Ethiopian soil laboratory infrastructure

CASCAPE scoping mission

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CASCAPE:
Capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia
www.cascape.info

Food security is one of the main issues in Ethiopia. Large amounts of money are spent on food security programs set up by federal- and regional governments and other organisations. Decision-makers, as well as researchers, share a dependency upon reliable data on soils, water and crops. The authors of this report believe that the data from the Ethiopian soil laboratories are not reliable enough for decision-making purposes. Ethiopian laboratories need to improve their analytical services. The main problems concern the organisational set-up, and not merely a lack of budgets for facilities. Apart from organisational problems, managerial-, human resources-, technical-, instrumental- and supply issues were identified.

Keywords: Ethiopia, soil laboratories

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List of abbreviations

AGP	Agricultural Growth Program
ARARI	Amhara Regional Agricultural Research Institute
ARNL	Agricultural and Nutritional Research Laboratories
ATA	Agricultural Agency
EIAR	Ethiopian Institute for Agricultural Research
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organization of the United Nations
GARI	Gambella Agricultural Research Institute
GoE	Government of Ethiopia
MEF	Ministry of Environment and Forest
MoA (or MoARD)	Ministry of Agriculture (and Rural Development)
MoE	Ministry of Education
MoFED	Ministry of Finance & Economic Development
MoWE	Ministry of Water & Energy
MoWR	Ministry of Water Resources
NSTC	National Soil Testing Centre
OARI	Oromia Agricultural Research Institute
PMO	Prime Minister's Office
RARI	Regional Agricultural Research Institutes
RBARD	Regional Bureau of Agriculture and Rural Development
SARI	Southern Agricultural Research Institute
SoRPARI	Somali Region Pastoral & Agro-pastoral Research Institute
RSTC	Regional Soil Testing Centre
TARI	Tigray Agricultural Research Institute
WWDSE	Water Works Design and Supervision Enterprise

Summary

Need for reliable data

Food security is one of the main issues in Ethiopia at the moment. Large food security programs have been established with extensive amounts of investment from federal- and regional governments, as well as from organisations, such as the Bill Gates foundation, UNDP, AGP and the World Bank. Decision-makers at governmental level, as well as researchers and farmers, share a profound dependency upon reliable data on soils, water and crops.

Current situation

After a thorough investigation of the soil related laboratories in Ethiopia, and the infrastructure around them, the authors of this report strongly believe that the data that are generated at the moment, in the chain of soil sampling to laboratory output, are not reliable enough for decision-making purposes.

The output of Ethiopian laboratories needs to be improved. Many of these laboratories offer soil-, water- and plant analytical services. However, the potential of these laboratories is not fully reached, due to a series of problems. The main problems were identified at organisational levels, and are not merely a matter of lack of budgets for facilities. Apart from organisational challenges, managerial-, human resources-, technical-, instrumental- and supply issues were also identified.

Laboratory staff, as well as the involved organisations, such as the relevant ministries and regional bureaus, are fully aware of the need to improve key conditions and are well motivated to implement these improvements.

Proposed chronological approach

In the past, much effort has already been invested in new equipment, training and partial standardisation (as indicated by Package II of the scheme below). Extended efforts have not, however, led to a lasting improvement in overall quality. A key conclusion of the current research is the recognition of the need for a chronological approach (according to the scheme below) in the measures to be taken. The background of this approach is that sustainable development of a laboratory is only possible when basic requirements are met. Therefore, it cannot be emphasized enough that Packages I.A and I.B must be completed to enable the measures defined in Package II to achieve a desirable and durable effect. Investments in effort and money of the measures from Package II cannot be justified, if packages I.A and I.B are not completed.

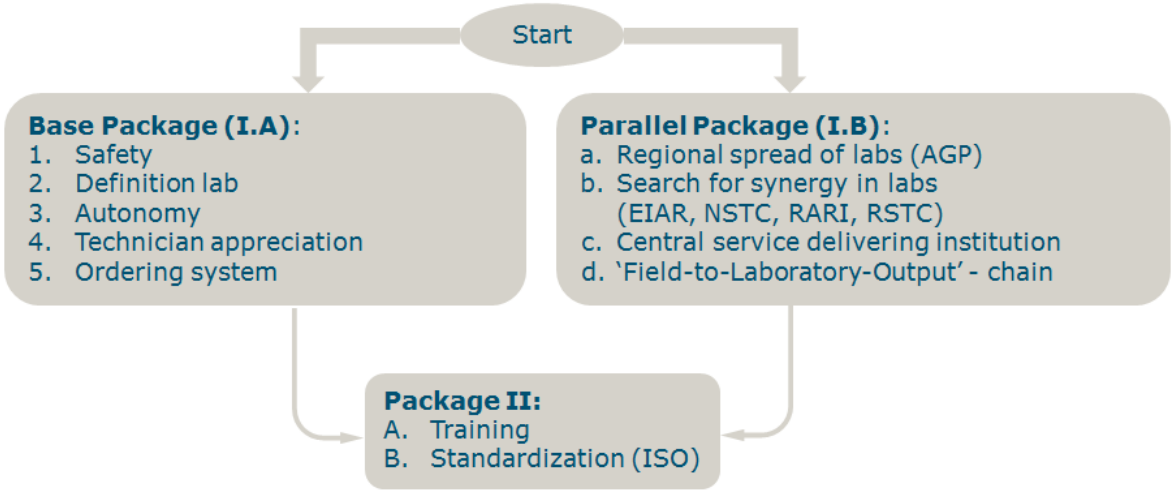

Figure S.1 *Chronological approach of the proposed measures.*

Package I.A and I.B

Package I.A is the most urgent and covers severe safety aspects, as well as the recognition of the fact that most established departments perform the same technical analytical laboratory experiments within their different consultancy roles. This recognition is important in order to understand the logical follow up of the measures in Package I.B. There is also a need for more self-ruling possibilities. These are required to improve laboratory technician-appreciation, and also to improve the quality and time-efficiency of ordering chemicals, equipment and spare parts. It should be noted that currently the appreciation of laboratory technicians, as well as the ordering system are both paralysing problems.

Package I.B can be performed in parallel with, or after completion of, Package I.A. It covers the inevitable need for merging soil-related laboratories, a necessity to establish fewer, but large, qualitatively strong and cooperating soil laboratories. The current structure of separate consultancies, as indicated in Package I.A, can be maintained, but the analytical services must be synergised. It is a misconception that reliable data can be accomplished by a large and strong laboratory only. Therefore, directly related to the setup of a strong laboratory structure throughout Ethiopia, this package covers integral adjustments in services and structures required to accomplish reliable field sampling, reliable sample transport and reliable sample preparation.

Safety
Many deviations from basic safety rules were observed and one death, one major injury (loss of eyesight) and multiple abortions were reported. Any laboratory that is unable to meet safety regulations should be closed immediately.

Organisational
Ethiopian laboratories are part of a number of different governmental organisations, that all offer the same analytical services. It appears that every governmental organisation has its own set of laboratories, each performing the same analytical experiments, but using them for different consultancy purposes. As a consequence, multiple soil laboratories are often in a single town or city. With limited budgets and substandard functioning of most laboratories, it is important to avoid redundancy, and strive to create one or more strong laboratories at appropriate locations. Therefore, one or more organisational mergers are strongly advised, leading to fewer but qualitatively stronger soil laboratories: it is better to improve a few selected laboratories, rather than trying to improve them all.

Adequate budget allocation
Most governmental laboratories do not have enough budget to purchase required materials and services. The consequence is that they perform below standard. Therefore, after reorganisation, allocation of enough budgets to the remaining laboratories is suggested. To stimulate entrepreneurship, it is suggested that laboratories are encouraged to generate their own income and replenish their budgets through delivering services to third parties, instead of submitting the generated money directly to the Government.

Purchasing policy
At present, the purchasing policy is a 'lowest bid wins' policy, in which quality and delivery time are not considered. Experts and laboratory heads have reported the delivery of useless, low-quality reagents, poor-quality instruments and spares. Moreover, frequent delivery delays are common. As a result, laboratories deliver inaccurate results and have considerable downtimes. It is recommended to change the present purchasing policy, such that, quality and delivery-time play a significant role. The purchasing policy should permit laboratories to define the requirements themselves.

Incentives
It was observed that different organisations use different incentives. For instance, housing allowances, scholarship opportunities, insurances, and better basic salaries, are extended to some and denied for others. Experts with the same level of qualifications, same experiences and responsibilities are rewarded differently by different organisations. Consequently, laboratories are not able to retain their (experienced) staff. This has a destructive impact on the operational quality of the laboratories. Appropriate actions are required.

Package II

Package II covers items that must only be addressed following completion of Packages I.A and I.B.

Future plans of laboratories
Once focus can be made on a selected number of laboratories, as indicated in Package I.B, other plans for improvement can be rolled out. All laboratory heads and technicians want to improve the status of their laboratories for better services to the customers. Therefore, they plan to improve the skills of technicians and maintenance personnel, to modernise their analytical equipment, to improve their manuals and procedures, to improve the efficiency and efficacy of the purchasing system and, finally, to expand their laboratory services from present standard fertility-oriented analysis to a broader range of analytical services. These plans cannot be achieved without sufficient resources and support. This illustrates the necessity behind reorganisation: it is impossible to upgrade all existing soil laboratories within the present budgetary constraints. After reorganisation, there are various challenges to address.

