



Identifying possible areas for level *Fanya juu* terrace in Central Ethiopia

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Abstract

Background: The costs of soil erosion are worsening in developing countries. In recent decades, government sectors and various organizations in Ethiopia have been implementing watershed management campaigns. Despite these achievements, soil loss from cropland has not been reversed to the productive limit. Therefore, this study attempts to provide information on appropriate sites for the level *Fanya juu* terrace in croplands located in Sodo watershed, central Ethiopia.

Methods: A spatial layer of soil loss, land use/land cover, slope, and topographic wetness index was managed using a multi-criteria decision analysis (MCDA) system. The suitability class of each layer was made based on the national guideline for soil and water conservation published in 2016. Then the analytical hierarchy process was used to obtain the relative weight of each layer. Finally, the suitability map was generated using the weighted combination method.

Result: The result shows that 5.5%, 3.2%, and 40.8% of the study area were highly, moderately, and less suitable for the level *Fanya juu* terrace. The remaining is not appropriate at all. Among ground-truthing points collected on an existing terrace, 95% falls into a less suitable class. Assertively, the MCDA provided imperative information. According to pieces of evidence from the level *Fanya juu* terrace, soil loss is estimated to be reduced by 77% in areas highly susceptible to soil erosion.

Conclusion: Implementing appropriate soil and water conservation measures in target locations is a central part of watershed management campaigns. In the long run, this could be effective where farmers' acceptance, proper execution, and regular maintenance of the structure are kept sustainable. In general, the procedure followed and results found in this paper can enable an informed decision on farmers' managed cropland to tackle soil erosion and boost productivity.

Keywords: Soil loss, Level *Fanya juu*, Suitability, Effectiveness

Highlights

- Soil erosion on cropland is close to twice higher than the soil loss at a tolerable rate in Ethiopia.
- Croplands prone to soil erosion were prioritized for level *Fanya juu* terrace construction.
- Multi-criteria evaluation has effectively identified suitable areas against existing terraces.
- The MCDA approach is found to be applicable to ease exhaustive field tasks of practitioners.

1. Background

Soil erosion, worsened by land use/ land cover (LU/LC) change, is the most common form of land degradation that covers 23% of Ethiopia (Gebreselassie et al. 2016). A gradual change in LU/LC features was observed, sourced from demographic changes, poverty, topography, and land policy, which are contributing to environmental changes such as biodiversity loss, soil erosion, local climate, and hydrological regime (Desta and Fetene 2020; Musie et al. 2020; Woldeesenbet et al. 2020).

In East Africa, the estimated mean annual gross soil loss by water erosion amounts to 4 billion tons with a mean soil loss rate of 6.3 tons/ha/yr, of which 50% originates from Ethiopia. The study adds that cropland contributed 34.8 tons/ha/yr of mean soil loss in Ethiopia (Almaw et al. 2020).

The share of cropland over the total estimated soil loss accounted for 86% in the northwest (Alemu and Melesse 2020), 42.6% in the Beshillo catchment, Blue Nile basin (Yesuph and Dagneu 2019), and 11% in the Meki River sub-basin, the central rift valley lake basin (Woldeesenbet et al. 2020). However, the rate of soil loss from cultivated land varies between 42 and 300 tons/ha/yr (Gebreselassie et al. 2016). Similarly, the upper catchments of the Meki River sub-basin are facing severe degradation irrespective of the land-use systems (Woldeesenbet et al. 2020). The risk of soil erosion in the north-eastern watershed is reported to be very high to severe levels (Woldeesenbet et al. 2020). Besides, 9% and 6.5% of the study area stated high to very high soil loss severity levels, respectively (Tadesse and Tefera 2020). In general, the annual cost of land degradation associated with LU/LC is estimated at \$4.3 billion (Gebreselassie et al. 2016).

Ethiopia has 500–700 years of implementing traditional soil and water conservation (SWC) measures (Wolka et al. 2018) and five decades of experience introducing physical SWC to degraded highlands (Herweg and Ludi 1999). Moreover, during the SWC campaign in the 1970s and 1980s, the transitional government (1980) promoted farmers' level development and conservation of forests by planting trees within its locality (Federal Negarit Gazeta 1980). In 2010, the Ethiopian government launched a community-managed land restoration program through physical and biological SWC measures in more than 3,000 watersheds, aiming to enhance agricultural productivity (Mekuria 2020). Also, the "Green Legacy" initiative was recently launched in June 2019 to rehabilitate degraded lands, increase forest cover and/or services, and tackle food insecurity (Getahun 2020).

