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# Implications of Prevalence and Intensity of Soil-Transmitted Helminthes (STHs) on Rural Farmers' Productivity in Selected Districts of Sierra Leone

**Abstract.** Soil-transmitted Helminths (STH) are among the most prevalent parasitic diseases that impair childhood physical and mental growth, hence hindering economic development. The study was a cross-sectional-designed survey, conducted in three districts in Sierra Leone between December and March 2022 on 625 individual farmers to determine: 1) the prevalence of soil-transmitted helminths; 2) the intensity of soil-transmitted helminths; 3) the effect of the prevalence and intensity on farm productivity, and 4) the implication of these effects on agricultural extension service delivery and the rural livelihood of the selected districts. Stool samples were collected from male and female farmers in fifteen chiefdoms in the selected districts and analyzed using the Kato-Katz technique. A total of 625 individuals were included, among whom 172 (27.0%) were vegetable farmers, 224 (35.8%) were tree-crop farmers and 226 (36.2%) were rice farmers. The result indicates a prevalence of parasitic infection among farmers shown by 58.4% eggs/ova in stool from the three districts. STH prevalence is higher in Bo (64.0%), Koinadugu (56.9%), and Kailahun (51,7%). STH infections, in various ways, affected extension services, delivery and the livelihoods of individual farmers. The recommendation is that farmers and children be periodically dewormed for STH infection in rural areas.

**Keywords**: soil-transmitted helminths, prevalence, intensity, farm productivity, extension services, rural livelihood

**JEL Classification**: R2, I15, P46

## Introduction

Soil-transmitted helminth (STH) infections refer to groups of parasitic diseases caused by nematode worms transmitted to humans by fecally contaminated soil, food and water (Zeleke et al., 2020). Soil-Transmitted Helminth infections of humans fall within the World Health Organization's (WHO) grouping termed neglected tropical diseases (NTDs), forgotten diseases or diseases of the poor (Fantal et al., 2020). The soil transmitted helminths of significant concern to humans includes the roundworm (Ascaris lumbricoides), the

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whipworm (Trichuris trichiura), and the hookworms (Necator americanus and Ancylostoma duodenale) (Hosea, Kator, and Philomena, 2019). Other species such as Strongyloides stercoralis, Enterobius vermicularis, and Toxocara cause hookworm infection, and Strongyloides stercoralis are transmitted by direct skin penetration while the rest gain entry by oral route. Enterobius spp., by autoinfection, enters children when they scratch their anus, fidget with their mouths or eat with unwashed hands (Brummaier et al 2021; Hassan and Oyebamiji, 2018). WHO (2018) linked soil-transmitted helminth infection to rural poverty, inadequate sanitation, waste disposals, lack of clean water supply, poor hygiene, limited access to health care and preventive measures such as health education. Polyparasitism occurs where different parasites co-exist (GBD, 2019), and when there is poor sanitation Simiyu (2022). Though soil-transmitted helminths rarely cause death, they significantly impact public health and lead to severe disability in the world's poorest countries (Brummaier et al 2021). The parasites can impair intellectual and physical development, significantly diminish economic productivity, and cause disabilities, resulting in stagnation and perpetuation of the poverty cycle (Cools et al, 2019).

Ascaris lumbricoides, Ancylostoma duodenale, Necator americanus, and Trichuris trichiura infections are soil-transmitted helminth (STH) infections that affect around 1.5 billion individuals globally (Ercumen et al., 2019). Since disease transmission primarily occurs through contact with soil contaminated with infected human feces, low- and middle-income countries (LMICs) that lack sufficient water, sanitation, and hygiene (WASH) are disproportionately affected by the disease burden (Khan et al., 2019).

In Sierra Leone, transmitted helminths are distributed across the country, with high prevalence of hookworm infections, particularly in the north and east districts of Koinadugu (range 21.6-82.1%), and Kailahun (range 43.5-52.6%) respectively and part of Bo District (Koroma et al., 2010). Soil-transmitted helminth affects not only people with limited resources but also indigenous groups, women of childbearing age, smallholder farmers in rural areas, migrant workers, prisoners, and refugee groups (Kabir et al., 2019). Other groups at high risks of these parasitic infections include preschool-age children (aged 1-4 years), school-age children (aged 5-14 years), pregnant women in their second and third trimesters and lactating mothers, vegetable farmers, sand miners, people who fish in stagnant waters, tree-crop harvesters and processers (Dabasa et al.2017; WHO, 2020). Realistically, farmers rank second to school-going children in harbouring multiple helminth species, though the impact of these parasites infections on them is still neglected in the helminthological literature (Pratinidhi et al., 2020).