Laboratory technicians
The quality of laboratories depends upon the availability of laboratory experts. In most cases, intelligent and basically motivated personnel were found to be in service, which did not have training for soil-, water- and plant laboratory analysis. Appropriate 'on-the-job' training of qualified laboratory experts is practically non-existent. Most laboratories have not invested in the setup of adequate training plans. A shortage of staff was frequently observed. There were few incentives to prevent staff leaving for better paid positions. In Package II, the development of proper training programmes for technicians on analytical procedures, operations and primary maintenance of instruments is recommended. The development of coordinated and better incentives to be able to retain well qualified staff is also recommended.

Maintenance technicians
A large number of unserviceable or uninstalled equipment, resulting from lack of maintenance experts in all laboratories was found. Therefore, it is recommended to train maintenance technicians and have at least two experts per device for a group of laboratories. Such an arrangement can be set up at a regional level, for example.

Analysis procedures manual

Different laboratories were found to follow different analytical procedures. Comparison of these results is difficult, if not impossible. This affects the quality of recommendations of required soil and water management and technologies on national, as well as regional/local levels. It is suggested that all laboratories use the same manual, updated when necessary, and refreshment courses could be offered to experts, once an update is implemented.

Quality control mechanisms

Laboratory quality control is designed to detect, reduce, and correct deficiencies in a laboratory's internal analytical process prior to the release of the results. None of the laboratories used acceptable quality control mechanisms. Laboratories should implement quality control mechanisms, as soon as possible after completion of Packages I.A and I.B.

1 Introduction

1.1 General

Food security is one of the main issues in Ethiopia at the moment. In its Agricultural Growth Plan (AGP), the Government of Ethiopia (GoE) aims for significant growth and development of the agricultural sector in a number of selected woredas. Success depends upon proper use of the soil- and other land resources. For this reason, adequate knowledge and management of soil resources is indispensable. Proper management of soils requires understanding of the physical, chemical and biological soil characteristics. To a large extent, this can be achieved through laboratory analyses. Therefore, the federal and regional governments of Ethiopia have established soil laboratories in different parts of the country. Proper soil management decisions depend upon the availability of reliable data, and, thus, on the quality of soil laboratories.

The Dutch Government has initiated and implemented the CASCAPE project (CASCAPE = capacity building for scaling up of evidence-based best practices in agricultural production in Ethiopia). The project focuses on the collection of information on soils by conducting soil surveys in AGP woredas in Tigray, Amhara, Oromiya and Southern Nations, Nationalities and Peoples Regions in Ethiopia. Its aim is to map the soil fertility of Ethiopian soils in complement to or by assisting the Ethiopian Agricultural Transformation Agency (ATA) initiative. The CASCAPE project has produced a large number of soil maps for the selected woredas. From these maps, a great deal of soil and geomorphology information can be extracted towards assisting soil- and agricultural management. It is obvious that knowledge on soil resources highly depends on reliable soil test results. Without reliable data, Ethiopian parties are unable to make appropriate agricultural decisions. CASCAPE has emphasized the need to strengthen Ethiopia's soil, water and plant (SWP) laboratories. It, therefore, has begun with an inventory of Ethiopia's laboratory infrastructure.

This inventory focuses on the collection of information on the status of existing soil laboratories. This status includes organisation, quality of manpower, available instruments and consumables, and potential-, as well as present problems.

1.2 Mission objective

The long term objective of this mission is to improve the contribution of the Ethiopian laboratories to agricultural growth and food security, by delivering high-quality analytical results.

In order to achieve the long term objective, a number of deliverables have been defined. The first phase of this project will:

1. Describe the present situation of Ethiopian soil laboratories.
2. Describe the desired future situation.
3. Discuss the shortcomings and recommend solutions.
4. Deliver a written mission report.

2 Working methods

This chapter describes previous work, as well as the working methods of the complementary work that was performed in 2015. The value of previous work is without doubt. It focuses on issues present within the laboratories to date. The current report follows a broader focus: it focuses on organisational issues that extend within a single laboratory. It also focuses on the laboratory- and supplementary structures in Ethiopia as a whole, and it emphasizes the most urgent steps that need to be taken in the authors' views.

2.1 Previous work

2.1.1 FAO 2011 Report

In 2011, Dr. Farina evaluated the current status of soil test calibration studies, soil acidity management, regional laboratory efficiency, and the soil fertility research agendas of federal- and regional research institutes. Focus here will be made on the conclusions of this research regarding soil testing facilities:

- Soil-test based activities in Ethiopia lack direction and co-ordination at the regional level. From an outsider's perspective, it is extremely difficult to decide just who is 'steering the ship'.
- Low morale among laboratory personnel, due to low salaries and consequent, rapid staff turnover, particularly of trained persons is a frequent encountered problem.
- Lack of key equipment such as AAS is frequently observed.
- Non-functional equipment is often not repaired.
- Poor water supply at some localities is a reported problem.
- Periodic shortages of chemicals is quite common.
- Administrative delays when orders are placed is common.

Farina believed that absence of a clearly defined mandate may also have been involved. In most countries, service laboratories are just that. They provide analytical services to clients. Usually, the clients are predominantly farmers – this is, in fact, the community, for which these laboratories were established– but other clients consist of research organisations, investors and universities. Except on a voluntary basis or in slack periods, laboratory personnel should not be expected to run field trials, as appears to be the case in several of the laboratories visited. It is hard to see how a chemist or laboratory technician can be expected to assume the responsibilities of an agronomist, soil scientist or field technician. Some of the laboratories did not use standard control samples. This is almost unthinkable, and urgently needs to be rectified.

2.1.2 Department of Geography and Environmental Studies 2012 Report

In 2012, Dr. Assen produced a more elaborated report on the status of the Ethiopian national and regional soil testing laboratories. Some of the conclusions of the report include:

Human capacity building:

- There are no appropriate on the job and higher level trainings.
- Lack of incentives causes a rapid staff turnover.
- An absence of qualified and experienced staff is observed.
- Absence of maintenance technicians.
- Inadequate supply of allowances for laboratory dresses, unavailability of safety kits and safety equipment, absence of protective gloves and safety glasses.

The report mentioned one death due to working with hazardous chemicals, as well as serious injuries.

Infrastructural services and instruments:
- Shortage of analytical benches.
- Shortage of instrument reading rooms.
- Absence or shortage of purified water.
- Frequent electrical power interruption.
- Absence or shortage of spares.
- Absence of local dealers/suppliers of analytical equipment.
- Frequent unserviceability of equipment.
- Poor computer and internet services.

Consumables and reagents:
- Inadequate budget allocation to purchase reagents/consumables.
- Reagents/consumables not available on the local market.
- Absence of suppliers/dealers of laboratory reagents.
- Slow and inefficient purchase systems.
- Low quality reagents.
- Delivery delays.
- Absence of stock monitoring systems.

The conclusions of the Farina (2011) and the Assen (2012) reports are similar.

2.2 Interviews

During October 2015, people from different organisations were interviewed (Table 2.1).

2.3 Laboratory visits

All the above mentioned laboratories were visited to obtain a general impression of their:
- Organisational structure.
- Infrastructure.
- Quality of equipment.
- Quality of personnel.
- Financial healthiness.

The detailed inventory that was performed previously was not repeated. All information on manpower, available equipment, capacity and performance, required reagents, laboratory safety equipment can be found in the Farina (2011) and Assen (2012) reports.

Table 2.1
Overview of all interviews.

Organisation	Location	Interviewees	Interviewers
MoA	Addis Ababa	Prof. Tekalign Mamo	Mohammed Assen, Gerben Bakker, Joop Okx, Tefera Solomon
NSTC	Addis Ababa	Dr. Fikre Mekuria Haile Dr. Tofik Hussein Girma Selassi (UNDP)	Mohammed Assen, Gerben Bakker, Joop Okx
EIAR	Addis Ababa	Dr. Solomon Abate	Mohammed Assen, Gerben Bakker, Joop Okx, Tefera Solomon
WWDSE	Addis Ababa	Dr. Netsanet Mengistie	Mohammed Assen, Gerben Bakker, Joop Okx, Tefera Solomon
HARCSL	Holeta	Solomon Abate Dereje Fekadu (Director) Kebede Hailu (Laboratory Head)	Mohammed Assen, Gerben Bakker, Joop Okx, Tefera Solomon
HRSTC	Hawassa	Tesgereda Bahiru	Mohammed Assen, Gerben Bakker, Joop Okx, Tefera Solomon
DARCSL	Bishoftu	Dr. Solomon Chanyalew (Director) Mohammed Emam (Expert)	Mohammed Assen, Gerben Bakker, Joop Okx, Tefera Solomon
ZSTC	Ziway	Dr. Yafyalew Assefe	Mohammed Assen, Gerben Bakker, Joop Okx, Tefera Solomon
Hawassa University	Hawassa	Dr. Gashaw Meteke	Mohammed Assen, Gerben Bakker, Joop Okx, Tefera Solomon
JIJE Labo	Addis Ababa	Gemechu Sorsa	Mohammed Assen, Gerben Bakker, Joop Okx, Tefera Solomon
Dutch Embassy	Addis Ababa	J.W. Nibbering	Gerben Bakker, Joop Okx

2.4 Report

After an introduction (Chapter 1) and working methods (Chapter 2), the present situation (Chapter 3) and a proposed future working scenario to improve the quality of the Ethiopian soil laboratory infrastructure (Chapter 4) are described. The report is finalised with some conclusive remarks.

