Soil health decision support for NERC digital soil platforms: A survey report

*Yvonne Tamba, Caroline Muchiri, Keith Shepherd,
Eike Luedeling, David Robinson*

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List of abbreviations

AfSIS	African Soil Information Service
APVC	Agricultural Product Value Addition Chains
ASHC	African Soil Health Consortium
CGIAR	Consultative Group on International Agricultural Research
CIAT	International Centre for Tropical Agriculture
GIS	Geographic Information System
ICRAF	World Agroforestry Centre
ICRISAT	International Crop Research Institute for the Semi-Arid Tropics
IK	Indigenous knowledge
IPNI	International Plant Nutrition Institute
ISFM	Integrated Soil Fertility Management
KALRO	Kenya Agricultural and Livestock Research Organization
KSS	Kenya Soil Survey
MIAD	Mwea Irrigation Agricultural Development Centre
NARL	National Agricultural Research Laboratories
NERC	Natural Environmental Research Council
NGO	Non-governmental Organization
NRM	Natural Resource Management
SA	Smart Agriculture
SDG	Sustainable Development Goals
SSSEA	Soil Science Society of East Africa
TIMPS	Technology, Innovation and Management Practices
UK	United Kingdom
USSD	Unstructured Supplementary Service Data
ZEF	Center for Development Research

Abstract

This working paper describes the results of a survey done on soil data availability and use in the agricultural sector in Kenya. The survey was commissioned by the National Environment Research Council (NERC) to assess the potential value of NERC digital tools such as the MySoil app, to decision makers in the region. The objectives of the survey were therefore to highlight the decision needs related to sustainable agricultural intensification that would be met through greater accessibility to soil information, identify the critical uncertainties surrounding those decisions and identify the potential information that could be provided by a digital app such as the MySoil app for Africa. Those surveyed were selected from research and academia, government, private sector, agricultural extension, community work and farmer groups. The survey was conducted through an online questionnaire on SurveyMonkey. The results showed that the greatest information need that could be met through a digital application was site- and crop-specific input recommendations while the biggest consideration when developing such a tool needs to be given to figuring out how to communicate effectively with end users. The report also recommends a horizontal approach to the development of the app. This would allow for contributions based on farmers' indigenous knowledge.

Key words: MySoil, digital tools, soil information, decision needs, decision makers

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Background

Ecological and agronomic scientists have increasingly acknowledged the role that soils play in the sustainable management of ecosystem services for benefits such as food production, climate change regulation and management of land degradation.¹ The result of this has been an increase in demand for soils data all along the agricultural value chain, from the research fraternity producing the data to farmers who are end users of the information.

With the increase in demand comes the opportunity to develop technologies that will deliver up-to-date soils information for varied uses. One such technology is MySoil, a digital application that delivers geospatial information to end users mainly through smartphones.² MySoil gives users access to soil properties information and has been used for varied purposes, from agricultural use by gardeners to planning by land use planners.³ The application is already in use in the UK and the National Environment Research Council (NERC) are looking to scale it outwards so as to deliver the same functionalities to African decision makers. However, to do so successfully would require an understanding of the decision-making environment peculiar to the African continent.

The aim of the survey was to uncover crucial details about the types of decisions made in the agricultural sector and the soils information that would prove useful in making the right decisions. The specific objectives were to:

1. Establish the alignment between major decisions for which stakeholders need soil information related to sustainable agricultural intensification.
2. Identify critical uncertainties pertaining to those decisions.
3. Identify potential information that could be provided for African agricultural stakeholders via the MySoil app.

To achieve these objectives, ICRAF carried out a survey of stakeholders in the agricultural sector, that is, research scientists and academia, government officials, actors in the private sector, extensions agents, community workers and farmer representatives.

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¹ Sanchez P, Ahamed S, Carre F, Hartemink A, Hempel J, Huising J. et al. 2009. Digital Soil Map of the World. *Science*, 325(5941), 680-681.
<http://dx.doi.org/10.1126/science.1175084>

² Westhead, R.K.1 , Smith.M.1 , Shelley, W.A. 2, Pedley, R.C. 2 , Ford, J2 . & Napier, B2. (2013). Mobile Spatial Mapping and Augmented Reality Applications for Environmental Geoscience. *Journal of Internet Technology and Secured Transaction*, 2(3/4), 185-190.
<http://dx.doi.org/10.20533/jitst.2046.3723.2013.0024>

³ <mailto:www-bgs@bgs.ac.uk>, B. (2017). mySoil App | British Geological Survey (BGS). Bgs.ac.uk. Retrieved 26 July 2017, from <http://www.bgs.ac.uk/mysoil/home.html>

Methodology

Survey population

The survey was carried out among five different stakeholder groups that is, farmer representatives, farm extension agents and community workers, private sector, government officials and the research and academia sector. Selection of prospective participants was targeted with contacts being sourced from ICRAF's partner databases and websites of agricultural organizations. To widen the pool of invited participants, respondents were asked to name a few of their contacts in the relevant stakeholder groups who would be interested in participating in the survey. For purpose of analysis, the survey questions posed to each group were exactly the same with the intention of expounding on group specific responses at a second follow-up interview stage.

Survey method

The survey was developed online on the SurveyMonkey® website and an invitation sent to prospective participants through the same website. The initial contact list had 150 participants with additional participants contacted following recommendations by the survey's respondents. The survey (Appendix B) comprised 18 questions in one page and was designed to collect contact information, job group, role and objectives of the work carried out before sourcing for soil-related information banking on the experiences of the individuals. The survey was pre-tested on a small sample of stakeholders and improved to address feedback received. Reminder email requests were also sent to respondents and phone calls made to a number to invite them to the survey once the SurveyMonkey® email invitation failed to gather an acceptable number of responses.

Results and analysis

An initial email inviting participants to respond to the survey was sent to 151 invitees. Of the 151 invitations, 70 opened the email (46.4%), 38 of the 70 clicked through the survey (25.2%) and of the 38, 15 completed the questionnaire. In the invitation to the questionnaire, respondents were asked to supply additional participants from their own contacts list who were involved in agriculture and who could be contacted and invited to participate in the survey as well. These participants were also contacted via the same email from SurveyMonkey.com. To increase the response rate, some respondents were contacted directly and offers were made to conduct interviews either through the telephone or a direct face-to-face interview. Nearly all declined to be interviewed, in the interest of time and due to their busy schedules, choosing instead to fill the online questionnaire. A link to the survey was created as an additional collector of responses and sent out to these invitees who were contacted by phone. Out of these, 13 responses were collected. In total, 28 responses were collected for the survey.

Figure 1: Categorization of stakeholder groups

Figure 1 shows the total responses received and the stakeholder groups the respondents belonged to. Of the 28 participants, two did not describe themselves as fitting into any of the stakeholder roles. One of the two worked on a national programme and was grouped with the government while the second, working on a programme supported by a bilateral donor on technological development, verification and dissemination of technologies, was grouped with researchers.

Stakeholder objectives

Analysis of the responses to the question on stakeholder objectives revealed three main themes: knowledge, productivity and management. The most frequent words occurring under these themes are presented in [Table 1](#). Knowledge encompassed the development and generation of technologies and innovations, access by farmers to these technologies and capacity building of farmers by providing access to knowledge products. The combined word count of dissemination, development and research (words used to refer to the development and generation of technologies) was 17. Productivity covered the use of technologies and knowledge products to increase the productivity of farms, issues of food security and safety as well as profitability of farms. Productivity had a word count of 15 while food security occurred 6 times. Profitability, which included the use of both income and profitability had a count of 6. The third theme of management covered the responses that touched on the sustainability of farm management practices, the improvement of soil health and the use of technologies such as integrated soil fertility management (ISFM) innovation intended to conserve soil, water and land resources. Sustainability topped the list of management themed texts with a word count of 8.

