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IMPROVEMENT OF SOIL SERVICES FOR AGRICULTURAL DEVELOPMENT (ETH/87/010)

SURVEY OF SOIL TESTING AND PLANT ANALYTICAL LABORATORIES IN ETHIOPIA

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1. INTRODUCTION

Agriculture is the mainstay of the Ethiopian economy employing about 85% of the labor force. It contributes about 45% of the GNP and accounts for about 90% of the total export earnings.

Ethiopia is endowed with potentially rich natural resources, of which land is the principal one. Out of the country's total land area of 122 million hectares, at present only 17 million hectares of land, whose fertility is continuously declining, are said to be under cultivation. On the other hand, the population of the country which stood at 52.1 million in 1992 is expected to rise to 67.1 millon by the year 2000, and 113.6 million by the year 2015.

With the rapidly increasing population, the pressure on land for the production of the increasing demand for food, fuel and fibre is becoming enormous. Moreover, the increasing cattle population and its competition for arable agricultural land is having a devastaling impact on the soil. TO meet the above demands, vast tracks of land are being brought into cultivation yearly. In addition, new and often marginal lands which are more susceptible to degradation with cultivation are also brought into production. Further, a combination of factors such as poor management of land and water resources and the low level of technology employed has resulted in many forms of soil degradation such as nutrient loss, erosion, salinity, and toxicity often resulting in desertification.

Considering the fact that the amount of land available for cultivation and its production potential is fixed, it is imperative that this scarce land resource be properly managed for sustained productivity. The immportance of soil at present and in the foreseeable future as the basis for food production is evident. In order to obtain acceptable economic yields and at the same time to conserve the soil fertility, it is imperative that a more rational and scientifec approach be pursued. Detailed soil studies supported by strong soil analysis laboratory services in order to better understand the physical and chemical characterisitics of the soil, constitute the essential tool that will enable a more rational and appropriate use of the soil.

Soil and plant analytical laboratories are important because they provide an essential support to agricultural research and development. Good soil management is essential to provide the food needs of the rapidly growing population on a sustainable basis. The increase in food production by improving the fertility of land presently under cultivation and by expansion of agriculture to virgin areas will be a bigger challenge to soil management. Soil and plant analysis laboratories play major role in guiding and improving soil management practices there-by increasing the food supply.

There are a number of soil and plant analysis laboratories under various institutions in the country. These laboratories, though established for similar purposes, are operating on indiviual basis lacking any kind of communication and exchange of information which are essential for the reliability and proper utilization of analytical data, Moreover, most of these laboratories receive insufficient support for proper functioning.

This problem was thoroughly discussed during the 1[st] Natural Resources Improvement conference held in, 1989. Being aware of the fact that under the present situation the soil testing services could not be expected to be efficient enough to fulfill the analytical requirements, the conference participants decided that a system shall be developed to coordinate the existing laboratories in the country.

As a first move towards standardization of analytical procedures and in order to come out with a rational proposal as to how these laboratories could be coordinated, the NSS of the MOA was given the task to asses the present status of all soil testing and plant analysis laboratories in the country.

Based on this proposal the NSS prepared a survey questionnaire and dispatched it to the different soil testing and plant analyses laboratories known to it. The questionnaire was intended to provide information on techincal personnel engaged in analysis, the type of analytical services rendered, the analytical methods employed and the type of instruments and facilities available to each laboratory. The findings of this questionaire are embodied in a final report entitled "A Survey of Soil Testing and Plant Analysis Laboratories in Ethiopia", by Sertsu and Baisa (1990).

In order to systematically tackle the common problems of the national soil and plant analytical laboratories in a more concerted manner, the Soil and Plant Analytical Laboratories Network of Ethiopia (SPALNE) was established in February 1992. The Network had 14 laboratories as founding memebers and the NSSP is an elected coordinator of the Network.

2. OVERALL GOAL

The network of soil and plant analytical laboratories has an overall goal of improving the soil and plant analytical services to support agricultural research and natural resource conservation and development endeavors at national level by increasing the activities and efficiency of the soil and plant analytical laboratories in the country.

3. OBJECTIVES

To achieve the overall goal the network (SPALNE) will concentrate on four major objectives.

i. Standaridize and adopt appropriate methods for soil and plant analysis

Most methods for soil and plant anaysis were developed in temperate regions for temperate soils and crops. The properties of soils of the tropics are often very different from those of temperate areas and methods developed for temperate region soils cannot always be used for soils in Ethiopia, which is located in the tropics.

As soils and crops in the different parts of the country also vary greatly in properties, many different methods may have to be considered for analysis. To improve compatibility of data from different soil and plant analytical laboratories in the country, it is essential to standardize the methodology as much as feasible.

ii. Establish close collaboration among soil and plant analytical laboratories in the country for better exchange of information

iii. Train laboratory technicians in both analytical methodologies and maintenance of laboratory equipment.

Well-trained staff are of prime importance for a well functioning soil and plant analysis lab. Such staff is scarce in Ethiopia and there is an urgent need to train technicians in analytical methodology and maintenance of lab. equipment. The network can organize in-country training for lab. technicians.

iv. Establish a data quality control system for soil and plant analysis which is suitable for all laboratories in the country.

The reputation of a lab. depends on the quality of data it produces. Large sum of money and excessive time can be wasted if the data produced by labs. are not reliable and valid. To improve the quality of data from the soil and plant analysis labs, in Ethiopia a system of quality control of data is required.

v. Establish Lab. Instrument Repair & Maintenance workshop at a National level.

vi. Establish a system for central procurement of chemicals, glasswares and spares.

The National Soil Service Laboratory as the coordinator of the Network and as part of its project activities, has the responsibilities of assessing and supporting the various laboratories. Needless to mention, the training offered for the technicians of many of these laboratories and instrument repair services rendered to a few of them. Given that the previous survey of the labs. conducted in 1990 was not very complete. The NSSP was also given the aassignment to evaluate the present condition of the laboratories existing in the different parts of the country, and also to assess additional potential areas for future establishment of satellite laboratories.

3.1 IMMEDIATE OBJECTIVES

In order to achieve the above objectives specific terms of reference were assigned to the NSSP as the coordinator of the Network and as part of the project activities in order that the acquired informatioon on the status of the regional laboratories and regional lab. needs could be used as framework for the implementation of the Network objectives.

The terms of reference were the following:

- By means of questionnaires and visits assess the existing capacities and requirements of other laboratories.

- Undertake an assessment of requirements for soil analyses at regional level through questionnaires and visits.

- Evaluation of the existing soil laboratory facilities at regional level to determine their capacities to provide the required services.

- Formulate a detailed proposal including investment requirements for pilot laboratory in a selected region.

- Evaluate the training needs at regional level for laboratory technicians, and devlopment personnel.

It was within the framework of these terms of reference that a team from the National Soil Service Project Visited Laboratories and Regional offices in the different parts of the Country, for a total of 40 days (between 20th January and April 8/1993).

The mission had three main objectives:

a) To visit the soil and plant analytical laboratories in the different regions as a follow up to the questionnaires earlier sent out to these laboratories to evaluate their present status as to the types of analyses effected, instrumentation, their capabilities and limitaions and how they would fit in within the Soil and Plant Analytical Network for Ethiopia (SPALNE). These on the spot visits were intended to make a more complete appraisal of these laboratories and ensure completion of the questionnaires.

b) To visit the Administrative Regional Agricultural Development Departments as a follow up to the questionnaires previously sent out to them to evaluate their laboratory needs and hence determine if new laboratories need to be set up in these regions or if existing laboratories where applicable need to be upgraded. Actual presence was necessary to effect a more complete evaluation of the agricultural constraints to agricultural productivity and assess if the presence of a laboratory could resolve some of the problems associated with the low productivity/unit area.

c) To assess the problems of the farmers relating to soil productivity and fertilizer use in agricultural production and indentify the most relevant constraints to crop production in order to refine the training material for the field extension staff to address the actual problems faced by the farmers.

3.2 COMPOSITION OF THE TEAM FOR THE MISSONS :-

The team that effected the missions was composed of the following:

Dr. Sahlemedhin Sertsu	NPC, & Coordinator of SPALNE
Dr. Tadele G. Selassie	Training Coordinator NSSP
Dr. Yerima B.P.K.	Soil Laboratory Specialist NSSP

4. LIST OF LABORATORIES SURVEYED

The questionnaires were sent to 25 laboratories (Fig.1) whose addresses were known to NSS. The following list shows the names and address of the twenty two laboratories which were visited. Laboratories that replied to the questionnaire are shown with asterics.

*1. Alemaya University of Agriculture (AUA) Soil Laboratory. Soil Science Department, P.O.Box: 138, Dire Dawa.

*2. Awassa Junior Agricultural College (AJAC) Soils Laboratory. P.O.Box 5, Awassa.

*3. Awassa Research Center (ARC) Soils Laboratory, Institute of Agriculture, P.O.Box: 6, Awassa.

*4. Bako Research Center (BRC) Soil Laboratory, Institute of Agricultural Research P.O.Box: 2003, Addis Abeba.

*5. Baro Akobo Basin Master Plan Project Laboratory, P.O.Box: 1086 , Addis Abeba.

*6. Holetta Research Centre (HRC) Soils Laboratory, Institute of Agricultural Research, P.O.Box: 2003, Addis Abeba.

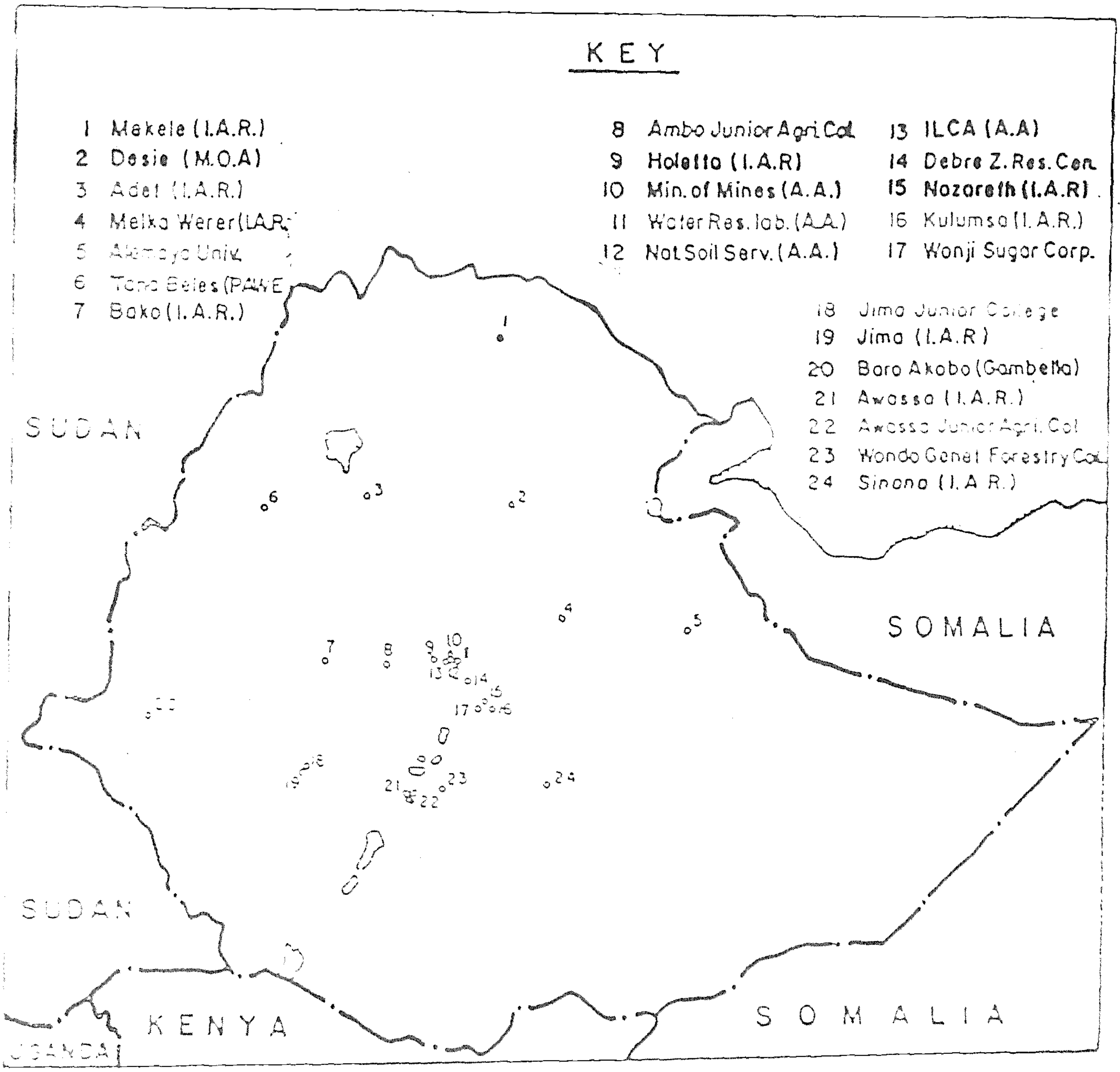
*7. Kulumsa Research Centre (KRC) Soils Laboratory, Institute of Agricultural Research, P.O.Box: 489, Asella.

*8. International Livestock Centre for Africa (ILCA). Soil and Plant Nutrition Laboratory, P.O.Box: 5689, Addis Abeba.

*9. National Soil Service (NSS), ETH/87/010, c/o FAOR Office, P.O.Box: 5536, Addis Abeba.

ETHIOPIA

Fig.1 Location of Soil Laboratories



Scale:- 1:10,000,000

*10. Water Resources Devlelopment Authority, (WRDA) Laboratory service, P.O.Box: 5673, Addis Abeba.

*11. Ambo Junior College of Agriculture/Laboratory

*12. Jimma Junior Agricultural College Soil Laboratory

*13. Jimma Research Centre Soils Laboratory .

*14. Adet Research Centre Laboratory.

*15. Mekele Research Centre Soils Laboratory: only building without doors & windows.

*16. Dessie Agricultural Office Soils Laboratory (only building present).

*17. Wonji Sugar Estate Laboratory.

*18. Melkassa Research Centre Soils Laboratory.

*19. Melka Werer Research Centre Soils Laboratory.

*20. Debre Zeit Research Centre Soils Laboratory (AUA).

*21. Sinana Research Centre Soils Laboratory.

*22. Ministry of Mines and Energy Research Laboratory.

*23. Tana Beles Project Laboratory.

*24. Wondo Genet Forestry School Laboratory.

*25. Soil Conservation Service Project Laboratory.

In this Survey report a synthesis of the findings obtained through the questionnaries and the on the spot visits to the laboratories is made as well as an attempt to analyse and discuss the present situations of these laboratories so that appropraiate steps to improve the situation could be taken in the future.

