Received: 25 November 2019 | Revised: 5 August 2020 | Accepted: 27 August 2020
DOI: 10.1002/ldr.3755

RESEARCH ARTICLE

WILEY

Erosion and soil and water conservation in South-Kivu (eastern DR Congo): The farmers' view

Aimé B. Heri-Kazi[1,2] | Charles L. Bielders[1]

[1]Earth and Life Institute, Environmental Sciences, Université catholique de Louvain, Leuven, Belgium

[2]Faculty of Agronomy (FA), Department of Soil Sciences, Université Catholique de Bukavu (UCB), Bukavu, DR Congo

Correspondence
Aimé B. Heri-Kazi, Earth and Life Institute, Environmental Sciences Université catholique de Louvain, Leuven, Belgium
Email: heri.kazi@ucbukavu.ac.cd

Abstract

Despite being one of the hotspots for soil erosion in the world, little is known regarding farmer's knowledge of soil erosion in the highlands of South-Kivu in the Democratic Republic of Congo. A proper understanding of farmers' knowledge regarding soil erosion and conservation measures is a prerequisite for implementing resilient erosion control measures. The objective of this study was therefore to assess farmers' knowledge of soil erosion, to document existing soil and water conservation (SWC) measures and to identify their adoption constraints in the highlands of South-Kivu. Data were collected using interviews with a semi-structured questionnaire involving 720 respondents from eight watersheds in four territories. Farmers reported eight main erosion indicators. As opposed to gullies (80% of farmers), rills were perceived as important erosion indicators by only 50% of farmers, despite their common occurrence. Farmers were largely unaware of the potential impact of their crops and cropping practices on erosion. Farmers knew about only a limited range of SWC measures, which were perceived to be little to moderately efficient. Furthermore, the average level of adoption was very low (21%). Adoption constraints varied widely depending on the SWC measure. Thus, future interventions need to place much greater emphasis on awareness regarding soil erosion and SWC measures, to strengthen farmers' capacity for experimentation and adaptation to new technologies and finally to create a policy and institutional environment that stimulates widespread adoption of SWC techniques.

KEYWORDS

cropping practices, DR Congo, farmers' perceptions, soil erosion, South-Kivu, SWC measures, watershed

1 | INTRODUCTION

Soil erosion by water is one of the greatest causes of land degradation in the world, with numerous environmental but also social and economic impacts (Eswaran, Lal, & Reich, 2001; Labrière, Locatelli, Laumonier, Freycon, & Bernoux, 2015). From an agricultural point of view, topsoil removal reduces the productive capacity of the soil through the loss of nutrients and organic matter, exposure of deep horizons of lesser quality and, in extreme cases, significant reduction in the volume of soil that can be exploited by roots (Crosson, 2003; Oldeman, 1992; Scherr, 2003). Soil erosion may also cause direct damage to crops through root exposure, uprooting of seedlings or plants or crop burial in deposited sediment (Prasuhn, 2011). In the case of gullying, soil erosion may also result in the permanent loss of cropland when the size of the gully is beyond what can be reclaimed through locally available means (Frankl, Poesen, Haile, Deckers, & Nyssen, 2013; Poesen, Nachtergaele, Verstraeten, & Valentin, 2003). In developing countries, the loss of arable land through soil erosion has been shown to enhance poverty, underdevelopment and food insecurity, which will further lead to increased pressure on land and accentuate soil degradation, creating a vicious cycle (Lal, 2009). It has been argued that this vicious cycle weakens the resilience of smallholder farmers (Scopel et al., 2013) and will also restrict the availability of resources and knowledge to generate adequate income and opportunities to overcome the degradation process (Bationo et al., 2006).

In response to this issue, major investments have been made across the world to promote soil and water conservation (SWC) technologies. However, their dissemination has encountered difficulties, and erosion continues to be a widespread issue, in particular in developing countries (Tenge, De Graaff, & Hella, 2004; Wildemeersch et al., 2015). As a result, factors affecting a farmer's adoption of SWC measures have been widely studied in order to identify possible bottlenecks. Such studies have most frequently focused on farming household characteristics and resource availability as a means to explain adoption constraints (Giller, Witter, Corbeels, & Tittonell, 2009; Kassie, Zikhali, Pender, & Köhlin, 2010; Wildemeersch et al., 2013). However, this has led to sometimes contradictory results because farmers across borders and regions live in different environmental, cultural and socioeconomic conditions. In addition, even though certain household characteristics may be necessary to ensure investment in SWC technologies (e.g., land tenure, sufficient labour or financial resources), these conditions are generally not sufficient to explain farmer behaviour.

The importance of taking into account farmer's perceptions has been emphasised as a key to a better understanding of farmer's acceptance and implementation of SWC measures (e.g., Birhanu & Meseret, 2013; Gould, Saupe, & Klemme, 1989; Haghjou, Hayati, & Momeni Choleki, 2014; Kiome & Stocking, 1995; Sterk & Haigis, 1998). In particular, Meijer, Catacutan, Ajayi, Sileshi, and Nieuwenhuis (2015) and Assefa and Hans-Rudolf (2016) confirmed the interplay between the implementation of soil conservation measures and the perception of soil degradation, that is, a greater awareness of the extent of land degradation and of the impact of on-farm activities on land degradation, increases the likelihood of implementing SWC measures. In addition, the implementation of conservation measures will also be affected by farmer's knowledge or perception regarding the advantages or disadvantages of a given SWC technology (e.g., Wauters, Bielders, Poesen, Govers, & Mathijs, 2010). Studying such perceptions is therefore crucial, not only for understanding the ways in which farmers react to the menace of soil erosion and plan their interventions in their respective environments but also because it helps identify key leverage points on which to act in order to induce greater adoption (e.g., raising awareness, increased knowledge). In addition, a better understanding of farmers' perceptions may help direct specific actions to specific farmer groups. For greater relevance, collecting such information is best performed using farmers' own criteria. Indeed, assessing the impact of agricultural activities on erosion using indigenous knowledge raises farmer's awareness regarding their responsibility in the changes observed in their landscape (Okoba & Sterk, 2006).

The East-African Highlands, with an altitude generally above 1,500 m, spread across Ethiopia, Kenya, Tanzania, eastern DR Congo, Rwanda, Burundi and Uganda (Hurni, 1990). This region is endowed with rather favourable soil and climatic conditions, making it one of the most suitable regions for agricultural activities in Africa. As a result, the East-African Highlands are also one of the most densely populated areas of Africa, with average population densities ranging between 158 (Ethiopia) and 410 (Rwanda) inhabitants per km^2 (Himeidan & Kweka, 2012). Nevertheless, high rainfall and steep slopes create favourable conditions for the occurrence of soil erosion, a process that has been strongly enhanced by poor resource-use practices and dramatic changes in land cover/land use during the last decades—a direct consequence of the high population pressure. This has in turn impacted food security and social livelihoods and contributed to the high overall poverty and agricultural crisis in the East-African Highlands (Assefa & Hans-Rudolf, 2016; Place, Pender, & Ehui, 2006; Wickama, Okoba, & Sterk, 2014).

Whereas soil erosion by water has been well documented in many countries of the East-African Highlands (Ethiopia, Kenya, Tanzania, Uganda, Burundi and Rwanda (Bagoora, 1988; Bizoza, 2014; El-Hassanin, Labib, & Gaber, 1993; Okoba & Sterk, 2006; Tenge et al., 2004), little is known to this date regarding the extent of soil erosion and conservation along the highlands of the South-Kivu Province in eastern DR Congo, which is part of the East-African Highlands. In this area, 80% of the population lives in the rural areas, and more than 90% of them practice subsistence agriculture under rainfed conditions (Moummi, 2010), making it especially susceptible to the consequences of land degradation by soil erosion. Land degradation also directly affects the urban population, since 70% of the food supply of cities in South-Kivu comes from surrounding rural areas (IPAPEL, 2010). Strategic documents for the reduction of poverty recognise land degradation as the major threat to agricultural production and a source of poverty in all DR Congo provinces (DSRP, 2005; DSRP, 2011). These documents emphasise that solutions should imperatively rely on an integrated approach to managing smallholder agriculture in watersheds in order to make agricultural production economically viable and environmentally sustainable (Hauser et al., 2007). Nevertheless, and unlike neighbouring countries, there is a general lack of scientific investigations in South-Kivu regarding soil erosion and indigenous SWC measures, despite it being identified as one of the hotspots of soil erosion in Africa (Van Oost et al., 2007). This situation can be largely attributed to the weak presence of government agencies, weak financing of national research institutions as well as the high level of insecurity that has lasted for several decades in the region.

