describes the safeguards, institutional arrangements and monitoring indicators intended to manage them.

Keywords

Small Dam, Smallholder Irrigation, Reservoir Aquaculture, Nile Tilapia, Water User Association, Benefit–cost Analysis, Oromia, Ethiopia

1. Introduction

Rain-fed smallholder farming leaves Ethiopian households exposed to rainfall variability, and storing wet-season river flow is one of the few practical ways to close the dry-season gap [1, 2]. Agriculture employs most of the population and contributes a large share of national output [3], yet most production depends on rainfall. Government plans therefore prioritize small-scale irrigation, water harvesting and livelihood diversification [3].

Evidence links agricultural water investment to better welfare. Household-level analysis in Ethiopia associates access to agricultural water management with lower poverty, and water investments [4], together with education and markets, have been identified as pathways out of the poverty trap [5]. Reservoirs can also host fish farming, which adds protein and cash income from the same water, although the fishery status of Ethiopian reservoirs shows persistent management challenges [6].

The Dawe River in Oromia Regional State is typical of mid-sized rivers whose flow peaks from June to September and falls sharply or ceases in parts of the dry season [1]. Farmers along it cannot yet store or divert this water. This paper presents an ex-ante assessment of a small multipurpose dam on

*Correspondence: Gamachu Busa Meskele (bgemechu7628@gmail.com), Gamachu Busa Meskele (gemechubu@wollegauniversity.edu.et)

Received: 22 October 2026; **Accepted:** 31 October 2026; **Published:** 25 November 2026

Copyright: © The Author(s), 2026. Published by Science Publishing Group. This is an **Open Access** article, distributed under the terms of the Creative Commons Attribution 4.0 License (http://creativecommons.org/licenses/by/4.0/), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

the Dawe River that serves irrigation and fish farming together. It aims to:

1) describe the technical concept and planning parameters of the dam, irrigation scheme and fish-farming component;
2) estimate investment cost and indicative economic returns; and
3) set out the safeguards, institutional arrangements, risks and monitoring framework needed for the scheme to be sustained.

2. Study Area and Project Concept

The project site lies on the Dawe River in Hababo Guduru woreda, Kenate 01 kebele, Oromia Regional State, Ethiopia. The final dam site will be chosen through topographic, geological and hydrological surveys that balance storage capacity [7], foundation conditions, command-area elevation and the number of households affected [8].

Table 1. *Beneficiary groups.*

Group	Estimated number	Benefit
Smallholder households in the command area	600 households (about 3,600 people)	Irrigated plots of about 0.5 ha, two to three cropping seasons a year
Women farmers and women-headed households	At least 40% of participants	Plot allocation, training, cooperative membership and leadership roles
Landless or unemployed youth	About 150 people	Work in fish ponds, nursery, input supply, transport and processing
Downstream and wider community	About 5,000 people	Dry-season water for livestock, better markets and food availability

The scheme stores seasonal flow behind an earth-fill dam and releases it for irrigation of about 300 ha and for fish production in ponds and in the reservoir [9]. It is planned over 36 months and is intended to serve the groups in Table 1. All household and population figures are planning estimates to be verified by a baseline survey in the first three months [10].

3. Methods

This is an ex-ante planning assessment, not a field study. Design values are indicative planning assumptions, to be fixed by a feasibility study and detailed design by a qualified dam engineer.

Technical concept. An earth-fill embankment was selected because local soils are generally suitable, cost is lower than concrete, and local labor and contractors can build it. The final type will follow geotechnical investigation. Planned studies cover hydrology and sedimentation, topographic and bathymetric survey, geotechnical investigation, soil and land suitability, an Environmental and Social Impact Assessment (ESIA), and dam-safety review by the regional water authority.

Cost estimate. Costs are indicative, in US dollars, grouped into nine items plus a 10% contingency on the subtotal. They will be revised once surveys give quantities and local unit rates.

Economic analysis. A simplified benefit–cost analysis used a 30-year horizon and a 10% discount rate. Annual benefits at full development were:

1) irrigated crops: 300 ha × USD 2,000 incremental net income per hectare;
2) fish: 27.5 t × USD 3,000 per tonne gross, with a 45% net margin;
3) annual operation and maintenance (O&M): USD 60,000.