Soil-transmitted helminth larvae develop in tropical and sub-tropical climates, with warm temperatures, high humidity and moist soils that are suitable for farming. Furthermore, unhygienic sanitation, inadequate water supply and untreated night-soil fertilizer are the environmental factors that favor soil-transmitted helminth buildups (Shumbeji et al.,2019; Jourdan et al., 2018).

The other behavioral risk factors include toilet usage, non-shoe wearing, personal hygiene and other habits such as inappropriate hand washing and eating raw food. Occupations with high soil contact during farming also increase the risk of soil-transmitted helminth infection (Center for Disease Control and Prevention, 2022). Both these environmental and behavioral risk factors commonly occur in poor socio-economic conditions, making poverty and limited education one of the critical risk factors for soil-transmitted helminth transmission (Grimes et al., 2018).

Educating, motivating and introducing rural farmers to use low-cost pit latrines improves and protects their farm families against parasitic worms (Oswald et al., 2017). But, where water supplies and sanitation are poor, without preventive measures, farmers and travelers are exposed to soil-transmitted helminth (Chard et al.2019). Since these worms do not multiply in hosts, reinfection occurs only due to additional contact with the infective stages. In fact, according to Hossain et al. (2018) and the WHO (2019) guiding principles, deciding to treat individuals (mass treatment) or only school children and other high-risk groups (selective treatment) once or more times a year depends on the prevalence of infection in a particular region or country.

In Sierra Leone, the rural farmers are poor and live in deprived environments without proper hygiene and sanitation facilities (Koroma et al., 2010). These farmers and their children walk barefoot, dress half naked, and live together with animals on the same premises. At night, their livestock – goats, sheep, poultry – sleep either in the verandas, kitchens or near the houses, and their dogs often eat the feces of the children. Most rural communities lack pit latrines, and the inhabitants use nearby bushes for defecating. Their children sit, play or sleep on dusty grounds, and their primary schools are often found close to dustbins and most are without toilets. Rural children practice poor hygiene – they do not wash their hands after attending to nature, use contaminated household items, and eat contaminated food, exposing both children and adults to soil-transmitted helminth parasite infections (Yahya and Tukur, 2017). Most rural Sierra Leonean farmers and their children are unaware of and careless about the consequences of contaminated environments.

The women and children fetch water and firewood, fish in open-mined pits in swamps, clear debris in farms after ploughing and transplanting rice seedlings and growing vegetables. They empty the stool of infants and children under five years, which exposes people to Multiparasitism (Nkouayep et al., 2017), a concurrent infection with two or more parasite species (Khan et al., 2019). These daily activities highly expose rural vegetable farmers (who use untreated night soils as fertilizers) to soil-transmitted helminthic infections. Some farm families care directly for livestock – they take animals out for grazing and return them to living quarters, but seldom wash their hands after these activities. These farmers seldom deworm livestock (they are reared on the free-ranges systems) or clean the animal pens with disinfectant, nor do they provide any drinking water for the animals (exposing the animals to drinking muddy-dirty-stagnant waters). Hence, rural livestock with high helminth infections often experience miscarriages in Sierra Leone (Atanásio-Nhacumbe and Sitoe, 2019). Nevertheless, there is no scientific data on such an unfortunate situation; not even the Ministry of Agriculture nor the University pay attention to this group of people.

No wonder the Ministry of Health in Sierra Leone has vehemently campaigned for deworming school children in the urban settlements for the past decade, though such campaigns did not extend to reach the rural poor communities, or their schools and children who are more vulnerable than the urban children. In fact, any effective plan for reaching sustainable intervention and control of human intestinal parasites requires reliable information on the prevalence and intensity of soil-transmitted helminth infection from rural and urban settlements. But Sierra Leone lacks scientific data on the prevalence and intensity of soil-transmitted helminths in rural farming communities that show factual-information for better planning and strategy for controlling this deadly but neglected infection in the country. Soil-transmitted helminths cause loss of appetite, reduced nutritional intake, impaired physical fitness, diarrhea and dysentery (WHO, 2023). Ásbjörnsdóttir (2017) reported that soil-transmitted helminths (STH) are “endemic in 120 countries and are associated with substantial morbidity and loss of economic productivity"; while Masangcay et al. (2021) stated that malnutrition of micronutrients such as iron, Vitamin A, and zinc, is attributable to soil-transmitted helminths (STH) that disturbs the digestive functions.

