Durham University

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The ABC of Soil Literacy

Evidence from Ghana, South Africa and Zimbabwe

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Republic of Ghana

The report was drafted by Prof. Karen Johnson, Prof. Dennis Philip and Christian Engels of Durham University Department of Engineering and Durham University Business School working closely with selected country-based partners and building on discussions with policymakers and academics interested in soil health. We are especially grateful for the support and contributions to this report from: Prof. Florence Mtambanengwe, Natasha Kurwakumire from University of Zimbabwe; Dr. Cathy Clarke from Stellenbosch University; Dr. Wilfred K. Anim-Odame from National Development Planning Commission, Ghana and also Dr. Steve Chivasa, Megan Gow, Kamlesh Kumar from Durham University.

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Durham University hosted a series of policy workshops from 2016-2017 on the shared vision to break the link between land insecurity and poverty in Africa; partners included Sudan, Zimbabwe, Ghana and South Africa. Topics surrounded soil and land research in relation to the Sustainable Development Goals (SDGs) and many relevant social, educational, environmental and economic issues were highlighted. The ideas in this concept report were born out of discussions at these workshops. As well as academics from UK and Africa, the workshops hosted representatives from local and external non-governmental organisations including CARE International, Hope for Tomorrow Global, Traidcraft and Growing Nations; representatives from New Partnerships for African Development (NEPAD) and land administration institutions in Africa.

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EXECUTIVE SUMMARY

Climate change and soil health are intimately linked, as reflected in the United Nation's Sustainable Development Goal (SDG) 15. Land degradation is responsible for a significant proportion of all global greenhouse gas emissions (WGII, IPCC, 2007), **thereby significantly contributing to climate change. At the same time,** the recognised impacts of climate change take various forms, all of which directly impact soil health, such as those caused by heat (wildfires and droughts) or wind and water (hurricanes and floods). In 2018, the lives and livelihoods of 39 million across the globe were affected by climate change (United Nations: Department of Economic and Social Affairs, 2020a). Taken together, **this constitutes a vicious circle between soil degradation and climate change with detrimental results.**

The **equal importance of combating climate change and securing soil health as global challenges** is represented by SDG13: "Take urgent action to combat climate change and its impacts" (United Nations: Department of Economic and Social Affairs, 2020a) and SDG15: "Protect, restore and promote sustainable use of terrestrial ecosystems" (United Nations: Department of Economic and Social Affairs, 2020b). More broadly, healthy soils are the key cornerstone for all 17 SDGs (United Nations, 2008). Therefore, understanding the attitudes, behaviours and competencies that drive individual interactions with soil, including factors that promote or harm soil health, is crucial to inform policy responses that aim at facilitating sustainable interactions with soil by future global citizens and farming communities.

This **report is the first to establish the concept of soil literacy, to provide approaches to its measurement and to report estimates of its levels** in the population of school children in three African countries: Ghana, South Africa and Zimbabwe. It defines soil literacy as a combination of attitudes, behaviours and competencies required to make sound decisions that promote soil health and ultimately contribute to the maintenance and enhancement of the natural environment. On the basis of this definition, a **bespoke soil literacy questionnaire was developed in close collaboration with experts in soil science, survey design and statistical modelling**. This questionnaire contains detailed questions capturing the constituent dimensions of soil literacy: attitudes, behaviours and competencies. The survey was fielded by partners in Ghana, South Africa and Zimbabwe, and 3,661 respondent-observations of school children aged 13-15 were obtained.

Attitudes towards soil are captured by a general attitude question together with others that elicit the specific cultural, societal and financial attitudinal dimensions of soil literacy (amounting to a total of 5 attitude questions). The findings suggest that **attitudes towards soil are mixed.** The majority of respondents think that soil is dirty; however, respondents largely think that soil work requires education and that healthy soils can improve the wealth or economy of a country. Unsurprisingly, across countries, enjoyment of the topic of soils is highly variable, with 31% to 66% of respondents stating they enjoy the subject.

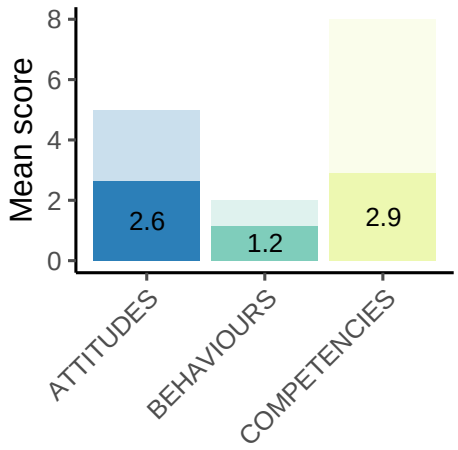
Behaviour towards soil is measured by establishing whether respondents planted anything at their homestead in the last 12 months, and if so, whether they used compost or manure (amounting to 2 behaviour question). The responses suggest that the **majority of respondents practically engage with soil and most engage in**

prudent soil practices. Between half and three-quarters of respondents planted at their homestead and of those approximately two-thirds to four-fifths used compost or manure.

Competencies and specific knowledge around soil were assessed via a set of 7 questions, which include understanding the relation between soil erosion and climate change, and in particular, knowing about the importance of soil in reducing climate change. The results show that **many respondents do not have basic soil competencies**. In particular, while around half of respondents are aware that climate change causes soil erosion, only around one-tenth know that soil erosion has led directly to increased climate change due to global greenhouse gas emissions. Taken together, this implies that **the vicious circle of climate change and soil erosion is not known to respondents**.

As shown in Figure 1, which depicts the average ABC scores (solid bars) in relation to the maximum achievable (transparent bars), **there is considerable scope for improvement in terms of overall levels of soil literacy**, across all dimensions of attitudes, behaviours and competencies. While, on average, respondents exhibit half of the desirable soil-related attitudes and behaviours, only around one-third of soil competencies are displayed.

Figure 1: Overall soil literacy
(solid bars indicate average scores and transparent bars maximum scores)



Further evidence suggests that **gender differences in soil literacy exist**, though the specific manifestation of these differences depends on the country in which respondents are domiciled. Moreover, **soil literacy is related to stronger beliefs that farming is a good way of making money**.

Overall, this report provides **three key implications for public policy** seeking to achieve the United Nation's 2030 Sustainable Development Goals by promoting and increasing soil health:

1. As the greatest lack in soil literacy is found with respect to soil competencies that can be taught in a classroom setting, **measures to increase soil literacy** can use countries' existing educational infrastructures to leverage established channels of knowledge transfer.
2. Respondents show good understanding of some areas of how soil interacts with the natural environment but not others. Importantly for future generations, **the benefits of maintaining and**

enhancing good soil health for climate change mitigation and adaptation should be integrated into educational curricula from school throughout university. In this way, by establishing a comprehensive knowledge of soil, future generations can be empowered to help address not only SDG15 ("Protect, restore and promote sustainable use of terrestrial ecosystems") but also SDG13 ("Take urgent action to combat climate change and its impacts") and break the vicious circle.

3. As soil attitudes vary by country, policymakers should shy away from one-size-fits-all approaches. More work is needed to **obtain quantitative and qualitative evidence for each country's particular attitudes, behaviours and competencies towards soil**. Tailoring policy to its specific challenges will maximise the likelihood of success.

In the future, on the basis of this report, more refined policy guidance can be developed to support the implementation of effective soil education initiatives across the world, ensuring the next generation of farmers can play their part in addressing climate change.

INTRODUCTION

> *Soil is an essential resource and a vital part of the natural environment from which most of the global food is produced. At the same time, soil provides living space for humans, as well as essential ecosystem services which are important for water regulation and supply, climate regulation, biodiversity conservation, carbon sequestration and cultural services. But soils are under pressure from increases in population, higher demands for food and competing land uses. Approximately 33% of our global soils are degraded and policy makers around the world are exploring opportunities to embrace sustainable development via the sustainable development goals.*
>
> Global Soil Partnership
> (Food and Agriculture Organization of the United Nations, 2020)

In 2015, through the 2030 Agenda for Sustainable Development, the United Nations adopted the 17 Sustainable Development Goals (SDGs): global objectives to guide the actions of the international community towards the year 2030 (United Nations, 2020). Healthy soils are the key cornerstone for all 17 Sustainable Development Goals (United Nations, 2008). Understanding the attitudes, behaviours and competencies that drive individual interactions with soil, including factors that promote or harm soil health, is thus crucial to inform policy responses that aim at facilitating sustainable interactions with soil for future citizens and farming communities.

SOIL LITERACY AND ITS MEASUREMENT

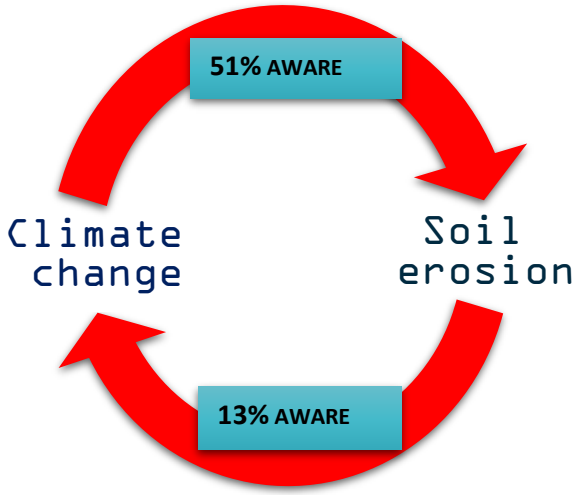
This document presents the first effort to provide a survey-based toolkit to measure the ABC of Soil Literacy: the individual attitudes, behaviours and competencies relating to soils in their environmental, social and financial contexts. It provides empirical evidence on the Soil Literacy of the next generation of farmers and the wider population in Ghana, South Africa and Zimbabwe: school children aged 13-15 across these countries. In 2030, the future generations of farmers will play an instrumental role in carrying forward into the future the global efforts encapsulated by the Sustainable Development Goals, and fostering soil literacy can provide their empowerment to succeed in rising to the challenges these goals lay out.

THE VICIOUS CIRCLE OF CLIMATE CHANGE AND SOIL EROSION

The recognised impacts of climate change take various forms, all of which directly impact soil health, such as those caused by heat (wildfires and droughts) or wind and water (hurricanes and floods). In 2018, the lives and livelihoods of 39 million across the globe were affected by climate change (United Nations: Department of Economic and Social Affairs, 2020a). Their equal importance as global challenges are represented by the United Nation's Sustainable Development Goal 13 ("Take urgent action to combat climate change and its impacts" (United Nations: Department of Economic and Social Affairs, 2020a)) and SDG15 ("Protect, restore and promote

sustainable use of terrestrial ecosystems" (United Nations: Department of Economic and Social Affairs, 2020b) (United Nations, 2020)).

Importantly, soil erosion also significantly contributes to climate change, resulting in a vicious, self-sustaining cycle between climate change and soil erosion. This study reveals that the majority of respondents (51%) are aware of the effect of climate change on soil erosion; however, only a small proportion (13%) of respondents know of the effects that soil erosion has on climate change. Taken together, this implies a key blind spot in the understanding of environmental interlinkages that contribute to the greatest global challenge of this century: combating climate change.



DATA COLLECTION IN GHANA, SOUTH AFRICA AND ZIMBABWE

The Durham University research group invited partners in South Africa, Ghana and Zimbabwe to use the ABC of Soil Literacy toolkit and submit the survey responses for analysis. In this fieldwork exercise, the population of interest are school children aged 13-15. The survey design relied on a pilot study approach, which gathered non-probability-based convenience samples to examine the proof of concept. Across these three countries, 3,661 respondent observations were collected (1,797 in Ghana, 956 in South Africa and 908 in Zimbabwe), covering a total of 39 schools of varying institution types (day school or boarding; agricultural-focused schools vs others; private or public; and mission or non-mission). Specifically, paper questionnaires were issued to each trained fieldwork team, who then organised trips to the respective schools to administer the survey between April and July 2019. The responses were then collated by Durham University for analysis.