Benefit–cost ratio (BCR) is the present value of net benefits divided by total project cost. Simple payback is total cost divided by net annual benefit. Ramp-up years were not modelled.

4. Results

The proposed scheme costs USD 3,542,000 and yields an indicative BCR of 1.54, with the dam taking 40.9% of cost.

4.1. Dam Design Parameters

Main components are an embankment with riprap and grass cover, a chute or side-channel spillway with energy dissipation, a bottom outlet with gated intake tower for irrigation and environmental-flow release, an access road, instruments (level gauge, piezometers) and a caretaker house [11].

Table 2. Indicative design parameters (planning assumptions).

Parameter	Indicative value	Basis
Dam type	Earth-fill embankment	Local materials, cost, labor intensity
Dam height	12–15 m	To be fixed by storage-elevation curve
Crest length	250–400 m	Valley shape from topographic survey
Live storage	2.0–3.0 million m ³	Irrigation demand, losses and fish water
Design flood	1 in 100 years (check flood 1 in 1,000)	Standard for small dams of this class
Command area	About 300 ha	Soil suitability and canal elevation
Design life	50 years	With catchment sediment management

4.2. Irrigation Component

Water is conveyed through lined or semi-lined main, secondary and tertiary canals to field turnouts [12]. Surface (furrow and basin) irrigation is used first, with drip kits for willing vegetable growers. Table 3 gives the cropping pattern; shares sum to a cropping intensity of 2.2.

A Water User Association (WUA) will run a rotational schedule agreed by farmers and collect fees for O&M. Extension covers improved seed, fertilizer, integrated pest management, post-harvest handling and cooperative marketing [13].

Table 3. Indicative cropping pattern.

Season	Main crops	Share of command area
Meher (main rains, supplementary irrigation)	Maize, teff, sorghum, pulses	100%
Belg / early dry season	Onion, tomato, potato, cabbage, pepper	70%
Late dry season	Vegetables, fodder, early-maturing maize	50%
Perennials / orchards	Banana, mango, avocado, coffee shade trees	10% (within plots)

4.3. Fish-farming Component

Nile tilapia is the primary candidate species, with African catfish and common carp as options, subject to fisheries-authority guidance on non-native species [6]. The target is 27.5 t per year by year 3 after commissioning [14].

Table 4. Fish-farming elements.

Element	Description
Pond culture	About 30 earthen ponds of about 500 m ² gravity-fed from the irrigation canal, with locally made feed
Reservoir cage culture	About 40 floating cages run by cooperatives, only where depth and water quality allow

Element	Description
Nursery / hatchery	Small hatchery supplying fingerlings to members and nearby farmers
Feed	Farm-level formulation from bran, oilseed cake and vegetable waste
Post-harvest and marketing	Cold storage, ice, simple processing; sales to towns, hotels and schools via a cooperative

Pond outflow can be reused for irrigation, and cage stocking density will be limited to protect dissolved oxygen.

4.4. Implementation

The 36-month plan has four stages: inception and design (months 1–9), land acquisition and procurement (months 6–12), construction (dam months 13–28; canals months 20–30; fish facilities months 24–30), and commissioning with handover (months 30–36). Earthworks are timed for the dry season (about October to May) to avoid flood interruption.

4.5. Investment Cost and Financing

Proposed financing is USD 3,010,700 (85%) from a funding partner, USD 354,200 (10%) from government in cash and in kind, and USD 177,100 (5%) from the community in labor and local materials [9].

Table 5. Indicative budget (USD).