Therefore, it is essential to investigate the intensity of the STH infections in rural farmers and their children and livestock to draw the attention of relevant stakeholders (including Ministry of Health and Sanitations and WHO) to explore areas to control the disease within the rural settlements in Sierra Leone. The study aims to describe and analyze the implications of the prevalence and intensity of soil-transmitted helminth infections in farmers in rural Sierra Leone. The study's specific objectives are to: 1) determine the prevalence of soil-transmitted helminths in farmers in Bo, Kailahun, and Koinadugu Districts of Sierra Leone; 2) determine the intensity of soil-transmitted helminths in farmers in the study area; 3) identify the effect of the prevalence and intensity on farm productivity in these districts, and 4) examine the implication of these on agricultural extension service provision in the selected districts.

## Methods

The study was conducted in three districts – Koinadugu District in the North, Bo District in the South, and Kailahun District in the Eastern Regions of Sierra Leone. According to the STH prevalence maps, the entire population in the country is at risk of STH (Koroma et al., 2010). Those in five coastal districts, Koinadugu and part of Bo District, about 2.84 million people, (school age children and adults and pregnant women) are at high risk of STH infection (Bah et al., 2019). Koinadugu district continues to have moderate STH prevalence with high baseline prevalence greater than 75%, while a high proportion of households in Kailahun still practice open defecation. Another 2.6 million people in the remaining areas of the country are at moderate risk of STH infection, therefore justified for annual treatment to pre-school children, school age children and at-risk adults.

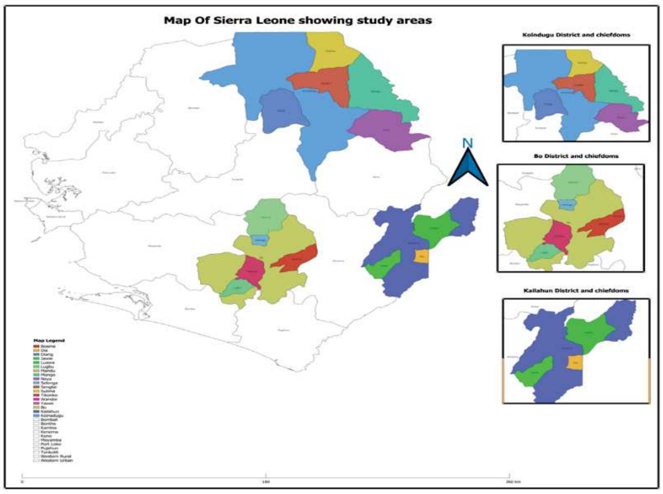


Fig. 1. Map of Sierra Leone showing study Districts and Chiefdoms

Source: Author's own elaboration.

These districts were selected using simple random sampling techniques. The main reasons for choosing each of these districts include their uniqueness. Koinadugu District is renowned for vegetable and livestock farming, Bo District is very prominent for diamond and sand mining, and Kailahun is paramount for tree crop production. Their populations are typically rural, with farming and livestock production as their main activities. These factors contribute to harboring and encouraging soil-transmitted helminth build-ups (Figure1).

The study adopted a cross-sectional design, examining stool from male and female farmers. The sampling technique was the stratified multistage cluster sampling technique. First, the names of all 14 districts were written on pieces of paper and placed in a black plastic bag. A simple random sampling was applied by blindly picking one paper from the black plastic bag. The researchers selected five chiefdoms from each district using simple random and purposive sampling techniques; each district (Total =15 Chiefdoms) and ten communities (totaling 150 precincts). A total of 625 individuals aged 18-65 (median: 52 years old) were registered and enrolled in the study. Among these enrollees, 339 (54.2%) were females, and 286 (45.8%) were males. In each selected district and community, the researchers held meetings with eligible individual farmers in court Berries, and those who consented to participate systematically underwent sample collection. All the participants provided stool samples for further analysis.

Table 1. The districts, chiefdoms, population, and sample size of farmers interviewed.

| Districts | Chiefdoms | Population | Sample size |
|---|---|---|---|
| | Boama | 5,300 | 61 |
| | Tikonko | 4,200 | 43 |
| Bo | Valunia | 3,500 | 55 |
| | Selenga | 1,200 | 38 |
| | Lugbu | 1,800 | 53 |
| **Total** | | **16,000** | **250** |
| | Yawei | 2.200 | 33 |
| | Jawie | 3,100 | 46 |
| Kailahun | Luawa | 2,500 | 38 |
| | Mandu | 2,800 | 44 |
| | Día | 2,400 | 42 |
| **Total** | | **13,000** | **203** |
| | Diang | 3,600 | 42 |
| | Maini | 2,300 | 37 |
| Koinadugu | Senbge | 2,400 | 38 |
| | Neya | 1,700 | 31 |
| | Sulima | 1,000 | 24 |
| **Total** | | **11,000** | **172** |

Source: Field survey 2022.

