Appraisal of Issues Affecting Soil-Steps Building for Sustainable Farmland Management in High Potential District, Ethiopia

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Abstract

Water caused soil degradation is a serious problem on farmlands in highland Ethiopia. Considerable investments in farmland conservation have been made to manage the problem in the past decades. However, the efforts have not been so pervasive to trim-down the danger to a desirable scale. This paper examines issues that impact application of soil-steps (bunds) as sustainable farmland management technology (SFLMT) by smallholder farmers in one of the high-potential production districts of northwest Ethiopia; Dangila woreda. Mixed method research designs involving concurrent acquisition and interpretation of quantitative and qualitative data were used in the study. Data were acquired from 201 randomly chosen farming households during the harvest seasons of 2011 and 2012. Structured questionnaire survey, participatory field observation, key informant interview and focus group discussion were mechanisms employed during the data acquisition. Descriptive statistics (means, standard deviations and percentiles), Chi-square test, t-test and the binary logit model were in use to interpret the quantitative data. The qualitative information was textually narrated to augment the quantitative result. The findings of the investigation confirm that age of the household head, the number of household members, the slope of the farmland, the size of the farmland household held, the households' participation in indigenous labour-sharing activities and the number of farm tools owned were significantly influenced by the building of soil-steps as SFLMT in the study district. Then again, taking part in off-farm activities and pest invasions were considerably hindering farmers from building soil-steps on their farms. In general, the results indicate that households' access to livelihood material goods are key promoters for farmers' implementation of soil-steps on their farmlands. Local resource conservation and development involvements should thus ponder on convalescing farmers' material endowments to improve their capability to use soil-steps as SFLMT in their farming activities.

KEYWORDS: Farmland management; sustainable technology; soil-steps building; Ethiopia.

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Introduction

Farmland is an important asset and base of agricultural economy. It is the prime resource for living in rural parts of the world (Rahman and Manprasert, 2006; Kastner and Nonhebel, 2010). Farmland in Ethiopia is the main base of socio-economic and political wealth (Adenew and Abdi, 2005). But, the size of cultivable land per family unit has been continuously diminishing and getting less productive in latest decades due to farmland abuse and maltreatment (Pender and Gebremedhin, 2007). Mounting demographic pressure in vast areas of the highlands (>1500 m.a.s.l.) forced farmers to stop using the indigenous fallowing system to renovate soil fertility (Rahmato, 2004). In immense areas of the highlands, resource exhaustion is more somber compared to other world regions and nearly all the mountain terraces have vanished their inborn productive capacities (Tesfay, 2006). Resource collapse, low farming output and escalating poverty have thus remained as grave challenges in the Ethiopian highlands (Pender and Gebremedhin, 2007). Population stress, inapt land use, land tenure insecurity and farmers' lack of awareness about the magnitude of the problem are ascribed as causes and factors for the aforementioned challenges in the said highlands (Hurni *et al*., 2005).

Sizeable endeavors have been undertaken to lessen the resource fatigue in the country throughout the recent past decades (Amsalu and de Graaff, 2007; Kassie *et al*., 2010). However, studies indicate that in various localities of the country the attainments in renovating damaged lands and halting the processes of soil removal have not been to a desirable scale, for different reasons(Hurni *et al*., 2005). Kassie *et al*. (2010) noted that natural resource management packages to endorse smallholder soil and water conservation (SWC) practices are missing except for promoting the use of commercial fertilizers and improved seeds. They added that the focus of the current government in this regard was so weak, restricted to temporary erection of bunds using obligatory free human labour through plain blanket frameworks.

Some researchers argue that farmers in Ethiopia are apathetic to install long-lasting and sustainable farmland management technologies (SFLMTs) because of their strong inclination to harvest short-range benefits in the milieu of the government ownership of land (Sutcliffe, 1995; Gebremedhin and Swinton, 2003). Technologies with long-range benefits are often discarded by the farmers, and in some cases even previously installed physical structures were soon ruined (Sutcliffe, 1995; Shiferaw and Holden, 1998; Tadesse and Belay, 2004). For instance, Tadesse and Belay (2004) indicated that out of 80 farmers interviewed in the Gununo area, southern Ethiopia, 41.3% partially and 36.3% completely removed previously installed SWC structures.

Various authors note that, in addition to land tenure insecurity, a number of factors influence farmers' use of SWC technologies(Shiferaw and Holden, 1998; Bekele and Drake, 2003; Gebremedhin and Swinton, 2003; Tadesse and Belay, 2004; Amsalu and de Graaff, 2007; Anley *et al*., 2007; Teshome *et al*., 2014; Wolka and Negash, 2014; Birhanu, 2016). For instance, Shiferaw and Holden (1998) reported that farmers' perceptions of soil erosion and new technologies, exposure to new practices, availability of per capita cultivable land, parcel area, land slope and effectiveness of used technology significantly and positively influence retention of SWC structures in central Ethiopia. They found also that age, family size and farm location significantly, but negatively affected retention of SWC structures.

According to Bekele and Drake (2003), in southeastern Ethiopia, farmers' conservation decisions were positively influenced by perception of soil erosion, wealth status of the households and start-up investment support. In their study, family size was found to negatively correlate with adoption of SWC technologies. Likewise, Gebremedhin and Swinton (2003) found that physical incentives, household capacities to invest and socio-institutional factors were important in influencing farmers' adoption of stone-bunds in northern Ethiopia. They reported that farmers prefer to build stone-terraces on middle and lower slopes. Gebremedhin and Swinton (2003) further indicated that labour and ownership of large plots favoured adoption of the stone-embankments. They also noted that plot distance from home and markets have negatively influenced its adoption .

Tadesse and Belay (2004) reported that number of economically active family members, farm location, and perception on soil erosion and farm size had positively and significantly influenced farmers' adoption of soil-bunds and *fanya juu* terraces in the Gununo area, southern Ethiopia. A study in central highlands of Ethiopia by Amsalu and de Graaff (2007) observed as well that age, farmland slope and farmland size significantly increasing technology adoption. Anley *et al*. (2007) also noted that education, farmland slope and farmland size significantly increased adoption of SWC structures in western Ethiopia. Plot distance from home, extension support and farmers' age were found negatively affecting technology adoption in the mentioned area.