Item	Cost (USD)	Share
Dam civil works	1,450,000	40.9%
Irrigation infrastructure (300 ha)	620,000	17.5%
Fish-farming infrastructure	260,000	7.3%
Project management, supervision, M&E	240,000	6.8%
Feasibility, surveys, ESIA, design	180,000	5.1%
Land acquisition and livelihood restoration	150,000	4.2%
Catchment management	120,000	3.4%
Capacity building and training	110,000	3.1%
Equipment, vehicles, instruments	90,000	2.5%
Subtotal	3,220,000	90.9%
Contingency (10% of subtotal)	322,000	9.1%
Total	3,542,000	100.0%

4.6. Economic Results

At full development, benefits are USD 600,000 from crops and USD 37,125 from fish net income (USD 82,500 gross sales), totalling USD 637,125 per year. After USD 60,000 O&M, net annual benefit is USD 577,125.

Table 6. Indicative economic indicators (30 years, 10% discount rate).

Indicator	Result
Total project cost	USD 3,542,000
Present value of net benefits	USD 5,440,508

Indicator	Result
Benefit–cost ratio	1.54
Simple payback (at full benefits)	6.1 years

The present value equals net benefits received for 30 years from year 1; since construction and ramp-up take years, the real return will be lower. Nutrition, livestock watering, drought resilience, reduced migration and reduced erosion are not valued.

5. Discussion

The economic case rests on irrigated crops, which supply 94% of annual benefit (USD 600,000 of USD 637,125), so extension support and market access matter more than fish output. The result also assumes farmers reach high-value crop yields of USD 2,000 net per hectare.

Risks. The most serious risks are medium-likelihood, high-impact: insufficient flow or poor geology, cost overruns, community conflict over land or water, and weak O&M after handover. Studies are completed before any construction contract so that dam size, site or command area can still change. A 10% contingency and fixed-price contracts address cost, and a fee system, WUA training, a spare-parts fund and two years of post-handover support address O&M.

Sedimentation. Siltation shortens reservoir life; sediment deposition in northern Ethiopian reservoirs is well documente [11]. The design therefore treats 250 ha of catchment and sets a target of under 1% storage loss per year, checked by annual bathymetric survey.

Health. Higher malaria incidence has been reported among children living near dams in northern Ethiopia [10]. Canal maintenance, health education, bed nets and coordination with the health office are planned, along with attention to schistosomiasis near reservoirs and canals.

Institutions. Water institutions do not work as one-size-fits-all solutions, so WUA by-laws, fees and plot allocation will be set with the community, with quotas so that at least 40% of plot holders and members are women.

Environment and fish. An environmental flow will be released for downstream users and ecosystems, agrochemicals near the reservoir will be restricted, and only species approved by the fisheries authority will be stocked. Reservoir fisheries in Ethiopia face management challenges [15], which is why cage culture is limited to suitable water and run through cooperatives.

Sustainability and monitoring. After month 36 the project team provides support for two further seasons before full transfer to the community and Woreda. Progress is tracked against indicators such as 300 ha irrigated, 600 households served, cropping intensity rising from 1.0 to 2.2, 27.5 t of fish per year, at least 85% WUA fee collection and household farm income up 100% by year 4, disaggregated by sex, age and household type [16].

Limitations. All parameters are planning assumptions without site data. The economic analysis ignores ramp-up, uses one benefit scenario and has no sensitivity tests; the feasibility study should add these.

6. Conclusions

On current planning assumptions, a small multipurpose dam on the Dawe River is economically attractive, with a BCR of 1.54 and payback of 6.1 years on USD 3,542,000, and it could serve about 600 households. These figures are indicative. Before construction, the feasibility study must confirm site hydrology and geology, add ramp-up and sensitivity analysis, and complete the ESIA. Community management through a WUA and fish cooperatives is central to sustaining the benefits.

Abbreviation

BCR	Benefit–Cost Ratio
ESIA	Environmental and Social Impact Assessment
O&M	Operation and Maintenance
WUA	Water User Association
M&E	Monitoring and Evaluation
ha	Hectare
m	Metre
m^3	Cubic Metre
t	Metric Tonne
USD	United States Dollar

Author Contributions

Gamachu Busa Meskele: Conceptualization, Data curation, Formal Analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Writing – original draft

Conflicts of Interest

The author declares no conflicts of interest.

