RWANDA AGRICULTURE BOARD



- Research
- Agriculture Extension
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FOREWORD BY THE CHAIRMAN OF THE BOARD

The agricultural sector remains at the Centre of Rwanda's development and is now recognized as the engine of growth that will drive poverty reduction in Rwanda and improve the living standards of its people.
This annual report shows the achievement of RAB for its 2 year of existence toward its renewed mission. Enclosed results reflect achievements related to Crop, Animal Resources, Research and Natural Resources Management based programs.

RAB has relied on the collaboration of its partners and stakeholders in the last twelve months and will continue to do so. We therefore hope that this report provides useful information and we welcome your feedback. The Rwanda Agriculture Board will continue to do its part in policy implementation and resource mobilization to achieve the targets for the agriculture sector that are so essential to attaining the EDPRS 2 and Vision 2020 goals. We look forward to collaborating with our partners to this end.

Through this report, we would like to express our gratitude to the Government of Rwanda, and development partners that during the fiscal year 2012/2013 spared no effort to enable the Rwanda Agriculture Board achieve its objectives. Let our thanks also go to members of the Board of Directors in particular, and to the staff of the Rwanda Agriculture Board in general for the commitment they all displayed in the fulfilment of their duties, May all accept our sincere gratitude for their frank collaboration and support.

Dr Nicolas HITIMANA

INTRODUCTION BY THE DIRECTOR GENERAL

It is with great pleasure to present the 2012-2013 RAB annual report as an-all inclusive account of the most significant achievements of the Board in the areas of agricultural research and extension and the activities related to agricultural infrastructure development during the last one year.

The activities of RAB were executed through its mandate-oriented and well structured research and extension programs and comprising of five special programs, six internally and 20 externally funded research projects having the financial outlay of about 8,484,936,721 RwF. The internally funded projects also included the "Market-Oriented Advisory Services and Quality Seeds" (BTC-SPATII) with financial outlay of 2,110,641,631 RwF to address the issue of quality seed availability and training the local Farmer Field School Master Trainers.

In the area of livestock research and extension, efforts were focused on improving the coverage and efficiency of artificial insemination, dissemination of fodder seeds and quality planting material to farmers and transforming Milk Collection Centers into Dairy Business Centres where farmers' delivering their milk to the centers will be able to get farm inputs and extension services. *Girinka* Program received the utmost attention through strengthening local initiatives and mobilization for cow sourcing. After the containment of the Foot-and-Mouth disease outbreak in Nyagatare, Gastibo, Kayonza Districts of the Eastern Province and Nyabihu District of the Western Province, RAB made further advances in animal disease control through the vaccination of economically important animal diseases. Further output was made in the area of containment of ticks and tick borne diseases in livestock; protocols for testing acaricide susceptibility of ticks were developed and acaricides on the market screened and suitable ones recommended.

Another significant achievement was the training and equipping 1,006 Community Animal Health Workers (two per cell) in Eastern Province to help fellow farmers in basic animal health care and act as grassroot extension agents.

During the year under report, new crop varieties were released; new natural resource management and farm mechanization technologies were developed to enhance land productivity and farm profitability, resource use efficiency and environmental sustainability.

Significant progress was made in the area of crop improvement: a number of crop varieties with enhanced productivity, quality and resistance to biotic and abiotic stresses were released. For wheat, 192 and 26 lines were evaluated in Kinigi and Rwerere stations. Based on yield data, 8 lines were selected in 2013A season and advanced to 2013B season for further testing. On average, their yield over two locations was ranging from 3,437 to 5,414 kg/ha. Rice

genotype (SKAU23, SKAU337, HR17570-21-5-2-5-2-2-1-5, 88088-TR1113-4-1-1, 88076-TR1101-9-2-1, X-JIGNA, SIM2SUMADEL, FOFIFA161) were selected for Rwamagana site and have a range of yielding between 6-7.5 t/ha in environment with many abiotic stresses. In the Sorghum program, F_1 seeds of an early maturing farmer preferred sorghum variety and a late maturing farmer preferred variety were generated. In the sweetpotato research activities eight varieties with a yield average of 22.5 t/ha were released, four clones namely RW11-2560, RW11-2910, *Gihingumukungu* and *Ukerewe* with orange or yellow-fleshed storage roots, while the remaining 4 clones RW11-17, RW11-1860, RW11-2419 and RW11-4923 are white or cream-fleshed varieties. New varieties of soybean namely SB24, Sc. Saga, Sc. Squire and Sc. Sequel with potential yield between 2.7-3.5 t/ha were released.

Several crop and resource management techniques for improving resource use efficiency, systems productivity and profitability were developed. A combination of limestone, farmyard manure and inorganic fertilizer generated two-three times yield as compared to that the yield obtained from farmer practice treatment mainly composed of farmyard manure from home-garden and known to be of poor quality. Irrigation and fertilizer application methods were developed to enhance the water and nutrient use efficiency, and reduce the input costs in different crops. NPK fertilizer application enhanced the yield of climbing bean by 60.6 % as compared with conventional fertilizer applications. In farmer managed experiments, NPK application significantly improved cassava yields by 30.0%.

Another indicator in the field of soil conservation was the launch of Soil Health Consortium in Rwanda and the Soil Erosion Control Baseline to coordinate all research and extension activities in the field of land husbandry and soil fertility. In addition, use of farm machinery through creation of Village Mechanization Centers and rain water harvesting through ponds development were popularized.

The Crop Intensification Programme focused on increasing the use of quality seeds for priority crops namely maize, wheat, rice, beans, Irish potato and banana plantlets and land use consolidation with 749,866 ha in season A and 608,639 ha in season B. Several training sessions for extension workers' skills upgrading and empowering farmers were conducted. Several quality publications in the form of scientific peer reviewed research papers and other extension materials were brought out by RAB staffs in various programmes.

For the financial year 2012-2013, a total budget (recurrent + development budgets = 9,417,195,537 Rwf) was executed at 99,7%, at the end june 2013 RAB had 391 permanent staff counting 133 women and 258 men. In addition to those permanent staff who are regulated by Labour law and General Status, RAB has 144 staff who work under contract including 79 who are paid on RAB revenues and government funds, and 65.paid by different projects as support staff in order of achieving the objectives of those projects.
All this could be not have been achieved without the persistent efforts of all RAB staff and development partners. Here I feel privileged to acknowledge the contributions made by Deputy Director Generals, Heads of Zones, Heads of Programmes, Administrative/ Finance Officers and the field staffs.

I strongly believe that achievements made this fiscal year, will have significant impact on providing income and food security to the nation.

Prof. Jean Jacques Mbonigaba Muhinda

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1. CROP IMPROVEMENT

The crop improvement program aim at enhancing productivity and improving nutritional quality in different food and cash crops through conventional breeding and experimental trials. A number of improved varieties suited to different environmental conditions and possessing resistance/tolerance to biotic and abiotic stresses with desirable traits were developed. Significant progress was also made in seed production and other aspects of seed quality and soil fertility to support the crop improvement programs.

1.1. CEREALS

1.1.1. Maize

Maize crop has become a major food security and income generating crop for small scale farmers in Rwanda and ranks first among pulse and grain crop in annual production. Maize cropping systems have known an unprecedented development and radical changes in the past five years. The Maize productivity increased from 1.2 MT/Ha in 2008 to 2.6 MT/Ha in 2012 and this increase represented approximately two fold in four years this was a result of CIP, breeding objectives changed from the development of adapted Open Pollinated Varieties (OPVs) to hybrid varieties that are high yielding and stress tolerant. However this productivity level is still low and more crop improvement initiatives are been undertaken to achieve the potential for maize productivity in the country.

a. Inbred line development

In 2013 twelve inbred developed from ZM607 and Pool32 (Table 1) were completed and are being used to generate hybrid varieties. In addition, 12 inbred lines were advanced from S5 to S6 (Table 2).

Table 1: **Twelve inbred lines developed from ZM607 and Pool32 completed in 2012.**

No	Pedigree	Germplasm	Heterotic group	Maturity	Grain color	Grain texture
1	ZM607-38-4-1-B*4-#	ZM607	A	Late	White	Semi-flint
2	ZM607-79-1-1-B*4-#	ZM607	A	Late	White	Semi-flint
3	ZM607-38-1-1-B*4-#	ZM607	A	Late	White	Semi-flint
4	ZM607-34-2-1-B*4-#	ZM607	A	Late	White	Semi-flint
5	ZM607-80-4-1-B*4-#	ZM607	A	Late	White	Semi-flint
6	POOL32-70-2-1-B*4-#	Pool32	B	Late	White	Dent/Semi-dent
7	POOL32-76-1-1-B*4-#	Pool32	B	Late	White	Dent/Semi-dent
8	POOL32-76-3-1-B*4-#	Pool32	B	Late	White	Dent/Semi-dent
9	POOL32-17-1-1-B*4-#	Pool32	B	Late	White	Dent/Semi-dent
10	POOL32-76-2-1-B*4-#	Pool32	B	Late	White	Dent/Semi-dent
11	POOL32-6-3-1-B*4-#	Pool32	B	Late	White	Dent/Semi-dent
12	POOL32-11-4-1-B*4-#	Pool32	B	Late	White	Dent/Semi-dent

Table 2: Twelve inbred lines for mid-altitudes advanced at S6 in 2013.

N0	Pedigree	Germplasm	Type of germplasm
1	ISARM 101-27-1-5-6-2-3	ISARM101	Normal
2	ISARM 101-41-2-2-7-7-1	ISARM101	Normal
3	ISARM 101-27-1-5-6-2-5	ISARM101	Normal
4	ISARM 101-41-2-2-7-7-5	ISARM101	Normal
5	ISARM 101-64-1-4-27-5-3	ISARM101	Normal
6	ISARM 101-64-1-4-27-5-6	ISARM101	Normal
7	ISARM 081-19-1-4-8-5-3	ISARM081	QPM
8	ISARM 081-19-1-4-8-5-4	ISARM081	QPM
9	ISARM 081-47-2-2-21-9-6	ISARM081	QPM
10	ISARM 081-47-2-2-21-9-4	ISARM081	QPM
11	ISARM 081-15-1-5-23-4-3	ISARM081	QPM
12	ISARM 081-15-1-5-23-4-5	ISARM081	QPM

b. Evaluation of maize hybrid varieties from East African seed companies

This study was undertaken to assess the adaptability of maize commercial hybrid varieties from East African seed companies to Rwandan environmental conditions. Thirteen hybrid varieties for mid altitudes and six for highlands were obtained. In mid-altitudes, the varieties were evaluated in four sites: Bugarama, Rubona, Karama seasons while in highlands they were also evaluated in four sites: Musanze, Kinigi, Rwerere and Tamira in during 2012 A, 2012 B and 2013 A seasons. The AMMI (Additive Main Effects and Multiplicative Interaction) model for grain yield was used to analyze data. It showed that grain yield variation due to environments, genotypes and Genotypes by Environments Interaction (GEI) was highly significant ($p<0.01$). Analysis of AMMI 1 and AMMI 2 biplots, and use of agronomic traits allowed seven hybrid varieties to be identified for the mid-altitudes: PAN63 (6.9 t/ ha), PAN53 (8.0 t/ha), PAN67 (7.2 t/ha), WH504 (6.9 t/ha), WH505 (7.3 t/ ha), WH507 (7.2 t/ha) and RHM102 (6.4 t/ha) three for highlands: PAN691 (6.5 t/ha), SC719 (6.6 t/ha) and SC637 (6.7 t/ha) which were stable across. During these evaluations, two new diseases were observed: Grey Leaf Spot caused by the fungus *Cercospora zeae-maydis* and Phaeosphaeria Leaf Spot caused the fungus by *Phaesphaeria maydis*.

c. Breeders' seed production from hybrid varieties

In 2013, the breeder's seed production and maintenance of parent inbred was initiated at Karama research station with the objective to make the three hybrid varieties which were established using CIMMYT's inbred lines and released in 2011 available to seed companies. (Table 3).

Table 3: **Hybrid varieties established using CIMMYT inbred lines.**

No	Name	Female Parent Single Cross		Male inbred line
		Female inbred line	Male inbred line	
1	RHM101	CML202	CML539	CML216
2	RHM104	CML442	CML444	CML445
3	RHM131	CML536	CML489	CML488

1.1.2. Wheat

Wheat (*Triticum sativum L.*) is an important cereal crop for small-scale farmers in highland altitudes (1,900-2,500 m a.s.l) in Rwanda. the average national wheat yield has increase from 900 kg/ha in 2007 to 2100 kg/ha in 2012 while the potential mean wheat yield for Rwanda under low, medium and high intensity production conditions respectively should be 3,681 kg/ha; 3,986 kg/ha and 4,151 kg/ha. One of the major factors constraining wheat productivity in Rwanda is lack of high yielding, pest and disease tolerant varieties. Selection for improved yield performance was undertaken from three sets of best-bet wheat accessions from CIMMYT.

a. Screening and yield trials

One hundred and eighty (143) lines and a local check (Njoro II BW) were planted in Rwerere and Kinigi stations in 2013B season for screening of the superior ones.

In Kinigi and Rwerere stations, 192 and 26 lines were evaluated in preliminary yield trials and advanced yield trials, respectively. Based on yield data, 8 lines were selected in 2013A season (Table 4) and advanced to 2013B season for further testing. On average, their yield over two locations was ranging from 3,437 to 5,414kg/ha. The higher yielding line was EN 213 and the lower yielding one was Musama (control). These lines will be tested in the farmer's fields for adaptability to different environmental conditions.

Table 4. Yield data of 8 superior lines at Kinigi and Rwerere sites, 2013A season

Entry	Kinigi	Rwerere	Average
EN 213	5,571.2	5,257.3	5,414.3
EN 235	5,356.4	6,250.0	5,803.2
EN 226	4,725.1	4,885.5	4,805.3
EN 6121	4,696.4	5,234.6	4,965.5
EN 103	4,613.3	4,607.4	4,610.4
EN 102	4,596.6	5,085.7	4,841.2
EN 6131	4,479.7	4,519.5	4,499.6
EN 6066	4,286.4	4,873.6	4,580.0
Musama (check)	3,902.0	2,973.4	3,437.7
Site Mean (n=9)	4,691.9	4,854.1	4,773.0

b. Adaptability testing

Samples of commercial varieties were obtained from Kenya and Tanzania and assessed in Rwanda in order to identify those that are adapted to the local environment and with acceptable levels of disease tolerance for multiplication and release to farmers. Thus, 9 varieties (KS Simba, KS Mwamba, Chozi, Kwale, Njoro II BW, Nyota, Chui, Farasi and Ndume) were from Kenya Seed Company; 8 (Eagle10, Kingbird, Robin, Korongo, K.Hawk12, K.Tai, K.Wren and K.Sunbird) from Kenya Agricultural Research Institute (KARI)-Njoro, 6 (Sifa, Juhudi, Riziki, Lumbesa, Mbayuwayu and Chiriku) from SUBA AGROTRADING AND ENGINEERING CO. LTD based in Arusha, Tanzania and 10 (SC Nduna, SC Sky, SC Select, SC Shield, SC Shine, SC Stallion, SC Sekuru, SC Shungu, SC Smart and SC Serena) from Seed Co Zimbabwe. The varieties from Kenya Seed Company, Seed Co and Tanzania were evaluated in Kinigi, Rwerere, Ruhunde, Gakuta and Nyamagabe Stations. Those from KARI were tested in Kinigi and Rwerere Stations

Preliminary results obtained by the end of 2013A season indicated that among the varieties provided by Kenya Seed Company the varieties Njoro II BW and Chozi are the best in terms of pest and disease resistance, maturity and grain yield. Both varieties were therefore recommended to farmers.

c. On-Farm technology verification trials for participatory variety selection

In the 2013 A and B season, on-farm trials have been established in 26 sites located in wheat growing districts of Burera, Gicumbi, Gakenke, Rulindo, Nyaruguru , Nyamagabe and Musanze (Figure 1). A set of 6 genotypes, namely the entries 213, 238, 312, 315, 316 and 2076 selected from on-station evaluation and Njoro II BW (check) were evaluated in farmer's fields to select the promising ones using a participatory variety selection (pvs) approach. The entries 213, 312 and 315 are among the top three lines appreciated by the farmers based on plant stand, head size, maturity and tolerance to pests and diseases.

Figure 1: Participatory wheat variety selection trial in Gataraga sector, Musanze District.

d. Breeding program with crossing blocks

Twelve (12) parents that consist of 4 local (Musama, Bisagi, EN161 and EN48) and 8 introduced bread wheat (Eagle10, Kingbird, Robin, Korongo, K.Hawk12, K.Tai, K.Wren and K.Sunbird) varieties were planted in 3 staggered crossing blocs to synchronize flowering dates and were crossed in a full diallel mating design to produced F1's populations (Figure 2). Five varieties (Musama, Bisagi, EN48 and Eagle10 and Robin) were used as parents tolerant to most of the pests and diseases.

Figure 2: Wheat crossing process

e. Pre-basic and basic Seed production

The objective was to multiply breeder, pre-basic and basic seed of released wheat varieties in order to meet the increasing seed demand from farmers. During the 2013A and B seasons, 246.5 kilos of breeder seed were produced in Kinigi station for the varieties Musama (30 kilos), EN161 (62.5 kilos) and EN48 (154 kilos) and 52.5 tons of pre-basic seed are expected to be obtained from Musama, EN161 and EN48 varieties planted in Kinigi station. Moreover, in both 2013A and B seasons 121.0 tons of basic seed were produced from Musama and EN161 planted in Kinigi, Rwerere, Ruhunde, Masogwe, Nyamagabe and Gakuta Stations.

1.1.3. Rice

Rice production in Rwanda covers about 12,000 ha/ season with average yield of 5 t/ha. The country is yet to achieve self-sufficiency in rice production. In the year 2012, total paddy

production was estimated at 78,076 tonnes from 15,615 ha, the consumption per capita as 9.4 and the self-reliance ratio was about 53%. To attain the self- sufficiency in rice and food security by 2018, an estimated increase of rice productivity by 0.5 tonne per hectare/year is required. There is need of cultivars and production technologies in rainfed and irrigated lowlands ecosystems that will help increase yields at farmer paddy fields. In this regard, rice crop improvement initiatives were undertaken to select high yielding varieties, requiring low water with good physical traits related to market and resistant to blast disease.

Rice varieties testing

Different germplasm evaluation trials at high elevation were carried out as part of the Africa-Wide Breeding Task Force activities, in collaboration with Africa Rice Center. A total of 134 varieties from IRRI were evaluated in Cyabayaga, Nyagatare district and 28 were promoted for the next stages. One hundred varieties with iron toxicity tolerance have been introduced in Rusuli and Rugeramigozi to select parents to be used in breeding activities. In Rusuli and Rwamagana, 35 cold tolerant varieties were advanced from Multilocation environmental trials (PET) to participatory advanced trials (PAT) where farmers were invited and participated to select the best lines .

PVS were conducted at Rusuli involving 30 farmers. The summary result of the selection is presented in figure 1. The selected materials are SCRID017-1-4-4-4-1, HR17570-5-2-5-2-2-1-5, FOFIFA 171, SCRID 037-4-2-2-5-2. At maturity, in Rugeramigozi, the best selected materials were CHOMRONG DAN, FOFIFA 1720, SCRIDO37-4-2-2-5-2, and in Base II, SCRID079-1-5-4-2, FOFIFA 171, SCRID017-1-4-4-4-1, HR17570-5-2-5-2-2-1-5,X-JIGNA,SCRID014-1-1-1-1, FOFIFA 167,SCRID006-2-4-2-3,SCRID0062-4-3-4,SCRID037-4-2-2-5-2.

From the PVS at Rwamagana the selected varieties are (SKAU23, SKAU337, HR17570-21-5-2-5-2-2-1-5, 88088-TR1113-4-1-1, 88076-TR1101-9-2-1, X-JIGNA, SIM2SUMADEL, FOFIFA161) and have a range of yielding between 6-7.5 t/ha in environment with many abiotic stresses.

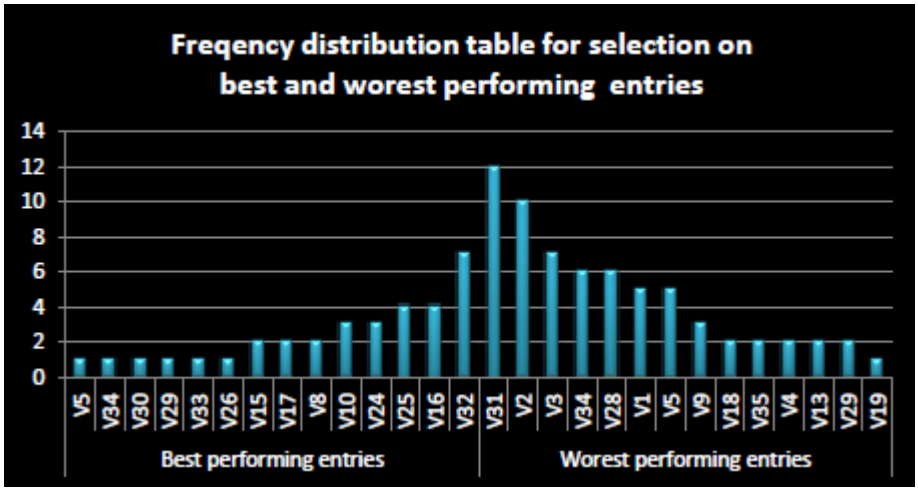


Figure 3: Frequency distribution table for selection on best and worst performing entries

Figure 4: Farmers in a rice Participatory Variety Selection session at Rusuli.

1.1.4. Sorghum

Sorghum productivity in the country is low. The major production constraints are *Striga* species weeds, lack of high yielding varieties, low soil fertility, pests and diseases. Therefore various initiatives towards improved sorghum productivity at farm level were undertaken.

a. Development of F_1 and F_2 high yielding and early maturing sorghum varieties

During the period under review, F1 seeds of an early maturing and late maturing sorghum varieties were developed for different clientele. In total more than 300 F_1 seeds were generated. Using pedigree breeding method for self-pollinated crops, in the second and the third quarter of the same fiscal year, the harvested seeds were planted to produce F_2 generation. Based on traits of interests, a number of individual plants were selected and in total 44 sorghum lines with desired traits were selected. These lines will serve as parental materials to produce F_3 generation in the next sorghum cultural season.

b. Development of F_1 and F_2 high yielding, white grain and early maturing high altitude sorghum lines

The germplasm of the local sorghum variety which has poor vigor and white grain and suited for high altitude was crossed with a short, high yielding and white grain variety to develop a high yielding, white grain and early maturing high altitude sorghum variety. As result, 106 F_1 seeds were generated. The F1 seeds were planted; self-pollinated and selected in order to produce F2 lines with desired traits. At harvesting time, 28 lines with traits of interests were selected for planting and generate F_3 lines.

c. Development of F_1 and F_2 high yielding, short and early maturing sorghum varieties

The development of F_1 and F_2 high yielding, short and early maturing sorghum varieties was carried out by crossing two sorghum varieties. The first variety is short height, good vigor, high yielding and early maturing while the second one is farmer preferred in Mayaga region, late maturing, and long height with more than 2 tillers per plant. A crossing between them was performed and as a result 162 F_1 seeds were generated. During the cultural season B, F_1

seeds were planted and then self-pollinated in order to generate 40 F_2 plants which were further selected to remain with F_2 lines showing traits of interests. These F2 lines will be used to generate F_3 high yielding, short and early maturing sorghum varieties.

d. Development of F_3 multipurpose sorghum varieties

Following pedigree method of breeding, 30 F_2 lines selected in previous sorghum season were planted and they were self-pollinated at flowering time. At harvesting time, 105 F_3 families from best rows were selected and they will be used to generate F_4 best plants in next sorghum cultural season (Figure5)

Figure 5: F_3 segregating population at grain fulfillment stage

e. Multiplication of sorghum breeder, pre basic and basic seeds for released varieties

Breeder seeds, pre basic seeds and basic seeds for Kigufi, Ikinyaruka, IS21219, IS8193, IS 20983, IS25377, N9, BM1, BM33, BM 27, Kat 369, Mabereyingoma and Muhimpundu sorghum released varieties were produced at Rubona, Karama, Mututu and Nyamagabe stations.. In total 120 kg of breeder seeds, 570 kg of pre basic seeds and 5180 basic seeds were produced.

1.1. PULSES

1.2.1. Beans

The goal of beans research was to contribute to increased food, nutrition and income security and livelihoods in Rwanda by overcoming the factors such as to Low yielding varieties, high incidences and severity of diseases. Which affect productivity Currently the beans productivity stand at 1.8 MT/ha and there is need for further crop improvement to achieve the potential of 3 MT /ha

a. Crossing and population development

During the year ,the key initiative was to introgress multiple diseases resistance against anthracnose, angular leaf spot, bean common mosaic virus, rust; micronutrient density (Fe) and preferred market seed types into commercial varieties. Selection for these traits among

early and advanced segregating populations in bush, climbing and snap beans was done in Rwerere, Rubona and Nyagatare research stations. Variable numbers of selected lines were being advanced for further selection and improvement in 2013/2014 (Table 5).

Table 5 : Some of the crosses and populations developed in 2012/2013.

2012 B	2013 A	2013 A	2013 B
Cross	**Backcross (anthracnose)**	**Backcross (commercial parent)**	
RWV3006 X Gitanga	F1 xG2333	F1 x RWV3006	
RWV3316 X Gitanga	F1 x G2333	F1 x RWV3316	
RWV3317 X Gitanga	F1 x G2333	F1 x RWV3317	
RWV 2872 X Gitanga	F1 x G2333	F1 x RWV2872	Selections and further improvement
Agorome X Gitanga	F1 x G2333	F1xAgronome	
Gasilida X Gitanga	F1 x G2333	F1xGasilida	
RWV2361 X Gitanga	F1 x G2333	F1xRWV2361	
RWV2070 X Gitanga	F1 x G2333	F1xRWV2070	
RWV2887 X Gitanga	F1 x G2333	F1xRWV2887	

b. Preliminary, intermediate and advanced yield trials

More than 1,000 lines or varieties of bush, climbing or snap beans were evaluated for yield, pest and diseases tolerance and general adaptation and farmers acceptability in preliminary yield trial (Pre-triage), intermediate yield trial advanced yield trial (ECV) and in two phases of multilocation or national performance yield trials I & II. This was done on seven research stations in Rubona, Rwerere, Nyagatare, Musanze, Karama, Ntendezi, Ngoma and Muhanga that represented high, mid and low altitude production environments. They included varieties for special traits and market niches such those with canning quality, drought nursery and sources of resistances for major diseases. Pre-liminary selections of best performing lines and varieties were made and will be advanced for further evaluation and selection in 2013/2014 seasons.

c. Multilocation yield trials

The multilocation and national performance trials were conducted in different agro-ecological zones on-farm.

d. New climbing bean varieties

Ten elite climbing bean varieties that had promising resistance to local diseases and marketable seed traits over 11 locations in the northern highlands 2000 – 2400 m above sea level were evaluated over two seasons. This included a released variety as a control. The trial was intended to capture genotype x season x location interactions. The experiments were a RCBD with three replications per location. Four of the varieties had mean grain yields equal or above that of improved commercial variety, Mamesa (G2331). The mean yield advantage for the two seasons was 100 – 109% over the control (Table 6). This was less than the mean yield advantage that was observed in first season, where four of the varieties had outperformed the same control by 110 – 129 %. The same experiment was again repeated in the 2013 B season in more locations.

e. Bush and climbing varieties in lowlands

Multilocation replicated yield trials of nine bush varieties with a local and improved controls were done on six lowland (1200 – 1400 masl) locations in Nyagatare district, while another nine climbers were evaluated in four similar environment locations. Preliminary data show that only two of bush varieties outperformed the control by 105 and 125% (Table 7). On the other hand, nearly all the climbing variety entries over yielded the local check, by more than 200%, for some (Table 8).