5. STAFF AND FACILITIES

5.1 Staff:

The variation in staff numbers by sex and qualifications for the laboratories surveyed are shown on Table 1. The total number of personnel directly involved in analytical services is 133. This figure is very similar to the total number of personnel involved in analytical services reported by Sertsu and Baisa (1990) for 11 labs surveyed. This low figure is largely associated with the restructuring programme in late 1993 which resulted in the loss of about 32 personnel from the NSSP. The extent the other government labs have been affected by this restructuring is not known since questionnaires from these labs had been received prior to the restructuring exercise.

TABLE 1. DISTRIBUTION OF STAFF IN THE LABORATORIES

No	Staff	NSSP 1		ILCA 2		Ministry of Mines & Energy 3		Holetta IAR 4		Alemaya AU 5		Debre Zeit IAR 6		Kulumsa IAR 7		Melka Werer IAR 8		Water Resource Dev. Authority 9		Wonji Sugar Estate 10		Tana Belles Project 11		Jimma IAR 12	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1	Graduates	6	-	-	1	3	4	-	1	8	-	1	1	1	-	3	-	4	-	-	1	-	-	3	-
2	Technicians	4	2	1	-	11	5	6	1	1	2	-	1	2	1	1	1	5	2	2	-	1	-	2	-
3	Administrative Personnel	1	5	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	Others	1	1	1	-	-	2	-	-	-	-	-	2	1	2	-	-	-	-	10	-	-	-	1	-
	TOTAL	12	8	2	1	14	11	6	2	9	2	1	4	4	3	4	1	9	2	12	1	1	-	6	1

No	Staff	Awassa IAR 13		Awassa College 14		Adet IAR 15		Bako IAR 16		Ambo Junior C. Agric. 17		Sinana IAR 18		Nazareth Melkassa IAR 19		Jimma Junior C. Agric 20		Wondo Genet C. Forestry 21		SCS Project Lab. 22		Mekele IAR 23		Dessie Agric. Office Lab. 24		Baro Akobo Basin 25	
		M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F	M	F
1	Graduates	1	-	1	-	-	-	1	-	1	-	1	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-
2	Technicians	-	-	1	-	1	-	-	1	-	-	-	-	1	-	-	-	1	-	-	-	-	-	-	-	3	-
3	Administrative Personnel	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
4	Others	2	-	-	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	-	-
	TOTAL	3	-	2	-	1	-	2	1	1	-	2	-	1	-	1	-	1	-	1	-	-	1	-	-	3	-

Where M = Male, F = Female

The largest number of staff is made up of technicians 59 (44%), followed by graduates 43 (32%) and then by staff with undefined functions 25 (19%), while administrative support personnel constitute only 6(5%). The NSSP laboratory has 6 Administrative personnel which could very adversely impact on analytical productivity.

5.1.1 **Graduates:**

There is at least one graduate per laboratory, except in Tana Belles, Adet IAR, Melkassa IAR, Wondo Genet College of Forestry, the Soil Conservation Service Project, Mekele IAR, Dessie Agric. Office lab and Baro Akobo Basia laboratories. The highest number of graduates is at Alemaya University (8)followed by Ministry of Mines and Energy Laboratory with 7 and then the NSS next with 6. For the rest of the labs the number of graduates ranges from 1-4. The highest ratio of technicians per graduate is 7:1 (Holetta), followed by Alemaya University (3:1) then The Ministry of Mines & Energy and Water Resources Laboratories with 2:1 respectively. The ratio of technicians to graduates at the NSSP is 1:1. The labs with a low ratio of technicians to graduates are likely to have very low analytical output.

5.1.2 Technicians:

The number of technicians in the different labs vary between 0 and 11. The highest number is in the Ministry of Mines & Energy (16), the next highest is at Holetta and Water Resource Development with 7 each. The NSSP is in 3rd place with 6 technicians. The technician problem appears acute. Apart from the above mentioned laboratories 8(32%) of the laboratories have only 1 technician and 7(28%) of the labortories have no technician. This is very disturbing since very little analytical work can be done.

5.2 **Facilities**:

The status of various essential facilities in the different laboratories surveged are shown on Table 2. Except for Jimma IAR, Bako IAR, Sinana IAR, Jimma Junior College of Agricultural Laboratory and Mekele which have poor quality water, all the laboratories surveyed have good quality water whose supply is reliable for most of the time. Electricity power supply is generally satisfactory for all the laboratories surveyed. Greenhouse facilities are only available to ILCA, AUA, Holetta IAR, Debre Zeit IAR, Awassa IAR , and Nazareth (Melkassa) IAR Laboratories. Field experiment facilities are available to all except NSSP, Ministry of Mines and Energy, the Soil Conservation Service Project and Baro Akobo Basin laboratories.

Following the responses 64% of the labs have spectrophotometers, 40% with colorimeters, 72% have Flame photometers and only 24% of the labs own atomic absorption spectrophotometers. X-ray diffraction apparatus are owned only by two labs, NSSP and Ministry of Mines Laboratory. Water distillers are owned by 80% of the labs. Water deionizers by 52% while it is only the NSSP which presently redistills alcohol. Only 44% of the labs can effect sample distiilation. PH meters

TABLE 2. FACILITIES AVAILABLE IN THE DIFFERENT LABORATORIES AND THEIR STATE

		Laboratories and Status of Equipment or Facilities																							
		NSSP 1		ILCA 2		Holetta IAR 4		Alemaya Univ. 5		Debre Zeit IAR 6		Kulumsa IAR 7		Melka Werer IAR 8		Water Resources Dev. A. 9		Ministry of Mines & Energy 3		Wonji Sugar Estate 10		Tana Belles Project 11		Jimma IAR 12	
No	Equipment or Facility	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
	Basic Facilities																								
1	Electricity(Reliable)	/		/		/		/		/		/		/		/		/		/		/		/	
2	Tap Water(Reliable)	/		/		/		/		/		/		/		/		/		/		/		X	
3	Tap Water-well(Reliable)	0		/		/		X		/		X		/		/		X		X		X		X	
4	Greenhouse	?		/2		/		/		/		X		X		X		X		X		X		X	
5	Experimental Field	0		/		/		/		/		/		/		/		X		/		/		/	
6	Structural Lab. Infrastructure	/		/		/		/		/		/		/		/		/		/		/		/	
7	Others (Computer)	/3		/		X		/		/1		X		X		X		/		X		X		X	
	Spectrometric Apparatus																								
1	Spectrophotometer	/3		1	Ca	1		2		2		1	Cc	X		3	Cd	1		1		1		2	Ca
2	Colorimeter	0		0		X		X		X		1		X		1		1		1		X		1	
3	Turbidimeter	0		0		X		X		X		X		X		X		X		X		X		X	
4	Flame Photometer	/3		1		X		2	Ka	1		1	Ka	2		3		1		1		1		1	Ka
5	AAS	2		1	Jb	1		1	Jc	1		X		X		X		8		X		X		X	
6	X-ray Diff. (XRD)	1		0		X		X		X		X		X		X		1		X		X		X	
7	DTA	1		0		X		X		X		X		X		X		X		X		X		X	
8	Others (Specify) XRF					X		X		X		X		X		X		1		X		X		X	
	Electro Mechanical Apparatus																								
1	Distiller																								
	i. For Water	9		2	Nb	X		1		2		1	Nc	1		4	Nd	6	Na	1		1		1	
	ii. For Alcohol	4		0		X		X		X		X		X		X		X		X		X		X	
	iii. For Samples	6		1		2		X		X		X		X		1		X		4		1		1	
2	Water Deionizer	2		2	La	1	Lb	1		1		X		1		2		2		1		X		1	
3	Stirrer	1		2		3		3		4		X		1		4		2		X		X		1	
4	Block digester	2		2	Ma	X		1		1		X		X		1		1		1		X		1	
5	Shaker	4		3	Da	2		3		1		1	Dc	1		2	Dc	4		2		2		1	
6	Grinders i. Soil	3		1		1		1		1		X		1		1		3		1		1		1	
	ii. Plant	2		1		1		X		1		1		1		X		X		1		X		1	
7	Magnetic Stirrer																								
	i. Ordinary	3		-		5		X		X		1		2		10		X		X		X		1	
	ii. With Heating	2		2		3		2		2		X		1		8		4		X		X		1	
8	Water Bath	1		1		4		1		1		1		3		1		4		X		X		1	
9	Sand Bath	1		1		2		X		X		X		X		X		6		X		X		X	
10	Electric Stove	1		-		1		3		3		10		3		X		-		2		X		X	
11	Drying Oven	4		5	Ea	4	Ee	4		X		2	Eb	2		3		3		3		1		1	
12	Heating Plate	2		-		4		X		X		5		1		3		11		2		X		2	
13	Refrigerator	4		2		1		X		1		1		2		2		1		X		X		1	
14	Centrifuge	2		1	Fd	1	Fc	1		2		1	Fc	2		2	Fe	3		1	F	1		1	

		1		2		4		5		6		7		8		9		3		10		11		12	
No	Equipment or Faciility	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
15	Balances	6	G	8	Ga	10	Ga	5		3		4	Gd	2		2		13	Gb	4		2		4	
16	Vacuum Pump	1		3		3		1		2		1		1		1		1		X		X		2	
17	Tensiometer					X		X		X		X		X		X		X		X		X		X	
18	Manitold+15+1/3 bar App.	3		2		X		X		X		X		1		X		X		X		X		X	
19	Infiltrometer			3		X		X		X		X		X		X		X		X		1		X	
20	Core Sampler	1		1		X		5		X		X		X		X		X		X		X		X	
21	Muffle Furnace	3	H	3	Ha	1	Ha	2		1		1	Hb	1		1		2	Hc	X		X		1	
22	Pycnometer	5		8		X		20		X		X		X		50		100		10		X		X	
23	Carbon Train					1		X		X		X		X		X		X		X		X		X	
24	Pipetting Apparatus for PSD	3		1		1		3		X		1		X		1		9		X		X		X	
25	Air Compressor	1		1		1		1		2		1		X		1		2		2		X		X	
26	Diluters	2		2		1		X		X		X		X		X		1		X		X		X	
27	Others (Specify) Fusion Furnace	X		X		X		X		X		X		X		X		1		X		X		X	
	Electrochemical Apparatus																								
1	pH Meter	2	I	1	Ic	2	Id	4	Ie	3		2	If	1		2		4		1		2		2	
2	EC Meter	2		1		2	Ob	4		1		1	Oc	1		1		X		1		X		X	
3	Calcimeter	-		1		1		X		X		X		X		1		X		X		X		X	
4	Manometer	-		-		X		5		X		X		X		X		X		X		X		X	
5	Others /Specify/	-		-		X		X		X		X		X		X		X		X		X		X	

TABLE 2. CONTINUED

No	Equipment or Faciility	Laboratories and Status of Equipment or Facilities																								
		Awassa IAR 13		Awassa College 14		Adet IAR 15		Bako IAR 16		Ambo Junior C. Ag. 17		Sinana IAR 18		Nazareth IAR 19		Jimma Junior C Agric. 20		Wondo Genet C. Forestry 21		SCS Project 22		Mekele IAR 23		Dessie Agric. Office 24		Bar Ako Bas 2
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A
	Basic Facilities																									
1	Electricity(Reliable)	/		/		/		/		/		/		/		/		/		/		X		/		/
2	Tap Water(Reliable)	/		/		/		/?		/		/		/		/		/		/		X		/		/
3	Tap Water-well(Reliable)	/		X		/		/		X		X		/		X		X		X		X		X		/
4	Greenhouse	/1		X		X		/		X		X		/		X		X		X		X		X		X
5	Experimental Field	/		/		/		/		/		/		/		/		/		X		/		/		X
6	Structural Lab. Infrastructure	/		/		/		/		/		/		/		/		/		/		/		/		X
7	Others (Computer)	X		X		X		X		X		X		X		X		X		X		X		X		X
	Spectrometric Apparatus																									
1	Spectrophotometer	X		1		1	C	1		1		X		1		X		X		X		X		X		X
2	Colorimeter	1		X		X		X		1		X		X		X		X		1		X		X		2
3	Turbidimeter	X		X		X		X		X		X		X		X		X		X		X		X		X
4	Flame Photometer	1	Kc	1		1	K	2		1		1		X		X		X		X		X		X		1
5	AAS	X		X		X		X		X		X		X		X		X		X		X		X		X
6	X-ray Diff. (XRD)	X		X		X		X		X		X		X		X		X		X		X		X		X
7	DTA	X		X		X		X		X		X		X		X		X		X		X		X		X
8	Others (Specify)	X		X		X		X		X		X		X		X		X		X		X		X		X
	Electro Mechanical Apparatus																									
1	Distiller																									
	i. For Water	1	Ne	1		3	N	1		X		1		X		X		1		X		X		X		1
	ii. For Alcohol	X		X		X		X		X		X		X		X		X		X		X		X		[illegible]
	iii. For Samples	X		1		1		9		X		X		X		X		X		X		X		X		X
2	Water Deionizer	1	Lc	X		X		1		1		X		X		X		X		X		X		X		X
3	Stirrer	3		1		X		1		X		X		X		X		X		X		X		X		X
4	Block Digester	1		1		X		X		X		X		X		X		X		X		X		X		X
5	Shaker	1	Db	1		1	D	1		X		X		X		X		1	De	X		X		X		1
6	Grinders i. Soil	-		1		1		1		X		X		X		X		X		5		X		X		1
	ii. Plant	1				X		1		X		X		X		X		X		X		X		X		X
7	Mangetic Stirrer																									
	i. Ordinary	X		1		1		2		1		X		X		X		21		X		X		X		X
	ii. With Heating	1				1		X		X		1		X		X		X		X		X		X		X
8	Water Bath	X		1		1		1		1		1		X		X		2		X		X		X		1
9	Sand Bath	X		X		X		X		X		X		X		[illegible]		X		[illegible]		X		X		1
10	Electric Stove	X		1		2		10		X		1		X		X		X		X		X		X		2
11	Drying Oven	3	Ea	1		2	E	1		2		1		2		X		2		2		X		X		5
12	Heating Plate	1		1		1		1		1		1		1		[illegible]		[illegible]		[illegible]		X		X		[illegible]
13	Refrigerator	X		X		1		X		X		X		1		X		1		1		X		X		2
14	Centrifuge	X		1		1	F	1		[illegible]		1		1		[illegible]		1	Fc	[illegible]		[illegible]		X		[illegible]

		13		14		15		16		17		18		19		20		21		22		23		24		25	
		A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
15	Balances	3	Ga	1		4	G	4		4		2		3		X		14	Gc	2		X		X		3	G
16	Vacuum Pump	1		X		1		2		X		1		X		X		X		X		X		X		X	
17	Tensiometer	X		1		X		X		X		X		X		X		X		1		X		X		X	
18	Manifold+15+1/3 bar App.	X		X		X		X		X		X		X		X		X		X		X		X		X	
19	Infiltrometer	X		X		X		X		X		X		X		X		X		X		X		X		X	
20	Core Sampler	X		X		X		X		X		2		X		X		X		8		X		X		X	
21	Muffle Furnace	X		1		1	H	1		1		1		1		X		X		X		[illegible]		X		2	[illegible]
22	Pycnonmeter	X		X		2		X		X		X		X		X		X		X		X		X		X	
23	Carbon Train	X		X		X		X		X		X		X		X		X		X		X		X		X	
24	Pipetting Apparatus for PSD	X		1		6		X		X		X		X		1		X		X		X		X		X	
25	Air Compressor	1		X		1		1		X		1		X		X		X		X		X		X		X	
26	Diluters	X		X		1		X		X		1		X		X		X		X		X		X		X	
27	Others (Specify)	X		X		X		X		X		X		X		X		X		X		X		X		X	
	Electrochemical Apparatus																										
1	pH Meter	2	Ig	1		2	I	2		2		1		1		X		10		1	[illegible]	[illegible]		X		5	
2	EC Meter	1	Ob	1		1	0	X		2		1		X		X		X		[illegible]		X		X		X	
3	Calcimeter	1		X		X		1		X		X		X		X		X		X		X		X		2	
4	Manometer			X		1		X		X		X		X		X		X		[illegible]		X		X		X	
5	Others (Specify)																										
	Densimeter	1		X		X		X		X		X		X		X		X		X		X		X		X	
	Hydrometer	X		X		1		X		X		X		X		X		X		X		X		X		X	
	Barometer	X		X		1		X		X		X		X		X		X		X		X		X		X	

Where A= Status (eg./= Available; X= Not Available, ?= Need repairs or Completion)
B= Mark or Make (C, D, E, F, G, etc= Different Marks).