Adopted SWC measures deposited 54–74% of soil loss and boosted soil quality in the northern Ethiopian highland (Subhatu et al. 2017). The outcomes of the SWC measure can be explained as 1) short-term (e.g., runoff control and moisture retention) and 2) medium-term (e.g., vegetation cover and soil fertility improvement) biophysical outcomes (Assefa and Kessler 2018). Numerous studies reported the positive short-term return of SWC measures (Wolanchu 2015; Saiz et al. 2016; Subhatu et al. 2017, 2018; Assefa and Kessler 2018; Sultan et al. 2018; Wolka et al. 2018; Alemu and Melesse 2020; Tekla et al. 2020; Mekonnen 2021). Vegetation cover and soil fertility improvements from SWC measures were also recently attested in Ethiopia (Assefa and Kessler 2018; Tekla et al. 2020). Over half a decade, over 3 million hectares of degraded forest land are under area enclosure; smallholder plantations cover 0.8 million ha, and state-owned industrial plantations stagnate at under 0.25 million ha (Lemenih and Kassa 2014). The global community proposed to rehabilitate 350 million hectares by 2030, and Ethiopia made the largest pledge - to restore 22 million hectares (Kassa 2018).

However, despite the efforts made, a steadily increasing rate of land degradation persists (Gebreselassie et al. 2016). Similarly, in recent studies, the

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effectiveness of SWC measures was not as expected after 4-5 decades of execution (Mekonnen 2021). In the Blue Nile basin, where the level *Fanya juu* terrace is implemented, soil loss in the treated catchment was not as expected and yet exceeds the tolerable limit in the Ethiopian Highland (Subhatu et al. 2017, 2018). Despite attentive farmers, the program was hardly effective for farmers who didn't obtain a short-term physical benefit (Assefa and Kessler 2018).

Level *Fanya juu* terrace is a contour terrace where the riser is built (throw up) at the shoulder of the ditch to block soil movement and enhance soil moisture content, which further developed into a bench terrace (Herweg and Ludi 1999; Hurni et al. 2016). Level *Fanya juu* terrace is reported as, among other SWC measures, the most effective and feasible in (i) reducing soil loss by nearly 70%, retaining sediment, moisture, and soil organic matter at the deposition zone (Herweg and Ludi 1999; Matere et al. 2016; Saiz et al. 2016; Subhatu et al. 2018; Hailelassie et al. 2020; Mekonnen 2021), (ii) reversing the slope gradient nearly by half (Subhatu et al. 2018; Sultan et al. 2018; Wolka et al. 2018; Mekonnen 2021), (iii) improved crop yield and household income (Wolka et al. 2018; Hailelassie et al. 2020; Tekla et al. 2020; Mekonnen 2021), and vegetation cover (Wolka et al. 2018; Tekla et al. 2020).

Nevertheless, the construction of the SWC measure needs considerable effort to not fall below technical standards (Assefa and Kessler 2018) and applicability ranges (Hurni et al. 2016). In almost all parts of Ethiopia, dozens of literature are published on the extent and severity of soil erosion and the urgency of SWC measures. However, to support decision-makers and

development agents (DAs), information on the applicability of SWC measures is rare (Kibret et al. 2020). Therefore, this study has aimed (i) to identify areas suitable for level *Fanya juu* terrace based on national SWC guidelines using the spatial-MCDA technique, and (ii) to estimate potential reduction in soil loss from *Fanya juu* terrace. This would be pertinent to ease the tasks of DAs (extension workers) and support initiatives working on tackling soil erosion and enhancing agricultural productivity.

2. Materials and Methods

2.1. Study area description

Sodo watershed (Fig.1) is found in the north-eastern tip of Meki River sub-basin, the central rift valley lake basin (Desta and Fetene 2020; Tadesse and Tefera 2020). The study watershed is found in the Sodo district with a total population of 181,499 (male 89,869 and Female 91,630) and a density of 205.9 people per square km (CSA 2019). Hence, the majority of the population are farmers and live in rural areas.

Sodo watershed covers 8,054 ha. The land use/land cover (LUL/C) feature shared with cropland (61%), bareland (16%), woodland (12%), forest (7%), settlement/residents (3%), and Enset (*Ensete ventricosum* Welw. Cheesman) (1%) (Tadesse and Tefera 2020).