Table 6 : Comparative yields of climbing bean varieties in 11 locations in highlands of Burera and Musanze districts in 2013 A season.

Variety	Location/Site and grain yield in kg per ha												% over check
	Rwerere	**Kinihira**	**Gakenke**	**Janja**	**Ruhunde**	**Nyamiyaga**	**Kinigi**	**Nyagahiga**	**Rugerero**	**Nyundo**	**Rushashi**	**Mean yield in kg/ha**	
Mugu-Kagogo	5444	2792	1722	2444	2944	3583	3333	3625	2525	2200	1950	2960	99
Agronome	4667	3375	1889	3222	3944	3542	2111	4250	2375	1900	1550	2984	100
Nyiramagorori C	4750	2667	2000	3111	4528	3417	2833	1900	2600	2250	2375	2948	98
Rwibarura 2	5056	1708	1944	2333	3833	2542	2833	1900	2600	2250	2375	2670	90
Ibanga B	5306	3375	2056	3222	4306	3083	2055	3500	3000	2350	2085	3122	109
645 SI-3	5333	4625	1444	2667	5500	3792	2055	3500	1850	2150	1950	3170	106
Nyiramagorori D	5500	2917	1000	2000	5389	3375	2833	3125	3100	2050	1600	2990	101
Claudine	5167	2083	1056	2278	3639	2625	2277	2375	1700	2400	1750	2486	87
G2331	5278	2500	1278	3000	3722	4417	2055	5000	1800	2150	1750	2995	100
Base X	5278	2458	1000	2111	4389	3167	3500	3000	2975	2250	2425	2959	99
Mel.Local	4889	2167	944	3667	3778	3333	2417	4250	2250	1950	1925	2870	96
Location means	**5152**	**2788**	**1485**	**2732**	**4179**	**3352**	**2573**	**3311**	**2434**	**2173**	**1976**	**2923**	

Table 7: Comparative yields of elite bush bean varieties in six locations in lowlands of Nyagatare district in 2013 A season

Variety	Total yield(kg)	Mean yield	% over control
BOA5-1/16	6.5	1.1	125.2
BOA5-1/8	3.9	0.7	75.1
NR1263-1/A	4.4	0.7	83.8
ECUADOD I	3.6	0.6	68.4
ECAB111	3.9	0.7	75.2
RWR1668 (improved check)	5.2	0.9	100.0
NUA566	4.2	0.7	80.0
KAB06-8-35	5.0	0.8	94.9
KAB06-8-27	5.5	0.9	105.1
ECUADOR II	4.4	0.7	85.0
Local mixture (Check)	3.3	0.6	63.7

Table 8: Comparative yields of new climbing bean varieties in four locations in lowlands of Nyagatare district in 2013 A season

Site	Total plots yield (kg)	Mean yield across locations	% yield over check
Varitey			
MBC77	7.2	1.8	235.3
MBC71	6.3	1.6	204.4
MAC44	6.5	1.6	210.9
RWV2872	3.6	0.9	117.6
MBC29	6.2	1.5	200.6
RWV2361	3.2	0.8	102.9
RWV3006	2.8	0.7	92.2
RWV1129	4.3	1.1	139.9
Local mixture (check)	**3.1**	**0.8**	**100.0**

f. Effects of soil fertility and cropping patterns on soil minerals (Fe/Zn) partitioning into bean seeds and their distribution within plant canopy

The objective of this study was to compare plant growth, yield, Fe and Zn accumulation into seeds for bean cultivars. Germplasm screening and evaluation was performed to select higher seed-Fe concentrations in bean cultivars across regions in Rwanda. Partitioning of soil minerals (Fe/Zn) into seeds and distribution of minerals within plant was also assessed on 10 varieties at 3 different AEZs. Foliar Fe (2%vFerrous Sulphate, FeSO4) was applied once three weeks after emergence of bean seedlings.Soil sample were collected at the beginning of the experiment and analyzed, and mineral concentrations in seeds were assessed at harvest using X-Ray Fluorescence Spectrometer (XRF). Genetic and environmental interactions for

bean seed concentration in iron and zinc was observed across sites and between Fe foliar treatments.

g. Effect of environment on concentration of Fe content in seeds

Genotype by environment Interactions evaluation for 10 varieties planted in five sites in three agro-ecological zones in north, south and eastern Rwanda. They included two control checks with low Fe, G2331 with 60 ppm Fe concentration and high Fe content, Gitanga with 110 ppm

Preliminary results season didn't show differences in grain Fe content across sites and soil type.

h. Select canning bean varieties that meet processing industry requirement

Advanced bean lines that combine good canning qualities with drought and disease tolerance from 35 canning bush beans were introduced from CIAT-Kawanda and Ethiopia. Ten of them (G22, G48, G 46, G 70, G 96, G 97, G 30, G 31, G 54 and G 72) were selected and introduced in Rubona and Nyagatare research stations for furher evaluation as IYT.

Canning quality, soaking and cooking time

Ten genotypes maintained their organoleptic properties after soaking, while field observations showed that only 4 varieties G72, G 48, SCFM 17011- 020 and BFC 55 had number of pods (32 pods for SCFM 17011-020). In collaboration with KIST, it was found that another variety, ISAR CB 104 (CAB2) soaked fast and cooked fastest among the released climbing and bush bean varieties (Figure 6). The pre-soaking beans reduced cooking time by about 50% without losing the original organoleptic properties.

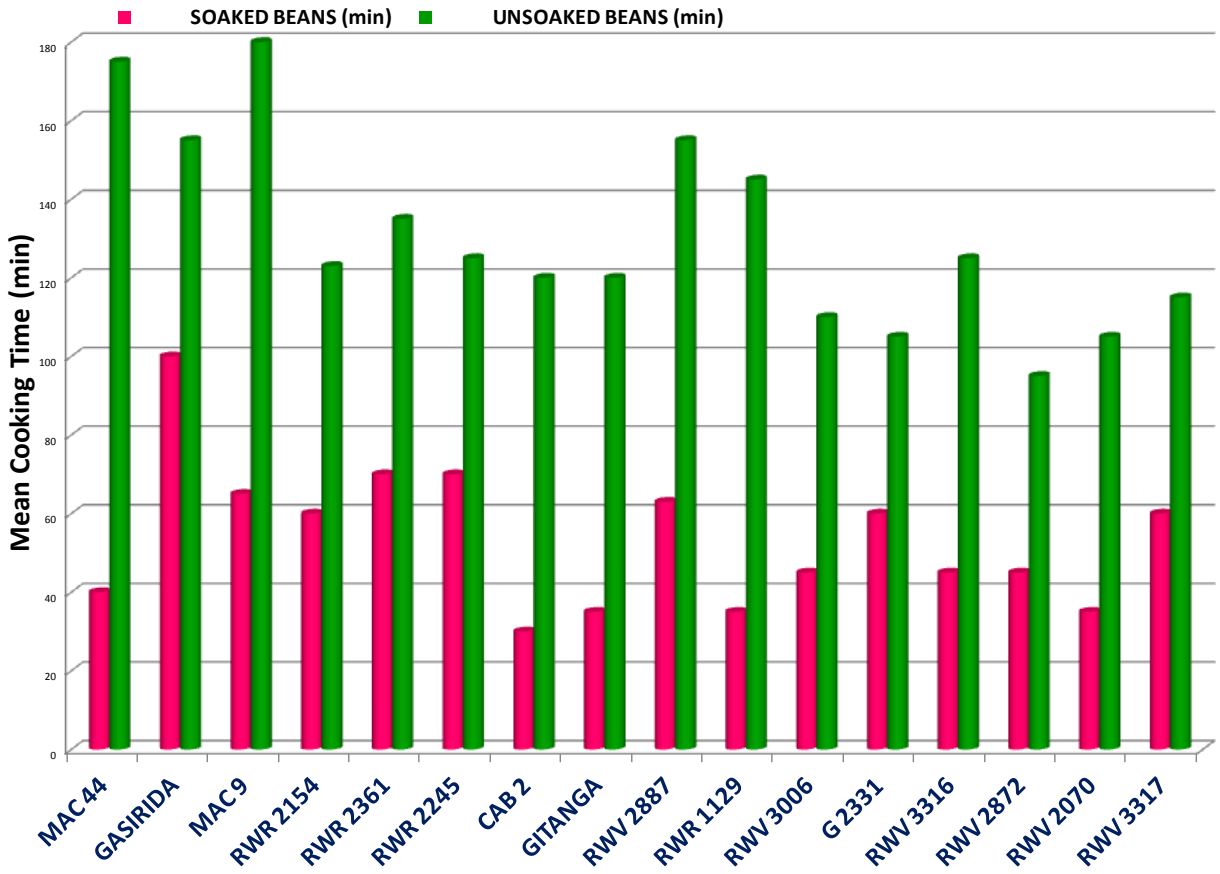


Figure 6: Cooking time of beans.

i. Evaluation of Fe in seed in local and regional nurseries

Rwandan and regional germplasm were screened for Fe content using XRF machine and in collaboration with ETHZ services in Australia. Preliminary results are shown in Figure 7.

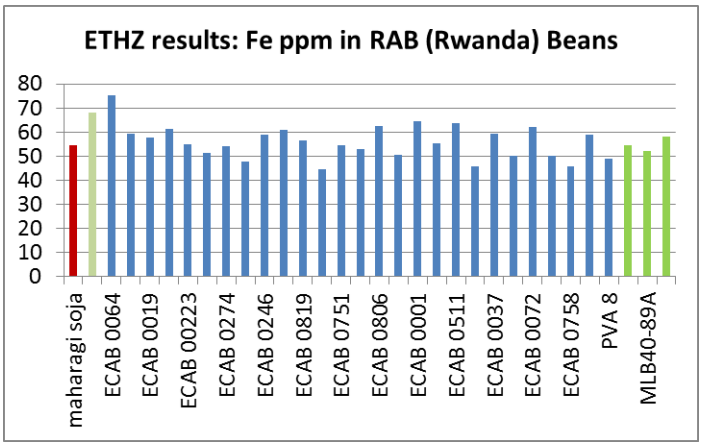


Figure 7: Results of Fe analysis of some of the varieties showing Fe content.

1.2.2. Soybean

Soybean (*Glycine max L.*) is an important food crop in the country and has recently been identified as one of the priority crops for the Crop Intensification Program (CIP). However, its productivity is low about 0.8 t/ha against the potential of 3-5 t/ha depending on varieties. Soybean crop improvement programme aimed at improving the productivity.

a. Best performance new varieties

PVS for four new varieties of soybean (SB24, Sc. Saga, Sc. Squire and Sc. Sequel) were established at Musambira, Muhanga, Ruhango, Cyeza, Nyamagabe and Nyamiyaga sites in farmer plot demonstrations for food crop in regard for farmer participation on best varieties selection. The results show that these varieties are high yielding (range between 2.7-3.5T/Ha) compared to local variety Peka6 at 0.8T/Ha. These varieties are also tolerant to rust and were released for production.

b. Rhizobium production at high scale

In an effort to identify elite strains for future use in legume inoculants, 90 and 210 isolates from soybean and bean were isolated, authenticated and characterized. This was in collaboration with N2Africa project. These isolates were screened for effectiveness against the commercial rhizobial strain USDA 110 and CIAT889 contain 10^9 cells per gram. To promote use of inoculums, 13,000 packets of soybean inoculants against 18,420 packets targeted and 1,000 packets of bean inoculants have been produced and will continue in order to meet the farmer's demand.

On performance assessment, 15 demonstration plots were established in Kamonyi for strains evaluation under low P then the results have shown that inoculums combined with farmer yard manure (5t/ha)and DAP (30kg/ha) could increase soybean yield of 20% compared to no application of inputs.

1.3. ROOTS AND TUBERS

1.3.1. Potato

Irish Potato is an important food security crop in Rwanda but the productivity is still low, although it has increased significantly in the last five years from 5.3 MT/ha in 2008 to 15 MT/ha with a 40 MT/ha potential yield. Currently research efforts focus on selection and breeding of potato varieties for high yield in order to improve productivity.

a. Participatory variety selection trial

PVS were carried out to evaluate potato cultivars with characteristics acceptable to farmers in order to select appropriate cultivars for release. Trials have been established in different sites including Base (Rulindo district), Rugarama (Burera district), Shingiro (Musanze district) Tare and Buruhukiro (Nyamagabe district). The potato cultivars involved in the trial were CIP393077.54, CIP393371.58, C200, C281, C62, Cruza and Victoria. From the previous results of 2012A, two clones CIP393077.54 and CIP393371.58 are promising for late blight resistance and for high yield (26.6 t ha^{-1} for CIP393077.5 and 33.3t $ha^{-1}$for CIP393371.6.

b. Production of breeder, pre basic and basic seeds

Breeder seeds (minitubers) for potato crop were produced using tissue culture technique in the laboratory. In total 290,000 plantlets were produced and distributed as follows: one set of 170,000 plantlets were planted in RAB screen houses and Aeroponic system, another set of 120,000 plantlets were supplied to private screen houses. A total of 511,000 minitubers were harvested both in RAB conventional screenhouses and aeroponic system and were used to produce 51 tons of pre basic seed, and 270.3 tons of basic seed have been produced.

c. Potato variety description

Potato variety description of selected cultivars to develop a catalogue showing the phenotypic characteristics to help potato breeders, consumers or processors to choose a variety according to their purpose was undertaken. A total of seven cultivars namely, 391047.34, Kinigi, C281, C200, 381381.13, C62, and Nyirakabondo were characterized. The phenotypic characteristics evaluated included tuber skin color, flesh color, resistance/tolerance to late blight, bacterial wilt and physiological age of maturity.

1.3.2. Sweet potato

a. Selection and multiplication of clean planting materials

Data was collected on both roots and above-ground part traits in order to select performing clones for dual purpose use**.** Regarding yield related characteristics, several root traits were considered such as: yield (t/ha), marketable root weight and number, non-marketable root weight and number. Quality and nutritional traits were also recorded such as skin color (SC) and flesh color (FC). Regarding vine characteristics, data were collected on vine weight (VW), vine vigor (VV), sweet potato virus disease (SPVD) and *Alternaria spp.* Among 268 clones evaluated in PYT, 25 clones were selected and advanced for further evaluation. A rapid multiplication for planting material of the selected clones was established. At least 320 cuttings for each variety were produced, in the framework of availing enough planting material for on-farm trials.

b. On-farm trials evaluation

On-farm trial for the selected clones were planted in 5 Districts Huye, Nyamagabe, Muhanga, Bugesera and Ngoma in the purpose of (1) introducing new performing clones for dual-purpose use in the farming systems, (2) evaluating their acceptability by farmers (Table 9). During season 2013 A, on-farm trials were repeated for the 10 clones in 5 Districts comprising nine sites in the framework of confirming the previous data.

Table 9: On-farm performance of the selected ten promising varieties, 2012 B.

No	Clone code	Root yield (t/ha)	Dry matter (%)	Flesh colour
1	2560	29.13	21.00	Deep Orange
2	3736	27.50	23.47	Light Orange
3	2910	25.28	31.13	Light orange
4	1860	22.92	37.78	Cream
5	2285	22.78	30.00	Cream
6	17	22.35	30.80	White
7	5091	20.69	28.83	Light orange
8	4923	20.14	37.33	Cream
9	2419	18.87	24.90	White
10	3074	15.58	33.43	White

1.3.3. Cassava

New Cassava variety development

The development of new cassava varieties was carried out to select clones which are resistant/tolerant to pests and diseases ,high yielding and acceptable by end users.

The on –farm evaluation was carried out on four cassava clones (NASE3 0P/4, NASE3 0P/3, PDB/11 and PDB/13) during season A 2012 in 17 sites countrywide. At each site/field, a control derived from local varieties was included for comparison purpose. After evaluation at harvesting time in December, three clones namely NASE4 0P/4, PDB/11 and PDB/13 were appreciated by farmers.

1.4.FRUITS AND VEGETABLES

1.4.1. Pineapple

Evaluation of the performance of the micro-propagated and macro-propagated pineapple plantlets and effect of spacing on growth

Pineapple production in Rwanda is hampered mainly by limited availability of planting materials. The crop has a very low natural multiplication rate, about 2 per year, and field grown suckers have a potential risk of propagating diseases. The need to solve this problem has led to the development of tissue culture (micro-propagation) and macro-propagation techniques for the pineapple. These two methods are an excellent tool for rapid production of homogenous plant material. However, the performance of the plantlets from these two techniques under field conditions is not known in Rwanda. Thus precise information of their rate of growth and development, and comparison of their performance is of fundamental importance to the farmers and the researcher. Thus, the objectives of this trial are; to investigate and compare the performance of macro propagated and tissue cultured pineapple plantlets under field conditions and, to evaluate the effect of different spacing on their growth. A complete randomized block design (CRBD) with three replications was employed.

Planting materials included tissue cultured and macro-propagation suckers. Plant spacing used included 60x 40 cm, 45 X 30 cm and 30 x 30 cm. Data on plant growth parameters (plant height, number of healthy standing leaves, and the length and width of the longest leaf) were observed on a monthly basis.

Results have shown that there is significance difference in growth between tissue cultured and macro-propagated plantlets. Macro-propagated plantlets were found to have better performance in terms of plant height, length and width of the longest leaf while tissue cultured performed well in number of functional leaves. Differences in growth could be due to their adaptation to the environmental conditions. Macro propagated plantlets were already adapted to the harsh conditions in the field and thus at the initial stage after transplanting they were quick to establish. Unlike the tissue cultured plantlets the growth rate was slow because of climate change from controlled to uncontrolled conditions. However, data collection on yields is on-going.

Figure 8: A trial of pineapple plants from tissue culture and micro-propagation at Rubona.

1.4.2. Water Melon

a. **Effect of spacing and mulching on watermelon (*C. lanatus*) production in Rwanda**

Water melon is a dessert fruit that grows and produces fruits ideally during dry, sunny periods. It becomes an important crop to Rwandan farmers. But as a new crop, farmers are facing difficulties with regard to the best agronomic practices required to grow well the crop. No studies have been conducted on the crop to help farmers stream line their production in the most profitable way possible. Thus, this investigation was carried out to evaluate the effect of plant density and mulch on water melon production.

Table 10: Yield and fruit size parameters performance

Treatment	Nbr of fruit/plt	Mean fruit length	Mean fruit width	Mean fruit weight	Nbr of fruit (ha)	Fruit yield (t/ha)
S1M1	2.2e	18.9e	18.3d	4.8de	21600a	104.6a
S1M0	1.9f	18.5f	17.8e	4.3f	18696b	81.5b
S2M1	2.5d	19.2de	18.7cd	5.0c	12338c	62.4c
S2M0	1.9f	19.0e	18.4d	4.5f	9733d	62.4c
S3M1	2.8c	19.7c	18.8bc	5.3b	6927e	37.2e
S3M0	2.1e	19.0e	18.6cd	4.8e	5367f	25.6fg
S4M1	3.0b	20.1b	19.2ab	5.5b	5054f	27.9f
S4M0	2.6d	19.5cd	18.9ac	5.0cd	4290g	21.3g
S5M1	3.2a	20.6a	19.3a	5.8a	3563h	20.8gh
S5M0	2.8c	19.6cd	19.0ac	5.1c	3138h	16.2h
Grand mean	2.5	19.4	18.7	5.0	9070	44.1
SED	0.07	0.20	0.23	0.10	3475	2.5
CV (%)	6.3	2.0	2.4	3.8	7.7	11.3
Season						
Season 1	2.4b	NS	NS	NS	8731b	42.6b
Season 2	2.6a	NS	NS	NS	9410a	45.7a
SED	0.04				155.4	1.12

Mean in each column followed by the same letter (s) are not significantly different (P<0,05)

Main effect of spacing was significant in the two different seasons. With wide spacing, fruit size increased and total yield per plot reduced. This agrees with earlier studies conducted by Brinem, G.H., et al (2010).

Main effect of mulching was highly significant in the two seasons. With mulch, fruit size and total yield per plot increased greatly compared to without mulch. This agrees with what Vicki, A.B (2010), who found that regardless of the material used, mulching results in overall increase in yield

Season also contribute to the production of water melon. The second season from September to December gave more yields per plot and number of fruits per plant compared to season 1 from March to June. Other parameters related to fruit size were not significantly different for

the two seasons. Too much rainfall in season one may have caused reduced fruit set compared to season two hence the difference in yield.

Water melon farmers targeting very high yields can employ S1 or S2 during cultivation. However in these cases the fruit sizes are reduced but as long as the farmers ensure good early management these two plant densities can be good.

Mulching is very vital in water melon production as it has been found to increase yield regardless of the plant density used. Farmers need to mulch their water melon fields in order to increase their yields.

1.4.3. Indigeneous vegetables

Effect of planting methods on growth and yield of three amaranth varieties

Amaranths (*Amaranthus* spp.) are vegetables that have high nutritional value and health promoting properties. There has been a significant change especially in some African countries where more people and researchers start realizing the value of indigenous vegetables like amaranth as a consequence, their demand has raised rapidly even in cities. Amaranths were neglected by the scientific community and the result was the lack of information on the crop and appropriate cultural practices.

This study was conducted in order to determine the effect of planting methods on growth and yield of three amaranth species (*A.cruentus, A.hypochondriatus and AM-Fune*).

Table 11: Effect of planting method on growth and yield of three amaranths varieties

Variety	Planting method	Days to 50% flowering	Leaf yield (t/ha)	Yield (kg/ha)
AM-Fune	Direct seeding	59.50a	9.73f	399.30d
AM-Fune	Transplanting	61.38a	10.7e	415.90c
Cruentus	Direct seeding	50.12c	13.10d	269.60f
Cruentus	Transplanting	53.62b	13.75c	277.70e
Hypochondriatus	Direct seeding	41.12e	14.70b	507.10b
Hypochondriatus	Transplanting	45.75d	14.96a	522.00
SED		1.077	0.079	0.446
LSD (0.05)		2.192	0.160	0.908
Grand mean		51.92	12.72	398.61
CV (%)		4.1	1.2	0.4

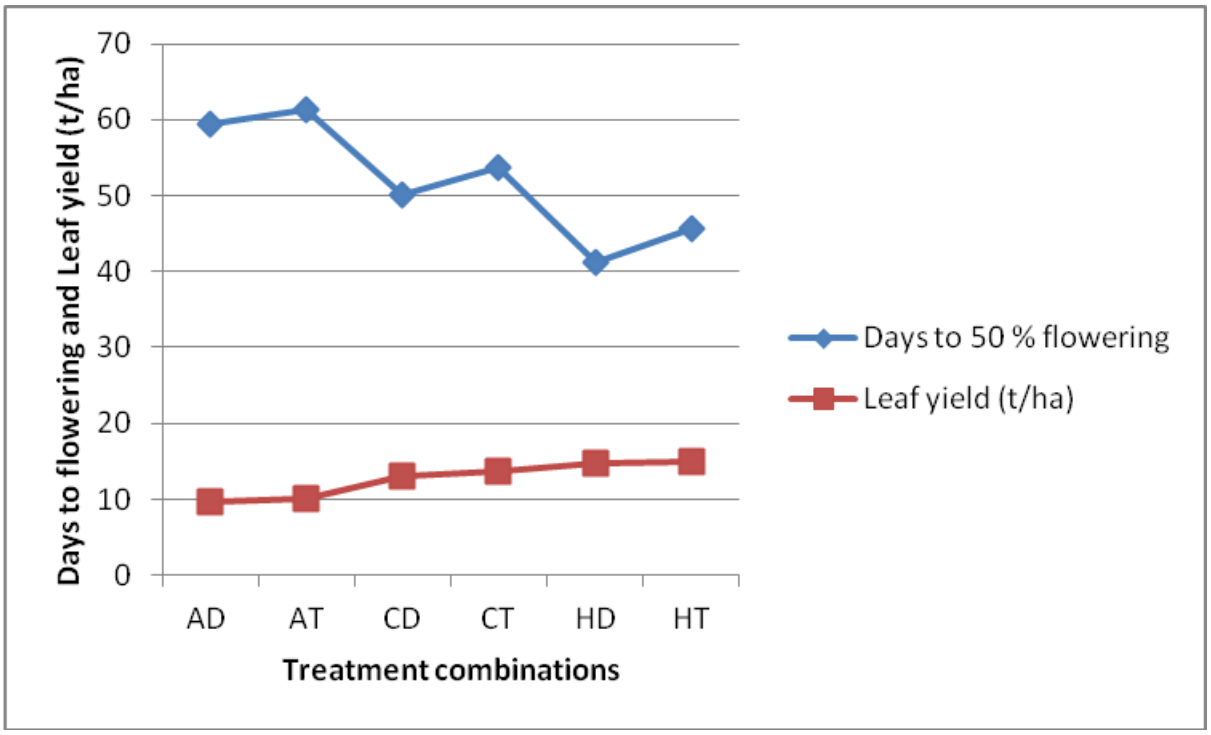


Figure 9: Correlation between leaf yield and days 50% flowering

This research revealed that three *amaranthus* varieties used in the experiment flowered at different times. Significant differences ($P<0.05$) were observed for 50% days flowering at 41 and 61days with seedlings from three varieties. Significant differences were observed in terms of leaf yield of transplanting method with 10 t/ha, 13.7t/ha and 14,9t/ha. Highly difference was observed in seed yield for two planting methods. There is a positive interaction between days to 50% flowering and leaf yield production (t/ha).Results from this study showed that transplanting was better than direct seeding for growth and yield of amaranth in heavy rain season such as during season 2012 A. *Amaranthus Hypochondriatus* gave a better leaf yield than other used varieties.

1.5.CASH CROPS

1.5.1. Coffee

Coffee is one of the major export commodities for Rwanda and together with tea, account for more than 90% of the value of agricultural exports thus significantly contributing to the foreign exchange earnings of the country. The major constraints to coffee production in Rwanda include erratic weather conditions, low soil fertility, pests and diseases especially Coffee leaf rust (CLR) and Coffee berry disease (CBD), low yielding varieties and inadequate agronomic practices. Activities carried out to increase coffee yield focused on evaluating the coffee leaf rust (CLR) trials including the Indian breeding lines 5A and 6; developing new coffee varieties with high yield, resistance to major diseases (CLR and CBD) and adequate cup quality; developing technologies for better management of coffee plantations (cover crops & banana coffee intercropping);developing integrated pest management (IPM) technologies against antestia bugs and Coffee berry borer; conserving the coffee germplasm collections and produce clean seeds for released varieties and

mobilizing key stakeholders including farmers to participate in farm based activities and establish linkages with farmers.

a. Evaluation of the CLR trials including the Indian breeding lines 5A and 6

Varieties with resistance to CLR including Indian breeding lines were evaluated in both on-farm and on-station trials in both six on-farm sites (i.e Ngoma, Kirehe, Gicumbi, Rusizi, Nyanza & Rutsiro districts) and one on-station trial (Rubona). Results indicated that new varieties (Selection 6 and Selection 5A) were resistant to CLR and CBD except that one of them (Selection 5A) was still segregating. Selection 6 had also a high yield and preliminary data showed it had the cup quality superior to that of BM139 (a preferred commercial cultivar by the Coffee Industry).

b. Development of new coffee varieties with high yield, CLR and CBD resistance and adequate cup quality

To achieve this objective, Ruiru 11, a Kenyan hybrid resistant to CLR and CBD, was selfed and the resulting progenies are currently growing in nursery (Plate 1). The aim is to improve Ruiru 11 through selection of the most promising genotypes from progenies obtained by selfing superior individual trees of this variety.