Researchers gave a 60 mL plastic screw-cap vial to each participant who brought it back to the investigators with sample stool to examine whether eligible individuals had intestinal helminths. The researchers examined the specimen using Kato-Katz technique, a single thick smear technique using a 41.7 mg template (WHO, 2020). Qualified lab technicians from Government hospitals in each district examined the prepared samples (Kato-Katz slides). These technicians did so within one hour after the slide design for identification of hookworm eggs and subsequently (later the same day or the following day) for other STH eggs or larval (Strongyloides stercoralis) detection. Researchers used bright field microscopy (magnification × 100 or × 400) to identify and count all eggs (or larvae) in the prepared sample stools and expressed results as eggs or larvae per gram of feces (EPG or LPG) for the intensity of infection. Data collected were recorded into an SPSS 26 version for statistical analysis and used the SPSS Statistics "Crosstabs" procedure for calculating the proportion of individuals infected by a given parasite species (single infection) or by two or more helminth species (multiple conditions).

In terms of data analysis, SPSS Statistics "Descriptive" procedure was used to compute the intensity of diseases when the egg or larval counts were available as arithmetic means and estimated sampling fluctuations using the standard deviation (SD).

The Sierra Leone National Ethics Committee approved this study for Human Health Research, Ministry of Health in each district. The eligible population, individuals and livestock farmers willing to participate in the study, signed an informed consent form and each enrollee was assigned a code. Participants harboring any STH infection later received a 500 mg single-dose Albendazole in the framework of this study.

## Results

### Prevalence of STHs among farmers

Five species of soil-transmitted helminths (A. lumbricoides, T. trichiura, N. americanus, S. stercoralis and Tania spp.) were in the stool samples collected as part of this study. Of the 625 individuals who provided stool samples, Bo accounted for 160 (64.0%) positive samples, Koinadugu had 98 (56.9%) positive samples and Kailahun presented 105 (51.7%) positive cases. With varying significance levels of Bo (P=0.005), Koinadugu (P=0.005) and Kailahun (P=0.001). At district level, Soil-Transmitted Helminths (A. Lumbricoides) prevalence in Koinadugu District (22.1.0%) is higher than those in Bo District (18.0%) and Kailahun District (17.2%). For A. duodenale, prevalence was higher in Bo district (19%), followed by Koinadugu (16.9%) and Kailahun (11.8%). For S. Stercoralis, the margin was close among the districts of Kailahun (8.4%), Bo (8.0%) and Koinadugu (7.0%). Taenia spp. cases were 4.8%, 3.5% and 2.0% in Bo, Koinadugu and Kailahun districts, respectively.

At chiefdom levels, the prevalence of soil-transmitted helminths for Valunia (16.8%), Tikonko (14.0%), and Lugbu (13.2%) was higher than the prevalence for Selenga (7.2%). In Kailahun, most soil-transmitted helminths were 14.3% for Mandu, 11.8%, and 11.3% for Jawie and Día Chiefdoms, respectively. Yawei Chiefdom displayed the lowest STH prevalence. In the northern district of Koinadugu, Diang (16.3%), Maini (12.8%), and Neya (11.0) chiefdoms exhibited high STHs prevalence. Of the five STHs discovered in the stools of the farmers who participated in the study in Bo District, Ascaris lumbricoides are highly prevalent in Valunia (5.6%), Lugbu (5.2%), and Tikonko (5.2%), while T. trichiura (3.2%) was prevalent in Boama Chiefdom. In Kailahun District, A. lumbricoides is prevalent in Mandu (6.9%), Día (5.4%), and Jawie (5.4%). In Koinadugu District, Ascaris lumbricoides and American duodenale (7.0%, 7.0%) are prevalent in Diang, and Maini (5.8% and 4.1%) and Senbge (3.5%), and 2.3% respectively. T. trichuira (4.7%) is prevalent in Sulima Chiefdom, while T.spp. (1.2%) is prevalent in Neya Chiefdom. The distribution of these parasites in the selected districts was generally similar. Ascaris lumbricoides are highly prevalent in almost all the study sections.