During colonial times, from the 1940s till the 1960s, projects such as the "Mission anti-érosive au Kivu" widely implemented linear landscape elements such as ditches, grass strips and bench terraces, but these have largely disappeared nowadays (Moeyersons, 1989; Moeyersons et al., 2004). According to Lunze (1990), adoption of SWC measures in the 1980s remained low despite the presence of various NGOs involved in extension and dissemination of SWC technologies in the South-Kivu highlands. Little is known as to how the situation has evolved since then, but it is unlikely to have improved, given the rapidly growing population, high poverty levels and persistent insecurity over the last two decades. Since it is nowadays well

TABLE 1 Main characteristics of the eight surveyed watersheds in the highlands of South-Kivu, DRC

	Kalehe		Kabare		Idjwi		Walungu	
Characteristics of watersheds	Kal1	Kal2	Kab1	Kab2	Idj1	Idj2	Wal1	Wal2
Main river	Sangano	Nyambasha	Chiranywabwa	Mushuva	Musheke	Mwiri	Mugera	Kadubo
Watershed area (ha)[a]	2,975	459	4,456	10,204	2085	1,417	12,297	3,690
Population density (hab/km^{-2})[b]	599	228	379	355	1,163	2,316	93	358
Surveyed villages (number)	9	4	8	9	2	7	10	6
Watershed altitude range (m.a.s.l)[c]	1,580 to 1,694	1,491 to 1823	1,482 to 1762	1,499 to 1728	1,488 to 1887	1,485 to 1728	1,530 to 1,644	1,471 to 1,679
Longitude range (DD[d])	28,89 to 28,92	28,85 to 28,86	28,84 to 28,86	28,69 to 28,84	29,03 to 29,08	29,02 to 29,04	28,83 to 28,89	28,65 to 28,76
Latitude range (DD[d])	−2,08 to −2,10	−2,12 to −2,14	−2,18 to −2,20	−2,34 to −2,38	−2,14 to −2,22	−2,12 to −2,22	−2,65 to −2,69	−2,73 to −2,80
Geomorphology	Hills; lowlands	Highlands; hills; lowlands	Hills; uplands	Hills; uplands; lowlands	Hills; lowlands	Hills; uplands	Lowlands; peneplains; hills and uplands	Hills and uplands
Types of soils (FAO, 1998)	*Mollic Andosols, systic Nitisols, humic Nitosols and eutric Cambisols*		*Mollic Andosols, systic Nitisols,humic Nitosols and eutric Cambisols*		*Orthic Cambisols, dystic Nitisols and humic Nitosols*		*Orthic Cambisols, dystic Nitisols and humic Nitosols*	

[a]Determined using ArcGIS 10.2.2.
[b]Based on data from population censuses in the first and last quarters of 2015 by health centers in the study area.
[c]m.a.s.l.: metres above sea level.
[d]Decimal Degree.

accepted that, for farmers to adopt SWC technologies, they need to be aware of the erosion issue and its effects, perceive it as serious enough and must be able to undertake action against it; this study aimed at assessing farmers' knowledge of (a) soil erosion and its causes and (b) soil and water conservation measures and their adoption constraints. Such information may then serve to guide future intervention strategies in South-Kivu.

2 | MATERIALS AND METHODS

2.1 | Study area

The survey was conducted in 55 villages across four territories (Walungu, Idjwi, Kabare, and Kalehe) of the South-Kivu highlands (Table 1). These four territories cover a wide range of biophysical et socioeconomic contexts encountered in the highlands of South-Kivu. Two watersheds per territory were selected taking into account the watershed's representativity in terms of soil type and smallholder farming systems but also their accessibility (Table 1). As a matter of fact, bad road conditions and insecurity (presence of some armed groups) are major constraints to access some areas (Ulimwengu, Funes, Headey, & You, 2009).

The watersheds were delimited based on the 30-m resolution DTM available from the ASTER GDEM2 website (METI, NASA, 2011) (Figure 1). The soils derive from volcanic and basaltic parent materials (*mollic Andosols, systic Nitisols, humic Nitosols and eutric Cambisols*) for the four watersheds in the northern part of the province (Kabare and Kalehe) or from ancient soil materials, mostly basaltic and strongly weathered (*orthic Cambisols, dystic Nitisols and humic Nitosols*) for the Walungu territory and the Idjwi Island (FAO, 1998) (Table 1). The study area experiences a tropical highland climate with a bi-modal rainfall distribution resulting in two wet (September–January and February–May) and one marked dry (June–August) seasons. As a result, there are two main cropping seasons per year. The 10-year average annual rainfall recorded in this area varies between 1,300 and 1,600 mm (IPAPEL, 2010).

In each watershed, the villages were selected using two criteria: (a) the absence of insecurity constraints and (b) a majority of the population being engaged in agricultural activities within the village. Indeed, in some villages, mining and brick-making activities dominate. Based on a list of villages bearing, these criteria for each watershed, a guided choice was made to cover as much as possible the cultivated areas in each watershed.

2.2 | Data collection

In order to have a comprehensive understanding of farmers' opinion on soil erosion and SWC practices, we collected information through individual semi-structured questionnaire interviews. A total of 720 randomly selected farmers were interviewed, 90 per watershed. The survey aimed at assessing (a) the severity of land degradation by

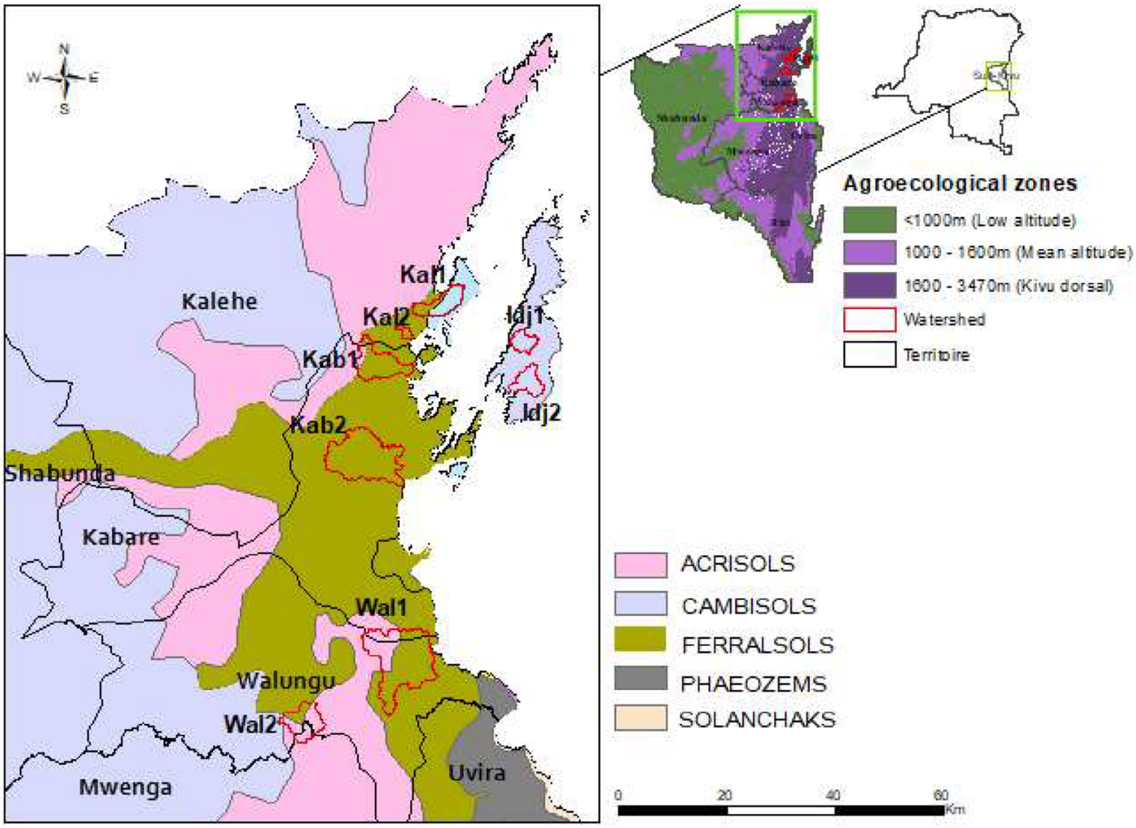

FIGURE 1 Surveyed watersheds as well as major soil groups and elevation within four territories forming the Kivu dorsal (Wal = Walungu, Kab = Kabare, Kal = Kalehe and Idj = Idjwi-Island) in South-Kivu, DRC. (SOTER data, Batjes, 2007) [Colour figure can be viewed at wileyonlinelibrary.com]

soil erosion and the soil fertility status, (b) farmer's knowledge regarding erosion and in particular indigenous indicators used by farmers to assess the occurrence and severity of erosion, (c) causes of soil erosion, with special emphasis on farmer's perception regarding the impact of their crops and cropping practices on soil erosion and (d) farmer's knowledge about SWC techniques and perceived constraints or reasons for non-adoption.

For this survey, respondents were heads of farming households (males or females). In case of absence, they were represented by their partners or grown-up children living within the household and having sufficient knowledge of the different activities of the household. The surveys were conducted in local languages, and, when needed, questions were explained by a member from the local development committee. The survey was done either at the farmer's home (when the farmer field was close to the house) or in his field so as to conform to their working programs, given that the period during which the survey was done coincided with the beginning of the cropping season. Being in or close to the field also allowed easy clarification or verification of the farmer's assertions.