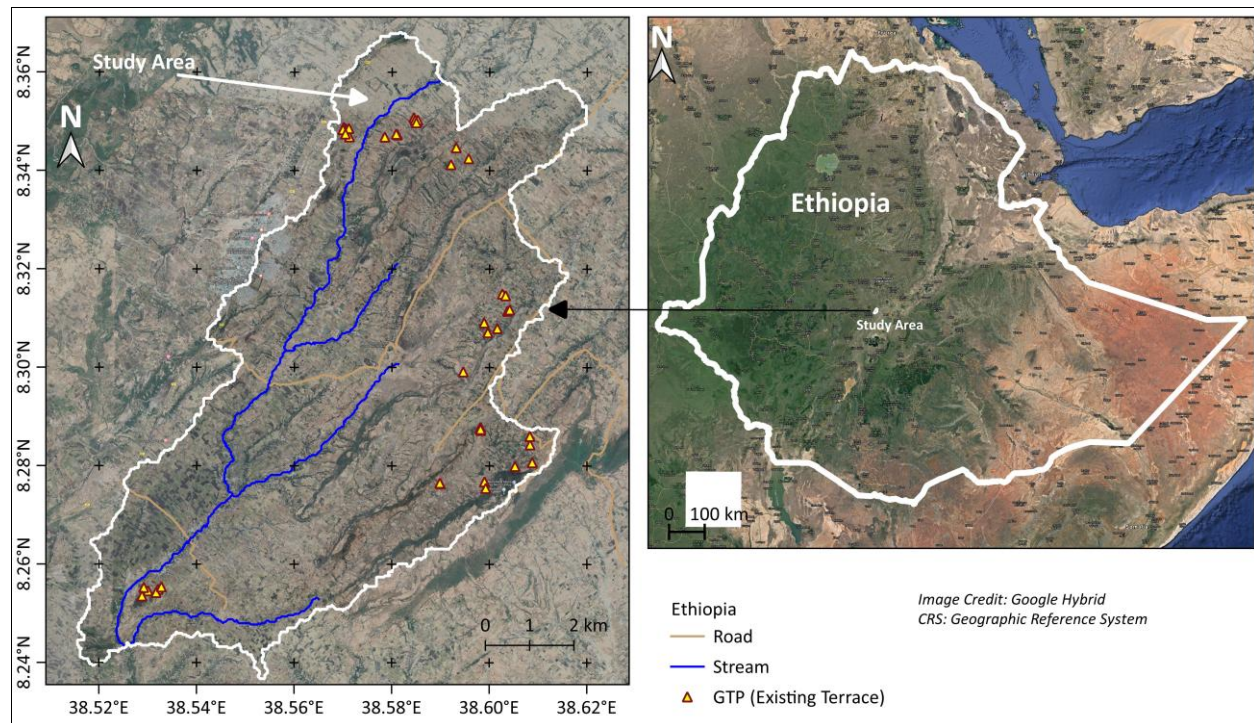


Fig. 1 Location map of the study area

The study area belongs to moist weyna dega and moist dega agro-ecology with a range of elevation 1893–2513 m.a.s.l., rainfall 900–1400 mm, and min-max temperature 10–20 °C (Hurni et al. 2016; Fentaw and Manaye 2019a). The watershed is dominated by Vertic cambisol by 56%, and the remaining takes chromic vertisol by 44% (Tadesse and Tefera 2020). Nineteen percent of the watershed has less than 5% slope, 30%, 34%, 10%, 5%, and 1% of the watershed area in a slope category of 5-10%, 10-20%, 20-30%, 30-50%, and >50%, respectively (calculated from Digital Elevation Model (DEM)).

Teff, maize, wheat, and Enset are subsistence crops, and the latter is mostly used by the growers (Tadesse and Tefera 2020; Woldeesenbet et al. 2020). The main sources of domestic water in the area include hand-dug wells and ponds, seasonal streams, and rarely available groundwater wells (Fentaw and Manaye 2019b; Tadesse and Tefera 2020).

2.2. Data collection

Data preparation

This study is a successor of the study that reported the level of risk and extent of soil loss using the Revised Universal Soil Loss Equation (RUSLE) in the same study area (Tadesse and Tefera 2020). To identify areas suitable to level *Fanya juu* terrace, data such as soil loss and LU/LC data that were mapped through a hybrid (supervised and manual) technique from (Tadesse and Tefera 2020) and slope steepness (%) and topographic wetness index (TWI) derived from DEM were used (Table 1).