Table 2. Prevalence of helminth parasites among farmers in three districts in Sierra Leone

| Districts | Chiefdom | No. sample examined | No of positive samples | Ascaris Lumbricoides | S-Stercoralis | T- Trichuira | A Duodenale | Taenia. Spp |
|---|---|---|---|---|---|---|---|---|
| Bo | Boama | 61 | 32(12.8) | 10(4.0) | 3(1.2) | 8(3.2) | 9(3.6) | 2(0.8) |
| | Tikonko | 43 | 35(14.0) | 13(5.2) | 6(2.4) | 7(2.8) | 8(3.2) | 1(0.4) |
| | Valunia | 55 | 42(16.8) | 14(5.6) | 7(2.8) | 7(2.8) | 12(4.8) | 2(0.8) |
| | Selenga | 38 | 18(7.2) | 12(4.8) | 2(0.8) | 3(1.2) | 1(0.4) | 0(0.0) |
| | Lugbu | 53 | 33(13.2) | 13(5.2) | 6(1.6) | 4(1.6) | 9(3.6) | 1(0.4) |
| | **Total** | 250 | **160(64.0)** | **62(18.0)** | **24(8.0)** | **29(10.8)** | **39(19.2)** | **6(4.8)** |
| | **p value** | < 0.001 | **0.005** | **0.018** | **<0.001** | **< 0.001** | **<0.001** | **< 0.001** |
| Kailahun | Yawei | 33 | 12(5.9) | 5(2.5) | 1(0.5) | 2(1.0) | 4(2.0) | 0(0.0) |
| | Jawie | 46 | 24(11.8) | 11(5.4) | 5(2.5) | 4(2.0) | 2(1.0) | 2(1.0) |
| | Luawa | 38 | 17(8.4) | 8(3.9) | 3(1.5) | 2(1.0) | 3(1.5) | 1(0.5) |
| | Mandu | 44 | 29(14.3) | 14(6.9) | 4(2.0) | 3(1.5) | 7(3.4) | 1(0.5) |
| | Dia | 42 | 23(11.3) | 11(5.4) | 4(2.0) | 3(1.5) | 5(2.5) | 0(0.0) |
| | **Total** | **203** | **105(51.7)** | **49(17.2)** | **17(8.4)** | **14(6.9)** | **21(11.8)** | **4(2.0)** |
| | **p value** | **< 0.001** | **0.001** | **< 0.001** | **0.005** | **0.005** | **0.002** | **0.009** |
| Koinadugu | Diang | 42 | 28(16.3) | 12(7.0) | 1(0.6) | 1(0.6) | 12(7.0) | 2(1.2) |
| | Maini | 37 | 22(12.8) | 10(5.8) | 2(1.2) | 2(1.2) | 7(4.1) | 1(0.6) |
| | Senbge | 38 | 14(8.1) | 6(3.5) | 3(1.7) | 1(0.6) | 4(2.3) | 0(0.0) |
| | Neya | 31 | 19(11.0) | 7(4.1) | 3(1.7) | 1(0.6) | 6(3.5) | 2(1.2) |
| | Sulima | 24 | 15(8.7) | 3(1.7) | 3(1.7) | 8(4.7) | 0(0.0) | 1(0.6) |
| | **Total** | **172** | **98(56.9)** | **38(22.1)** | **12(7.0)** | **13(7.6)** | **29(16.9)** | **6(3.5)** |
| | **p value** | **< 0.001** | **0.005** | **<0.001** | **< 0.001** | **0.005** | **< 0.001** | **0.005** |

Statistically significant; $p < 0.05$; Mean (SD)

Source: Field survey 2022.

## The intensity of STHs infection in farmers

The intensity of the STH infection ranged between 1412.2 and 5233EPG (mean: 11,234.21; SD: 14,254.51) for Ascaris lumbricoides, 103.11 and 447.12EPG (mean: 321.33; SD 2312.02). for S. stercoralis, 45.26 and 23.03EPG (mean: 213.07; SD: 102.11) for T trichiura with 1.1 and 6.1EPG (means: 10.14; SD: 3.32) for Taenia spp and 11.67 and 33.01EPG (mean: 6.13; SD:1.85) for A duodenale. Also 2.32 and 34.22EPG (mean: 24.24; SD:18.72) for Tania. Spp. 1.35 and 43.11 EPGepg (mean: 3.12; SD:2.43). Table 2 reveals the arithmetic means (with standard deviation) intensity of infection for each parasite species. The mean egg or larva count was quite variable between chiefdoms within the districts. In Bo District, S. stercoralis, T. trichiura, and A. duodenale and Taenia spp. ($p<0.001$), but different for A. lumbricoides (<0.018). For Kailahun District, district, S. stercoralis and T. trichiura ($p=0.005$) differ from A. lumbricoides ($p<0.001$) and A. duodenale ($p = 0.002$). For Koinadugu District, A. lumbricoides, S. stercoralis and A. duodenale ($p<0.001$) differ from T. trichiura and T. spp. ($p=0.005$).