Kammer (2014) remarked that awareness about the technologies and support in agricultural practices have influenced farmers' SWC investment decisions in the Magersa and Konso communities of southern Ethiopia. Physical efficiency, financial competence and social adequacy of SWC structures are also reported as factors influencing farmers' investment decisions to use SWC technologies in northwest Ethiopia (Teshome *et al.*, 2014). Wolka and Negash (2014) also noted that farmland size and workability of SWC structures significantly correlated with adoption of SWC practices in Bokole sub-watershed, southern Ethiopia. These authors added that distance to a nearby market significantly decreased SWC adoption in another sub-watershed named Toni.

Birhanu (2016) reported that sex, age, farmland slope; plan to continue farming activities, training and extension service significantly increased adoption of SWC measures in northern Ethiopia. According to the same author farm size, off-farm work and credit access negatively influenced farmers' adoption decisions of the measures.

Farmers' decisions on the use of multiple SWC technologies were assessed by many previous studies conducted in different parts of Ethiopia and also in other parts of the world as indicated above and elsewhere in the manuscript (e.g. see Bekele and Drake, 2003; Gebremedhin and Swinton, 2003; Shiferaw and Holden, 1998; Lapar and Pandey, 1999; Medhin and Kohlin, 2009; Mbaga-Semgalawe and Folmer, 2000; Tadesse and Belay, 2004; Amsalu and de Graaff, 2007; Anley *et al*., 2007; Belay and Bewket, 2012a; Gebre and Woldemariam, 2013; Kammer, 2014; Teshome *et al*., 2014; Wolka and Negash, 2014; Erkie 2016; Birhanu, 2016). Some researchers have also examined the application of specified technologies like stone-bunds and fanya juu terraces in northern and central parts of Ethiopia (e.g. Desta *et al.*, 2005; Vancampenhout *et al*., 2006; Amsalu and de Graaff, 2007; Nyssen *et al*., 2007). Such studies could help to understand and identify the constraints encountered during the use of the specific technologies.

Soil-steps[1] are among such technologies used by many farmers in Ethiopia and in the study area. The erection of soil-steps has been encouraged in SWC interventions (from 1975-1991) in combination with 'stone-terraces', and is also endorsed by the existing government (Belay and Bewket, 2012a and b). The exploratory survey carried out during the first phase of this research also confirmed that soil-steps are widely practiced on farm fields in the study district. Moreover, no previous study, as far as is known to the author, has been undertaken on soil-steps formation in northwestern Ethiopia and also in the study district. Identifying the key factors that determine the application and use of soil-steps is thus helpful to deal with the challenges of sustainable farmland management improvement in the mentioned study district and in other comparable environments.

Hence, this study examines issues that influence farmers' actions of building soil-steps (i.e. construction of soil embankments on farmers' fields) as SFLMT in a high-potential district named Dangila *woreda*, in northwestern highlands of Ethiopia.

Study Area and Methods

The study district

The study district (Dangila *woreda*) is located, between $11^0$04'48''-$11^0$24'36"N latitude and $36^0$34'48"-$37^0$00'37"E longitude (Fig. 1); approximately 480 kms to the northwest of Addis Ababa, the capital city of Ethiopia. Dangila woreda is 918.4 km^2 wide (CSA, 2010), and its elevation traverses between 1500 and 2400 m.a.s.l. (Belay, 2013). Volcanic materials mainly belonging to the quaternary and tertiary formations overlying the older geological formation of the ancient eras dominate the area (e.g. see Arndt and Menzies, 2005). Lithosols, Nitosols, Vertisols, Luvisols, Gleysols, Cambisols and rocky surfaces are major soil covers in the district (Fig. 2).

[1] Soil-steps are terraces /bunds made of soil-piles or mounds to control soil loss by running water

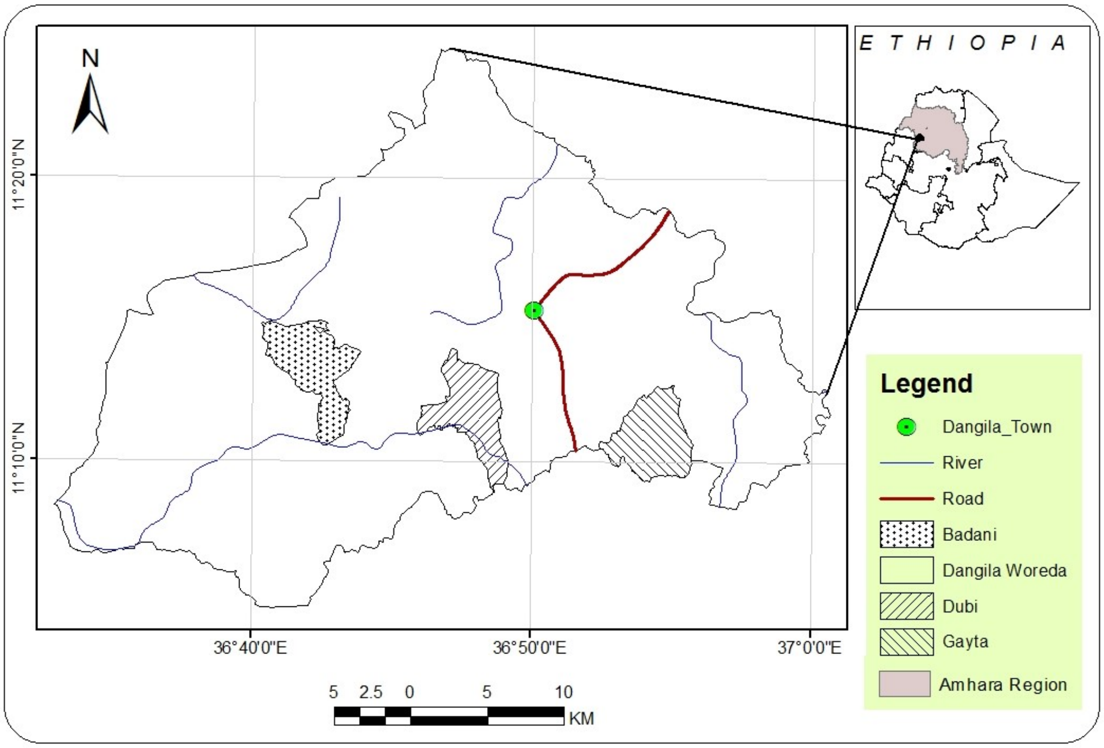

Fig. 1. Location map of the study area (Belay and Bewket, 2013a)