C= Spectrophotometer

Ca= Spectronic 20, 21
Cb= Cecil
Cc= Hitachi
Cd= Hach

D= Shakers

Da= Gallenkamp
Db= England
Dc= Stuart
De= Swedish
Df= Italy

E= Drying Oven

Ea= Gallenkamp
Eb= Memmert
Ec= Australia
Ed= Pickstone
Ee= B & T
Ef= Russia

F= Centrifuge

Fa= General Electric (ICE)
Fb= Labofuge
Fc= Haereus
Fd= USA
Fe= Jouan
Fg= Italy

G= Balances

Ga= Mettler
Gb= Sartorius
Gc= Thaus
Gd= Shimadzu
Ge= Russia

H= Muffle Furnace

Ha= USA
Hb= Heareuse
Hc= Austrailian
Hd= Carbolite
He= Russia

I= pH Meters

Ia= Germany
Ib= Jenway
Ic= Gallenkamp
Id= England
Ie= Beckman
If= Metrohum
Ig= Philips
Ik= Hach
Il= Russia

J= Atomic Absorption Spectrophometer

Ja= Varian
Jb= Perkin Elmer
Jc= Beckman

K= Flame Photometer

Ka= Jenway
Kb= Corning 400/4.
Kc= Gallemkamp
Kd= Russia

L= Water Deionizer	M= Block Digester	N= Water Distiller	O= EC Meter
La= England	Ma= Sweden	Na= Aquatron	Oa= Keort Eil
Lb= Kotterman	Mb= Tecator	Nb= Gallenkamp	Ob= England
Lc= Permo		Nc= Buchi	Oc= Metrohm
		Nd= Fujixeisakusyo	
		Ne= Manesty	
		Nf= Russia	
		Ng= Karl Kolb	

are owned by 84% of the labs while EC meters only obtain in 52% of the laboratories. Some of the equipment which are very necessary for laboratory analyses and the percent of the labs that have them are as follows : Block digesters (44%), shakers (76%), soil grinders (64%), plant grinders (40%), Drying ovens (84%), Heating plate (56%), Refrigerator (56%), Centrifuge (76%), Balances (88%), Muffle furnace (64%), Tensiometers (8%), Apparatus for PF determination (12%), Infiltrometer (8%), Pipeting Apparatus for PSD (32%), Magnetic stirrer (48%), Water bath (68%), Sand bath(44%), Core sampler (20%), and Air compressors (52%).

Except for the following laboratories, NSSP, ILCA, wongi Sugar Estate, Water Ressources Development, Ministry of Mines and Energy, Jimma IAR, Adet IAR, Sinana IAR, Awassa College and Debre Zeit AUA, most of the other labs have equipment that is considerably depreciated and hardly functional for most analysis.

The survey also indicates that the range of equipment among the different labs is very wide, eg atomic absorption, flame photometers and spectrophotometers used by most laboratories are of different makes.

6.0 TYPE OF ANALYSIS EFFECTED BY THE DIFFERENT LABORATORIES.

The type of analysis effected by the different laboratories and the year started is indicated in Table 3. Some form of soil analysis is carried out in 76% of the laboratories. 28% of the labs had been functioning before 1970, 24% started soil analytical work in the 1980' while 8% of the labs started analytical work after 1990.

Plant analysis is currently carried out in only 28% of the laboratories. Except for Holetta IAR, Kulumsa IAR and Wonji Sugar Estate where plant analysis had been effected on or before 1970, plant analysis in the other labs were started after 1987.

Water analysis is carried out in 36% of the laboratories. Except for NSSP (1990) Awassa IAR (1985) and ILCA (1983) water analysis has been effected in the 4 labs prior to or before 1977.

Fertilizer analysis is only being effected in 16% of the labs while compost and manure analysis is being effected in only 12% of the laboratories. This survey indicates that very few labs are presently involved in compost and mineral fertilizer analysis, this is largely attributed to the lack of an analytical manual for these parameters

7.0 LABORATORY ANALYTICAL OUTPUT.

The total number of samples analyzed by each laboratory during the seven years (1986-1992) and the breakdown by the types of samples (soil, water, plant, fertilizers) is shown on Table 4.

The total number of samples analysed by the 13 laboratories that responded to this question for the 7 year period 1986-1992 is 379930 and range from 78 in the Sinana IAR to 29494 in the Ministry of Mines Laboratory assuming that the total of 52031 value reported by Holetta IAR relates to the number of determinations made rather than the number of samples analyzed.

TABLE 3. TYPE OF ANALYSIS AND YEAR STARTED

Type of analysis	NSSP	ILCA	Ministry of Mines & Energy	Holetta IAR	Alemaya Univ.	Debre Zeit IAR	Kulumsa IAR	Melka Werer IAR	Water Resources Dev. A.	Wonji Sugar Estate	Tana Belles Project	Jimma IAR
	Laboratories and Status of Equipment or Facilities											
	Type of Analysis and Year Started											
Soil (S)	1968	1983	1985	1968	1950	1985	1970	?	1961	1960	?	1991
Plant (P)	1991	1987	0	1968	0	1985	1970	0	0	1960	0	1991
Water (W)	1990	1983	0	1975	1977	0	0	?	1961	1960	?	0
Fertilizer (F)	1986	0	0	1979	0	0	1974	0	0	1974	0	0
Compost Manuare (C)	0	0	0	1985	0	0	1974	0	0	1990	0	0

Type of analysis	Awassa IAR	Awassa College	Adet IAR	Bako IAR	Ambo Junior C.Agri.	Sinana IAR	Nazareth IAR	Jimma Junior C.Agri.	Wondo Genet C. Agric.	SCS Project	Mekele IAR	Dessie Agric. Office	Baro Akobo Basin
	Type of Analysis and Year Started												
Soil (S)	1982	?	0	1969	0	1991	0	0	?	1988	0	0	1984
Plant (P)	0	?	0	?	0	0	0	0	0	0	0	0	0
Water (W)	1985	0	0	0	0	0	0	0	0	0	0	0	0
Fertilizer (F)	0	0	0	0	0	0	0	0	0	0	0	0	0
Compost Manuare (C)	0	0	0	0	0	0	0	0	0	0	0	0	0

Where S= Soil, P= Plant, W= Water, F= Fertilizer, C= Compost and Animal Manure.
?= Did not indicate when analysis was started, 0= Do not yet do the analysis indicated.

The average value for all laboratories is 8456/7 years with an average of 1208 samples/lab/year. This value shows very few labs (4) analyze more than 1208 samples/year which value is very low. The poor state of equipment in most labs, the lack of adequate water distillation facilities and increasing costs of chemicals and disposable equipment may be responsible for this low level of production. Also generally there is a net decreasing trend in the number of analyses effected from 1987 to 1992. This may be attributable in some cases to aging in equipment or inadequate support from donor agencies for purchase of chemicals and disposable lab. material. In terms of number of samples analyzed/ type of analysis, soil samples head the least with 109779 followed by plant analysis (26000), water(1564), compost(1010) and fertilizers(66). Most of the plant analysis are being effected in IAR laboratories and are largely linked to fertility studies.

8.0 ANALYTICAL TECHNIQUES

8.1 METHODS OF SOIL ANALYSES

8.1.1 Methods of Chemical Analysis

8.1.1.1 pH Determination:

Table 5 gives the number of laboratories using different extractants and soil : solution ratios for the determination of pH. Electrometric determination of pH in water is done by 60% of the labs. Only one laboratory determines pH colorimetrically. Seventy six percent of the labs determine pH in water, 40% determine in 1N KCl and only 20% of them determine pH in 0.1M $CaCl_2$.

The majority of the labs favor the 1:1 soil solution ratio for the determination of pH in all of the extracting solutions, followed by the 2:5 ratio and then the 1:2 extration ratio. pH on the saturated paste extract is determined by only 6 laboratories in the country.

8.1.1.2 Determination of Soluble Salts:

Table 6 gives the number of laboratories using different soil: solution ratios for the determination of soluble salts. A total of 5 laboratories determine soluble salts. One lab uses the 1:2 extraction ratio while the 1:5 and 1:10 soil solution ratios is used by 3 and 2 labs, respectively. The soluble salt determination on the saturated paste extrat is done by only 16% of the laboratories. Units of expression of results favored are meq/l (20%) and meq/100g (8%) of labs.

8.1.1.3 Determination of Exchangeable Bases:

This determination is done by 9 laboratories (Table 7). Five labs use 1:10 soil: extractant ratio, 2 the 1:20, another 2 the 1:50 and one uses the 1:25 ratio. Ammonium acetate pH 7 is used for the displacement of the bases in all labs. A modification for preleaching to remove soluble salts and using a mixture of 50:50 NH_4OAc: ethanol for the displacement of bases to obviate $CaCO_3$ dissolution is only carried out at the NSSP. Except for the

TABLE 4. TOTAL NUMBER AND TYPES OF ANALYSIS EFFECTED IN THE LABORATORIES

	Instituions & Type of Analysis	Year							
		1986	1987	1988	1989	1990	1991	1992	Total
1	NSSP: Soil	3293	3936	2608	3458	3007	2611	1593	20506
	Plant	-	-	-	-	-	30	384	414
	Water	-	-	-	-	-	48	29	77
	Fertilizer	-	-	-	-	-	-	-	-
	Compost/ Animal Manure	-	-	-	-	-	-	-	-
	Total								20997
2	ILCA: Soil	1900	1359	907	1085	1569	939	1132	8892
	Plant	-	808	692	2976	2602	2348	2080	11506
	Water	46	600	137	17	-	79	-	339
	Fertilizer	-	-	-	-	-	-	-	-
	Compost/ Animal Manure	-	-	-	-	-	-	-	
	Total								20737
3	Ministry of Mines and Energy Soil (Geochemicals) (1)	1000	1200	1100	1400	3995	1815	1752	12162
	Wet assay Au+Ag(2)					12941	2514	1524	17039
	Fire assay Ag (3)					8231	1359	703	10293
	Total								29494
4	Holetta IAR:								
	Soil		6787	13394	6900	7162	4100	6003	44346 ?
	Plant		3689	1136	1102	560	150	568	7205 ?
	Water		123	104	147	13	-	-	387
	Fertilizer		86	7	-	-	-	-	93
	Compost/ Animal Manure		-	-	-	-	-	-	-
	Total								52031 ?
5	Alemaya University:								
	Soil								2509
	Plant								200
	Water								49
	Fertilizer								-
	Compost/ Animal Manure								-
	Total								2758

TABLE 4. CONTINUED

		1986	1987	1988	1989	1990	1991	1992	Total
6	Debre Zeit IAR:								
	Soil								1410
	Plant								3250
	Water								-
	Fertilizer								-
	Compost/ Animal Manure								-
	Total								4660
7	Kulumsa IAR								
	Soil							1438	1438
	Plant								
	Water				1006	998	1010	1006	
	Fertilizer								
	Compost/ Animal Manure								4020
	Total								5438
8	Melka Werer IAR								
	Soil				601	1322	1495	1500	4918
	Plant				-	-	-	-	-
	Water				98	89	482	460	1136
	Fertilizer				-	-	-	-	-
	Compost/ Animal Manure				-	-	-	-	-
	Total								6054
9	Water Resources Dev. Authority								N.a
	Soil								
	Plant								
	Water								
	Fertilizer								
	Compost/ Animal Manure								
	Total								
10	Wonji Sugar Estate								
	Soil	2284	4498	1053	192	435	528	266	9256
	Plant	1390	1731	523	78	-	-	752	4474
	Water	232	108	92	88	111	39	39	709
	Fertilizer	-	-	40	20	3	3	-	66
	Compost/ Animal Manure	-	-	-	-	956	54	-	1010
	Total	3906	6337	1708	378	1505	624	1057	15515

TABLE 4. CONTINUED

		1986	1987	1988	1989	1990	1991	1992	Total
11	Tana Belles Project								N.a
	Soil								
	Plant								
	Water								
	Fertilizer								
	Compost/ Animal Manure								
	Total								
12	Jimma IAR								
	Soil						300		300
	Plant						1350		1350
	Water						-		-
	Fertilizer						-		-
	Compost/ Animal Manure						-		-
	Total						1650		1650
13	Awassa IAR								
	Soil	368	100	6	440	492	820	476	2702
	Plant	-	-	-	-	-	-	-	-
	Water	2	1	-	-	-	-	-	-
	Fertilizer	-	-	-	-	-	-	-	3
	Compost/ Animal Manure	-	-	-	-	-	-	-	-
	Total	370	101	6	440	492	820	476	2705
14	Awassa Agricultural College								N.a
	Soil								
	Plant								
	Water								
	Fertilizer								
	Compost/ Animal Manure								
	Total								
15	Adet IAR								N.a
	Soil								
	Plant								
	Water								
	Fertilizer								
	Compost/ Animal Manure								
	Total								

TABLE 4. CONTINUED

		1986	1987	1988	1989	1990	1991	1992	Total
16	Bako IAR								
	Soil	261	205	427	232	115		22	1262
	Plant	-	-	-	-	-		-	-
	Water	-	-	-	-	-		-	-
	Fertilizer	-	-	-	-	-		-	-
	Compost/	-	-	-	-	-		-	-
	Animal Manure								
	Total	261	205	427	232	115		22	1262
17	Ambo Junior College of Agriculutre								N.a
	Soil								
	Plant								
	Water								
	Fertilizer								
	Compost/								
	Animal Manure								
	Total								
18	Sinana IAR								
	Soil						24	54	78
	Plant						-	-	-
	Water						-	-	-
	Fertilizer						-	-	-
	Compost/						-	-	-
	Animal Manure								
	Total						24	54	78
19	Nazareth IAR								N.a
	Soil								
	Plant								
	Water								
	Fertilizer								
	Compost/								
	Animal Manure								
	Total								
20	Jimma Junior College of Agriculture								N.a
	Soil								
	Plant								
	Water								
	Fertilizer								
	Compost/								
	Animal Manure								
	Total								

TABLE 4. CONTINUED

		1986	1987	1988	1989	1990	1991	1992	Total
21	Wondo Genet College of Forestry								N.a
	Soil								
	Plant								
	Water								
	Fertilizer								
	Compost/ Animal Manure								
	Total								
22	**Soil Conservation** Service Project								**N.a**
	Soil								
	Plant								
	Water								
	Fertilizer								
	Compost/ Animal Manure								
	Total								
23	Mekele IAR								N.a
	Soil								
	Plant								
	Water								
	Fertilizer								
	Compost/ Animal Manure								
	Total								
24	Dessie Agric. Office								**N.a**
	Soil								
	Plant								
	Water								
	Fertilizer								
	Compost/ Animal Manure								
	Total								
25	Baro Akobo Bassin								
	Soil			13719	3176	1116			18031
	Plant			108	15	-			123
	Water			200	1631	971			2802
	Fertilizer			-	-	-			-
	Compost/ Animal Manure			-	-	-			-
	Total								20955

NSSP which also uses (mol)/kg all labs express their results in meq/100g soil.