Table 1 Data used for the study

Data	Unit	Resolution	Source
Soil loss	tons/ha/yr	30x30	(Tadesse and Tefera 2020)
LU/LC	Category	30x30	(Tadesse and Tefera 2020)
Slope	%	30x30	Derived from DEM
TWI	---	30x30	Derived from DEM

DEM: sourced from <https://earthexplorer.usgs.gov>

Table 2 Suitability ranges of MCDA parameters for the level *Fanya juu* terrace

Parameters	Suitability level				Remark
	Highly suitable	Moderately suitable	Less suitable	Not suitable (Null)	
Soil loss (tons/ha/yr)	>30	18-30	≤18	---	(Hurni 1985)
LU/LC	Cropland	---	---	Other LU/LC	(Hurni et al. 2016)
Slope %	3-15	15-30	30-50	<3 & >50	(Hurni et al. 2016)
TWI	≤1	1-7	---	≥7	---

The quantity of soil loss not exceeding 18 tons/ha/yr is the upper limit where production is possible in the Ethiopian highlands (Hurni 1985). Here, areas signifying a severe level of soil loss need SWC measures and are scaled to be highly suitable for the level *Fanya juu* terrace. TWI shows the level of moisture concentration (Halefom and Teshome 2019). Areas with a higher TWI value, >7, fell on gullies and stream channels. Therefore, these values are excluded from the analysis and set to null (not suitable) (Table 2).

Soil depths less than 50 cm are not suitable for level *Fanya juu* terrace (Hurni et al. 2016). The study area belongs to moist weyna dega and moist dega agroecology, and the soil depth to bedrock obtained from the International Soil Reference and Information Centre ranges from 1.13-1.75m, which is suitable for level *Fanya juu* terrace (Hurni et al. 2016). Therefore, because of its homogeneity across the study area, agroecology, and soil depth, which are prominent to device SWC measure (Kibret et al. 2020) are excluded from the analysis.

Afterward, all variables were scaled from 1 (less suitable) to 3 (highly suitable), inappropriate variable values were excluded from the analysis, and pairwise comparisons were executed.

2.3. Pairwise comparison of variables

Using a multi-criteria decision analysis (MCDA) system and analytical hierarchy processes (AHP) (Saaty 2008) have recently been used to identify soil erosion hotspots (Halefom and Teshome 2019) and identify enclosure-based conservation (Kibret et al. 2020). Therefore, MCDA with the AHP technique was employed to assess the pairwise suitability of variables for level *Fanya juu* terrace using the Weight Module in IDRISI Selva. Using a 1-7 standard scale, pairwise values were entered based on the level of importance till the consistency ratio is acceptable (<0.1) (Saaty 2008), the measure of pairwise agreement, is achieved. To tackle the risk of soil loss, it has given a higher weight (0.48) followed by LU/LC (0.36) (Table 3).

Table 3 Pairwise comparison matrix to identify areas suitable for *Fanya juu* terrace

Variables	Soil loss	LU/LC	Slope	TWI	Weight
Soil loss	1				0.48
LU/LC	1	1			0.36
Slope	0.143	0.33	1		0.09
TWI	0.143	0.2	1	1	0.07

Note: Consistency ratio = 0.03

Table 4 Reports depicting the role of level *Fanya juu* terrace in reducing soil loss

Study Sites	Elevation (m)	Rainfall (mm)	Soil loss reduced (%)	Rainfall months	Source
Minchet Catchment (Ethiopia) ¹	2430-2460	1690	60	5	(Subhatu et al. 2018)
Maybar (Ethiopia) ¹	2000-3000	1211	72	7	(Herweg and Ludi 1999)
Hunde Lafto (Ethiopia) ¹	2000-3000	935	100	6	(Herweg and Ludi 1999)
Afdeyu (Eritrea) ²	1000-2000	382	83	3	(Herweg and Ludi 1999)
Gikuuri (Kenya) ²	1300-1500	900-1200	80 (S 6-15%), 58 (S >32%)	5	(Tenge et al. 2011)

1; Used to estimate an expected percentage of soil loss would be reduced from level *Fanya juu*. Therefore, the calculated mean of the three percent reduction is 77%.

2; not accepted because the rainfall (Afdeyu) and elevation (Gikuuri) are below the minimum range of the study area.

S: slope (%).

In this study, cropland suitability for the level *Fanya juu* terrace is scaled into three categories: highly suitable, moderately suitable, and less suitable (Table 2). According to the SWC manual for development agents of Ethiopia (Hurni et al. 2016), level *Fanya juu* terrace is appropriate for cropland, and slope steepness between 3% and 50%. Hence, gentle slope which is less sensitive to soil erosion, and very steep slope areas where experiencing instability and mass movement are excluded for better effectiveness of the level *Fanya juu* terrace. Therefore, these slope categories are set to null (not suitable) (Table 2).