Figure 10: Selfed progenies of Ruiru 11

At the same time, a number of F1 hybrids were developed especially between Indian breeding lines 5A & 6 and other resistant varieties crossed with the local cultivars (Plates 2 & 3). The reason is, hybrid varieties have the advantage of combining the good attributes of local cultivars with disease resistance from introduced varieties in single individual genotypes, exploiting heterosis for yield, often exhibited when crosses are made among such genetically diverse coffee populations, and having improved stability, a common feature of such hybrids.

Figure 11: F1 hybrids between Jackson and Ruiru 11.

c. Technology development for better management of coffee plantations

Technologies for best agronomic practices were developed and disseminated to coffee growers. These include (i) stumping all the heads at the same time, (ii) stumping the heads in succession (iii) stumping all heads simultaneously but having pruned beforehand the same heads to allow proper development of suckers. The use of proper pruning systems in coffee is very important in regulating flowering hence cropping levels over the years as well as improving pest and disease control i.e creating unfavorable habitat for Antestia and improving pesticide spray coverage for control of both antestia bugs and Coffee leaf rust. The use of cover crops instead of mulch as alternative soil, water and nutrient management systems in coffee included species such as *Viscia*, *Mimosa* and *Arachis which* were tested for the period covering December 2012 to March 2013. Viscia proved to give better results compared to the other species and corresponding seeds were multiplied (Figure 12) In

addition, the banana – coffee intercropping trial was evaluated on-farm in Gisagara and Kirehe districts and so far the results are promising.

Figure 12: F1 hybrids between Jackson and Selection 6

Coffee – banana intercropping is more beneficial to the farmer compared to the mono-cropping in terms of land utilization efficiency and economic returns. Furthermore, it was reported that coffee grown under shade gives stable yields with high cup quality. Trials thereof are under evaluation to test whether shades regulate extreme environmental variations.

d. Development of IPM technologies against antestia bugs and Coffee berry borer

A survey was conducted in Western province, a place with the highest CBB severity, with the aim of monitoring the pest population dynamics. Results indicated that its severity reduced and traps were more effective compared with chemical sprays. Simultaneously, a number of pyrethrum based products were tested against antestia bugs along with their doses and results indicated that one of them **Pyrethrum 5EW** was the most effective at the dose of **1.5 ml per liter** of water and was **certified**. Following these results, Agrofarm Africa gave us three other products to test namely **Pyrethrum EWC**, **Pyrethrum 5EW – US** and **Pyrethrum EWC (2.5%).** These products were tested both through laboratory assays and field testing and results were very encouraging. Some of these products could control antestia bugs at very

low doses. Data analysis is still going on to come up with the final report and certification of some of these products.

1.5.2. Tea

Tea is one of the most important export crops in Rwanda. However, yields are relatively low although tea plantations use the available recommendations on soil fertility management practices. The tea program focused on research in soil fertility management so as to come up with recommendations for maximum productivity.

Fertilizer formulations and doses for increased tea production specified

There are two ongoing fertilizer experiments namely, "Response of clone 6/8 tea to rates and formulations of NPK fertilizers", a multilocal experiment set up on farm at Kitabi, Gisovu and Mulindi and "Yield response of selected clonal tea to inorganic fertilizers" established on station at Gakuta.

Data collected over a period of four years were compiled and subjected to statistical analysis. This involved testing three commercial fertilizer formulations that is, NPK 25:5:5, NPK 20:10:10 and NPK 26:4:8 together with 5 fertilizer rates viz. 0, 75, 150, 225 and 300 kg N ha^{-1} $annum^{-1}$. Progress findings revealed that the 3 formulations did not result into yield difference implying that any of the formulation could be used by the farmers. It was also found that yield reached peaks at the rate of 300 kg N ha^{-1} $annum^{-1}$ at Kitabi and Mulindi and 225 kg N ha^{-1} $annum^{-1}$ in Gisovu. However, higher net returns from nitrogenous fertilizers were observed in the rates below 225 kg N ha^{-1} $annum^{-1}$ in all sites. At Kitabi, for example, 1 kg N could yield 5 and 6 kg of made black tea at the rates of 75 kg N ha^{-1} yr^{-1} while the yield was 2.8 and 3.7 kg of made tea per 1 kg N respectively in the 2^{nd} and 5^{th} years of the experiment. Therefore, it was recommended to Kitabi tea growers to adopt the fertilizer dose of 75 kg N ha^{-1} yr^{-1} instead of the commonly used dose of 150 kg N ha^{-1} yr^{-1} commonly used in normal tea production.

1.6. CROP GENETIC RESOURCES CONSERVATION

1.6.1. Wheat Variety maintenance

To regularly maintain wheat germplasm, seed quality and availability, variety maintenance was carried out in both 2013A and B seasons in Rwerere and Kinigi stations using the principle of germination tests and seed viability. The genotypes maintained consist of 143 bread wheat, 14 durum wheat, 45 triticale and 12 barley varieties. This is a useful source of parental materials which would provide agronomic and economic or nutritional traits, such as resistance to pests and diseases, early maturity, drought tolerance and good baking qualities that can be used in a breeding program.

1.6.2. Sorghum variety maintenance.

Variety maintenance experimentations were conducted from January 2013 to July 2013 at Rubona and Karama experimental stations. Each variety was sown continually in an unrepricated plot of 4 rows of 4 m of length against 3m of width. At flowering stage, at least 4 plants showing original traits of a concerned variety were isolated using paper bags in order

to maintain its genetic purity. At maturity stage, isolated panicles were harvested and kept in Rubona and Karama stations storage. In total, 234 sorghum varieties were maintained.

1.6.3. Conservation of the coffee germplasm collection and production of clean seeds

The coffee *ex-situ* germplasm collection in Rwanda includes accessions from Ethiopia, Democratic Republic of Congo (DRC), Brazil, Uganda and Kenya. The collection includes *Coffea arabica*, *Coffea canephora* and *Coffea liberica*. Though the commercial coffee varieties grown in Rwanda were selected among these accessions, many others are of no direct commercial value but represent an important source of genetic variation for characteristics such as canopy architecture, pests and disease, yield, quality and other agronomic and industrial traits. The Coffee germplasm collection in Rwanda includes 184 accessions located at Rubona, Mwito and Ngoma. This year, 14 new accessions were added to the existing collection.

As regards the production of clean coffee seeds; two thousands and five hundred kilograms (2,500 kg) of clean coffee seeds were produced and given to the National Export Development Board (NAEB) for nursery preparation.

1.6.4. Tea germplasm preserved in tea growing zones

Tea germplasm preservation is a continuous activity aimed at collecting tea genetic resources from different Rwanda tea plantations and from abroad to be conserved on RAB stations' tea gardens. More than 50 clones of tea (*Camellia sinensis)* are available in Rwanda; however, field visit reports revealed that some eight clones such as BB 35, TRFK 31/11, TRFK 100/5, BB10, TRFK 11/4, TRFK 6/8, TRFK 31/8 and 475 in addition to seedling tea of unidentified genetic makeup have been consistently grown in most of those plantations. This implies that tea farmers in Rwanda are not effectively and efficiently utilizing the existing genetic resources. Moreover, most of those unutilised tea genetic materials are threatened with extinction. These should therefore be preserved for optimal use and future tea crop improvement programs.

For the year 2012-2013, the activity in relation to germplasm conservation consisted of extension of tea gene bank at Ntendezi. For this purpose, 1.5 ha was planted with 16 tea clones in Ntendezi station; the population of 300 plants was established for each clone. These include clone BU/90, TRFK 6/10, BU/92, TRFK 12/56, BU/105, BW-G/5, TRFK 12/9, K 27, SR 2 BI/57, SR 14 U/49, BU/95, SR 18 U/49, L9, SR 7 U/49, TRF 303/577, TRFK 301/4, TRFK 301/5, TRFK 54/40, TRFK 12/12, BB 14, BB 15 and B 9. In addition 10,000 tea cuttings of 6 tea clones not yet collected in station were planted in nursery at Mata (Nyaruguru) for the same purpose. These are: SFS 204, SFS 371, Pc 81, SFS 150, SFS 110 and SFS 475 and originated from Malawi and were found in SORWATHE LTD tea estate at (Kinihira). It is planned to establish them on field by March/April 2014.

2. ANIMAL RESOURCES IMPROVEMENT

2.1. CATTLE GENETIC IMPROVEMENT

During the year 2012-2013, activities were geared towards improving livestock efficiency/ productivity in a sustainable manner. Emphasis on genetic improvement through proper animal identification, improved parentage and production recording, artificial insemination, embryo transfer and improvement of statistics in genetic evaluation system were undertaken.

The achievements in different target areas included:

i) Training

Cattle farmers were mobilized and trained in cattle breeding and record keeping. In addition, 1,160 Community Based Animal Health care workers were selected from farming communities, two from each cell from both Eastern and Southern provinces. Another training targeting improved farm management and animal feeding practices was conducted in 30 districts; 150 farmers (30 were selected from each agricultural zone division) were trained. Two training manuals were produced.

ii) Research in animal breeding

Supervision and research on Masaka bull semen quality was done and one scientific publication entitled 'Influence of breed, season and age on bovine semen quality' was written and results are shown in Tables 1, 2 and 3). In addition, research on PRID DELTA hormone implant was done on 50 cows and a scientific paper 'Efficacy of Progesterone Releasing Intra-vaginal Device (PRID) in pure Ankole and its crossbreds with three exotic cattle breeds' and results are shown in Table 4. Other scientific works include a publication on genetic and non-genetic factors that affect growth of cattle at Songa station in Southern Rwanda. A report on nutrient content of fresh milk and fermented milk products from local bred cows (Ankole) and crossbred cows (Ankole × Friesian) has also been written.
Promotion of utilization of hormones to enhance fertility was achieved; hormones were distributed in all zones up to the end of March; cattle were synchronised and AI performed.

iii) Improved breeding technologies

An evaluation of success rates of artificial insemination involved 800 cows in Rwamagana, Bugesera and Nyamagabe was done. In addition, six RAB staffs were trained in embryo transfer technology and reproductive management. A scientific paper entitled 'Factors affecting suitability of surrogate dams for embryo transfer in cattle was published in Journal of Animal Science Advances. In order to improve AI service delivery, six crushes were constructed.

iv) Record keeping

Individual cow recording system was established and a total of 1,500 cattle were registered in all zones.

v) Beef production

A program aimed at increasing beef production was initiated in Nyagatare and Kirehe districts in eastern Rwanda. A beef innovation platform was initiated. The Mirama feedlot demonstration was established and activities are still in progress.

2.1.1.Research and extension achievements in cattle breeding genetic improvement

a. Influence of breed, season and age on bovine semen quality

A study aimed at investigating the factors that affect semen quality of Friesian, Jersey and Nyambo bulls kept at Masaka bull stud, Rwanda was understand factors that impact on success of AI.

Semen was collected bi-weekly, from 2011 to 2012 by using an artificial vagina. Semen volume, colour, mass, motility, live sperm percentage and post-freeze motility were evaluated. Ejaculate volume, mass motility, individual sperm motility, density and post freeze motility significantly differed (P <0.05) among seasons, bull breeds and age. Friesian bulls had superior (P<0.05) semen volume (5.76 ml) to that of Jersey (4.29 ml) and *Inyambo* (3.37 ml). However, Friesians had an inferior (P<0.05) semen colour (52.7%) to that of Jersey (65.2%) and *Inyambo* (64.9%) (Table 12). The short rain season (October to December) gave semen with the best quality characteristics; but was not significantly (P>0.05) better than the long rains except in mass motility and post-freeze motility. Semen volume (4.61 ml) and post-freeze motility (38.51%) were poorest in the long dry season (January to February) [Table 2]. Age of the bulls negatively affected (P<0.05) all the parameters studied. while the semen volume dropped with age from 5.16 to 5.10 ml (Table 3). In conclusion, the Friesian breed should be promoted at the bull station. Most semen should be collected during the rainy season, particularly the short rains.

Table 12: Influence of bull breed on semen quality.

Parameters	**Bull breed**		
	Friesian	**Jersey**	***Inyambo***
Volume (ml)	5.76±0.08[a]	4.29±0.09[b]	3.37±0.1[c]
Libido score	3.14±0.01[a]	3.97±0.01[b]	2.81±0.03[c]
Semen color(%)			
Cream	52.7%	65.2%	64.9%
Milk	31.9%	25.3%	34.5%
Watery	4.3%	5.4%	0.6%
Semen Concentration (10^9spz/ml))	3.12±0.03[b]	3.31±0.05[a]	3.29±0.07[a]
Mass motility (%)	2.67±0.03[c]	3.05±0.04[a]	2.90±0.06[b]
Individual motility (%)	62.04±0.6[b]	68.14±0.9[a]	66.01±1.04[a]

Live-dead %	35.96±0.5[a]	29.37±0.7[b]	34.12±1.05[a]
Post freezing motility(%)	40.43±0.5[b]	43.45±0.9[a]	42.20±1.1[a]

Table 13: Influence of season on semen quality

Parameters	Season			
	Long dry season	**Short rain season**	**Long rain season**	**Short dry season**
Volume (ml)	4.61±0.15[b]	5.31±0.12[a]	5.01±0.09[a]	5.28±0.13[a]
Libido Score	3.05±0.04[b]	2.97±0.02[c]	3.0±0.09[c]	3.22±0.02[a]
Semen color (%)				
Cream	59.5%	53.5%	67.5%	49.7%
Milky	35.6%	34.4%	21.2%	36.6%
Watery	4.9%	3.8%	5.0%	3.1%
Yellowish		7.0%	6.3%	9.8%
Semen Concentration ((10^9spz/ml))	3.14±0.08[b]	3.11±0.04[b]	3.36±0.04[a]	3.07±0.05[b]
Mass motility (%)	2.71±0.06[b]	2.58±0.04[c]	2.86±0.04[a]	2.94±0.04[a]
Individual motility (%)	65.29±1.17[a]	63.79±0.78[b]	62.09±0.98	65.85±0.78
Live-dead %	34.70±1.17[ab]	36.06±0.79[a]	32.7±0.74[c]	33.97±0.78[ab]
Post freezer motility (%)	38.51±1.41[b]	42.45±0.76[a]	42.85±0.78[a]	39.68±0.96[b]

Table 14: Influence of Age on semen quality

Parameters	Years		
	2011		**2012**
Volume (ml)	5.16±0.09		5.10±0.08
Libido Score	3.27±0.02[a]		2.95±0.01b
Cream	62.8%		54.0%
Milky	21.5%		37.5%
Watery	6.5%		2.4%
Yellowish	8.2%		5.7%
Semen Concentration (10^9spz/ml)	3.28±0.04[a]		3.11±0.03[b]
Mass motility (%)	2.98±0.03[a]		2.65±0.03[b]
Individual motility (%)	65.08±0.8[a]		63.12±0.5[b]
Live-dead %	30.44±0.6[b]		36.76±0.5[a]
Post freezer motility (%)	40.50±0.8[a]		41.93±0.5[a]

b. Genetic and non-genetic factors affecting cattle growth performance in the Southern Province of Rwanda

Large stocks (cattle) play a vital role in the whole agricultural system of Rwanda, and so have a large influence on the rural economy of the country. It is envisaged that the genetic improvement of growth of crossbred cattle has high impacton the large stocks development in Rwanda.

The aim of this study therefore, was to evaluate effects of various non-genetic and genetics factors on growth performance of crossbred (AF, AJ,AS, AJJ,AJS, ASS, and EPF) reared at Songa genetic improvement farm. The above study will help to formulate suitable evaluation procedures especially in organized farms for improving economic traits of these breeds. The

results shown that birth weight (BWT) was significantly (P <0.05) affected by the sex of calf, with males weighing 31.5 kg while females weighed 26.3 kg and the rest of the factors were not significant (P > 0.05). The weaning weights (WWT) of AF, AJ, AS and EPF genotypes were 178.1 kg, 171.2 kg, 159.7 kg and 154.7kg, respectively (Figure 14).

The calves weaned during the long rainy season had a significantly (P < 0.05) higher WWT (186.8±5.0 kg) than those weaned during the short rainy season (168.1±4.9 kg), short dry season (164.9±5.0 kg) and long dry season (156.7±7.0 kg). Ankole-Jersey calves had the yearling weight (175.2 kg), while AJJ calves had the least (139.1 kg) (Figure 15). Generally, results showed that crosses with 50% exotic blood were better than those with higher proportions exotic blood. It was recommended that AF and AS genotypes be used under management of Songa station and weaning should preferably be done during the long rains to avoid weaning depression.

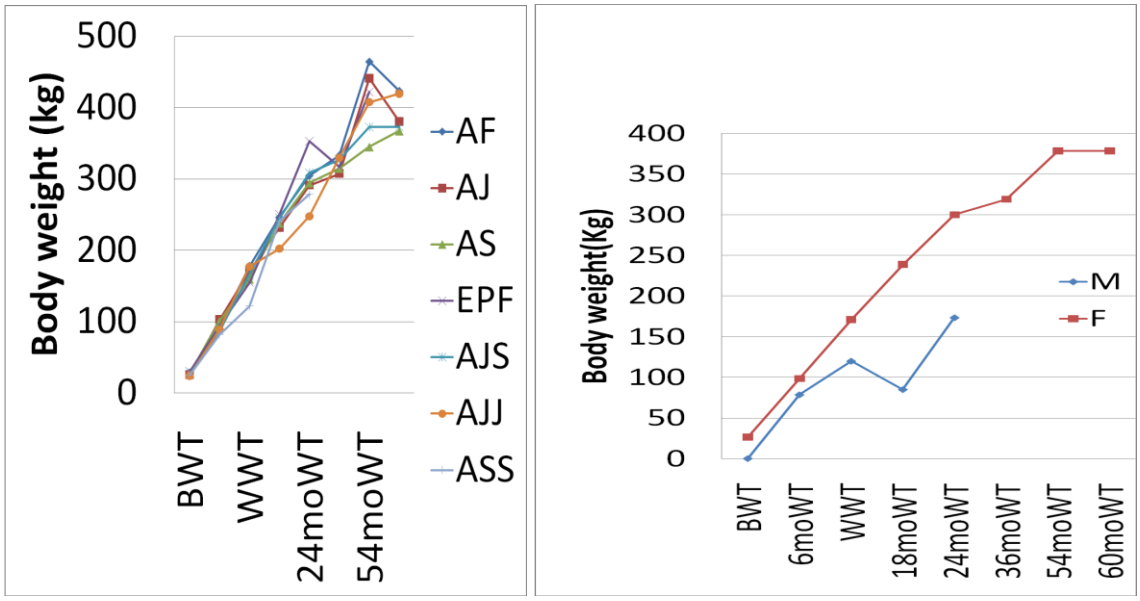


Figure 13: Effect of genotypes and sex on growth performance of crossbred cattle between one and five years. **AF=Ankole×Friesian; AJ=Ankole×Jersey; AS=Ankole×Sahiwal; EPF=Elite Producer Female; AJS=Ankole×Jersey×Sahiwal; AJJ=Ankole×Jersey×Jersey; ASS=Ankole×Sahiwal×Sahiwal**

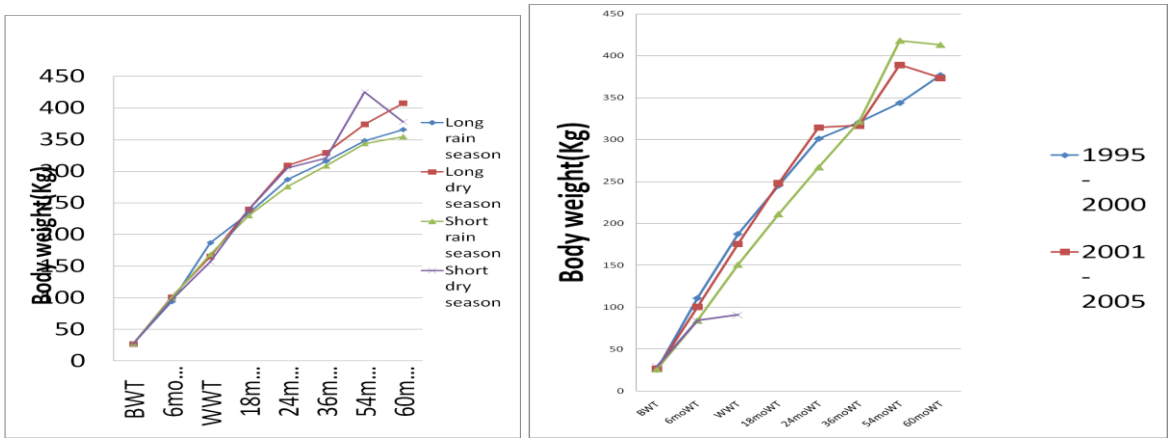


Figure 14: Effect of season and year on growth performance of crossbred cattle between one and five years. A indicates T**he Long rain season(Mar – May); Long dry season (June – Sept); Short rains (Oct – Nov); Short dry season(Dec – Feb).**

In RAB animal genetic improvement station, we have more than 4 types of crossbred(AJ, AF, AS, AJS) and Ankole breed (refer to the figure 3 and 4)

A **B.**

Figure 15: A. Ankole x Jersey and B. Ankole xFriesian

Figure 16: C Ankole x Sahiwal **D. Ankole X Jersey**

c. Nutrient content of fresh milk and fermented milk products from local bred (Ankole) and crossbred cows (Ankole × Friesian)

The objective of this study was to test and compare the nutrient content of milk products from local breed cows (Ankole) and cross breed cows (Ankole × Friesian). Nutrients especially lactose, total protein, total fat, some minerals (Ca, Na, K, Mg, Mn, Zn) were tested in fresh milk and lactic acid in fermented milk produced from the 2 breeds having the same environmental background. The samples were obtained from cows from Songa, RAB Genetic Improvement farm. The test of lactose was carried out using polarimetry which involves the precipitation of other components with lactose remaining in solution. The polarimeter was used to determine the optical rotation of the lactose solution; calculations were done to find the lactose concentration of the different samples. The results showed that the Ankole cow

milk contained 1.926% lactose, 3.558% protein, 3.2% fats, 1.236% lactic acid (in fermented milk), 55.69% calcium, 51.95% potassium, 3.963% magnesium,17,276% sodium and 0.221% zinc; whereas for crossbred-Ankole × Friesian there were 2.575% lactose, 3.23% protein, 2.8% fats, 49.499% calcium, 88,45% potassium, 3.54% magnesium, 0.054% manganese, 15,99% sodium and 0.319% zinc .

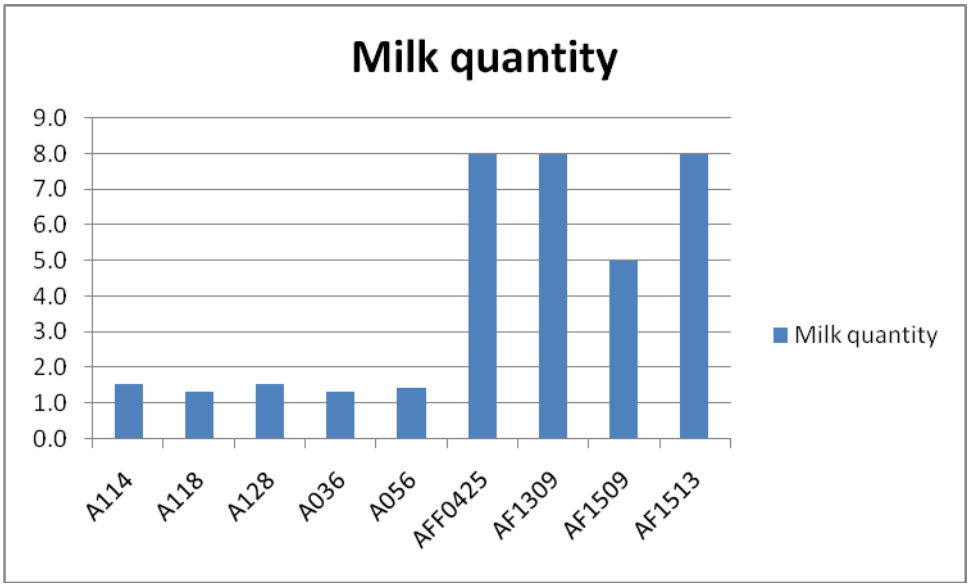


Figure 17: The yield of milk production in population sample (liters).

A= indicates Ankole;AFF; AF: Ankole x Friesian

Table 15: Nutrient results

Nutrients	Ankole (%)	Ankole × Friesian (%)
Protein	3.558	3.230
Lactose	1.926	2.575
Fats	3.240	2.800
Lactic acid	1.236	0.993
Calcium	55.690	49.499
Potassium	51.95	88.45
Magnesium	3.963	3.54
Manganese	0.215	0.054
Sodium	17.276	15.99
Zinc	0.221	0.319

It is concluded that milk quality and quantity of cows reared at SONGA RAB farm are influenced by genetic factors that are interacting with environmental management factors.

d. Use of Artificial Insemination and Embryo Transfer in increasing milk production

Artificial insemination

Efficacy of Progesterone Releasing Intra-vaginal Device (PRID) in pure Ankole and its crossbreds with three exotic cattle breeds

The control of estrous in cow herds is an important technique in farm management that aims at improving lifetime reproductive performance.

The use of AI in combination with effective synchronization protocols can reduce the number of days open and accelerate genetic progress. Artificial insemination after the use of an estrus synchronization treatment is one of the reproductive management tools that will aid in advancing animal breeding. The success of artificial insemination is usually dependent on the fixed time of the heat induction. This was the basis for undertaking this study, with the aim of assessing the efficacy of PRID® Delta to induce heat in cows in Rwanda. The PRID® Delta (CEVA santé Animal, France) is a newly developed device made up of Bi-matter of a polyamide skeleton covered with an elastomer and it ensures an effective contact with the vaginal mucous membrane, an optimal release of progesterone as effectiveness in the synchronization of heat in cows.

For all the cows used in the study, the results revealed that the retention rate of the PRID was 100% and 96% of animals exhibited signs of oestrus after the PRID removal. The rate of induced estrus was 93.3% (28/30) in crossbred as against 100% (20/20) in Ankole cows (Table 16). The behavioral signs observed in the synchronized cows are presented in Figure. 19, 20,21 and 22. Rectal palpation for active corpora lutea also indicated a relatively high incidence of an ovulatory oestrus post PRID treatment. In conclusion , the results of this study indicate that oestrus can be stimulated successful by PRID combined with GnRH in cows, and that successful pregnancy can be achieved by fixed time artificial insemination.