Table 1: Results of text frequency analysis of question on the objectives of stakeholders

Theme	Key word	Word count
Knowledge	Dissemination	7
	Development	6
	Research	4
	Access	4
	Capacity building	3
	Awareness	2
Productivity		
	Productivity	15
	Food security	6
	Income	4
	Profitability	2
Management		
	Sustainability	8
	Management	7
	Soil health	4

Words commonly used were grouped under themes to represent the context of their occurrences

While these are the main areas that emerged from the responses, a breakdown of the responses based on the specific stakeholder groups is necessary to understand the individual motivations of each group.

Farmer representative groups included farmers' associations and group leaders. The respondents' answers to their main objectives touched on increasing membership of their organizations, capacity building through creation of awareness of farm management practices as well as ensuring access to both resources and appropriate technologies.

Extension agents often function as the connection between the different stakeholders but particularly between farmers and the agricultural products and technologies produced in both

the public and private sectors. There was therefore a capacity building element to the responses from this group. The objectives of the group are to equip farmers with modern farm management skills and to build the capacity of farmers to commercialize their farm products. They also work to improve access to technology and innovations to do with Integrated Soil Fertility Management (ISFM) approaches.

The motivations of the private sector actors were business-oriented (profitability) as well as socially-oriented (environmental protection, sustainability and creating awareness on soil fertility management products). For government stakeholders, the objectives were aligned with achieving SDGs such as improving food security and providing support to farmers through providing access to inputs and farm management options (e.g. integrated pest management options).

For the research and academia fraternity, the goals of their participation were to generate and distribute agricultural technologies that would be solutions to the current and future food security and safety issues. Their contribution to farmers is therefore to enhance the capacities of farmers so as to increase their productivity by producing science based facts. This is not to mean that the group does not give farmers a chance to participate in the development of products for their use as evidenced by the response of one respondent:

“Use of citizen science in soil and water management”

Stakeholder decision problems

On the main decisions that have to be made by the different stakeholder groups based on the objectives identified, out of the 28 respondents, one person chose not to respond to the query.

On the theme of knowledge, the main decisions were around adoption of the knowledge products and how to scale up and scale out their use among farmers. Another major decision problem is on how to train farmers in the use and application of technologies and innovations. In relation to that, another problem faced by decision makers is how best to communicate these technologies to the end users of the products. Other than these was the issue of how to prioritize investments among the available technologies for optimized outcomes.

Allocative efficiency came up as a decision question under the management theme as well, that is, how to invest limited resources so as to achieve production objectives and how to optimize supply chain investments. Additional decision problems that affects the management-themed objectives are to do with identifying the knowledge gaps in available knowledge and answering the question of how to maintain soil quality for sustainability of environmental resources.

The productivity objective faces decision problems particularly surrounding market uncertainties. These include questions on the costs of innovative technologies and products, their availability in the market and how to deal with the presence of counterfeit goods that undermine the successful dissemination of appropriate technologies. Beyond uncertain markets there was also the question of how to inform farmer input choices despite variability in biophysical and socioeconomic conditions. As an illustration, the decision of how to achieve

balanced fertilizer recommendations needs to be based on varied soil types and agro-ecological zones. As per the comment of one respondent that described the decision problem:

“Can farmers use one type of fertilizer on a range of different soils?”

To achieve their objectives, the farmer representatives are confronted with a number of issues, such as:

1. How to improve farm productivity
2. How to create a platform to create awareness on the importance of soil testing
3. How to carry out training for farmers
4. How to ensure sustainability of the farmer organizations
5. How to achieve access to resources and markets

The decision questions that follow the extension agents' objectives are to do with:

1. Input recommendations and the scaling-up of evidence based agricultural technologies
2. Providing linkages in the agricultural sector between farmers and other actors such as agro-input suppliers
3. How to provide farmers with necessary information
4. How to carry out proper recommendations based on specific farm properties.

To achieve their objectives, the private sector's main decision questions revolved around production:

1. How to produce more with limited resources (allocative efficiency)
2. Optimization of supply chain structure
3. Marketing – how to market effectively to smallholder farmers
4. Pricing – how to price products for smallholder farmers

For the government, the objectives were aligned with achieving the second SDG of Zero Hunger. The decision questions that accompanied these objectives were on the type of fertilizers required by farmers based on the identified agro-ecological zones as well as the best application methods for these fertilizers that would increase productivity.

The main decisions faced by the research fraternity connected to their objectives were in determining gaps in agricultural productivity and how to efficiently develop and disseminate appropriate technologies, innovations and management practices as solutions to the gaps. Related to this is the decision problem of how to effectively build the capacity of farmers and how to effectively communicate complex issues and the science of agricultural productivity to farmers.

Soil information

The question on soil information had a 100% response rate. Text analysis reveals four main sources of information, literature, internet sources, soil surveys and soil testing labs. Second-hand data sources as well as the products of research appeared to be the most frequent source of soil data with a combined count of 11. Labs were the second most frequently named source with a count of 7 ([Table 2](#)). The information sourced from these were often on soil

fertility and soil properties data as well as information on crop suitability and crop nutrition. Soil fertility appeared 5 times in the responses while soil properties appeared 4 times ([Table 3](#)).

Table 2: Frequency analysis of words used to describe the source of soil data used by respondents

Sources		Word count
Labs		7
Surveys		6
Literature	Research	4
	Literature	4
	Reports	3
Internet		3

Table 3: Common words used by respondents to describe the type of soil information commonly used by stakeholders in agriculture

Soil information	Word count
Fertility	5
Soil properties	4
Soil quality	4
Maps	2
Crop nutrition	2
Crop suitability	2
Nutrients	1

The source of soil information currently used by farmer groups are the internet and available technologies currently in the market such as a soil scanner provided by Soil Cares. From these sources, this group is able to know about the quality of soils as well as the cost of soil testing

The frontline extension agents utilize information on soil fertility levels from soil tests usually made available to them from either the private sector or public institutions. An additional source is surveys that establish the soil management approaches used by farmers for deteriorated soils as well as information on type of fertilizers used. They also use literature in the form of soil data reports from the Kenya Agricultural and Livestock Research Organization (KALRO) and farm inputs data usage records from the Ministry of agriculture

The private sector sources for data from institutions such as KALRO and commercial soil labs such as Crop Nutrition Laboratory Service (Cropnuts) in addition to government data and soil maps to obtain information on crop nutrition and crop suitability.

The research and academia group had access to the most sophisticated soil information from reliable sources such as the Africa Soil Information Service (AfSIS), the African Soil Health Consortium (ASHC), the Soil Science Society of East Africa (SSSEA) and subject matter specialists in soil science. This group used these networks to access specific soil information such as:

1. The impact of climate change on soil properties.
2. Information on Integrated soil fertility management from the Kenya Soil Health Consortium.
3. Soil physical properties from soil physics labs and field evaluations
4. Soil-moisture water holding capacity data
5. Soil fertility data
6. Soil characteristics and land topography

Soil data gaps

On soil data gaps, the main themes that emerged were input recommendations, access to data sources and management. Of the 28 respondents, 27 responded to the question. Fertilizer recommendations topped the text frequency list with 11 counts while soil nutrients, occurring 11 times, emerged as the soil data that was the most valuable ([Table 4](#)).