Different rivers [including Awsi, Ghizani, Quashini, Guder, Gilgel Abay (the little Blue-Nile) and its tributaries] and several streams flow across the district (Negash, 2006). The Tiski waterfalls form striking land features in the district. *Weina-Dega* (a moist sub-tropical agroecology) dominates its broad climate. Temperature and rainfall records ($11^0$16'00"N and $36^0$50'00"E) accessed from the Ethiopian Meteorological Agency (EMA, 2010) indicate that the yearly average temperature is 17^0C and that the annual rainfall is 1578 mm. Months from May to October experience the highest proportion (93%) of the total rainfall with highest values occurring in August, July and June, respectively. The driest month in the area is January (with 2 mm rainfall) while the wettest is August with about 358 mm rainfall (Belay and Bewket, 2013b). Except the forest plantations at both sides of the Addis Ababa-Bahir Dar asphalt road, and on the ridges of Senbu, Gundri, Gayta, Gishen, and Agew-mender, no intact natural forests are found in the district. Remnant forests with broad Eucalyptus plantations are observed on remote villages such as Muksi, Jibana, Chiwaghi, Dimsa, Washa, Alefa-Kacha and on the ridges of Kansen.

The 2017 mid-year total population in Dangila district is 199,197 of which 98,282 are females and 100,814 males (CSA, 2013). Using this data, the crude density of population for the district in the mentioned period is calculated at 216.9 persons per km^2 giving a much larger figure compared to the national average density of 85.4 persons per km^2 computed for the same period. The number of people residing in towns accounts for 23.6% of the total district population. This figure is also much larger than the national average which is calculated at 20.23%.

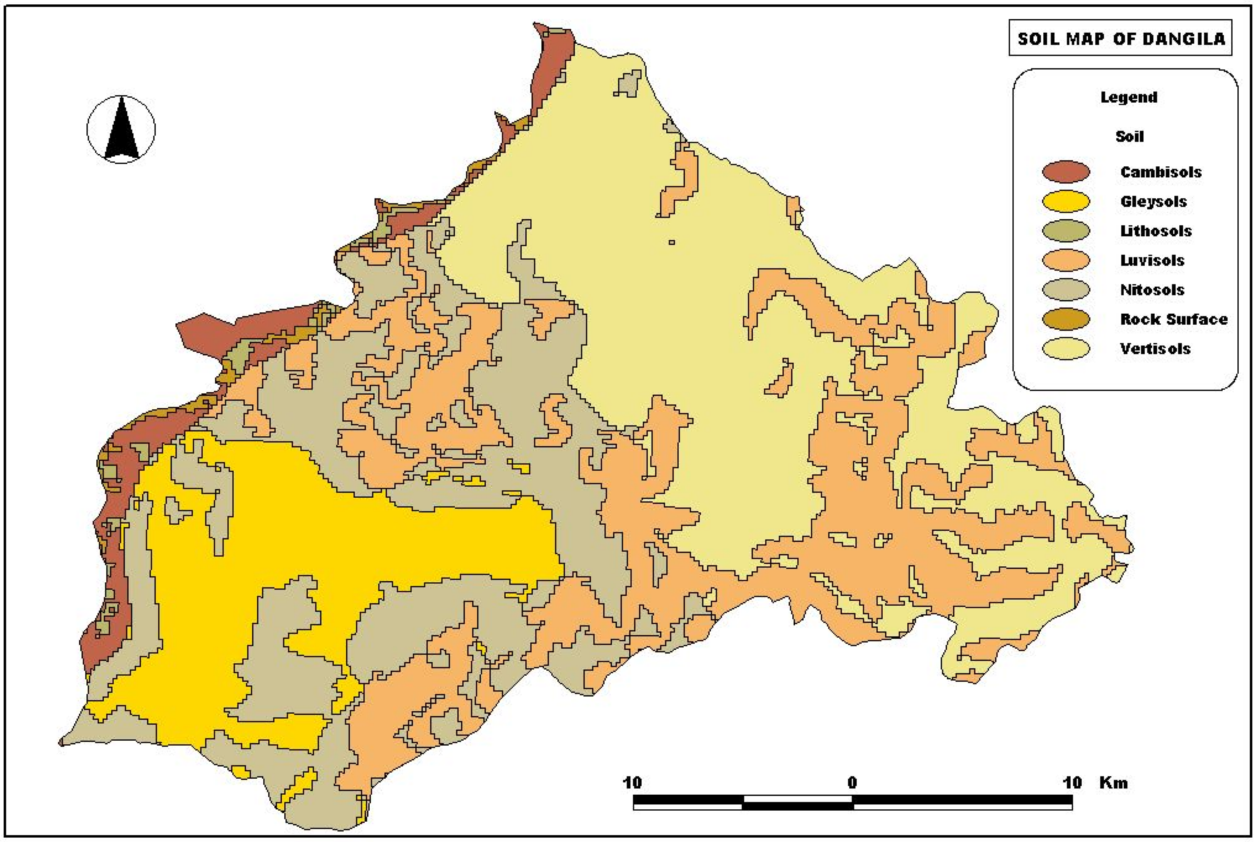

Fig. 2: Soil map of the study district (Belay, 2013)

Mixed agriculture is the main stay of over 80% of the population in Dangila. Farmland, livestock and family labour constitute the most important livelihood assets in the district. Crop cultivation, livestock keeping for milk, farm power and cash, petty trading, charcoal and wood selling (Fig. 3a), participation in daily labour and in off-farm business are among the main livelihood strategies of the people in the district. Growing potato (*Solanum tuberosum*), maize (*Zea mayas*) and vegetables using irrigation around the homesteads (Fig. 3b) is a common practice in most villages (see Belay and Bewket, 2013b, 2015; Belay *et al*., 2017).

Despite its high-rainfall and favourable agricultural setting, Dangila district is rapidly losing its agricultural potential due to intensified land degradation instigated by dense population. Soil fertility depletion, gully expansion, declining water potential, and poverty are major problems in the area (Negash, 2006; Belay and Bewket, 2012 a, and b). Since the inclusion of Dangila district in the 'high-potential'- high-yielding crop-zone following the regional agroecology classification (ALZR, 2007), research attention has diverted away from the district; and hence, there are no major recent studies on SFLMTs in the district. This study, therefore, was conducted with the primary intention of bridging this gap. Three rural villages named Badani, Dubi and Gayta (Fig. 1) were selected on purpose as the specific focus areas for the study.