Ten labs(40%) use ammonium acetate as the saturating agent, 3 labs use sodium acetate and one lab uses $CaCl_2$ (Table 8). Potassium Chloride is the favored displacing agent used by 4 labs followed by NH_4Ac and $NaCl_2$ with 3 labs each and KNO_3 with 1 lab.

Distillation is the favored method of CEC determination and is determined by 36% of the labs. Seven labs determine exchangeable Na and K by flame emission and 7 labs determine it by flame photometry. Only 3 labs determine Ca & Mg by atomic absorption. This indicates that complexiometric titration is the most used method for determination of Ca + Mg. All labs report results in meq/100g soil.

8.1.1.4 **Determination of available phosphorus:**

The Olsen and Bray I methods are most frequently used for P-determination (Table 9) with 9 labs each followed by the Bray II (5 labs), the Mehlich (2 labs) and the Hach method with 1 lab. ppm is the most preferred means of expression of results. In all cases available P is read by spectro photometer.

8.1.1.5 Determination of Total Nitrogen:

Total N is determined in 12 laboraties (48% of labs) using conc. H_2SO_4 + salt mixture(Table 10) and the results are all reported in %.

8.1.1.6 **Determination of organic carbon:**

The most prevailent method for organic carbon determination is the Walkley and Black effected by 50% of the labs(Table 11) followed by the carbon train combustion and Ignition methods with 1 lab each(4%). Titration is favored detection method (56%) while the gravimetric method is favored for the latter two methods. All the labs express the results in %.

8.1.1.7 **Determination of gypsum:**

Gypsum determination is done only in 4 laboratories (Table 12). The preferred detection method is by Electrical conductivity reading with reporting units either in % or meq/100g.

8.1.1.8 **Determination of calcium carbonate equivalent:**

The preferred method of $CaCO_3$ determination is by acid neutralization done by 40% of the labs followed by the calcimeter method(12%) and then the gravimetric, Fusion with Lithium Borate and Hach methods with 4% each (Table 13). All the labs report their results in %.

8.1.1.9 **Determination of exchangeable acidity:**

Very few labs determine exchangeable acidity. Two methods are used. $BaCl_2$. Triethanolamine and 1N KCl extraction methods (Table 14). The 1:10 soil extractant ratio is favored for both methods while meq/100g are the reporting units favored.

TABLE 5. NUMBER OF LABORATORIES USING DIFFERENT EXTRACTANTS AND SOIL SOLUTION RATIOS FOR pH DETERMINATION

Method of Determination		Solution	Saturated Paste	Soil: Solution Ratio			
Electrimetric	Colorimetric			1:1	1:2	2:5	1:5
15	1	Water	6	9	4	5	1
9	-	1N KCl	-	6	1	2	1
5	-	0.1 $CaCl_2$	-	2	1	1	1

TABLE 6. THE NUMBER OF LABORATORIES USING DIFFERENT SOIL: SOLUTION RATIOS FOR THE DETERMINATION OF SOLUBLE SALTS

Extractant	Saturated Paste Extract	Soil: Solution Ratio					Units Used in Reporting				
		1:2	1:5	1:10	1:20	1:50	meq/100g	meq/l	(mol)/kg	g/kg	[illegible]
Water	4	1	3	2	-	-	2	5	-	-	1

TABLE 7. THE NUMBER OF LABORATORIES USING DIFFERENT EXTRACTANTS AND SOIL: SOLUTION RATIOS TO DETERMINE EXCHANGEABLE BASES

Extractant	No. of Lab	Soil: Solution Ratio						Units Used in Reporting		
		1:2	1:5	1:10	1:20	1:25	1:50	meq/100g	meq/l	(mol) kg
Ammonium acetate	10	-	-	5	2	1	2	9	_	1

TABLE 8. NUMBER OF LABORATORIES USING DIFFERENT SALTS FOR SATURATION AND DISPLACEMENT FOR THE DETERMINATION OF CEC AND EXCHANGEABLE BASES AND THE METHODS OF DETECTION

Method	No.of Labs	Detection Methods				Units Used in Reporting	
		Distillation and Titration	Atomic Absorption	Flame Emission	Flame Photometry	meq/100	(mol(+))/kg
Saturating Salts							
Ammonium Acetate	10	9	3	3	4	10	[illegible]
Sodium Acetate	3	1	-	4	3	3	-
Barium Chloride	-	-	-	-	-	-	-
Calcium Chloride	1	-	-	-	1	1	-
Displacing Salts							
Ammonium Acetate	3	-	-	1	-	2	-
Sodium Chloride	3	2	-	-	-	2	-
Potassium Chloride	4	1	1	-	-	[illegible]	-
Potassium Nitrate	1	-	-	-	-	1	-

TABLE 9. NUMBER OF LABORATORIES USING DIFFERENT EXTRACTANTS FOR DETERMINATION OF PHOSPHORUS AND THE METHODS OF DETECTION

Extractant	No. of Labs	Soil:Extractant Ratio						Units Used in Reporting		
		1:5	1:7	1:10	1:20	1:40	1:50	ppm	mg/kg	kg/ha
Olsen (0.5M $NaHCO_3$)	9	1	-	-	9	-	-	9	-	-
Bray I (0.03M NH_4F + 0.25NHCl)	9	1	4	3	1	-	-	6	-	-
Bray II (0.03M N H_4F + + 0.1M HCl)	5	-	1	2	1	-	-	5	1	-
Mehlich (0.1N HCl + 0.025N H_2SO_4	2	2	-	-	-	-	-	2	-	-
Hach Method	1	-	-	-	-	-	-	-	-	1

TABLE 10. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR THE DETERMINATION OF TOTAL NITROGEN

Method	No.of Labs	Method of Detection			Units Used in Reporting	
		Distillation & Titration	Specific ions Electrode	Colorimetric	%	g/kg
Conc. H_2SO_4 + Salt Mixture	12	12	-	-	12	-

TABLE 11. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR THE DETERMINATION OF ORGANIC CARBON

Method	No.of Labs	Method of Detection			Units Used in Reporting	
		Titration	Colorimetric	Gramimetric	%	g/kg
$K_2Cr_2O_7$ Oxidation Walkley & Black Method	14	14	-	-	14	-
Carbon Train Combustion	1	-	-	1	1	-
Ignition	1	-	-	1	1	1

TABLE 12. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR THE DETERMINATION OF GYPSUM

Method	No.of Labs	Method of Detection			Units Used in Reporting		
		A.A	Titration	Ec Meter Reading	%	g/kg	meq/100g
Precipitation with Acetone	3	-	1	3	2	-	2
Electrical Conductivity	1	-	-	1	-	-	-

A.A= Atomic Absorption

8.1.1.10 Determination of EC:

EC on the saturated paste extract is determine by 6 labs (24% of the labs) (Table 15) while EC in the soil: solution ratio is determined by 12 labs. The 1:1 and 1:5 soil: solution ratios are done in 5 labs each while the 1:2.5 ratio is done in 2 labs. The reporting unit favored is mmhos/cm (done by 92% of the labs doing EC).

8.1.1.11 Determination of lime requirement:

Lime requirement is done by the $BaCl_2$ - TEA, gravimetric, fusion with Lithium borate, $Ca(OH)_2$ and Hach methods. (Table 16). The $BaCl_2$ - TEA method is used by 4 labs(44% of the labs doing this determination). The method of detection most favored is by titration (89% of labs doing the determination). Reporting units are either % (4 labs), g/kg (3 labs) or meq/100g (1) lab.

8.1.1.12 Determination of sulfates in soil:

The gravimetric and turbidemetric methods are the most common for the determination of sulfates with 5 and 6 labs doing the determinations, respectively. The results are generally reported in ppm by most of the labs, with only 2 labs reporting in meq/l (Table 17).

8.1.1.13 Determination of inorganic P-fractions:

Currently only two labs are doing P-fractionation of the Fe-P and Al-P and only 1 lab does occluded Al-Fe-P, Ca-P, Reductant soluble Fe-P and Saloid P (Table 18). The spectrophotometer is used as the detection method with only ppm as the unit of reporting.

8.1.1.14 Determination of free Fe and Al- Oxides:

This determination is carried out by only 2 laboratories (8% of the labs) (Table 19). The phenanthroline colorimetric method is used for the determination of Fe while Al is determined by atomic absorption and one labs does it by the colorimetric aluminon method. Results are reported in ppm.

8.1.1.15 Determination of amorphous Fe, Al and Si:

Only one lab (4% of the labs) determines amorphous Fe and Al by ammonium oxalate extraction. Atomic absorption is the mode of detection while the reporting units are in ppm (Table 20).

8.1.1.16 Determination of available Iron:

Available iron is determined by a range of methods: DTPA(16% of the labs), NH_4OAc (8%), EDTA(4%) and HCl(4%) (Table 21). The 1:2 soil extractant ratio is favored by 70% of the labs doing the determination and the 1:10 ratio by 20% of the labs doing the determination. Only 10% of the labs doing this determination use the 1:50 ratio. Fifty percent of the labs doing the determination use a shaking period of 2 hours, 40% use 1/2 hour and 10% of labs doing the determination shakes overnight. The detection method

TABLE 13. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR THE DETERMINATION OF CALCIUM CARBONATE EQUIVALENT

Method	No. of Labs	Method of Detection				Units Used in Reporting	
		Calcimeter Reading	Titration	A.A	Other	%	g/kg
Calcimeter Acid	3	3	-	-	-	3	-
Neutralization	10	10	-	-	-	10	-
Gravimetric	1	-	-	-	1	1	-
Fusion with Lithium Borat	1	-	-	1	-	1	-
Hach Method	1	-	-	-	-	1	-

TABLE 14. NUMBER OF LABORATORIES USING DIFFERENT TYPES OF EXTRACTANTS AND SOLUTION RATIOS FOR THE DETERMINATION OF EXCHANGEABLE ACIDITY

Extractant	Soil: Extratant Ratio			Units Used in Reporting	
	1:25	1:20	1:10	meq/100g	mol/kg
$BaCl_2$- Triethanolamine	-	-	2	2	-
1N KCl	1	-	2	3	-

TABLE 15. NUMBER OF LABORATORIES USING DIFFERENT SOIL: SOLUTION RATIOS TO DETERMINE EC

Solution	Saturated Paste	Soil: Solution Ratio			Units Used in Reporting		
		1:1	1:5	1:2.5	mmhos/cm	mS/cm	ds/m
Water	6	5	5	2	11	1	1

TABLE 16. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR THE DETERMINATION OF LIME REQUIREMENT

Method	No. of Labs	Method of Detection			Units Used in Reporting		
		Titration	Atomic Absorption	Other	%	g kg	meq 100g
$BaCl_2$-Triethanolamine	4	4	-	-	2	1	1
Gravimetric	1	-	-	-	-	-	-
Fusion with Lithium Borate	1	-	1	-	1	-	-
$Ca(OH)_2$	2	4	-	-	-	2	-
Hach Method	1	-	-	1	1	-	-

TABLE 17. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR THE DETERMINATION OF SULFATES IN SOILS

Method	No of Labs	Method of Detection				Units Used in Reporting		
		Gravimetric	Turbidimeter	EC Meter	Spectrophotometer	ppm	g/kg	meq/l
Gravimetric	5	5	-	-	-	4	1	-
Turibidimetric	6	-	6	-	-	5	-	1
EC Bridgeas $CaSO_4$	1	-	-	1	-	-	-	1

TABLE 18. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR THE FRACTIONATION OF INORGANIC PHOSPHOROUS

Form of Inorganic Phosphorous	Extractant	No.of Labs	Method of Detection Spectrophotometer	Units Used in Reporting	
				ppm	mg/g
Saloid bound P	1M NH_4Cl	1	1	1	-
Fe-bound P	0.1M NaOH	2	2	2	-
Al-bound P	0.5M NH_4F	2	2	2	-
Occluded Al-Fe P	0.1M NaOH	1	1	1	-
Redcutant Soluble Fe-P	Sodium dithionite & Sodium Citrate	1	1	1	-
Ca bound P	0.25M H_2SO_4	1	1	1	-

TABLE 19. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR THE DETERMINATION OF FREE IRON AND ALUMINIUM IN SOILS

Element	No. of Labs.	Method of Extraction DCB	Method of Detection			Units Used in Reporting	
			A.A	Colorimetric (Al)	Phenanthroline	ppm	mg/g
Al	2	2	1	1	-	1	1
Fe	2	2	-	-	2	1	1

DCB= Dithionite-Citrate-Bicarbonate; A.A= Atomic Absorption

TABLE 20. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR THE DETERMINATION OF " AMORPHOUS IRON, ALUMINIUM AND SILICA

Element	No. of Labs.	Method of Extraction		Method of Detection		Units Used in Reporting	
		0.2M NH_4-Oxalate	0.1N NaOH	A.A	Colorimetric	ppm	mg/g
Al	1	1	-	1	-	1	-
Fe	1	1	-	1	-	1	-
Si	-	-	-	-	-	-	-

used by >70% of the labs doing the determination is the atomic absorption while colorometric detection is done by < 30% of the labs. The reporting uints by all labs is ppm.