The theme of input recommendations highlighted the lack of information on fertilizer recommendations that took into consideration the type of crops and the type of soils and soil nutritional content. Of concern also is the recommended rate of fertilizer use and the soils' fertilizer requirements based on its physical and chemical properties. Another gap in soil information related to this theme is the productive potential of soils compared with the current productivity of the soils. These are important information to achieving food security and increased productivity objectives. They answer or guide decision problems of input choice.

Access covers both physical and financial access, particularly soil testing facilities. It addresses the decision problem of allocative efficiency and how to make investments in soil technologies. Respondents noted an absence of open source data repositories which would improve access to knowledge products at lower costs while also reducing the prevalence of uncertainties in markets.

The theme of management is considered from the perspective of missing soil information that details farming practices already used to maintain soil fertility vis-a-vis modern innovation in soil fertility management. This information is crucial to achieving the objective of sustainability and environmental protection.

Table 4: Text frequency analysis on information that was perceived as having the most value in improving farmers' decisions

Theme	Word	Count
Recommendations	Fertilizer/fertility	11
	Production	4
	Requirement	2
	Application	1
	Use	1
Soil	Nutrients	11
	pH	3
	Organic carbon	1
	Quality	1
	Nutrition	1

Theme	Word	Count
Access	Location	1
	Cost	2
Management	Management	2
	Sustainability	1

The gaps in soil information used by farmer group representatives include how to maintain and improve soil quality, inherent soil nutrient levels and soil structure for different geographies. This soil information would be useful in determining sustainable soil use and environmental protection, targeted fertilizer and agronomy recommendations. Soil maps would help in learning of extension officers as a visual tool

Frontline extension agents responding to the survey highlighted soil maps as being a key soil gap. The soil maps would be used to able to provide site-specific soil information such as soil pH to be used to recommend fertilizers and soil-appropriate technologies such as liming. High resolution maps would be used to advise farmers on spacing and understand plant nutritional value. On fertilizer use, soil information that would detail appropriate use of fertilizers in terms of application rates as well as the location of agro-input suppliers for easy access by farmers is missing. Other soil information gaps highlighted by this group are soil bacterial analysis reports which would be used to focus plant monitoring mechanisms.

The government respondents indicated nutrient deficiencies. Soil pH values and soil nutrient levels which would be useful in providing suitable fertilizers and the nutrient compositions required for each agro-ecological zones. The decisions highlighted in text analysis are decisions on soil management and soil investment.

For the private sector the soil gaps highlighted were in recommendations that would maintain soil quality and improve soil fertility keeping in mind the objective of environmental sustainability. Information on soil nutrient levels and soil structure would be used by private sector actors to make decisions on fertilizer and agronomy recommendations. For the purpose of weighing the costs, returns and risks of soil investments, the private sector requires crop-specific soil information to balance between the costs of soil nutrient correction, the level of improved yields to be expected and the risks involved. Similar to the farmer extension groups, the problem of soil maps arose. To the private sector, soil maps could be used by extension agents to visualize soil problems and set a path toward correcting them. Soil maps would also be used by the manufacturing sector to provide information on balanced fertilizer use, showing the need and therefore demand of specific fertilizers which manufacturers can then use to inform production decisions.

For government linked resource persons, soil information gaps arose in specific soil information, i.e., soil acidity and nutrient deficiency which can be used in fertilizer recommendations and zone-specific nutrient requirements, respectively.

The research group of respondents identified soil information gaps in best-bet Technology, Innovation and Management Practices (TIMPS), appropriate pathways for the dissemination of these practices and in capacity building resources. The group also highlighted traditional knowledge on soil management as a missing link as well as information on current soil nutrient

status. Traditional knowledge is deemed important for its ease of use for end users who are already familiar with the practices. Information on other biophysical factors and how their interaction with soil affects soil properties is also not readily available as noted by one respondent who highlighted the absence of “*A continuously ‘up-datable’ database on the role of climate change on soil conditions based on emerging information*”.

Soil maps would also be a useful source of information to be used in precision application of soil-crop-water-requirements in planning and resource allocation. Also important in preventing soil and nutrient loss through erosion and nutrient flushing is site specific data on land characteristics, physical features and topography. There is a lack of information on whether soil constraints are due to physical, chemical or biological issues which is information that can be used to recommend interventions to reduce or limit soil degradation. For instance, information of soil physical changes as a result of mechanization is useful when making decisions on the farming equipment to be promoted. Soil stability is another set of important soil data as soil stability affects sustainability. Threshold values for key soil quality indicators are necessary for the decision makers to classify soils and from the classification generate spatial suitability information.

Farmers’ decisions

The survey also covered the farmer’s decision-making environment. The response rate on this question was 100%. Analysis of responses highlighted three themes in the decisions that farmers struggle with, i.e., markets, management and input choice. The market theme is an umbrella covering both the supply side and demand side market factors for the farmers. Demand side decision problems include lack of information on the market for farm produce detailing the produce demanded and their prices. Related to this, farmers are faced with decisions of whether or not to join collective bargaining groups so as to enjoy better prices for their produce and also the best time to sell so as to enjoy better prices.

Supply side decision problems are related to the farmers’ investment decisions, i.e., the value chains they should spend their limited resources on for maximum profits. Another decision problem linked to investment is limited start-up capital and lack of credit facilities to enable farmers invest in their inputs of choice. The combined word count of words referring to markets was 27. The word market itself occurred 10 times within the responses ([Table 5](#)).

The problem of investment decisions is closely related to the second theme of input choices. While the presence of money is a determinant of the inputs the farmers choose to buy, these decisions are made problematic by additional factors such as farmers’ limited knowledge on the soil fertility status and crop varieties suitability for the soil. Input choices as a theme also covers the responses highlighting that decisions on input use are affected by uncertainties on whether patterns, yield response to fertilizer (suitability of fertilizer) and suitability of crop varieties. Farm management is the other theme which can be unpacked into decisions problems around soil management, water management and crop management.

Table 5: Frequency text analysis of stakeholders' perspectives on the main decisions problems that farmers struggle with.

Theme	Word	Count
Markets	Markets	10
	Access	4
	Capital	3
	Price	3
	Investment	2
	Credit	2
	Profits	1
Input choice	Soil	15
	Crop	12
	Fertilizer	5
	Use	3
Management	Soil management	2
	Crop management	2
	Water management	2

On individual stakeholder group responses, frontline extension agents' view is that farmers' main decisions have to do with market factors, how to source for credit and start-up capital, agronomic information such as soil fertility issues and input use as well as how to remedy soil quality issues. To the private sector respondents, the results were largely the same, where the respondents cited soil fertility management, how to improve productivity, crop and input choices, use of resources and where to access resources as the major decisions. The respondents from governmental organizations highlighted the same issues of investment choices, rainfall and fertilizer application, and soil characteristics.

The research sector perceives farm management and production decisions (particularly on value addition and market information) as well as market risk factors as being the major decision problems. The farmers' management decisions revolve around soil management i.e., proper application of soil enriching nutrients, water and crop management. Another factor is soil characteristics and input choices. An additional angle to this is the decision of farm inputs vs financial capability. The lack of initial capital affects farmers' decisions on input choices and what resources to use as there are many financial commitments. Farmers are also faced with the decisions of whether or not to adopt or trust the recommendations made by different sources such as researchers and extension agents. Market factors are important to the farmer who needs to identify suitable markets, markets with highest prices and maximize profits.

Farmers' soil data needs

The problem of input choice can be solved if information on yield response to fertilizers is made available along with site and crop specific fertilizer recommendations. With information on soil fertility status and its chemical and physical characteristics, the farmers can be advised on the best planting methods to use as well as the quantities of inputs such as fertilizers.