Table 3. Intensity of STH infection in farmers in the selected districts of Sierra Leone

| Districts | Chiefdom | No. sample examined | Mean A-Lumbricoides EPG(SD) | Mean S-Stercoralis EPG(SD) | Mean T-Trichiura EPG(SD) | Mean Duodenale Lpg(SD) | Mean Taenia. Spp EPG(SD) |
|---|---|---|---|---|---|---|---|
| Bo | Boama | 61 | 5233.14(14254.51) | 447.12(2312.02) | 23.12(223,34) | 33.01(1.85) | 6.09(93.32) |
| | Tikonko | 43 | 3543.24(15345.42) | 311.22(2214.03) | 26.23(132.12) | 23.12(2.11) | 5.5(2,54) |
| | Valunia | 55 | 4254.17(23341.53) | 414.31(3241.12) | 37.02(146.28) | 14.35(2.43) | 6.1(3.32) |
| | Selenga | 38 | 3182.32(12321.34) | 2303.23(123.04) | 23.11(321.38) | 12.36(1.43) | 3.1(0.21) |
| | Lugbu | 53 | 4332.15(32132.42) | 413.12(4321.21) | 34.24(423.09) | 13.53(2.12) | 4.1(41.32) |
| Kailahun | Yawei | 33 | 3671.23(12325.12) | 321.14(1421.24) | 31.11(187.21) | 14.2(3.31) | 2.02(18.72) |
| | Jawie | 46 | 424.87(22654.32) | 432.18(213.14) | 45.26(213.07) | 24.5(1.21) | 4.14(7.16) |
| | Luawa | 38 | 5431.73(13123.43) | 425.25(123.05) | 23.03(102.11) | 24.1(2.32) | 4.2(25.24) |
| | Mandu | 44 | 329.15(14234.12) | 210.98(234.21) | 34.23(192.22) | 22.2(3.21) | 3.2(45.23) |
| | Día | 42 | 323.34(12123.23) | 121.29(187.23) | 32.11(203.26) | 22.1(2.12) | 2.5(12.32) |
| | Diang | 42 | 2823.12(11214.12) | 124.86(213.22) | 41.24(112.41) | 12.3(4.11) | 1.4(22.24) |
| | Maini | 37 | 2213.23(12231.03) | 227.56(321.21) | 32.22(214.23) | 14.12(2.14) | 4.2(19.24) |
| Koinadugu | Senbge | 38 | 1412.21(11234.21) | 116.4(134.24) | 23.36(123.12) | 13.11(3.12) | 2.1(14.23) |
| | Neya | 31 | 1923.11(12112.04) | 114.22(314.32) | 32.22(231.17) | 12.03(2.33) | 1.2(9.14) |
| | Sulima | 24 | 1526.02(13532.12) | 103.11(321.33) | 31.23(113.46) | 11.67(6,13) | 1.1(10.14) |

EPG = eggs per gram of stool; LPG = larvae per gram of stool; SD = standard deviation

Source: Field survey, 2022.

## Levels of the effect of the prevalence and intensity of STH on farm productivity

The result showed that 97.9% of the farmers indicate that high STH medication expenses halt most farming activities, and 96.0% say STH resistance in the various species causes persistent unhealthy conditions in the farmers. Furthermore, 93.9% of the participants say that STH-resistance causes constant unhealthy conditions in the farmers, while 91.8% say the STH prevalence and intensity burdened farmers. Moreover, 89.3% of the farmers said that multiple STH infections bring repeated farm economic losses, and 76.6% say that high STH-medication expenses halt farming activities in most communities. In some cases, the STH-anemia conditions reduce the available community-labor force. Only 64.2% of the farmers pointed out that STH infections impair growth and physical development in farmers. (Table 4)

When further asked to rate the level of STH infections on farm productivity, 40.6% of the farmers ordered the prevalence and intensity of STH burden on farmers as very high, and 32.2% rated multiple STH medication expenses as a reason halting most community-farming activities as very high. STH-anemia conditions reduce the available community-labor force (32.4%), and STH-induced malnourishment reduces the farm population (32.5%) were rated moderately. Furthermore, STH resistance causes persistent unhealthy conditions in the farmers (33.9%), STH infections impair growth, and physical development in farm families (40.2%) was rated moderate. and 25.4% of the farmers' rated worm-induced malnourishment reduces the farm population also as moderate. (Table 4)