Fig. 3. a) Farmers selling charcoal and firewood in Dangila town (June 2012), and
b) Maize and potato growing on irrigated homestead farm in Gayta (Oct. 2012)

Soil and water conservation practices in the area: a brief review

Contour farming, soil-steps building, stone-bund construction, plantation of trees and grass-strips; and adoption of cut-off drains, traditional ditches and check-dams are main SWC technologies installed in the study villages (Belay and Bewket, 2012a). Contour farming is an indigenous technology commonly practiced by farmers everywhere in Ethiopia and used by all the farmers in the study area (Belay, 2013). It is often conducted before crop sowing using a plough dragged by a pair of oxen. As indicated in Belay and Bewket (2012a), maximum tillage is a habitually accepted common practice in the study district. As confirmed during the field work, the district's Agriculture Office is also currently encouraging this practice with the aim of enhancing agricultural yield.

Soil-steps are terraces/embankments made of soil mounds (see Fig. 4) across the sloping lines of farmlands to improve the water retention capacity of soil and to divert/control water runoff caused by torrential rainfall. They are seldom established on about 32% of the farms of the study villages (Belay, 2013) using soils available on the farmland itself or soils that can be easily accessed from nearby surfaces. Sometimes they are built with stone supports to increase their strengths. Soil-steps can be built by digging the soil with a spade or else by ploughing using a pair of oxen. In other areas, soil-steps are often installed in association with fanya juu[2] terraces in micro-watersheds to enhance soil water retention behavior through obstruction of up-coming flood (Teshome *et al*., 2014). They are preferred farm management technologies in areas where stones are scarce. In areas of abundant stone-cover, stone-terraces are preferred to soil and fanya juu bunds because they are durable and cannot be easily damaged by trampling animals (Desta *et al.*, 2005). Fanya juu terraces are preferred by farmers to soil-steps in many locations because their ditches effectively trap up-coming flood and form bench terraces in short time periods. As the downhill placed channels cannot be easily crossed and grazed by livestock; fanya juu terraces are not easily broken by trampling animals compared to the soil-steps. Soil-steps are easily crossed and grazed by livestock and are more susceptible to damage. Fanya juu terraces are vital SWC technologies in arid and semi-arid environments where cultivation is constrained by scarce soil moisture (Teshome *et al*., 2014).

Both Fanya juu terraces and soil embankments are installed in similar fashion by excavating soil along the contour using human labour. But, the soil dug in the case of fanya juu bund is dropped upslope against what would happen during the construction of soil-terraces where the excavated bimass is placed downslope. With respect to this, fanya juu construction requires more labour than the soil-embankment which can possibly be built with the help of oxen-dragged ploughs. Soil and fanya juu bunds can store water in the depressions during rainstorms, and sometimes they can be affected by waterlodging and silt deposition. Both are stabilized by planting trees, shrubs and grasses on the risers. The plants grown in this way may eventually serve for fuel or animal feed purposes. Maintenance is retained through improving the structures by means of reforming broken parts and increasing the quality of the structures and vegetative supports. Nevertheless, maintenance of both structures is not an easy task, particularly the soil-steps (Teshome *et al.*, 2014).

[2] Fanya juu in Kiswahili means throwing soil uphill

Fig. 4. Samples of partially damaged soil-steps constructed at different times (Sept. 2012)

Unlike soil and fanya juu bunds, stone-terraces are usually erected in areas rich with surface stones. Stone-terraces are commonly practiced indigenous conservation structures in northern Ethiopia (Gebremedhine and Swinton, 2003). No more digging of soil is required during construction of stone-terraces because they are built from piling of stones found in the vicinity. Stone-terraces do not demand frequent maintenance as is common in soil and fanya juu bunds, but, require more labour during construction. They are durable and strong; not easily damaged by floods and trampling animals like the soil and fanya juu bunds. Nevertheless, they are not suitable for farming operation using oxen and shelter pests that can cause damage on crops (Vancampenhout *et al*., 2006). Stone-terraces can drain excess water along the joints of the stones, and hence waterlodging is not a serious problem compared to the soil and fanya juu bunds (Gebremedhine and Swinton, 2003; Teshome *et al.*, 2014). The use of stone-embankment technologies in the study villages is rather limited; used by few farmers, covering some 19% of the farmlands (e.g. see Belay and Bewket, 2012a).

Traditional ditches are used by many farmers (on more than 50% of the farms) to drain excess water from farmlands. Cut-off drains are installed on about 42% of the farms to catch and divert upcoming flood (Belay, 2013). They are often built at the head of the farms so as to collect water coming from upslope to avoid damage and more erosion (MoA, 2016). Check-dams are often used to control gully erosion on steep lands (Belay and Bewket, 2012b).

Grass-strips and trees are planted to check soil erosion and to serve as livestock feed, fuel and construction material. They are also sold in the market to generate income. Scattered trees are observed almost over all the farmlands as part of an agricultural enterprise while grass-strips cover around 39% of the farmlands in the studied villages (Belay and Bewket, 2012a).

Data and methods

Mixed method research designs were used in this study to retain the concurrent acquisition and analysis of quantitative and qualitative information. Based on this approach, both numerical and qualitative data were gathered from 201 randomly chosen farm households, three focus groups (containing six members each), nine key informants and from observation and participatory field tours in three rural villages in the north-western highlands of Ethiopia. A multi-stage sampling technique was used to determine the households studied. Primarily, three villages, Badani, Dubi and Gayta (Fig. 1) were purposely picked on account of the proximity and accessibility to the district town (Dangila) and availability of road transport network. Then, the records of the households' were accessed from the respective village administration offices and stratified by sex. From the stratified records, 31 female-headed and 170 male-headed households (201 in total) were systematically chosen from 1993 total households proportionately. Additional 27 households were also chosen for focus group discussion (FGD) and for key informant interview, owing to their outstanding knowledge of the area.

For data acquisition, well-structured questions focusing on farmers' household demography, resource endowment, SWC technology use and perception were designed and translated into the native language (Amharic). Before gathering the data, the designed questions were pre-tested for fitness and validity. From the pre-test feedback, relevant improvements were made.The items were then filled by the sampled households during the harvest seasons of 2011 and 2012 through face-to-face interviews. Three university graduated assistants and the researcher conducted the face-to-face interviews with the support of development agents (DAs). The quantitative data generated from the structured questionnaire surveys were then enriched by FGDs, key informant interviews and participatory field observations.