8.1.1.17 **Determination of available Mn, Zn and Cu:**

Tables 22, 23 and 24 indicate that these determinations are perfomed on the same extract as for available Fe on Table 21 viz : DTPA, NH_4OAc , EDTA and HCl solutions. As such the 1:2 soil: extractant ratio and the 2 hours shaking time are similar as for available Fe. Atomic absorption is the method of detection except for zinc where 1 lab uses colorimetric methods. Again all the results are reported in ppm. Similarly < 12% of the labs do these determinations using each of the extractants indicated above.

8.1.1.18 **Determination of available boron:**

Boron is determined by hot water extraction by 16% of the labs. The 1:2 soil: extraction is used by 3 of the labs (75% of labs doing the determination). The time of extraction for all labs is 5 minutes. All labs use spectrophotometry for detection and report the results in ppm.

8.1.1.19 **Determination of available** molybdenum:

Eight percent of the labs determine Molybdenum by extraction with $(NH_4).C_2O_4$ in a 1:10 soil: extractant ratio and extraction time is 3-4 hrs and 8-16 hrs for each of the labs (Table 26). Four percent of the labs determine Mo by NH_4OAc extraction in a 1:10 soil: extractant and an 8-16 hour shaking time. Detection is done on atomic absorption and spectrophotometer and the reporting units for 2 labs are in ppm and for 1 lab in mg/g.

8.1.1.20 **Determination of total elemental analysis:**

A range of digestion methods are used for the determination of total elements (Table 27). Sodium carbonate fusion is done by 8-12 % of the labs, aqua regia digestion by 4%, HF by 4%, $HClO_4$ digestion by 8-24 %, and H_2SO_4 digestion by 4% of the labs. About 16% of the labs use atomic absorption as a means of detection, < 8% use flame emmission for K determination, <4% do Ca + Mg by titrimetry and 8% determine Na and K by flame photometry and 8-12% determine N and S by spectrophotometry. About 4-16% of the labs use ppm in reporting while 4-8% use ug/g. Four percent of the labs use cmol/kg for reporting Ca, Mg, Na and K.

8.1.1.21 **Particle Size Determination** (PSD):

Particle size determination by the hydrometer method is done by 44% of the labs while only, 2% determine it by the pipette method (Table 28). All labs (44%) determining texture by the hydrometer use Na-Hexa-metaphosphate dispersant while 2 of the 3 labs doing texture by the pipette method also use Na- Hexa-Metaphosphate as dispersant. All the 3 labs doing texture by pipette do organic matter pretreatments. Free iron is removed by 8% of the labs in either method while $CaCO_3$ removal is only done by 4% of the labs for the hydrometer method & not effected for the pipette method. The USDA fractionation method is used by 36%

TABLE 21. NUMBER OF LABORATORIES USING DIFFERENT EXTRACTANTS AND SOLUTION RATIOS FOR THE DETERMINATION OF AVAILABLE IRON

Extractant Conc.	No. of Labs	Soil:Extractant Ratio					Time of Extraction Hours					Method of Detection		Reporting Units	
		1:2	1:25	1:10	1:20	1:50	1/6	1/2	1	2	Over night	A.A	Colorimetric	ppm	mg/g
DPTA 0.005 M	4	4	-	1	-	1	-	4	-	1	1	4	2	4	-
NH_4OAC 1N	2	1	-	1	-	-	-	-	-	2	-	2	1	2	-
EDTA	1	1	-	1	-	-	-	-	-	1	-	2	-	2	-
HCl	1	1	-	1	-	-	-	-	-	-	-	1	-	1	-

TABLE 22. NUMBER OF LABORATORIES USING DIFFERENT EXTRACTANTS AND SOLUTION RATIOS FOR THE DETERMINATION OF AVAILABLE MANGANESE

Extractant Conc.	No. of Labs	Soil: Extractant Ratio						Time of Extraction Hours				Method of Detection		Units Used in Reporting	
		1:2	1:2.5	1:5	1:10	1:20	1:50	1/2	1	2	Other	A.A	Colorimetric	ppm	mg/g
DTPA 0.005M	2	2	-	-	-	-	-	-	-	2	-	2	-	2	-
NH_4OAC 1N	3	3	-	-	1	-	1	1	-	-	1	1	1	2	-
EDTA	2	2	-	-	-	-	-	1	-	1	-	2	-	2	-
HCl	1	1	-	-	-	-	-	-	-	1	-	1	-	1	-

TABLE 23. NUMBER OF LABORATORIES USING DIFFERENT EXTRACTANTS AND SOLUTION RATIOS FOR THE DETERMINATION OF AVAILABLE ZINC

Extractant Conc.	No. of Labs	Soil: Extractant Ratio						Time of Extraction Hours			Detection Method		Units Used in Reporting	
		1:2	1:2.5	1:5	1:10	1:20	1:50	1/2	1	2	A.A	Colorimetric	ppm	mg/g
DTPA 0.005M	2	2	-	-	-	-	-	-	-	2	2	-	2	-
NH_4OAC 1N	1	2	-	1	-	-	-	-	1	-	-	1	1	-
HCl 0.2N	2	2	-	-	-	1	-	-	1	1	2	-	2	-
HCl 0.1N	1	1	-	-	1	-	-	-	1	-	1	-	1	-
EDTA	1	1	-	-	-	-	-	-	-	1	1	-	1	-

TABLE 24. NUMBER OF LABORATORIES USING DIFFERENT EXTRACTANTS AND SOIL: SOLUTION RATIOS FOR THE DETERMINATION OF COPPER

Extractant Conc.	No. of Labs.	Soil: Extractant Ratio					Time of Extraction Hours			Detection Method		Units Used in Reporting	
		1:2	1:10	1:20	1:50	Other	1/2	1	2	A.A	Colorimetric	ppm	mg/g
DTPA 0.005M	2	2	-	-	-	-	-	-	2	2	-	2	-
NH_4OAC 1N	2	1	-	-	-	-	-	1	1	-	1	2	-
HCl 0.2N	1	1	-	-	-	-	-	-	1	1	-	1	-
HCl 0.1N	2	-	-	-	-	1	-	-	2	2	-	2	-
EDTA	1	1	-	-	-	-	-	1	1	1	-	1	-

of the labs while only 8% use the S.I system for the hydrometer method. Three labs (100%) use the S.I system of fractionation for the pipette method. Also 3 of the labs (100%) who do PSD by the pipette method report their results in % while 40%(10 labs) that do PSD by the hydrometer also report results in ppm. Only 4% of the labs report results in g/kg.

8.1.1.22 **Bulk density (BD) Determination**:

Twenty eight percent of the labs use the core method for BD, 8% use the saran method and 8% the paraffin method. The same percent of labs respectively use g/cc in reporting the results.

8.1.1.23 **Determination of Particle Density (PD):**

Thirty two percent of the labs use the pycnometer method for the determination of PD (Table 30). The same % use g/cc in reporting. Only 4% of the labs use another method in reporting.

8.1.1.24 **Determinationn of soil moisture content:**

Forty eight (48)% of the labs determine moisture content gravimetrically and also report their results in % (Table 31). 12% use the Neutron Probe Technique for moisture content determination.

8.1.1.25 **Water Retention Determination:**

Field capacity is determined by 20% of the labs and wilting point, 15 bar is determined by 20% of the labs in 15 bar pressure plates while 8% of the labs use the pressure membrane for the determination of 15 bar water retention capacity. (Table 32). All the moisture contents are reported in %.

B. **PLANT ANALYSIS**

8.1.1.26 **Determination of total plant elemental content:**

Digestion, detection and reporting units are given in Table 33. About 12% of the labs do dry ashing and uptake in HCl while 4-8% do dry ashing digestion and uptake in HNO_3. About 4-8% do wet digestion in HF and $HClO_4$. About 4-24% use atomic absorption as a means of detection while 28-36% of the labs use flame photometry for Na and K detection. Boron and P are detected spectrophotometrically by 8% and 28% of the labs respectively. About 4-16% of the labs report results in %, 4-12% report the results in g/kg, 8% use mg/kg, 4% use cmol/kg and 4-8% use ppm. Very few labs are presently doing plant analysis.

8.1.1.27 **Determination of total Nitrogen:**

Total N in plants is determined by 11 laboratories (Table 34). About 40% of the labs use conc. H_2SO_4 + salt mixture while only 4% use H_2SO_4 + H_2O_2 for digestion. 40% of the labs use distillation and titration detection methods while only 4% of the labs use colorimetric methods. All the labs report their results in ppm.

TABLE 25. NUMBER OF LABORATORIES USING DIFFERENT EXTRACTANTS AND SOIL: SOLUTION RATIOS FOR THE DETERMINATION OF BORON

Extractant Conc.	No. of Labs.	Soil: Extractant Ratio		Time of Extraction Hours		Detection Method		Units Used in Reporting	
		1:2	Other	5min	15min	A.A	Spectrophotometer	ppm	mg/g
Hot Water	4	3	1	4	-	-	4	4	-
Boiling Water	-	-	-	-	-	-	-	-	-

TABLE 26. NUMBER OF LABORATORIES USING DIFFERENT EXTRACTANTS AND SOIL: SOLUTION RATIOS FOR THE DETERMINATION OF MOLYBDENUM

Extractant Conc.	No. of Labs	Soil: Extractant Ratio			Time of Extraction Hours			Detection Method		Units Used in Reporting	
		1:1	1:10	1:15	3-4	8-16	12-24	A.A	Spectrophotometer	ppm	mg g
$(NH_4)_2C_2O_4$	2	-	2	-	1	1	-	-	2	1	1
NH_4OAC 1N	1	-	1	-	-	1	-	1	-	1	-

TABLE 27. NUMBER OF LABORATORIES USING DIFFERENT DIGESTION, EXTRACTION AND DETECTION TECHNIQUES FOR THE DETERMINATION OF TOTAL ELEMENTAL ANALYSIS OF SOILS

Element	No. of Labs.	Method of Digestion					Method of Detection					Units Used in Reporting			
		$NaCo_3$ Fusion	Aqua Regia	HF	$HClO_4$	H_2SO_4	A.A	FE	S	T	FP	ppm	ug/g	(mol/kg)	%
Ca		3	1	1	2	-	4	-	-	1	-	2	-	1	1
Mg		3	1	1	2	-	4	-	-	1	-	2	-	1	1
Na		2	1	1	2	-	4	-	-	-	2	2	1	1	1
K		3	1	1	6	1	4	2	-	-	2	2	1	1	1
Zn		3	1	1	3	-	4	-	-	-	-	3	1	-	-
Fe		2	1	1	3	-	4	-	-	-	-	4	1	-	-
Mn		3	1	1	4	-	4	-	-	-	-	3	1	-	-
Cu		2	1	1	3	-	4	-	-	-	-	3	1	-	-
P		3	1	1	3	1	-	-	3	-	-	4	2	-	1
N		-	1	-	1	1	-	-	2	3	-	1	1	-	3
Cr		-	1	-	-	-	-		-	-	-	1	1	-	-
Cd		-	1	-	-	-	-	-	-	-	-	1	1	-	-
Co		-	1	-	-	-	-	-	-	-	-	1	1	-	-
Pb		-	1	-	-	-	-	-	-	-	-	1	1	-	-
Hg		-	1	-	-	-	-	-	-	-	-	1	1	-	-

A.A= Atomic Absorption, FE= Flame Emission, S=Spectrophotometry, T= Titration,

TABLE 28. NUMBER OF LABORATORIES USING DIFFERENT METHODS OF PARTICLE SIZE DETERMINATION

Method	No. of Labs.	Dispersing Agents		Pretreatments Removal of			Fractionation		Units Used in Repr	
		Na-Oxalate	Na-Hexa -meta-P	O.M	$CaCO_3$	Free Fe	USDA	Int.System	%	g kg
Pipette	3	1	2	3	-	2	1	3	3	-
Hydrometer	11	-	11	7	-	2	9	2	10	1

TABLE 29. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR BULK DENSITY DETERMINATION

Method	No. of Labs	Units Used in Reporting	
		g/cc	mg/g
Core Method	7	7	-
Saran Coated	2	2	-
Parafin Coated	2	2	-

TABLE 30. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR PARTICLE DENSITY DETERMINATION

Method	No. of Labs	Units Used in Reporting	
		g/cc	mg/g
Pycnometer	8	8	-
Other	1	1	-

TABLE 31. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR SOIL MOISTURE DETERMINATION

Method	No. of Labs	Units Used in Reporting	
		g/cc	g/g
Gravimetric	12	12	-
Neutron probe Technique	3	3	-

TABLE 32. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR SOIL WATER RETENTION CHARACTERISTICS

Methods	No. of Labs.	Moisture Capacity		Units Used in Reporting		
		Field Capacity	Wilting Point	g/g	%	Other
Pressure Plate 0-4 bars	5	5	-	-	5	-
15 bar Pressure Membrane	2	-	2	-	2	-
15 bar Pressure Plate	5	-	5	-	5	-
Other	-	-	-	-	-	-

8.1.1.28 **Determination of total Molybdenum:**

Table 35 indicates that 4% of the labs use $HClO_4$ + HNO_3 for Mo digestion while another 4% uses $AgNO_3$ + HNO_3. One of the labs reports results in ppm and the other in mg/kg.

8.1.1.29 **Determination of sulfates and chlorides:**

No laboratory is currently carrying out these determinations. Plant analysis is mostly restricted to the cations.

C. **WATER ANALYSIS**

8.1.1.30 **Determination of pH, EC and total dissolved salts:**

Table 36 indicates that 52% of the labs determine pH in water electrometrically. It also indicates that 48% of the labs determine EC and that 8% of the labs report results in ms/cm while 40% of them report in mmhos/cm. 28% of the labs determine total dissolved solids gravimetrically and also report their results in g/l.

8.1.1.31 **Determination of carbonates, bicarbonates, total alkalinity, sulfates and chlorides in water:**

Table 37 indicates that 32% of the labs determine carbonates and bicarbonates by titrimetric procedures. 16% of the labs in either case report results in mg/l while 20% of the labs in either case report in meq/l. Total alkalinity as $CaCO_3$ is only determined in 16% of the labs.

20% of the labs determine sulfates both gravimetrically and by turbidimetric methods and report the results both in mg/l and in meq/l. Chlorides are determined by 36% of the labs and 16% report the results in mg/l while 24% report the resullts in meq/l.