3 Present situation

This chapter is setup in three main parts:
- Motive and timing for improvement (Paragraph 3.1).
- Current situation *within* the laboratories, and the main problems encountered (Paragraph 3.2).
- Current *structure* of the laboratories in Ethiopia in general (Paragraph 3.3).

Chapter 4 gives a possible scenario that complies with the key measures, as mentioned in this chapter.

3.1 Need to improve

The interviews held during the period 14th October to 28th October 2015, generated a considerable amount of information regarding the organisational structure within the separate laboratories, and also the organisational structure around the laboratories. The latter also appeared to be of great importance for the well-functioning of each separate laboratory.

As discovered during the survey, there is a great understanding among laboratory heads, laboratory technicians, and policy makers of the potential benefits from a high quality laboratory infrastructure, and more importantly, a willingness to strive for improvements.

This urge for quality and improvements can be understood from ambition, pride, vexation, but most of all, from the collective need for reliable data for the national food security programs that are being operated in their full extent at the moment. This must also be seen in the context of the extensive amounts of investments that are made from the federal- and regional governments, as well as from organisations, such as the Bill Gates foundation, UNDP, AGP and the World Bank. Decision-makers at governmental level, as well as researchers, share a profound dependency upon reliable data on soils, water and crops.

After a thorough investigation of the soil related laboratories in Ethiopia, and the infrastructure around them, the authors of this report strongly believe that the data that are generated at the moment, in the chain of soil sampling until laboratory output, are not reliable enough for decision-making purposes.

The main problems were mainly identifiable at organisational levels, and are not merely a matter of lack of budgets for facilities, or malfunctioning of personnel. In the view of many contributors in the mentioned 'Field-to-Laboratory-Output' - chain, and in the view of the authors of this report, the chances for improvement are optimal in the current stage of development of Ethiopia; large improvements can be implemented without extended additional budgets, and should, therefore, preferably be effectuated without delay.

A set of basic conditions must be met in order to obtain a successful 'Field-to-Laboratory-Output' - chain. The laboratories are an important link, but cannot operate independently, and cannot generate reliable data, if other links are omitted. This chapter gives the key measures required to improve the components within the laboratories, as well as measures that exceed a single laboratory.

This report focuses on possible improvements. Aspects that do not need to be changed are only mentioned sporadically. This chapter provides an overview of the main aspects that require attention. The subjects are addressed in order of importance, with the most important one first. Firstly, the internal issues are addressed (Paragraph 3.2), and secondly, the laboratory exceeding issues are addressed (Paragraph 3.3).

3.2 Internal laboratory issues

3.2.1 Safety

In all components of the 'Field-to-Laboratory-Output' chain, safety is the far most important subject. Many deviations from basic safety rules were observed and one death, one major injury (loss of eyesight) and multiple abortions were reported.

Deviations from basic safety rules observed included:
- A fume hood was not available, had no outlet connection, was not accessible due to lack of free space, or was out of order (Figure 3.1).
- The absence of suction points force technicians to perform chemically risky experiments outside (!).
- Safety gloves and safety glasses were often not available.

Figure 3.1 *A fume hood with no outlet; another is worn out and not sufficiently accessible.*

As mentioned by the laboratory managers, the reason for malfunctioning of the fume hoods and the lack of sufficient safety gloves and safety glasses was the lack of budget.

3.2.2 Budget continuity, appreciation of technicians and autonomy

A laboratory can be regarded as an independent organisation. In order to be able to develop, it requires a transparent and more or less continuous amount of budget: continuity is even more important than the budget level. Only then is the laboratory capable of structurally planning its long-term investments, with regard to equipment, as well as personnel.

It is very unprofitable to let qualified people leave the organisation. Unfortunately, laboratory technicians often leave within one or at the most a few years for better circumstances to other organisations, leaving the former institute with lack of qualified personnel and continuity in the laboratory process. This was found to be a severe problem in most of the laboratories. Reasons for leaving were mainly salary, safety, insurance and recognition. The lack of recognition was partly found in the lack of continuous training required to support adaptation to changing standards, equipment, safety rules, etc. It was also found in salary. Salaries that keep up with competitors motivate technicians to be loyal to the current laboratory. Loyalty was also found to be fundamentally difficult

to achieve, as a result of the conditions mentioned previously. These conditions are required to facilitate technicians as part of a qualified team and, therefore, not only give them the feeling of importance, but actually support them as important team members and enable them to build on further improvements.

Laboratories currently lack autonomy. This prevents smarter and more efficient allocation of available budgets.

3.2.3 Ordering system and maintenance of laboratory and equipment

The ordering system caused many and severe problems for most of the laboratories visited. It relates to chemicals, spare parts, equipment, and also to qualified manpower for maintenance of laboratory and equipment. Not only it is difficult to find the right local- or international supplier, but also the ordering times are far too long (six months or more is not exceptional), and the quality of the materials received is insufficient most of the time. There is also a severe lack of qualified personnel present in the laboratories to perform maintenance, causing parts of the laboratory to remain out of action for years. Much new equipment was observed to have never been installed, and, thus, had been unused for several years (Fig. 3.2). The result of all this is that the laboratories:

- operate under unsafe situations, when there is a lack of spare parts for fume hoods or the like.
- are unable to perform experiments for a long period of time with defective equipment, missing chemicals, lack of demineralised water, or a non-working backup generator.
- leave personnel hours un-allocated, thus, generating a costly manpower overcapacity.
- generate unreliable results, when using chemicals with insufficient purity, or insufficiently operational equipment.

Bid-system

In the governmental-financed laboratories, the bid-system is used most frequently. The set up of this system is meant to reduce manpower and costs. This is understandable, but in the current situation, it is no longer working well. The procedure, as told by the laboratory heads, is as follows:

1. It is obliged to make use of the standard bid-system.
2. A standard ordering form must be completed and sent to the financial department of the Ministry or Bureau.
3. The financial department collects the forms of different users.
4. When a sufficient number of forms are collected, the department contacts different suppliers with the demand to make an offer for delivery of the goods.
5. Ultimately the less-expensive supplier is granted the application.

Points 3 and 4 in particular cause unacceptable delays in delivery. Point 5 often causes the delivery of goods that do not comply the requested quality, making it necessary to use these goods, almost per definition with resultant unreliable determinations, or when the material is send back to the supplier, resulting in further delays in (already long) delivery times. The net result is a waste of manpower, resulting in a significant waste of budget. As the laboratories are (partly) out of action for a longer period of time, this system is experienced as one of the most bothersome problems of all.

Figure 3.2 *Costly equipment that is not in use, due to a lack of knowledge for installation and operation, or missing spare parts.*

3.3 Ethiopian laboratories (larger infrastructure)

3.3.1 Laboratory versus consultancy

Regarding the Ethiopian laboratory infrastructure, an important issue to be addressed is the definition of the word 'laboratory'. When talking about a laboratory in Ethiopia most people we spoke and interviewed did not only talk about the facility in which experimental determinations are performed, but also about the consultancy part that belongs to it.

Most laboratories in Ethiopia operate independently from each other. This is historically driven, where budget allocations are independently assigned by MoFED, or by one of the federal ministries (e.g. MoA, MoE), or by one of the regional bureaus (e.g. BoA, BoE and alike). Most of the laboratories not only consist of a place where the experimental analyses are performed, but also consist of an integrated consultancy bureau, with the latter providing solutions for a specific problem (e.g. soil fertility, soil acidification or ground water pollution). Historically, some of these bureaus required (experimental) laboratory facilities. Moreover, when these bureaus comprised of different departments, often more than one of these departments required a laboratory. As not all departments were financed by the same Ministry (the issues to be solved relate to different ministries), it was quite common to develop more than one laboratory within one organisation at one location, even if the experimental laboratory determinations were more or less the same.

In this report, focus is mostly on the (experimental) 'laboratories': *How do they perform? Where are they located?* and *How can the sampling to laboratory time be reduced?* A lot of money can be saved, and a lot of vexation can be circumvented by making a clear distinction between a 'laboratory' and a 'consultancy functionality' (the first being the chemical determinations that serve the consultancy, the latter being consultancy issues, such as soil acidification, soil irrigation, soil fertility, and soil salinisation).

3.3.2 Number of laboratories

Table 3.1 gives an overview of the 69 existing Ethiopian soil laboratories. An earlier EthioSIS inventory (Bulens and Okx, 2012) showed more laboratories. The differences can be explained as the EthioSIS inventory counted:

- all Ethiopian Institute for Agricultural Research (EIAR) laboratories instead of only the EIAR 'soil' laboratories.
- not only existing Ministry of Environment & Forest (MEF) laboratories, but also the planned ones.
- all private laboratories instead of only the private 'soil' laboratories.