An erosion severity index was calculated as follows. First, farmers were asked to list all signs of erosion observed in their fields. For each sign, farmers were asked to rate its severity on a scale from 1 (weak) to 4 (very high) and to justify the score based on what could be seen in their fields. Because farmers were not asked to rank the relative importance of each sign, a weight was calculated for each observed sign by dividing its frequency by the total frequency of all signs, that is, more weight is given to signs commonly reported by the surveyed farmers. Then, the erosion severity index of a given field was obtained by adding up the weighted severity indexes of all signs observed in that field.

Based on the actual erosion signs reported by each farmer, farmers were asked to list the main causes of water erosion in their fields and to rank the importance of each cited cause on a scale from 1 to 4. Whether or not crops or farming practices were cited as causes of erosion, farmers were requested to express their opinion regarding the possible impact of these two factors on erosion (promote, neutral, restrict).

Farmers were also asked about the SWC measures implemented in their fields and to rank the effectiveness of each SWC measure on a scale from 1 (low) to 4 (very high). Based on these ratings, an average effectiveness index was calculated for each technique. Finally, all farmers were asked to provide the reasons why they did not implement a range of conservation measures.

2.3 | Data analysis

Data were processed and analysed with XLSTAT (version February 2, 2016). Analyses involved descriptive statistics, including frequency distributions and graphs. Chi-squared tests were used to test for differences across watersheds. Simple logistic regression was performed to analyse the relationship between the erosion severity index and the presence/absence of SWC techniques.

3 | RESULTS

3.1 | Erosion indicators

Nine main erosion indicators were reported by the farmers, of which eight were listed by more than 50% of the respondents (Table 2). Two indicators relate to forms of erosion (rills and gullies), while the remainder refer to the impacts. Impact indicators relate mostly to the consequences of erosion or sedimentation on soils or crops, though one indicator also relates to the impact on labour. Whereas the presence of gullies was reported by 80% of farmers as a sign of erosion, rills were only mentioned by 50% of farmers. The frequency of observation of erosion indicators varied significantly across watersheds ($p < .0001$). On average over all nine indicators (excluding 'others'), erosion signs were most frequently reported in Kal2 and Idj1 (> 80% of farmers on average) and least in Wal1 and Wal2 (< 45% of farmers on average). Although gullies were commonly cited in all watersheds (>60% of farmers), some other indicators were extremely variable. This was for instance the case for 'hampering of tillage' (4–93%) and 'stoniness/rock outcrop' (1–94%) but also for 'rills' (13–88%).

Not all farmers reported all erosion signs (Figure 2). Nevertheless, the severity of the signs was, on average, perceived by 21% of the respondents who mentioned a given erosion sign as high to very high. The severity was highest for root exposure (high to very high for 38% of respondents) and lowest for rills (high to very high for 9% of respondents).

Based on the severity of the observed erosion signs, a severity index was calculated for each farmer's field. Across the watersheds, erosion severity was 2.3 ± 1.1 (mean ± SD; Figure 3). On average, 14.4% of fields are subject to severe to very severe erosion (index ≥3) (Figure 3).

3.2 | Causes of water erosion

The most commonly quoted causes of soil erosion (>50% respondents) in all the eight watersheds were high rainfall, steep slopes, occurrence of runoff and nature of the soil (Table 3). Overall, less than 20% of farmers associated erosion to their choice of crops and farming practices. Nevertheless, the perception of the main causes of soil erosion varied significantly across watersheds (Table 3). On average, causes were most frequently listed in Kal2 and Idj1 (the six main causes were listed by >70% of farmers on average) and least in both Walungu watersheds (the six main causes were listed by <40% of farmers on average). High rainfall was perceived as a cause of erosion in all watersheds (> 69% of respondents). Slope was viewed as a cause by a majority (>70%) of farmers in all watersheds except in Wal2 where only 50% of farmers mentioned this factor. Regarding crops and farming practices, their contribution to erosion was nearly fully ignored in Kal1, Wal1 and Wal2 (<5%) compared to the other watersheds where 21–36% of the farmers considered that these factors contribute to erosion.

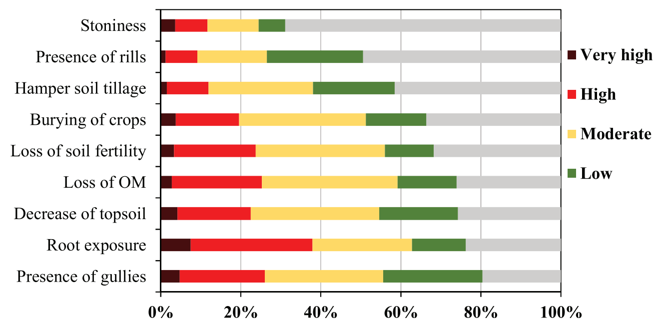

FIGURE 2 Frequency distribution of perceived severity of observed signs of erosion (% farmers, n = 720). No answer refers to the farmers that did not observe the sign in their field [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 2 Frequencies of observed signs of erosion within the eight watersheds and Chi-square test results (% farmers; n = 90 for each watershed)

Signs of erosion	Avg.	Kal1	Kal2	Kab1	Kab2	Idj1	Idj2	Wal1	Wal2	Chi^2	p-value
Presence of gully	**80.4**	76.7	97.8	78.9	84.4	91.1	84.4	70.0	60.0	56.6	<.0001
Root exposure	**76.3**	74.4	98.9	75.6	75.6	93.3	81.1	54.4	56.7	84.0	<.0001
Decrease of topsoil depth	**74.3**	76.7	97.8	76.7	73.3	93.3	82.2	57.8	36.7	126.2	<.0001
Loss of organic matter	**73.9**	61.1	96.7	80.0	81.1	84.4	83.3	53.3	51.1	89.3	<.0001
Loss of soil fertility	**68.2**	65.6	93.3	72.2	73.3	85.6	85.6	38.9	31.1	146.0	<.0001
Burial of crops	**66.3**	70.0	97.8	63.3	60.0	74.4	68.9	51.1	45.6	72.1	<.0001
Hampered tillage	**58.5**	63.3	93.3	52.2	55.6	90.0	77.8	31.1	4.4	234.3	<.0001
Presence of rills	**50.6**	46.7	87.8	64.4	45.6	71.1	56.7	13.3	18.9	160.8	<.0001
Stoniness/rock outcrops	**31.1**	20.0	94.4	16.7	10.0	64.4	28.9	13.3	1.1	299.0	<.0001
Others	**0.6**	0.0	0.0	0.0	0.0	0.0	3.3	1.1	0.0	16.1	.024

Note: The sum of frequencies for each watershed is greater than 100 as farmers could provide more than one response.
Abbreviations: Kal, Kalehe; Kab, Kabare; Idj, Idjwi; Wal, Walungu.

The contribution of rainfall, slope steepness, runoff and soil properties to soil erosion was perceived as being of moderate to very high importance by 86, 61, 51 and 33%, respectively, of those farmers who identified the causal factor (Figure 4). In addition to the fact that few producers identified cropping practices and crops as causal factors, more than half of those who listed these two factors considered them to be of low importance.

3.2.1 | Effect of crops on erosion

Table 4(a) lists the 12 most important crops grown in the study area. Beans, cassava and maize are staple crops and are grown by more than 85% of farmers. Sweet potato, banana and taro are cultivated by 35 to 64% of the farmers. The remaining crops are grown by approximatively 10–20% of the farmers. Most crops were perceived by farmers as being neutral with respect to erosion [Table 4(a)]. Regarding coffee and banana, 57 and 55% considered these crops as having an anti-erosion effect. Consistent with the above-mentioned results, very few farmers considered that crops could promote erosion. In this respect, beans appeared as the least favourable crop, though only by 8% of the respondents.

3.2.2 | Effect of farming practices on erosion

Eleven main agricultural practices were reported. Weeding, tillage and intercropping as well as household waste, crop residue or compost application were performed by more than 75% of the farmers [Table 4 (b)]. Most farming practices were perceived as neutral with respect to soil erosion, except for hilling and ridging which were perceived to limit erosion by 83 and 42% of adopters because they slow down runoff water flow. Hilling and ridging are, however, restricted to specific crops such as yam and sweet potato. An anti-erosive effect was also attributed to farmyard manure (27%) and intercropping (10%), although the majority of respondents view these two techniques as neutral. Ploughing and weeding were generally perceived as neutral, but, on average, 15% of the respondents considered that these practices favour erosion.