8.1.1.32 **Determination of Ca, Mg, Na, K and Bo:**

Table 38 indicates that Ca and Mg are determined by 40% of the labs. 8% of the labs use atomic absorption for detection while 28% of them use titrimetric procedures for detection. 16% of the labs report their resullts in mg/l while 28% report their results in meq/l. Na and K are analyzed by 44% of the labs, 20% of the labs used flame emmission while 20% use flame photometry for detection; the remaining 4% use titrimetric procedures. In reporting 24% use mg/l while another 24% also use meq/l.

Boron determination is done only in 16% of the labs with half the labs reporting their results in mg/l and the other half in meq/l. All labs determine boron spectrophotometrically.

8.1.1.33 **Determination of Nitrates and Phosphates:**

Table 39 indicates that Nitratees are determined by 3 labs with one lab using colorimetric detection methods while the other 2 use titrimetric procedures. All the results are reported in mg/l.

B. PLANT ANALYSIS

TABLE 33. NUMBER OF LABORATORIES USING DIFFERENT METHODS OF DIGESTION, EXTRACTION AND DETECTION

Element	No.of Labs	Method of Digestion				Method of Detection				Units Used in Reporting				
		OA	AB	DF	Other	A.A	FP	T	S	%	g/kg	mg/kg	mol/kg	ppm
Ca		3	2	2	-	6	-	1	-	3	3	-	1	1
Mg		3	2	2	-	5	-	1	-	3	3	-	1	1
Na		3	2	2	-	-	7	-	-	3	3	-	1	1
K		3	2	2	2	-	9	-	-	4	3	-	1	2
Zn		3	1	1	-	5	-	-	-	1	1	2	-	1
Fe		3	1	1	-	5	-	-	-	1	1	2	-	1
Mn		3	1	2	-	5	-	-	-	1	1	2	-	1
Fe		3	1	2	-	5	-	-	-	1	1	2	-	1
Cd		-	1	-	-	1	-	-	-	-	-	-	-	-
Cr		-	1	-	-	1	-	-	-	-	-	-	-	-
Co		-	1	-	-	1	-	-	-	-	-	-	-	-
Pb		-	1	-	-	1	-	-	-	-	-	-	-	-
B		-	2	-	-	1	-	-	2	-	-	1	-	1
Other		-	2	1	2	-	-	-	7	2	3	1	1	1

Where: OA= Dry Ashing without HF and Uptake in HCl; AB= Dry Ashing without HF and Uptake in HNO_3; DF= Wet Digestion with HF and Final Medium HClO.

Dectection: A.A= Atomic Absorption; FP= Flame Photometry; S= Spectrophotometry; T= Titration

TABLE 34. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR TOTAL N DETERMINATION

Methods of digestion	No. of Labs.	Method of Detection		Units Used in Reporting		
		Distillation + Titration	Colorimetric	%	g/kg	ppm
Conc. H_2SO_4 + Salt Mixture *	10	10	-	10	-	-
H_2SO_4 + H_2O_2	1	-	1	1	-	-

* Salt Mixture= K_2SO_4 or Na_2SO_4 + $CuSO_4.5H_2O$ + Selenium

TABLE 35. NUMBER OF LABORATORIES USING DIFFERENT METHODS FOR TOTAL MOLYBDENUM DETERMINATION

Methods	No. of Labs.	Method of Detection			Units Used in Reporting		
		Atomic Absorption	Colorimetric	Titration	%	ppm	mg kg
$HClO_4$ (60%) + HNO_3 (70%)	1	1	-	-	-	1	-
Other $AgNO_3$ + NH_3	1	-	-	1	-	-	1

C= WATER ANALYSIS

TABLE 36. NUMBER OF LABORATORIES THAT DO pH EC AND TOTAL DISSOLVED SALT ANALYSIS

Determination	No. of Labs.	Method of Detection				Units Used in Reporting		
		Colorimetric	pH Meter	EC Meter	Gravimetric	mS/cm	mmho/cm	g/l
pH	13	-	13	-	-	-	-	-
EC	12	-	-	12	-	2	10	-
Total Solids	7	-	-	-	7	-	-	7

TABLE 37. NUMBER OF LABORATORIES THAT DO CARBONATES, CARBONATES, TOTAL ALKALINITY, SULFATES AND CHLORIDES DETERMINATION IN WATER

Determination	No. of Labs.	Method of Detection					Units Used in Reporting		
		Phenolpthalein	Methyl Orange end Point	Gravimetric	Turbidmetric	Titrimetric $AgNO_3$	mg/l	meq/l	Other (ppm)
Carbonates	8	8	-	-	-	-	4	5	-
Bicarbonates	8	-	8	-	-	-	4	5	-
Total Alkalinity as $CaCO_3$	4	-	-	-	-	-	3	1	-
Sulphates	5	-	-	5	5	2	5	4	1
Chloride	9	-	-	-	-	1	4	6	-

TABLE 38. NUMBER OF LABORATORIES THAT DO Ca^{++}, Mg^{++}, Na^{+}, K^{+} AND Bo^{+} DETERMINATION IN WATER

Determination	No. of Labs.	Method of Detection					Units Used in Reporting	
		A.A	FE	FP	T	SP	mg/l	meq/l
Ca^{++}	10	2	-	-	7	-	4	7
Mg^{++}	10	2	-	-	7	-	4	7
Na^{+}	11	-	5	5	1	-	6	6
K^{+}	11	-	5	5	1	-	6	6
B^{+}	4	-	-	-	-	4	2	2

Where: A.A= Atomic Absorption; FE= Flame Emission;
FP= Flame Photometer; T= Titrimetric;
SP= Spectrophotometer /Carmine Method/

Phosphate analyses are carried out in 4 labs (16%). Colorimetric detection using vandomolydic acid is the method of choice of the 4 labs. Two report their results in mg/l while the other 2 report in ppm.

D. **FERTILIZER ANALYSIS**

8.1.1.34 **Determination of Ca, Mg, K, P, Cu, Mn, Fe, Zn, Mo and B:**

Table 40 indicates that 4-8% of the labs carry out fertilizer analysis on the above elements with > 90% using Boiling in HCl as the degestion method. Except for P which is determined colorimetrically, atomic absorption is used as a means of detection. Ca, Mg, Na, K, and P results are reported in % while the micronutrient results are reported in ppm.

8.1.1.35 **Determination of sulfur:**

As table 41 indicates sulfur analysis is only done in 1 lab using the method of boilling in HCl + HNO_3 followed by turbidimetric detection and reporting results in %.

8.1.1.36 **Determination of total N, NH_3-N and NO_3-N in fertilizers:**

Total N analysis is carried out in 20% of the labs using H_2SO_4 + salt mixture for digestion and distillation and titration in detection, with all reporting results in %.

Ammonia-N and NO_3-N are only carried out in 8% of the labs, using distillation and titration for detection. For NH_3-N the 2 labs report their results in ppm while for NO_3-N one of the labs reports in ppm while the other reports in %.

E. **COMPOST ANALYSIS**

8.1.1.37 **Determination of total N and P in compost:**

Three labs (12%) determine total N by digestion in H_2SO_4 + salicylic acid + salt mixture and use distillation and titration in detection; while all report the results in % (Table 43).

8% of the labs carry out P analysis by digesting in boiling acid mixture (HNO_3 + H_2SO_4 + $HCIO_4$), detecting colorimetrically and reporting their results in % (Table 43).

8.1.1.38 **Determination of mineral elements in compost and animal waste:**

4-8% of the labs carry out elemental analysis on compost and animal wastes using H_2SO_4 + salt mixture for digestion for all elements except K & Na while 4-8 % of the labs use dry ashing for digestion. Except for P which is detected colorimetrically the other elements are determined on the atomic absorption. Except for the micronutrient results which are reported in ppm, all the other results are in %.

TABLE 39. NUMBER OF LABORATORIES THAT DETERMINE NITRATES AND PHOSPHATES IN WATER

Determination	No. of Labs.	Method of Detection				Units Used in Reporting		
		Colorimetric Phenol Dis.	ISE	Colorimetric Vanado. Acid	Titrimetric	mg/l	meq/l	ppm
Nitrates	1	1	-	-	-	1	-	-
	2	-	-	-	2	2	-	-
Phosphates	4	-	-	4	-	2	-	2

Where: Phenol Dis= Phenol Disulphonic Method;
ISE= Ion Selective Electrode;
Vanado Acid= Vanadomolybdophosphoric Acid Method

D. FERTILIZER ANALYSIS

TABLE 40. NUMBER OF LABORATORIES DETERMINING Ca, Mg, K, Cu, Mn, Fe, Zn, Mo, B AND P IN FERTILIZERS

Element	No.of Labs.	Method of Digestion		Method of Detection			Units Used in Reporting		
		Boiling in HCl	Boiling in $HClO_4$ & HF	A.A	FE	S	%	g/kg	Other/ppm
Ca	1	1	-	1	-	-	1	-	-
Mg	1	1	-	1	-	-	1	-	-
Na	1	1	-	-	1	-	1	-	-
K	2	1	-	-	2	-	2	-	-
Cu	1	1	-	1	-	-	-	-	1
Mn	1	1	-	1	-	-	-	-	1
Fe	1	1	-	1	-	-	-	-	1
Zn	1	1	-	1	-	-	-	-	1
Mo	-	1	-	1	-	-	-	-	1
P	1	1	1	-	-	2	2	-	-

Where: A.A= Atomic Absorption; FE= Flame Emission; S= Spectrophotometry

TABLE 41. NUMBER OF LABORATORIES THAT DETERMINE SULFUR IN FERTILIZERS

Methods of digestion	No. of Labs.	Method of Detection			Units Used in Reporting	
		Gravimetric	Turbidimetric	S	%	g/kg
Boiling HCl - HNO_3	1	-	1	-	1	-

Where: S= Spectrophotometric

TABLE 42. NUMBER OF LABORATORIES DETERMINING TOTAL N, AMMONIACIAL AND NITRATE N IN FERTILIZERS

Determination	No.of Labs	Method of Digestion	Method of Detection		Units Used in Reporting		
		H_2SO_4 + Salt Mixture	Distillation & Titration	ISE	%	g/kg	Other (ppm)
Total N	5	5	5	-	5	-	-
Ammonia N	2	-	2	-	-	-	2
Nitrate N	2	-	2	-	1	-	1

Where: ISE= Ion Selective Electrode

E. COMPOST ANALYSIS

TABLE 43. NUMBER OF LABORATORIES THAT DETERMINE TOTAL NITROGEN AND TOTAL P IN COMPOST

Element	No.of Labs.	Method of Digestion		Method of Detection		Units Used in Reporting			
		A	B	Distillation & Titration	Colorimetric	%	g/kg	meq/100g	ppm
N	3	3	-	3	-	3	-	-	-
P	2	-	2	-	2	2	-	-	-

Where A= H_2SO_4 + Salicylic Acid + Salt Mixture (K_2SO_4 + $CuSO_4.5H_2O$ + $FeSO_4.7H_2O$
B= Boiling Acid Mixture (HNO_3 + H_2SO_4 + $HClO_4$)

TABLE 44. NUMBER OF LABORATORIES THAT DETERMINE MINERAL ELEMENT IN COMPOST AND ANIMAL WASTE

Element	No.of Labs.	Method of Digestion		Method of Detection				Units Used in Reporting		
		H_2SO_4 + Salt Mixture	Dry Ashing	A.A	FE	FP	S	%	g/kg	ppm
Ca	1	1	-	1	-	-	-	1	-	-
Mg	1	1	-	1	-	-	-	1	-	-
Na	1	-	1	-	-	-	-	1	-	-
K	2	-	2	-	1	-	-	2	-	-
Fe	1	1	-	1	2	-	-	-	-	1
Mn	1	1	-	1	-	-	-	-	-	1
Cu	1	1	-	1	-	-	-	-	-	1
Zn	1	1	-	1	-	-	-	-	-	1
Mo	-	-	-	-	-	-	-	-	-	-
B	-	-	-	-	-	-	-	-	-	-
P	2	1	1	-	-	2	-	2	-	-

Where: Salt Mixture= $CuSO_4.5H_2O$ + Sodium Sulfate + Selenium
A.A= Atomic Absorption; FE= Flame Emission;
S=Spectrophotometry; T= Titrimetric;
FP= Flame Photometry

F GENERAL QUESTIONS ON THE LABORATIONRY OPERATION.

After considering personnel, equipment and the different analytical methods for soil, water, plant, fertilizers and organic manures and compost it was also necessary to evaluate the laboratories in terms of mode of acquistion of chemicals, users of the laboratory, quality control procedures, training, need for the adoption of standardized procdures and problems that hinder the smooth running of the laboratories. This was deemed necessary in order to make overall assessment of the laboratory and make the necessary recommendations for improvements. The questions posed and the responses given are examined here after.

8.1.1.39 **Question on how laboratories acquire chemicals and equipment:**

The results to this question (Table 45) indicate that 52% of the labs obtain aid for purchase of equipment and chemicals from Aid Organizations apart from government while the source of funding for 24% of the laboratories is from goverment. 8% of the labs obtain the funding from their own organization while only 4% of the labs acquire the chemicals and equipment through receipts from their analytical services rendered to the public. This indicates that without aid from Aid organizations and government very few labs can function properly.

8.1.1.40 **Question on the number of laboratories that redistill alcohol for reuse:**

The results (Table 46) indicate that only 8% of the labs redistill alcohol while the majority (60%) do not redistill alcohol. To get a better understanding why very few labs redistill alcohol a follow up question indicates that most labs lack the equipment (36%) while 24% of the labs never thought about it.

8.1.1.41 **Question on the clientel that supply the bulk of soil, water and plant analysis:**

The results (Table 47) indicate that research bodies are the biggest users (48%) followed by government organizations (36%), then by own user's of the lab results; International Organizations and Schools and Universities each constitute about 20% of the users while the local farmers who are supposed to benefit most from these analytical services use them least (12%).

8.1.1.42 **Question on reason for the few analysis effected in the laboratory:**

Results (Table 48) indicate that most labs (60%) lack the chemicals and equipment to do the anlysis, 32% of the labs attributed it to inadequate personnel, 24% putting the blame on lack of methods developed for the analysis, while some labs (12%) attribute it to lack of knowledge by farmers about the existing services. Some labs (12%) also attribute the low number of samples to the fact that farmers do not yet feel the need for these analyses. Other reasons, like lack of finances by farmers (8%), laboratory located too far away from users (8%), and the fact that previous recommendations did not provide the increases in yields expected (4%) were advanced as factors hindering increased analyses of samples. Solution of some of the problems indicated could greatly inhance the amount and quality of analytical services rendered to farmers.

8.1.1.43 **Question on the number of laboratories that have made efforts to sell their products:**

The results (Table 49) indicate that very few labs (12%) have taken the trouble to market their services. Few labs still (4%) have used radio and the written press as a means of marketing while 12% of the labs have used both formal and informal contacts for this purpose. No lab has used the TV as a means to get to the population. The low percentage of response indicates that very few people are aware of the existence of analytical laboratories and the functions they perform.