The data generated through other approaches were concurrently interpreted using quantitative and qualitative data analysis methods. T-test, Chi-square test and binary logit model were used in the examination of the data with the support of information from FGDs and field observations.

T-test and Chi-square test were correspondingly used to primarily check the differences and level of associations of variables within the groups and categories. The t-test was specifically used to appreciate the mean difference in age, education level, and number of family members, farmland size and farmland distance from home, frequency of contact with DAs and the number of farm tools owned between soil-steps builder and non-builder household groups. The Chi-square test was also used to analyze the relationship between categorical variables such as the sex of the household heads, farmers' involvement in off-farm business and indigenous labour associations and their perceived farmland slope, tenure insecurity, waterlodging and pest infestation problems. The variables showing significant differences/associations in the t-test and Chi-square test were then further integrated in the binary logit model.

The binary logit model was employed to evaluate the variables influencing farmers' soil-steps building decisions. It was chosen for suiting to manipulate dummy and categorical variables that are not fitting linear regression models (Chan, 2004). Soil-step building was the criterion factor defined as a dummy: '1' categorized as building soil-steps and '0' considered as not-building soil-steps. Households were classified as soil-step builders and non-builders. Soil-step builders were households who started constructing soil-steps on their farm fields during the past three years (2009-2011) whilst non-builders were those who had not started building the structures during the mentioned years.

The quantitative results of the analysis were triangulated with FGD and field observation data. Data preparation and analysis procedures were managed using Microsoft Excel and the Statistical Package for Social Scientists (SPSS Version 20). The fitness of the data used in the study to the binary logit model was evaluated using the Pearson's Chi-square (χ^2), the Hosmer and Lemeshow's test of goodness-of-fit (Hosmer and Lemeshow, 2000) and the classification tables of the sample cases. The degree of linear relationship among the predictor factors were also checked using a correlation matrix.

Choice of Predictor Issues/Factors

Issues controlling implementation of SFLMTs and practices like that of soil-steps are numerous and multidimensional. For this case study, 14 issues that were anticipated to influence farmers' soil-step application decisions were considered via assessment of previous SWC literatures. The portrayals, assumptions and sources of the 14 issues considered are explained in Table 1 under three major subheadings.

Table 1. Description of predictor issues used in the analysis, assumptions and sources

Influential issues	Postulates	Supporting Literature
Household demographic issues		
Sex of the household head (1 if male, 0 otherwise)	Male-headed households build more soil-steps than female headed households	Holden *et al.* (2001); Pender and Gebremedhine [2007].
Age of the household head (in years)	Expected to have a mixed effect (±)	Shiferaw and Holden [1998]; Lapar and Pandey [1999]; Amsalu and de Graaff [2007].
Education of the household head (school attended years)	More school exposure increases soil-steps building behaviour	Lapar and Pandey [1999]; Amsalu and de Graaff [2007]; Anley *et al.* [2007].
Number of household members	Soil-steps building increases with increased number of household members	Tadesse and Belay [2004].
Household resource endowments		
Farmland size (ha)	Ownership of large farms encourage soil-steps building interest	Bekele and Drake [2003]; Gebremedhin and Swinton [2003]; Tadesse and Belay [2004].
Farmland slope (1 if steep, 0 otherwise)	Steep slope farm location pushes farmers to build more soil-steps	Shiferaw and Holden [1998]; Anley *et al*. [2007]; Medhin and Köhlin [2009].
Problem of waterlodging (1 if yes, 0 otherwise)	Waterlodging problems discourage farmers' soil-steps building interests	Kassie *et al*. [2007, 2010]; Gebre and Woldemariam [2013].
Problem of pest infestation (1 if yes, 0 otherwise)	The problem of pest infestation reduces soil-steps building interventions	Vancampenhout *et al*. [2006]; Kassie *et al.* [2007]; Gebre and Woldemariam [2013].
Proximity of farmland distance from home (in kms)	Long distance between homesteads and farms reduce farmers' soil-steps building actions	Gebremedhine and Swinton [2003]; Anley *et al.* [2007].
Household socio-economic issues		
Partaking in local labour groups (1 if yes, 0 otherwise)	Participation in local labour groups increases soil-steps construction	Lapar and Pandey [1999]; Mbaga-Semgalawe and Folmer [2000].
Performing off-farm work (1 if yes, 0 otherwise)	Performing off-farm work reduces soil-steps construction	Shiferaw and Holden [1998]; Amsalu and de Graaff [2007].
Number of contact days with DAs in a year	Frequent meeting with DAs promotes farmers' soil-steps building activities	Gebremedhine and Swinton [2003]; Amsalu and de Graaff [2007]; Anley *et al*. [2007].
Sense of tenure insecurity (1 if yes, 0 otherwise)	Strong sense of tenure insecurity discourages soil-steps building practices	Gebremedhine and Swinton [2003]; Rahmato [2004]; Belay *et al*. [2017].
Number of farm tools owned	Expected to have positive influence	

Results and Discussion

Descriptive results

Household demographic issues

As can be inferred from the descriptive data offered in Tables 2 and 3, there are important variations between soil-step builders and non-builders across many of the demographic factors. Soil-steps builder households tend to have higher mean ages (46 Vs to 38 years for non-builders) and family members (7 Vs to 5 for non-builders) and the variation was statistically significant for both (P<0.01, Table 2). Likewise, the share of female-headed households in the soil-steps builder group is considerably inferior to that in the non-soil-steps-builder groups, entailing that female-headed households have lesser possibilities of erecting soil-steps (χ^2 =7.47, P<0.05, Table 4). Nevertheless, no significant variation was observed between soil-step builders and non-builder households with regard to education level of household heads (Table 2).

Table 2. T-test comparison of soil-step builder and non-builder households

Factors	Builders (n=44) Mean	SD	Non-builders (n=157) Mean	SD	T-test
Age in years	45.80	12.66	37.88	13.42	3.50[a]
Education (year attended)	1.14	2.09	1.34	2.60	-.473
Number of family members	7.09	2.13	5.19	1.94	5.62[a]
Size of farmland owned (ha)	1.92	0.71	1.28	0.59	6.04[a]
Farm distance from home (km)	1.38	1.14	1.30	0.98	0.44
Meeting with DAs (days yr^{-1})	1.89	0.95	0.73	0.49	11.03[a]
N^0 of farm equipments owned	1.16	0.57	0.46	0.54	7.55[a]

[a] refers to significance at < 0.01 level.