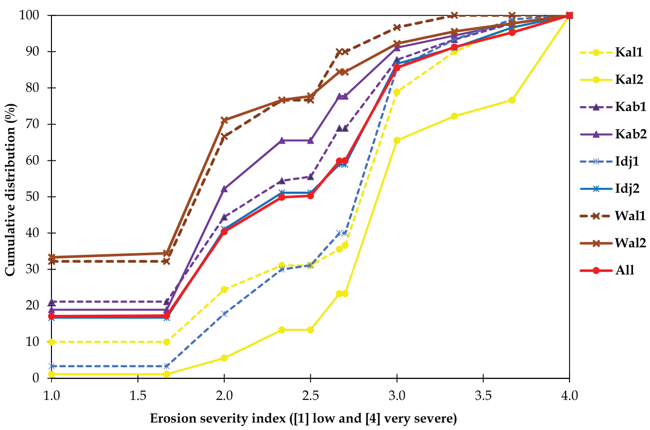

FIGURE 3 Cumulative distribution of erosion severity index in the eight watersheds of Kivu dorsal (*N* = 90 in each watershed). Kal = Kalehe; Kab = Kabare; Idj = Idjwi; Wal = Walungu; All = the total of eight watersheds [Colour figure can be viewed at wileyonlinelibrary.com]

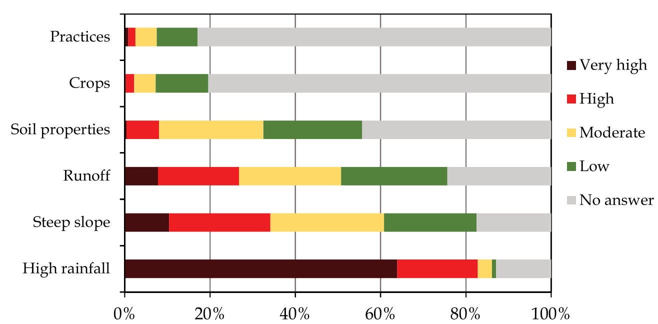

FIGURE 4 Frequency distribution of perceived importance of the soil erosion causal factors listed in Table 4 (% farmers, *N* = 720). No answer refers to the farmers that did not report the causal factor. 0% 20% 40% 60% 80% 100% [Colour figure can be viewed at wileyonlinelibrary.com]

TABLE 3 Frequencies of perceived causes of soil erosion within the eight studied watersheds and Chi-square test results (% farmers, n = 90 for each watershed)

Cause	Avg.	Kal1	Kal2	Kab1	Kab2	Idj1	Idj2	Wal1	Wal2	Chi^2	*p*-value
High rainfall	**87.1**	88.9	98.9	84.4	88.9	96.7	90.0	80.0	68.9	50.8	<.0001
Steep slope	**82.5**	85.6	98.9	81.1	87.8	96.7	90.0	70.0	50.0	110.8	<.0001
Runoff	**75.7**	75.6	98.9	78.9	73.3	97.8	87.8	53.3	40.0	144.9	<.0001
Soil properties	**55.7**	60.0	64.4	57.8	53.3	81.1	61.1	34.4	33.3	63.2	<.0001
Crops	**19.6**	4.4	35.6	30.0	31.1	31.1	21.1	1.1	2.2	85.9	<.0001
Practices	**17.1**	1.1	30.0	25.6	24.4	30.0	22.2	0.0	3.3	77.6	<.0001
Other	**0.1**	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.0	.428

Note: The sum of frequencies for each watershed is greater than 100% as farmer could provide more than one response.
Abbreviations: Kal, Kalehe; Kab, Kabare; Idj, Idjwi; Wal, Walungu.

TABLE 4 Frequency distribution for perceived effect of crops and common farming practices on soil erosion (promote, limit or no effect) (% farmers, *n* = 720). Adopters correspond to the farmers cultivating a given crop or applying a given farming practice. Respondents correspond to the fraction of adopters that evaluated the crops'/farming practices' impact on erosion

		Adopters (%)	Respondents (% of adopters)	Promote (%)	No effect (%)	Limit (%)
(a) Crops						
Banana		56.4	83.0	0.0	45.1	54.9
Bean (climbing and ground)		94.7	85.3	8.2	91.4	0.3
Cassava		93.2	85.1	1.6	89.1	9.3
Coffee tree		16.4	81.4	0.0	42.7	57.3
Gardens (cabbage, tomatoes, eggplant, onions…)		10.0	62.5	0.0	86.7	13.3
Groundnut		21.4	76.6	5.1	94.9	0.0
Maize		85.4	82.8	3.3	95.5	1.2
Soy		13.9	89.1	4.4	95.6	0.0
Sunflower		12.6	44.0	2.5	87.5	10.0
Sweet potato		63.5	81.8	0.5	86.9	12.6
Taro (Colocasia esculenta)		35.3	68.9	1.1	91.4	7.4
Yam		19.4	62.9	0.0	86.4	13.6
(b) Common farming practices	Acronyms					
Weeding		100.0	46.8	13.9	84.6	1.5
Ploughing/tillage		99.3	62.1	15.8	79.1	5.2
Intercropping	INTERC	98.1	73.5	0.2	89.6	10.2
Household waste application	WASTE	96.5	41.3	0.0	97.2	2.8
Crop residue application	RESIDUE	79.2	61.0	0.6	95.4	4.0
Compost application	COMPOST	75.3	70.5	0.8	94.2	5.0
Hilling (extended ridges)	HILL	48.5	22.1	0.0	16.9	83.1
Farmyard manure application	FYM	34.8	52.6	0.8	72.7	26.5
Mulching	MULCH	29.3	58.3	0.0	96.7	3.3
Crop succession/rotation	ROTATION	27.9	81.7	0.0	95.7	4.3
Ridging	RIDGE	5.1	100.0	1.0	57.3	41.7

Note: Percentage does not add up to 100 because of multiple responses.

3.3 | SWC measures and adoption constraints

As mentioned above, common cropping practices such as mulch or compost application, tillage or intercropping were seldom perceived as beneficial for erosion control [Table 4(b)]. Consistent with this, their average effectiveness was perceived as low on average (1.1–1.4 on a scale from 1 to 4; not shown). Besides the cropping practices, farmers reported seven specific soil erosion control measures (Table 5), of which drainage ditches (69% of farmers) and agroforestry systems (42% of farmers) were most commonly applied. Additionally, 15% of farmers knew about drainage ditches and 13% knew about agroforestry for erosion control but did not implement these techniques. Planting a hedge along the contour was a known anti-erosive measure for 39% of farmers, but only half of them declared planting such hedges. On the contrary, all farmers who knew about anti-erosive bunds for erosion control also implemented them (15%). Only very few farmers (<4%) declared knowing or maintaining a permanent vegetation cover, ploughing along the contour or placing brushwood fences. Drainage ditches and permanent vegetation cover were deemed most effective for erosion control, closely followed by contour hedges and contour bunds (Table 5). The effectiveness of all four measures was rated 2.3 to 2.6, that is, between moderate and high. Agroforestry was deemed moderately effective. Brushwood fences were reported as being of low effectiveness, but only seven farmers had practical experience with this technique, and among those, only four reported on the effectiveness. The rating of contour plowing and permanent vegetation cover may similarly be questioned given the low number of evaluators.

Although there were significant differences across watersheds regarding the implementation of SWC measures, no systematic pattern could be identified (not shown). Drainage ditches and agroforestry were rather less common in Wal2. Earthen bunds were more common in Kal1 and Idj1, whereas permanent vegetation cover was more often mentioned in Kal1 and Kab1.

The main reasons formulated by farmers (Table 6) when asked why they did not adopt certain SWC measures were small farm size, labour requirements, availability of suitable equipment, insufficient money and labour and perceived inefficiency of some techniques. In

TABLE 5 Reported soil and water conservation (SWC) measures: percentage farmers aware of the anti-erosive function, percentage adopters and frequency distribution regarding the perceived effectiveness for erosion control (n = 720)

				Effectiveness					
		Aware	Adopt	Very high (4)	High (3)	Moderate (2)	Low (1)	No answer	Avg. Effectiveness[a]
Acronyms	SWC measures	%	%	%	%	%	%	%	
DITCH	Drainage ditches	84	69	15	41	30	14	0.4	**2.6**
PCOVER	Permanent vegetation cover	4	4	0	60	30	5	5	**2.5**
HEDGE	Hedge along contour	39	20	3	45	43	8	1.4	**2.4**
CONTOUR	Earthen bunds along contour	15	15	8	26	59	4	3	**2.3**
PLOUGH	Contour ploughing	1.7	1.7	0	33	33	33	0	**2.0**
AGROF	Agroforestry	54	42	2	25	41	29	3	**1.9**
BFENCE	Brushwood fence	1.5	1.0	0	14	29	14	43	**1.1**

[a]On a scale from 1 to 4.

TABLE 6 Reported constraints/reasons for non-adoption of soil and water conservation (SWC) measures (n = 567)

Acronyms	Constraints	Number of respondents	% of farmers
FSIZE	Small farm size	107	19
WORK	Requires a lot of work	95	17
MOTIV	Motivation (laziness or neglect of farmers; neighbours do not get involved)	64	11
NO-EROS	Erosion is not a big problem in my plot	60	11
EQUIPMENT	Suitable equipment not available	49	9
COST	Requires a lot of money	46	8
LABOUR	Insufficient labour availability	44	8
EFFECT	Not interesting/ineffective method (technique)	38	7
TENURE	Technique not allowed in the rental plots	16	3
DIST	Large distance from the house to the plot	11	2
COMPOST	Domestic waste and mulches are usually composted	11	2
NOTFAM	Not familiar with the technic	10	2
PEST	Mulch and hedge hide pests within plots	7	1
COMPET	Trees in the plot bother the crops	5	1
LIVEST	No livestock within the household	4	1
Total		567	100

addition, some producers did not consider soil erosion as a big problem in their fields, so that there was no need for them to adopt SWC measures.