Table 4. Levels of the effect of the prevalence and intensity of STH on farm productivity

| Effects of prevalence and intensity of STHs | No | Low | Moderate | High | Very High |
|---|---|---|---|---|---|
| STH prevalence and intensity create burden on farmers | 574(91.8) | 123(19.7) | 138(22.1) | 254(40.6) | 110(17.6) |
| STH-anemic conditions reduce available community-labor force | 479(76.6) | 156(25.4) | 199(32.4) | 138(22.4) | 122(19.8) |
| Worm-induced malnourishment reduces farm population | 587(93.9) | 103(16.5) | 203(32.5) | 113(18.1) | 206(33.0) |
| Multiple STH-infections bring repeated farm economic losses | 558(89.3) | 116(18.6) | 104(16.6) | 201(32.2) | 204(32.6) |
| High-STH-medication expenses halt most community-farming activities | 612(97.9) | 103(165.5) | 98(15.7) | 198(31.7) | 226(36.2) |
| STH-resistance causes persistent unhealthy conditions in the farmers | 600(96.0) | 101(16.2) | 212(33.9) | 208(33.3) | 104(16.6) |
| STH-infections impair growth and physical development in farm families | 401(64.2) | 109(20.8) | 211(40.2) | 103(19.6) | 102(19.4) |

Frequency (percentages).

Source: Field survey 2022.

Perceptions of farmers and extension workers on the implication of STHs on agricultural service provisions and the livelihood of the farmers was also surveyed. The farmers perceived that the effects from STH infections have significantly impacted the extension delivery services and the livelihood of the farmers in their communities. Table 5 indicates that 40.0% of the farmers expressed that STH infection is causing poverty among farmers, reducing food productivity at community levels (35.2%), restraining youths from adopting agricultural extension innovations (26.9%), and forcing farmers not to cooperate with extension agents (26.3%). Furthermore, the infection causes farmers to divert agricultural innovations (24.8%), while most farmers do not use farm inputs from agricultural extension agents.

Table 5. Distribution of farmers and extension workers on the extent of implications of STHs on service provision and livelihoods

| **Perception on implications STHs** | **Very great extent** | **Great extent** | **Some extent** | **No extent** | **Can't know** |
|---|---|---|---|---|---|
| Perception of farmers (n=505) | | | | | |
| Sick farmers cannot attend extension meetings | 111(22.0) | 102(20) | 113(22.4) | 110(22) | 69(13.7) |
| Farmers affected accept but do not adopt innovations | 122(24.2) | 113(22) | 119(23.6) | 104(21) | 47(9.3) |
| Farmers do not cooperate with extension agents | 133(26.3) | 123(24) | 111(22) | 102(20) | 36(7.1) |
| Farmers diverse the use of farm innovations like seeds | 125(24.8) | 115(23) | 116(23) | 117(23) | 32(6.3) |
| Youths restrain from adopting extension innovations | 136(26.9) | 112(22) | 132(26.1) | 102(20) | 23(4.6) |
| STH infections have reduced community-farm productivity | 178(35.2) | 121(23) | 98(19.4) | 85(17) | 23(4.6) |
| STH infections have caused poverty | 202(40) | 214(42) | 64(12.7) | 21(4.2) | 4(0.8) |
| Perception of extension workers (n = 120) | | | | | |
| Infected farmers consume agricultural seed inputs | 78(65) | 23(19) | 15(12.5) | 3(2.5) | 1(0.8) |
| Number of agricultural innovation adoption has reduced | 77(64.2) | 33(28) | 10(8.33) | 0(0) | 0(0) |
| Infected farmers cannot disseminate innovation | 59(49.2) | 33(28) | 23(19.2) | 3(2.5) | 2(1.7) |
| Farmers' household expenditure has increased | 49(40.8) | 44(37) | 24(20) | 82(1.7) | 1(0.8) |

Frequency (percentages).

Source: Field survey 2022.

To a great extent, the extension agents also perceive that STH-infected farmers consume agricultural farm seed inputs (65.0%). The number of agricultural innovation adopters is drastically reduced (64.2%), while the infected farmers no longer disseminate agricultural innovations (49.2%) which has increased the farm household expenditure (40.8%), affecting the extension delivery and the farmer's livelihoods.

## Discussion

The overall prevalence of the different STH species follows very similar trends. The finding is in line with Means et al. (2018); Oswald et al. (2019). However, the results in this study were higher than those found by the authors. Furthermore, significant differences in the STH prevalence existed between the selected chiefdoms (Table 2), which supports the findings of WHO (2017). The high prevalence recorded in the various chiefdoms is ascribed to poor nutrition (starvation), management practices of feces (lack of toilets), and frequent human exposure to contaminated soils during farming activities.