As general data regarding existing soil laboratories is scarcely available, some difference between the results and the actual situation might still exist.

Table 3.1

Available Ethiopian soil laboratories in 2015. In brackets, the number of laboratories from an earlier inventory (Assen, 2012).

Cat	Organisation/ Institute	Federal	Regional	Total
1	EIAR Soil Laboratories	9 (16)	21 (27)	30 (43)
2	Higher Education Institutes (HEI)	9	0	9
3	Ministry of Environment and Forest (MEF)	1	0 (5)	1 (6)
4	Water Works and Design Supervision Enterprise (WWDSE)	1	7 (4)	8 (5)
5	MoA/BoA Soil Laboratories	1	17	18
6	Private laboratories	3 (9)	0	3 (9)
	Total	**24 (37)**	**45 (53)**	**69 (90)**

Three major groups of laboratories can be distinguished:

1. **(Governmental) University or Higher Education soil laboratories**.
   Main purpose: education and training;
2. **Governmental Agricultural laboratories**.
   Main purpose: support of agriculture and agricultural research;
3. **Private laboratories**.
   Main purpose: support of agriculture and agricultural research.

The organisational structure of the education and private laboratories is quite straightforward. The governmental agriculture laboratories do not differ in terms of performed analyses, but they can be distinguished in terms of their 'parental' organisations:

a. The EIAR and the MoA/BoA soil laboratories depend financially upon (get their budgets from) different organisations, (MoFED and MoA/BoA), but are all accountable to (need to inform) MoA (EIAR and MoA) and BoA (BoA);
b. The MEF soil laboratories;
c. The market-oriented WWDSE laboratories.

3.3.3 Organisational and financial infrastructure

The budgets for the three above mentioned groups of Ethiopian laboratories are allocated from seven different sources, as is indicated in Table 3.2. The accountability is slightly less complicated, as can be seen in the table. The EIAR labs, as well as the MoA/BoA labs, are accountable to MoA/BoA. Although seven different sources were identified, ultimately the budgets come from only three main sources (see Figure 3.3):

- federal tax;
- regional tax; and
- the market.

Table 3.2

Budget sources and accountability.

Cat	Organisation/ Institute	Number	Budget from	Accountable to
1F	Federal EIAR Soil Laboratories	9	MoFED/Federal tax	MoA
1R	Regional EIAR Soil Laboratories	21	BoFED/Regional tax	BoA
2	Higher Education Institutes (HEI)	9	MoE/Federal tax	MoE
3	Ministry of Environment and Forest (MEF)	1	MEF/Federal tax	MEF
4F	Federal WWDSE Soil Laboratory	1	market*	WWDSE
4R	Regional WWDSE Soil Laboratories	7	market*	WWDSE
5F	Federal (MoA) Soil Laboratories	1	MoA/Federal tax	MoA
5R	Regional (BoA) Soil Laboratories	17	BoA/Regional tax	BoA
6	Private laboratories	3	market	-
	Total	**69**		

* market: largest input comes from Ministry or Bureau of Water Works and Energy projects

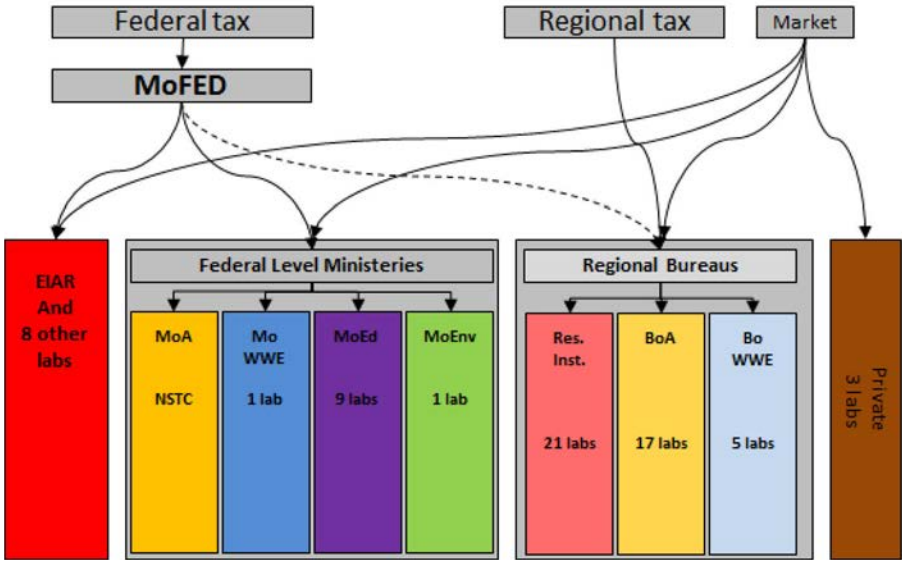

Figure 3.3 *Budget sources.*

3.3.4 Spatial distribution of Ethiopian soil laboratories

The locations of the laboratories more or less correspond to the AGP woredas (Figures 3.4 and 3.5). The laboratory density in the country is very high, except for Afar, Somali and the southern part Oromiya. The 69 laboratories are distributed over 35 cities, which means that on average 35 cities have two or more labs.

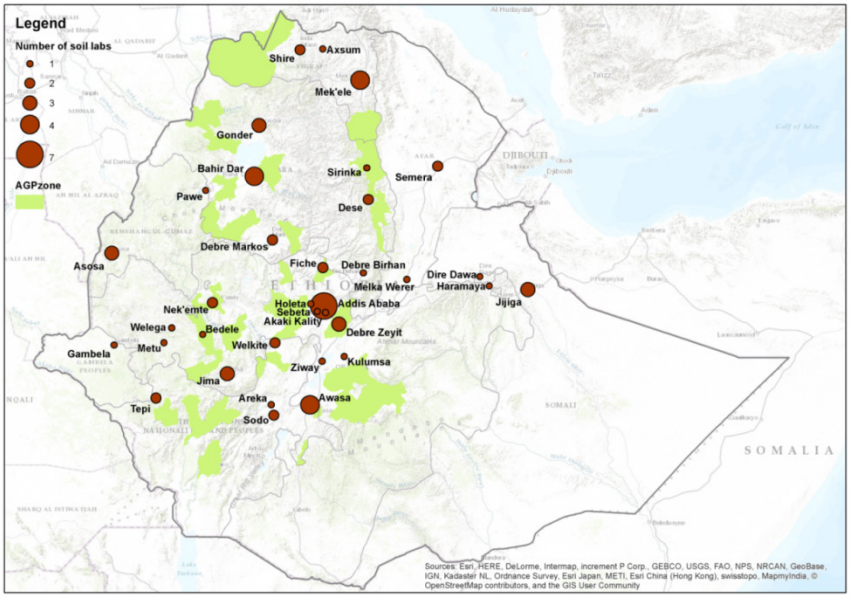

Figure 3.4 *Distribution of the laboratories over the country.*

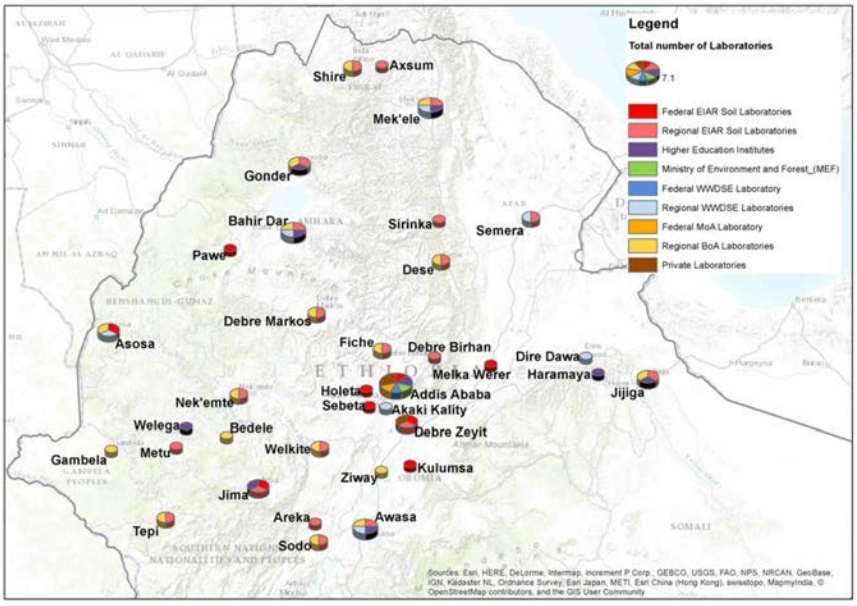

Figure 3.5 *Distribution of the different laboratory groups over the country.*

3.3.5 Coordination of fieldwork

Generally, to be able to generate reliable data, all the components in the 'Field-to-Laboratory-Output' – chain (Figure 3.6) must be performed in a reproducible and, thus, standardised manner. This is not only valid for a laboratory, but also for fieldwork. Standardised procedures must be followed, preferably conforming to ISO: obligatory notes to be recorded in the field, the method of closure of the sample box after sampling, cooling during transport, maximum delays between the several steps, and analysis methodology in the laboratory. The laboratories are an important link, but cannot operate independently, and cannot generate reliable data if other items are addressed without knowledge. Data is as reliable as its weakest link. Therefore, focus here was made on the most crucial parts in the chain.