The main constraint for hedges and agroforestry systems was the small size of farms (Table 7). Adoption of hedges is affected by the work requirement and cost. In addition, farmers justify its non-adoption by its low-perceived effectiveness, and the fact that erosion on their plots is not such a big problem. This is also apparent in the high number of farmers that declare little motivation to implement hedges. Besides farm size, adoption of agroforestry systems suffers from cost and equipment availability. Although labour requirement is less of a problem than for hedges, farmer motivation appears as a serious constraint. Both techniques are restricted on rented plots. Drainage ditches are mostly constrained by perceived lack of erosion, labour requirements, perceived effectiveness and motivation but only little by farm size. Motivation and perceived lack of erosion also constrain the adoption of contour bunds. The use of organic amendments such as household waste and compost is constrained by the amount of work required for composting and, in the case of household waste, transportation to the fields. Availability of material is also an issue for mulches and compost, including the availability of manure to be added to the compost.

TABLE 7 Number of respondents for each constraint identified in the adoption of each soil and water conservation (SWC) measure (*n* is variable for each constraint)

	Soil and water conservation measure									
Constraints	HEDGE	DITCH	AGROF	CBUND	PCOVER	PLOUGH	BFENCE	COMPOST	MULCH	WASTE
FSIZE	24	6	28	2	3	2	0	6	4	3
WORK	14	24	5	0	0	1	1	38	10	1
MOTIV	20	16	13	2	2	0	0	6	4	0
NO-EROS	21	30	1	7	0	0	0	0	0	0
EQUIPMENT	8	7	13	0	0	0	0	16	5	0
COST	13	8	11	0	2	1	0	6	1	1
LABOUR	10	9	6	1	2	1	0	7	5	2
EFFECT	13	10	1	3	0	0	0	2	1	1
TENURE	5	2	8	0	0	0	0	0	0	0
DIST	0	0	0	0	0	0	0	2	0	9
COMPOST	0	0	0	0	0	0	0	0	5	6
NOTFAM	1	2	0	0	0	0	1	2	1	0
PEST	7	0	0	0	0	0	0	0	0	0
COMPET	0	0	5	0	0	0	0	0	0	0
LIVEST	0	0	0	0	0	0	0	4	0	0
Total of respondents	136	114	91	15	9	5	2	89	36	23

Note: Abbreviations of SWC measures and constraints are explained in Tables 4 and 5.

TABLE 8 Summary results of logistic regression analysis between erosion severity index and each adopted soil and water conservation (SWC) measure in the study area (variables and model parameters)

Variables (practices)	Source	Value	Standard error	Wald Chi-Square	Pr > Chi^2	Odds ratio (OR)
WASTE	Intercept	0.126	0.146	0.741	0.389	2.038
	Erosion index	0.712	0.103	48.229	**<0.0001**	
DITCH	Intercept	0.081	0.142	0.326	0.568	1.720
	Erosion index	0.542	0.094	33.551	**<0.0001**	
AGROF	Intercept	−0.727	0.142	26.203	<0.0001	1.311
	Erosion index	0.271	0.083	10.575	**0.001**	
PCOVER	Intercept	−1.825	0.184	98.282	<0.0001	1.345
	Erosion index	0.297	0.102	8.445	**0.004**	

Note: Abbreviations of SWC measures are explained in Tables 4 and 5. Only significant results are shown.

Based on logistic regression, adoption of four practices shows a positive relationship with erosion severity: drainage ditches, agroforestry, permanent cover and application of household waste (Table 8). This appears to indicate that these practices are implemented, at least in part, in response to erosion.

4 | DISCUSSION

4.1 | Farmer perception of soil erosion problems and causes

A range of impact indicators were reported by farmers, indicating a broad understanding of the impacts of erosion both on soils (reduced depth, loss of SOM and fertility, stoniness where applicable) and crops (root exposure, burial of crops). Besides these impact indicators, farmers also mentioned gullies and, less often, rills. Local farmers refer to gullies as permanent incisions which cannot be removed by routine manual land preparation activities, while rills were seen as small entwined or parallel incisions, easily erased by manual tillage operations. Given the steep slopes and heavy rainfall, gullies are very common in South-Kivu in areas impacted by human activities, and they are fully recognised by farmers as a sign of erosion (Figure 5a–d). Rills were generally among the least cited indicators, despite their common occurrence in the majority of fields and watersheds (personal observations; Figure 5b,c), and the severity of rilling was mostly ranked as medium to low. In the highlands of South Kivu, it is the ephemeral nature of rills that appears to explain the low rating as an indicator.

FIGURE 5 Pictures of surveyed farmers' fields illustrating erosion status: (a). low erosion; (b). moderate affections by rills, compaction and loss of organic matter; (c) permanent gullies and rills affecting all the field and (d) permanent gullies and affected by big rills [Colour figure can be viewed at wileyonlinelibrary.com]

Indeed, rills form only after significant rainfall events and are easily erased by routine land management activities (tillage or weeding). Thus, farmers do not perceive the high quantities of sediments that can be lost by this form of erosion, and the overall severity of erosion may be largely underestimated.

The rate of reporting of erosion signs varied greatly across watersheds. Similarly variable results regarding erosion signs (e.g., rills) have been reported in other studies (Okoba & de Graaff,2005; Takele, Chimdi, & Abebaw, 2015). Rates of reporting (Table 2) were always lowest in the Walungu territory. Based on personal observations, erosion was not less severe in the Walungu area than in the other surveyed watersheds (Heri-Kazi, 2020). However, Wal1 is closest to the City of Bukavu, and brick making is commonplace in the vicinity of this watershed. Wal2 is located in an area where mining activities are widespread. Although villages were selected where agriculture was the main activity, access to non-farming activities that are more lucrative than farming nevertheless seems to have impacted the rates of reporting. It may be that, because of these external sources of income, agriculture carries less importance, and farmers are less sensitive to existing signs of erosion. Whereas pairs of watersheds from the same territory were generally quite similar in terms of frequencies of responses, there is a marked contrast between Kal1 and Kal2, with much higher frequency of responses in Kal2. The explanation in this case seems to lie in the generally steeper slopes in Kal2 compared to Kal1 (Heri-Kazi & Bielders, 2020) but also in higher adoption rates of earthen bunds (+20%) and permanent vegetation cover (+31%) in

Kal1 compared to Kal2 (not shown). In addition, plot sizes tend to be smaller in Kal2, such that farmers may be somewhat more sensitive to the degradation of their land than in Kal1. Finally, the Idjwi territory is on average characterised by higher reporting frequencies than the other territories. Besides steeper slopes, part of the explanation may lie in the replacement of banana fields by large-scale cassava cropping as a result of the Banana Xanthomonas Wilt (BXW) disease. Cassava has been shown to cause more serious soil erosion than many other crops (Howeler, 2008).

Similarly to other studies in the east African highlands (e.g., Okoba & de Graaff, 2005 in Kenya; Mashi et al., 2015 in Nigeria; Rutebuka, Kagabo, & Verdoodt, 2019 in Rwanda), farmers believe that high rainfall, steep slopes and runoff are the main causes of erosion in the study area (Table 3). Soils play a lesser role, while less than 20% of farmers on average link erosion to their crops and cropping practices (e.g., Bitijula & Lal, 1983). With the exception of banana plants and coffee trees which have a dense rooting system (soil stabilization), offer a permanent vegetation cover (reduced surface crusting and splash) and are therefore perceived as beneficial for soil conservation, most crops are perceived as neutral with respect to soil erosion. Farmers explained this neutrality by the fact that other external factors such as rainfall and slope steepness are so overwhelming that most crops have little impact on erosion. Besides, farmers do not perceive that growing crops cause erosion because cropping is a necessity, engrained in their livelihoods and there is no alternative to this practice. Similarly, most cropping practices are perceived as neutral, even though some farmers recognised that practices that favour the mechanical destruction of soil structure promote runoff and erosion. Regarding the neutral role of most farming practices, producers again stated that the negative impact of heavy rainfall and steep slopes is so overwhelming that the effect of farming practices becomes negligible, for example, the positive effects of good farming practices on erosion are not perceived. Even so, raising awareness about the role of crops and cropping practices on soil erosion would be an important step in order to convince farmers to adapt their practices and adopt conservation measures.

There were significant differences across watersheds regarding causes of soil erosion. As for the erosion signs, frequency of responses tended to be lowest in the Walungu territory and highest in the Idjwi territory. Frequencies were also again noticeably lower in Kal1 than Kal2. It seems therefore that the same local contexts that explained differences in reporting of erosion signs also affected reporting of causes of erosion.