2.4. Merging of variables, suitability, and pairwise weight

To map area suitability for level *Fanya juu* terrace, layers ranked with suitability level (X) and corresponding weight (W) were merged using a weighted sum (WS) approach (Eq.1).

$$WS = \sum X*W \quad \dots (1)$$

In the end, cropland suitability maps for the level *Fanya juu* terrace were generated. And the result was re-classed; < 2.146 to less suitable, 2.146-2.528 to moderately suitable, and > 2.528 to highly suitable.

2.5. Validation of cropland suitability for level *Fanya juu* terrace

To check the consistency of the modeled suitable site for level *Fanya juu* terrace, 42 ground-truthing points (GTPs) were collected on existing terrace structures that are maintained for a long time. Where the length of the existing terrace exceeds 30m, one or more GTPs were taken with a fixed length of 30m difference. This has aimed to test whether areas less susceptible to soil erosion are modeled in need of level *Fanya juu* terrace or not? Vise-versa.

2.6. Estimating expected reduction in soil loss from level *Fanya juu*

Level *Fanya juu* terraces are the most effective SWC practice in reducing soil loss, slope gradient, and runoff (Chen et al. 2017; Subhatu et al. 2018; Sultan et al. 2018; Wolka et al. 2018; Mekonnen 2021). Corresponding with the climatic and physical setting of the study area, studies reported estimates of soil loss reduced by level *Fanya juu* terraces in East Africa (Herweg and Ludi 1999; Subhatu et al. 2018). Therefore, the study area has min-max ranges of elevation (1893–2513 m.a.s.l.) and rainfall (900–1400 mm) were considered, and the mean percentage of soil loss reduced (77%) of Minchet catchment (Subhatu et al. 2018) and Maybar and Hunde Lafto (Herweg and Ludi 1999) were taken to estimate a potential reduction of soil loss using level *Fanya juu* terrace (Table 4).

3. Result and Discussion

3.1. Suitability parameters

Table 5 shows that the majority (78%) of estimated soil loss fell within a normal level of soil erosion (≤ 18 tons/ha/yr) and is set to a less suitable level

Table 5 Extents of variables suitability class

Suitability class	Soil loss		LU/LC		Area		Slope		TWI	
	ha	%	ha	%	ha	%	ha	%	ha	%
Highly suitable	1231	15	4922	61	5145	64	3124	39	3124	39
Moderately suitable	577	7	---	---	1806	22	4365	54	4365	54
Less suitable	6246	78	---	---	417	5	---	---	---	---
Not suitable (Null)	---	---	3132	39	686	9	565	7	565	7
Total	8054	100	8054	100	8054	100	8054	100	8054	100

Besides, areas inappropriate for level *Fanya juu* terrace that are excluded with null value takes 39% of LU/LC, 9% of slope, and 7% of TWI (Table 6). Layers with null values have contributed to maintaining unsuitable areas in the final weighted overlay map.

In recent studies reported that areas depicting a high rate of soil erosion need urgent priority and intervention (Belayneh et al. 2019; Yesuph and Dagnew 2019; Almaw et al. 2020; Ashraf 2020; Jothimani et al. 2020). Here, 15% of the study area shows >30 tons/ha/yr (Tadesse and Tefera 2020) which is

Fanya juu terrace. Soil loss accounting for 15%, cropland (61%), slope gradient (64%), and TWI (39%) are supposed to estimate and map areas in need of intervention and highly suitable for level *Fanya juu* terrace (Table 5; Fig.2). Due to the pairwise importance weight given, the extents of the suitability scale of the variables (Table 5; Fig.2) would not be consistent for the final map (Fig.3; Table 6).

prioritized first for level *Fanya juu* terrace (Table 5). Also, in Ethiopia, an extensive amount of soil erosion was reported in cropland, those needs reversing action (Gebreselassie et al. 2016; Almaw et al. 2020) (Table 5). Again, for slope gradient, 64% and 22% of the study area is high to moderately suitable for level *Fanya juu*, respectively. In support of this, physical SWC measures are prominently effective in reducing slope gradient and increasing sediment deposition (Subhatu et al. 2017, 2018; Mekonnen 2021).