Resource endowment and biophysical issues

Normally, soil-step builder households had larger farmland holdings and larger number of farming equipments. Possession of farmland and farm equipments were noted to considerably vary between the two groups (between soil-step-builder and non-builder households) (P<0.01, Table 2). Supposed slope situation of the farmlands investigated was non-steep for most of the households approached and was statistically variable between builders and non-builders of soil-steps (χ^2 = 9.22, P < 0.01, Table 3).

A relatively large percentage of the households (≈ 61%) in the soil-steps builder group perceived facing the problem of waterlodging compared to the 43% facing the same in the non-soil-steps-builder groups (χ^2 = 4.493, P < 0.05, Table 3).

The problem of perceived pest infestation was reported by the majority of the farmers of both groups (i.e. by 93% of the builders and 75% of the non-builders of soil-steps). The risk of pest infestation was thus found to significantly vary between the two groups (χ^2 = 6.754, P < 0.01, Table 3). Conversely, farmers' round-trip distance from home to farmlands has not explained efficient statistical deviation between the soil-steps-builder and non-builder farmers (Table 2).

Table 3. Chi-square comparison of soil-step builder and non-builder households (in %)

Factors	**Categories**	**Builders** (N=44)	**Non-builders** (N=157)	χ^2
Sex of the head	M	98	81	7.47[b]
	F	2	19	
Performing off-farm job	Yes	27	48	5.88[a]
	No	73	52	
Involvement in local labour groups	Yes	61	86	13.33[b]
	No	39	14	
Tenure insecurity	Yes	43	39	0.27
	No	57	61	
Farmland slope	Steep	20	46	9.22[b]
	Non-steep	80	54	
Waterlodging problem	Yes	61	43	4.493[a]
	No	39	57	
Pest infestation Problem	Yes	93	75	6.754[b]
	No	7	25	

χ^2: Pearson's Chi-square

[a,b] refer to significance at < 0.05 and 0.01 levels.

Socio-economic and institutional issues

There were statistically marked variations between builders and non-builders of soil-steps concerning partaking in off-farm jobs and indigenous labour-sharing assemblies. The percentage of farmers engaged in off-farm employment was 27% for builders and 48% for non-builders of soil-steps (χ^2 =5.88, P < 0.05, Table 3). This demonstrates that most of the farmers who built the structures do not join off-farm businesses compared to the non-builders. Roughly, 61% of the soil-step builders joined indigenous labour associations, whilst the equivalent stature for non-builders was 86% showing a meaningful statistical variation (χ^2 =13.33, P < 0.01).

A sharp deviation was traced between soil-step builder and non-builder farmers pertaining to expert backing (help received from DAs). The middling contact of soil-step builders with DAs was ≈2 days yr^{-1}, while the equivalent mean contact of the non-builders was <1 day yr^{-1} (P < 0.01, Table 2). This implies that soil-step builders acquire more support from DAs than the non-builders. Regularity of farmers' contact with agricultural experts enhances their exposure to new information and develops their consciousness and insights on soil erosion and the help of easily acquiring SWC technologies (Shiferaw and Holden, 1998; Amsalu and de Graaff, 2007). Expert help is thus a critical issue in soil-steps building in the study villages. Conversely, no statistically important distinction was viewed in alleged land tenure insecurity between the soil-step builders and non-builders. Greater than 55% of the households from each group (from builders and non-builders) perceived that they had a secured tenure (Table 3).

Binary logit results on controls of soil-steps building

Numerical evaluations offered above (Tables 2 & 3) signify occurrence of major statistical disparity between builders and non-builders of soil-steps related to factors like household heads' age and sex, the number of household members and size of farmlands, the number of farm equipments owned by the households, perceived farmland slope cultivated by the households, perceived pest infestation and waterlodging problems, frequency of meeting with DAs for help, and households' interest in off-farm and indigenous labour-sharing activities. Nevertheless, educational status of the household heads', farmland distance from residence and perceived tenure insecurity do not reveal logical variance between soil-steps builders and non-builders. These three factors denied inclusion during computations passing through the binary logit model. The t-test results (Table 2) demonstrate existence of statistically meaningful divergence between stone-embankment builders and non-builders with regard to the frequency of farmers' meeting with DAs. But, this factor was excluded from further use in the logit model due to correlation problems.

Table 4. Issues influencing soil-steps building: binary logit outputs

Factors/issues	B	S.E.	Sig.	Exp(B)
Sex of the head (1)	-1.356	1.284	.291	.258
Age of the head	.039	.021	.065	1.040
Number of household members	.382	.156	.015	1.465
Farmland size	1.271	.430	.003	3.563
Partaking in local labour groups (1)	2.420	.704	.001	11.241
Farmland slope(1)	1.717	.595	.004	5.568
Problem of waterlodging (1)	-.662	.544	.223	.516
Performing off-farm work (1)	-1.373	.683	.044	.253
Problem of pest infestation (1)	-1.979	.927	.033	.138
Number of farm equipments owned	2.322	.542	.000	10.192
Constant	-9.386	1.733	.000	.000
Model-$\chi2$	105.746		0.000	
-2Log likelihood ratio	105.513			
Correctly predicted [a]	87.1%			
Sensitivity [b]	65.9%			
Specificity [c]	93.3%			
Hosmer and Lemeshow statistic			0.871	
Nagelkerke R Square	0.629			

[a] Based on a 50-50 probability classification scheme
[b] Correctly predicted adopters based on a 50-50 probability classification
[c] Correctly predicted non-adopters based on a 50-50 probability classification scheme

Table 4 presents estimation results of the logit model on issues influencing farmers' decisions on building of soil-steps as SFLMTs. The Pearsons' Chi-square ($\chi^2 = 105.75$, $P < .001$, df =10) signifies a statistically noteworthy value showing that the data are en suite to the logit model. The Hosmer-Lemeshow statistic has signified a correct replica (at $P>0.05$ level). The summary table classification of the sample cases (Table 4) has also reported an 87% total precision of accomplishment of evaluation (i.e. 66% for builders and 93% for non-builders of soil-steps). Except the sex of the household head, the course of influence of the rest of the issues was consistent with our initial postulates. Household heads' age, number of household members and farmland size, number of farm equipments owned and membership in indigenous labour groups appreciably and positively affected soil-terrace building practices whilst the impact of involving in off-farm jobs and the problem influx of pests (weeds, rats & mices) found to be momentous, but negative. Sex of the household head and the risk of perceived watelodging were hypothesized to appreciably affect soil-steps building. Furthermore, a statistically important association was also observed between soil-steps builders and non-builders with these factors in the Chi-square test (Table 3). Nevertheless, the logit analysis (Table 4) showed the non-significant effect of these variables indicating that they are not important determinants of soil-steps building in the study villages.