Problems with the management of the farm's resources are informed by soil erosion prevention strategies to improve the status of soils. Additionally, the soil moisture data can inform planting times while soil microbiology can inform pest management. Market information systems guide the farmers' investment decisions. For instance, farmers can use information on available seeds to decide what crop varieties to grow.

Table 6: Text frequency analysis on respondents' perspectives on soil information that could improve farmers' decisions

Word	Count
Fertilizer	10
Crop	7
Production	7
Market	6
Soil fertility	4
Yield response	3
Soil nutrients	3

The soil information needed by farmer group representatives to improve their decision-making includes information on soil fertility, crop specific requirements compared to soil nutritional content soil quality, information on soil planning and budgeting, how to maintain soil fertility, improve soil texture and input recommendations, how to maximize output per acre and address quantity and quality of farm produce.

The frontline extension agents cite yield response to fertilizers and lime, the quality and type of fertilizers, impact of fertilizers on soil and crops and how to prevent soil erosion. The importance of this soil information is farmers would know which fertilizers to use and how to manage soil health to improve yields as well as give farmers the information necessary to maximize nutritional value through management.

For the private sector soil pH, soil nutrients and soil management information were needed by farmers so as to use it for crop specific recommendations. This information would contribute to the farmers' decisions by improving their capacity to make decisions on input choices and in the long run improve the quality of their investment decisions. The use of the soil information would therefore contribute to solving their decision problems.

Government officials cite expected production per unit area as being soil information critical to the farmer's investment decision. Beyond soil, weather patterns were also considered as vital knowledge resources for farmers' production decisions. By providing information on expected yields after soil treatment, farmers can make informed decisions about whether or not to treat their soils.

The research fraternity had varied responses to the main soil information used by farmers. The main themes that emerge from the responses, however, revolved around soil types, soil pathology, soil microbiology, soil fertility and soil physical status. An important note is that this information has to be translated into a language that farmers would understand and directly apply to their farm management practices. The main information produced from this data would be fertilizer recommendations based on the crop requirements and soil status.

Information on soil physical status should be accompanied with facts on the appropriate tools or machinery to use to protect soils from degradation. Data on soil water-holding capacity/soil moisture level would be useful to farmers once translated into useful information such as appropriate soil planting depth which would reduce losses during germination. Information on soil microbiology and pathology could be used for successful integrated pest management.

On the types of additional information (aside from soil) that would have the most value in improving farmers' decisions, respondents mentioned market information and other biophysical factors such as weather. Farmers require market information particularly on the inputs available in the market as well as their prices and the price of farm produce to help them make decisions on allocation of their resources.

Technology use in providing soil information

The response rate on technology use in providing soil information was 82%. Only five digital technologies were mentioned. The [WeFarm](#) mobile platform, the website, which offers free access to soils data globally, and the Soil Cares handheld soil scanner are mostly used by the research group to access soil information.

Table 7: Use of technologies used to access soil information by respondents

Word	Count
Web or app	3
App	2
Google maps	2
Mobile	2
No/Not yet	13

On how to deliver information on soils, SMS and phone calls were considered more suitable by smallholder farmers. For more commercialized farms, or wealthier farmers with access to internet, information could be posted on social media such as Whatsapp, or passed on using emails. Soil test results could also be delivered via email.

Table 8: Effective communication channels

Word	Count
Messaging service (SMS/Whatsapp)	7
Mobile	4
Phone call	2
Email	2
Web/Online	1
Social media	1

Insights

Major decision problems

Major decisions to be made varied depending on the stakeholder group. In summary, the objective of the agricultural stakeholders is to increase the productivity of smallholders. To achieve this, they have to solve issues around capacity building for farmers, improving access to technologies and knowledge products and inform the farm management practices of smallholders. The attainment of these goals is made difficult by multiple issues including uncertain markets, lack of guidance to farmers regarding input choices, sustainability of environmental resources, and adoption of best-bet TIMPS. The stakeholders are faced with critical uncertainties in these areas which affects their ability to make fully informed decisions while carrying out their roles. While soil data has no direct impact on market factors, it does affect input choices, and sustainable farm management. Farmers require information on the best inputs to use with their soil types as well as the practices that they can apply to maintain or improve the quality of their soils.

Critical uncertainties

To achieve their respective objectives, the stakeholders surveyed highlighted quite a few uncertainties they and the farmers they work with face. One such is market uncertainties where the end users are unaware of the cost of technologies in the market, making sensitization a key agenda for any new technologies being released. They were also uncertain about where to source soil information. While researchers have access to and knowledge of soil resources, few of the other stakeholder groups have access to practical information that can be applied to their roles. This is particularly true of farmers who would be unable to use raw data, instead requiring it to be translated into terms that are relevant on the farm. Even with recommendations, there can be uncertainty in the response of the farm land to recommended technologies. Interaction between TIMPS and the soil, i.e., the soil properties, determine the best practices but on the flip side the practices affect the soil quality, sometimes negatively, necessitating proper data on the impact of the technologies on the farm's resources. These uncertainties are costly since one wrong decision can lead to heavy losses, both in terms of farm productivity and financially.

Potential information

The information required by farmers has to be delivered in an easy-to-understand format. They should be able to translate soil data gathered into practical information such as fertilizer and crop recommendations (Table 1). An example is data on land characteristics, physical features and topography could be translated into practices that limit erosion and nutrient losses.

The research and academia group is both a resource and user of soil data. A database repository of soil information already being produced by soil scientists could be used to reduce the doubling of efforts in gathering and disseminating of soil information. This group could also use data on soil properties such as soil texture, water holding capacity and hydraulic conductivity to develop site specific ISFM strategies for on farm use.

Extension agents are tasked with relaying information on the best-bet TIMPS to farmers and therefore need both soil data and practical information to build the capacity of farmers. The challenges faced by the extension system in Kenya is lack of personnel to serve all farmers efficiently. An application that allows farmers to upload local observations of their environment, which can be used to refine recommendations on best-bet technologies, innovations or management practices could fill the gap of limited extension agent services. Of concern to extension agents is also the tools of delivering soil information to farmers. Extension officers require soil information in maps, not only to identify site-specific soil characteristics but also because they are useful as visual tools to teach farmers.

The private sector uses soil data to produce technologies for mass use. Similar to research and academia, they require soil data to facilitate mass production of recommended inputs.

Table 9: Soil information that can be delivered by digital apps and its uses

Soil information	Use (decision problem solved/objective achieved)
<i>Input recommendations</i> • Crop specific fertilizer recommendations vis a vis soil nutritional content • Type and rate of fertilizer use • Productive potential of the soil • Soil chemical and physical status	Improve productivity, farm management
• Location of agro-input suppliers • Prices of inputs • Location of soil testing facilities and cost of soil testing	Allocative efficiency Informs investments in soil improvement
• Site appropriate TIMP, ISFM practices	Sustainability of resources and environmental protection
• Open source soil data repositories	Access to knowledge products Reduced uncertainties in market
<i>High resolution soil maps</i> • Site specific soil information such as soil pH	Visual aid as a tool for communication Site specific input recommendations (see above)

Recommendations and conclusion

Given the analysis of responses from the stakeholder groups, a few considerations to be made while producing a digital application include the following:

1. For smallholders, the priority use of a digital soil service would be practical information on input recommendations. Key among these is crop suitability information and fertilizer recommendations that can be applied directly to their farms. Also of importance to the decision-making process is market information. Farmers need up-to-date information on local agro-input supplier detailing their stock, location and prices. Non-farming participants in agriculture have use for specific soil data. For the private sector, extension agents, government policy makers and researchers, data on physical and chemical soil properties is useful in achieving their objectives. Soil maps would be a useful tool to deliver spatial data on soil types, nutrient levels, soil pH values, structure, texture, porosity and other physical data. Further, spatial data on topography and land characteristics would be necessary to develop site specific soil management techniques.
2. End users require easy-to-use information that applies to their specific situation. It is essential to make sure that the information is simplified and communicated to farmers in an easy-to-understand format.
3. The format of a digital application should depend on the resources available to farmers. To make sure all farmers have access, it would be necessary to roll out a platform that is useable with varying levels of technology. While some users may have access to sophisticated smartphone technology, currently a majority of smallholders only have access to basic phones and would most benefit from USSD alerts or phone calls.
4. Coordination among various stakeholders is necessary not only as a source of data but also as a resource that would make a final product easy to understand. For instance, the research community needs to translate data into recommendations for farmers. Extension officers need to effectively communicate what is recommended to farmers.
5. Indigenous knowledge and citizen science can also be useful to achieving the goals of the application and a space needs to be made to allow for farmers themselves to make contributions.