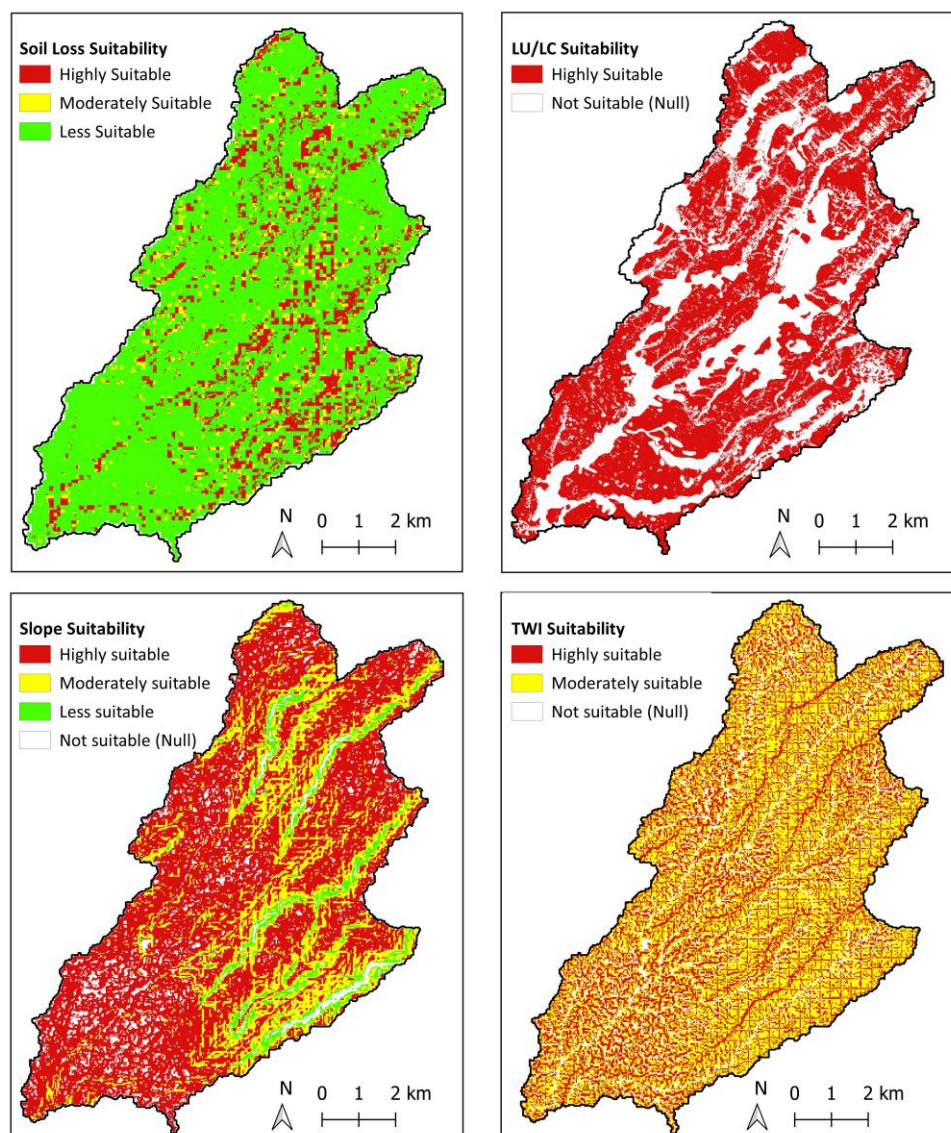


Fig. 2 Suitability of variables for level *Fanya juu*; soil loss suitability (top left), LU/LC suitability (top right), slope suitability (bottom left), and TWI suitability (bottom right)

3.2. Site suitability validation

Among the 42 GTPs collected on the existing terraces, 40 (95%) fall into the range of less suitable class, and the remaining 2 GTPs (5%) are into a moderately suitable class. Here, the status of the slope around the existing terraces influenced the modeled suitability, which causes 5% of GTPs to fall into a moderately suitable class.

3.3. Site suitable for level Fanya juu terrace

The weighted overlay results in Table 6 and Fig.3 show that 5.5% and 3.2% of the study area are urgently recommended and highly to moderately suitable for the level *Fanya juu* terrace. In line with Fig.2, the final suitability map (Fig.3) attempts to subset croplands with a severe rate of soil erosion and then masked for promising relevance of level *Fanya juu* terrace (Table 6 and Fig.3).

Table 6 Extents of suitability class for level *Fanya juu* terrace

Suitability level	Area (ha)	Area (%)
Highly suitable	442	5.5
Moderately suitable	258	3.2
Less suitable	3286	40.8
Not suitable (Null)	4068	50.5
Total	8054	100

Recent reports confirmed that appropriately executed level *Fanya juu* terrace has efficiently trapped sediment and soil organic matter, reduced runoff and slope gradient, and improved crop yield (Saiz et al. 2016; Aga et al. 2018;

Subhatu et al. 2018; Wolka et al. 2018; Alemu and Melesse 2020; Teka et al. 2020; Mekonnen 2021). Half (50.5%) of the study area is not applicable for level *Fanya juu* terrace. The reason is that this portion of the area could be either possible for a bench terrace (very steep slope and/or non-cropland) or soil moisture conservation measures that couldn't yield waterlogging (Hurni et al. 2016; Wolka et al. 2018).