In the logit result (Table 4), the age of the household head was found feebly and positively correlated with soil-steps building (significant at $P<0.10$ level). This entails that the mounting in farmers' age advances the skill of farming and the possibility of soil-step building by farmers as SFLMT. Via long years of exposure to farming, aged farmers can perceive better that soil-steps are sustainable SWC structures and can develop more soil-steps than younger farmers. The soil-steps building effort of young farmers might be constrained by smaller farmland holdings and more connection to off-farm jobs (Amsalu and de Graaff, 2007). Amsalu and de Graaff (2007) observed a positive effect of age on stone-terrace construction in central Ethiopia. As observed in local reality, young farmers suffer from farmland shortages (e.g. see Belay *et al*., 2017) because the farmlands owned by their parents are too small to be shared and there are no reserve cultivable lands that can be allocated to the youth population or to the newly emerging households in many of the villages. Due to this, most young farmers cultivate contracted lands, or else, join the off-farm business. Off-farm work attracts most of the youngsters because it provides them with the chance of accessing cash money that can enable them to ease short-term problems and to satisfy daily necessities. Hence, most of them become reluctant in soil-steps building and in performing other SWC activities.

However, the above claim is contrary to the findings of (Shiferaw and Holden, 1998; Gebremedhin and Swinton, 2003; Anley *et al*., 2007) in central, northern and western Ethiopia, respectively and to that of Lapar and Pandey (1999) in the Philippines; all of which had reported the significant decreasing impact of age on technology adoption. Such studies argue that aged farmers are reluctant to adopt new technology and also lack the labour required to install SWC structures. Young farmers instead have the labour needed and receive up-to-date technological information that motivates them to apply SWC structures on their farmlands.

A unit increase in the size of household members was found to increase the likelihood of farmers' building of soil-steps by about 1.5 times ($P < 0.05$, Table 4). This indicates that having many family members is a potential for having more household labour. This outcome is well in agreement with the results of Medhin and Kohlin (2009) for six districts in Amhara Region, Ethiopia and that of Gebremedhin and Swinton (2003) for other six districts in Tigray, northern Ethiopia. These studies reported that family labour availability had a significant positive effect on adoption of SWC technologies in highland Ethiopia. Nevertheless, other studies claim that having more young children may sometimes increase the number of dependent population in a family and may not always be a potential for labour. It may rather worsen the burden of feeding the family (e.g. see Bekele and Drake, 2003). In such circumstances, household heads may divert to off-farm business to harvest additional income to fulfill family needs. This can hinder them to apply soil-steps and other SWC technologies on their farmlands.

Ownership of large farmlands was hypothesized to positively influence application of soil-steps. As expected, the regression model has showed a positive significant effect at $P < 0.01$ (Table 4). This implies that ownership of large sized farmlands enhances the likelihood of soil-steps building, and this finding conforms to many previous studies (Shiferaw and Holden, 1998; Mbaga-Semgalawe and Folmer; 2000; Tadesse and Belay, 2004; Amsalu and de Graaff, 2007; Anley *et al*., 2007; Medhin and Kohlin, 2009). Having smaller farmland may not give confidence for soil-steps building. This is because it causes the loss of part of the farmland for the embankments and even makes ploughing complicated (Shiferaw and Holden, 1998; Bekele and Drake, 2003; Gebremedhin and Swinton, 2003; Amsalu and de Graaff, 2007). Gebremedhine and Swinton (2003) reported ownership of large plots favoured building of bunds in Tigray, northern Ethiopia. Farmers with large farmlands don't worry about the land lost for bund construction because they can grow sufficient crops from the rest of the land contrary to farmers who fear losing part of their land for it; because it can significantly impact household food supplies.

Farmland slope was another factor estimated to appreciably initiate construction of soil-steps in high-rainfall areas. The effect of this issue was also observed meaningful and positive in the logit result ($P < 0.01$, Table 4). This signifies that a unit increase in farmland slope forces farmers to boost the probability of constructing soil-steps by about 5.6 times. Since slope is a factor for rapid soil erosion, farmers' with sloping lands are forced to frequently build soil-steps to avoid sever soil losses. Such farmers are always in touch with maintenance and improvement of the structures in the study villages and in other parts of northern Ethiopia; for otherwise, they lose their precious soils. Previous studies reported that farmland slope has significant positive relation with adoption of SWC structures (e.g. Shiferaw and Holden, 1998; Lapar and Pandy; 1999; Bekele and Drake, 2003; Gebremedhine and Swinton, 2003; Amsalu and de Graaff, 2007; Anley *et al*., 2007). Gebremedhine and Swinton (2003) for instance showed that the degree of slope intensified the building of soil and stone structures in Tigray, northern Ethiopia. This study is thus in conformity with other similar studies in Ethiopia and elsewhere in the world.

The problem of weed and pest infestation in areas covered with stone-structures was reported to prevail in different parts of Ethiopia (e.g. Vancampenhout *et al*., 2006; Nyssen *et al*., 2007). The result in this paper is also negative and significant ($P < 0.05$, Table 4). Pest infestation (invasion of rats and weeds) is thus significantly deterring farmers' soil-steps building decisions in the study district. Weeds safely grow on and along the soil-steps and compete for nutrients with the crops. This retards crop growth and even causes a reduction in yields. This discourages farmers' interest of building soil-steps. Soil-steps also harbor pests (rats, cockroaches and mice) that potentially attack crops which may cause physical damage on the growing crop and finally on yield reduction. Due to this, farmers' are discouraged to build the soil-steps on their farmlands.