I. THE CONCEPT AND MEASUREMENT OF SOIL LITERACY

This report has been developed in response to the challenges set out in the United Nation's Sustainable Development Goals (SDGs). The 17 SDGs address global challenges relating to poverty, inequality, climate change, environmental degradation, peace and justice (United Nations, 2020). Healthy soils are a key cornerstone of all 17 Sustainable Development Goals (United Nations, 2008).

Soil literacy is a combination of attitudes, behaviours and competencies necessary to make sound decisions that promote soil health and ultimately contribute to the well-being of the natural environment.

However, no prior work considers the conceptualisation and measurement of soil literacy, as well as its constituent components of attitudes, behaviours and competencies, which allow decision-making to enable good soil health and positive impacts on the environment. Understanding the attitudes, behaviours and competencies that drive individual interactions with soil, including factors that promote or harm soil health, is

crucial to inform policy responses that aim at facilitating sustainable interactions with soil of the future citizens and farming communities.

As such, the work laid out in this report is the first to conceptualize and measure soil literacy. The groundwork began in 2016 to develop a common questionnaire to measure the various dimensions of soil literacy. The core questionnaire, together with additional fieldwork instruction, was developed in consultation with experts in soil science and statistical survey design. The Soil Literacy toolkit encompasses the survey questionnaire, methodological guidance on how to obtain samples of the population of interest, in addition to advice on how to prepare the fieldwork teams.

The questionnaire was designed to elicit the attitudes, behaviours and competencies of respondents regarding various cultural, societal and financial dimensions of soil and its properties; engagement with soil and fertilizers in the respondents' everyday lives; as well as respondents' knowledge about soil, fertilizer use and other determinants of soil health, as well as soils' relationships to changes in the natural environment, such as climate change, carbon sequestration and wind or water erosion.

While answers to individual question are informative, the questionnaire was specifically designed to enable the capturing of information that can be used to create aggregated scores indicative of the respondents' overall levels of soil literacy. Accordingly, this report considers a set of fourteen questions: 5 relating to soil attitudes, 2 to behaviours and 7 to competencies, which are used to create aggregate scores across the individual dimensions of soil literacy. The survey further captures a range of respondents' individual- and household-level demographic and background characteristics, as well as broader questions relating to agriculture and soil-related professions.

II. Soil Attitudes

This section reports the survey questions capturing soil attitudes and the respondents' answer distributions for Ghana, South Africa in Zimbabwe. Table 1 provides an overview of the question covered in this section, the possible answer choices available to respondents, as well as additional comments on question purpose that informed the question design.

Table 1: Soil attitudes questions

ID	Text	Possible responses	Purpose
A1	Rate the subject/topic of soils	5-point Likert scale [favourite, enjoyable, neutral, dislike, worst, I do not know]	Captures respondent's attitude towards learning about soil
A2	Soil is medicinal and has healing properties	True/False	Captures a cultural dimension to soil; for instance, some communities use clays as antiseptic
A3	Soil is dirty	True/False	Captures societal attitudes towards soil, i.e. whether engagement with soil is an

			accepted occurrence or considered dirty and to be avoided
A4	Working with soils/agriculture is for the less educated	5-point Likert scale [strongly agree, agree, neutral, disagree, to strongly disagree, I do not know]	Captures societal stigma associated with soil-related professions
A5	A healthy soil can improve the wealth/economy of the country	5-point Likert scale [strongly agree, agree, neutral, disagree, to strongly disagree, I do not know]	Captures financial attitudes towards soil, such that considering soil health is an economic input with positive monetary gains

ATTITUDE TOWARDS LEARNING ABOUT SOIL

In order to elicit the general respondents' inclinations towards the subjects of soils, the survey's first attitudinal question captures individual degrees of like or dislike of the subject of soils. Expressions of negative views towards soils can be a cause of particular concern as they can be indicative of potential underinvestment in knowledge about soil, and agriculture more generally, or enable the propagation of environmentally harmful individual behaviours. The question serves as a useful entry point to the study of the more granular aspects of the societal, cultural and financial soil-related attitudes

Accordingly, Figure 2 reports respondents' answer choices to the general attitudinal question (A1) regarding their liking of the subject of soils. Possible responses are on a 5-point Likert scale, ranging from "favourite" to "worst", with an additional option of "I do not know".

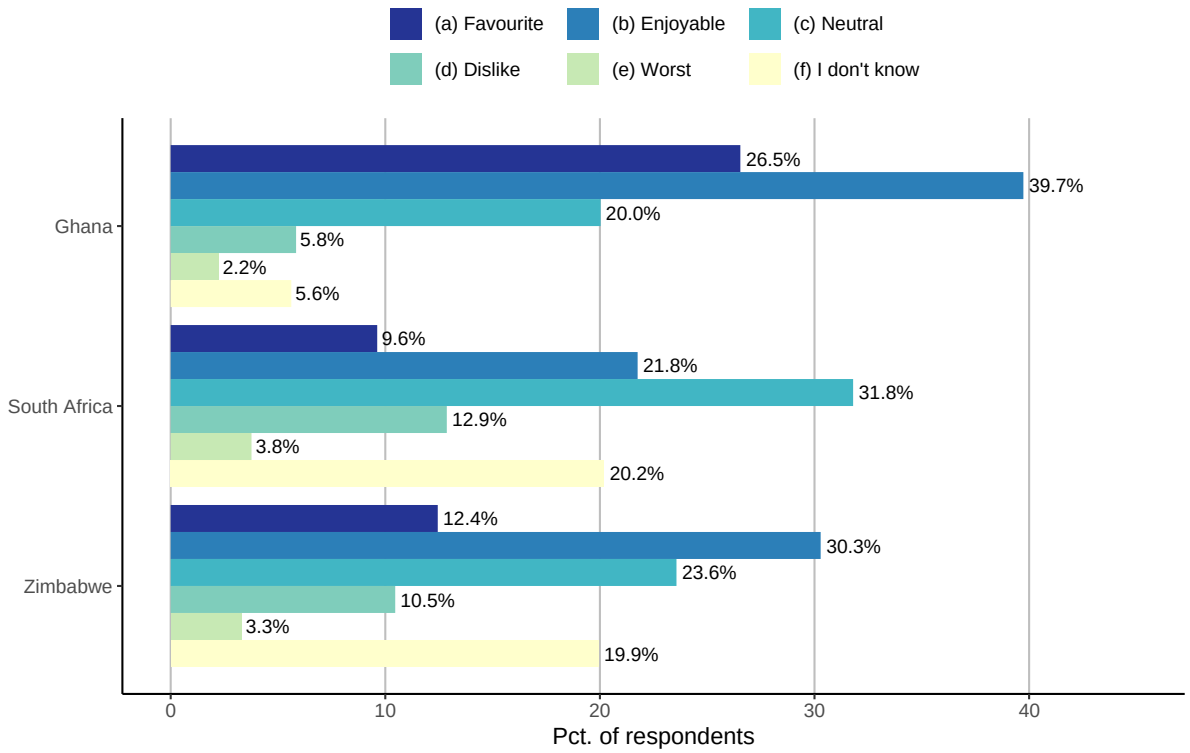
Regarding positive views towards the subject of soils, Figure 1 reveals that in Ghana two-thirds (66.2%) of respondents expresses a liking of soil; specifically, there was a very strong tendency for respondents to say that soil is either their favourite subject (26.5%) or enjoyable (39.7%). This is in stark contrast to responses from individuals in South Africa or Zimbabwe, where only the minority expresses a liking for the subject of soils (31.4% and 42.7% for South Africa and Zimbabwe, respectively), few respondents rate soil as their favourite subject (9.6% and 12.4%) and a relatively larger fraction find it enjoyable (21.8% and 30.3%).

Consequently, the corresponding mirror image of neutral or negative attitudes towards soils shows that approximately one-fourth (28%) of respondents in Ghana expressed negative views, while larger proportion do so in South Africa (48.5%) and Zimbabwe (37.4%). Interestingly, the respondents answering that they do not know how they rate the subject of soils is low in Ghana (5.6%) but significantly higher in South Africa and Zimbabwe (20.2% and 19.9%).

Together, these numbers set out challenges to create enthusiasm for the subject of soil that differ across countries. In Ghana, the focus would be to sustain the positive, majority views towards soils while creating excitement towards soil for respondents that currently hold neutral and negative views. In South Africa and

Zimbabwe, the challenge appears to be to convince the greatest groups of respondents that hold neutral or negative views that soil is indeed a subject to engage with and increase favourable attitudes. In these countries, great opportunity lies with respondents that are undecided in their soil preferences, as fostering positive attitudes with those respondents may be easier than convincing those with negative ones.

Figure 2: (A1) Liking of the subject of soils

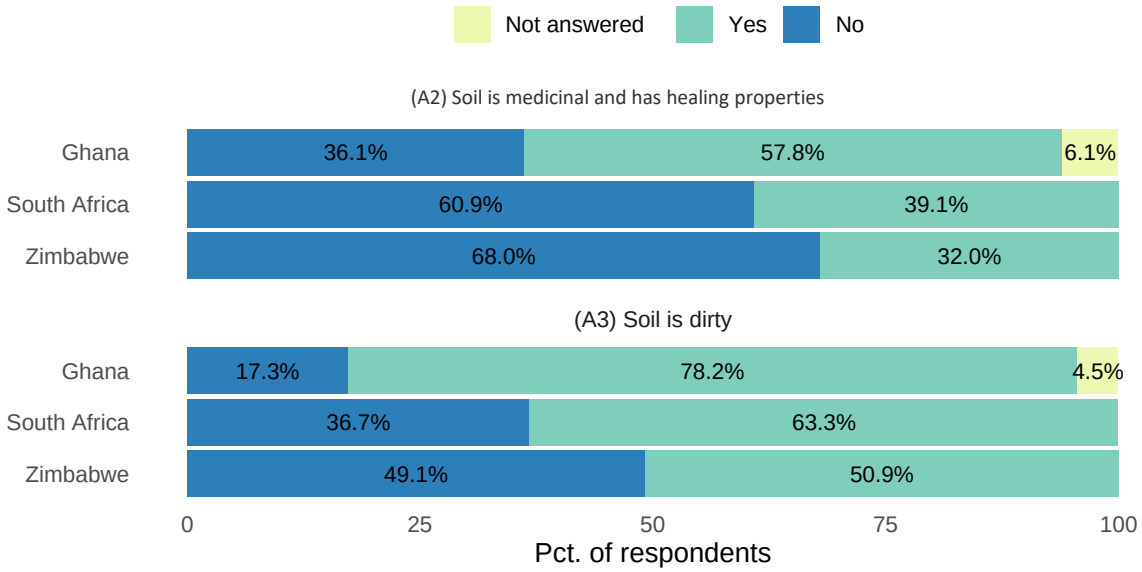


CULTURAL AND SOCIETAL ATTITUDES TO PARTICULAR SOIL PROPERTIES

Cultural and societal differences encompass differing attitudes to the natural environment. The questionnaire is designed to capture two specific attitudes towards soil. First, whether respondents consider soil to have medicinal properties (cultural dimension); second, whether respondents' view soil as dirty (societal dimension). The particular response distributions to these two statements can uncover more specific insights into soil-related attitudes.