Field sampling
Many different people (farmers, field workers or researchers) are occupied with field sampling in Ethiopia. Therefore, it is hard to ensure standardisation.

Transport times
Transport time, defined here as the time between field sampling and sample preparation (drying, grinding and sieving), must be reduced as far as possible, but should in any case be less than 24 hours for samples that are sensitive to change, such as nitrate and ammonia, and preferably less than 48 hours for other sample determinations. Longer transport times will result in unreliable laboratory output data. In Ethiopia, the time between sampling and sample preparation is generally far too long. The interviews made clear that transport times in Ethiopia vary from eight hours to several months. The latter being more common than the first. The first is perfect; the latter, unacceptable.

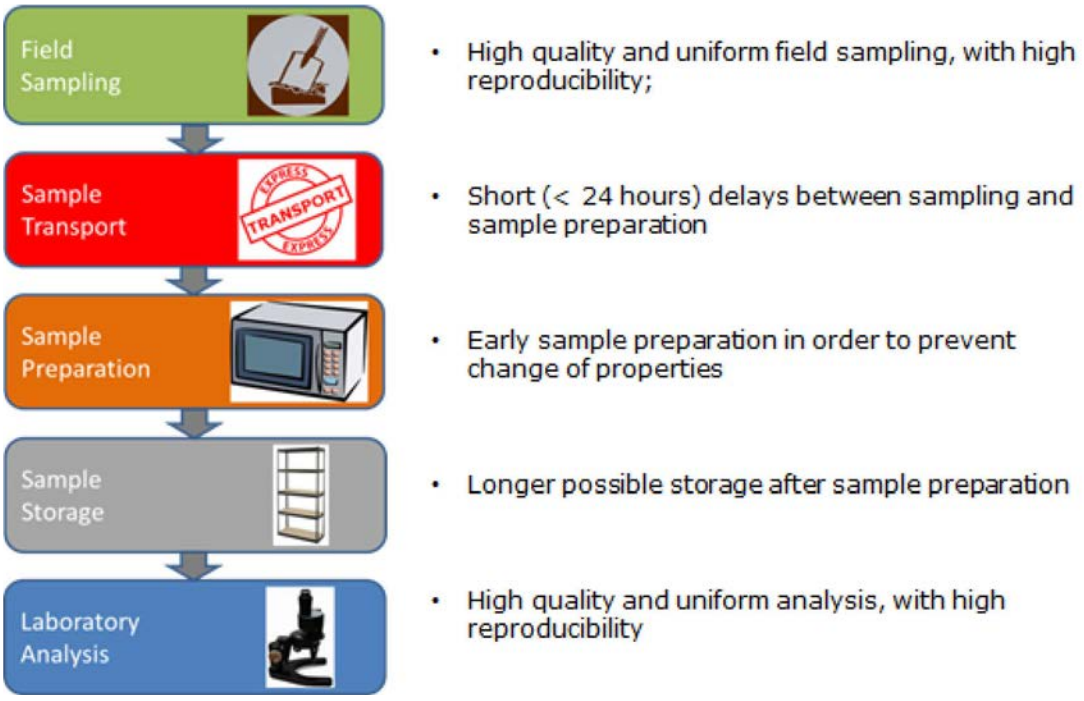

Figure 3.6 *The 'Field-to-Laboratory Output' – chain.*

Often field moist samples from several locations are collected during a longer period of time, and are temporally stored in un-cooled stocks before they are transported to the laboratories, where they can be prepared.

Sample preparation
Sample preparation is currently performed within the laboratories. The drying procedure is normally performed in stock houses by drying on air. Drying can take several days to weeks, dependent on the sample size.

Figure 3.7 *Drying in air can take too long.*

3.4 Institutional settings

To be able to define a scenario (Chapter 4) that incorporates most of the important problems mentioned in this report, and that can really be implemented, it is necessary to know the institutions that are involved in any part of the chain.

3.4.1 Major players on federal level

The following institutions are considered as major players on the federal level:

- Ministry of Agriculture and Rural Development (MoA): The Ministry of Agriculture and Rural Development is the Ethiopian Government Ministry that covers the agricultural- and rural development policies of Ethiopia on a federal level. The powers and duties of the MoA include: conservation and use of forest- and wildlife resources, food security, water use and small-scale irrigation, monitoring events affecting agricultural development and early warning system, promoting agricultural development, and establishing and providing agriculture and rural technology training. MoA is the key decision-maker for the Ethiopian Soil Laboratory Infrastructure www.moa.gov.et;
- National Soil Testing Centre (NSTC): The National Soil Testing Centre under the Ministry of Agriculture and Rural Development. It carries out various activities related to soil, such as soil chemistry, soil physics, soil fertility, soil biology, soil mapping, and database management. It provides service to investors and governmental institutions. www.nstc.gov.et;
- Ethiopian Institute of Agricultural Research (EIAR): EIAR is responsible for running the federal research centres. In addition to conducting research at its federal centres, EIAR is charged with the responsibility of providing the overall coordination of agricultural research countrywide, and advising the government on agricultural research policy formulation.

3.4.2 Regional players

- Soil Laboratories accountable to the Bureau of Agriculture (BoA): these soil laboratories are dedicated to soil testing for agricultural purposes. Their work is directly linked to the Ethiopian agricultural production;
- Soil Laboratories accountable to the Regional Agricultural Research Institutes (RARI): the laboratory work of the RARI's is aimed at supporting agricultural research.

3.4.3 Supporting players

- Agricultural Growth Program (AGP)/The World Bank: one of AGP's objectives is strengthening Soil Testing Laboratories by building the capacity of soil analysis techniques; provision of analytical equipment, chemicals and training to promote improved fertilizer use, based on soil analysis. AGP is a program of the World Bank;
- United Nations Development Programme (UNDP): UNDP is currently renovating the NSTC facility in Addis Ababa. The project will address laboratory safety, workflow efficiency, physical sustainability, long-term usability, functionality, and environmental sustainability;
- Water Works Design and Supervision Enterprise (WWDSE): WWDSE operates a number of soil laboratories in the country. Their specialty is soil (hydro) physics analyses;
- Environmental Laboratory of the Ministry of Environment (MoEnv): operates a central laboratory in Addis Ababa and is planning to build a number of additional laboratories in the regions.

4 Proposed measures

4.1 Structure of the measures

As shown, Ethiopian laboratories need to improve their analytical services. Many of these laboratories offer soil-, water- and plant analytical services. However, the potential of these laboratories is not fully used due to a series of problems. The main problems were identified at organisational levels, and are not merely a matter of lack of budgets for facilities. Apart from organisational problems, managerial-, human resources-, technical-, instrumental- and supply issues have been identified.

The proposed measures in this chapter are organised into three work packages. The need for a chronological approach of the recommended measures is emphasised according to the scheme below. In the past, much effort is already invested in new equipment, training and partial standardisation (as indicated by Package II of the scheme below). The extended effort, however, did not result in a lasting improvement of the overall quality. A key conclusion of the current research is the need for a chronological approach (according to the scheme below) to the measures to be taken. The background of this approach is that sustainable development of a laboratory is only possible when basic requirements are met. Therefore, it cannot be emphasized enough that Packages I.A and I.B need to be completed in order to enable the mentioned measures of Package II gain a desirable and durable effect. Investments in effort and money of the measures from Package II cannot be justified, as long as Packages I.A and I.B are not completed.

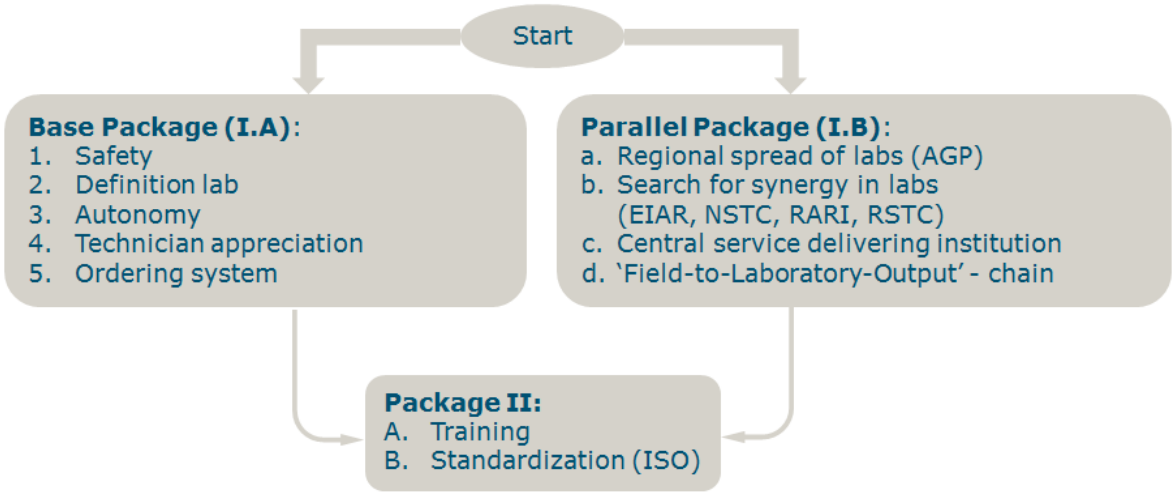

Figure 4.1 *Chronological approach of the proposed measures.*

Package I.A is most urgent and covers severe safety aspects, as well as the recognition of the fact that most established departments perform the same technical analytical laboratory experiments, despite their different consultancy jobs. This recognition is important to understand the logic of the follow up of the measures in Package I.B. However, there is also need for more self-ruling possibilities. They are required to improve technician appreciation, and also to improve the quality and time-efficiency of the ordering of chemicals, equipment and spare parts. It should be noted that currently the appreciation of laboratory technicians, as well as the ordering system, are both paralysing problems.