4.2 | Adopted control measures and their effect on soil erosion

Whereas beneficial cropping practices such as composting or spreading of waste are widespread but deemed ineffective for erosion control, specific soil conservation measures were often judged fairly effective by farmers, yet their adoption is rather limited, with the exception of drainage ditches and agroforestry (Table 5). Overall, adoption levels are substantially lower than what has been reported in other regions (Wildemeersch et al., 2013; Assefa & Hans-Rudolf, 2016). This was also observed in the Central Rift Valley of Ethiopia where, despite farmers' awareness of both water erosion and soil fertility decline, no significant investments in land management practices were made (Adimassu, Kessler, Yirga, & Stroosnijder, 2013). This is to some extent surprising given the widespread awareness of farmers of the occurrence of erosion in their fields in the study area. Indeed, de Graaff et al. (2008) showed that the first step in adoption of SWC technology is the knowledge or perception of the erosion problem. This is also supported by Tenge et al. (2004) and Haghjou et al. (2014) who stated that a good perception of erosion is the most decisive factor in the adoption of SWC technologies. It thus appears that other criteria, no less important (access to land and extension services, institutional support,… which are widespread problems in this region and neighbouring countries such as Rwanda and Burundi; that is, Rutebuka et al., 2019), are to be considered in the adoption process or are needed to ensure continued adoption of SWC technologies (Wildemeersch et al., 2013; Assefa & Hans-Rudolf, 2016, Rutebuka et al., 2019). Ragasa et al. (2015) showed that agricultural extension services suffered from the negative effects of decades of insecurity experienced in the study region, which could also be responsible for the low adoption rates of dedicated SWC measures.

Significant differences in adoption rates of SWC measures across regions were observed (not shown), but these regional differences varied from one SWC measure to another. Low adoption rates of ditches and agroforestry in Wal2 may have resulted from a lesser interest to invest in agricultural activities given the importance of mining as a source of income. However, in Wal1, adoption rates were similar to the other watersheds despite the importance of brick making as an external source of revenue, implying that availability of external sources of revenue does not necessarily lead to lower adoption rates. High adoption rates of earthen bunds in Kal1 and Idj1 coincide with a high percentage of farmers growing sweet potatoes, which are typically grown on bunds. Similarly, the high percentage of farmers referring to permanent vegetation cover in Kal1 and Idj1 coincides with a high percentage of farmers growing coffee (Heri-Kazi & Bielders, 2020). Hence the adoption rate of some of the SWC measures is intimately linked to regional differences in cropping systems.

The fact that farmers often did not mention crops and cropping practices as possible causes of erosion may reflect the perception that the problem is largely outside their control, given the overriding importance of rainfall and topography in the process. Nevertheless, our results indicate that much could be gained by simply raising the level of awareness regarding existing technologies since, for many of them, the level of awareness is not vastly different from the level of adoption (Table 5). In addition, farmers identified a range of constraints for each of the technologies that will have to be taken into account when promoting them. Several of these constraints relate to farmer motivation, perception of efficiency or perception that erosion is not severe enough to justify investment in these technologies. Training farmers to better assess signs of erosion, and especially rilling, and, at the same time, enhancing their knowledge regarding proper ways to implement SWC technologies to enhance their effectiveness may thus help with the adoption process.

Positive relationships were observed between the adoption of some SWC techniques and perceived erosion severity (Table 8). This may seem counter-intuitive because one could expect adoption of SWC measures to be correlated to lower erosion severity (e.g., Adimassu et al., 2013). The above-mentioned result, however, supports the perceived seriousness of the erosion phenomena by concerned farmers and may indicate that they may be more likely to invest in water erosion control practices when perceived erosion is high. Additionally, the positive correlation between adoption of practices and severity of erosion may also be an indication that these measures have little effect. This seems to indicate the need for training on the implementation of adequate techniques to combat soil erosion. Indeed, the effectiveness of an SWC measure will, in practice, depend very much on the suitability of the technique for a given form of water erosion (sheet, rill, gully) and how the SWC techniques are implemented (e.g., too great spacing between hedges …), or even by the approach adopted (issue of design versus environment, scale issue: field, hillslope or watershed).

Additional major constraints for specific SWC measures are cash and labour requirements as well as farm size and land tenure. These constraints have frequently been mentioned in other studies which addressed adoption issues of SWC technologies (e.g., Tenge et al., 2004; Birhanu & Meseret, 2013; Wildemeersch et al., 2013; Haghjou et al., 2014). Because of the small size of most farms (about 0.3 to 0.4 ha on average; Van Asten et al., 2013), farm size is seen as a constraint for technologies that compete for space with food crops (e.g., hedges and agroforestry systems). However, this does not necessarily have to be the case, as agroforestry systems and hedges may very well contribute to household food security and income if properly designed (Magcale-Macandog, Rañola, Rañola, Ani, & Vidal, 2010; Sharma et al., 2016). The fact that farm size is mentioned in relation to these technologies seems to indicate that current practices are not optimally designed. Nevertheless, the issue of farm size is likely to be exacerbated in the future because families are large (seven to eight children) and access to land happens essentially through inheritance, leading to further fragmentation (e.g., van Asten et al., 2013). Farmland ownership is a significant constraint for all technologies that involve long-term investments such as agroforestry, hedges and, to a lesser extent, drainage ditches, as has been reported elsewhere (Tenge et al., 2004). Besides the fact that such investments require approval by the landowner, there is the additional risk that, once the land has been improved, the owner will claim the parcel for his own use (Lunze, 2000).

In the study area, adoption rates mostly reflect farmers' own initiative compared to what has been observed in many other regions (with higher reported adoption rates) where adoption occurs in the context of multi-institutional programmes (e.g., Assefa & Hans-Rudolf, 2016; Rutebuka et al., 2019). Indeed, as a result of the persistent insecurity and weak government support, there have been very few soil conservation projects or programmes during the last decades. This also explains the near absence in our study region of dedicated soil erosion control measures (i.e., measures whose main purpose is erosion control such as ditches and terraces, as opposed to measures which may contribute secondarily to erosion control such as organic amendments or intercropping) that farmers would find too costly to implement without external support. In addition, adoption of dedicated SWC techniques by smallholder farmers is frequently limited by the lack of immediate returns on investment (Adimassu, Langan, Johnston, Mekuria, & Amede, 2017). However, in South-Kivu, because of the severity of the erosion process (Heri-Kazi & Bielders, 2020) and low inherent fertility of soils (Bitijula & Lal, 1983), this constraint may be less than in other environments. Indeed, it is expected that stopping erosion will more quickly lead to increased crop productivity, especially if fertility enhancing techniques are promoted alongside the SWC measures.

While dedicated SWC measures (e.g., drainage ditches, contour bunds, hedges) may be most effective at reducing soil erosion, the range of constraints associated with these techniques implies that their adoption will always be limited to certain categories of farmers (more motivated, owning larger farms, with external sources of income or having access to more labour, etc…). Hence efforts should not neglect existing practices whose main purpose is often not to control erosion but which, given proper advice, may significantly contribute to erosion control (e.g., organic amendments, surface mulching, intercropping). Such technologies are already widely adopted (98% for intercropping, 97% for spreading of household waste, 75% for compost; Table 4(b)). In fact, Roose (1993) among others alleged that farmer techniques could be just as effective as new technologies, provided that they are conducted efficiently. Nevertheless, reinforcing these practices also face constraints, in particular, in terms of availability of raw material for compost or mulching or in terms of transportation for household waste. Hence, depending on the farmer's resources and motivation, different solutions combining conventional techniques with dedicated erosion control measures may have to be proposed to the farmer, the so-called 'basket of best-bet technologies' as also proposed for soil fertility management (Giller et al., 2011).

The last finding of this study is that bench or progressive terraces were not reported or observed, even though they have been promoted by soil conservation projects in the region in the past two decades but also during the colonial period (Moeyersons, 1989). If well maintained, this technique can be very effective at controlling erosion and improving productivity (Bizoza & De Graaff, 2012). Besides the very heavy financial and labour constraints associated to this technique, the principal reason for their absence may be the lack of institutional support. Such institutional support is largely responsible for their widespread occurrence in neighbouring Rwanda, for instance (Bizoza, 2014).

5 | CONCLUSIONS

This study provides the first large-scale overview of farmers' perception of erosion and SWC measures in South-Kivu. Albeit with some degree of variability across watersheds, it demonstrates the widespread occurrence of erosion in this region, and that farmers seem well aware of the occurrence of erosion in their fields. Nevertheless, many farmers appear not to recognise erosion to its full extent given that the role of rilling in the erosion process is hardly acknowledged. Farmers similarly appear to underestimate the impact of cropping and cropping practices on erosion.

Some dedicated SWC measures are currently being implemented by farmers, and their greater effectiveness is acknowledged compared to their ancestral practices, yet adoption levels are rather low. The implementation of SWC measures by farmers appears to be a response to the perceived erosion severity, but they turn out to be little effective overall, which also is an indication of their weak implementation. A wide range of constraints restricts the adoption of SWC measures. Most constraints are external factors, among which the most relevant in the study area are the small farm size, week access to financial credits and insufficient manpower. The observed constraints will not be equally applicable to all farmers, such that future extension efforts will have to be tailored to farmers' characteristics, including their motivation towards SWC.

As part of future extension efforts, it will be essential to further raise awareness regarding erosion and the impact of human activities on soil loss. The findings of this study suggest that particular attention has to be given to the recognition of the roles that farmers play in the problem of soil degradation by erosion. New projects and extension services must therefore place much greater emphasis on strengthening farmers' capacity for experimentation and adaptation to new technologies. This will require institutional support to enhance the security needed for large-scale extension efforts and reduce the constraints that result from the increasing land fragmentation.