Figure 3 reports the responses to statements eliciting these particular attitudes to soil. The exact wordings of the statements considered are (A2) "Soil is medicinal and has healing properties" and (A3) "Soil is dirty". Possible answers are "Yes" and "No". Regarding statement A2, the majority of individuals (57.8%) in Ghana responded "Yes", while a smaller fraction did so in South Africa and Zimbabwe (39.1% and 32.0%). In Ghana, a small fraction of respondents did not supply either answer choice (Yes/No), while no missing answers are recorded for South Africa and Zimbabwe. Turning to statement A3, responses from Ghana, South Africa and Zimbabwe indicate that the majority in all these countries consider soil to be dirty, with the majority proportions being decisive in Ghana and South Africa (78.2% and 63.3%), while the majority in Zimbabwe is marginal (50.4%).

Figure 3: (A2, A3) Cultural attitudes to soil properties



In Ghana, these figures suggest, prima facie, an ambivalent cultural view towards soil. On the one hand, respondents indicate the positive belief that soil has medicinal or healing properties; on the other hand, respondents perceive soil to be dirty: clearly a negative attribution. Possibly, this reflects the common perception that taking most medicine, though beneficial for the recovery from illness, is unpleasant in terms of taste and feel. In contrast, while respondents in South Africa and Zimbabwe appear less likely to view soil as dirty, the view that soil has medicinal properties is strikingly less common, not exhibiting the tensions in views expressed by respondents in Ghana.

ATTITUDES TO WORK WITH SOIL OR AGRICULTURE

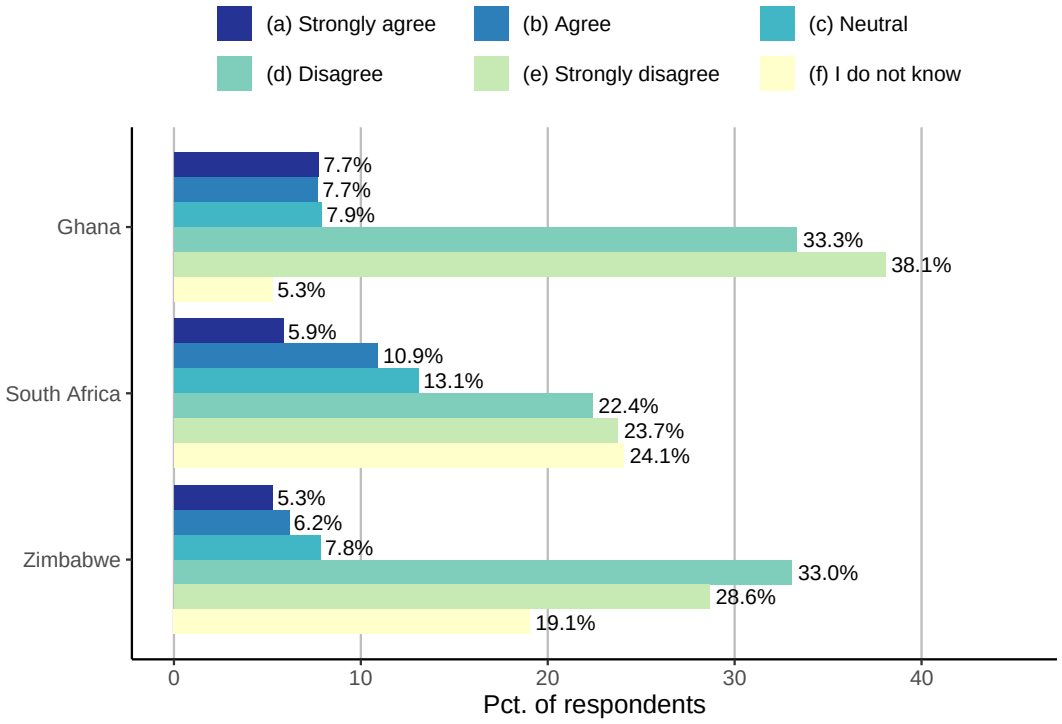
Labour-intensive agricultural professions are widely subject to societal stigma. The soil literacy questionnaire includes one question specifically aimed at capturing the stigmatising view that working with soils or agriculture is for the less educated. As stigma can be one strong factor driving individual choices, such as what occupation to pursue, estimates of the prevalence of this particular soil attitude can inform informational campaigns that aim at illuminating soil-related professions and encouraging individuals to engage in career paths in agriculture.

Figure 4 reports the responses to the statement that working with soils or agriculture is for the less educated. Individuals indicate their agreement or disagreement on a 5-point Likert scale, ranging from “Strongly agree” to “Strongly disagree”, with inclusion of the additional answer choice “I do not know”.

Across all three countries, Ghana, South Africa and Zimbabwe, a small but stable proportion of individuals strongly agrees that soil or agricultural work is for the less educated (7.7%, 5.9% and 5.3%, respectively). Moreover, while the responses “Agree” and “Neutral” were chosen with comparable, low frequencies in Ghana and Zimbabwe (in total, 15.6% and 14%), individuals in South Africa chose those responses at a notably higher frequency (24%). These results indicate that attitudes towards the required education to work with soil or

agriculture are most favourable in Ghana and Zimbabwe, while respondents in South Africa are more likely to view such work as an activity the less educated engage in.

Figure 4: (A4) Working with soils or agriculture is for the less educated

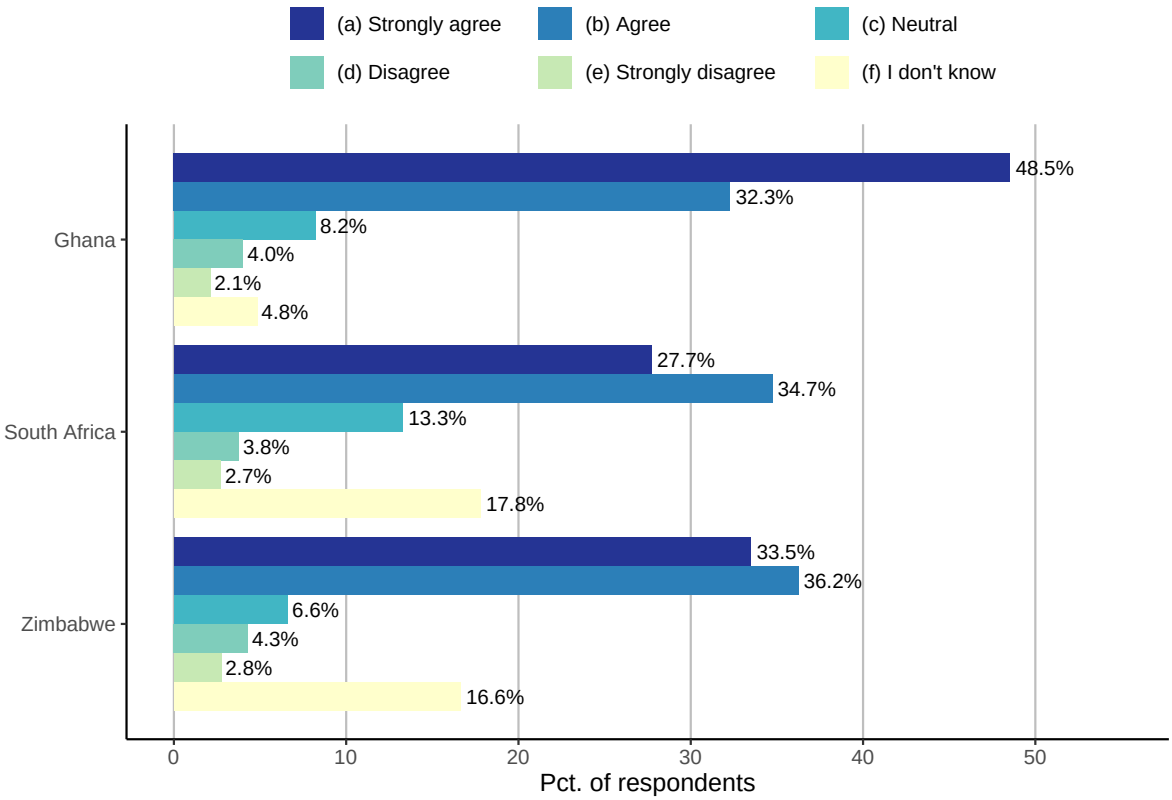


Given that stigma can play an important deciding factor in employment choices, the results suggest that policy measures to increase the proportion of the workforce engaged in agricultural activities would be relatively more effective in Ghana and Zimbabwe than in South Africa.

FINANCIAL ATTITUDES REGARDING SOIL

As a rule, policymakers consider the public's views of economy-wide interventions in their considerations of which policy measures to implement and what particular form these should take. Financial benefits of policies can be powerful motivators for their adoptions and generally enjoy more wide-ranging support if the general public shares the perception of potential monetary gains. Accordingly, to gauge the possibility of public policy that supports soil health stemming from potential financial benefits, the soil literacy questionnaire measures whether individuals believe that the presence of healthy soil in a country can improve the nation's wealth or economy. Figure 5 shows the response distributions to this particular question. Individuals again indicate their agreement or disagreement on a 5-point Likert scale, ranging from "Strongly agree" to "Strongly disagree", with inclusion of the additional answer choice "I do not know".

Figure 5: (A5) A healthy soil can improve the wealth/economy of the country



Across all countries, the majority of respondents either strongly agree or agree that a healthy soil is beneficial to a country's economy. The greatest proportion of respondents that does so is domiciled in Ghana (80.8%) and is followed by Zimbabwe (69.7%) and South Africa (62.4%). Notably, in Ghana, almost half (48.5%) of respondents strongly agree with the statement, with one-quarter (27.7%) in South Africa, and one-third (33.5%) in Zimbabwe. The respondents that chose either of the responses "neutral", "disagree" or "strongly disagree" is small and comparable across countries. Again, in Ghana the fraction of "I do not know responses" is small (4.8%), while in South Africa and Zimbabwe a relatively larger proportions of respondents chose this option (17.8% and 16.6% in South Africa and Zimbabwe, respectively).

These figures shine an encouraging light on potential public support for measures that improve the health of a country's soil, given the majority views that healthy soil can yield beneficial aggregate economic outcomes.

III. SOIL BEHAVIOURS

This section reports the survey questions capturing soil behaviours and the respondents' answer distributions for Ghana, South Africa in Zimbabwe. Table 2 provides an overview of the question covered in this section, possible responses, as well as additional comments on question purpose.