References

[1] A. A. Berhanu, Z. B. Ayele, and D. C. Dagnew, "Impact of climate-smart agricultural practices on smallholder farmers' resilience in Ethiopia," J. Agric. Food Res., vol. 16, no. March, p. 101147, 2024, https://doi.org/10.1016/j.jafr.2024.101147

[2] S. S. Manugula and G. B. Meskele, "Evaluation of the influencing factors and causes of pedestrian crashes at both intersections and along roadways using Regression Analysis : A case of Nekemte, Ethiopia" Journal of Emerging Technologies and Innovative Research, 2024, 11(2), 225–234.

[3] R. Meinzen-Dick, "Beyond panaceas in water institutions," Proc. Natl. Acad. Sci. U. S. A., vol. 104, no. 39, pp. 15200–15205, 2007, https://doi.org/10.1073/pnas.0702296104

[4] R. P. Spencer, "Correspondence," Nucl. Med. Commun., vol. 13, no. 12, pp. 897–901, 1992, https://doi.org/10.1680/geot.1968.18.1.92

[5] Y. E. Anteneh, S. W. Mamo, A. W. Yisheber, and D. T. Seyneh, "Current fishery status in Ethiopian reservoirs: challenges and management," Fish. Aquat. Sci., vol. 26, no. 5, pp. 305–317, 2023, https://doi.org/10.47853/FAS.2023.e26

[6] S. RC and O. H, "Landslides: Processes, Prediction and Land Use. Washington, DC: American Geophysical Union.," Am. Geophys. Union, 2006.

[7] G. Meskele, "Enhancing Agricultural Resilience Through Climate-Smart Practices: A Case Study of Smallholder Farmers in Horro Guduru Wallaga Zone, Hababo Guduru Woreda," Int. J. Econ. Energy Environ., vol. 11, no. 4, pp. 117–125, 2026, https://doi.org/10.11648/j.ijeee.20261104.12

[8] N. Haregeweyn et al., "Reservoirs in Tigray (Northern Ethiopia): Characteristics and sediment deposition problems," L. Degrad. Dev., vol. 17, no. 2, pp. 211–230, 2006, https://doi.org/10.1002/ldr.698

[9] Gerishu Bati Waritu, & Abayomi Samuel Oyekeale. (2024). Farmers' Participation in Climate Smart Agriculture Initiatives and Adoption Decisions in the Arsi and East Shewa Zones of Oromia Region, Ethiopia. Research in Agriculture Livestock and Fisheries, 11(1), 79-91. https://doi.org/10.3329/ralf.v11i1.73088

[10] L. Ayalew and H. Yamagishi, "The application of GIS-based logistic regression for landslide susceptibility mapping in the Kakuda-Yahiko Mountains, Central Japan," Geomorphology, vol. 65, no. 1–2, pp. 15–31, 2005, https://doi.org/10.1016/j.geomorph.2004.06.010

[11] A. W. Bishop, "The use of the slip circle in the stability analysis of slopes," Geotechnique, vol. 5, no. 1, pp. 7–17, 1955, https://doi.org/10.1680/geot.1955.5.1.7

[12] D. Varnes, "Slope Movement Types and Processes," Spec. Rep., vol. 176, pp. 11–33, 1978.

[13] M. H. Gudina and E. A. Alemu, "Factors influencing small holder farmers adoption of climate SMART agriculture practices in Welmera Woreda, Central Ethiopia," Front. Clim., vol. 6, no. May, 2024, https://doi.org/10.3389/fclim.2024.1322550

[14] N. Caine, "The rainfall intensity-duration control of shallow landslides and debris flows.," Geogr. Ann. Ser. A, vol. 62, no. 1–2, pp. 23–27, 1980, https://doi.org/10.1080/04353676.1980.11879996

[15] G. B. Meskele, "Role of Geospatial Surveying in Enhancing Crop Quality through Land Assessment and Resource Optimization : A Case Study of Smallholder Farmers in Guduru District," vol. 7, no. 3, pp. 101–109, 2026.

[16] D. Conway and E. L. F. Schipper, "Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia," Glob. Environ. Chang., vol. 21, no. 1, pp. 227–237, 2011, https://doi.org/10.1016/j.gloenvcha.2010.07.013