By and large, soil information needs are driven by the productivity and profitability objectives. The end goal of all stakeholders can be summed up as maximizing their objectives, and this objective is to be more productive, whether it refers to a farmer's productivity in the growing and sale of farm produce or a private actor's productivity in producing commercially viable farm inputs. A digital application makes this possible by ensuring access to soil data and information at all levels.

Appendices

Appendix A: Invitation email to participate in the survey

We are conducting a survey that will target respondents from different stakeholder groups in the agricultural and natural resource management discipline, to establish the kinds of major decisions they require soil information for and the critical uncertainties pertaining to those decisions. Insights from the survey will assist in the development of a mobile application – ‘MySoil’ for use in Africa to support and raise soil health awareness and improve decision-making.

To expand on the responses and assist in the development of the app, we request that you recommend participants from your network who could be useful or might be interested in such an app. Please also comment on your availability for a follow-up interview (telephone or face to face) as a response to this email and you will be contacted to set up an agreeable time.

We're conducting a survey and your input would be appreciated. Click the button below to start the survey. Thank you for your participation!

Appendix B: Online questionnaire

Thank you for taking part.

This stakeholder survey targets respondents from different stakeholder groups in the agricultural and natural resource management discipline. By completing this survey, you will help us establish the kinds of major decisions they require soil information for and the critical uncertainties pertaining to those decisions. Insights from the survey will assist in the development of a mobile application – 'MySoil' for use in Africa to support and raise soil health awareness and improve decision making.

If you discontinue the survey for some reason, you can come back to it later.

Once you have submitted all your answers, you will receive a confirmation message.

1. Please enter the following details:

Your Name

Name of Your Organization

Your Mobile Phone Number

Your Current Job Position/Title

How would you describe your role in your organization?

2. Which of the following stakeholder groups would you be best categorized under?

Farmer Representatives (farmer association/group leaders, (including women's groups) or farmer leaders)

Front-line Extension Agents (community development workers, NGOs, extension officers)

Private sector (fertilizer companies, food production companies, soil-testing labs)

Agricultural and Environmental Researchers (national, regional, international)

Government Policy Makers

Other (please specify)

3. What are the 3 main objectives you hope to achieve in your role as a stakeholder?

Comment (if any)

4. What are 3 primary decisions or questions you struggle with in your role that have major consequences in meeting your objectives? (These could be single major decisions or minor decisions that keep recurring)

Comment (if any)

5. In relation to the 3 decisions you have listed for your work, what soil information do you currently use, if any, and where do you source it from?

Comment (if any)

6. For each decision you listed in Question 4 above, would relevant additional information on soils have value in improving the decision?

	Yes	No

Decision 1		

Decision 2		

Decision 3		

7. If Yes, please specify what soil information has value that would improve decisions.

Comment (if any)

8. How would the specific soil information you have mentioned above, improve decision-making?

Soil information for decision 1

Soil information for decision 2

Soil information for decision 3

Comment (if any)

9. For each decision listed in Question 4 above, what other types of additional information would have value for improving decision-making? (other types apart from information on soil).

Comment (if any)

10. What do you think are the MAIN decisions that farmers struggle with that may have significant consequences on their livelihoods or business interests?

Comment (if any)

11. For each decision you listed in Q10 above, would relevant additional information on soils have value in improving the farmers' decision-making?

Yes   No

Decision 1

Decision 2

Decision 3

12. If YES, please specify what soil information is useful to improving the farmers' decisions.

Comment (if any)

13. How would this specific soil information be used by the farmer to improve their decision-making and help attain their objectives.

Soil information for decision 1

Soil information for decision 2

Soil information for decision 3

Comment (if any)

14. For each decision listed in 10 above, what other types of additional information would have the most value in improving farmers' decision-making? (other types apart from information on soil).

Comment (if any)

15. Have you previously accessed and used web or app information on soils for your work? If so, please give details on the app and the soil information sourced from it.

16. Do you think there is a practical way for you or for farmers to receive relevant information on soils via mobile phone apps? If so, please give details.

17. Could you suggest contacts who could contribute more information (email and/or phone contact) to the survey? Kindly do so below next to the relevant stakeholder group.

Farmer representatives (farmer association/group leaders (including women groups) or farmer leaders)

Front-line extension agents (community development workers, NGOs, extension officers)

Private sector (fertilizer companies, food production companies, soil-testing labs)

Agricultural and environmental researchers (national, regional, international)

Government policy makers

18. Please verify your availability for the follow-up discussion interview. This is a necessary component of the data collection process. Someone will contact you to set up an agreeable time.

Yes, I am willing to participate

No, I do not wish to participate

Done

Appendix C: Responses

Q 3. What are the 3 main objectives you hope to achieve in your role as a stakeholder?

Q 4. What are 3 primary decisions or questions you struggle with in your role that have large consequences for meeting your objectives? (These could be single big decisions or smaller decisions that commonly re-occur).

Farmer representatives

Farmer representatives	Objectives	Decisions and decision questions
1	Increased membership	How do we ensure higher accountability to memberships?
	Enhanced capacity building	How do we ensure sustainability of organizations?
	Access to resources	How do we improve on access to markets?
2	Access to appropriate technology and research	Soil poisoning
	Crop production and value addition	Soil nutrition
	Agricultural value chain	How to replenish soil nutrients
3	Awareness creation regarding importance of soil analysis	Platform for awareness creation on importance of soil testing
	Increased farm productivity	Training farmers on farm productivity
	Minimize fertilizer input through guess work	Which fertilizer to use

Extension agents	Objectives	Decisions and decision questions
1	Food security and safety	Market uncertainties for farmers' produce
	Have farmers equipped with modern farming skills. Link farmers to research findings	High cost of inputs
	Sensitize farmers to do farming as a business	Counterfeit inputs e.g. seeds and agricultural chemicals
2	Improve access by smallholder farmers and other stakeholders to integrated soil fertility management (ISFM) innovations	How to scale up soil fertility technologies

	Enhance the generation and dissemination of ISFM innovations by harmonizing the approaches, recommendations and protocols by key institutions engaged in agricultural research	How to increase the rate of adoption of soil fertility among smallholder farmers
	Advance the dissemination of ISFM innovations by developing and hosting the soil database and appropriate knowledge products	How to link farmers to agroinputs suppliers
3	Analysing results	Amounts of fertilizer required for different crops
	Recommended amounts of fertilizer for different crops	Calculating amounts of fertilizer required per acre
	Other alternatives for improving soil health apart from fertilizer	Required/recommended ratios when mixing soil with water to get solutions for testing
4	Share experiences in soil management over the years	How can farmers eliminate soil bacterial infection to crops?
	Get detailed soil use analysis reports	Can farmers use one type of fertilizers over a wide range of soil types?
	Evaluate and monitor soil use patterns across different zones.	How is drip irrigation applied on a commercial scale?
5	Improved food security (better yields)	How can farmers eliminate soil bacterial infection to crops?
	Improved soil health	Can farmers use one type of fertilizers over a wide range of soil types?
	Improved household health	