8.1.1.44 **Question on why the laboratories do not market their labs:**

The results (Table 50) indicate that most labs (52%) do not market their services. Some labs (36%) do not market their services because it is for their own use; some labs (8%) have never thought about it while some labs (4%) attribute it to the fact that their labs are not fully operational.

8.1.1.45 **Question on what quality control procedures are used**

The results (Table 51) indicate that most labs(36%) use reference samples, followed by 20% of the labs who use recovery techniques with chemicals of known concentration. About 12% of the labs participate in sample exchange programmes while another 12% just adopt long established procedures without any control methods. About 4% of the labs use standard control, duplicate control, internal control, external control and abitration as a means for quality assurance.

8.1.1.46 **Question no how laboratories recruit staff to the laboratory:**

The results (Table 52) showed that most labs (36%) have staff posted to them by government irrespective of field of competence: while some labs (24%) select their staff based on competence through exams. Only 16% of the labs have staff selected by the government based on the interest of the staff for the vocation.

8.1.1.47 **Question no the problems labs have in retaining their qualifield staff:**

Most labs (36%) think most staff leave the lab due to danger from chemical use (Table 53) while 28% think staff leave due to low salaries, laborious and monotonous lab work and the fact that they have few prospects of moving up the ladder as technicians. Some 20% of the labs find that most technicians shift to other

TABLE 45. QUESTION ON HOW LABORATORIES ACQUIRE CHEMICALS AND EQUIPMENT

Source	No. of Labs	Response %
Government Grant	6	24
Other Aid Organizations	13	52
Own Resources Through Analytical Services	1	4
Other: Own Organization	2	8

TABLE 46. NUMBER OF LABROATORIES THAT REDISTILL ALCOHOL FOR USE

Source	No. of Labs	Response %
Labs that Redistill Alcohol	2	8
Labs that do not Redistill	15	60
Reasons: - Never thought about it	6	24
- Lack Equipment	1	36
- Other, Specify	1	4

TABLE 47. CLIENTEL THAT SUPPLY THE BULK OF SOIL, WATER AND PLANT ANALYSIS IN ORDER OF BIGGEST USERS

Organization	No. of Labs	Response %
Government Organizations	9	36
International Organizations	5	20
Local Farmers	3	12
Schools and Universites	5	20
Research Bodies	12	48
Own Users	6	24

TABLE 48. RESPONSE TO THE REASON FOR THE FEW ANALYSIS EFFECTED IN THE LABS.

Responses	No. of Labs	Response %
a. Lack of finances by clients to pay for analysis	2	8
b. Lack of knowledge about existing services offered by the lab	3	12
c. Need or importance of analysis not yet felt by farmers	3	12
d. Methods not yet developed for required analysis	6	24
e. Lack of equipment and or chemicals to effect analysis	15	60
f. Inadequate lab. personnel	8	32
g. Clients not confident in our analysis results	1	4
h. Laboratory located too far from most potential users	2	8
i. Previous recommendations did not considerably increase yields hence reluctance on the part of users for further analysis	1	4
j. Other reasons; specify	1	4

TABLE 49. NUMBER OF LABORATORIES THAT HAVE MADE EFFORTS TO SELL THEIR LAB. PRODUCT TO POTENTIAL USERS

	No. of Labs	Response %
Those that have made efforts to market lab. services	3	12
Means of Marketing		
a. By radio	1	4
b. Press	1	4
c. Television	0	0
d. Both formal and informal contacts	3	12

TABLE 50. NUMBER OF LABORATORIES THAT DO NOT MARKET THEIR LABS. AND WHY

Response	No. of Labs	Response %
Do not market their lab. services:	13	52
a. Never thought about it before	2	8
b. Lack of means of communication	-	-
c. Laboratory intended for own use only	9	36
d. Lab not yet fully operational	1	4
e. Other, specify	1	4

TABLE 51. WHAT QUALITY CONTROL METHODS DO YOU USE BOTH TO DEVELOP METHODOLOGIES AND OR ASSESS ROUTINE DATA QUALITY ?

Response	No. of Labs	Response %
a. Recovery technics with chemicals of known concentrations	5	20
b. Use of reference samples	9	36
c. Participation in sample exchange programmes with other labs	3	12
d. Non, just adopt long established procedures	3	12
e. Standard Control	1	4
f. Duplicate Control	1	4
g. Internal Control	1	4
h. External Control	1	4
i. Abitration Control	1	4

disiciplines due to much work in the laboratory. Some labs (4%) indicate technicians leave due to lack of milk, medical checkup and care, and lack of insfrastructure to maximize productivity. Only 4% of the labs reported that they have no problem retaining the staff.

8.1.1.48 **Question on where lab staff are trained:**

Most labs (44%) (Table 54) responded that they train their technicians in other labs within the country while an additional 12% specifically indicated that they train their staff at the NSSP. 36% of the labs train their staff on the job in their labs while some 32% of the labs train their technicians broad.

8.1.1.49 **Question on how to determine where to train the staff:**

Most labs (48%) indicate that they train their staff in labs which are well-equiped and manned (Table 55). 24% of the labs train their staff in labs that accept them while 12% of the labs train their personnel in labs that would give the training at the least cost. Only 4% of the labs train their technicians in areas with similar geographic and climatic conditons.

8.1.1.50 **Question on what criteria is used to select staff for training:**

Most labs (48%) select their staff for training based on competence in the area indicated (Table 56) while 16% of the labs select technicians on the basis of first come first served basis. 12% of the labs select their technicians for training based on competitive exams, while only 4% of the labs have technicians for training selected by government without their input.

8.1.1.51 **Question on whether results gained by trainees are incorporated into the lab practice to increase efficiency:**

Results (Table 57) indicate that 40% of the labs incorporate the results of the trainees after they return from training in their regular programmes. However, some labs (20%) do not incorporate these results. The reasons for non-inclusion range from methods not available to lack of equipment in the lab (8%), nothing new is brought back from the training (4%), for fear of distabllizing the established procedures (4%), and because of little experience of the technicians (4%).

8.1.1.52 **Question on if labs will be willing to standardize procedures & equipment if different from their's:**

To this question 56% of the labs responded positively to standardize procedures, while 64% of the labs will be willing to standardize the equipment (Table 58). On the standardization of equipment some labs though willing indicated that in cases where the donors gave the equipment they had little choice but would cooperate if the conditions of the donors were flexible.

TABLE 52. QUESTION ON HOW LABS RECRUIT STAFF TO THE LABORATORY

Response	No. of Labs	Response %
a. Staff posted by government irrespective of field of competence	9	36
b. Staff selected by us based on competence through exams	6	24
c. Staff selected by government based on interest of staff for the vocation	4	16
d. Other, specify	2	8

TABLE 53. QUESTION ON RETAINING STAFF THAT ARE TRAINED

Response	No. of Labs	Response %
a. Staff demand salaries and allowances comensurate with work load effected	7	28
b. Staff complain of much work in relation to counterparts in other field	5	20
c. Staff complain of danger from use of chemicals	9	36
d. Laboratory work becomes very repetitous and monotonous	7	28
e. Staff do not see any head way in moving up in the profession as a lab. technician	7	28
f. No milk	1	4
g. No medical check up	1	4
h. Lack of essential equipment and chemicals to maximize use of trained staff	1	4
i. Have no problems retaining qualified staff	1	4

TABLE 54. QUESTION ON WHERE LAB. STAFF ARE TRAINED

Response	No. of Labs	Response %
a. On the job in our laboratory	9	36
b. In other labs in the country	11	44
c. Abroad	8	32
d. Other, specify NSSL (MOA)	3	12

TABLE 55. QUESTION ON HOW TO DETERMINE WHERE TO TRAIN YOUR STAFF ?

Response	No. of Labs	Response %
a. Labs located in similar geographic and climatic conditions	1	4
b. Labs well-equiped in instrumentation and manpower	12	48
c. Labs with equipment similar to ours	2	8
d. Labs willing to give us training at the least cost	3	12
e. Labs willing to accept our staff	6	24

TABLE 56. QUESTION ON WHAT CRITERIA IS USED TO SELECT STAFF FOR TRAINING

Response	No. of Labs	Response %
a. Based on first come first serve	4	16
b. Based on competence in the area indicated	12	48
c. Based on government selection with little influence from us	1	4
d. Based on competitive exams	3	12

TABLE 57. QUESTION ON WHETHER THE RESULTS OF THE TRAINING GAINED BY TECHNICIANS UPON RETURN FROM TRAINING ARE INCORPORTATED INTO LAB. PRACTICE TO INCREASE EFFICIENCY

Response	No. of Labs	Response %
a. Do incorporate their training results	10	40
b. Do not incorporate-because:	5	20
i. Because often they bring nothing new to what we already practice in the lab.	1	4
ii. For fear of distabilizing the established procedures	1	4
iii. Because some of the methods though good are not adaptable to the equipment we have	2	8
iv. Other, specify, little experience of the technicians	1	4

8.1.1.53 **Questionn on if lab adequately serves the needs of its community:**

Results (Table 59) indicate most labs (32%) do not adequately serve the needs of the community, while only 24% of the labs serve the needs of the community.

8.1.1.54 **Question on other problems encountered in the lab:**

The results (Table 60) indicate the problem faced by most labs (12%) is the lack of instrument repair facilities. Also 8% of the labs responded the following problems where also encountered; electricity failures (8%), inability to retain manpower (8%), inadequate training of senior technicians (8%), lack of well-trained man power (8%), indadequate storage and analytical work facilities (8%). Though the number of respondents is low these problems are really present and would need very urgent attention.

8.1.1.55 **Question on suggestions to be made to improve the technicians job:**

Most labs (36%) feel that technicians should be properly trained and also receive periodic refresher courses. Motivation and incentives is considered by some labs(20%) to be very important, so is insurance and medical care (20%), free milk supply (12%), adaptation of technicians to universally accepted procedures (16%), salary increment (8%), and job guarantee(8%). Observations also indicate that the low productivity achieved in most laboratories is strongly linked to the points outlined above and in Table 61. Also factors like establishment of appropriate promotion structures for technicians (12%), exposure of technicians to labs with well experienced staff (8%), standardization of working methods and safety procedures (8%) and shortening the length of working days to minimize contact time with chemicals (4%) could also enhance the productivitity of the lab technician. These suggestionns merit adequate consideration.

9. SUMMARY AND CONCLUSION.

In order to assess the present status of the soil , plant, water, fertilizer and compost testing labortories in the country, questionnaries were dispatched to a number of laboratories whose addresses were known to the investigators. Out of the twenty five laboratories to which questionnaires were sent replies were obtained from 22 of them. A follow up visit to the labs was done to do on the spot evaluation of the present status as to the types of analysis effected, instrumentation, their capabilities and limitions and to ensure the questionnaires were properly commpleted. As a result information was obtained on the 25 laboratories.

There are many laboratories existing in the country for soil, plant, water analysis but the infrastructure of most of these labs are in very bad state with the result that they cannot adequately assure the task for which they had been established to do.

TABLE 58. QUESTION ON IF LABS WILL BE WILLING TO ADOPT STANDARDIZED ANALYTICAL PROCEDURES IF DIFFERENT FROM THEIRS AS WELL AS ALSO STANDARDIZE EQUIPMENT FOR FUTURE PURCHASES

Response	No. of Labs	Response %
a. Standardize analytical procedures	14	56
b. Standardize equipment	16	64
c. If it is site specific (1 response)	1	4
d. Difficult because Univ. receives most equipment from donors, but would be willing to standardize if the donors cooperated or if conditions were favorable	1	4

TABLE 59. QUESTION ON IF LAB. ADEQUATELY SERVES THE NEEDS OF ITS COMMUNITY

Response	No. of Labs	Response %
Serves needs of community	6	24
Does not serve needs of community	8	32
Lab not well equiped	2	8

TABLE 60. ADDITIONAL PROBLEMS ENCOUNTERED IN THE LAB.

Response	No. of Labs	Response %
Electrical failures	2	8
Inability to retain manpower	2	8
Inadequate training of senior professionals	2	8
Lack of well-trained manpower	2	8
Lack of instrument maintenance and repairs expert	3	12
Inadequate communication links with other labs	2	8
Inadequate lab. facilities for storage and analytical work	2	8

TABLE 61. QUESTION ON WHAT SUGGESTIONS SHOULD BE ADAPTED TO IMPROVE THE SOIL LABORATORY TECHNICIANS JOB IN ORDER TO INCREASE BOTH QUALITATIVE AND QUANTITATIVE OUTPUT

Suggestions	No. of Labs	Response %
1. Proper training and periodic refresher courses for technicians	9	36
2. Motivation and incentives	5	20
3. Insurance and medical care	5	20
4. Salary increment	2	8
5. Free milk supply	3	12
6. Job garantee	2	8
7. Adapt technicians to universally accepted and updated standardized procedures	4	16
8. Information exchange	1	4
9. Establish appropriate career structure for moving up in the profession as lab. technicians	3	12
10. Exposure or visits to soil analysis laboratories with experienced staff and specialized equipment	2	8
11. Shorter length of working days to minimize daily contact with chemicals	1	4
12. Collaborate with similar regional, national and international laboratories to standardize the working methods and the laboratory safety conditions to prevent chemicals hazards	2	8

9.1 PERSONNEL:

Following the data obtained on personnel through the questionnaires about a year ago most labs have adequate personnel for the level of analytical outputs reported. However, since the survey was done there has been restructuring which has adversely affected some laboratories. For example the staff at the NSSP dropped from 58 before the restructuring to 15 after this exercise. If this is an indication of what has taken place in the other labs then the situation for the analytical services in Ethiopia would be bleak.

9.2 LABORATORY EQUIPMENT:

Most of the labs have reliable electric and water supplies, though occasional power failures and erratic water supplies have been observed. Experimental facilities like greenhouse are available only to limited laboratories.

The necessary laboratory equipment like pH meters, E.C meters, spectrophotometers and flame photometers are owned by a majority of the established laboratories. Atomic absorption spectrophotometer is owned only by 6 laboratories. The major problem reported by most of these laboratories are the malfunctioning of these instrument and the lack of qualified repair workshops in the country. There is much variation in the makes (or marks) of the equipment and further many labs have very old equipment and most in disuse to which spare parts cannot be found today. Most labs lack adequate fumehoods and in most labs where they exist they have undergone much deterioration. Supply of chemicals and other consumable items are also reported to be the major problems of the majority of the laboratories.

9.3 LABORATORY OUTPUT:

The analytical output of most of these laboratories are low or nil and except in few cases show decreases through time. This is mainly attributable to non-functional equipment, limited supply of chemicals and other supplies, the lack of adequate personnel in some laboratories and the fact that many of these labs are still in the process of being setup. The majority of the laboratories are analyzing only soil; plant, water, fertilizer, compost samples are analyzed only in a few laboratories.