Table 2: Soil behaviour questions

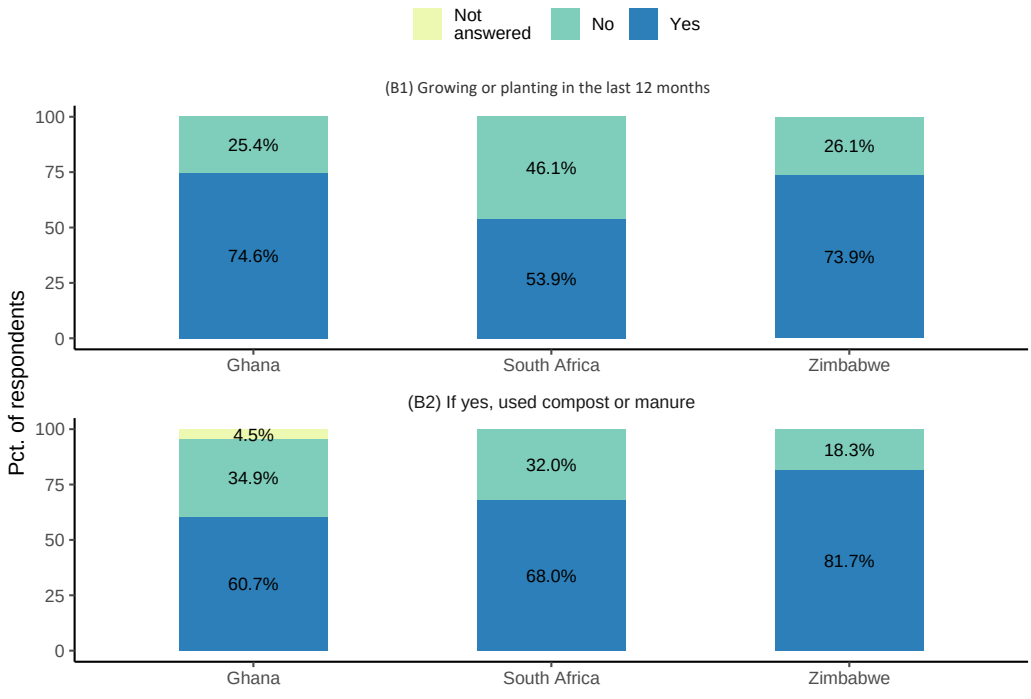
ID	Text	Possible responses	Purpose
B1	In the last 12 months, have you planted or grown anything at your homestead or farm?	Yes/No	Captures respondents' recent, direct interactions with soil by planting or growing in the family context
B2	If YES [answer to B1]: Did you add compost or manure to the soil?	Yes/No	Captures the good practice of adding organic matter to reduce chemical fertiliser use, which saves money and improves the soil's water holding capacity

HOMESTEAD PLANTING AND ORGANIC MATTER ADDITION

Planting or growing is a key activity that can increase knowledge about soils and foster environmentally friendly behaviours. One such behaviour is the use of compost or manure in lieu of, or complementary to, synthetic fertilisers. Questions B2 and B3 capture, respectively, whether individuals engaged in planting or growing in the last 12 months at the point of being surveyed and if they did, whether they used compost or manure.

Figure 6 reveals that large proportions of individuals across Ghana, South Africa and Zimbabwe use their homestead for planting or growing; specifically, approximately three quarters in Ghana (74.6%) and Zimbabwe (73.9%), and over half (52.9%) in South Africa. Of those individuals, approximately two-thirds of individuals Ghana (60.7%) and South Africa (68.0%) used compost or manure, while the proportion increases to approximately four-fifths (81.7%) for Zimbabwe.

Figure 6: (B1, B2) Growing plants and use of compost/manure



IV. SOIL COMPETENCIES

This section reports the survey questions capturing soil competencies and the respondents' answer distributions for Ghana, South Africa in Zimbabwe. Table 3 provides an overview of the question covered in this section, possible responses, as well as additional comments on question purpose.

Table 3: Soil competency questions

ID	Text	Possible responses	Purpose
C1	Why is soil important?	Multiple choice [plant growth, reducing climate change, building, habitat for insects/organisms, water filtration, I do not know]. Multiple selections allowed.	Designed with focus on "reducing climate change" response: aims to capture the understanding that soil is the biggest store of carbon after the oceans (except fossil fuels) and that soil erosion increases climate change as well as exploring the large potential to use soil for climate change mitigation (and adaptation)..
C2	Soil is a living thing	True/False	Captures understanding of the important role of the living things in soil (for example, microorganisms and plants exchanging nutrients for carbon some of which can then be stored in the soil)
C3	Soil is a possible pollutant of dams and rivers	True/False	Captures knowledge of soil as a pollutant in the wrong place ie in rivers and dams. This soil has not only been lost from fields but also there are economic costs for removing sediment from dams and rivers. If soil contains chemicals like fertilisers and pesticides, then these pollute rivers and dams.
C4	Soil holds on to water/prevents drought	Yes/No	Captures knowledge of importance of soil in storing water and reducing both drought and flash floods
C5	Soil erosion has increased due to climate change	5-point Likert scale [strongly agree, agree, neutral, disagree, strongly disagree, I do not know]	Captures knowledge that climate change which causes increased extreme weather events leads to wind erosion in the global south and water erosion in the global north both of which cause significant soil erosion
C6	Fertilizer may harm the soil and environment	5-point Likert scale [strongly agree, agree, neutral, disagree, strongly disagree, I do not know]	Captures knowledge that chemical fertiliser can result in water pollution when added to degraded soils via eutrophication of waters (algal blooms, etc)
C7	How can you tell whether soil is healthy?	Multiple choice [colour, taste, presence of soil animals, none of these, I do not know]	Captures practical knowledge derived from interactions with soil. This knowledge includes physical (for example, friability and water content), chemical (colour relating to organic matter content or mineral content) and biological observations (for example, presence of soil animals)

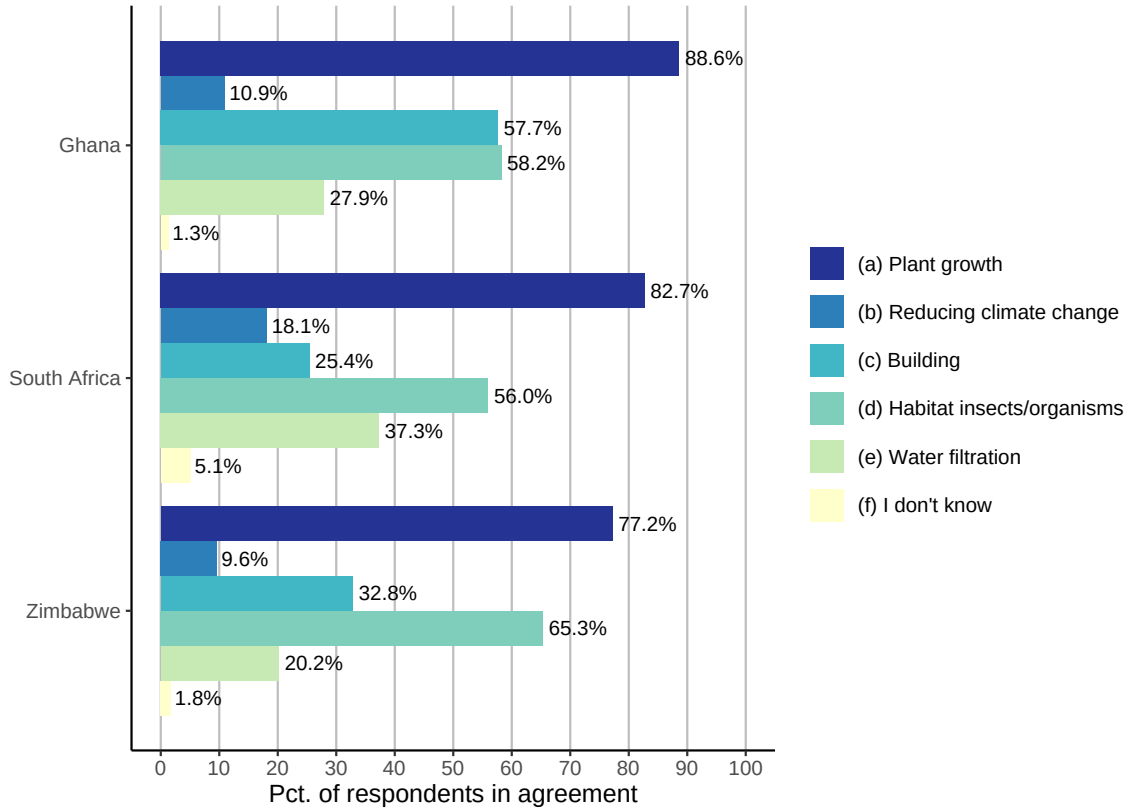
IMPORTANCE OF SOIL

Soil has various important environmental functions, such as aiding plant growth; providing a habitat for insects and other organisms; and filtering water, as well as carbon and water storage. Awareness of these functions can foster environmentally conscious behaviours, such as those that prevent soil erosion and increase soil health. Question C1 "Why is soil important?" elicits the respondents' understanding of importance of soil. Possible answers to the question include "Plant growth", "Reducing climate change", "Building", "Habitat for insects/organisms" and "Water filtration", in addition to the answer choice "I do not know".

Figure 7 reports the relative frequencies with which respondents indicated that soil is important for the various listed functions. Regarding plant growth, the great majority in Ghana (88.6%), South Africa (82.7%) and Zimbabwe (77.2%) is aware of soil's importance. However, these numbers are drastically lower for respondents' considerations of whether soil is important in reducing climate change or filtering water: low agreement is observed in Ghana (10.9% and 27.9%), South Africa (18.1% and 37.3%) and Zimbabwe (9.6% and 20.2%).

The low figures across the surveyed countries reveal a strong need for increased focus on the importance of soil in the educational curriculum; particularly around the message of soil being part of the solution to mitigate climate change and its effects. The next generation of farmers in Africa and around the world need to know that healthy soils are not only important to grow plants, increasing crop yield, and to hold onto water better, but that soil is an important store of carbon and should be used as part of climate change mitigation strategies.

Figure 7: (C1) Why is soil important?

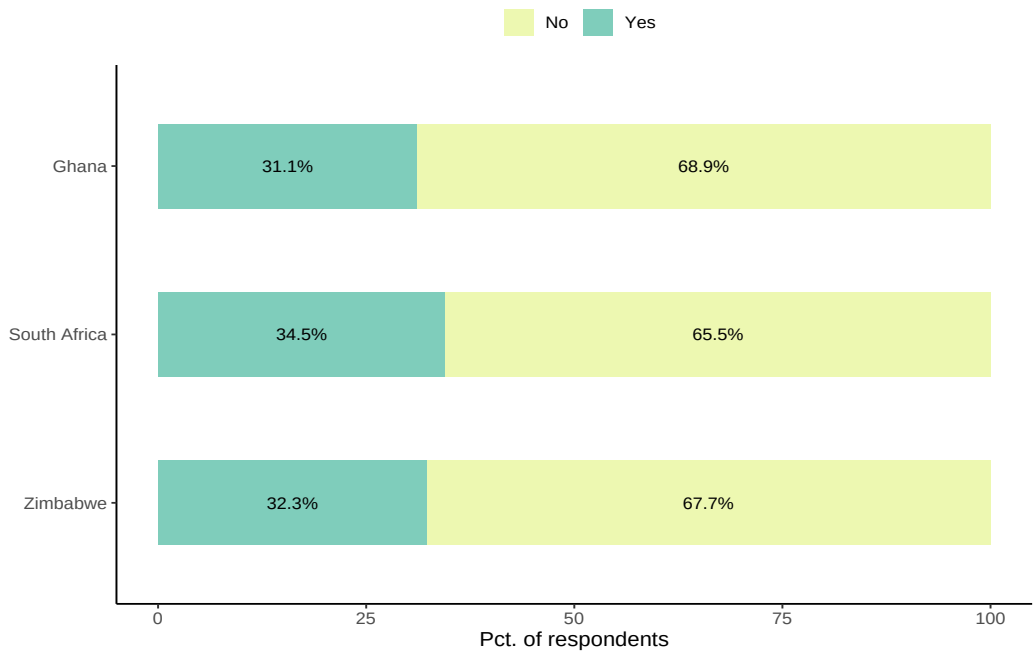


SOIL IS A LIVING THING

The distinction between alive and inanimate objects has direct implications for the care with which they are treated. As a rule, animals are treated with more considerations than are rocks, with plants and trees falling somewhere in between. Similarly, soil can and should be regarded as living matter. Without living microorganisms, soil cannot fulfil its essential functions of plant growth, retaining water or storing carbon. However, it is unclear how widespread this understanding is in the general population. In fact, it seems likely that there are few people outside of the soil science disciplines who would know that soil was a living media. And yet this understanding is crucial to our ability to safeguard our soils for future generations.

Accordingly, the survey invites respondents to choose between "Yes" and "No" in regard to the statement C2 "Soil is a living thing". Reporting the survey results, Figure 8 shows that approximately one-third of respondents in Ghana (31.1%), South Africa (34.5%) and Zimbabwe (32.3%) consider soil to be a living thing. These results speak to a need of increased educational efforts with respect to the living nature of soil.