Private sector	Objectives	Decisions and decision questions
1	Sustainability in production	How do we maintain soil quality?
	Environmental protection	How do we produce more with the same resources?
	Profitability	
2	Awareness	Soil poisoning
	Understanding	Soil nutrition
	Sustaining	How to replenish
3	Reliable, sustainable supply	Optimizing supply chain structure
	Competitive supply	Optimizing farm/supply chain investments vs risk vs returns
	Optimal farm yields & margins	Optimizing partnerships
4	Empower farmers to get access to soil testing	Farmers are still unaware of the importance of making fertilizer decisions based on soil information
	Provide crop and soil specific soil fertility recommendations	Despite soil testing and consequent data the availability of more tailored/balanced fertilizers is lacking

	Improve soil fertility/health by changing the scope of available fertilizers, lime etc.	Cost of testing equipment is relatively high
	Create farmer awareness on the importance of soil fertility management	Discussions on the quality and usability of different testing methods

Government policy makers	Objectives	Decisions and decision questions
Respondent 1	Food security	What type of fertilizer do farmers require?
	Support farmers in purchasing cereals and pulses produces	Recommended rates of application of fertilizer
	Support farmers in fertilizer distribution	The recommended fertilizers for each eco zone
2	Information on management of pests	N/A
	Integrated pest management options	N/A

Research and Academia	Objectives	Decisions and decision questions
1	Research and development in agricultural and NRM	How efficient are we in the development of appropriate technologies innovations and management practices?
	Capacity building in NRM	How efficient is our role in the capacity building of appropriate technologies innovations and management practices?
	Dissemination of agricultural and NRM technologies	How efficient is our role in the dissemination of appropriate technologies, innovations and management practices?
2	Improve agricultural productivity through science based facts	What are the gaps in agricultural productivity: ecological, information and policy?
	Create soil-based innovations that have potential for use in farmers' sphere	How to bridge the current soil related challenges through innovations
	Address current and future challenges in food security	What are the current soil related limitations and the future scenarios?

3	Use of citizen science in soil and water management	How can we reverse the loss of topsoil and by extension manage deteriorating productivity levels?
	Networking with key soil specialists	Who are the key soil specialists whom we can engage with in order to put soil erosion under control (at local scale)?
	Exposure to recent/up-to-date soil information sources	How can I access and freely update soil information?
4	Outline salient climatic/weather roles in agricultural production	Assumption of actual role climate change plays in agricultural production
	Pinpoint predictions of production changes based on climate change, economic and social settings	Communicating complex issues of agricultural production to end-users for their maximum benefits
	Influence policy decisions for sustainable local, national, regional and global food security	Lack of use of best-bet protocols (resources, institutions, personnel, procedures) for efficient production
	The role environment in the broader sense plays in explaining changes in production for poverty alleviation, income generation and social well-being is critical for humanity survival in this planet	Once these issues are sorted our production systems will be sustainable
5	Provide solution to constraints affecting agriculture	Access soil information
	Build capacity	How long will it take to access soil information?
	Provide information	Do I have funds for this?
6	To increase food production through Irrigation	Financial capacity to enlighten farmers on Smart Agriculture (SA) Technologies
	To increase farmer income	Lack of appropriate agricultural tools for use by farmers
	To educate farmers on cost-effective irrigation	Inability of farmers to comprehend soil-water-crop requirements for optimum production from minimal water applied
7	To better address the soil infertility issues brought to our attention	How to access reliable, safe and effective options for clients
	To understand alternative options available to improve soil fertility	How to access finances to support the setting up of demonstrations of identified options
	To participate in dissemination of soil improvement-related knowledge/information	How to access funding for documentation of the tested and tried cases for future use by others

8	To ensure that Kenya is able to feed herself through improved soil health	Mechanization of all farming operations and not just tillage
	To help Kenya control soil erosion on all farms for sustainable crop production	Marketing of increased crop produce for increased farmer's incomes Poor roads networks
	To make Kenya conserve water and soil fertility for increased and sustainable pasture production for her livestock	N/A
9	Improvement (modernization) of soil laboratory analytical services	How to influence thought in new soil science and building a critical mass of (local) competent team
	Development of key quality soil attributes and GIS-based management system	How to modernize research infrastructure (sample laboratory analyses, field data collection)
	Development of (thematic) effective technology to improve production and enhance soil health	How to link effectively with purveyors and users of soil-related information Basic challenge is on how to rapidly generate quality soil information in a friendly format
10	Easy access to and affordability of a reliable soils information	Availability or the right source of soils information, especially for fertilizer recommendation at farm level
	Information that will support or encourage the development of a soils policy for Kenya	High costs of soil analysis and delay in obtaining laboratory data
	Information that will interest graduates to take up soil science-related courses	Lack of information on who is doing what in the field of soil science research
11	Identify ways to improve agricultural productivity	Why agricultural productivity has stagnated
	Contribute to increase in incomes for rural farmers	What can be done to unlock the agricultural potential
	Contribute to alleviating poverty	Commercialize agriculture

5. In relation to the 3 decisions you have listed for your work, what soil information do you currently use, if any, and where do you source it from?

7. Please specify what soil information has value that would improve decisions.

8. How would the specific soil information you have mentioned above, improve decisions?

Farmer representatives	Current soil information used	Soil need gaps	Uses
1	Rides on other stakeholders meeting to demonstrate how Soilcare scanners work	Crop specific requirement vis-a-vis current soil nutritional content	Plant most appropriate crop for maximum yield
	My training materials are sourced from the Internet	Demonstrated optimal production level per acre visa vis current production level	Maximize output per acre Soil information for decision
	Soilcare Scanner has recommendations which I use for those who can afford	Crop-specific requirement vis-a-vis current macro- and micro-nutrient levels	Address quality and quantity being produced by adding lacking elements
2	Biological Nitrogen fixation from N2Africa	Maintaining soil fertility	Increased productivity
	Organic farming from organic farmer magazine	Improving soil texture	Low-cost farm inputs
	Organic products from Moi University.	Zero tilling	Timely markets for farmer produce
3	Quality of soil	What is the status of a farmers' soils? This could impede productivity	Farmers would be guided on the correct type and measure of inputs
	Cost of testing soils	Help in planning and budgeting for production	When can one get their soil tested. When do I schedule the testing.
	Where to test soils	Where can a farmer find a facility to test their soils? This would help break the myth of the process being difficult and costly.	How can one reach the soil testing facility? Does one need additional information on locating the facility? Is the facility known to the farmer?