Table 16: Estrus and pregnancy diagnostic rate after PRID removal

		Estrus results		**Pregnancy Diagnosis Rate**	
Stations	**Breed**	**Synchronised cows**	**Cows exhibited signs of estrus**	**Artificially inseminated cow**	**PD Positive after 3 months**
Kinigi	Crossbred	10	9	10	8
Karama	Ankole	10	10	10	7
Songa Station	Crossbred	20	19	18	8
	Ankole	10	10	8	5
Total		**50**	**48**	**46**	**28**
Total in %		100	**96**		**60,87**

Figure 18: Withdrawal facilitated with only "drawing on the string" and not from incision nor the intervention of a scalpel

Figure 19 : Crossbred cows showed estrus after 11 days. Picture 1 indicates mucus traces on the croup and picture 2 indicates lumbar reflex.

Figure 20: **Vaginal mucus discharge during heat**

Figure 21: Picture A indicates cow lowing and picture B indicates the milk reduction in a cow.

- **Comparison of conception rate by artificial insemination using synchronization and natural heat**

Due to increasing Rwandan population there is high demand for milk and dairy products. To meet this demand, there is need to utilise high yielding and fast growing animal breeds. The Government of Rwanda adapted a strategy of using hormones for mass synchronization and artificial insemination of cattle so as to increase production. However, the success rate of AI compared to bull breeding in some administrative sectors has not been evaluated. The objective of this study was to compare the conception rate by artificial insemination using synchronization and natural heat in three sectors of Huye district (Kinazi, Rusatira and Ruhashya).

The result showed that conception rates of cows in the three sectors served under natural heat over three years was almost the same under both first and second insemination. i.e. 67.9% and 67.6% respectively (Table 17).The results also showed that from records obtained in RAB farms (Songa and Rubona) were also higher for cows inseminated under natural heat with 80.2 % and 83.5 % on first and on repeat inseminations respectively (Table 18). Therefore, the conception rates were higher in cows inseminated under natural heat, than those inseminated after hormonal synchronization. Reliance by farmers on natural heat will

not only lead to better conception rates, but also significantly lower the costs of synchronization, especially due to costly hormones. It should therefore be promoted by bovine artificial insemination stakeholders.

Table 17: Results of artificially inseminated cows in three selected sectors

	Cows inseminated		**Cows conceived at 1st* insemination**	
years	**Synchr**	**Natural heat**	**Synchr**	**Natural heat**
2007	40	38	20(12)	21(8)
2008	56	60	27(17)	41(13)
2009	240	211	119(84)	148(46)
Total	366	309	166(113)	210(67)
Conception	**49.40%**	**67.90%**	**66.40%**	**67.60%**

Note: *Cows that conceived after heat insemination are presented in brackets

Table 18: Results of artificially inseminated cows in Songa and Rubona station

Year	**Cows Inseminated**		**Cows Conceived* at 1st insemination**	
	Synchr	**Natural heat**	**Synchr**	**Natural heat**
2007	182	215	119(54)	170(43)
2008	75	173	45(19)	132(36)
2009	90	165	61(29)	142(22)
Total	347	553	225(102)	444(91)
Conception	**64.80%**	**80.20%**	**83.60%**	**83.50%**

Embryo transfer

Factors Affecting Suitability of Surrogate Dams for Embryo Transfer in Cattle

Multiple Ovulation and Embryo Transfer (MOET) technique trials are still on going. From 2012 up to 2013 ; 15 embryos have been transplanted and only one was successfully done at Songa Genetic mIprovement farm. The establishment of prudent balance between pure indigenous and exotic cattle and the crossbred for milk production were assisted by reproduction techniques. The performance of surrogate dams indicated that the main factors were surrogate genotype and hormone treatment method. It was recommended that selection of surrogates for embryo transfer should primarily focus on the Ankole × Jersey crossbred cows . The same cow was confirmed to be pregnant for the second embryo transfer calf.

A B

Figure 22: A.Embryo transfer training; B. Ankole × Jersey crossbred Surrogates for embryo transfer which is pregnant for the second time.

2.2. CONSERVATION OF INDIGENOUS ANIMAL GENETIC RESOURCES

The need to increase productivity has compelled agricultural sector to adopt high livestock breeds to match production of animals products to the rising demand of the population. Both breed substitution and breed synthesis threaten indigenous conservation efforts under the International Conventions of Conservation of Plant and Animal Genetic Resources. The Ankole longhorn is the major indigenous cattle genetic resource in Rwanda, however, it is threatened by uncontrolled crossbreeding and the inevitable introduction of high yielding breeds (Figure 24). Efforts have endeavoured to establish a herd of 500 pure Ankole *in-situ* conservation at Karama stations (Bugesera and Nyagatare districts) and 200 herd in Songa (Genetic Improvement farm), in order to respond to this concern. For increasing the herd size of indigenous breed, Rwanda Agriculture Board (RAB) signed MOU with *Urukari*.

Figure 23: Inyambo (Ankole longhorn) at Karama farm, Nyagatare district

Figure 24: Ankole longhorn cattle at Urukari Cultural Centre

Cattle genetic improvement through artificial insemination

Emphasis was put on upgrading artificial insemination coverage through the creation of artificial insemination inputs supply subcentres at district level, training of new inseminators. 71,740 cows were inseminated and 31,300 were tested positive in the pregnancy diagnosis leading a conception rate of 43,6 %, for the same year 12,000 AI born calves were recorded.

30 new inseminators were trained and equipped to take- up AI work in their respective village.

Figure 25: Training session for AI workers at Songa Livestock Research Farm

2.3.FEED RESOURCES AND ANIMAL NUTRITION

Research was carried out to identify feed resources used by livestock owners across the country. It was found that, 30 feed resources are being used by livestock owners in Rwanda and some of them are used as a coping measure during the dry season. These included grasses, legumes, crop residues, brewers' and home wastes, and non-conventional feeds. The major feed used during the rainy season was Napier grass (*Pennisetum purpureum*), which accounted for 20% of the feeds. It was followed by roadside grass (10.5%) and maize stover (8%). The least used feed resources were groundnut haulms (1.1%) and home wastes (0.1%). The high variability of feed resources indicates the shortage of feedstuffs in the country

2.3.1. Napier stunt and smut diseases in Rwanda

Napier is the most important forage for smallholder dairy production in Rwanda. Napier stunt and smut diseases (NSSD) have been reported to be a major threat to Napier grass production in small holding systems in neighbouring countries in the region. However, research to establish the status of the diseases and farmers' awareness was carried out among smallholder dairy farmers. The incidence of Napier stunt was 4.23 %. The level of awareness was low (11.3%) and predominantly (66%) among households who have the disease in their fields. The major symptoms were yellowing (63.2%) and stunting (60.5%). In addition, 66.7% of farmers noticed the disease during the coppicing stage. There was no incidence in northern and southern provinces. Severity was moderate in western province and high in Eastern province (Figure 26). The highest prevalence was in Kirehe (65%). The incidence was higher in improved (69.8%) than in local (14%) Napier grass variety. Healthy and diseased napier grass is shown in Photo 14.

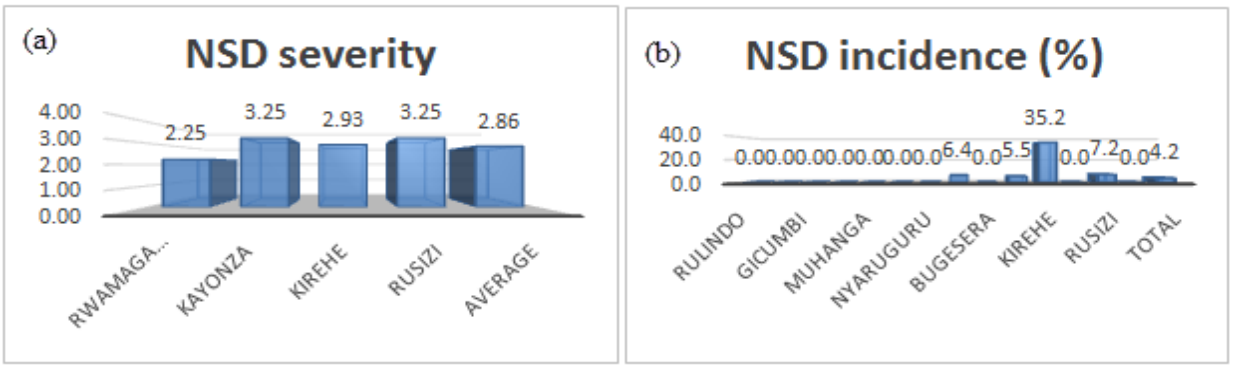


Figure 26: Severity of stunt (a) and incidence (b) in surveyed sites

Figure 27: Napier stun disease in Rusizi district, Bugarama sector

2.3.2. Evaluation of *Mucuna pruriens* and *Lablab purpureus* as protein supplements in the diets of lactating dairy cows

Napier is major source of feed for cows in Rwanda with low protein and mineral sources. Forage legumes are the cheapest sources of protein for ruminant livestock but they differ in their quality as supplement to basal diet. A study to evaluate the effect of feeding Napier grass (N) supplemented with *Mucuna pruriens (N+M)* and *Lablab purpureus (N+L)* on milk yield and milk quality for dairy cows was conducted in Rwamagana district. Eight fourth-calving cross-breeds Ankole x Friesian (average = 5 years; live weight: 350 – 450 kg) were fed the treatment diets after 12 to 15 days postpartum in a Completely Randomized Block Design for six weeks. Average milk yield (L/day) was higher in cows fed *Mucuna* and *lablab* than in cows fed on Napier alone. The highest daily body weight gains were observed in the

cows fed with supplemented diets. Both protein and solid not fat (SNF) contents were significantly affected by type of supplement while butter fat (BF) was not affected. N+L and N+M increased protein content by 22% and 12.6% respectively.

2.4. ANIMAL HEALTH

One of the most the most limiting constraint to improved livestock productivity in the country is the prevalence of livestock diseases. Research in animal health aimed at identification of priority livestock diseases and development research programs to address these challenges. Broadly, the research activities were categorized in the following themes:

-Control of ticks and tick borne diseases
-Zoonotic viral diseases
-Zoonotic Parasitic diseases

2.4.1. Control of ticks and tick borne diseases

a. In vitro characterisation of acaricide resistance to major acaride types in Rwanda

Reduced effectiveness of acaricides against cattle ticks was reported the the Eastern Province. To address this problem, systematic investigations of acaricide susceptibility were carried out on the major tick that infests cattle viz. *Rhipicephalus appendiculatus.* To enable improved numbers of ticks on which to make investigations, engorged female ticks were collected from Nyagatare, Gatsibo and Kayonza districts, Eastern Province, incubated in the laboratory until eggs were laid; eggs were further incubated until larvae hatched and tested for resistance with four acaricides *viz,* Flumethrin, Amitraz, Cypermethrin and Deltamethrin available on market in Rwanda. With this technique, a single female tick lays thousands of eggs which hatch into enough larvae to work on.

b.Lethal dose causing 90% and 99% larval mortality

Lethal dose (LD) of larvae causing mortality of 90% and 99% of *R. appendiculatus* larvae respectively is shown in Table 19. The effective concentration necessary to kill 90% and 99% of larvae were higher for Deltamethrin and Cypermethrin than concentrations for Amitraz and Flumethrin.

Table 19: Predictive LD 90 and LD 99 (mg / µl) for the four acaricide types

	Amitraz	**Flumethrin**	**Deltamethrin**	**Cypermethrin**
LD 90	8.7×10^{-7}	5.1×10^{-6}	1.6×10^{-4}	4.3×10^{-5}
LD 99	1.5×10^{-5}	8.9×10^{-5}	2.8×10^{-3}	7.7×10^{-4}

Using general linear model and probit as a link function to fit larval mortality data, all acaricides showed significant effect on survival of larvae ($P<0.05$) compared to the untreated control group. However, Cypermethrin and Deltamethrin had higher effective concentrations than Amitraz and Flumethrin. A similar pattern was observed for individual acaricide lethal

dose (LD) causing 90% mortality of tick larvae (LD 90) and LD 99 calculations for the four acaricides. The more effective acaricide is one that killed more larvae even when applied at low concentration (Figure 28). Amitraz and Flumethrin were more effective than Cypermethrin and Deltamethrin.

Observations from this experiment showed that *R. appendiculatus* larvae had reduced susceptibility to some acaricides and the response depended on the geographical area and acaricide concentration. Basing on results obtained from this study, it is recommended that constant monitoring of acaricide resistance at individual farms and area-wide be regulary undertaken.

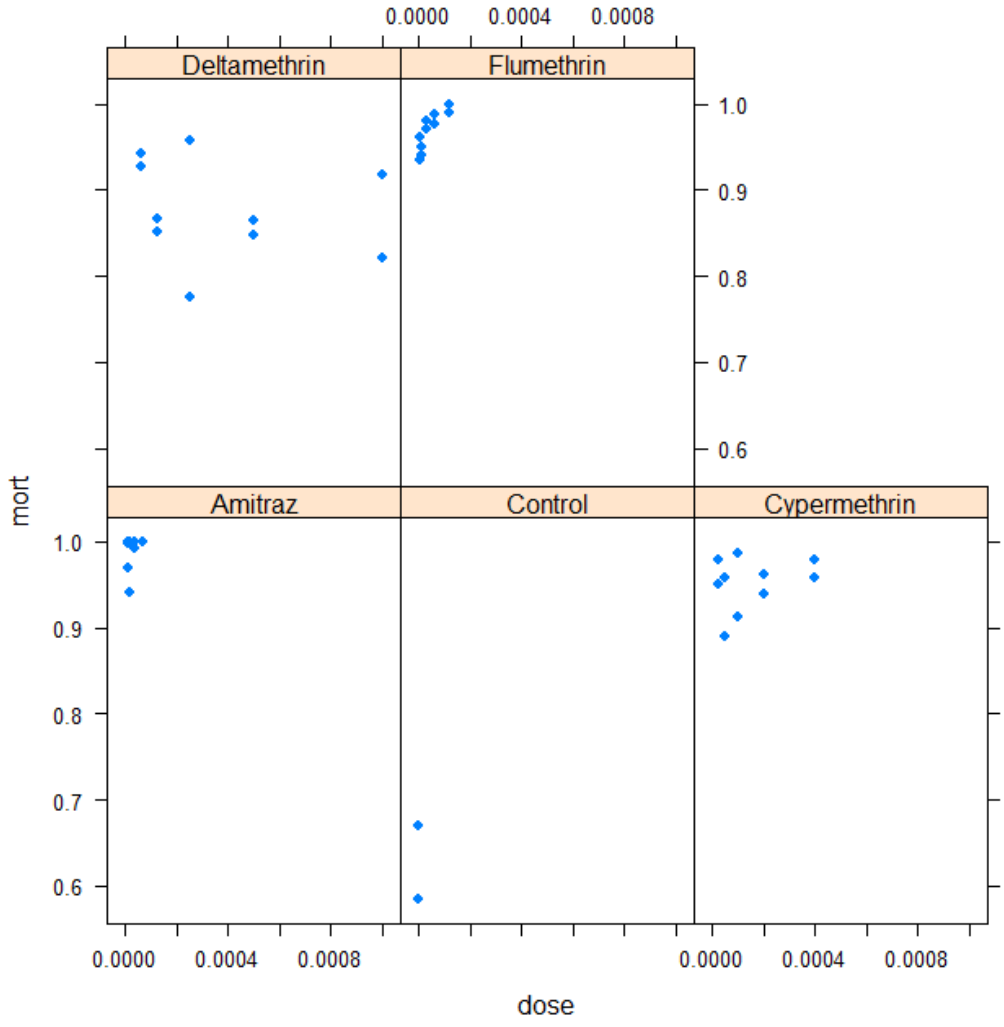


Figure 28: Mean mortality of *R. appendiculatus* larvae (%) at differing acaricide concentration (mg / µl).

c. The efficacy of Inkuyo grease as acaricide for major ixodid ticks infesting cattle in Rwanda

Among the major acaricide types used to control ticks in cattle *viz.* synthetic pyrethroids, amitrazes, avermectins and dinitrophenyl derivatives, none of these is locally manufactured. An agropharmaceutical company located in Musanze District formulated an acaricide from extracts of pyrethrum locally grown in the Northern Province. Before licensing the product and subsequent release for use to control ticks in Rwanda, research of its efficacy was

conducted on-farm in Nyagatare, Bugesera and Huye districts (Table 20). *Inkuyo* acaricidal activity was evaluated over a period of 48 hours and killed more than 90% of the live feeding ticks on cattle. This result is satisfactory and the product was recommended for use as acaricide in Rwanda.

Table 20: *E*ffectiveness of *Inkuyo* in respect of tick species in the three districts

Tick species	Number of feeding ticks on cattle	Total dead (in number)	% mortality
R. appendiculatus	1,982	1,770	90
Boophilus decolaratus	422	413	98
Amblyoma variegatum	2	2	100
Total	**2,406**	**2,185**	**91**

2.4.2. Zoonotic diseases research

Investigations on causes of abortion storms in livestock in Bugesera district in 2012 showed presence of Rift Valley Fever in Rwanda

Abortion storms in livestock have continually been observed in Rwanda and common causes of abortion have been identified. However, abortion outbreaks of 2010 and 2012, efforts to identify identified an extra cause, hitherto not known in Rwanda before. Rift Valley Fever (RVF) was for the first time unequivocally demonstrated as the cause; the demonstration of RVF in Rwanda raised the issue of human safety since it is a zoonotic disease.

Table 21: Summary of RVF results from initial investigation of abortion in livestock in Bugesera district

Diagnostic technique	number of positive goats	Number of positive cattle
Competition ELISA (c-ELISA)	4 / 7	5/17
Inhibition ELISA (I_ELISA)	5 /7	3/17
Reverse transcriptase Polymerase chain reaction (RT-PCR)	0/7	1/17

Two types of serological tests were done (c-ELISA and I-ELISA) on seven blood samples from goats and seventeen samples from cattle. The two tests gave slightly varying results. Only one sample gave a positive test with reverse transcriptase Polymerase chain reaction (PCR).

The serological positive results (c-ELISA and I-ELISA) imply that the animals were exposed to RVF but with no reference whether it is a current or previous infection; the RT-PCR demonstrated presence of the virus in a sample. This investigation for the first time demonstrated presence of RVF in Rwanda and the following initiatives were recommended: possible increase of potential vectors for RVF virus and increased observations of abortions

indicate that RVF is an emerging disease in Rwanda and should be considered for inclusion on the control programs of animal diseases; RVFV is a zoonotic disease and key players in animal health care should be sensitized to take precautionary measures when handling animals and animal products; traders and consumers of animal products need to be sensitized about possible means of contracting of RVF; further investigations of RVF exposure in people living in the high risk zones should be done in order to advise policy on control of animal diseases on control strategies for RVF in livestock.

2.4.3. Zoonotic parasitic diseases research

Control of *Taenia solium* cysticesis using TSOL 18 vaccine

A baseline survey on the prevalence of *T. solium* cysticercosis was performed among pigs in Gisagara district, Southern province of Rwanda and results of examination of pigs by tongue palpation indicated 21/137 pigs were positive (Table 22) .In Gisagara district, it was observed that *T. solium* infection in pigs was not influenced by age, breed or sector where the pig was reared (Chi-square test using SPSS v 17). *T. solium* cysticercosis in pigs may be more widely spread in Gisagara district. The method used to examine pigs has low sensitivity (16%).

The TSOL18 vaccine trial will be performed in Gisagara district and if protectiveness is demonstrated, it can be recommended for use in Rwanda.

Table 22: Numbers of pigs examined by farmers and confirmed by our team for *T. solium* cycticercosis

		No. positive	No. negative	Total	$\chi 2$	df	Sign.
Sector	Kansi	18	91	109	0.58	1	P > 0.05
	Nyanza	3	25	21			
	Total	21	116	137			
Breed	Cross	8	38	46	221	1	p > 0.05
	Local	13	78	91			
	Total	21	116	137			
Sex	Female	10	69	79	1.03	1	p > 0.05
	Male	11	47	58			
	Total	21	116	137			
Age	< 4	7	45	52	13.6	4	p > 0.05
(months)	5-9	9	36	45			
	10-14	2	14	16			
	15-19	1	6	7			
	> 20	2	15	17			
	Total	**21**	**116**	**137**			

2.4.4. Prophylactic measures against animal diseases

Animal diseases control was carried out through mass vaccination of cattle against the following economically important livestock diseases: Foot and Mouth Disease, Contagious Bovine Pleuropneumonia, Lumpy Skin Disease, Brucellosis and Black quarter/Anthrax. A total of 470,546 cattle were vaccinated across the country (Table 23). In addition, strengthening boarder control of trans-boundary animal diseases, strict control of cattle movement and inspection for animals and animal products were enhanced. To support this initiative, a total of 1,006 Community Animal Health Workers were trained in Eastern Province in basic animal health practices and good animal husbandry practices to provide proximity animal health primary care.

Table 23: Vaccination against animal diseases

Disease	**Number of cattle vaccinated**
Black quarter/Anthrax	225,000
Contagious Bovine Pleuropneumonia	75,000
Lumpy Skin Disease	167,500
Brucellosis	2,900
Foot- and-Mouth Disease	146.363
Total	**470,546**

Figure 29: Practical training session for community animal health care workers in Eastern Province

2.5.Poultry

Public Private Partnership was embraced in view of increasing the production of day old chicks to meet the farmers demand in the country. During the year, a total of approximately **550,000 Day Old Chicks** were produced and distributed to the farmers with the private

sector contributing approximately **40 % (=220,000 DOCs)** of all the annual national production . To support this initiative a small (mini) incubator/hatcher machine with the capacity of 4400 eggs was installed at the Rwanda Best Farm in Rulindo District. The farm was provided with a total of 3237 fertilized eggs (2049 eggs for layers and 1188 eggs from broilers) by RAB/ Rubirizi Hatchery and set for incubation.

2.6.Fisheries

Rwanda is endowed with enormous potential for fish production to become self-reliant and even with a capacity to export. Despite this potential, fish production has remained low, however efforts have been put to increase the production which has improved from 77 11 tons in 2006 to 21,740 ton in 2013.

The major objective during the year was to increase fish production, a lot more effort were put in activities that would lead to this output among those achieved were; restocking of 15 inland Lakes, which was done to revitalize the genetic material of the existing tilapia that had degenerated due to overfishing and inbreeding; 218 ha of fish ponds and dams were rehabilitated and stocked with 21,056,416 fingerings (Table 15). Lakes Bulera, Ruhondo, Muhazi and Kivu were installed with 678 8m3 stocked cages. Kigembe fish center was upgraded and rehabilitated to a modern tilapia fish hatchery and the road linking it to the main was also rehabilitated, Kigembe started producing tilapia nilotica fingerlings with sex reversal producing a total of 1,290,387 fingerlings of which 527,790 underwent sex reversal successfully. These activities led to an annual fisheries products production reaching 21,740 tones. In an effort to build a strong genetic material and prepare to give farmers better growing tilapia, a selective breeding program was started at Kigembe.

In support to the fish feed making machines which were given to cooperatives last year, 160 tones of floating fish feeds from Israel was procured and distributed to some cooperatives. In order to stimulate demand and demonstrate the importance of feeding fish using these feeds, and demonstrate to farmers that aquaculture would be profitable if practiced commercially. Results showed that after 7 months of using this feeds farmers harvested fish weighing 500g as opposed to getting fish weighing 100g in two years.

Table 24: Stocking of Lakes with Tilapia fingerings

Zone	Number of Fingerings
L. Ruhondo	240,533
L. Bulera	224,043
L. de Gisaka	660,299
L. Bugesera	561,658
Lakes in the Nasho Valley	322,434
L. Muhazi	169,568
L. Kivu	
- Rusizi	3,974,335
- Nyamasheke	5,954,975
- Karongi	2,205,428
- Rutsiro	2,655,327
- Rubavu	2,055,237
Akagera National Park	2,032,579
Total	**21,056,416**
Zone	**TOTAL**
Barrage de Kanyonyomba	**14,609**
Barrage de Cyabayaga	**56,840**
Barrage de Cyimpima	**701**
Barrage de Kiriba	**1,429**
Barrage de Kajevuba	**805**
Pisciculture en Etangs	**347,378**
Pisciculture en cages	**262,143**
	683,905

Table 25: Fish Harvest from Ponds

Zone	TOTAL
Barrage de Kanyonyomba	14,609
Barrage de Cyabayaga	56,840
Barrage de Cyimpima	701
Barrage de Kiriba	1,429
Barrage de Kajevuba	805
Pisciculture en Etangs	347,378
Pisciculture en cages	262,143
	683,905

Fish production in Kg for the year 2012-2013 from every fishing zone is summarized in the table below:

Zone	Q1	Q2	Q3	Q4	TOTAL
1.1. Bulera - Ruhondo Zone					
L. Ruhondo	53,616	54,521	61,085	71,311	240,533
L. Bulera	52,673	51,318	59,958	60,094	224,043
S/Total 1.1	**106,289**	**105,839**	**121,043**	**131,405**	**464,576**
1.2.Gisaka-Bugesera Zone					
L. de Gisaka	106,864	81,949	128,645	342,841	660,299
L. Bugesera	67,185	69,185	141,829	283,459	561,658
S/tot 1.2	**174,049**	**151,134**	**270,474**	**626,300**	**1,221,957**
1.3. Nasho – Akagera Zone					
Lakes in the Nasho Valley	109,256	93,280	32,653	87,245	322,434
Akagera National Park	459,351	464,430	503,921	604,877	2,032,579
S/tot 1.3	568,607	557,710	536,574	692,122	2,355,013
1.4. Zone Muhazi					
L. Muhazi	**42,076**	**32,258**	**32,406**	**62,828**	**169,568**
1.5. Zone Kivu					
- Rusizi	767,201	891,048	989,175	1,326,911	3,974,335
- Nyamasheke	978,014	1,468,228	1,519,530	1,989,203	5,954,975
- Karongi	548,704	373,952	495,889	786,883	2,205,428
- Rutsiro	527,515	699,044	582,846	845,922	2,655,327
- Rubavu	398,123	406,860	497,320	752,934	2,055,237
S/tot 1.5	**3,219,557**	**3,839,132**	4,084,760	5,701,853	16,845,302
Total	**4,110,578**	**4,686,073**	**5,045,257**	**7,214,508**	**21,056,416**

3. LAND AND CROP MANAGEMENT FOR IMPROVED PRODUCTIVITY

3.1. LAND USE CONSOLIDATION

The crop intensification program advocates for consolidation of land use by farmers. The consolidation of land use involves successfully rearranged land parcels to consolidate the use of farm holdings. Under the land consolidation policy, farmers in a given area need to grow specific food crops in a synchronized manner that will improve the productivity and environmental sustainability. Advantages of land consolidation include: reduced volume/cost ratio, logistics and transportation costs of inputs and outputs; increased accessibility of inputs, by providing a focused market for farm inputs; increased coverage of proximity extension services; equitable distribution of natural resources such as soil and water and increased land- and crop productivity.

Land consolidated countrywide during the year is 749,866 ha, that was under the following priority crops:
Maize: 238,545 ha; Beans: 345,201.2 ha; Cassava: 79,371 ha; Irish Potato: 63,868 ha; Wheat: 9,330 ha; Soybeans: 5,501 ha and Rice: 8,050 ha. The season implementations joint force showed that the land use consolidation increased from 26000 ha (2008) to 749,866.2 ha (2013).