Using similar guideline (Hurni et al. 2016), with 90% accuracy, 8% of the total landmass, 0.4% of agricultural land, and 7.6% of non-agricultural land of Ethiopia were reported to be suitable for area enclosure (Kibret et al. 2020). The study adds that in the central rift valley lakes basin, where the study area is located, 0.7% of agricultural land and 8.1% of non-agricultural land were suitable for area enclosure. This implies that the MCDA approach, among other applications, is capable of identifying areas in need of interventions.

Obtaining information about area applicability for SWC measures is not a simple task, where development agents (DAs) are expected to measure and analyze landscape elements (Hurni et al. 2016). However, trained manpower and exhaustive time are necessary to suggest appropriate SWC measures. Therefore, this MCDA, the technique has been attributed to spatial layers and decision criteria. This would have important information backing DAs to identify and easily track appropriate areas mapped for level *Fanya juu* terrace. Notably, before execution, this physical suitability information is a preliminary decision support tool, and further ground survey and community involvement are pertinent to sustain the intervention (Wolka et al. 2018; Kibret et al. 2020). In line with that, despite its implementation and promising results on sediment depositions, terraces with wider spacing in steep slope cropland didn't reverse soil loss to a tolerable limit (Subhatu et al. 2017).

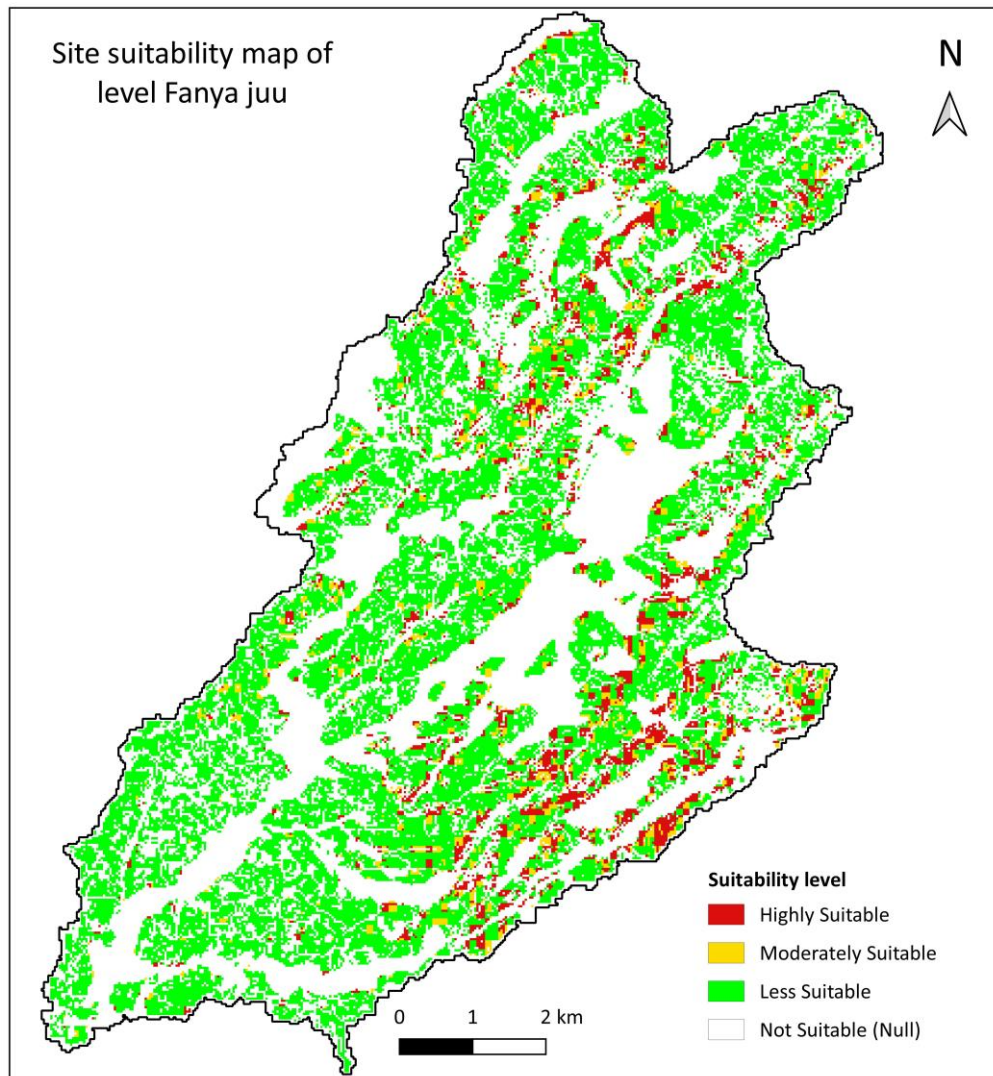


Fig. 3 Site suitability map for level *Fanya juu* terrace

3.4. Potential reduction of soil loss from level *Fanya juu* terrace

According to the reference proportion (Herweg and Ludi 1999; Subhatu et al. 2018), 77% of soil loss will be presumed to be reduced after implementation of level *Fanya juu* terrace (Table 7). Accordingly, in areas prominently in need of level *Fanya juu* terrace, the soil loss will be expected to reduce from 105,990 tons/ha/year to 4,378 tons/ha/year (Table 7).

Table 7 Expected reduction in soil loss from level *Fanya juu* terrace

Level of suitability	Soil loss (tons/ha/year) (Tadesse and Tefera 2020)*	77% estimated reduction (tons/ha/year)
Highly suitable	105,990	24,378
Moderately suitable	22,361	5,143
Less suitable	5,625	1,294
Grand Total	133,976	30,814

* The soil loss was quantified using the final suitability map (Fig.3) as a mask layer.

However, temporal (i.e., age), spatial (i.e., agro-ecology), detail of implementation, maintenance service, and farmers' acceptance determine the effectiveness of the SWC measure (Herweg and Ludi 1999; Subhatu et al. 2017; Sultan et al. 2018; Wolka et al. 2018; Alemu and Melesse 2020; Mekonnen 2021). For instance, the development of level *Fanya juu* terrace to the bench terrace takes a minimum of 7 years to a decade (Herweg and Ludi 1999; Subhatu et al. 2017). Besides, effectiveness