Possession of farm equipments is strongly and positively affects the building of soil-steps ($P < 0.001$, Table 4). This indicates that farmers who do own different farm tools are more likely to build soil-steps than those who do not. Farm equipments (such as the iron-plough, pick axe, the hoe, spade, trowel etc.) are essential tools in agriculture and in SWC technology adoption. Having such tools motivate farmers to invest on SWC structures and on other agricultural undertakings. The lack of the tools in question conversely deters farmers' soil-steps building activities and even their entire agricultural engagements. The regression result is thus tangible and conforming with the objective reality.

Taking part in off-farm job appreciably reduces the probability of building of soil-steps (P<0.05, Table 4). It places farmers outside of farming activities and lessens the labour and time available to SWC installation. The finding in this study thus unswervingly matches to the opinions of Amsalu and de Graaff (2007) that mentioned access to off-farm job can redirect household labour from farming to non-farming business. Off-farm work helps poor farmers' to generate cash income for immediate household needs, and hence, attracts more poor people to engage in it. When poor people concentrate on off-farm business, they frequently depart from the farm venture and then from constructing of soil-steps. This can in turn cut the labour contribution on soil-steps application and even conceal the improvements gained from farmland management using soil-steps building. Gebremedhine and Swinton (2003) also described that rigorous constructions of terraces were more common in remote villages where off-farm prospects are restricted. In the context of this study, many farmers living nearer to Dangila town were observed engaged in the charcoal and firewood business (Fig. 3a) rather than working on their agricultural fields (see also Belay and Bewket, 2013a, 2015; Belay *et al.* 2017). Off-farm business entices farmers' interest from farm to non-farm projects.

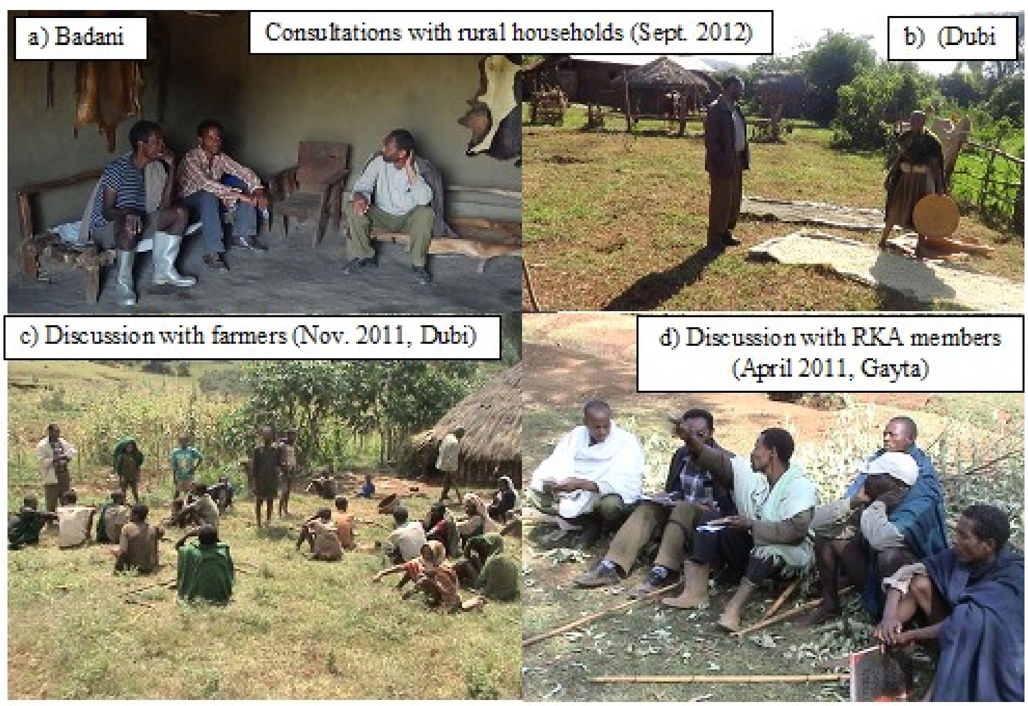

Fig. 5. Discussions with different farmers and farmers' groups
Note: RKA/Rural Kebele Administrations refer to rural village administrations

Attachment to indigenous labour associations is found notably and positively affecting soil-steps building (P<0.001, Table 4). *Wonfel* and *wobera* grant soil-step builders the chance to get agricultural labour when required and thus help soil-terrace construction. The groups are organized by companion farmers and close relatives living in the neighborhoods; hence, their implementation is mostly unproblematic. They also improve and strengthen the social relationship among the farmers. The finding has support from the works of Lapar and Pandey (1999) in the Philippines and Mbaga-Semgalawe and Folmer (2000) in Kenya. During data gathering activities, it was noted that farmers were working in groups on their farmlands (see Belay and Bewket, 2013a, 2015; Belay *et al*. 2017). However, during FGDs and key informant interviews (Fig. 5), farmers were complaining that their indigenous labour-sharing experience is being disrupted by the recently introduced politically enforced 'one-to-five'[3] farmer arrangement. Hence, care must be taken not to needlessly upset the culturally inbuilt labour-sharing associations of the farmers in the study villages and everywhere in Ethiopia.

Generally, the odds of farmers' soil-steps building choices are appreciably getting higher with rising in household heads' age, number of family members, farmland size, farmland slope, connecting to indigenous labour groups and possession of farm equipments. However, the possibility of soil-steps building diminishes with more partaking in off-farm jobs and pest infestation risks.

Conclusion

This paper assessed issues impacting farmland management practices and the use of soil-steps as SFLMT in a high-potential district named Dangila *woreda*, in the northwestern highlands of Ethiopia. Structured household survey on 201 farm households, FGDs and participatory field observations and transect tours were the sources of data. Results indicated that a number of factors are affecting farmers' building of the soil-steps. Household heads' age, number of household members, farmland size, and farmland slope, involvement in indigenous labour-sharing associations and number of farming tools owned by the households have appreciably and positively affected soil-steps use and building practices. Conversely, the problem of pest infestation and engagement in off-farm work were found to significantly hinder farmers' soil-steps application practices. The results in general indicated that household endowments noticeably determine farmers' soil-steps use and building practices and decisions as SFLMT. Future farmland management interventions ought to focus on improving farmers' resource endowments in order to strengthen their capacity to invest on SFLMTs. Farmers' participation in indigenous community labour groups has to be promoted and care should be taken not to further reduce farmers' farmland sizes.

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[3] A politically imposed labour organization sponsored by government offices

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