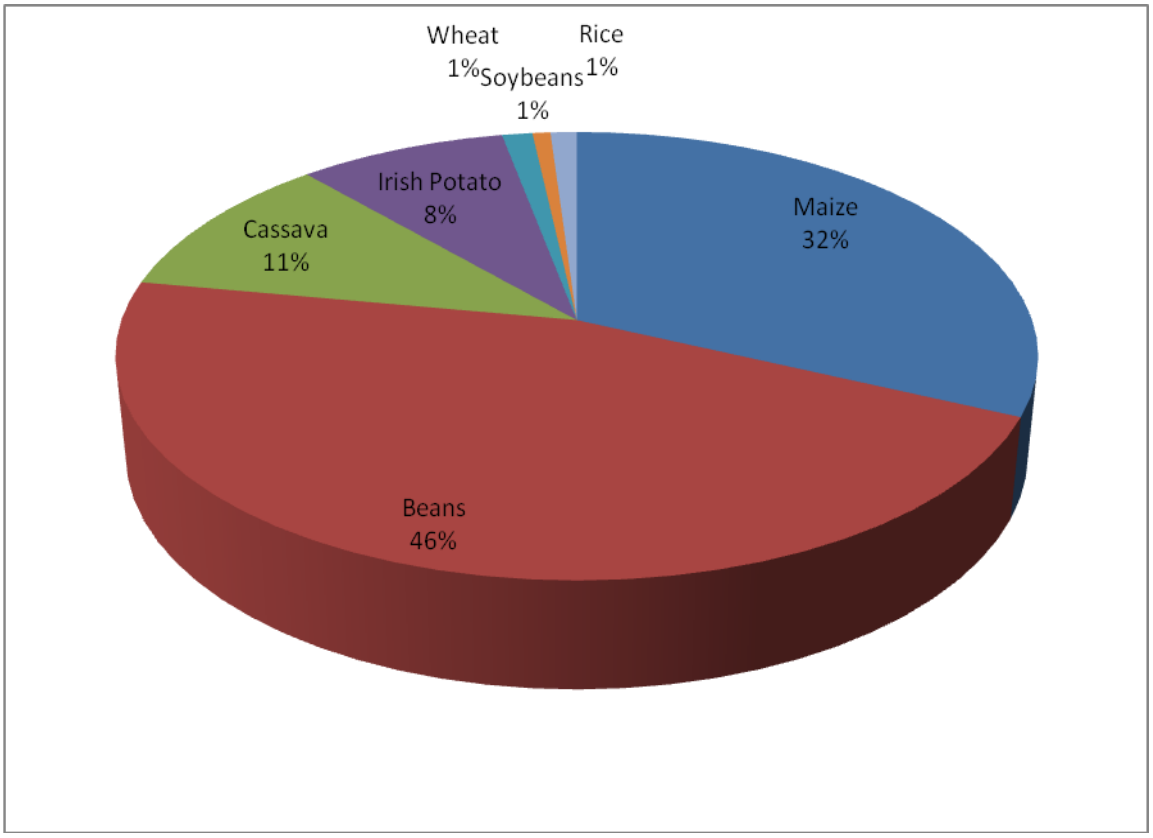


Figure 30: **Land use consolidation of priority crops**

This was achieved through the following activities - Farmers mobilization: meetings with local Government at Village, District and Province level; Identification and organization of consolidated sites; Awareness campaign and awareness through local media and radio spot.

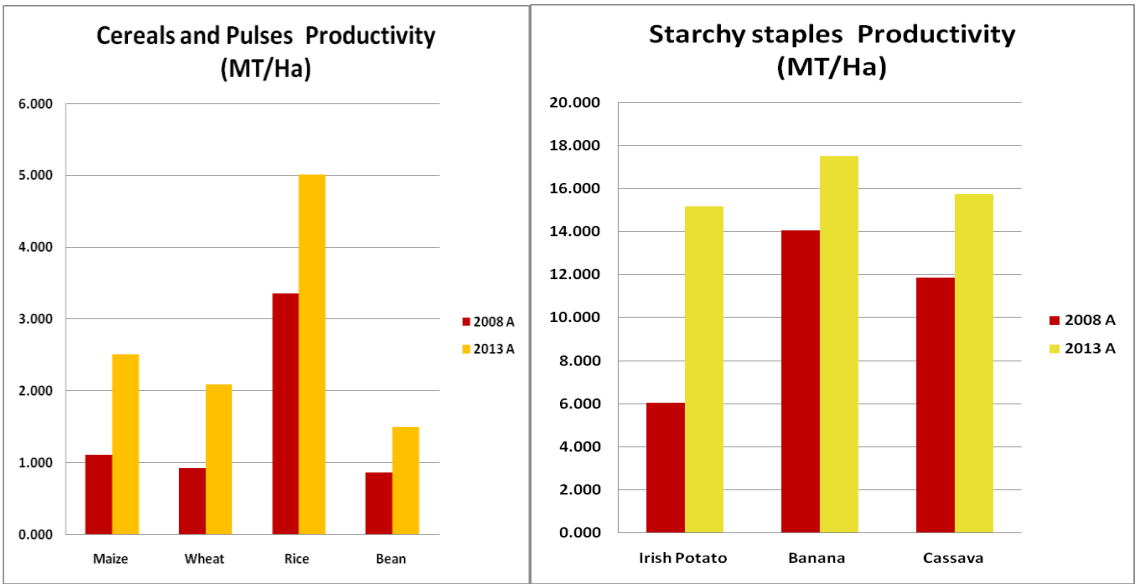


Figure 31: Land consolidation and crop productivity of CIP priority crops in the last five years

Increased land under cooking banana production

New banana planting material in form of tissue culture (macro-propagated plantlets) and conventional suckers derived from local and regional tissue culture laboratories, farmer-based macro-propagation units and informal seed multipliers throughout the country. This material was used to establish new banana fields on a total of 883.4 ha (Table 26).

Table 26: Newly established banana yields per province, FY 2012-2013

Province	Planted Area (Ha)	% achievement
Western	180.8	120.5
Eastern	433.5	173.4
Northern	123	123
Southern	146.14	146
TOTAL	**883.44 Ha**	**147**

3.2. Multiplication and distribution of seeds and Planting materials

Access to high quality and clean seeds and planting material is a key contributing element towards improved productivity.

In view of this the following activities were undertaken during the reporting period: Pre-basic and Basic seed multiplication: Production of commercial seed (certified and quality declared seed); Seed quality control and certification; Seed processing, Marketing and Sales. The achievements included the increased pre-basic seed production (Table 27) and seed production which were distributed to farmers across the country (Table 28). Other achievements were seed processing, marketing and Sales, where by a total of 290 seed multipliers were, trained in the seed production and multiplication techniques for Maize seed, Potato, cassava and Soybeans. Seed quality control and certification was also attained through field inspection 2012B and seed sampling. To improve availability of sweet potato planting materials tissue culture (TC), rapid multiplication techniques (RMT), positive and negative selection were used where by Cacearpedo, Ejumula, and gihingumukungu varieties were promoted.

Table 27: Increased pre-basic seed multiplication

Crop	**Annual target**	**Achievements certified seed produced (MT)**
Beans (Climbing & Bush beans)	1098MT	558.48
Maize	4,332MT	7,123.5
Irish potato	11,500MT	2,924.45
Soybeans	306.5MT	664.309
Wheat	1,244MT	587.750 644
Rice		193.5

Table 28: Quality seeds distribution

Crop	**Amount distributed (MT)**
Beans (Climbing & Bush beans)	1176.1
Maize	6,110.11
Irish potato	2,924.45
Soybeans	408.84
Wheat	1,540.74
Rice	435.8

3.2.1. Cassava

Dissemination of improved cassava varieties

Production and dissemination of improved cassava varieties was carried out throughout the year. A total of 2,620,000 cuttings with 3 CMD resistant varieties (Seruruseke, Garukunsubire and Mavoka) were produced in seven Districts: Karongi (370,000 cuttings), Gakenke (190,000 cuttings), Muhanga (1000, 000 cuttings), Huye (600,000 cuttings), Nyaruguru (120,000 cuttings), Gicumbi (40,000 cuttings) and Ngoma (300,000 cuttings). The total area planted with these varieties is 262 ha. These varieties are adapted for the low and mid altitude Cassava growing zones, the average yields for these varieties are between 30 – 45 t/ha and they have good quality cassava flour.

Figure 32: Multiplication site for Seruruseke variety.

3.2.2. Maintenance of avocado, mango and citrus mother gardens

The maintenance of the avocado, citrus and mango mother gardens was done in different RAB stations namely Rubona, Karama, Musenyi, Nyagatare, Mahama, Kinigi, Bugarama and Tamira stations in order to avail enough scions. The main activities conducted in those orchards are weeding, mulching and fertilization application. 444,830 scions of avocado, 42,000 scions of citrus and 45,150 scions of mango were produced during this period and disseminated to different beneficiaries including local NGOs, public institutions like NAEB, projects and individual persons.

a. Production of grafted seedlings of avocado and citrus

A total of 78,800 grafted avocado seedlings of preferred varieties of Hass, Fuerte and Ettinger were produced. In addition, 15,000 seedlings of citrus and 30,000 seedlings of mango were also produced during this period at Rubona, Karama and Kinigi stations. These planting materials were distributed to the farmers.

b. Production of pineapple plantlets

Through tissue culture technique, 6,000 plantlets were distributed for planting in farm's fields during this period. 18,000 plantlets were weaned in the greenhouse and will be transplanted in season 2014A. About 7,000 plantlets are still in the laboratory at rooting stage. 45,000 suckers from pineapple plantations were obtained and distributed to NGO's and other beneficiaries.

3.3. FERTILIZERS USE

Fertilizer use is important for increased crop productivity in the country. Fertilizer use has improved from 4Kg/ha in 2007 to 30kg/ha in 2012. However the rate of fertilizer use is still low and the following efforts were undertaken so as to stimulate fertilizer demand; awareness creation and sensitizing the farmers on the importance of fertilizer use; building capacity of proximity service providers farmer facilitators and promoters on fertilizer use; voucher printing to increase demand of fertilizer and execute fertilizer subsidy; enhancing the purchasing power of farmers by linking farmers and agro dealers to financing options through cooperatives, SACCOS, BK, and importers. Subsidies facilitated increased access to fertilizers which in turn improved the use of fertilizers; for example, between 800,000 - 1,000,000 smallholder farmers benefited from affordable fertilizers during the year, for maize and wheat crops. Rice, Irish Potato and vegetable farmers also benefited from affordable fertilizers through International Transport subsidy.

As a result a fertilizer distribution network system comprising a pool of 19 distributors and 1,062 agro dealers was established in the year, thereby improving the availability and access of fertilizers at the proximity of farmers. Agro dealers were trained in business and fertilizers management and certified. This improved fertilizer distribution to farmers especially in season 2013A (Table 29).

Table 29: Fertilizer distribution within districts in season 13A

DISTRICT	NPK 17.17.17 (kg)	DAP (kg)	UREA (kg)	TOTAL (kg)
GASABO	57,600	22,900	21,550	102,050
NYARUGENGE	15,500	12,000	6,000	33,500
KICUKIRO	26,000	30,280	17,580	73,860
RAB	81,880	34,918	23,934	140,732
NAEB	0	0	15,000	15,000
Sub-Total	180,980	100,098	84,064	365,142
KAMONYI	40,000	71,250	54,250	165,500
MUHANGA	35,000	58,500	39,500	133,000
RUHANGO	10,000	39,000	34,500	83,500
NYANZA	90,000	95,000	52,500	237,500
HUYE	170,000	45,000	20,000	235,000
GISAGARA	113,150	178,400	140,400	431,950
NYARUGURU	41,500	316,000	167,500	525,000
NYAMAGABE	58,500	367,650	202,475	628,625
Sub-Total	558,150	1,170,800	711,125	2,440,075
RUSIZI	615,360	1,122,950	790,000	2,528,310
NYAMASHEKE	145,000	520,000	310,000	975,000
KARONGI	110,000	300,000	125,000	535,000
RUTSIRO	300,000	250,000	135,000	685,000
RUBAVU	895,000	461,330	232,390	1,588,720
NYABIHU	1,285,750	300,150	145,075	1,730,975
NGORORERO	40,000	321,900	160,930	522,830
Sub-Total	3,391,110	3,276,330	1,898,395	8,565,835
MUSANZE	1,032,000	451,200	225,600	1,708,800
GAKENKE	20,000	554,600	276,450	851,050
BURERA	1,220,000	520,550	260,275	2,000,825
RULINDO	20,000	77,330	38,665	135,995
GICUMBI	100,000	250,750	125,375	476,125
Sub-Total	2,392,000	1,854,430	926,365	5,172,795
NYAGATARE	150,850	116,300	88,750	355,900
GATSIBO	134,900	156,100	139,225	430,225
KAYONZA	15,000	222,050	106,675	343,725
NGOMA	20,000	299,550	137,525	457,075
KIREHE	15,000	988,350	495,700	1,499,050
RWAMAGANA	106,614	297,200	197,450	601,264
BUGESERA	140,850	131,500	94,875	367,225
Sub-Total	583,214	2,211,050	1,260,200	4,054,464
Grand Total	**7,105,454**	**8,612,708**	**4,880,149**	**20,598,311**

3.4. CROP PROTECTION

The main objective of Crop Protection Program was to improve agricultural production through development and dissemination of pests and disease management technologies.
The program activities included collecting and regularly updating information on the disease and pests situation in country and developing programs for their management; providing information to farmers on the practices to control disease and pests outbreaks and follow up on management of pests in seed storage facilities.

The key activities carried out during the year include; Monitoring and control of weeds; pests and diseases of CIP crops and other crops; Constitution of a strategic stock of pesticides for pest and disease management; establishing phyto-sanitary early warning and surveillance system of pest and diseases and updated pest & disease list of crops; promoting and strengthening plant clinic approach; development of extension materials in area of crop protection; improving management of white grub pest;assessing post-harvest storage losses of some major crops and evaluate various storage methods for storage pests' management and capacity building of farmers promoters, IDP's and sector agronomists in crop pests and diseases management (Figure 33)

Different pests and diseases of major crops in CIP (maize, rice, wheat, beans, cassava, and soybean) and other crops managed at 92 %. Management of Pests such as Maize stalk borer, Black aphids, Caterpillars & white grub **(**Figure 34 procurement and distribution of different pesticides in affected areas whereby 1479 liters of insecticides, 1,200 kg for seed treatment, 1,095kg of fungicide were distributed. Establishment and updating *of* Pests and diseases lists for major crops (maize, wheat, soybean, rice, beans, banana, cassava, *I. potato*). Assessment of white grub on economic loss on different crops (wheat, beans, Irish potato, peas, maize, sweet potato, cassava, cabbage, was done in collaboration with ISAE Busogo & MINAGRI and 240 litres of bio-pesticides were distributed to farmers for white grub control.

Figure 33: Identification of the new maize disease

Figure 34: showing white grub Maize

Five new plant clinics were established and there are 13 operational plant clinics in the country. A total of 22 plant doctors were trained on plant clinic data management so as to run

and manage the plant clinics (Figure 35) Storage pest's assessment was carried out in different seed storage facilities and recommendations for the management of identified pests which included maize weevil, rice weevil, bean bruchid were given.
The district and sector agronomists from West, East and Northern Provinces and 6720 farmer promoters and IDP's were trained on pest and disease management for priority crops (Figure 36)

Figure 35: Farmers bring their sick plants in plant clinic

Figure 36: Farmer promoters training on disease and pests identification

4. NATURAL RESOURCES MANAGEMENT FOR SUSTAINABLE ENVIRONMENT

4.1. SOIL MANAGEMENT AND FERTILITY IMPROVEMENT

4.1.1. Increasing productivity in acidic soils

In acidic soils of Rwanda, a significant improvement of crop production requires a combination of limestone/travertine with farmyard manure and inorganic fertilizers. This has been demonstrated by several on-farm demonstration trials carried out in the Nile Congo ridge especially in Nyaruguru and Nyamagabe districts. Results from these trials **(Figures 37, 38, 39,40,41)** have shown that a combination of limestone, farmyard manure and inorganic fertilizers generate 2 -3 times the yield as well as the benefit as compared to that obtained from farmer practice treatment mainly composed of farmyard manure from home-garden and known to be of poor quality. The gross margin is also higher with the combination of limestone, farmyard manure and inorganic fertilizer compared to that due to a sole application of one of these inputs or a farmer practice treatment.

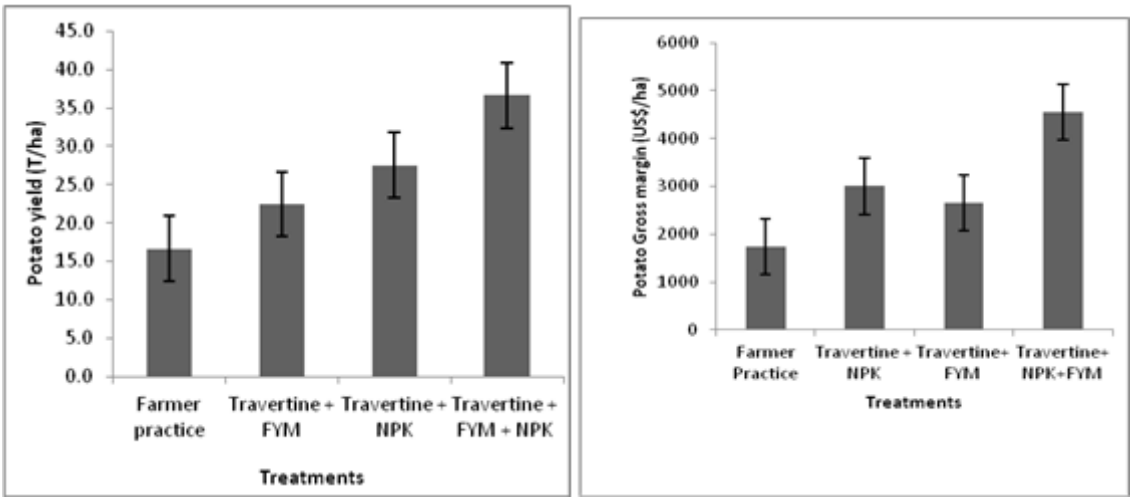


Figure 37: Effect of agricultural inputs on potato yield in Nyaruguru district **Figure 38: Potato cost benefit analysis**

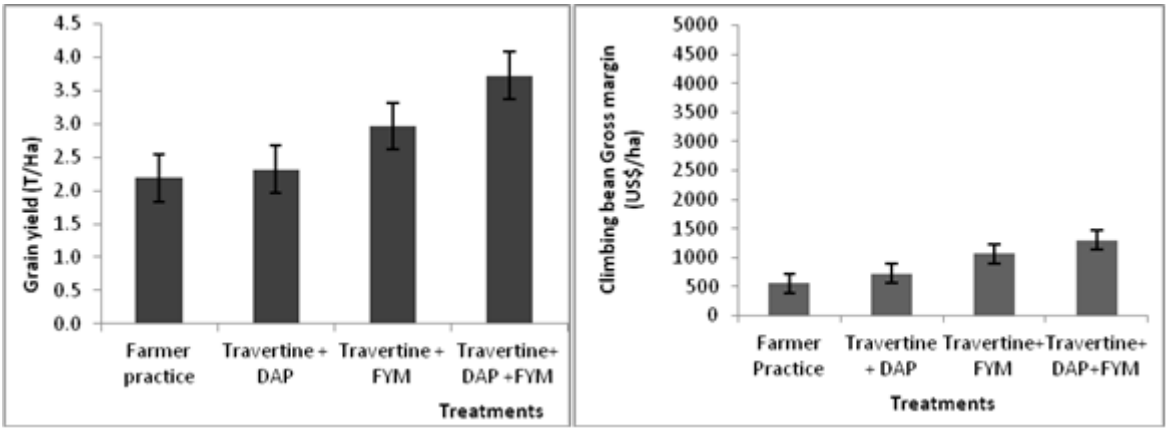


Figure 39: Effect of agricultural inputs on climbing bean yield in Nyaruguru district **Figure 40: Climbing bean cost benefit analysis**

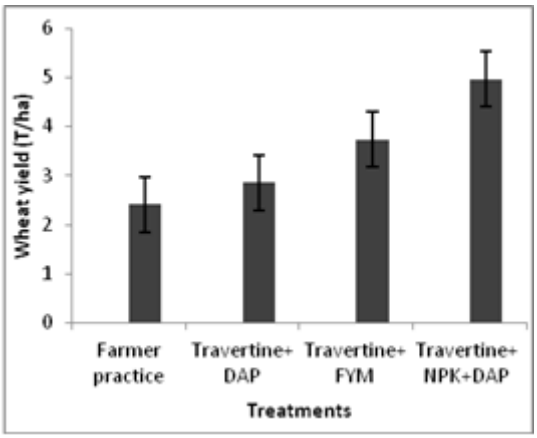


Figure 41: Effect of agricultural inputs on wheat yield in Nyaruguru district

4.1.2. Improving soil nutrients and crop productivity with the cover crop

A trial on improving soil nutrients and crop productivity with cover crop consisted of four species namely Lablab, *Vescia sativa*, *Mimosa scabrella*, and Mucuna. These species were planted in alley cropping with maize crop at the first season and potato at the following season. The trial was carried out in Mpanga cell, Kibeho sector, Nyaruguru District during seasons 2013A and 2013B. Preliminary results from this study indicate an effect of cover crops on increasing crop maize and potato yields as illustrated by the figures 42 and 43 below. The effect is the highest with Mucuna and *Vescia sativa*. However, the obtained yields are generally very low compared to the potential for each crop. This could be due to the fact that during the first season, these species were still under growth stage so that little nutrients were recycled. In the following season, yields were affected by short rains during this period across the entire region.

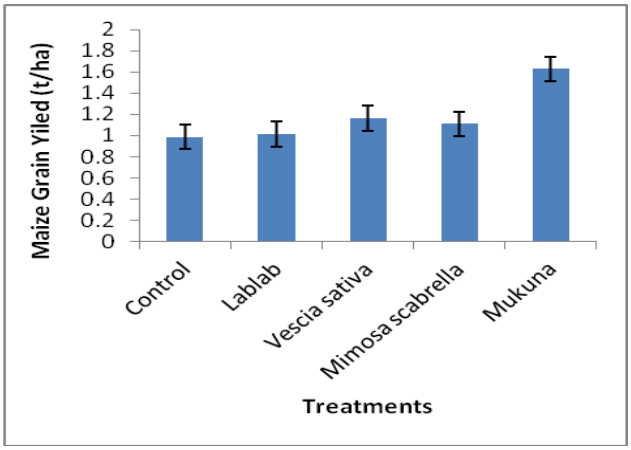


Figure 42: Effect of cover crops on Maize yield

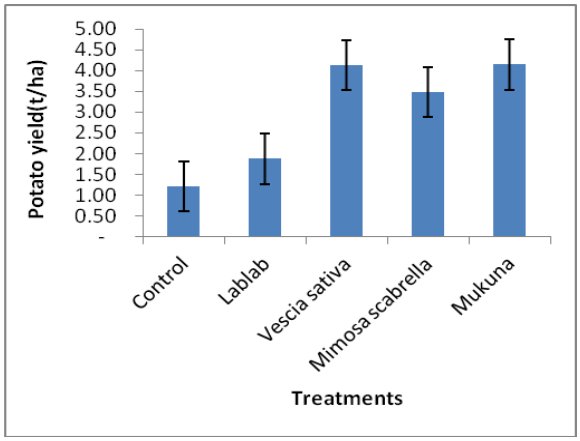


Figure 43: Effect of cover crops on Potato yield

4.1.3. Fertilizer recommendation and integrated soil fertility management (ISFM) components.

Integrated soil fertility management is a crucial condition to maintain the highly weathered and acidic soils in Rwanda. The existing blanket fertilizer recommendations also do not incorporate integrated soil fertility management (ISFM) practices such as inclusion of organic sources of nutrient for example farmyard manure, cereal-legume rotation/intercropping, use of improved seeds, timely planting and weeding. Thus these fertilizer recommendations do not respond to the sustainability of the environment. To address this challenge, various projects in soil conservation, trials were implemented; research was carried out and scientific recommendations were provided.

4.1.4. ISFM activities in the southern and Eastern province

Maize, climbing bean and soybean trials were implemented on farm level and on-research stations (Kamonyi, Nyanza and Huye district in Southern Province) and also E astern Province Bugesera, Ngoma and Kirehe districts in Eastern province. Each field was geo-referenced for better mapping and sampling. From each plot, a composite sample of four topsoil samples (0 - 20cm) was taken using a soil auger based on the Y-sampling frame used in the AfSIS sentinel sites before land preparation and planting. The priority crops were Climbing beans (MAC 44), Maize (ZM 607), Rice and Soybean (PeKa 6). Rice was cultivated in Mukunguri, and Cyili marshlands of Mayaga agro-ecological zone, Rwasave and Rusuli marshlands of Central Plateau zone.

Analysis of variance was conducted to determine the effects of different treatments in all sites, and all seasons in Southern, Western and Eastern Province of Rwanda using a mixed linear model (MIXED procedure, GenStat, 2003). The effects of the different treatments were compared by computing least square means and standard errors of difference of means (SED); significance of the differences was evaluated at $P = 0.05$.

Generally, climbing beans responded positively (Figure 44) and significantly to the applied fertilizer inputs ($P < 0.001$) in Eastern Province.

The grain yield was increased by (%) 37.1, 40.2, 25.7, 48.6, 52.7, 56.5, and 60.6, respectively by N, P, K, NP, NK, PK, and NPK. The t-test analysis revealed that all treatments significantly improved the yield compared to the control. Higher yields were recorded from NPK treatments, and were significantly higher than the yield from single N and K applications, but not significantly different from single P. It seems that yields were driven by P followed by N application.

Also the highest yield was recorded from NPK treatment at farm level trials in Eastern Province as the figure 45 shows and also again NPK treatment had highest yield compared to the other treatment in Southern Province, Table 30 shows.

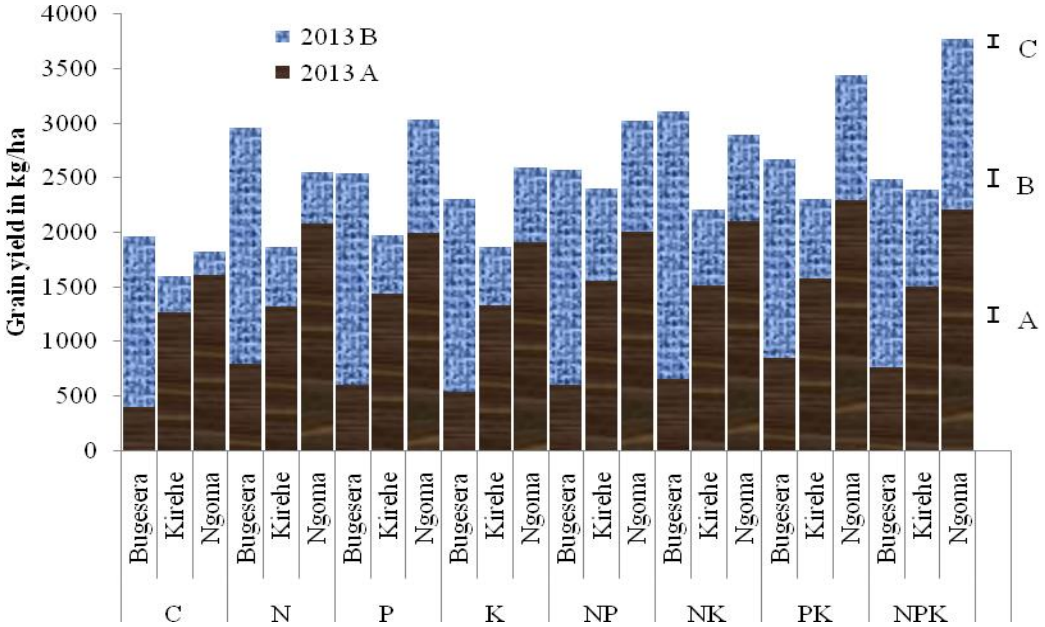


Figure 44: Grain yield of climbing bean in kg ha^{-1} in 2013 short and long rain seasons across the South-Eastern Rwanda. Presented yields are from researcher managed experiments. A, B, and C are SED bars: A for short rains, B for long rains, and C for yield general means in two seasons. On the axis bar, C represents the fertilizer control.