Package I.B Package I.B can be performed in parallel with, or after completion of, Package I.A. It covers the inevitable need for merging soil related laboratories, which is necessary to establish fewer,

but large, qualitatively strong and cooperating soil laboratories. The current structure of separate consultancies, as indicated in Package I.A, can be maintained, but the analytical services must be synergised. It is a misconception that reliable data can be accomplished by a strong laboratory only. Therefore, directly related to the set up of a strong laboratory structure throughout Ethiopia, this package covers integral adjustments in services and structures that are needed to accomplish reliable field sampling, reliable sample transport and reliable sample preparation.

Package II covers training of personnel and standardisation issues. However, Packages I.A and I.B need to be completed first.

4.2 Package I.A: Key solutions

With respect to the current situation, some first key measures must be implemented. They can be implemented without Package I.B, but it is recommended to perform the actions together with the merger actions, as mentioned under Package I.B. The measures of Package I must be implemented before continuing with Package II.

4.2.1 Safety

Safety is by far the most important issue to be addressed. As mentioned by the laboratory managers, the reason for the malfunctioning of the fume hoods and the lack of sufficient safety gloves and safety glasses is lack of budget. Insufficient safety has already resulted in one death, one major injury (loss of eyesight) and multiple abortions.

The authors believe that there is no justification in spending budgets first on chemicals, or any other laboratory item, while safety aspects are not met.

Safety should never be a compromise. Safety comes first and at all times.

Any laboratory unable to meet safety regulations should be closed immediately.

4.2.2 Laboratory versus consultancy

In most countries, service laboratories are just that. They provide analytical services to clients. Except on a voluntary basis or in slack periods, laboratory personnel should not be expected to run field trials, as appeared to be the case in several of the laboratories visited. Each chemist, laboratory technician and field worker has their specific 'know-how', which cannot be interchanged between agronomists, soil scientists or field technicians. Their function should be well defined. A clear distinction between laboratory functionality and consultancy functionality is required. Therefore we urge to make a clear distinction between a 'laboratory' and a 'consultancy' functionality, in daily terminology, as well as in organisational structures.

By doing so, the definition of a laboratory (= a room or building equipped to conduct experiments or tests, especially under controlled conditions) is more general applicable than in the present context. When subsequently making an inventory of all the 'soil laboratories' in Ethiopia, it will become clear that many soil laboratories are clustered, and perform more or less the same experiments. A huge benefit can be gained by recognising this phenomenon, and by searching for collaboration possibilities, in which many of the budget related problems can be solved.

Moreover, it must be noted that there is also a great overlap in determinations and equipment when considering 'soil testing laboratories' in relation to 'water testing laboratories', increasing the potential benefits of collaboration even more.

4.2.3 Budget continuity, appreciation of technicians and autonomy

Not only do budget allocations need to be transparent and continuous, but the organisation of budget flow must also be such that a laboratory is rewarded for hard work, and that it is allowed to make progress. Therefore, it requires a certain amount of autonomy. Most laboratories that now serve under a Ministry are obliged to return income from determinations for third parties, partly or completely, to the Ministry. Although this seems a quite straightforward and honest rule, it prevents the laboratory from being creative and discourages hard work. By giving the laboratory self-ruling possibilities, it is stimulated to search for better circumstances for the laboratory itself, as well as for its personnel. It can be very profitable to share facilities and knowledge with other laboratories in the neighbourhood, for example. This is, ultimately, of course, profitable for the Ministries too.

4.2.4 Ordering system

There are several options for improvement:
- Give laboratories autonomy in ordering goods. They know best what is good for their laboratory, also from a financial point of view.
- Change the bid-system, such that there is a long list of 20 possible suppliers. The first time the first three suppliers are requested for a delivery. If the results are poor, the supplier will be transferred to a blacklist, whereas the next supplier from the long list will be invited next time.
- Apply knowledge of laboratory issues at the financial department, e.g. by installing laboratory experts at the ordering post.
- In order to drastically reduce delivery times, omit the collection of forms, as indicated in Point 3. Reduction of the needed manpower in this step can be organised by authorising the laboratory manager to place the order (e.g. via the bid-system).
- Organise a help-desk for laboratory heads and other partners in the 'Field-to-Laboratory Output' – chain to share knowledge regarding possible local and non-local suppliers.

4.3 Package I.B: Inter-laboratory structure

4.3.1 Some first directive remarks

In order to understand the reason for the proposed measures of the following paragraphs, some directive remarks can be made.

Number of laboratories
Some general recommendations regarding soil laboratories in Ethiopia:
- The number of laboratories in Ethiopia is very high, and can be reduced without negatively affecting the service level, provided that the infrastructure is adapted.
- Attribute one central registration to all soil laboratories operating in Ethiopia. This registration should include information on the demand of certification.

Organisational and financial infrastructure
In the search for collaboration possibilities between the three major groups of laboratories, as mentioned in Paragraph 3.3.2, the educational laboratories differ in goal and financial dependency from the other two groups. From a financial and organisational point of view, governmental agricultural laboratories offer the best opportunities. Therefore, the recommendations will focus mainly on these laboratories:
- Since the EIAR and the MoA/BoA laboratories perform very similar duties, and are accountable to the same organisation, it is beneficial to merge them into one organisation.
- Investigate the possibility of merging the 30 EIAR (federal and regional) and the 18 MoA/BoA laboratories into one organisation.
- Maintain the total budget, but reduce the number of laboratories to a set of five to eight, strong, fully equipped, high capacity laboratories, and introduce a relatively high number of cheap sample preparation satellites equally distributed over the AGP areas, all financed by MoFED/MoA directly.

The Ministry and the Bureaus of Environment and Forest are seemingly planning for five, new regional laboratories. It is recommended not to invest in new laboratories, but to opt for structural support of the above-mentioned five to eight laboratories instead.

Spatial distribution of Ethiopian soil laboratories
Recommendations regarding the spatial distribution of the governmental laboratories:

- Even if the university laboratories, the private laboratories and the Addis Ababa based laboratories are not taken into account, many cities with more than one laboratory can be found. In 16 cities, there are both EIAR and MoA/BoA laboratories. All of them offer the same services, but suffer from lack of budget, equipment and supplies. A merger of the EIAR and MoA/BoA laboratories could – provided the total budget remains as it is - improve their situation.
- It would be even more beneficial if the merger would include the MoF and the WWDSE laboratories. The WWDSE laboratories have managed to change their business model in such a way that they no longer depend on the financial input of the Ministry or Bureaus of Water Works and Energy. It is recommended to investigate how this business model could be adapted over a period of time.

Coordination of field work
Preferably sampling should be performed by a fixed group of people that use the same standards, especially for research and consultancy projects. However, sampling by third parties cannot always be prevented. In all cases, the report of the laboratory results must be accompanied by the relevant field-standard.

As transportation from field to laboratory normally takes a long time, the solution for shortening these times can be divided into:

- Better distribution of the laboratories over the country.
- Creating a fine mesh of relatively simple sample preparation locations.

Sample preparation must also be standardised and performed, such that drying times are as short as possible (preferably within 24 hours at 40 ◦C in an oven). Treated as such, the samples can be kept in a closed bottle for years before the need of analysis. Care must be taken to prevent inter-contamination during drying.

To shorten transport times, with the right people doing the right things at the right moment, there needs to be an organisational structure around the complete set of 'Field-to-Laboratory Output' – chain. This is further explained in 4.3.3. and 4.3.4.

4.3.2 Proposed working scenario

The proposed working scenario involves strategical-, tactical-, as well as operational decision-making, and requires involvement at political-administrative level, of the laboratory heads, as well as the different unit heads within the laboratories:

- **Strategic plans** must be designed with the entire inter-laboratory organisation in mind, and begin with an organisation's mission. Top-level managers will design and execute strategic plans to paint a picture of the desired future and long-term goals of the organisation. Essentially, strategic plans look ahead to where the organisation wants to be in three-, five-, or even ten years.
- **Tactical plans** support strategic plans, by translating them into specific plans for the different laboratories. Tactical plans are concerned with the responsibility and functionality of the laboratories to fulfil their parts of the strategic plan.
- **Operational plans** are the plans that are made by frontline, or the unit heads within the laboratories. All operational plans are focused on the specific procedures and processes that occur within the lowest levels of the organisation. Unit heads must plan the routine tasks of the unit using a high level of detail.