Figure 8: (C2) Soil is a living thing



SOIL AS A POSSIBLE POLLUTANT OF DAMS AND RIVERS

Ensuring soil is healthy results in positive effects on the natural environmental; however, inadequate maintenance produces negative environmental, social and economic consequences. For instance, not maintaining soil health means soil is more likely to be eroded and to end up polluting both damns and rivers. In line with these observations, respondents are again asked to respond with either "Yes" or "No" to statement C4, stating "Soil is a possible pollutant of dams and rivers".

Figure 9: (C3) Soil is a possible pollutant of dams and rivers

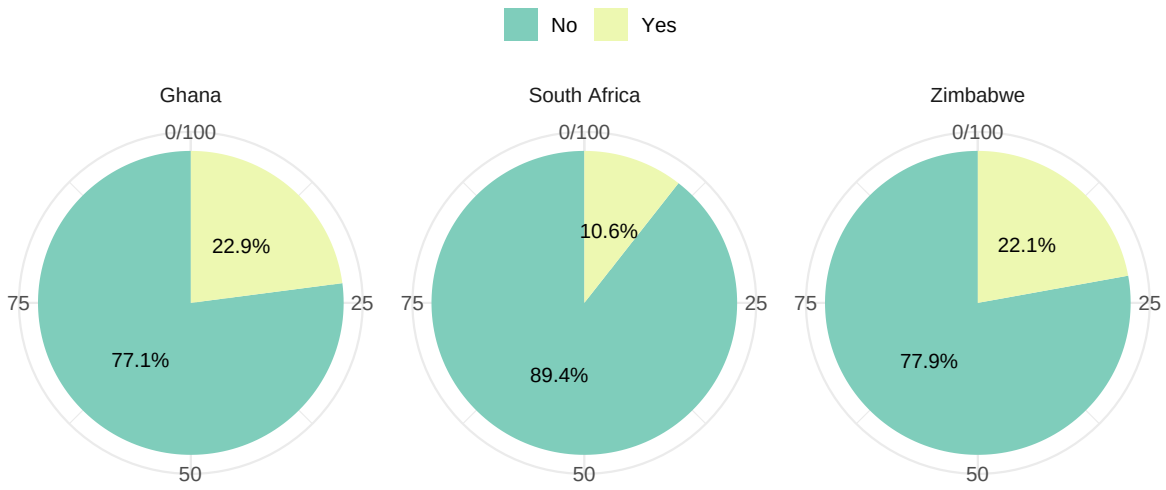


Figure 9 shows that around one-fifth of respondents in Ghana (22.9%) and Zimbabwe (10.6%) are aware that soil is a possible pollutant of dams and rivers; in South Africa, this figure amounts to approximately one-tenth (10.6%) of respondents.

In relation to the results of previous questions, an intriguing observation emerges: respondents reveal a disconnect in their understanding between water and soil. While they hold the belief that soil is dirty, and understand the concept of soil erosion, the low proportion of respondents reporting that soil is a possible pollutant of dams and rivers indicates that how eroded soil enters the water cycle is not understood. One possible reason why this disconnect exists can be that the water cycle and soil subjects are generally taught separately. This suggests the consideration to jointly integrate the teaching of soil and water in the educational curricula, beginning in school and continuing throughout university,

SOIL HOLDS ON TO WATER/PREVENTS DROUGHT

A commonly taught characteristic of soil is that it holds on to water or prevents drought. The questionnaire includes a question that captures the respondents' knowledge of this soil property. Possible answers are "Yes" and "No".

Figure 10: (C4) Soil holds on to water/prevents drought

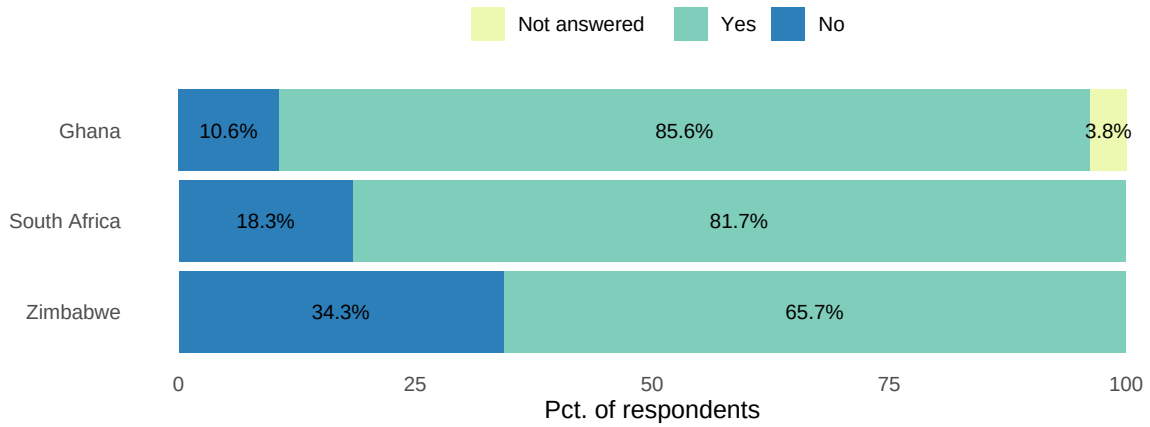


Figure 10 presents the answer distributions. The majority of respondents across all three countries are aware that soil holds on to water or prevents drought. However, cross country differences exist: while the respondents in Ghana and South Africa have large proportions of respondents (85.6% and 81.7%) that display the considered knowledge, the proportion is notably lower for respondents in Zimbabwe (65.7%).

CLIMATE CHANGE AND SOIL EROSION

As climate change unfolds, one striking consequence is the observed increase in soil erosion globally. To measure this awareness in respondents across Ghana, South Africa and Zimbabwe, statement C5 invites them to state their agreement or disagreement with the statement “Soil erosion has increased due to climate change”. Possible responses range from “Strongly agree” to “Strongly disagree”. Respondents are also given the option of “I do not know”.

Figure 11: (C5) Soil erosion has increased due to climate change

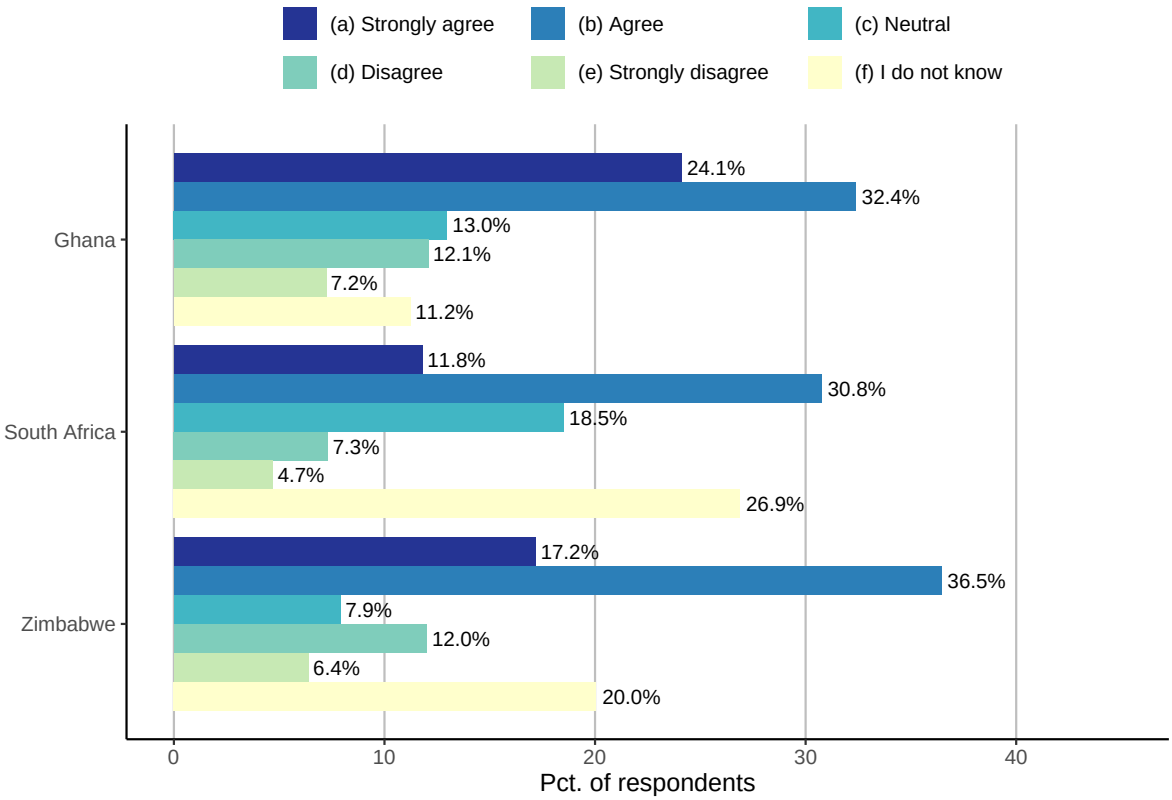


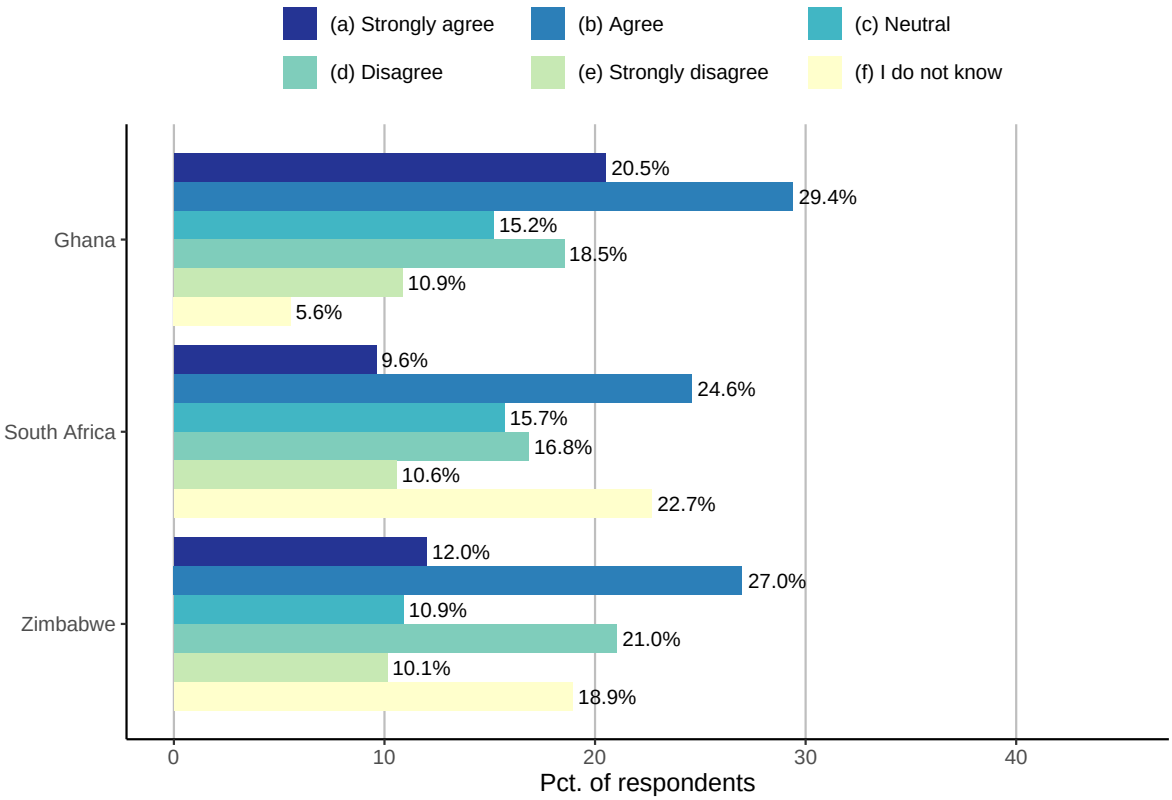
Figure 11 reports the response distributions to statement C5. The majority of respondents in Ghana (56.5%) and Zimbabwe (53.7%) voice either agreement or strong agreement, whereas in South Africa approximately four in ten respondents (42.6%) do so. Non-responses are most pronounced in South Africa (26.9%), followed by Zimbabwe (20.0%) and Ghana (11.2%). These figures suggest a tentative understanding of an increase in soil erosion due to climate change; however, there is great potential for further awareness.