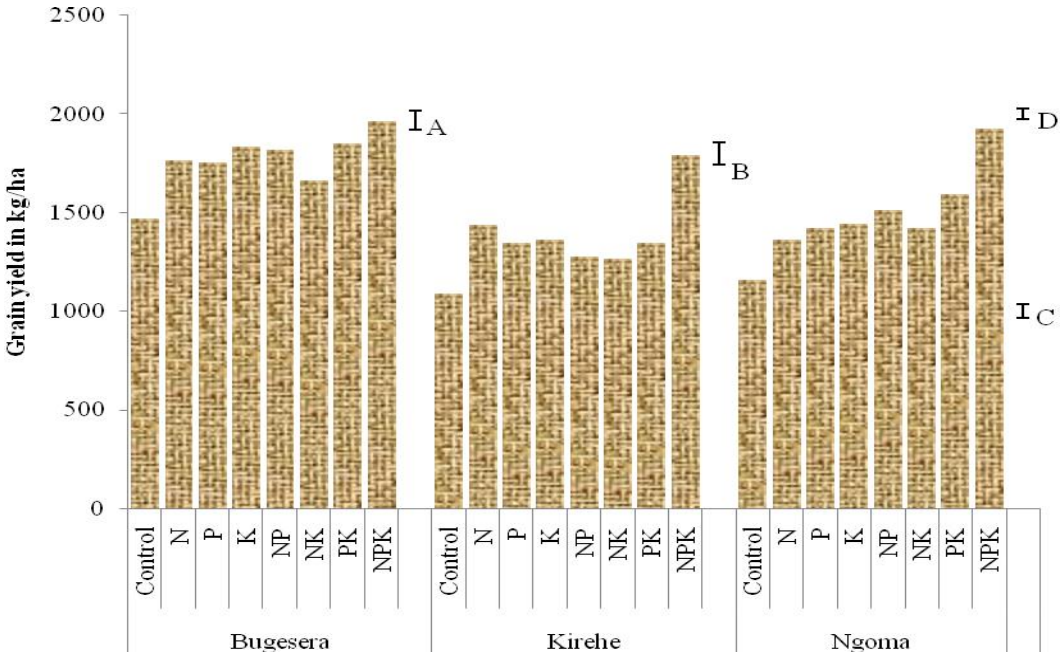


Figure 45: Yields of climbing bean in farmer managed experiments in the South-Eastern Rwanda during 2013 long rains. SED bars are A: in Bugesera, B: in Kirehe, C: in Ngoma, and D: for general means per treatments.

Table 30: Yield grain (t.ha-1) of climbing beans for omission trials of central plateau of Rwanda (Season 2012B)

Treatment	Treatment description	District sites (t.ha^{-1})			
		Huye	Kamonyi	Nyanza	Average
T1	Control	1.19	0.95	0.35	0.83
T2	N_{30}	1.27	2.29	0.39	1.31
T3	P_{30}	1.76	2.02	0.55	1.45
T4	K_{30}	1.97	1.74	0.29	1.33
T5	N_{30} P_{30}	2.13	1.94	0.30	1.46
T6	N_{30} K_{30}	2.46	2.01	0.28	1.59
T7	P_{30} K_{30}	1.75	2.42	0.36	1.51
T8	$N_{30}P_{30}$ K_{30}	2.86	2.85	0.43	2.05

Maize grain yields

For maize production in Bugesera District, the combination of N, P, and K made higher yields than other treatments. It was followed by N containing treatments, then by PK, and finally K. Such a scenario would mean that N was the most limiting element than P and K. However, their combination is better. In Ngoma District, combining N, P, and K gave higher yields, followed by P containing treatments. This would imply that P drove the yield than any other element, but combining it with N, and K brings about synergies towards high yields. In Kirehe District, the combination of N, P, and K is necessary to have good maize yields.

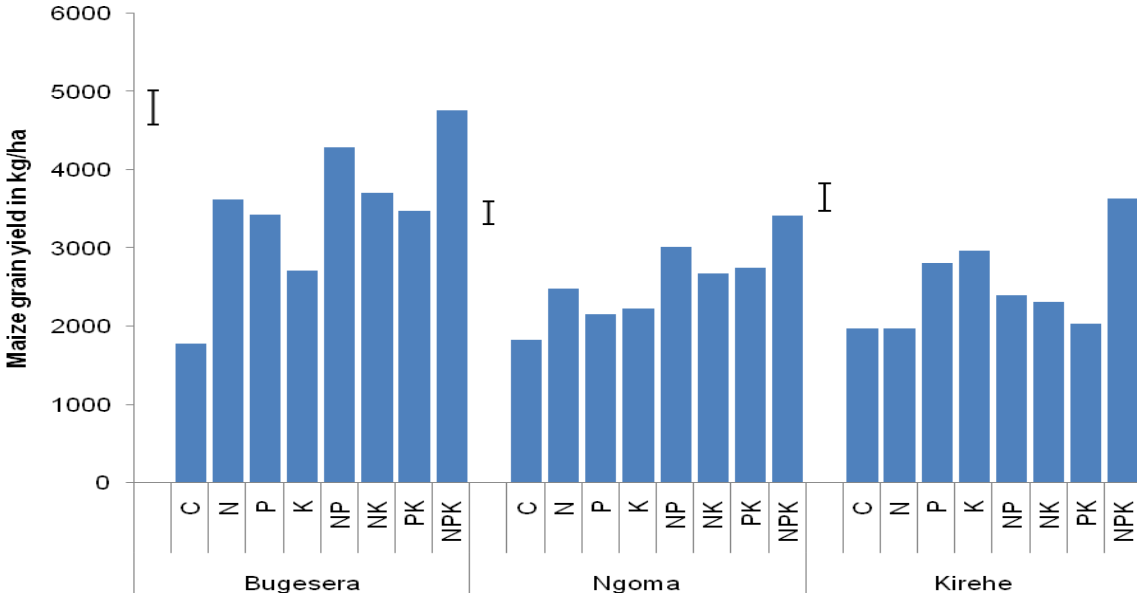


Figure 46: Maize grain yield (kg/ha) by fertilizer treatments in Bugesera, Ngoma, and Kirehe districts. Bars indicate SED (standard error of differences to the mean) bars at each district.

From the scientific reports, rice grain yield was the highest for the IFDC recommendation (100 Kg N- 30 Kg P- 30kg K/ha) with 3.75 t/ha, followed by 2.82t/ha of FAO with K

recommendation (57kgN + 30kgP + 30kgK/ha). Rusuli was showing higher grain yield compared to other sites in all treatments. For omission trials, the grain yield (t/ha) exhibited that the treatments with N, P, K nutrient combination have a highest yield. This showed that the soil major nutrient status of these marshlands is low and hence, their soils are likely to show the highest responses with N, P and K fertilization. P and K nutrients had a strong grain yield response to fertilizer application in Cyili and Rusuli respectively while N was strongly responsive to fertilizer application in Mukunguli and Rwasave. Therefore, the highest response nutrients on grain yield were the most limiting nutrients in a given marshland.

The grain yield was generally good in all sites compared to the previous season 2012B for climbing bean. The results showed that these fertilizer application rates NPK 100 Kg/ha, DAP 120 Kg/ha and urea 10 Kg/ha, and DAP 100 Kg/ha plus rhizobium were giving higher yield on average of all sites with 2.15, 2.28 and 2.34 t/ha respectively in the season 2013A. The highest best bet recommendation were (DAP 140 Kg/ha and 20 kg/ha urea), DAP 100 Kg/ha and DAP 120 Kg/ha and urea 10 Kg/ha with an average for all sites of 1.53, 1.42 and 1.36 t./ha respectively.

For omission trials in the season 2012A showed that NPK and P fertilizer application gave the highest grain yield in all district sites but nutrient response at Kamonyi site was not effective due to incapacity of soils to hold nutrients, and soils prone to erosion and low in organic matter.

For maize trials in Southern Province, IFDC recommendation with NPK 250 Kg/ha and 100 Kg/ha of urea gave the highest grain yield while omission trial of NPK and single P gave the highest yield in season 2012B; NPK combination and K revealed significant grain yield for season 2013A**.**

Adaptation of ISFM components in Cassava systems in Rwanda

Cassava system productivity under different spacing and row arrangement cropping system, fertilizer management, researcher-managed and farmer adaptive trials were carried out involving 295 farmers in ten locations in Rwanda between 2010 and 2012. The study was carried out in Kirehe, Rwamagana, Kayonza, Gatsibo and Bugesera district in the Eastern Province; Kamonyi, Muhanga, Ruhango, and Huye District in the Southern Province; and Rusizi from the Western Provinces of Rwanda.

Cassava yield

In researcher managed experiments, the application of NPK to cassava planted at 1m x 1m increased the yield by 17.9% (3.0 t/ha). In improved cassava + common bean intercrops, NPK increased cassava yields by 29.9% (5 t/ ha) (Figure 3). The integration of common bean in cassava production under the local practice of broadcasting beans increased cassava yields by 10.9% compared to 1m x 1m without NPK (1.8 t/ha). Rearranging cassava cuttings into 2m x 0.5m spacing and planting common bean in the inter-row space increased cassava yields by 55.7% (9.3 t /ha), while the application of NPK to this cropping system increased cassava yields by 85.6% (14.3 t/ha), compared to 1m x 1m cassava spacing.

In farmer managed experiments, cassava yield was significantly (P = 0.003) higher by 3.5% in cassava–soybean system than in cassava–common bean systems. The interaction legume species intercropping treatments was not significant (P > 0.05). In cassava–common bean, improved intercrops significantly (P < 0.001) improved cassava yields by 28%. The addition of NPK to the improved intercrops brought about a marginal yield of 30.6% (P < 0.001). In cassava–soybean systems, the improved intercrop significantly (P < 0.001) improved cassava yields by 17.5%. The NPK application significantly improved cassava yields by 30.0% (P < 0.001).

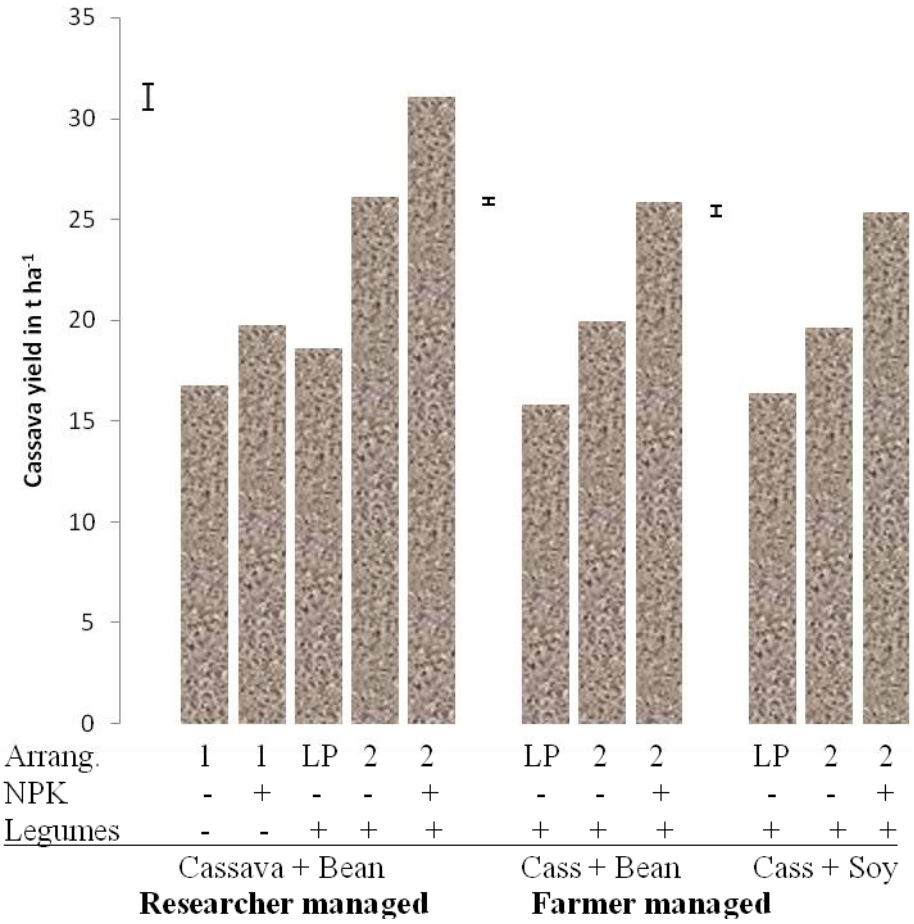


Figure 47: Cassava yield under intercrops and NPK application in Rwanda. Cass means cassava. Arrang. means cassava row arrangement under 1m x 1m or 2m x 0.5m. LP means local practice.

a. Intercropping grain legumes and maize

Both common bean and soybean tended to increase their yields in 1:2 intercrop than 1:1 and 2:2 intercrops. In 2:2 intercrops, yields of common bean and soybean were also higher compared to 1:1 intercrop. This is probably due to the relatively lower both aerial and underground competition exerted by the associated maize in 1:2 and 2:2 treatments. In 1:2, the light penetration is relatively higher as the treatment has single rows of maize 1m distant to one another. Root density is also lower in this treatment compared to others. On the other hand, common bean and soybean could have been completely shaded by maize in 1:1

association as the distance between maize rows was only 0.75m. The improvement in common bean and soybean yields from this 1:2 treatment evolved therefore from the reduced competition in the photo-synthetically active radiation – PAR – through light penetration (air) and reduced underground competition by maize roots compared to the 2:2 intercrop and 1:1 intercropping treatment.

b. Scaling up integrated soil fertility management for improved livelihoods project

At the end June 2013, the activities that have already been accomplished can be grouped in the following categories: (i) results of field demonstration plots; (ii) farmer field days; (iii) training of farmers and farmer's selection for the coming season 2014 at sentinel sites in Bugesera and Kamonyi districts. Maize, beans and legumes (Amaranthus) were selected in this project in order to improve knowledge of farmers about technology uptake, value addition and market access. The experiment was conducted in four sentinel sites: Runda and Kayenzi in Kamonyi district and Gashora and Mareba in Bugesera district.

e. Field demonstration plots

Bean and Maize

During these experiments, farmers were taught new technologies of ISFM up scaling. FYM was combined with mineral fertilizer at planting to improve synergy in nutrient utilization. NPK, urea, lime (travertine), rhizobium and Yala fertilizers were used as source of nutrients and amendments. Bush bean RWR2245 and climbing bean MACC44 were grown. Agronomic data was collected and data analysis was done to produce scientific reports.

Figure 48: Photos showing the amaranth in the fields of farmers

Gender responsive on ISFM technology

Women farmers were effectively involved in the ISFM demonstration trials in the four sentinel sites.

Table 31: Selected farmers for the maize and bean demonstration trials in season 2013A

No	Sentinel sites	Total number of Farmers	Female	Male
1	Kayenzi	42	9	33
2	Runda	42	8	34
3	Gashora	42	11	31
4	Mareba	42	15	27

Results of amaranth demonstration trials

Results generated from four amaranth varieties and the DAP application levels are summarized in the Table 32 and Table 33. Results showed that there was a significant difference between varieties for measured parameters and among varieties, the best variety was ML-AM 3 and TZSMN 60-40 in Kamonyi and Bugesera sites respectively (Runda). Fertilizer applications had a significant effect on amaranth growth for all varieties except the parameter of number of lateral branches ($P<0.05$).

Table 32: Growth parameters of the four varieties at Kamonyi

Sites	Varieties	Days to 50%flowering	Plant height at flowering	Nber of lateral branches	Height of lateral branches	Panicle length	Panicle width
Kamonyi	TZSMN 60-40	55.00 ^{d}	72.08 ^{d}	5.18 ^{b}	19.03 ^{a}	33.32 ^{c}	6.56 ^{b}
	UG-AM 40	55.25 ^{c}	84.31 ^{c}	5.54 ^{ba}	17.80 ^{a}	38.29 ^{a}	7.60 ^{a}
	ML-AM 3	62.25 ^{b}	93.65 ^{b}	5.88 ^{a}	14.06 ^{b}	35.51 ^{bc}	5.81 ^{c}
	Hypocondriathus	69.00 ^{a}	105.33 ^{a}	0.05 ^{c}	0.20 ^{c}	36.97 ^{ba}	6.45 ^{b}
Bugesera	TZSMN 60-40	55.00 ^{c}	52.25 ^{b}	5.43 ^{a}			
	UG-AM 40	55.50 ^{c}	50.94 ^{b}	4.00 ^{b}			
	ML-AM 3	61.75 ^{b}	67.71 ^{a}	3.50 ^{b}			
	Hypocondriathus	67.50 ^{a}	74.13 ^{a}	0.44 ^{c}			
P value		<.0001	<.0001	<.0001	<.0001	<.0001	<.0001

Table 33: Effect of the fertilizer on growth of amaranthus at Kamonyi

Location	Fertilizer (DAP)	Days to 50%flowering	Plant height at flowering	Nber of lateral branches	Height of lateral branches	Panicle length	Panicle width
Kamonyi	0 Kg/ha	60.43 ^{a}	79.05 ^{c}	4.05 ^{a}	11.10 ^{b}	32.72 ^{b}	5.90 ^{b}
	75Kg/ha	60.43 ^{a}	89.42 ^{b}	3.94 ^{a}	11.84 ^{b}	37.51 ^{a}	6.82 ^{a}
	150Kg/ha	60.25 ^{b}	98.04 ^{a}	4.49 ^{a}	15.39 ^{a}	37.83 ^{a}	7.11 ^{a}
Bugesera	0 Kg/ha	59.81 ^{a}	58.78 ^{a}	3.09 ^{a}			
	75Kg/ha	60.00 ^{a}	57.64 ^{a}	3.65 ^{a}			

	150Kg/ha	60.00 [a]	67.34 [a]	3.27 [a]			
P value		0.0014	<.0001	0.126	<.0001	<.0001	<.0001

f. Testing of in-situ harvesting with associations and different fertilizer (DAP and Urée)

Effect assessment of farmyard manure on soil fertility and moisture conservation along a transect of Murama watershed

The trial aimed at assessing the effect of applied manure with and without the compensating quantity of mineral source on the effectiveness in increasing the yield of bean by improving soil fertility and moisture conservation. The specific objectives were: to assess the effect of organic source mixed or not with mineral source on increasing soil fertility; to monitor soil moisture variation within the plots and along the transect to assess the impact of applied fertilizers on its status; to determine the effect of applied fertilizers on bean yield and water use efficiency; to determine the appropriate dose of fertilizers ensuring best use of soil moisture for good production.

The treatments were T1: farm practice (average qty of farmyard manure "FYM" applied in general by farmers); T2: Farm practice + rhizobium; T3: DAP + FYM (recommended doses say 100 kg DAP + 2.5T dry basis of FYM); T4:DAP + FYM + Rhizobium. The treatments were replicated 30 times i.e. 30 farmers and each farmer represented a whole experiment. 10 were taken at the top, 10 at the medium and other 10 at the bottom of the watershed. The evaluated factors were: (i) dose of organic manure, (ii) interaction with rhizobium (iii) effect of topography of the watershed transect.

Figure 49: Beans trials in Murama watershed

g. Productivity improvement with lime application and potatoes varieties

Preliminary results indicated that Cruza variety that is known to be more resistant to disease and environmental stress which was cultivated with lime, NPK and manure gave good yield (Figure 50) as compared to the non-treated Cruza variety.

Figure 50: treatment (Cruza variety) NPK+ Lime + Manure (Cruza Variety)

4.2. SOIL EROSION CONTROL

4.2.1. Soil erosion control baseline in Rwanda

After validating the new methodology which was developed for monitoring and evaluating soil conservation infrastructure, soil erosion control baseline for all 416 sectors was conducted. The key feature of this approach is the use of GIS, topographic maps and 0.25 m resolution orthophotos tools for recognition of sites and areas to be assessed. These land mapping tools were used to estimate soil erosion and the efficiency of soil erosion control infrastructure. This study aimed at generating baseline data on soil erosion control infrastructure in order to guide all interventions by providing annual district targets for soil erosion control and to recommend suitable infrastructure to be put in place.

The baseline consisted of desk work to explore, understand and process the orthophotos with 0.25 m spatial resolution coverage, DEM 30 m resolution from ASTER Images band, The Land sat ETM+7 Satellite Images for land use classification to get the agriculture land and validated by the available orthophotos. Data were downscaled by sectors and then aggregated at District level. The report of this baseline survey shows:
(i) an in-depth assessment of the major types soil erosion infrastructure types (progressive terraces/improved bench terraces mixed with agroforestry practices, bench/radical terraces); (ii) the coverage of those infrastructures in terms of the area (ha) and coverage (%) of existing infrastructures and compare them to the area that should be protected resulted from the desktop work as described above (iii) the rate of efficiency of existing infrastructures in controlling soil erosion and (iv) the District targets for the next 5 years (2013-2017).

Results from the survey showed the following results:

- The total cropped area for the whole country was 1,502,726 ha
- The total potential land area suitable to progressive terraces (calculated on the slope ranges of 3-25% and >55%) was 1,124,328 ha.
- The current area covered with progressive terraces was 808,868 ha and represented a weighted national average of 76.0%.
- The unprotected land area was 315,461ha and represented 28.0% of the potential suitable progressive terraces areas.

- The total potential land area suitable to bench terraces (calculated on the slope ranges of 25-55% and soil depths >1.5 m and other related soil characteristics) was 245,163 ha.
- The current progress for bench terraces establishment in Rwanda is 50,213 ha and represents a weighted national average of 21.1% of the potential suitable bench terraces areas.
- The unprotected land area suitable to bench terraces was 194,950 ha.
- The total coverage of soil conservation structures is estimated to 1,136,448 ha representing 75.7% of the national arable land. This total coverage includes progressive terraces, bench terraces and woodlots (Table 34).
- The overall efficiency of soil conservation structures was 53%. This low value was due to inadequate design and management of progressive terraces. The efficiency varied from one province to another, being high in the Northern (68%) and Southern (57%) Provinces.

Table 34: District coverage of progressive terraces

Province	District	Total district area (ha)	Arable area (ha)	Potential area suitable to progressive terraces (ha)	Current status of progressive terraces (ha)	Current coverage (%) based on potential area	Remaining unprotected area (ha)
Eastern	Kirehe	118,485	68,869	60,038	48,323	80.5	11,715
	Ngoma	86,774	43,304	36,410	22,356	61.4	14,054
	Rwamagana	68,196	38,776	33,740	21,510	63.8	12,230
	Kayonza	193,496	106,041	92,512	37,133	40.1	55,379
	Gatsibo	158,232	94,394	81,509	51,932	63.7	29,577
	Nyagatare	192,011	95,720	85,609	42,645	49.8	42,964
	Bugesera	129,056	88,235	80,279	62,912	78.4	17,367
Northern	Burera	64,456	47,545	29,442	28,090	95.4	1,352
	Gakenke	70,406	57,211	27,047	26,618	98.4	429
	Gicumbi	82,952	56,301	34,988	23,617	67.5	11,371
	Rulindo	56,698	47,747	28,467	28,135	98.8	332
	Musanze	53,038	37,332	29,203	27,380	93.8	1,823
Western	Karongi	99,303	59,558	33,296	27,780	83.4	5,516
	Rusizi	95,859	18,756	11,829	10,615	89.7	1,214
	Nyabihu	53,150	37,262	20,494	18,059	88.1	2,435
	Rubavu	38,834	28,396	21,921	11,623	53.0	10,299
	Ngororero	67,899	57,011	29,450	21,934	74.5	7,517
	Nyamasheke	117,399	33,404	19,939	14,604	73.2	5,335
	Rutsiro	115,729	46,756	27,942	9,199	32.9	18,743
Southern	Huye	58,153	34,069	27,099	20,648	76.2	6,451
	Gisagara	67,920	42,694	34,013	26,594	78.2	7,420
	Nyanza	67,214	55,241	49,701	37,606	75.7	12,096
	Ruhango	62,678	59,822	52,991	44,740	84.4	8,251
	Kamonyi	65,553	60,169	54,244	46,970	86.6	7,274
	Nyaruguru	101,027	25,627	15,751	12,938	82.1	2,813
	Nyamagabe	109,036	57,012	30,657	25,231	82.3	5,427
	Muhanga	64,771	53,930	33,155	23,514	70.9	9,641
Kigali city	Kicukiro	16,671	11,195	9,818	9,121	92.9	698
	Nyarugenge	13,395	10,309	8,407	6,738	80.2	1,669
	Gasabo	42,921	30,041	24,375	20,305	83.3	4,070
	Total/ Average	2,531,313	1,502,726	1,124,328	808,868	76.0	315,461

4.2.2. Protecting developed quick-wins marshlands against soil erosion

Due to the mountainous nature of most parts of the country and particularly near these marshlands, these areas tend to be vulnerable to soil erosion. To ensure long term sustainability of developed quick wins marshlands, Nature Resources Management developed strategies aimed at protecting them. Various beneficiaries were sensitized on putting up appropriate mechanisms of protecting developed quick wins marshlands. In Southern Agriculture Division Zone, a 2-month road map was agreed upon with Local Government for protection of Ruvugangoma catchment with farmers' participation.

In Western Agriculture Zone division, local authorities and farmers were sensitized on soil erosion occurrence. It was observed that the Kibati marshland had almost 100% of its above catchment protected through dense land cover on steep slopes along belt irrigation canals, contour ditches and bench terraces.

Figure 51: Catchment protection of Kibati developed marshland in Western province/Nyamasheke district/Gihombo sector

4.2.3. District coverage of bench terraces

Generally, the Northern Province has the best conservation rate (Table 35).