ACKNOWLEDGEMENTS

We are very grateful to all farmers and the enumerators who took part in the research, in particular, Mr Christian Mushayuma. We also wish to thank the graduate students of the Université Catholique de Bukavu (UCB) for their assistance in collecting additional data in the field. The first author is finally grateful for a Doctoral Fellowship granted by the Université Catholique de Louvain (UCLouvain), later complemented by an ARES Fellowship.

CONFLICT OF INTEREST

The data presented in this manuscript have not been published or submitted for publication elsewhere. We declare that the authors are not in a situation of conflict of interest, that they have all accepted this submission and that, together, they have participated in all stages of the data collection, analysis and writing.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ORCID

Aimé B. Heri-Kazi https://orcid.org/0000-0002-1797-9919

REFERENCES

Adimassu, Z., Kessler, A., Yirga, C., & Stroosnijder, L. (2013). Farmers' perceptions of land degradation and their Investments in Land Management: A case study in the central Rift Valley of Ethiopia. *Environmental Management*, *51*, 989–998. https://doi.org/10.1007/s00267-013-0030-z

Adimassu, Z., Langan, S., Johnston, R., Mekuria, W., & Amede, T. (2017). Impacts of soil and water conservation practices on crop yield, run-off, soil loss and nutrient loss in Ethiopia: Review and synthesis. *Environmental Management*, *59*(1), 87–101. https://doi.org/10.1007/s00267-016-0776-1

Assefa, E., & Hans-Rudolf, B. (2016). Farmers' perception of land degradation and traditional knowledge in Southern Ethiopia - resilience and stability. *Land Degradation & Development*, *27*(6), 1552–1561. https://doi.org/10.1002/ldr.2364

Bagoora, F. D. K. (1988). Soil erosion and mass wasting risk in the highland area of Uganda. *Mountain Research and Development*, *8*(2/3), 173–182. https://doi.org/10.2307/3673445

Bationo A, Hartemink AE, Lungo O, Naimi M, Okoth P, Smaling, EMA, Thiombiano L. (2006). African soils: Their productivity and profitability of fertilizer use. Paper presented at: Background paper for the African Fertilizer Summit 9-13th June 2006, Abuja, Nigeria. IFDC

Birhanu, A., & Meseret, D. (2013). Structural soil and water conservation practices in Farta District, North Western Ethiopia: An investigation on factors influencing continued use. *Science, Technology and Arts Research Journal*, *2*(4), 114–121. https://doi.org/10.4314/star.v2i4.20

Bitijula M. and Lal R. (1983). Socioeconomic constraints and soil degradation in Kivu region of Zaïre. Project report founded by the IFIAS. ISRIC Library, Wageningen. The Netherlands, 55.

Bizoza, A. R. (2014). Three-stage analysis of the adoption of soil and water conservation in the highlands of Rwanda. *Land Degradation & Development*, *25*(4), 360–372. https://doi.org/10.1002/ldr.2145

Bizoza, A. R., & De Graaff, J. (2012). Financial cost–benefit analysis of bench terraces in Rwanda. *Land Degradation & Development*, *23*(2), 103–115. https://doi.org/10.1002/ldr.1051

Crosson, P. (2003). Global consequences of land degradation: An economic perspective. In K. Wiebe (Ed.), *Land quality, agricultural productivity, and food security* (pp. 36–46). Cheltenham, England: Edward Elgar.

De Graaff, J., Amsalu, A., Bodnar, F., Kessler, A., Posthumus, H., & Tenge, A. (2008). Factors influencing adoption and continued use of long-term soil and water conservation measures in five developing countries. *Applied Geography*, *28*(4), 271–280. https://doi.org/10.1016/j.apgeog.200e8.05.001

Document de Stratégie de Croissance et de Réduction de la Pauvreté—2. (2011). Document de Stratégie de Croissance et de Réduction de la Pauvreté. RDC, Ministère du Plan. p. 126.

DSRP (Document de Stratégie de Réduction de la Pauvreté), (2005). *Province du Sud-Kivu. République Démocratique du Congo, Ministére du Plan*, Unité de Pilotage de Processus du DSRP, Kinshasa. p. 96

DSCRP-2 (Document de Stratégie de Croissance et de Réduction de la Pauvreté- 2) (2011). République Démocratique du Congo, *Ministére du plan*. p. 126

El-Hassanin, A. S., Labib, T. M., & Gaber, E. I. (1993). Effect of vegetation cover and land slope on runoff and soil losses from the watersheds of Burundi. *Agriculture, Ecosystems & Environment*, *43*(3-4), 301–308. https://doi.org/10.1016/0167-8809(93)90093-5

Eswaran, H., R. Lal and P.F. Reich. (2001). Land degradation: An overview. In: Bridges, E.M., I.D. Hannam, L.R. Oldeman, F.W.T. Pening de Vries, S.J. Scherr, and S. Sompatpanit (eds.). Responses to land degradation. Paper presented at: Proc. 2nd. International Conference on Land degradation and desertification, Khon Kaen, Thailand. Oxford Press, New Delhi, India.

Food and Agriculture Organisation (FAO) International Society of Soil Science (ISSS); International Soil Reference and Information Centre (ISRIC) (1998). World reference base for soil resources, vol 84.

Frankl, A., Poesen, J., Haile, M., Deckers, J., & Nyssen, J. (2013). Quantifying long-term changes in gully networks and volumes in dryland environments: The case of northern Ethiopia. *Geomorphology*, *201*, 254–263. https://doi.org/10.1016/j.geomorph.2013.06.025

Giller, K. E., Tittonell, P., Rufino, M. C., Van Wijk, M. T., Zingore, S., Mapfumo, P., … Rowe, E. C. (2011). Communicating complexity: Integrated assessment of trade-offs concerning soil fertility management within African farming systems to support innovation and development. *Agricultural Systems*, *104*(2), 191–203. https://doi.org/10.1016/j.agsy.2010.07.002

Giller, K. E., Witter, E., Corbeels, M., & Tittonell, P. (2009). Conservation agriculture and smallholder farming in Africa: The heretics' view. *Field Crops Research*, *114*(1), 23–34. https://doi.org/10.1016/j.fcr.2009.06.017

Gould, B. W., Saupe, W. E., & Klemme, R. M. (1989). Conservation tillage: The role of farm and operator characteristics and the perception of soil erosion. *Land Economics*, *65*(2), 167–182. https://doi.org/10.2307/3146791

Haghjou, M., Hayati, B., & Momeni Choleki, D. (2014). Identification of factors affecting adoption of soil conservation practices by some rainfed farmers in Iran. *Journal of Agricultural Science and Technology*, *16*(5), 957–967.

Hauser, S., Sonder, K., Binsika Bi Mayala, G., Mafuka, M.M., Lema, K.M., Coyne, D., Van Asten, P., Legg, J., Abele, S., Alene, A., Hanna, R., Ajala, S., Abaidoo, R., Ingelbrecht, I., Dixon, A., Sanni, L., Winter, S., Kadiata, B., Janssens, M. (2007). Programme prioritaire de la recherche agricole. Projet 9 ACP ZR 13/1 (GCP/DRC/036/EC selon codification FAO). Programme de réhabilitation de la recherche agricole et Forestière en République Démocratique du Congo. p. 91.

Heri-Kazi, B.A. (2020). Caractérisation de l'état de dégradation des terres par l'érosion hydrique dans le Sud-Kivu montagneux à l'Est de la R.D. Congo. Ph.D. dissertation, Université catholique de Louvain. p. 279.

Heri-Kazi, B.A., Bielders, C.L. (2020). Dégradation des terres cultivées au Sud-Kivu, R.D. Congo: perceptions paysannes et caractéristiques des exploitations agricoles», BASE [En ligne], Volume 24 (2), pp. 99–116. Retrieved from https://popups.uliege.be:443/1780-4507/index.php?id=18544

Himeidan, Y. E., & Kweka, E. J. (2012). Malaria in east African highlands during the past 30 years: Impact of environmental changes. *Frontiers in Physiology*, *3*, 315. https://doi.org/10.3389/fphys.2012.00315

Howeler, R., 2008. Does cassava cultivation degrade or improve the soil ? Paper presented at: Proc. 8th regional workshop “a new future for cassava in Asia: Its use as food, feed and fuel to benefit the poor.” Vientiane, Lao PDR. pp. 320–354

Hurni, H. (1990). In B. Messerli & H. Hurni (Eds.), *Degradation and conservation of soil resources in the Ethiopian Highlands, in African Mountains and highlands: Problems and perspectives* (pp. 51–63). Missouri: Wadsworth Press.

Inspection Provinciale de l'Agriculture, Pêche et Élevage. 2010. Rapport annuel. Inspection Provinciale de l'Agriculture, Pêche et Élevage; Province du Sud Kivu. RD Congo. p. 87.