Extension agents

Extension agents	Soil information used	Soil information needed	Uses
1	None soil fertility levels as analysed at the nearest lab-MIAD	Soil analysis for farmers' fields.	To get required nutrient deficiencies and correct them as per the recommendations.
2	The type of soils (micronutrients available in soils) – soil testing and analysis	Soil pH in a given area	Soil pH informs the type of measures needed to replenish soils; e.g. lime for acidic soils
	The type of approaches that farmers use to replenish depleted soils – from surveys and current literature	The rate of fertilizer use/application among smallholder farmers	The rate of application of fertilizers will inform whether farmers are under, over or misapplying fertilizers
	The type of fertilizers that farmers use – from surveys	The location of agro-inputs suppliers and what they stock	The location of agro-inputs suppliers informs accessibility of smallholder farmers to organic fertilizers
3	Solution ratio: from private practitioners	Fertilizer requirements for different crops	Do proper ratios
	Analysis: private practitioners	Solution ratios	Know required amounts of fertilizer for proper recommendation
	Testing: private practitioner	Analysing results	Give good analysis
4	Soil data reports from KALRO	Soil bacterial analysis reports	Have focused planting monitoring mechanisms
	Farm inputs data usage records from ministry of agriculture	Fertilizer usage data from specific counties	Accurate application of the right type of fertilizer
	Irrigation roll-out reports from Amiran limited	Green house installation and commissioning data by Amiran	Better decisions lead to better yield per acre
5	Soil spectroscopy lab	More accurate and stable measurements, high resolution soil maps	Better calibrate fertilizer and plant spacing
	Soil spectroscopy lab	More accurate and stable measurements, high resolution soil maps	Improve liming and fertilizer recommendations
	Soil spectroscopy lab and some small-scale XRF data	More accurate and stable measurements, high resolution soil maps	Understand plant nutritional value

Private sector	Current soil information used	Soil need gaps	Uses
1	Soil analysis – crop nutrition	Ways of maintaining soil quality	Sustainable soil use
		Ways of improving soil fertility without environmental degradation	Environmental protection with increased productivity
2	From labs i.e. SoilCare, KALRO, NARL	Soil analysis	Soil analysis gives status
	Crop nutrition	Soil care	Improves/maintains the soil
	KALRO centres, practical training centre in Thika	N/A	N/A
3	None	Inherent soil nutrient levels, soil structure	Targeted fertilizer and agronomy recommendations
	From commercial soil labs, Government data	For each crop, balance between expected yields, risks and costs of soil nutrient correction to achieve yield targets sustainably	Match cost, risk and returns to soil investments
	None	Partners who can deliver soil information, advice in different geographies, partners who can conduct continued research	Identify the right partners to use
4	Soil maps	Visualizing soil (deficiencies) data would help to educate farmers and extension officers	N/A
	Crop suitability data	The same maps linked to crop specific models will show need for balanced fertilizers enabling manufacturers to produce them	N/A
	Sourced from our own data systems	N/A	N/A

Research and Academia	Current soil information used	Soil need gaps	Uses
Respondent 1	African Soil Information Service (AfSIS)	Information on best-bet TIMPS (Technology, Innovation and Management Practices)	Enhance decisions on best-bet TIMPS
	African Soil Health Consortium (ASHC)	Appropriate capacity building information	Enhance decisions on appropriate capacity building methodologies
	Soil Science Society of East Africa (SSSEA)	Information on appropriate pathways for dissemination of best-bet TIMPS	Improve decisions on appropriate pathways for dissemination of best-bet TIMPS
2	I use the latest research findings: literature, farmers' innovations and technologies	Availability of open source research publications	Reduce duplication of effort and direct resources to where clear research gaps have been identified
	Mostly literature and data obtained from own research projects	Availability of analytical tools for analysis of current datasets	Makes it easier to make intervention decisions
	Field observations and literature, conferences and workshops	Sharing of current updated digital and modelling applications	Visualization of current and future scenarios for better de
3	Soil survey of Kenya, KALRO	Traditional methods of soil management. This includes conservation agriculture methods	Control soil erosion
	Literature	Latest soil management techniques	Improve water holding capacity
	Internet sources	Status of soil nutrient and fertility levels	Management of nutrient levels in soils
4	A lot of documentation on role of climate change on soil properties can be obtained by use of appropriate models designed to simulate changes in soil properties	A continuously up-datable database on role of climate change on soil conditions based on emerging information need to be established	Like any other database an update would significantly improve on its suitability for researchers, extension and farmers
	Tested socio-economic protocols exist that compare end-user knowledge with the complex scientific methods/terms and hybrid methods of communication established (e.g. Indigenous knowledge)	Plenty of indigenous knowledge (IK) on soil qualities of direct relevance to production should be documented before it is lost when the new generation of farmers become the main players	It is easier for local end-users to understand and use simplified (IK-related) and understandable information which will ensure enhanced production

	vis-a-vis complex soil taxonomy and participatory rural appraisals etc.)		
	Well known subject matter specialists in soil science (taxonomists, geologists, surveyors) and institutions (e.g. Kenya soil survey) are usually consulted based on specific need	A professional registration body of soil scientists based on qualification and experience should be made and utilized by the development stakeholders and partners	The professional body would reduce misappropriation of resources and ensure
	A concerted effort is required for successful utilization of available resources without use of non-qualified staff and mis-allocation to inappropriate institutions	Soil information especially related to enhanced agricultural production should be documented and availed in simple utilizable terms for its usage by small scale agricultural producers	
5	Soil physical properties – from the Soil Physics Lab	Soil physical properties (texture, bulk density, water holding capacity, hydraulic conductivity)	Be able to understand agricultural systems (physical)
	Soil physical properties from field evaluations	Soil fertility	Be able to understand agricultural systems (chemical)
	Soil chemical properties – from the chemistry lab	Soil health (nematodes, etc.)	Understanding soil status
6	Soil-moisture water holding capacity data	Soil maps showing soil characteristics	It would help in precision application of soil-crop water requirement for optimum yield production
	Soil fertility data	Soil chemical elements, physical parameters and fertility status	Right amount of fertilizer application
	Soil characteristics and land topography	Land physical features and topography	Prevention of soil and nutrient loss through soil erosion and nutrient flushing
7	What is available in our research reports and from the internet	Information on whether the constraint is due to physical biological or chemical related soil issues	Correct or workable interventions would be given to clients
	Depend on support from the national government yet delays timing of release of funds, jeopardizes activities	Information on time required to restore the problem	The commitment to support demonstrations would be better once the length of time for intervention effects to be seen is understood

	Support for documentation still a constraint though it depends on the support from government	N/A	N/A
8	ISFM information from the Kenya Soil Health Consortium	Soil physical changes as a result of mechanization	To select appropriate equipment to improve soil physical change
	Agriculture sector policy documents from the ministry of agriculture	Quantities of soil nutrients removed by high crop yields	Select appropriate fertilizers and quantities for sustainable increased crop yields & income
	All aspects of agricultural and environmental research publications by KALRO, universities and international organizations such as IPNI, ICRAF, ICRISAT, CIAT Africa, CGIAR, etc.	Water harvesting from improved roads for crop production	Selection of appropriate water harvesting techniques and equipment
9	Since 1972 Kenya Soil Survey (KSS) has conducted field soil survey and mapping using conventional methods	Maps on key soil types, their characteristics and distribution	More accurate soil maps support planning and resource allocation
	Soil laboratory at KALRO - Kabete conducts laboratory analyses	Soil stability, fertility and crop/plant (yield) response	Soil stability is key for sustainability; soil fertility inform fertilizer use recommendation; crop response enable accurate yield prediction allow
	A GIS laboratory at KSS is a repository of soil information	Critical (threshold) values for key quality soil indicators	Critical values allow classification and (spatial) suitability information
	Low intensity soil information: 1:1 million country-wide; 30-40% at 1: 0.1-0.25 million, and; 15-20% larger scale		Generation of information amenable to geo-processing is important
10	Research results from relevant institutions, journal papers and students' theses	Still the level of soil mapping is very coarse in Kenya	On the right type fertilizer and management practices to apply, preferably at field or farm level
	N/A	Perhaps mobile soil labs, but which should give	N/A

		reliable data should be encouraged	
	N/A	Once it is known who is doing what in the field of soil research, there might be cost saving as there will be no need to re event the wheel	N/A
11	Causes of declining soil quality	Soil nutrients	Make rights investments in soil quality
	Investment in improving soil quality	Deficient/ sufficient nutrients	Improve agronomic practices
	Impact of investment in soil quality	N/A	N/A

10. Farmers main decision problems

12. If YES, please specify what soil information is useful to improving the farmers' decisions

13. How would this specific soil information be used by the farmer to improve on their decisions and reach their objectives.