Table 35: Coverage of bench terraces

Province	District	Potential area suitable to bench terraces (ha)	Current area (ha) with bench terraces	Current coverage (%) for bench terraces	Remaining area (ha) for bench terraces		
					Total	Partially protected (a)	Totally unprotected
Eastern	Kirehe	5,187	255	4.9	4,932	3,890	1,042
	Ngoma	4,365	244	5.6	4,121	1,792	2,329
	Rwamagana	3,407	1,207	35.4	2,201	788	1,413
	Kayonza	7,759	952	12.3	6,807	951	5,856
	Gatsibo	7,894	1,492	18.9	6,402	1,606	4,796
	Nyagatare	4,333	100	2.3	4,233	446	3,787
	Bugesera	2,290	179	7.8	2,111	139	1,972
Northern	Burera	10,829	4,789	44.2	6,040	5,628	412
	Gakenke	19,838	2,580	13.0	17,257	13,818	3,439
	Gicumbi	13,427	7,910	58.9	5,517	12,411	-
	Rulindo	11,212	4,453	39.7	6,760	7,505	-
	Musanze	4,785	1,786	37.3	2,999	2,998	1
Western	Karongi	18,629	1,769	1,884	10.1	16,745	13,940
	Rusizi	4,901	728	749	15.3	4,152	2,342
	Nyabihu	11,134	1,567	1,729	15.5	9,405	7,691
	Rubavu	3,906	100	328	8.4	3,578	1,599
	Ngororero	18,709	1,500	1,793	9.6	16,917	8,441
	Nyamasheke	10,026	1,700	1,947	19.4	8,080	5,332
	Rutsiro	13,600	1,161	1,220	9.0	12,380	7,140
Southern	Huye	5,537	418	418	7.5	5,119	1,086
	Gisagara	6,701	204	339	5.1	6,362	335
	Nyanza	3,493	870	1,062	30.4	2,432	856
	Ruhango	4,390	478	478	10.9	3,912	331
	Kamonyi	2,778	471	553	19.9	2,225	721
	Nyaruguru	7,561	3,688	3,881	51.3	3,681	3,217
	Nyamagabe	18,911	4,239	4,299	22.7	14,612	7,134
	Muhanga	14,365	1,636	1,686	11.7	12,679	4,551
Kigali city	Kicukiro	843	189	189	22.4	654	354
	Nyarugenge	959	421	421	43.9	538	38
	Gasabo	3,391	1,293	1,293	38.1	2,098	1,478
Total/Average		245,163	46,246	50,213	21.1	194,950	118,559

(a) Refers to areas which are found in the class of bench terraces. They are partially protected with progressive terraces. In reality, these areas have to be protected by bench terraces as they appear in bench terraces class.

4.3. SMALL AND MEDIUM SCALE IRRIGATION

A total of 113.5 hectares of land is now under irrigation and the source of water is from 104 runoff ponds constructed in various districts. A total of 120 new water ponds were constructed in different districts hence exceeding the targeted 104 water ponds. Overall, 1,166 farmers were trained on rain water harvesting and irrigation techniques; in addition, 250 different stakeholders were sensitized on co-financing investments in small scale irrigation.

- **Developing water users organizations (WUOs) for irrigation management transfer on hillside and marshland**

Due to the scarcity of water both in quantity and quality, proper management of water resources enhances its equitable distribution. In collaboration with key stakeholders, 76 WUOs were established and sensitized in water use efficiency, maintenance of irrigation and drainage systems and prevention of illegal water withdrawals. A special training on basic by laws regarding the revised WUO statutes, internal WUOs regulations, administrative and financial management and operation and maintenance of irrigation facilities. Four marshland sites i.e. Nyabuyogera /Gisagara; Busogwe/Nyanza; Ruboroga /Kamonyi and Bahimba/Rulindo were supported. District Irrigation Steering Committees (DISC) were established in 13 Districts (Nyanza, Bugesera, Kirehe, Ngororero, Gakenke, Huye, Gisagara, Rulindo ,Ruhango, Kamonyi, Muhanga, Nyamagabe and Nyamasheke).

4.4. MECHANIZATION EXTENSION

The government of Rwanda seeks to transform farming into a productive, high value, market oriented sector by modernizing 50% of its agriculture by 2020, with the aim of improving livelihoods of the rural population and achieve food security. The major limitation on the already cultivated area is the heavy reliance on the hand hoe used by the human labor. During the reporting year, mechanization activities focused on promotion of utilization of farm machineries to support crop intensification programme (CIP) by raising awareness among different stakeholders, imparting knowledge on agricultural machinery as well as keeping an inventory of exiting agricultural machineries in the country.

Create awareness on farm machinery in pilot sites and support users

Sensitization sessions for farmer cooperatives (Figure 52) and meeting with district officials were held. Village Mechanization Service Centers (VMSC) to support plan for CIP were prepared and 13 VMSCs set up in different places across the Eastern Province, Northern province and Southern province hence availing machines to the users.

Figure 52: Cooperative members attending mobilization meetings in Eastern Province

a. Field demonstrations

The demonstration was carried out at Karama – RAB Station in the Bugesera District - Eastern Province and the following topics were covered:

i) Operating the new Mahindra Tractors

ii) Handling of Agricultural Machinery

iii) Hitching and adjustment of tractor attachments (Disc ploughs and Disc harrows)

iv) Trailer's tipping

v) Service and maintenance (on all tractor systems and on all implements Photo XX)

vi) Field operations (on ploughing and harrowing).

Other activities included demonstration on tractor fuel consumption in Nyagatare district and launching of farm machinery use in Musanze from 27th – 28th February 2013. Twenty four (24) operators were trained on fields operation, maintenance, and basic repairing of farm machinery especially agricultural tractors and power tillers.

Figure 53: Tractor primary and secondary tillage implements

b. Identification of existing farm machineries and implements

Different machineries were identified and included 132 public owned and 94 private owned tractors. The Power tillers identified include; 250 public and 16 private while Implements were 1,020 public and 180 private, 35 rice transplanters and 1,200 attachment tools (i.e. disc ploughs, mouldboard ploughs, rotovators, iron wheels, potato digger & seed drills) for tractors and power tillers, mainly dominated by TYM (Tong Yang Moolsan) tractor models, Massey Ferguson, Sonalika, Landini, Agria 9900, CAT, New Holland and MAHINDRA. The range of agric-machines power is varying from 12hp up to 120hp (Figure 54).

Discs plow **Rice transplanter** **Power tiller**

Figure 54: Tractors and their accessories

5. FORESTRY AND AGRO FORESTRY

During 2012-2013 fiscal year, under financial support by projects (AAP and LDCF) and government, attention focused on the promotion and scaling-up of integrated agroforestry activities in order to increase adoption by many farmers. The capacity of farmers to manage agroforestry technologies was also built through trainings in each intervention site.

5.1. Management practices in agroforestry technologies

Decentralized nurseries enabled to avail adapted agroforestry seedlings to farmers. A package of technologies for production of green manure, tree fodder for livestock, fruits, stakes for climbing crops (e.g. beans), fuel wood, and for erosion control were promoted in four watersheds and serve as agroforestry demonstration sites. These sites were monitored regularly and farming communities were provided with information on best planting and management practices of trees in agroforestry systems.

Few on-farm and on-station experimentations were carried out and consisted of (i) the evaluation of the potential of indigenous tree species to be managed in agroforestry systems, and (ii) assessment of effects of agroforestry biomass and inorganic fertilizer rates and methods of application on yields of crops for two consecutive seasons.

Research in Forests management has led to preliminary results on the suitable forest and agroforestry tree species more performing and adapted to different agro ecological conditions prior to their country wide dissemination. In this context, 9 species were selected to be tested in southern province. These tree species included *Bischoffia javanica, Vitex keniensis, Pterygota mildbraedii, Eucalyptus camaldulensis, E. tereticornis, E. urophylla, E. microcorys, Pinus caribaea* and *Syzygium guineense.* At the same time, PSPs were set up and monitored in two plots of *Bischofia javanica and Podocarpus falcatus* in Ruhande Arboretum in the Southern Zone and 28 PSPs were established for 11 species and preliminary data collected at Muyira Sector- Nyanza. Monthly phenological monitoring was done on 40 indigenous species under observation in Nyungwe NP, Gishwati, Makera and RAB Karama where data are available.

5.2. Establishment of tree seed stands

Tree Seed Centre (TSC) worked on its on-going activities and established new seed stands. Tree seed collection and distribution as well as maintenance of existing seed stands were undertaken. Additional activities comprised of establishment of new seed stands for quality tree seed production and seed testing although some of seed users did not respect the minimum time required for seed ordering. Of the targeted 10 tons, a half was delivered due to timely received orders and availability of seeds in the store. Although establishment of two ha tree seed stands was the target in the reporting year, nine ha were established.

5.3. Promotion of wood technologies

An improved method of charcoal production *viz.* Rectangular kiln with chimneys was introduced and further testing on its efficiency in charcoal production is in progress. Promotion of charcoal residues valorisation by making bee hive briquettes (BHB) was undertaken and further tests of three types of BHB are being conducted. About the determination of optimum age of harvest for use of Eucalyptus species, the program collected some old samples for one Eucalyptus species from Ruhande arboretum.

6. POSTHARVEST TECHNOLOGY

With the success of the Crop Intensification Program (CIP) that has resulted in increased crop yields, unanticipated surpluses in key staple grains and cereals have been realized. To better address the issues of post-harvest loss resulting from the lack of capacity in post-harvest handling and storage, the postharvest program aimed to maximize net profits for smallholder farmers and reduce food insecurity by reducing post-harvest losses.

6.1. BANANA

6.1.1. Establishment of refined protocols for banana juice production

The developed protocols were screened from different literatures and the first trial was conducted at Rubona research station. Two protocols were screened from a list of available protocols in literature. One was for juice extraction using zymex as the enzyme containing pectinase to extract the juice. The other protocol was on juice processing specifically juice clarification using the zymex followed by physical filtration to give clear and shelf stable juice. The enzymatic juice extraction has shown to increase the extraction yield. The refinement will be conducted after laboratory analyses.

6.1.2. Review of the national standards for commercialization of banana juice

Due to the absence of formal commercialization of well packed banana juice and lack of banana juice quality standards, the program started the process by collecting the required documents and conducted 2 meetings with stakeholders in banana value chain. A draft report on standards on banana juice quality has been drafted. An application to acquire the quality mark for banana juice was made to Rwanda Bureau of Standards.

6.1.3. Distribution of banana plantlets to the farmers

The distribution of 1,009 banana suckers of FHIA 25 to 54 farmers (13 females and 41 males) took place on 26th March 2013 in Mutendeli Sector, Ngoma district in the presence of farmers, coordinator of Mutendeli Sector, and RAB and COPROVIBA representatives.

6.1.4. Knowledge and information dissemination on banana processing technologies and products

An inception workshop was conducted on 3rd and 4th April 2013 in the District of Rwamagana, Eastern Province. During the inception workshop, different journalists were invited and the news about promotion of banana juice in Rwanda was broadcasted on Rwanda Television, Radio Rwanda and the online news journal of Newtimes and the website of Igihe Ltd.

6.2. CASSAVA

6.2.1. Evaluation of CMD resistant lines for processing: "Sensory evaluation of cassava thick porridge as affected by soybean flour fortification"

Cassava is an important staple crop for most of Rwandans. It is processed into flour and consumed as thick cassava flour porridge. However, cassava flour is known as nutritionally poor in terms of protein, vitamins and minerals as compared to other sources of energy such sweet potato (orange-fleshed), maize and wheat. A study has therefore been undertaken to improve its nutritional value through bio-fortification which is a complementary strategy to food fortification in order to address the problem of protein malnutrition in the Rwandan society. This was done through the supplementation of cassava flour with soy bean flour known to be a rich source of protein at different levels.

The current study showed that it is possible to produce thick porridges supplemented with soybean flour at 10, 20, 30 and 40% substitution levels. However, only cassava thick porridges containing 0, 30, 40% were selected and subjected to sensory evaluation to determine consumer perception. Samples were analysed by 65 judges on a 9 points hedonic scale with 9 "extremely like" and 1 "extremely dislike".

Figure 55: Cassava-soy composite thick porridges: 1) control; 2a) cassava: flour from non-dehulled soy bean (70:30, w/w), 2b) cassava: flour from dehulled soy bean (70:30, w/w), 2c) cassava: roasted flour from dehulled soy bean (70:30, w/w) and 3a) cassava: flour from non-dehulled soy bean (60:40, w/w), 3b) cassava: flour from dehulled soy bean (60:40, w/w), 3c) cassava: roasted flour from dehulled soy bean (60:40, w/w)

6.2.2. Sensory evaluation of cassava-soy composite thick porridges

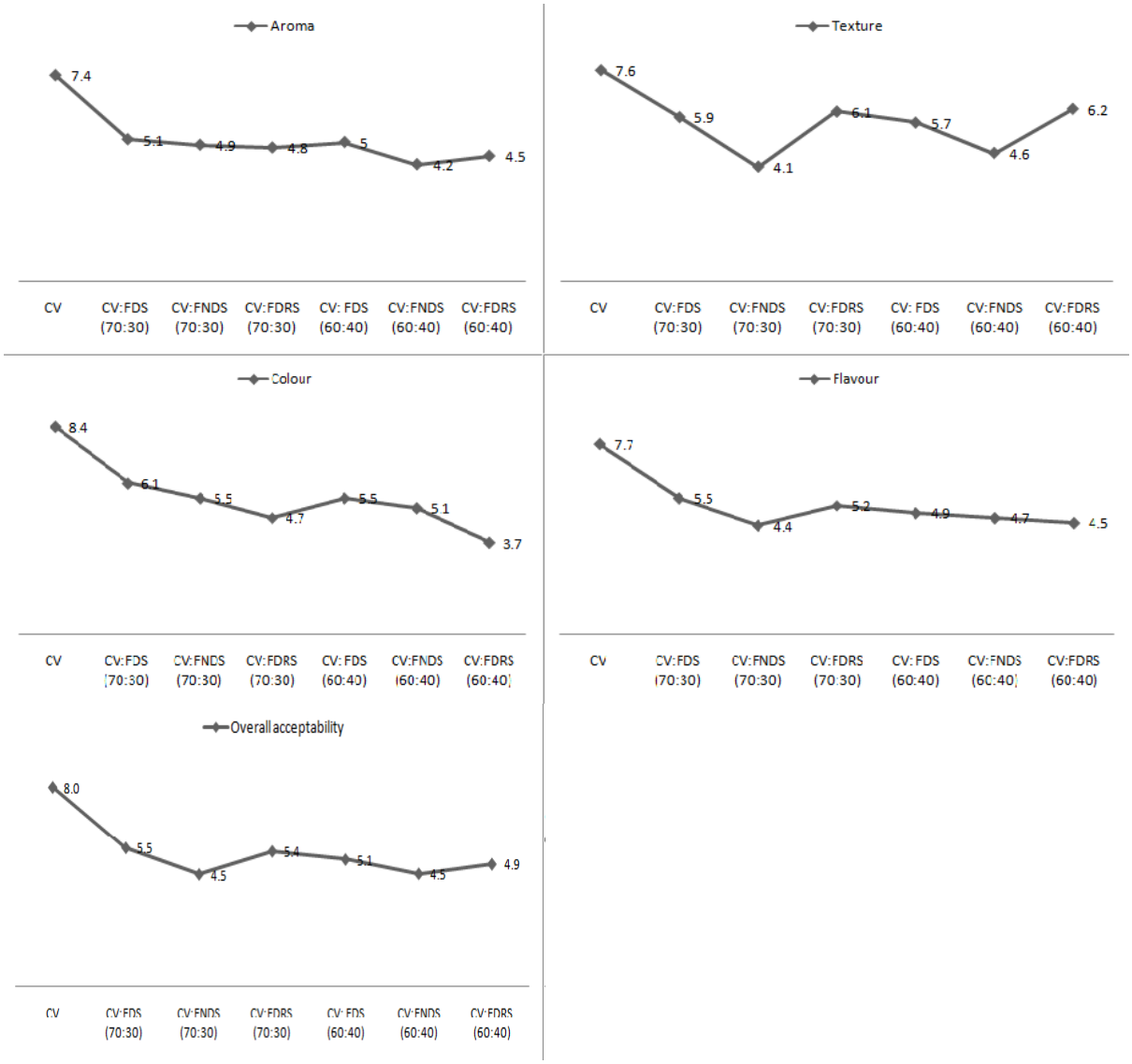


Figure 56: CV: cassava, FDS: flour from dehulled soybean, FNDS: flour from non-dehulled soy bean and FDRS: flour from dehulled and roasted soy bean flour.

Thick porridge produced from 100% cassava flour had a whitish colouration and was the most preferred in terms of colour. Unlike samples supplemented with roasted soybean flour, samples containing soybean flour had a creamy colour and this became more pronounced as the amount of soybean flour increased. Small black spots could be observed in samples containing soybean flour from non-dehulled beans. This was probably due to the presence of black eyes on the beans. Thick porridges containing roasted soybean flour had a brownish colour presumably due to the roasting process and were rated the lowest when compared to samples produced from non-roasted soybean flours.

Samples containing roasted soybean flour obtained the lowest score in terms of aroma as compared to thick porridge containing cassava flour alone. Although roasting is known to reduce the bean aroma in products containing legumes, it has not improved the aroma of thick

porridges. This was probably because consumers are not familiar with roast aroma in thick porridges.

Among thick porridges containing soybean flour, thick porridge containing 30% FDS was rated the highest in terms of flavour followed by thick porridge samples containing roasted soybean flour. A decreasing trend was observed when more soybean flour was supplemented to thick porridges. This was attributed to the beany flavour commonly associated with food products containing legumes.

Samples containing non-dehulled soybean flour (at 30 and 40% substitution levels) were significantly different from others as they were rated the lowest in terms of texture. This was probably because these samples contained high proportions of fiber since hulls of soybean is rich in fiber. In contrast, all samples produced from dehulled soybean including those containing roasted soybean flour were rated the highest at all levels of substitution.

Overall acceptability ratings showed that thick porridges containing cassava flour alone were the most acceptable, with thick porridges containing non-dehulled soybean flour being the least acceptable. However, thick porridges containing dehulled soybean flour and roasted soybean flour at 30% substitution levels were the most acceptable among samples containing soybean flour. It is believed that they would contribute to the improvement of the nutritional status of thick porridge consumers. However the nutritional value of the samples needs to be analysed.

6.2.3. An assessment of maize and bean storage systems and associated losses in Rwanda

Maize and beans were found to be affected by weevil *Sitophilus zeamais* Motsch and bruchids (mainly *Acanthoscelides obtectus* (Say) respectively. *Sitophilus spp* develop inside the grain kernel during their larval stage and feed on the grain during that stage. Maize grains were more affected than beans in all regions evaluated. This was confirmed by a high number of emergence windows in maize when compared to beans. Farmers indicated that the infestation of maize grains may start in the field especially when harvesting was delayed.

6.3.BEANS

The study was conducted and among the respondents, 84% were individual farmers and 16% were cooperative members; 68.4% of respondents had metal roofs while the rest had clay tile roofs. Most of the walls were unburned bricks or mud (71.1%), 18.4% were burned bricks, 7.9% were cement blocks while 2.6% were metal. Floors were either concrete (60.5%) or earth. 68.4% used storage platforms and the rest did not. Platforms were less than one metre in height; 68.4% of the storage conditions were rated by enumerators as fairly good to good; 7.9% were very good while the rest were poor condition. Most of respondents (84.9%) used woven polystyrene bags as containers. A few used baskets or paper barrels, or no container. The majority of farmers (29%) used sun-drying or sun-drying + commercial insecticide (39.5%) as pest control measures. Others used ash + other plant materials, commercial pesticides only (7.9%), sun drying + removal of infested grain + insecticide, sun drying +

commercial pesticide + plant material, sun drying + plant materials, sun drying + commercial pesticide + ash, and sun drying + commercial pesticide + lime.

6.4.MAIZE

Among the maize farmers, 75% of respondents were individual farmers while 25% belonged to cooperatives; 74.3% of respondents had metal roofs while the rest had clay tile roofs. Most of the walls were unburned bricks or mud (68.6%), 17.1% were burned bricks. Others included metal and cement blocks. Floors were concrete (57.1%), earth (40.0%) and brick (2.9%); 53.1% used storage platforms and the rest did not. Platforms were less than one metre in height. 68.4% of the storage conditions were rated by enumerators as very good (15.6%), good (25.0%), fairly good (34.4%) or poor. Most of respondents (69.6%) used woven polystyrene bags as containers or no container. A few used baskets, calabashes or paper barrels. The majority of farmers (62.9%) relied on sun-drying or commercial insecticide (20.0%) as pest control measures. Others used sun drying + removal of infested grain + insecticide (5.7%) while a few used ash + other plant materials, picking out infested grain, or sun drying + commercial pesticide + lime.

Evaluation of hermetic storage of beans

The experiment was set at Karama Station in December 2012 and results collected over a six month period showed that beans stored in PICS bags were not affected by insects. Their weight and moisture content remained stable; germination rate was 86%, level of infestation (number of eggs, pupae window) remained below 100 and the market price varied between 300-500 Frs. per kg. in comparison, the control beans that were stored in Polystyrene bags were affected by insects and their market value was reduced considerably (varied from 0-100 Frs. per kg) and germination rate below 10% and the number of eggs and pupae windows more than 1,500. The weight was reduced to almost a third of initial weight. They were ranked very poor quality beans due to the level of infestation. Unlike other parameters, the moisture content remained stable.

7. CROP PROTECTION

The main objective of Crop Protection Program was to improve agricultural production through development and dissemination of pests and disease management technologies. The key activities carried out included***;***

i) Monitoring and control of weeds, pests and diseases of CIP crops and other crops
ii) Constitution of a strategic stock of pesticides for pest and disease management
iii) Establishment phyto-sanitary early warning and surveillance system of pest and diseases and updated pest & disease list of crops
iv) Promotion and strengthen plant clinic approach
v) Development of extension materials in area of crop protection
vi) Improvement management of white grub pest
vii) Assessment post-harvest storage losses of some major crops and evaluate various storage methods for storage pests' management
viii) Capacity building of farmers promoters, IDP's and sector agronomists in crop pests and diseases management.

The main achievements in the period under review included:

i) Different pests and diseases of major crops in CIP (maize, rice, wheat, beans, cassava, and soybean) and other crops managed at 92 %. Pests like Maize stalk borer, Black aphids, Caterpillars & white grub managed)

ii) Different pesticides procured and distributed in affected areas; 1,479 L of insecticides, 1,200 Kg for seed treatment, 1,095Kg of fungicide distributed

iii) Pests and diseases lists established and updated for major crops (maize, wheat, soybean, rice, beans, banana, cassava, Irish Potato .

Five new plant clinics were established bringing the total to 13 clinics that are operational; 22 plant doctors were trained on plant clinic data management (Figure 57)

Figure 57: Training of plant doctors

Figure 58: Farmers bring their sick plants in plant clinic

Visits to different seed storage facilities were made for storage pest's assessment and recommendations for their management were given. Pests like maize weevil, rice weevil, bean bruchid were identified and methods for their control developed.

All districts and sector agronomists (West, East and Northern Provinces) and 6,720 farmer promoters & IDP's were trained on pest and disease management and the training was conducted on 8 priority crops (Maize, Cassava, Beans, Banana, Rice, Potato, Soybean & Wheat, (Figure 59).

Figure 59: Farmers in the field for disease & pests identification

Assessment of white grub on economic loss on different crops (wheat, beans, Irish potato, peas, maize, sweet potato, cassava, cabbage, was done in collaboration with ISAE Busogo & MINAGRI. About 240 litres of bio-pesticides have been distributed to farmers for white grub control.

7.1. WEED MANAGEMENT (STRIGA)

7.1.1. Sorghum

Evaluation for adaptability of *Striga* resistant varieties and drought tolerant sorghum lines in Striga infested region in Rwanda

These *Striga* resistant and drought tolerant sorghum lines were developed at Agricultural Research Corporation (ARC) Sudan and were obtained through ASARECA funded project. In total 40 lines were evaluated for adaptability in Mututu, Karama Rubona stations representative of *Striga* infested areas in Rwanda. The following figures presents *Striga* resistant and drought tolerant sorghum lines before flowering at Rubona site (Figure 60).

Figure 60: Field of *Striga* resistant and drought tolerant sorghum lines under evaluation at Rubona site

As results 40 *Striga* resistant and drought tolerant sorghum lines that showed good performance in terms of early maturity compared to the local ones in Karama, Mututu and Rubona sites and in terms of yield, 6 lines that exhibited good performance were selected.

8.STRATEGIC RESEARCH

8.1. Increasing crop productivity through dissemination of in vitro clean planting materials

Biotechnology program has already finalized protocols for mass production of some priority crops. During the reporting period, there was production of clean plantlets of banana, pineapple, potato and sweet potato through tissue culture (Figure 61). After weaning of the plantlets, they were disseminated to farmers, mainly organized in Innovation Platforms. These platforms were commodity-based and located in Nyamagabe (sweet potato platform), Muhanga (banana platform) and Gicumbi (potato platform). Low cost nurseries and demo plots in the respective platforms were created in order to bring plantlets closer to farmers. In order to increase the relevance of tissue culture to agricultural and forestry productivity,

additional priority crops and trees such as pyrethrum, Tamarillo, passion fruit and bamboo were included for protocol development.

Figure 61: **Production of tissue culture planting materials**

8.2. ENHANCING CROP PRODUCTIVITY THROUGH DEVELOPMENT OF EFFICIENT DISEASE DIAGNOSIS AND/OR CHARACTERIZATION PROTOCOLS

Utilization of clean planting materials alone cannot increase productivity; they also succumb to diseases in field. Protocols on disease diagnosis and pathogen characterization were developed and validated (Figure 62). The pathogen genetic and phenotypic diversity was studied using serological, biochemical and molecular methods; the results generated will be utilized in Integrated Pest Management (IPM) and deployment of resistance breeding initiatives

Figure 62: **Disease diagnostics and characterization**

9. AGRICULTURAL METEOROLOGY

9.1. STATISTICAL ANALYSIS OF HISTORICAL RAINFALL DATA OF RWANDA WITH IMPLICATIONS FOR CLIMATE CHANGE AND AGRICULTURE

The agrometeorology program started collecting climatic data for Rwanda starting with historical rainfall data and conducting analysis for possible implications of climate change on agriculture in Rwanda. Representative data from the entire country covering the different agro ecological zones was collected from 20 weather stations (Figure 63) as provided by the Rwanda Meteological Services. Although there is a long time-series extending between 1907 to 2012, a large amount of missing data was missing (Figure 64).