Phase I: The political-administrative level should make decisions on the amount of soil laboratories, their regional spread, the sample preparation locations, and the establishment of a central institution. This last institution sets quality levels (standardisation and certification aims) of the connected laboratories.

Phase II: The laboratory heads should make decisions on the implementation plan and they are responsible for the implementation of the plans within a given time framework.
Phase III: The unit heads will focus on specific analytical procedures and processes, such as analytical quality control (AQC).

The result is that laboratories will work according to a fixed format, which will lead to an overall quality improvement. This will guarantee better soil classification and thematic maps (fertility, OM, etc.).

4.3.3 Merger of EIAR and MoA/BoA laboratories

The locations of the laboratories correspond more or less to the AGP woredas (see Figures 3.4 and 3.5). The laboratory density in the country is very high, except for Afar, Somali and the southern part of Oromiya. The 69 (non-certified) laboratories are distributed over 35 cities, meaning that on average 35 of them have two or more laboratories. From the total amount of 69 soil laboratories, EIAR, MoA and BoA laboratories account for 48.

The analytical laboratory output results of these 48 laboratories are used for decision making in agriculture, which is the most important economic sector in Ethiopia. Results from non-certified laboratories are not acceptable, because reliability is not guaranteed, and could therefore result in disastrous decision-making. More equipment or more training will not structurally increase the output quality. A key issue is that the total available budget is not enough to run 48 laboratories in a proper way.

Figure 3.3 shows that there are nine federal EIAR laboratories, 21 regional EIAR laboratories, one federal MoA laboratory and 17 regional BoA laboratories. They are all dedicated to agriculture and all offer the same analytical services (the consultancy focus only may differ).

It is suggested that the Ministry of Agriculture seriously considers a reorganisation that consists of merging EIAR and BoA/MoA laboratories into one solid co-operating structure, financed by either MoFED or MoA, leading to a heavy reduction of the total amount of laboratories, but in an increase of cheap, sample preparation satellites.

The EIAR-MoA-BoA merger makes sense, because:
- the amount of 69 laboratories in Ethiopia is heavily excessive.
- EIAR and MoA/BoA operate 48 of them. The number can be strongly reduced, without negatively affecting the analytical services needed.
- the total budget is too small to maintain 48 high quality certified labs.
- all laboratories suffer from a lack of technical support, regarding: technical maintenance, ordering of proper spare parts and chemicals. This kind of support can be delivered by one central institution.
- personnel satisfaction is currently low and ambitions are high.
- field sampling-to-laboratory times are currently far too long

Main laboratory structure
The following main laboratory structure is suggested:
- the establishment of (see Figure 4.3):
  - one central institution (Ethiopian Quality Unit for Agricultural Laboratories – EQUAL, e.g. based at NSTC or EIAR Head Office).
  - five to eight, strong, fully equipped, high capacity labs, equally distributed over the AGP areas;
  - surrounded by cheap and low equipped (!), sample preparation locations, to reduce sampling to laboratory times.
- all entities within the laboratory structure should be financed by MoFED/MoA directly.

Additional remarks
As far as can be concluded in this survey:
- EIAR laboratories operate under better financial circumstances than the MoA/BoA laboratories, and have more advanced standardisation and qualified staff.

- The Ministry and the Bureaus of Environment and Forest (MoF) are planning five new regional laboratories. It is recommended not to invest in new laboratories, but to support the above instead.
- It would be even more beneficial if the merger would include the MoF and the WWDSE laboratories.
- The WWDSE laboratories have managed to change their business model, such that they no longer depend upon the financial input of the Ministry or Bureaus of Water Works and Energy. It is recommended to investigate if this business model can be adopted for the long-term.

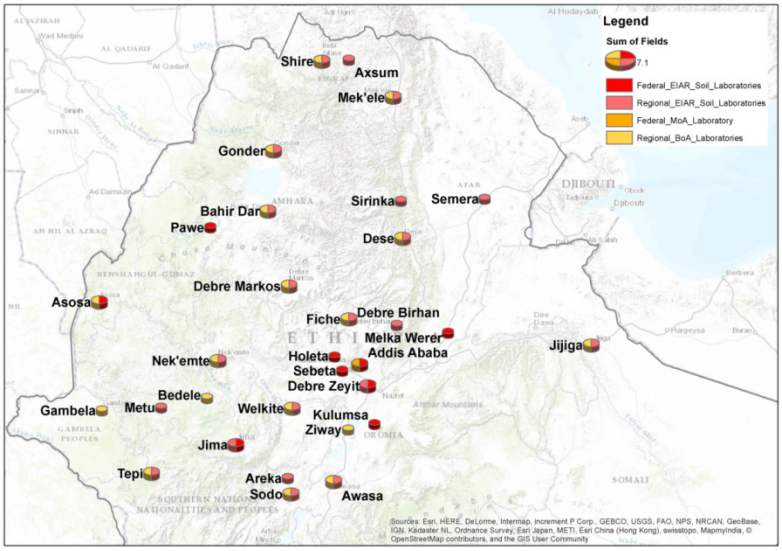

Figure 4.2 *EIAR and MoA/BoA laboratories.*

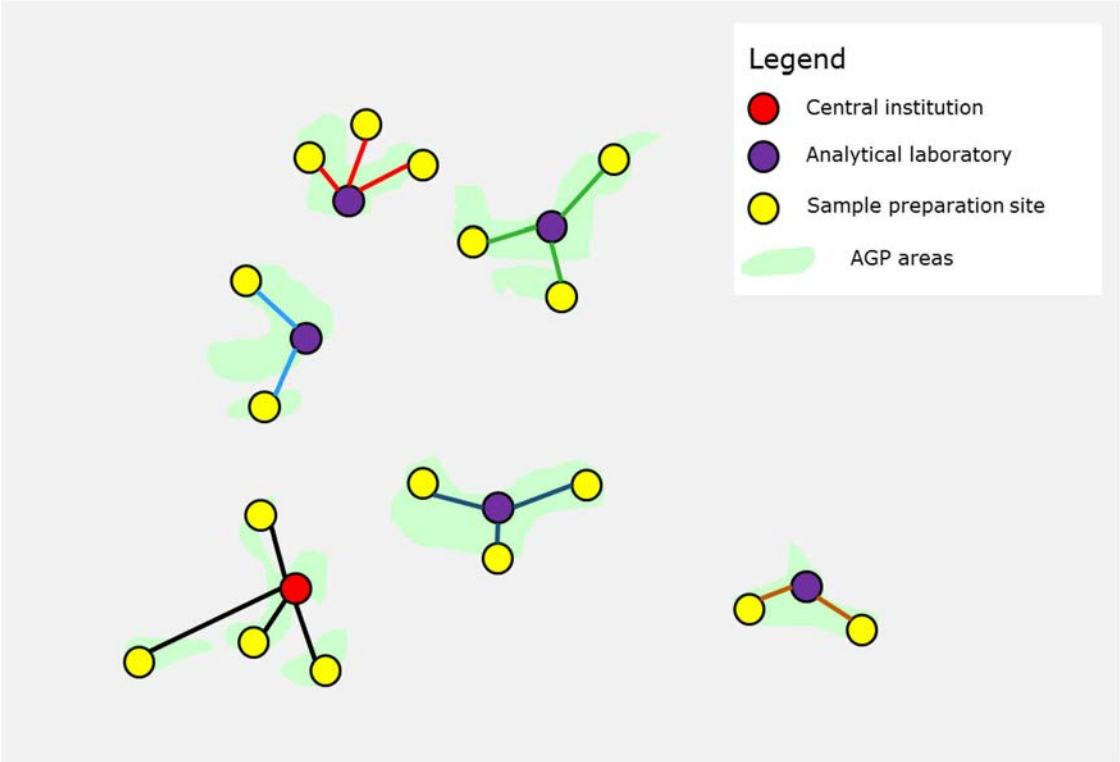

Figure 4.3 *Possible constellation for a central institution, several regional laboratories plus satellites.*

4.3.4 Establishment of a central institution

A central institution should be established with a coordinating and service delivering task. Its first assignment, however, should be to drive forward the fundamental restructuring of the professional, institutional, and material conditions for soil analysis in Ethiopia. Its focus should be ensuring a high quality analytical chain with the ability to keep up with the growing international competition. After the restructuring is complete, it will maintain more structural service delivering tasks, such as:

1. Central purchase of cheap and high quality chemicals.
2. Central purchase of cheap and high quality equipment.
3. Coordination of qualified people for maintenance of laboratory infrastructure.
4. Coordination of qualified people for maintenance of equipment.
5. Coordination of sampling flow from field to laboratory intake.
6. Standardisation (procedures, equipment) and certification (ISO 17025).
7. Purchasing of chemicals, equipment and spare parts.
8. Advise on laboratory design/maintenance.
9. Development and coordination of technical courses on:
    a. Sampling.
    b. Soil classification.
    c. Sample routing.
    d. Analytical procedures.
    e. (ISO) standards.
10. Coordination of inter-laboratory control.
11. Laboratory results control, output standardisation (EthioSIS data model).