FERTILIZER MAY HARM THE SOIL AND ENVIRONMENT

Unbalanced or excessive use of synthetic fertilizer can harm the soil and environment. Consequently, in their official guidelines, the United Nations have adopted the recommendation to reduce the use of industrial fertilizer in place of compost or manure. To measure the public understanding of the potential of harm when using industrial fertilizer, the survey elicits respondents' agreement or disagreement with statement C5: "Fertilizer may harm the soil and environment".

Figure 12 reports the results. Half (49.9%) of respondents in Ghana agree or strongly agree that fertilizer may harm the soil and environment; South Africa and Zimbabwe show lower levels (34.2% and 39%).

Figure 12: (C6) Fertilizer may harm the soil and environment

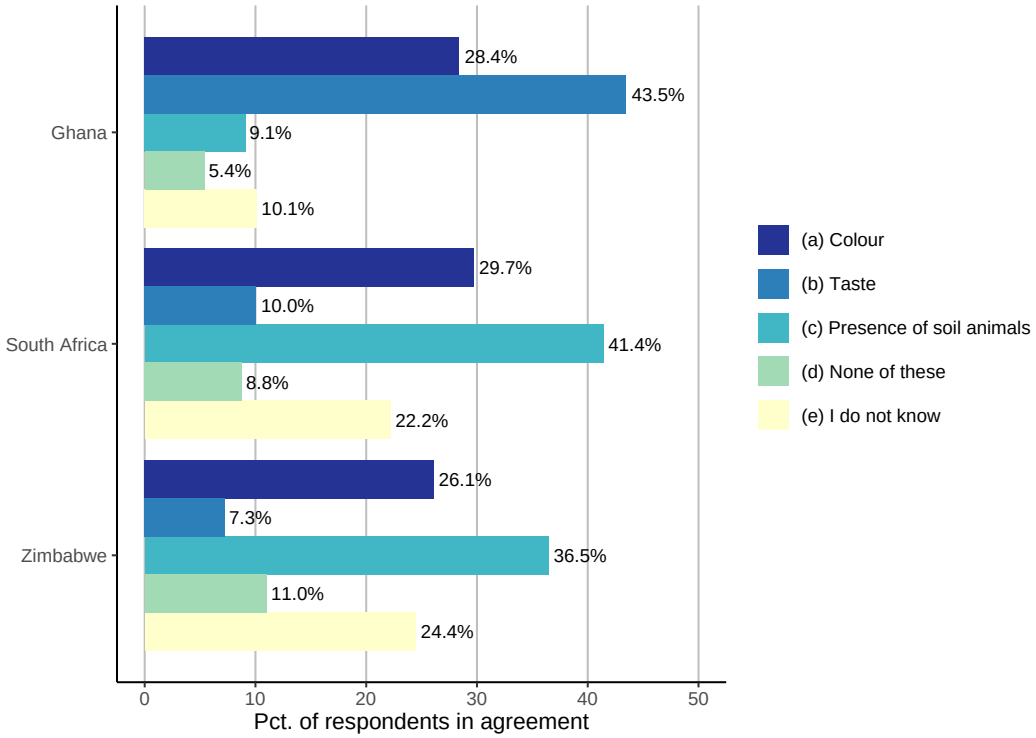


SIGNS OF SOIL HEALTH

Soil-related competencies include the ability to recognise signs that soil is healthy. Survey respondents are asked to indicate from a list of possible answer which soil characteristics they believe are indicative of its health.

Figure 13 shows the answer distributions. The proportions of respondents identifying the correct answers "Presence of soil animals" and "Colour" show that only about one-tenth (9.1%) of respondents in Ghana identify the presence of soil animals as a sign of good soil health. This is in striking contrast to four-tenth (41.4%) respondents in South Africa and over one-third (36.5%) of respondents in Zimbabwe doing so. With respect to colour, patterns across countries are largely consistent, under one-third of respondents in Ghana (28.4%), South Africa (29.7%) and Zimbabwe (26.1%) correctly identify this property.

Figure 13: (C7) Signs of soil health



V. Overall Levels of Soil Literacy

Variable transformations for aggregation

This section presents the results of aggregating the individual ABC questions into overall scores for the soil literacy dimensions of attitudes, behaviours and competencies. This enables the inspection of intra-country strengths and weaknesses across the ABC dimensions, the study of their determinants and the exploration of downstream effects that soil literacy has on other socioeconomic dimensions.

To create these ABC scores, responses are transformed into zero/one indicator variables that capture whether the respective respondents exhibit the specific attitude, behaviour or competency the question captures. For each respondent, these binary indicators are summed, yielding the respondents' individual ABC score for the particular dimensions under consideration. On the basis of these transformed variables, computing the mean score for each country leads to the country-specific aggregate ABC score.

The averages for the individuals transformed variables that enter into the ABC score calculations are reported in Table 4, while Appendix 1 provides explanations of the exact ways in which the raw question answers choices are transformed into the binary variables. Further, Table 4 reports the differences-in-means across countries, as well as their corresponding statistical significance.

Consistent with the discussions of the previous sections, Table 4 reveals significant variability in the proportions of individuals that reveal favourable soil attitudes, prudent soil behaviour or desirable soil competencies. These differences are clearly indicative of differences in the individual levels of soil literacy; at the same time, some attitudes, behaviours or competencies can be more challenging to develop, participate in or acquire.

ESTIMATING QUESTION DIFFICULTY

In order to obtain estimates of the difficulty levels associated with the questionnaire's soil literacy questions, this study adopts the methodological approach known as Item Response Theory (IRT). Intuitively, given a set of respondent-level observations that indicate whether questions were answered correctly, IRT allows the joint estimation of the respondents' unobservable ability to successfully answer the considered questions, together with a question-specific ability threshold required to succeed in answering the respective questions, which can be interpreted as the question difficulty. Annex 2 includes some key technical details.

Table 5 reports the IRT estimation results. Three notable observations emerge. First, 4 out of the 5 most difficult question are competencies. Second, the two most difficult relate to soil as a pollutant of dams and rivers (C3) and the importance of soil in reducing climate change (C1). Third, the question relating to soil erosion having increased due to climate change (C5) is a question of average difficulty.

Taken together, this implies that the most difficult aspects of soil literacy are competencies, which can be taught. Moreover, acquisition of the specific knowledge captured by question C1 (the importance of soil in reducing climate change) is of crucial importance to raise awareness of the vicious cycle of climate change and soil erosion.

Table 4: Summary statistics for questions entering ABC scales

		Ghana	South Africa	Zimbabwe	Difference		
Item		(1)	(2)	(3)	(1) - (2)	(1) - (3)	(2) - (3)
A1.	Rate the subject/topic of soils	0.66	0.31	0.43	0.35***	0.24***	-0.11***
A2.	Soil is medicinal and has healing properties	0.58	0.39	0.32	0.19***	0.26***	0.07***
A3.	Soil is dirty (inverted scale)	0.17	0.37	0.49	-0.19***	-0.32***	-0.12***
A4.	Working with soils/agriculture is for the less educated (inverted scale)	0.71	0.46	0.62	0.25***	0.10***	-0.16***
A5.	A healthy soil can improve the wealth/economy of the country	0.81	0.62	0.70	0.18***	0.11***	-0.07***
B1.	In the last 12 months, have you planted or grown anything at your homestead or farm?	0.75	0.54	0.74	0.21***	0.01	-0.20***
B2.	If planted on farm or homestead, did you add compost or manure to the soil?	0.45	0.37	0.60	0.09***	-0.15***	-0.24***
C1.	Why is soil important? Reducing climate change	0.56	0.43	0.54	0.14***	0.03	-0.11***
C2.	Soil is a living thing	0.31	0.35	0.32	-0.03*	-0.01	0.02
C3.	Soil is a possible pollutant of dams and rivers	0.23	0.11	0.22	0.12***	0.01	-0.12***
C4.	Soil holds on to water/prevents drought	0.86	0.82	0.66	0.04**	0.20***	0.16***
C5.	Soil erosion has increased due to climate change	0.11	0.18	0.10	-0.07***	0.01	0.09***
C6.	Fertilizer may harm the soil and environment	0.50	0.34	0.39	0.16***	0.11***	-0.05**
C7. (i)	How can you tell whether soil is healthy? Presence of soil animals	0.09	0.41	0.36	-0.32***	-0.27***	0.05**
C7. (ii)	How can you tell whether soil is healthy? Colour	0.28	0.30	0.26	-0.01	0.02	0.04*

Note: $p < 0.1$ *, $p < 0.05$ **, $p < 0.01$ ***

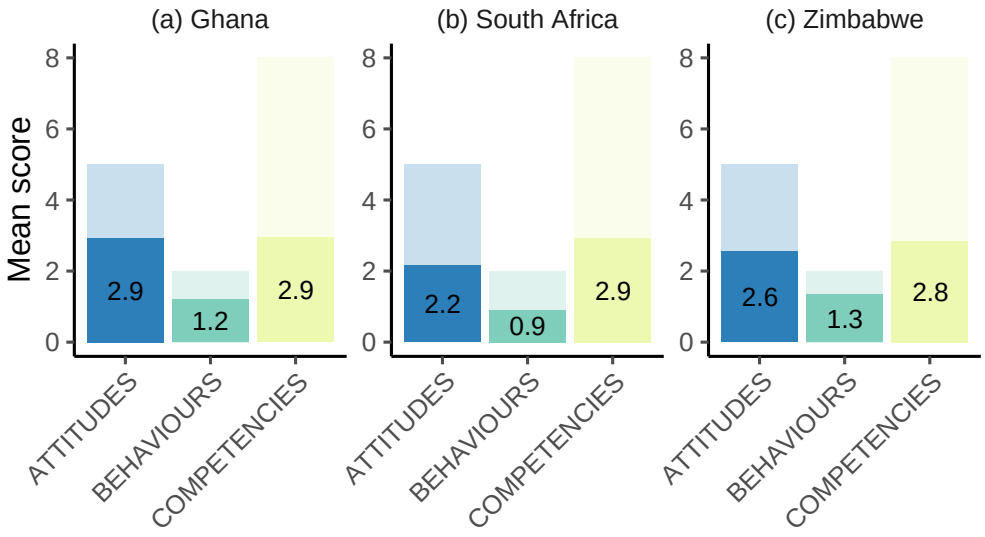
Table 5: Question difficulty estimates

	Item		Category	Difficulty estimate	95% confidence interval	
					Lower limit	Upper limit
Easier	C4.	Soil holds on to water/prevents drought	Competency	-2.60	-2.80	-2.40
	A5.	A healthy soil can improve the wealth/economy of the country	Attitude	-1.93	-2.10	-1.76
	B1.	In the last 12 months, have you planted or grown anything at your homestead or farm?	Behaviour	-1.53	-1.69	-1.38
	A4.	Working with soils/agriculture is for the less educated (inverted scale)	Attitude	-0.97	-1.11	-0.83
	C5.	Soil erosion has increased due to climate change	Competency	-0.16	-0.29	-0.04
	B2.	If planted on farm or homestead, did you add compost or manure to the soil?	Behaviour	0.25	0.13	0.38
	A2.	Soil is medicinal and has healing properties	Attitude	0.27	0.14	0.40
	C6.	Fertilizer may harm the soil and environment	Competency	0.54	0.41	0.67
	C2.	Soil is a living thing	Competency	1.42	1.27	1.57
	A3.	Soil is dirty (inverted scale)	Attitude	1.60	1.45	1.76
	C7. (ii)	How can you tell whether soil is healthy? Colour	Competency	1.79	1.63	1.96
	C7. (i)	How can you tell whether soil is healthy? Presence of soil animals	Competency	2.17	1.99	2.35
	C3.	Soil is a possible pollutant of dams and rivers	Competency	2.70	2.50	2.91
	C1.	Why is soil important? Reducing climate change	Competency	3.70	3.44	3.96
More difficult						

AGGREGATE SCORES FOR SOIL ATTITUDES, BEHAVIOURS AND COMPETENCIES

Figure 14 reports the country-level ABC scores, computed as the averages of the individual soil literacy scores across soil attitudes, behaviours and competencies. The actual country level scores are indicated by the solid bars, where the numbers report the actual scores achieved, while the transparent bars show the maximum possible ABC score in the respective dimension.