Frontline extension agents	Farmer decisions	Soil information needed	How soil information is used
1	Market for their produce	N/A	They would not waste time and money on fertilizers that do not add value to their soils
	Startup capital	N/A	
2	Whether to take credit to improve their agricultural enterprise	N/A	N/A
	Whether to sell their produce as individuals or through aggregation centres	N/A	N/A
	What time farmers should sell their produce; immediately after harvest or wait until prices rise. Those without proper storage facilities may have their produce destroyed by pests	N/A	N/A
3	Soil fertility issues	Types of fertilizers for different crops	N/A
	The type of fertilizers to apply	How to know status of soils in terms of fertility	N/A
	Remedies for acidic or basic soils	What to do when farms are acidic or basic	N/A

4	Crop storage facilities during bumper harvest	Quality and type of fertilizers	When and how to apply fertilizers
	Poor farm gate prices for produce	Impact of fertilizers on soil and crops	Quality and quantity of crop yield
	Changing weather patterns	Latest soil erosion prevention interventions	Impact on environment
5	Which fertilizer and how much? How to apply	Yield response to fertilizer	They'd know which fertilizer to use to improve yields
	How much lime, how to apply?	Yield response to lime	They'd know how to manage soil health to improve yields
	How to provide nutrition through ag. Management	N/A	They'd maximize nutritional value through management

Private sector	Decisions	Soil information needed	How soil information is used
1	Crop varieties and livestock breeds with high returns	Soil pH	Manage pH to specific crop requirements
	Soil fertility management	Soil nutrients	Provide required nutrients at each development stage for optimal production
	Crop husbandry practices for sustainability	Soil management recommendations	For soil quality sustainability
2	How to make their farm fertile	Getting correct soil status	Collective learning
	How to improve their yields	Doing the right thing in improving soil status	Sharing experiences
3	What crops to grow each season	N/A	N/A
	How much to invest in each crop, versus risks and returns	N/A	N/A
	Where to access reliable inputs	N/A	N/A
4	Which crop to plant	Crop suitability information but is less dominant than market options for selling crop	To tell which crop suits his field, soil, region

	How to prepare their land/fertilize	Critical to know soil status	pH to lime, organic matter to use compost, NPK, etc. to select the best fertilizer

Government policy makers	Decisions	Soil information needed	How soil information is used
1	What are the prices of agricultural produce in the market?	Expected production per unit area	N/A
	Are the rains likely to fail?	Expected rainfall pattern	N/A
	Is it necessary to apply fertilizer?	Expected yield after soil treatment	N/A
2	Soil pH	Nutritional levels	Design on which crop to grow
	Soil nutritional levels	Soil-borne pathogen load	N/A
	Soil borne pathogens status	N/A	N/A

Research and Academia	Decisions	Soil information needed	How soil information is used
1	Farm management and production decisions	Additional information on soils that would improve farm management and production decisions	Additional information on soils that would improve farm management and production decisions for enhanced and sustainable NRM
	Market information systems on agricultural products	Additional information on market information systems on agricultural inputs (fertilizers), manures, farm management, bioeconomic, biophysical, agronomic models and agricultural products	Additional information on market information systems on agricultural inputs (fertilizers), manures, farm management, bioeconomic, biophysical, agronomic models and agricultural products would enhance in efficiency in the reallocation of the available resources

	Agricultural Product Value Addition Chains (APVC) decisions	Additional information on making decisions on appropriate Agricultural Product Value Addition Chains (APVC)	Additional information on making decisions on appropriate Agricultural Product Value Addition Chains (APVC) for optimum productivity
2	Is it viable given my current resource ability?	Crop requirements vs soil conditions	Help decide suitability of the crop enterprise based on soil conditions and locality
	What are the risks and opportunities available?	Market and risks analysis trends	Help to prepare the farmer to expected risks
	Where are the markets for my produce and at what price?	Available markets and prevailing prices	Help the farmer to plan for the quantity and quality of produce
3	Nutritional status of their soils	Continuous monitoring and providing feedback to farmers	Choice of crops to grow
	Kind of seeds to use given that the soil conditions are deteriorating	Avail information on the latest types of seed available	Type of seeds to purchase
	Value for money with improvement of soil condition	Production and market sources	Value for investment known
4	Lack of initial capital to invest in farming for business amidst the many other urgent financial commitments	Increase/subsidize investment of initial capital to spur soil-based small business	This would encourage hesitant farmers to utilize the funds for business
	Few if any policies of insurance against loss due to unforeseen circumstances	Authorities should come up with policies that use soil information for production to insure against possible calamities	This would encourage bottom-up approaches in policy formulation and ensure enhanced production by end-users
	Lack of link between the available policies but are usually not used to enhance agricultural production	Create working linkages between policy makers and implementing agencies to ensure sufficiency in allocation and utilization of resources	Someone would be taken to task if policies are not implemented as is presently evident

	For commercial purposes there are a number of cartels and/or agents who keep major benefits designed for the producer		
5	Soil management	Soil fertility information	Correct application of fertilizers
	Water management	Water holding capacity	Correct management of water
	Crop management	N/A	N/A
6	Adequate knowledge on soil-crop-water needs and inter-relationships	Soil physical and chemical characteristics/data	Farmers would know how much fertilizer and which type to apply for their soil types
	Weather predictions	Soil moisture capacities/data	Farmers would know when to plant their crops at the right soil moisture level hence avoid germination losses
	Farm inputs versus financial capability	Soil type data for workability and cost of operation.	Farmers would know the cost of tillage and the best period of tilling the land.
7	To use or not use soil amendments	Is it going to improve the inherent fertility	They would attempt it on a section of their farms
	To change or not change the way they are doing their basic farming	Will it affect the quantity and quality of produce from the acreage	They would adopt the method that ensures higher production
	To trust or not to trust the many recommendations shared with them from different sources	N/A	N/A
8	Types of crops to grow and how to grow them easily	Soil physical status for selection of appropriate machinery & tools	Selection of appropriate machinery & tools for the required farming operations
	Accessing high paying markets for their produce	N/A	N/A
	Sending crop produce to markets using poor roads	N/A	N/A
9	How to manage vagaries of weather, pests/diseases on crop calendar and yields	Soil micro-biology	Soil micro biology to inform integrated

			pest management (IPM)
	Access to inputs (type, timing, pricing, application rate)	Soil test and crop response test and fertilizer use recommendation	Timely soil test for timely fertilizer use
	Post-harvest losses, market for produce and how to maximize profit	Soil pathology; grain moisture	Soil pathology for effective IPM; grain moisture to avoid aflatoxin,)
10	To increase yields – most do not know the existence or importance of soils analysis	Not clear based on the information give above	N/A
	As a result of 1) above, they use the bracket recommendation of fertilizers	N/A	N/A
11	Responsiveness/non-responsiveness of nutrient additives	N/A	N/A
	Which nutrients improve production	N/A	N/A
	When, and in what quantities to apply soil enriching nutrients	N/A	N/A

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