Kassie, M., Zikhali, P., Pender, J., & Köhlin, G. (2010). The economics of sustainable land management practices in the Ethiopian Highlands. *Journal of Agricultural Economics*, *61*(3), 605–627. https://doi.org/10.1111/j.1477-9552.2010.00263.x

Kiome, R. M., & Stocking, M. (1995). Rationality of farmer perception of soil erosion: The effectiveness of soil conservation in semi-arid Kenya. *Global Environmental Change*, *5*(4), 281–295. https://doi.org/10.1016/0959-3780(95)00063-T

Labrière, N., Locatelli, B., Laumonier, Y., Freycon, V., & Bernoux, M. (2015). Soil erosion in the humid tropics: A systematic quantitative review. *Agriculture, Ecosystems and Environment*, *203*, 127–139. https://doi.org/10.1016/j.agee.2015.01.027

Lal, R. (2009). Soil degradation as a reason for inadequate human nutrition. *Food Security*, *1*(1), 45–57. https://doi.org/10.1007/s12571-009-0009-z

Lunze, L. (1990). Possibilité de gestion des sols au Sud-Kivu montagneux. Rapport annuel de l'Institut National pour l'Etude et la Recherche Agronomique (INERA-Mulungu). Décembre, 1990. p. 28.

Lunze, L. (2000). Possibilités de gestion de la fertilité des sols au Sud-Kivu montagneux. *Cahiers du CERPRU*, *14*, 23–26.

Magcale-Macandog, D. B., Rañola, F. M., Rañola, R. F., Ani, P. A. B., & Vidal, N. B. (2010). Enhancing the food security of upland farming households through agroforestry in Claveria, Misamis Oriental, Philippines. *Agroforestry Systems*, *79*(3), 327–342. https://doi.org/10.1007/s10457-009-9267-1

Mashi, S. A., Yaro, A. & Jenkwe, E. D. (2015). Causes and consequences of gully erosion: perspectives of the local people in Dangara area, Nigeria. *Environment, Development and Sustainability* *17*(6), 1431–1450. https://doi.org/10.1007/s10668-014-9614-x

Meijer, S. S., Catacutan, D., Ajayi, O. C., Sileshi, G. W., & Nieuwenhuis, M. (2015). The role of knowledge, attitudes and perceptions in the uptake of agricultural and agroforestry innovations among smallholder farmers in sub-Saharan Africa. *International Journal of Agricultural Sustainability*, *13*(1), 40–54. https://doi.org/10.1080/14735903.2014.912493

METI (The Ministry of Economy, Trade, and Industry of Japan and NASA (the United States National Aeronautics and Space Administration). (2011). ASTER Global Digital Elevation. Model-GDEM V2. http://asterweb.jpl.nasa.gov/gdem.asp. (Accessed, May 2015).

Moeyersons, J. (1989). La nature de l'érosion des versants au Rwanda. *Annals of the Royal Museum of Central Africa, Series Economical Sciences*, *19*, 396.

Moeyersons, J., Tréfois, P., Lavreau, J., Alimasi, D., Badriyo, I., Mitima, B., … Nahimana, L. (2004). A geomorphological assessment of landslide origin at Bukavu, Democratic Republic of the Congo. *Engineering Geology*, *72*, 73–87. https://doi.org/10.1016/j.enggeo.2003.06.003

Moummi, A. (2010). Analysis of Poverty in the Democratic Republic of Congo. Working Paper 112- (987). African Development Bank, Tunis, Tunisia.

Okoba, B. O., & de Graaff, J. (2005). Farmers' knowledge and perceptions of soil erosion and conservation measures in the Central Highlands of Kenya. *Land Degradation & Development*, *16*(5), 475–487. https://doi.org/10.1002/ldr.678

Okoba, B. O., & Sterk, G. (2006). Farmers' identification of erosion indicators and related erosion damage in the Central Highlands of Kenya. *Catena*, *65*(3), 292–301. https://doi.org/10.1016/j.catena.2005.12.004

Oldeman, L.R. (1992). Global extent of soil degradation. Published in ISRIC Bi-annual report 1991-1992, Wageningen, The Netherlands; pp. 19–36.

Place, F., Pender, J., & Ehui, S. (2006). In J. Pender, F. Place, & S. Ehui (Eds.), *Key issues for the sustainable development of smallholder agriculture in the east African highlands, in strategies for sustainable land Management in the East African Highlands* (pp. 1–30). Washington, DC: International Food Policy Research Institute.

Poesen, J., Nachtergaele, J., Verstraeten, G., & Valentin, C. (2003). Gully erosion and environmental change: Importance and research needs. *Catena*, *50*, 91–133. https://doi.org/10.1016/S0341-8162(02)00143-1

Prasuhn, V. (2011). Soil erosion in the Swiss midlands: Results of a 10-year field survey. *Geomorphology*, *126*, 32–41. https://doi.org/10.1016/j.geomorph.2010.10.023

Ragasa, C., Ulimwengu, J., Randriamamonjy, J., & Badibanga, T. (2015). Factors affecting performance of agricultural extension: Evidence from Democratic Republic of Congo. *Journal of Agricultural Education and*

Extension, *22*(2), 113–143. http://dx.doi.org/10.1080/1389224X.2015.1026363

Roose, E. (1993). Innovations dans la conservation et la restauration des sols. Cah. Orstom, sér. *Pédol*. *XXVIII*(2), 147–155. https://horizon.documentation.ird.fr/exl-doc/pleins_textes/cahiers/PTP/10009088.PDF

Rutebuka, J., Kagabo, D. M., & Verdoodt, A. (2019). Farmers' diagnosis of current soil erosion status and control within two contrasting agro-ecological zones of Rwanda. *Agriculture, Ecosystems & Environment*, *278*, 81–95. https://doi.org/10.1016/j.agee.2019.03.016

Scherr, S. J. (2003). Productivity-related economic impacts of soil degradation in developing countries: An evaluation of regional experience. In K. Wiebe (Ed.), *Land quality, agricultural productivity, and food security* (pp. 223–261). Cheltenham, England: Edward Elgar.

Scopel, E., Triomphe, B., Affholder, F., Da Silva, F. A. M., Corbeels, M., Xavier, J. H. V., & de Carvalho Mendes, I. (2013). Conservation agriculture cropping systems in temperate and tropical conditions, performances and impacts. A review. *Agronomy for Sustainable Development*, *33*(1), 113–130. https://doi.org/10.1007/s13593-012-0106-9

Sharma, N., Bohra, B., Pragya, N., Ciannella, R., Dobie, P., & Lehmann, S. (2016). Bioenergy from agroforestry can lead to improved food security, climate change, soil quality, and rural development. *Food and Energy Security*, *5*(3), 165–183. https://doi.org/10.1002/fes3.87

Sterk, G., & Haigis, J. (1998). Farmers' knowledge of wind erosion processes and control methods in Niger. *Land Degradation & Development*, *9*(2), 107–114. https://doi.org/10.1002/(SICI)1099-145X(199803/04)9:2<107::AID-LDR285>3.0.CO;2-5

Takele, L., Chimdi, A., & Abebaw, A. (2015). Socio-economic factors affecting soil fertility management practices in Gindeberet area, Western Ethiopia. *Science, Technology and Arts Research Journal*, *4*(1), 149–153. https://doi.org/10.4314/star.v4i1.25

Tenge, A. J., De Graaff, J., & Hella, J. P. (2004). Social and economic factors affecting the adoption of soil and water conservation in west Usambara highlands, Tanzania. *Land Degradation & Development*, *15*(2), 99–114. https://doi.org/10.1002/ldr.606

Ulimwengu, J.M., Funes, J., Headey, D.D., You, L. (2009). Paving the way for development: The impact of road infrastructure on agricultural production and household wealth in the Democratic Republic of Congo (No. 319–2016-9799).

Van Asten, P., Vanlauwe, B., Ouma, E., Pypers, P., Van Damme, J., Blomme, G., … Manzekele, M. (2013). CIALCA's efforts on integrating farming system components and exploring related trade-offs. In *Agro-ecological intensification of agricultural Systems in the African Highlands* (pp. 117–133). London, England; New York, NY: Routlage.

Van Oost, K., Quine, T. A., Govers, G., De Gryze, S., Six, J., Harden, J. W., … Merckx, R. (2007). The impact of agricultural soil erosion on the global carbon cycle. *Science*, *318*(5850), 626–629. https://doi.org/10.1126/science.1145724

Wauters, E., Bielders, C., Poesen, J., Govers, G., & Mathijs, E. (2010). Adoption of soil conservation practices in Belgium: An examination of the theory of planned behaviour in the Agri-environmental domain. *Land Use Policy*, *27*(1), 86–94. https://doi.org/10.1016/j.landusepol.2009.02.009

Wickama, J., Okoba, B. O., & Sterk, G. (2014). Effectiveness of sustainable land management measures in west Usambara Highlands, Tanzania. *Catena*, *118*, 91–102. https://doi.org/10.1016/j.catena.2014.01.013

Wildemeersch, J. C., Timmerman, E., Mazijn, B., Sabiou, M., Ibro, G., Garba, M., & Cornelis, W. (2015). Assessing the constraints to adopt water and soil conservation techniques in Tillaberi, Niger. *Land Degradation & Development*, *26*(5), 491–501. https://doi.org/10.1002/ldr.2252

How to cite this article: Heri-Kazi AB, Bielders CL. Erosion and soil and water conservation in South-Kivu (eastern DR Congo): The farmers' view. *Land Degrad Dev*. 2020;1–15. https://doi.org/10.1002/ldr.3755