in trapping sediment decreases with increasing age of the terrace; on the contrary, higher crop yield was obtained on aged structures than on recently constructed measures (Mekonnen 2021). The return of the SWC measure couldn't come into effect in a short period after execution (Wolka et al. 2018). To sustain the benefits of SWC measures, regular maintenance is recommended every three to 5 years of implementation (Mekuria 2020).

However, the ex-ante reduction of soil loss needs considerable attention in terms of technical and socioeconomic collaboration. As a result, the gradual

enrichment of the level *Fanya juu* terrace would have a significant contribution to improving crop/biomass yield and reducing soil loss below the tolerable limit (Subhatu et al. 2018; Wolka et al. 2018; Alemu and Melesse 2020; Mekonnen 2021). In the end, level *Fanya juu* terrace is expected to reduce soil/sediment loss (Subhatu et al. 2017, 2018) and the costs of land degradation due to soil erosion by water (Gebreselassie et al. 2016).

4. Conclusion

This study has sought to present areas suitable for level *Fanya juu* terrace using multi-criteria evaluation of four contributing parameters: soil loss, LU/LC, slope, and TWI. In addition to that potential reduction of soil, the loss was estimated using an equivalent proportion sourced from literature. The result shows that 5.5%, 3.2%, and 40.8% of the area was highly, moderately, and less suitable for the level *Fanya juu* terrace. The validation result indicated that 95% of GTPs collected from the existing terrace fell into a less suitable class. And the remaining 5%, with the effect of slope, falls into the moderately suitable class. This implies that the MCDA tool, trending a decade of application, is efficient to determine a site appropriate for the level *Fanya juu* terrace.

Frequently reported issues allied to farmers' acceptance, structure age, regular maintenance, and proper implementation are important to define the effectiveness of SWC measures. Taking into consideration these issues, the level *Fanya juu* terrace has a 77% reported mean potential to reduce soil loss. Accordingly, level *Fanya juu* terrace would have the potential of reducing soil loss from 105,990 tons/ha/yr to 24,378 tons/ha/yr in areas highly susceptible to soil erosion.

Providing local-level information on the appropriateness of SWC measures is pertinent to support development agents (DAs) and make an informed decision on farmers' managed croplands. Therefore, this study has provided technical information on croplands suitable for the most effective physical SWC measure, the level *Fanya juu* terrace. Indeed, for the further effectiveness of level *Fanya juu* terrace, incorporating a biological approach is importantly recommended, and also practitioners need to work accordingly.

Declarations

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