The establishment of such a central institution could be part of the UNDP NSTC Phase 2 Programme. In that case, this institute would likely be linked to the NSTC, and should lead to the development of Ethiopia-wide unified standards and their consistent implementation. EQUAL must partly be financed directly by MoFED/MoA and be partly self-supporting by gaining income for the delivered services on a package basis (to prevent laboratories from contacting EQUAL, when without need).

4.4 Package II: Training and Standardisation

Training is important, even in the current situation. However, the authors of this report believe that training is a waste of money and effort within the current situation, because it will only increase the output results for a very limited period of time. The main reason for this is mentioned Paragraph 3.2.2. Investments in structural trainings should therefore only be implemented after realisation of Packages I.A and I.B. In which, Package I focuses on creating the *conditions*, environment, and structure, in which quality improvement becomes viable, and Package II focuses on the actual realisation of quality improvement by trainings and standardisation.

4.4.1 Sampling

Learning goals
Correct procedures for soil sampling and sample preparation depend upon the type of analysis performed. Soil samples for nutrient management are typically dried and sieved or pulverized to provide a stable homogeneous mixture for convenience of laboratory analyses. For soil (hydro) physics determinations, undisturbed soil core samples must be taken in the field. Proper sampling procedures and the use of standards are essential for accurate analytical results. In the sampling training, the trainees learn how to take and prepare samples in the right way.

Prior knowledge
Some affinity with soil science and analytical procedures is beneficial.

Teachers
Wageningen UR – Chemical Biological *Soil Laboratory* (CBLB) staff and Soil (hydro) Physics Laboratory (SPL) staff.

Duration
Three days.

4.4.2 Sample logistics

Learning goals
For some types of analysis, the time between the actual sampling and sample preparation is irrelevant. For other types of analysis, the time is fixed to a maximum and should not be surpassed. After this course, participants should have understanding of: 1) the relation between sampling, sample preparation and analysis, and 2) maximum storage times.

Prior knowledge
Some affinity with soil science and analytical procedures is beneficial. Good knowledge of English.

Teachers
Wageningen UR – Chemical Biological *Soil Laboratory* (CBLB) staff and Soil (hydro) Physics Laboratory (SPL) staff.

Duration
1 day.

4.4.3 Analytical procedures

Learning goals
Analytical quality control (commonly shortened to AQC) refers to all those processes and procedures designed to ensure that the results of laboratory analysis are consistent, comparable, accurate and within specified limits of precision. Quality control begins with sample collection and ends with data reporting. AQC is achieved through laboratory control of analytical performance. Initial control of the complete system can be achieved through specification of laboratory services, instrumentation, glassware, reagents, solvents, and gases. However, evaluation of daily performance must be documented to ensure continual production of valid data. A check should first be done to ensure that the data is precise and accurate. Next, systematic daily checks, such as analysing blanks, calibration standards, quality control check samples, and references, must be performed to establish the reproducibility of the data. The checks help certify the reliability of the methodology. After successful completion of the course, attendees will be able to implement AQC according to (ISO) standards in their laboratory.

Prior knowledge
BSc and MSc level in chemistry. Good knowledge of English.

Teachers
Wageningen UR – Chemical Biological *Soil Laboratory* (CBLB) staff and Soil (hydro) Physics Laboratory (SPL) staff.

Duration
Five days.

4.4.4 Soil classification

Learning goals
After this introductory course, participants should have a (general) understanding of: 1) terminology and concepts in soil classification, 2) World Reference Base for Soil Resources, 3) The groupings of major soils in Ethiopia, and 4) use of soil classification for interpretative purposes.

Prior knowledge
BSc and MSc level in soil science. Good knowledge of English.

Teachers
ISRIC – World Soil Information.

Duration
Five days.

4.4.5 ISO/IEC 17025 Laboratory Accreditation

Learning goals
ISO/IEC 17025 General requirements for the competence of testing and calibration laboratories is the main ISO standard used by testing and calibration laboratories. In most countries, ISO/IEC 17025 is the standard for which most laboratories must hold accreditation to be deemed technically competent. In many cases, suppliers and regulatory authorities will not accept test or calibration results from a laboratory that is not accredited. Originally known as ISO/IEC Guide 25, ISO/IEC 17025 was initially issued by the International Organization for Standardization in 1999.

The ISO/IEC 17025 standard itself comprises five elements: Scope, Normative References, Terms and Definitions, Management Requirements and Technical Requirements. The two main sections in ISO/IEC 17025 are Management Requirements and Technical Requirements. Management requirements are primarily related to the operation and effectiveness of the quality management system within the laboratory. Technical requirements include factors that determine the correctness and reliability of the tests and calibrations performed in the laboratory.

Laboratories use ISO/IEC 17025 to implement a quality system aimed at improving their ability to consistently produce valid results. It is also the basis for accreditation from an accreditation body. Since the standard is about competence, accreditation is simply a formal recognition of a demonstration of that competence. A prerequisite for a laboratory to become accredited is to have a documented quality management system. The usual contents of the quality manual follow the outline of the ISO/IEC 17025 standard.

After successful completion of the course, attendees will be able to:
- Recall the differences between registration, certification and accreditation.
- List the steps in the accreditation process.
- Implement ISO/IEC 17025:2005.
- Identify the documents and records required by ISO/IEC 17025:2005; and
- Describe the A2LA policies for Traceability, Proficiency Testing and Advertising.

Prior knowledge
BSc and MSc level in chemistry. Good knowledge of English.

Teachers
To be decided.

Duration
Five days.

Recommendations
Training development is a responsibility of EQUAL.

5 Conclusions

Food security is the main issue in Ethiopia at the moment. Large food security programs have been established with extensive investment from federal- and regional governments, as well as from organisations, such as the Bill Gates foundation, UNDP, AGP and the World Bank. Decision-makers at governmental level, as well as researchers and farmers, share a profound dependency upon reliable data on soils, water and crops. After an in depth investigation of the soil related laboratories in Ethiopia, the authors of this report strongly believe that the data that are generated at the moment, in the chain from soil sampling until laboratory output, are not reliable enough for decision-making purposes. The output of the laboratories needs to be improved.

The main problems were identified at organisational levels, and are not merely a matter of lack of budgets for facilities. Apart from organisational problems, managerial-, human resources-, technical-, instrumental- and supply issues were identified.

In the past, much effort has been invested in new equipment, training and standardisation. This extensive effort, however, has not led to a lasting improvement in the overall quality. A key conclusion of the current research is the need of a chronological approach of measures to be taken via three work packages. The background of this approach is that sustainable development of a laboratory is only possible when basic requirements are met.

A first **Package I.A** of proposed measures covers safety aspects, as well as the recognition of the fact that most of the already established departments perform the same technical analytical laboratory experiments, despite their different consultancy roles. There is also need for more self-ruling possibilities. They are needed to improve technician appreciation, and also to improve quality and time-efficiency of the ordering of chemicals, equipment and spare parts. It should be noted that currently the appreciation of laboratory technicians, as well as the ordering system, are both paralysing problems.

A second **Package I.B** of proposed measures covers the inevitable need to merge soil related laboratories. The current number of soil laboratories is high. To establish a high quality Ethiopian laboratory infrastructure without large additional investments, it is necessary to establish fewer, but large, qualitatively strong, and cooperating soil laboratories. The current structure of separate consultancies can be maintained, as long as the analytical parts synergise. It is a misconception that reliable data is dependent on a strong laboratory only. Therefore, directly related to the set up of a strong laboratory structure throughout Ethiopia, this package covers important adjustments in services and structures that are required to accomplish reliable field sampling, sample transport and sample preparation.

After completion of the first two packages, other plans for improvement can be rolled out:
Package II. All laboratory heads and technicians want to improve the status of their laboratories for better services to the customers. Therefore, they plan to improve the skills of technicians and maintenance personnel, to modernise their analytical equipment, to improve their manuals and procedures, to improve the efficiency and efficacy of the purchasing system, and, finally, to expand their laboratory services from present standard fertility-oriented analysis to a broader range of analytical services. Different laboratories were found to follow different analytical procedures. Inter-comparison of these results is therefore difficult, if not impossible. This affects the quality of recommendations of required soil and water management and technologies on the national-, as well as regional/local levels. Thus, it is suggested that all laboratories use the same standards/manual and update when needed, and offer refreshment courses to experts, once an update is implemented. Last, but not least, a focus on quality control mechanisms is suggested. Laboratory quality control is designed to detect, reduce, and correct deficiencies in a laboratory's internal analytical process, prior to the release of the results to improve the quality of the results reported by the laboratory. None of

the laboratories used acceptable quality control mechanism. Therefore, it is suggested that all laboratories implement quality control mechanisms, following completion of Packages I.A and I.B.

These plans cannot be achieved without sufficient resources and support and that is exactly the reason why reorganisation must be considered before taking action, for it is impossible to upgrade all existing soil laboratories within the present budgetary and organisational constraints.

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