Figure 14: ABC scores



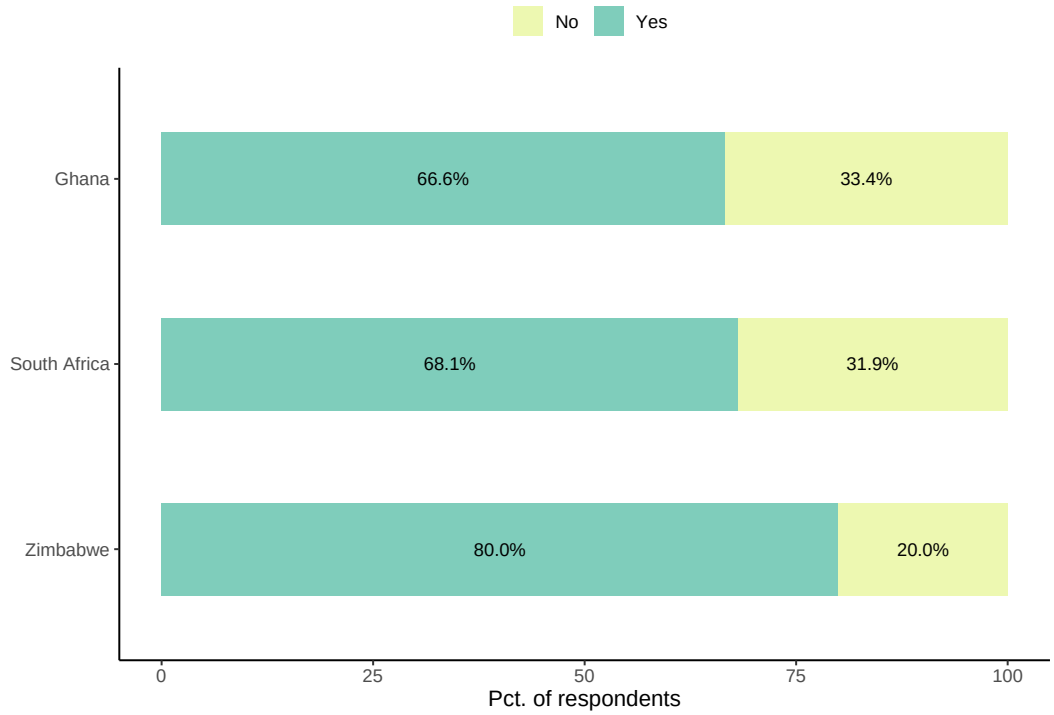
Two key observations emerge. First, Ghana, South Africa and Zimbabwe all exhibit similar soil literacy levels across all dimensions. Second, as the differences between the solid and transparent bars indicate, the greatest gap between actual and maximum soil literacy can be seen for soil competencies: soil competencies are around 11%-16% of the maximum score. The numbers are slightly more encouraging for soil attitudes and behaviours, for which the actual scores expressed as a fraction of the maximum vary approximately between one-third and one-half.

VI. INFORMATION SOURCES OF SOIL CARE

Receiving information by others about soil care can be a powerful motivator to engage in environmentally conscious behaviours. Aside from the actual information conveyed, the act of communicating information on soil care can be indicative of the formation of peer effects, where other behaviours affect individual behaviour through the existence of social preferences. For example, if neighbours engage in good soil care, members of the own household can derive more satisfaction from looking after soil properly themselves.

Figure 15 shows the responses to question B4, reporting the proportions of individuals indicating that they were told they ought to take care of soil. The proportion answering "Yes" equals two-thirds in Ghana (66.6%) and South Africa (68.1%), and four-fifth (80%) in Zimbabwe.

Figure 15: (B4) Did anyone tell you that you should take care of soil?



The large proportions of individuals that report having received advice that soil ought to be taken care of is surprising in light of the low levels of soil literacy uncovered in the preceding sections. This suggests that respondents fail to internalise the soil care information received or that the sources from which they receive information about soil care either do not follow up on their directive with specific information on how to nurture soil health or were unsuccessful in acquiring comprehensive soil literacy themselves. Though the questionnaire does not capture at what point information transmission is impeded, it does elicit from which sources respondents received information.

Figure 16: Information sources of soil care

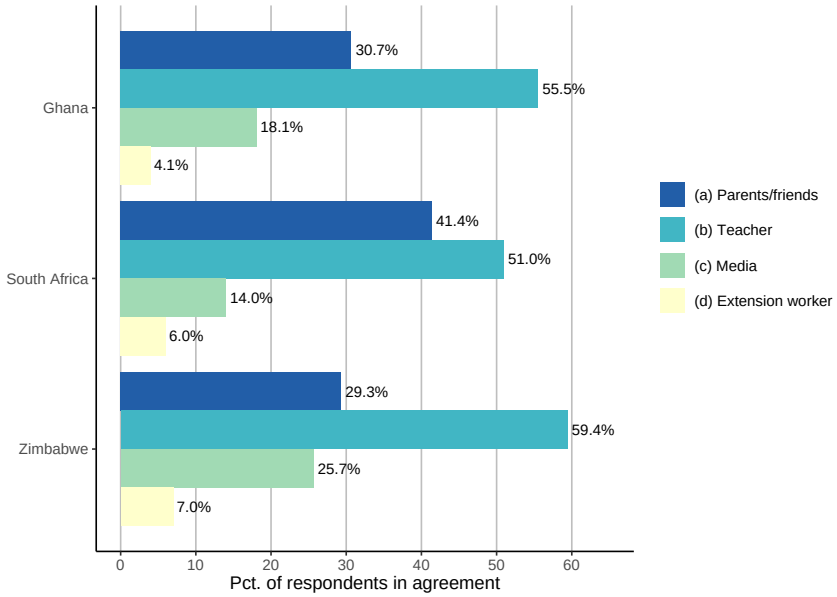


Figure 16 reports the distribution of the reported sources from which respondents received information about soil care. The answer distributions appear stable across countries: teachers are the information source cited most frequently by respondents, with proportions greater than one-half in each country (55.9% in Ghana, 51.0% in South Africa and 59.4% in Zimbabwe). The second most frequently cited source is parents, chosen by roughly one-thirds of respondents (30.7%, 41.4% and 29.3% followed by around one-thirds. The third source most cited is media (18.1%, 14.0% and 25.7%), while with negligible proportions fall towards extension workers (4.1%, 6.0% and 7.0%).

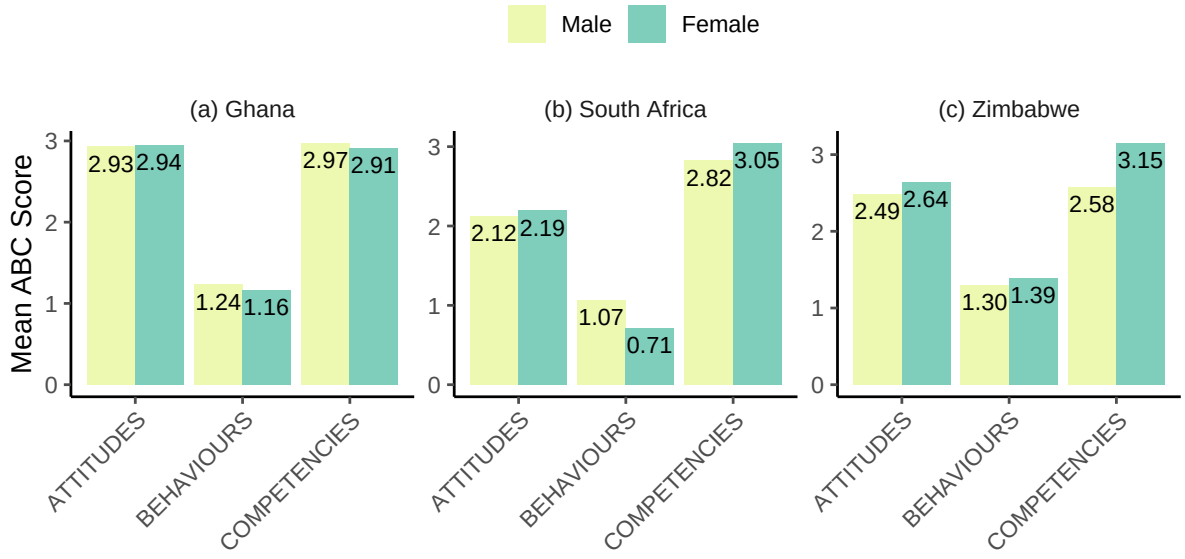
These figures suggest the natural place for interventions to be most effective is in the educational curriculum in order to raise soil literacy levels. Given that the majority of respondents is aware that soil care information is likely to be imparted in this environment, measures that increase the efficient information dissemination and quality of information can, in the first instance, utilise these established channels of knowledge transfer.

VII. Soil Literacy and Gender

Gender is an important dimension in socioeconomic analyses and of great importance in the global policy agenda, arguably underpinning all 17 United Nation Sustainable Development Goals (SDGs) (United Nations, 2020), but being specifically represented by SDG 5 (United Nations: Department of Economic and Social Affairs, 2020). Prior literature documents substantial gender difference with regards to subsistence farming; accordingly, splitting country-level ABC scores by gender can be informative of differences in soil-related attitudes, behaviours and competencies across men and women.

Accordingly, Figure 17 reports the country-level A, B and C scores by the gender identification of the respondent.[1] In Ghana there appears to be little difference in soil literacy between men and women, though men score marginally higher in the dimensions of behaviours and competencies. Their attitudinal scores are approximately equivalent. In South Africa men score higher than women with respect to soil behaviours, while women score more highly across attitudes and competencies. In Zimbabwe women score more highly than men across all dimensions of soil literacy. The differences in scores for attitudes and behaviours are small albeit notable, while the difference in soil competencies is striking: females' soil competencies are 22% higher than those of males.

Figure 17: ABC scores split by gender



To facilitate understanding which specific questions drive the differences in soil literacy across men and women, Table 6 reports the averages for the questions underlying the scores for each gender, together with differences-in-means estimates and their statistical significance. Estimates are reported for each country in the indicated columns.