9.4 ANALYTICAL TECHNIQUES:

9.4.1 Soil:

With regard to analytical techniques, determinations of soil pH vary in most laboratories due to the use of varying soil:solution ratios. Most labs determine pH using the glass electrode. 60% of the labs determine pH in water followed by 36% in KCl and then 20% in $CaCl_2$. Most labs use the 1:1 soil: solution ratio. Only 6 labs determine pH on the saturated paste extract.

For the determination of soluble salts varying soil: solution ratios are used but the 1:5 ratio is the most used. Soluble salt determination of the saturated paste extract is done only in 4 laboratories.

For the determination of CEC and exchangeable bases most labs use ammonium acetate as the saturating salt, followed by sodium acetate and calcium chloride. For displacing the salts most labs use KCl followed by ammonium acetate and sodium chloride.Varying soil: solution ratios are used but 1:10 is the most prevailent. Most labs determine CEC by distillation and titration. The determination of Ca and Mg is done by EDTA titration in most labs while the atomic absoprtion spectroscopy is used in fewer labs. Na and K are determined in most labs by flame photometer; few labs use flame emmission. Most laboratories still report their data in Non-S.I units.

For the determination of available phosphorus the most popular method used is the Olsen method, followed by Bray I and then Bray II, Mehlich and lastly the Hach method. There are great variations among the soil: extractant ratios; for the Olsen method most labs use the 1:20 ratio.

Total Nitrogen is determined in 48% of the laboratories with conc. H_2SO_4 + salt mixture used for digestion and detection done by distillation and titration; results are reported in %.

Organic carbon is determined by 56% of the laboratories using $K_2Cr_2O_7$ oxidation method of Walkley and Black. Four percent of the labs each determine organic carbon by carbon train combustion and Ignition methods. All labs report results in %.

Gypsum is only determined in 4 laboratories in the country. The method of precipitation with acetone is used by 3 of the laboratories.

Most laboratories (40%) determine $CaCO_3$ by the acid neutralization method while 12% use the calcimeter method. Four percent each of the labs use the gravimetric, fusion with lithium borate and Hach methods. The reporting units are %.

Varying soil: solution ratios are used for EC determination. 24% of the labs determine EC on the saturated paste extract, 20% each use the 1:1 and 1:5 soil: solution ratios. Again most of the labs (44%) use non-S.I units in reporting while only 4% use S.I units.

Lime requirement (LR) is done by 16% of the labs using the $BaCl_2$-TEA method. gravimetric and fusion with lithium borate methods are used by 4% of the labs.

Sulfates are determined using the gravimetric (20% of labs) and the turbidimetric (24% of the labs) methods; the EC method as $CaSO_4$ is used by 4% of the labs.

Fractionation of inorganic P is done by < 8% of the labs. The detection method is colorimetric and results are reported in %.

Free Fe and Al and amorphous Fe, Al and Si are determined in less than 8% of the labs. The DCB method is used for the extraction of free Fe and Al while ammonium oxalate is used for the extraction of amorphous Fe, Al and Si.

Micronutrients (Fe, Mn, Cu, Zn, B, Mo) are determined in 4-16% of the labs. The popular extractants used in order of magnitude are DTPA, ammonium acetate, EDTA and HCL for Fe, Mn, Cu and Zn. Different soil: extractant ratios are used; the most used is the 1:2 ratio. Varying times of extration are used with the 2hr extraction favored by most labs followed by the 1/2 hr extraction. Most readings are obtained on the atomic absorption. Hot or boiling water is used for boron which is determined in 20% of the labs while ammonium oxalate is used for molybdenum extraction by 8% of the labs. All the results by these labs are in ppm.

Total elemental analysis for the determination of Ca, Mg, Na, K, Zn, Fe, Mn, Cu, Zn, P is done by <12% of the labs using Na_2CO_3 fusion, by 4% of the labs with aqua regia, by 4% of the labs in HF, while 4-16% determine it in $HClO_4$ and 4% in H_2SO_4 digestion. The atomic absorption is used for detection by 16% of the labs. Results are reported mainly in ppm, but also in g/kg and fewer still in cmol/kg.

For soil texture determination the dispersing agent used by all laboratories is Na-hexameta-phosphate and is determined mainly by the hydrometer method(44% of the labs) though some labs (12%) use the pipette method. Preatment for organic matter removal are used by 28% of the labs in case of the hydrometer method, while free Fe removal is done by 8% of the labs. Most labs use the USDA(36%) method of fraction sizes with < 12% using the international system. More than 90% of the labs doing texture also report results in %.

Bulk density is detemined by the core method by 28% of the labs while 8% of the labs each determine it by saran coated and parafin coated methods. Results are reported in g/cc.

Particle density is largely determined by the pycnometer method (32% of the labs) and report results in g/cc.

Water retention characteristics are done on the 1/3 bar and 15 bar pressures by 20% of the labs and results are reported in %.

9.4.2 __Plants.__

Plant analysis of the elements Ca, Mg, Na, K, Cu, Zn, Mn, Fe, P is carried out by 8-20% of the labs using varying dry ashing and wet digestion methods. Addtionally, the elements Cd, Cr, Co, Pb, B, and Mo can be determined in < 4% of the laboratries. The detection method used by most labs is the atomic absorption spectrophotometer. The flame photometer is used by most labs for Na and K determination and the spectrophotometer for P determination. Reporting units are varied and include % (4-16%) of labs, g/kg (4-12%), mg/kg (8%), cmol/kg (4%) and ppm (4-8%) of labs.

Total N in plants is determined by 40% of the labs using conc. H_2SO_4 + salt mixture.Titrimetric methods are used for detection and the results are are reported in %.

9.4.3 **Water**:

The determination of pH, EC and total solids in water is done by 52%, 48% and 28% of the labs, respectively. EC results are largely reported in mmh/cm (40% of labs) while total solids are reported in g/l.

The anions determined in water by the different laboratories include: carbonates (32% of labs), Bicarbonates (32% of labs), sulfates (20%) and chlorides (36% of the labs). Except for sulphates which are determined gravimetrically (20% of labs) and turbidimetrically (20 % of labs) the other anions are determined titrimetrically. There is an equal proportion of reporting results about 1/2 as mg/l and the other 1/2 of the labs report it in meq/l.

The cations determined in water include Ca, Mg, Na, and K carried out by 40-44% of the labs. Most labs (28%) do Ca and Mg by EDTA titration while fewer labs (8% use the atomic absorption spectrophotmeter. Na and K are determined both by flame photometry (20%) and flame emission (20%). Reporting units used by most labs are are meq/l and mg/l.

Very few labs determine Nitrates (8%) and phosphates (16% of labs) in water. Titrimetric and colorimetric techniques are used for detection of NO_3 and phosphates, respectively. The units of reporting by most labs is mg/l though some labs also use ppm for reporting P.

9.4.4 **Fertilizers:**

Fertilizer analysis for elemental content is carried out by only 4-8% of the laboratories either using Boiling in HCl or Boiling in $HClO_4$ + HF in digestion. The atomic absorption is the favored detection method. All results are reported in %. Procedures for fertilizer analysis have not yet been prepared in most labs. Fertilizer analysis for total N is done by 20% of the labs. NH_3-N and NO_3-N determinations are carried out in 8% of the labs.

9.4.5 **Compost and Animal Wastes:**

Compost and animal waste analysis for element contents is carried out only in 4-8% of the labs using conc. H_2SO_4 + salt mixture and dry ashing as digestion methods. The atomic absorption unit is used by these labs for detection of the elements. Total N and P are determined by 8-12% of the labs. Procedures for compost analysis have not yet been developed in nearly all the laboratories and may be the reason for the low number of labs carrying out this determination.

9.5 OBSERVATIONS RELATING TO THE GENERAL LABORATORY: OPERATIONS:

The question of sustainability of the laboratories is crucial. Most laboratories receive financies for acquisition of chemicals and equipment from aid donors and government grants. Less than 4% of the labs are self-sustaining.

Alcohol redistillation can greatly reduce the operating costs of most laboratories but unfortunately due to lack of equipment or knowhow about this procedure only 8% of the labs benefit from it.

The clientel that supply samples to the labs are Research Bodies, Government organizations, own users, international organizations, schools and universites and local farmers in decreasing order. This is unfortnate as the target population ie. the farmers still benefit least from this process.

Reasons for few number of analyses effected in the laboratories in decreasing order of importance include: lack of chemicals and equipment, inadequate lab personnel lack of adequate analytical methods, lack of knowledge about services offered by labs, apathy by farmers on analyses of samples, laboratories located far from users, and lack of confidence by users on the analyis. These shortcomings in the labs need to be addressed.

One of the reasons for the low number of samples sent to the labs is the fact that only 12% of the labs have made efforts to advertise their labs and what its function is. This marketing needs to be done by radio, press, television and both formal and informal contacts if the farmers and public are to be acquainted with the essence of the existencee of these laboratories.

There are an array of quality control methods in decreasing order: reference samples, recovery techniques, sample exchange programmes and use of established procedures. Less than 5% of the labs use Standard, Duplicate, Internal, External, and Abitratrion control methods. The low percentage of labs using any form of control methods is a cause for concern since the reliability of data produced cannot be depended upon.

Quality control and productivity starts with the quality of personnel recruited by the government irrespective of field of competence of the staff. Labs that recruit staff based on competence come next and those selected by government based on interest of the staff for the vocation but not necessarily competence come last. For the lab profession there is need to review these recruitment procedures.

Most labs have problems retaining qualifed staff for a variety of reasons paramount among which are complains of danger from use of chemicals, low salaries incomensurate with work load, repetitious and monotonous work, few possibilities to move up the ladder as lab technicians. Other reasons given but of less importance include lack of milk, no medical checkup, and lack of essential equipment.

Most labs (> 50%) train their technicians in laboratories within the country and some on the job in the labs. 32% of the labs train some of their technicians abroad. Consideration of where to train the staff for most labs (48%) is where there is qualified manpower and adequate instrumentaion followed by labs willing to accept the staff. Cost constraints, similarities in equipment and similarities in geographic condition in that order also play a great part in determining where to train the staff. It is hearty to note that selection of staff for most labs (48%) for training is based on competence, but a significant 16% of the labs train their staff on a first come first serve basis while the responsibility for the selection is done by the Government with little influence from the labs themselves.

Most labs (40%) incoporate the results obtained by the trainees on return to their labs but some labs do not incorporate these results because of the following reasons in order of decreasing importance: methods and results may be good but not adaptable to available lab equipment, technicians bring nothing new to what already exist, fear of distabilizing established procedures and for lack of confidence in the ability of the technicians.

Most labs will be willing to standardize analytical procedures and equipment, but the difficulty of standardizing equipment is that many labs receive equipment from aid donors and have no choice as to the type of equipment they would prefer.

Very few labs serve the needs of the community. This is attributed to lack of equipment, chemicals, distance from users, lack of knowledge about their existence and functions.

Other problems that have been observed by some labs are electrical failures, the inability to retain manpower, inadequate training of senior professionals, lack of well-trained personnel, lack of instrument maintenance and repairs personnel and workshops, inadequate communication links with other labs and inadequate lab facilities for storage and analytical work.

Some suggestions which have been proposed to be adopted to improve the lab technicians job an hence increase productivity in order of importance include: proper training and periodic refresher courses, motivation and incentives, insurance and medical care, adapt technicians to universally accepted standardized procdures, supply of free milk, establish appropriate career structures for technicians to progress, give salary increments, give job quarantees standardize procedures and safety standards in collaboration with other labs, increase information exchange and shortening of working days to minimize daily contact with chemicals.

9.6 <u>CLASSIFICATION OF LABORATORIES</u> according to capability classes for soil, plant, water, fertilizer and compost and manure analysis.

Based on the following criteria the laboratories can be classified into 5 capability classes. The criteria for classification include:

a) Adequateness of infrastructure (buildings and ventilation, fume hoods, lab desk, water and electricity supply, etc.)

b) Adequateness of equipment (atomic absorption spectrophotometer, flame photometer, spectrophotometers, pH and EC meters, pF assembly, water distillers, block digesters, analytical balances, centrifuges, etc).

c) Adequateness of laboratory personnel (lab. technicians and others).

d) Adequateness of chemicals and small materials (chemicals, filter paper, glassware, plastic materials, etc.)

e) Existence of manuals for analytical procedures.

f) Ease of accessibility to the clientele.

Based on the above criteria the labs can be classified into classes I, II, III, IV, and V in order of decreasing capabilities.

Class	Laboratories	Location
I.	1. National Soil Service Laboratory 2. ILCA Soil Laboratory 3. Ministry of Mines and Energy	Addis Ababa " " " "
II.	1. Holetta IAR 2. Wonji Sugar Estate 3. Water Resources Development Authority 4. Debre Zeit IAR 5. Kulumsa IAR 6. Melka Werer IAR 7. Alemaya University	Holetta Wonji Addis Ababa Debre Zeit Kulumsa Melka Werer Dire Dawa
III.	1. Awassa College 2. Baro Akobo Bassin 3. Tana Belles Project 4. Jimma IAR 5. Awassa IAR 6. Adet IAR	Awassa Jimma Tana Belles Jimma Awassa Adet
IV.	1. Bako IAR 2. Ambo Junior College of Agriculture 3. Sinana IAR	Bako Ambo Sinana
V.	1. Nazareth IAR 2. Jimma Junior College of Agriculture 3. Wondo Genet College of Forestry 4. Soil Conservation Service Project 5. Mekele IAR 6. Dessie Agric. Office Lab.	Nazereth Jimma Wondo Genet Addis Ababa Mekele Dessie

Within the classes above the laboratories are again classified based on their diminishing capabilities. The criteria used to differentiate each class from one other are as follows:

CLASS I: Laboratories within this class have almost no limitations except for minor restrictions; they are fully operational.

CLASS II: These laboratories can do most of the analyses and have acceptable infrastructure facilities but in some cases the equipment is old and not very functional and needs replacement. These laboratories are plagued by shortages of chemical and small materials.

CLASS III: These laboratories generally have a limitation of one or combination of the following: Poor infrastructure (inadequate fumehoods, inadequate or poor water quality), insufficient equipment, absence or near absence of laboratory technicians, some are very remote from potential users. However, they have the capability to do some analyses.

CLASS IV: These laboratories lack most of the basic materials needed to do routine work or equipment exist in degraded or ususable state. They are also plagued by poor infrastructure (like poor water quality, lack of adequate fumehoods etc), lack of laboratory technicians, and lack of chemicals. Very few analysis are being carried out in these laboratories, for example pH.

CLASS V: These laboratories have very limited infrastructure, equipment, chemicals, generally have no laboratory technicians, no analytical manuals. Some of these laboratories are only constituted of empty buildings. These laboratoies do not effect any type of analyses presently.