Kailahun District shares a similar culture, but their farming patterns differ significantly, which might be responsible for the predominant occurrence of the different parasites among the farmers. The intensity of infections and the values recorded in our study were generally from light intensity to high, based on the WHO classification (WHO, 2020). The observed outcome is actual because participants in this study were either adults or young adults. A close look at some of the behavioral habits of the farmers in these three districts and the fifteen chiefdoms concerning personal hygiene reveals that a good number of them are highly predisposed to infection with intestinal helminths. Most of the farmers in Bo District are upland rice farmers, who primarily farm very close to their communities, without proper feces disposal. Their farming patterns also involve playing with soil and shrubs; these farmers seldom wear protective clothing during their farming operations. In addition to farming, most are sand and illicit miners—the women fish in the stagnant pits and streams, harboring STH eggs and larvae. In Kailahun District, most of the farmers are tree crop farmers, who use the local processing techniques, sitting on the ground, peeling, packing, and transporting the products. During the harvesting period, most farmers walk barefooted, half- nakedly dressed, with no protective gear, a situation that exposes farmers to STH infections.

Epidemiological surveys show that poor sanitary conditions such as defecation and fecal contamination of water bodies are the most critical factors leading to intestinal infestation (Benjamin-Chung et al., 2020). Similarly, in Koinadugu, most farmers are vegetable growers who cultivate their crops in lowland ecology during the dry seasons and upland during rainy seasons. These farmers use night soils as fertilizers for the vegetables they produce. Like those in Kailahun and Bo districts, farmers in Koinadugu do not use protective clothing when at work. They mix the night and garden soils using their bare hands thereby contacting STH eggs or larvae.

### The effect of STH infections and levels of impacts on farm productivity

Infections with parasitic nematodes restrict the welfare of the farmers and farm productivity, as these farmers rely heavily on administering anthelmintic drugs, as Taiwo et al. (2017) discovered in their study. The results showed that 97.9% of the farmers expressed that high STH medication expenses halt most farming activities, and 96.0% say that STH resistance in the various species causes persistent unhealthy conditions in the farmers (Table 4). These findings align with Campbell et al. (2018) that soil-transmitted parasites are prevalent and cause different disease conditions among poor rural dwellers in developing countries (Ayele et al.2019). Helminth infections are challenging to cure – the drugs are costly and scarce. Some commercially available drugs include benzimidazole, imidazothiazole and macrocyclic lactone groups (Gyang et al., 2019. This high cost is a burden on farm families. Some farmers take loans from money lenders to pay medical bills, reducing the area cultivated annually.

Furthermore, 93.9% of the participants say that STH-resistance causes constant unhealthy conditions in the farmers, while and 91.8% say that the STH prevalence and intensity burdened farmers. The findings agree with Darlan et al. (2018) that the cost of medical treatment for STH infections has a tremendous negative impact on farmers in the rural areas of West Africa. Such high cost affects the economic earning capacity of the farmers, making them incapable of farming anymore. As the number of farmers affected by STH infections increases, the farming population reduces. STH illnesses cease farmers' abilities to innovate, experiment, and implement changes and to acquire technical pieces of information through extension activities. Also, absenteeism from work due to frequent illness and/or morbidity (and eventual death); family time diverted to caring for the sick. Healthcare expenses may consume resources useful for improved seeds, fertilizers, equipment, and other farm inputs that can improve farm productivity. Sick family members seldom adopt labor-intensive techniques, negatively affecting farm productivity.

Furthermore, the impact of ill health results in a decline in household income, food insecurity and severe deteriorated household livelihood (Bah, et al., 2919). Farmers have accumulated technical and managerial skills that are not easily substitutable through the labor market or family and other social connections; their inability to perform agricultural activities because of STH infection significantly negatively impacts overall efficiency (Koroma et al., 2010). Unhealthy farmers deteriorate physically and mentally, reducing their concentration on farm activities, while increasing medical expenditure and taking loans, thus becoming indebted. Most rural farmers do not have accumulated money/income, especially from agriculture; they use their physical power very heavily for the commencement of the farming operations during the cropping times.

## Conclusions

STH prevalence is relatively high among the farmers in selected chiefdoms in the study area. Farmers were observed to have moderate and high-risk levels and farmers harboring the parasites are likely to constitute potential parasite reservoirs and sources of dissemination and persistence of these infections. Moreover, the most infected farmers are those engaged in tree crop production – rice and vegetable farming in Kailahun, Koinadugu and Bo Districts. Most farmers' main form of parasite control is a small number of anthelmintic compounds, mainly bought from quack drug peddlers. These findings underscore the need for robust research into the health effects of STH in farm families. Hopefully, the findings presented here will help encourage future investigations to consider the three surveyed districts, and to also consider the social and geographical differences across the region and country during the course of such investigations.

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