Table 6 indicates that no clear gender differences in soil literacy manifest in Ghana and South Africa, while in Zimbabwe women's soil literacy appears to be statistically greater than men's in the majority of questions. Of particular interest is whether gender differences exist in awareness of the vicious cycle between eroding soil health and climate change. With respect to the question on soil health and climate change – captured by the question of importance of soil for reducing climate change (C1) –, in Ghana women show slightly greater awareness than men do; whereas for South Africa and Zimbabwe the differences across gender are not

[1] In its current form, the questionnaire does not make an accommodation for non-binary gender identities; however, future work can explore the impact of gender stereotypes on engagement with agriculture and acquisition of soil literacy.

statistically significant. Regarding the question on climate change causing soil erosion – captured by the question eliciting whether soil erosion has increased due to climate change (C5) – statistically indistinguishable gender differences emerge in Ghana and South Africa, while women in Zimbabwe are significantly more likely to be aware of this relation.

Overall, this evidence indicates that while gender differences in different constituent parts of soil literacy exist, raising awareness of and breaking the link between climate change and soil erosion is an effort that transcends the boundaries of gender.

Table 6: Question summary statistics split by gender

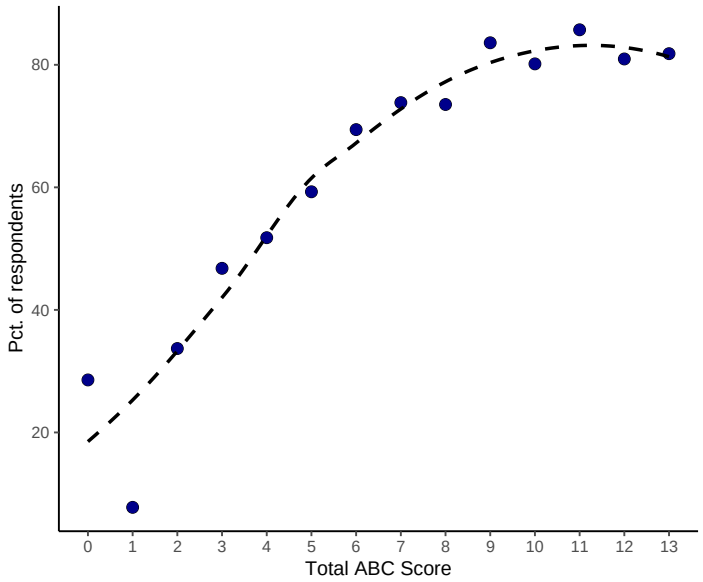
	Ghana			South Africa			Zimbabwe		
Item	M	F	Difference	M	F	Difference	M	F	Difference
A1. Rate the subject/topic of soils	0.70	0.73	-0.03	0.44	0.49	-0.05	0.55	0.69	-0.14
A2. Soil is medicinal and has healing properties	0.25	0.21	0.03	0.10	0.12	-0.02	0.18	0.26	-0.08
A3. Soil is dirty (inverted scale)	0.46	0.44	0.02	0.45	0.27	0.18	0.57	0.64	-0.06***
A4. Working with soils/agriculture is for the less educated (inverted scale)	0.77	0.72	0.05	0.62	0.45	0.17	0.72	0.76	-0.03***
A5. A healthy soil can improve the wealth/economy of the country	0.80	0.81	-0.01	0.64	0.61	0.03	0.65	0.76	-0.11***
B1. In the last 12 months, have you planted or grown anything at your homestead or farm?	0.68	0.65	0.03**	0.31	0.31	0.00***	0.43	0.43	0.00
B2. If planted on farm or homestead, did you add compost or manure to the soil?	0.13	0.09	0.04	0.19	0.17	0.02***	0.09	0.10	-0.02*
C1. Why is soil important? Reducing climate change	0.17	0.18	-0.01**	0.36	0.38	-0.02	0.54	0.44	0.10
C2. Soil is a living thing	0.58	0.58	0.00	0.38	0.41	-0.02**	0.32	0.32	0.00**
C3. Soil is a possible pollutant of dams and rivers	0.85	0.86	-0.02*	0.78	0.86	-0.08	0.61	0.70	-0.09***
C4. Soil holds on to water/prevents drought	0.58	0.55	0.03	0.40	0.45	-0.05***	0.46	0.62	-0.15**
C5. Soil erosion has increased due to climate change	0.48	0.52	-0.04	0.30	0.40	-0.10	0.36	0.43	-0.07***
C6. Fertilizer may harm the soil and environment	0.09	0.09	0.00	0.44	0.38	0.06***	0.37	0.36	0.01**
C7. (i) How can you tell whether soil is healthy? Presence of soil animals	0.29	0.28	0.01	0.32	0.28	0.04*	0.22	0.31	-0.09
C7. (ii) How can you tell whether soil is healthy? Colour	0.31	0.31	0.00	0.31	0.39	-0.08	0.28	0.37	-0.08***

Note: p < 0.1 *, p < 0.05 **, p < 0.01 ***

VIII. SOIL LITERACY AND OCCUPATIONAL CHOICE

Soil literacy may have a direct effect on individual considerations to seek out employment in agricultural professions. One way by which soil literacy could influence occupational choices is that by engaging with soils individuals may acquire specific negative or positive information about what it means to be a farmer.

Figure 18: Farming is an occupation with good financial returns



Earnings play an important element in most employment decision. Accordingly, this section investigates the proportion of individuals that strongly agree or agree with the statement "Farming is a good way to make money" given the different levels of soil literacy. For simplicity of presentation, we create a total ABC score for each respondent, derived by summing up the individual soil attitudes, behaviour and competency scores. Using these total ABC scores, Figure 18 reports the proportions of respondents holding the view that farming is a good way to make money. Strikingly, the figure reveals a strong positive relation between soil literacy and the view that farming is as an occupation with attractive earnings.

These results hold promise for policymakers hoping to increase employment rates in agricultural profession: implementing efforts to increase soil literacy may lead to more favourable views towards the economic incentives of working with soil and agriculture, thereby leading to more individuals engaging in such professions.

IX. POLICY IMPLICATIONS

This report provides three key implications for public policy seeking to achieve the United Nation's 2030 Sustainable Development Goals by promoting and sustaining soil health. Specifically, education-related strategies are set out that facilitate the increase in population-wide soil literacy levels to leverage soil as a powerful mean of combating climate change and thereby mitigating its effects.

First, as the greatest lack in soil literacy is found with respect to soil competencies that can be taught in a classroom setting, measures to increase soil literacy can use countries' existing educational infrastructures to leverage established channels of knowledge transfer, such as schools and universities. This approach has the great advantage of not requiring separate informational campaigns, outside of the educational system, to raise awareness of soil and how it fits into the environmental cycle. By virtue of leveraging these existing educational structures, cost-efficiency can be achieved.

Second, as respondents show good understanding of some areas of how soil interacts with the natural environment but not others, the functions of soil and consequences of good soil health should be integrated in comprehensive ways into education curricula from school throughout university. In this way, fragmentation of knowledge can be avoided, and a comprehensive knowledge of soil established. This is particular important in light of the report's findings that only 13% of respondents are aware of the impact of soil health on climate change. The complex environmental interlinkages require a holistic approach to soil and water education informed by practitioners and academics in the field of soil science.

Third, as soil attitudes vary by country, policymakers should shy away from one-size-fits-all approaches and obtain empirical evidence on their own country's particular affinities towards soil. For instance, in a country such as Ghana in which the majority holds positive views towards soil, the focus challenge would be to sustain these positive attitudes towards soils while creating excitement towards soil for those individuals negative (or neutral) views. In countries like South Africa and Zimbabwe, the challenge takes the form of convincing the greatest groups of respondents that hold neutral or negative views that soil is indeed a subject to enjoyably engage with. In these countries, great opportunity lies with respondents that are undecided in their soil preferences as raising awareness of the subject of soils can increase more favourable views towards it. In light of these varying attitudes, bespoke policies are likely to maximise their likelihood of success.

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ANNEX 1: QUESTIONS FOR TOTAL ABC SCALE CONSTRUCTION

ID	Text	Possible responses	Transformation
A1	Rate the subject/topic of soils	5-point Likert scale [favourite, enjoyable, neutral, dislike, worst, I do not know]	=1 if favourite or enjoyable, =0 otherwise
A2	Soil is medicinal and has healing properties	True/False	=1 if True, =0 otherwise
A3	Soil is dirty	True/False	=1 if False, =0 otherwise
A4	Working with soils/agriculture is for the less educated	5-point Likert scale [strongly agree, agree, neutral, disagree, strongly disagree, I do not know]	=1 if strongly disagree or disagree, =0 otherwise
A5	A healthy soil can improve the wealth/economy of the country	5-point Likert scale [strongly agree, agree, neutral, disagree, to strongly disagree, I do not know]	=1 if strongly agree or agree, =0 otherwise
B1	In the last 12 months, have you planted or grown anything at your homestead or farm?	Yes/No	=1 if Yes, =0 otherwise
B2	If YES [answer to B2]: Did you add compost or manure to the soil?	Yes/No	=1 if Yes, =0 otherwise
C1	Why is soil important? Reducing climate change	Multiple choice [plant growth, reducing climate change, building, habitat for insects/organisms, water filtration, I do not know]	=1 if reducing climate change, =0 otherwise
C2	Soil is a living thing	True/False	=1 if True, =0 otherwise
C3	Tick all the possible pollutants of dams and rivers: soil	True/False	=1 if True, =0 otherwise
C4	Soil holds on to water in the ground and can help reduce drought	True/False	=1 if True, =0 otherwise
C5	Soil erosion has increased due to climate change	5-point Likert scale [strongly agree, agree, neutral, disagree, strongly disagree, I do not know]	=1 if strongly agree or agree, =0 otherwise
C6	Fertilizer may harm the soil and environment	5-point Likert scale [strongly agree, agree, neutral, disagree, strongly disagree, I do not know]	=1 if strongly agree or agree, =0 otherwise
C7 (i)	How can you tell whether soil is healthy? Presence of soil animals	Multiple choice [colour, taste, presence of soil animals, none of these, I do not know]	=1 if presence of soil animals, =0 otherwise
C7 (ii)	How can you tell whether soil is healthy? Colour	Multiple choice [colour, taste, presence of soil animals, none of these, I do not know]	=1 if colour, =0 otherwise

ANNEX 2: SHORT PRIMER ON ITEM RESPONSE THEORY (IRT)

The idea underlying the Item Response Theory approach is to model the latent soil literacy of each respondent while accounting for question difficulty. This is achieved by jointly estimating the probability to answer each question correctly, together with the respondents' abilities (z_j) and the question's difficulty (b_i).

For each respondent j, the probability to answer question i correctly is given by

$$P(Y_{i,j} = 1 | z_j) = \frac{exp\{a(z_j - b_i)\}}{1 + exp\{a(z_j - b_i)\}}$$

where a is a discrimination parameter. The latent respondent abilities are modelled as a standard normal distribution, $z_j \sim N(0,1)$, for all j. Estimation is achieved using Maximum Likelihood. This study considers 3,661 respondent answer choices to the fourteen question of Annex 1 as a basis for estimation.

Through the latent soil literacy levels of the respondents, the IRT approach has similarities to factor or principal component analyses. Implicit in this approach is that there is a common driver of the respondents' answer choices, and that this factor can be mapped to the concept of soil literacy.

The questions' difficulty parameters have two key interpretations. First, respondents with ability levels equal to a specific question's difficulty, $z_j = b_i$, achieve a 50% probability of answering this question correctly. Put differently, at ability levels corresponding to the question difficulty, providing an educated guess yields a random chance of obtaining the correct response. Second, given that respondent abilities are modelled as a standard normal distribution, the question difficulties can be interpreted as percentiles of a standard normal distribution. From this follows that computing $\Phi(b_i)$, where the function $\Phi(.)$ equals the standard cumulative distribution function, yields the expected proportion of individuals to answer the question incorrectly. Alternatively, $1 - \Phi(b_i)$ is the fraction of respondents to provide the correct answer.