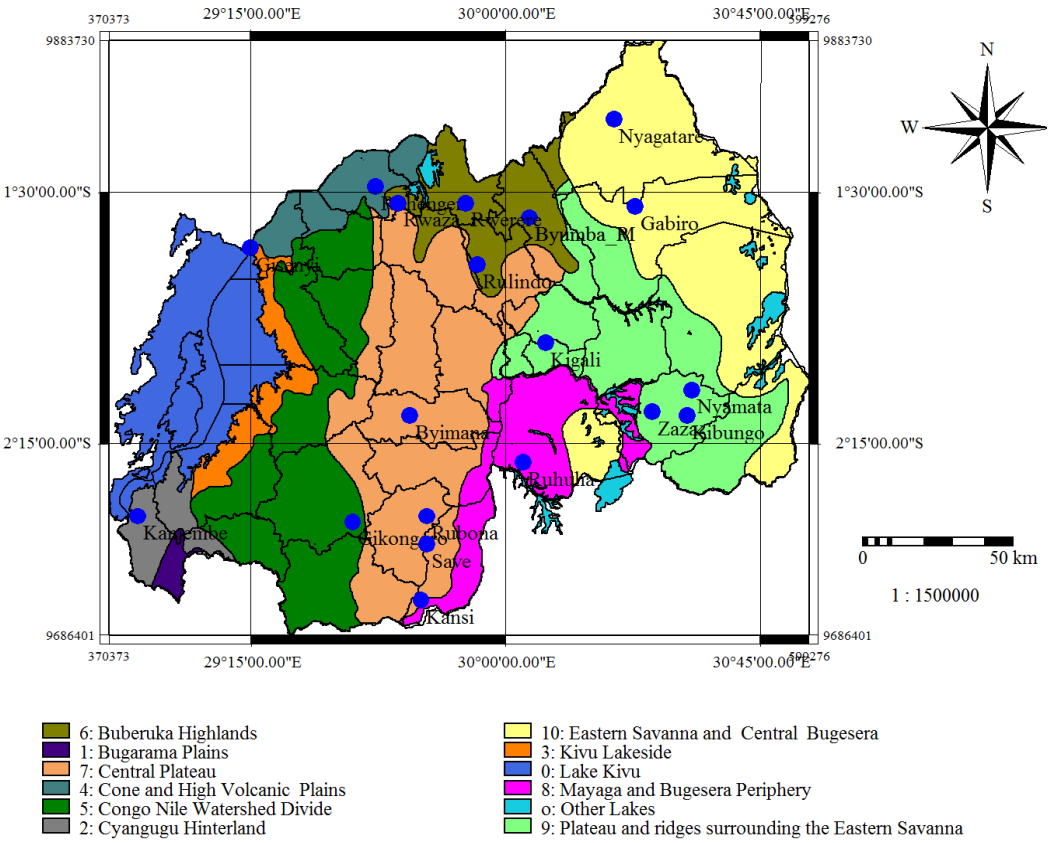


Figure 63: A map of Rwanda's agro-ecological zones and the location of main climatic stations;

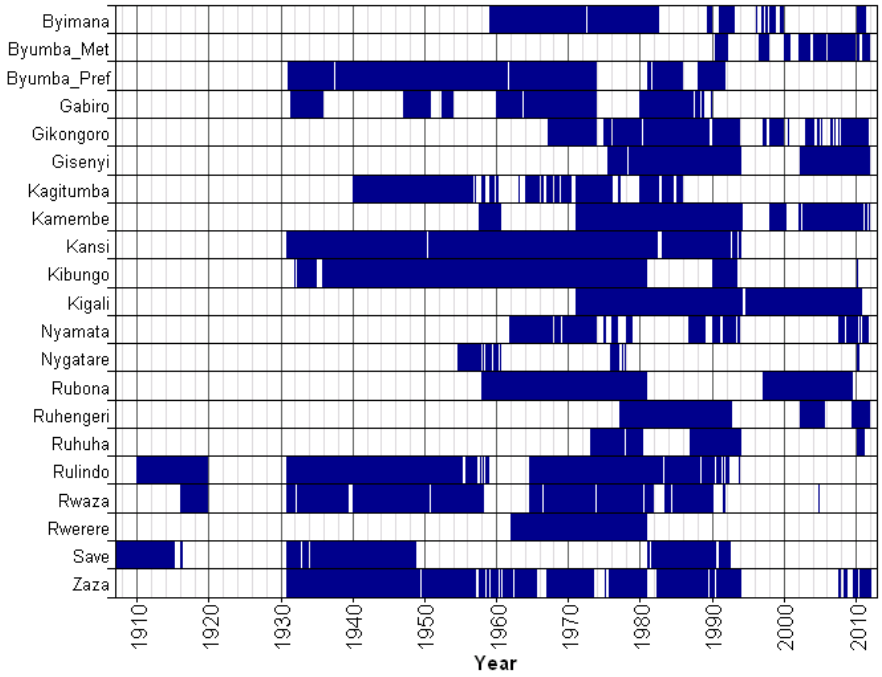


Figure 64: Data availability for the 20 Rwandan stations (available data is shown in blue).

There is a significant gap from 1994 due to the genocide.

Table 36: Climatic Characteristics of the Agroecological zones in Rwanda

Altitudinal Zones	Elevation range (m)	Agroecological Zones	Rainfall (mm)	ann. Tmean, (°C)
Highlands	> 1,900	Cone and High Volcanic Plains	1344	17
		Congo-Nile Watershed Divide	1663	17
		Buberuka Highlands	1272	16
Midlands	1,600-1,900	Cyangugu Hinterland	1766	19
		Kivu Lakeside	1183	20
		Central Plateau	1281	19
Lowlands	1,000-1,600	Mayaga and Bugesera Periphery	1184	21
		Plateau and ridges surrounding the Eastern Savanna	1068	20
		Eastern Savanna and Cenral Bugesera	1020	22
Lowlands	< 1,000	Bugarama Plains	1154	24

Table 37: Crop suitability in the Agroecological zones in Rwanda

Crop	Agroecological Zones									
	1	2	3	4	5	6	7	8	9	10
Banana	+	+	+	+		+	+	+	+	+
Cassava	+	+	+	+				+	+	+
Sweet potato	+	+	+	+		+	++	+	+	+
Potato				+	+	+				
Common bean	+	+	+	+		+	+	+	+	+
Sorghum	+	+	+	+		+	+	+	+	+
Maize	+	+	+	+	+	+	+	+	+	+
Rice	+						+	+	+	
Wheat					+	+				

9.2. DATA ANALYSIS

Analysis for existence of trends in the rainfall data at each station, the occurrence of events and the relationship between Rwandan rainfall and large scale weather forcing such as El Nino was conducted for data from each of 20 stations. Due to the large amount of data being analysed, it was not feasible to include all the results for all the stations in this report; however, only data from Kansi station has been presented and results extrapolated for the rest of the stations. R and Instat softwares were used to produce all the graphs. Significant amount of quality control on the data was performed and included studying the time-series alongside contemporaneous temperature records, checking station locations against satellite imagery, plotting seasonal box-plots to identify possible outliers (Figure 65), mapping the seasonal cycle and looking at summary statistics. Since the September-December rainy season is considered the first rainy season of the year, the first day of the season was shifted to start on 1st of July. The country has a bimodal rainfall distribution.

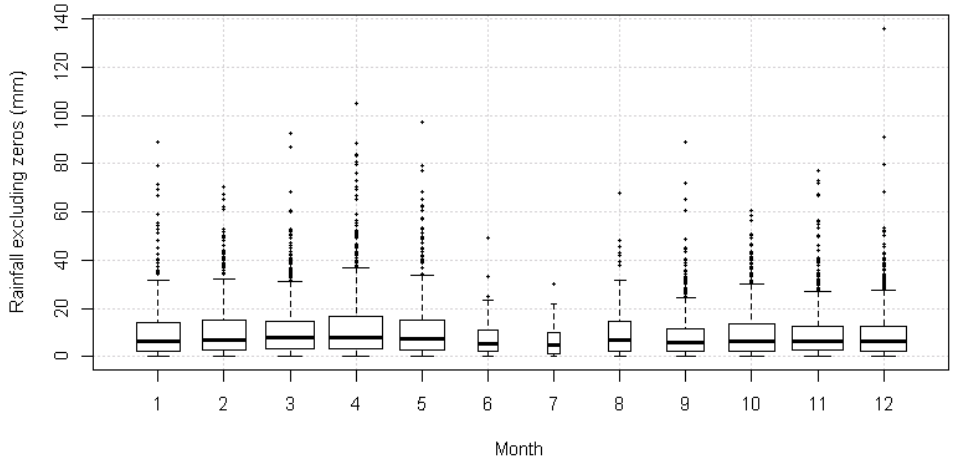


Figure 65: Rainfall boxplot for Kansi, excluding zero-rainfall.

This plot shows both the seasonal cycle of two rainy seasons and also allows the identification of outliers

9.3. RAINFALL TRENDS

Trends in rainfall statistics were then calculated to test if there was a change in Rwanda's climate. First, annual rainfall totals were considered, plus the number of rainy days with different thresholds to eliminate errors of recording small rainfall values. The plot is dominated by the rainfall total in 1963, an El Nino year shows a trend in increasing rainfall (p-value = 0.012) and a year was considered as missing if it has more than 10 missing values.

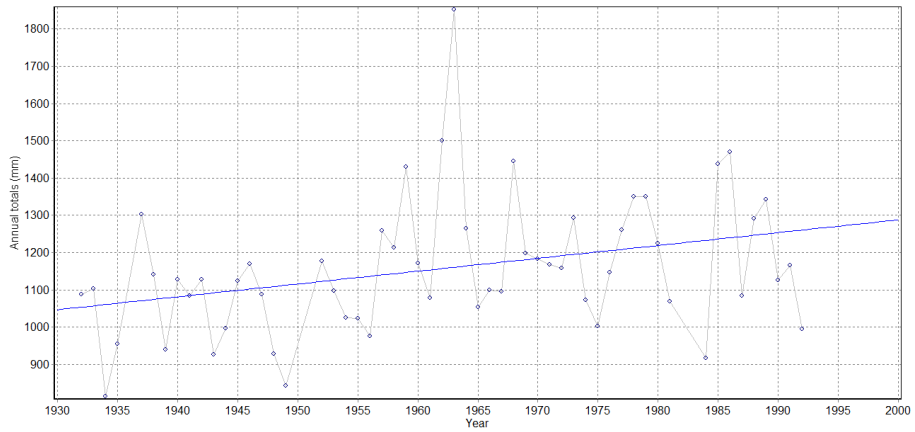


Figure 66: Annual rainfall totals at Kansi.

A significant positive slope was found of +3.6 mm per year (standard error of 1.32)

9.4. RAINY DAYS

The number of rainy days on the graph in figure 6 shows a non-linear trend after the year 1960. This does not affect the significance of the decreasing trend but could indicate long-scale fluctuations in climate.

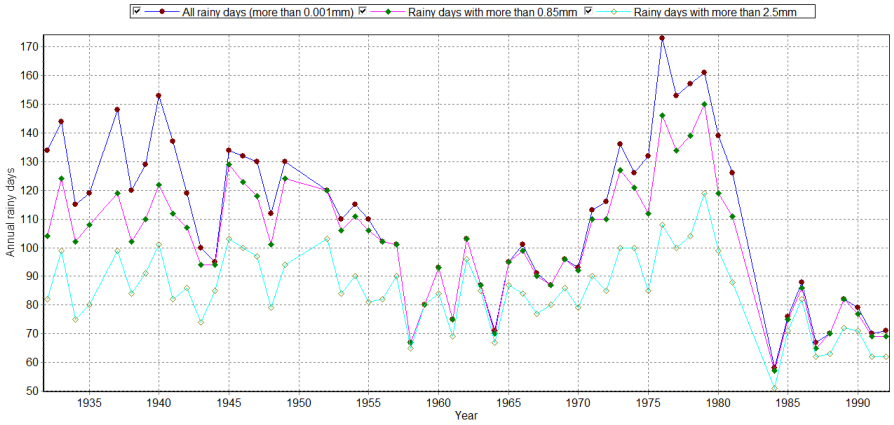


Figure 67: Annual number of rainy days with different thresholds (0.001, 0.85 and 2.5)

Monthly rainfall trends were investigated (Figure 68 to 70) whereby a threshold of 0.85mm was used to determine a rainy day. It was observed that there was much less obvious split in the rainfall record in the 1960s (with the exception of perhaps November), indicating that the entire rainfall regime changed rather than a shift in the rainfall cycle.

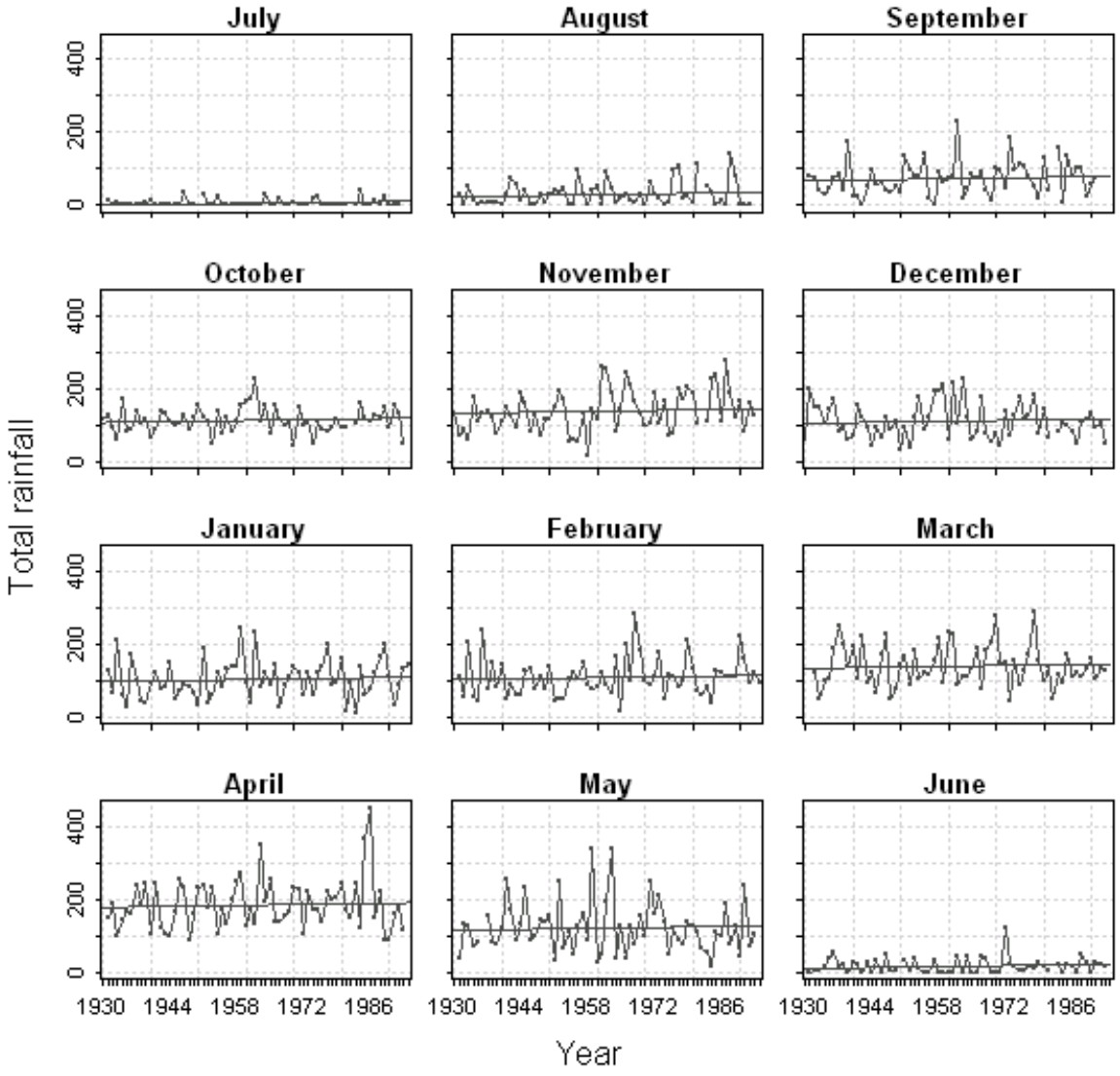
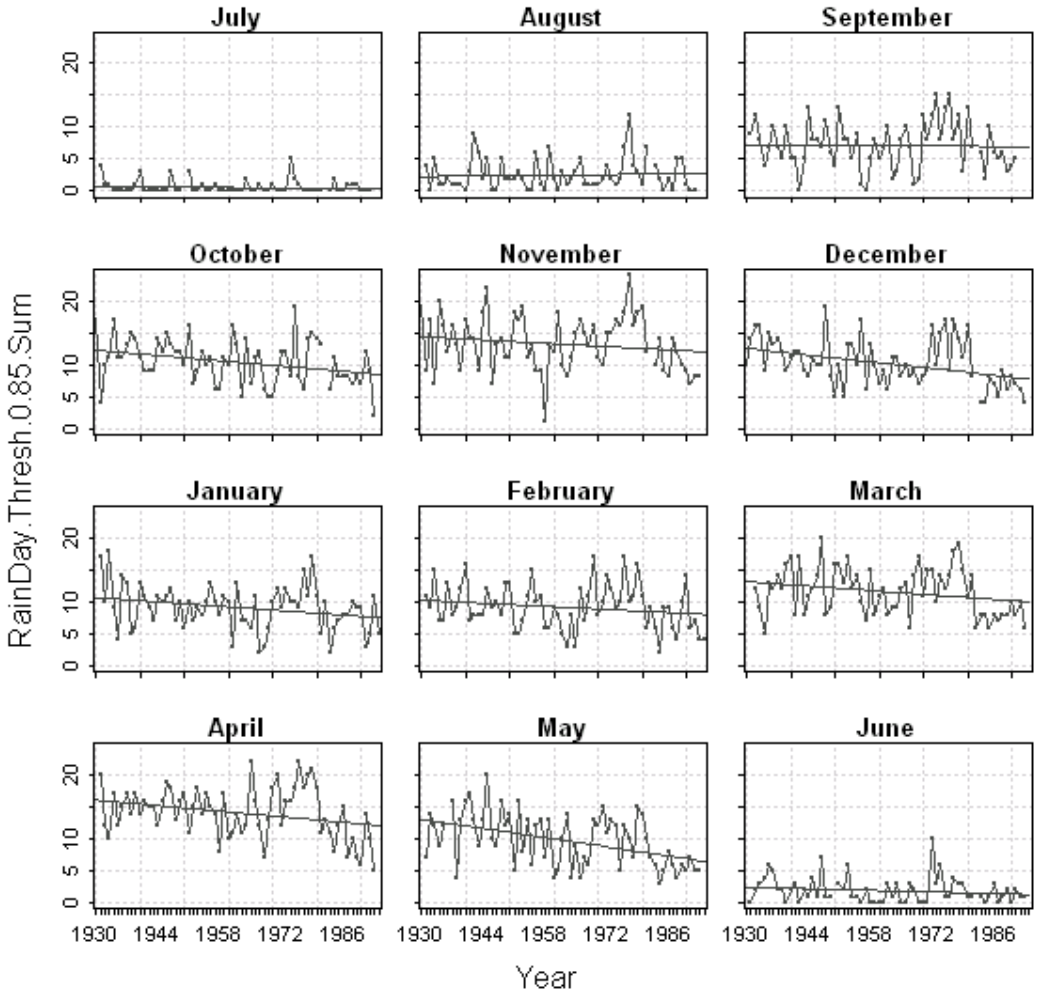


Figure 68: Monthly total rainfall for Kansi.

A positive linear fit (with intercept according to month) was modelled as the most significant fit (p-value < $2x10^{-16}$). The slope was modelled to be +0.19 mm per month (standard error, 0.1). When the error on the slopes was taken into account, it fit well with the annual modelled slope of 3.6 mm/year. *Any month with any missing value was excluded from the analysis.*

When the number of rainy days were analysed, (Figures 69 and 70) rainfall appeared to be more intense with less rainy days over time. However, care should be taken over this conclusion as the effect of the 1960s and the abrupt change in the 1980s had a large effect on the fit.


July
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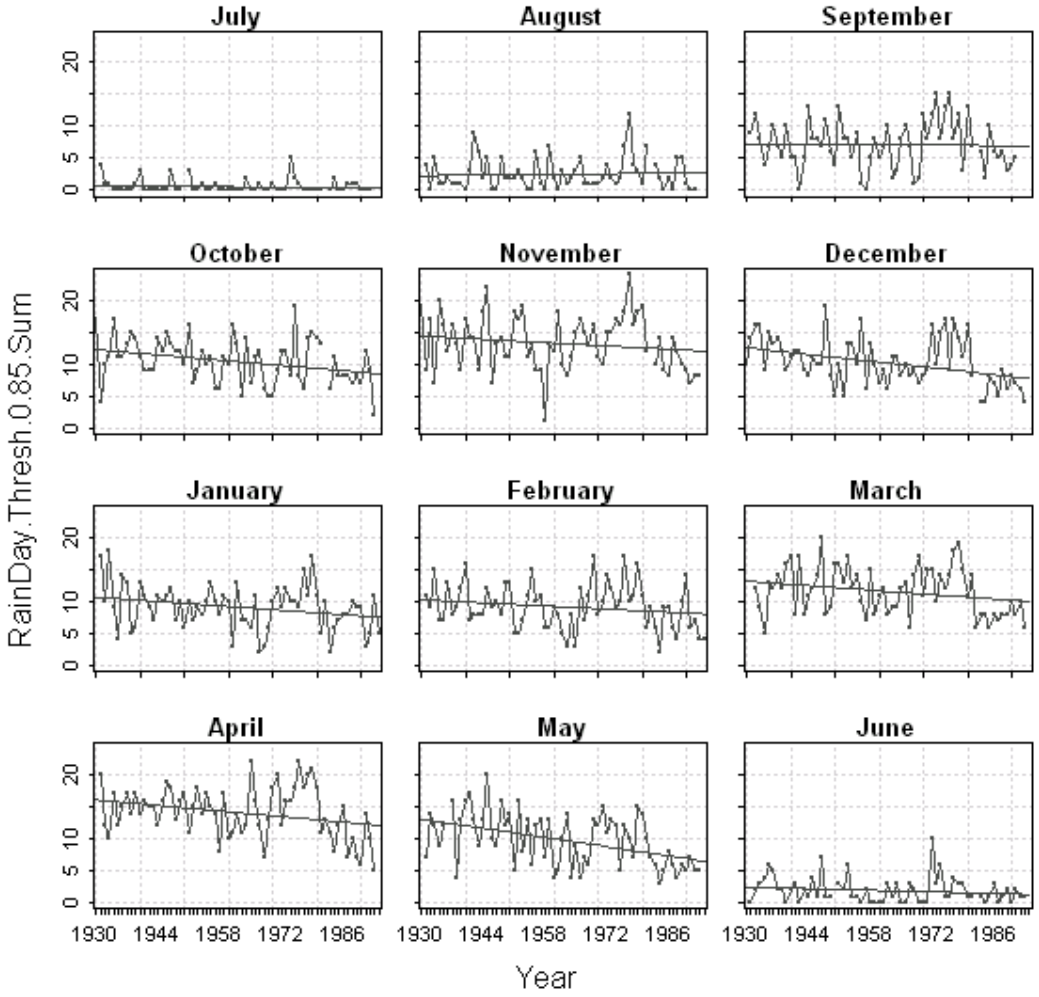


Figure 69: The sum of rainy days in each month.

Rainfall values of less than 0.85 were considered as 'dry days'. The most significant fit had a gradient varying by each month. Slopes were either zero or negative.

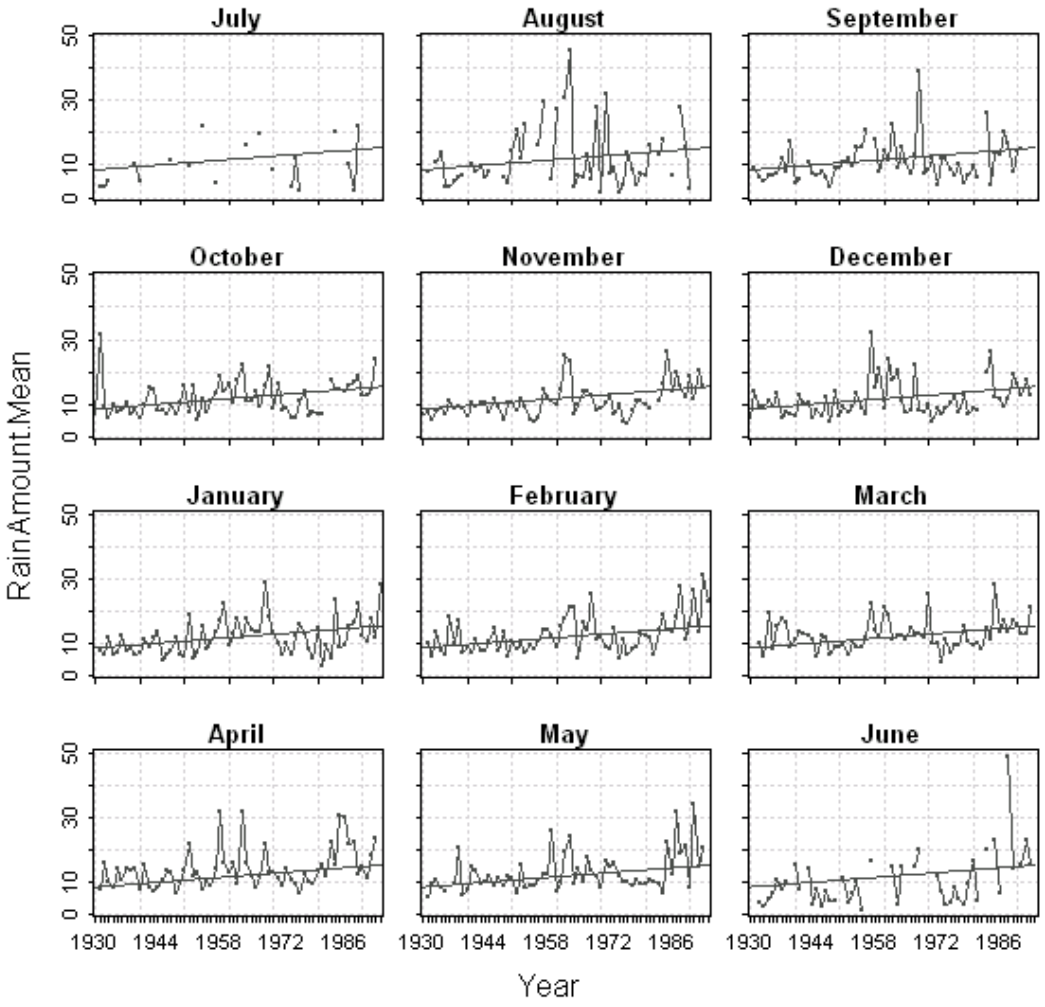


Figure 70: Monthly mean rainfall amount, if raining.

Rainfall values of less than 0.85 were considered as 'dry days'. A positive linear trend was found to be most significant with a slope of 0.11 mm/month (standard error = 0.01)

9.5. PLANTING DATES

An analysis of the onset of the rains against the risks of replanting due to dry spell after the on set, shows that season A which commences in September experienced many dry spell compared to season B which commences in February. It is also observed that farmers practicing early planting are susceptible to the risk of replanting due to a dry spell which is experienced nine days after the onset of the rains. (Table 38)

Table 38: Summarize the results for each season

Station	**Season1 (Min, Mean, Max Planting Date Interval and risk of replanting in brackets**		**Season 2 (Min, Mean, Max Planting Date Interval and risk of replanting in brackets)**		**Observed Planting dates**
	September	October	February	March	
Kansi	26th Sep - 2nd Oct (25%)	20th-24th (12%)	22nd – 27th (26%)	20th -24th (6%)	15 Oct/Mar
Kigali	27thSep-8th Oct (13%)	23rd – 30th (0%)	23rd Feb-2nd Mar (10%)	21st – 27th (3%)	15 Oct/Mar
Save	27th Sep-7th Oct (15%)	22nd-28th (3%)	20th-25th (11%)	18th-22nd (3%)	15 Oct/Mar
Kibungo	1stOct-13thOct (31%)	24th-30th (18%)	20th - 24th (20%)	20th - 24th (4%)	25 Oct/Mar
Gabiro	2ndOct-13thOct (12%)	21stOct-7thNov (9%)	28thFeb-11thMar (23%)	22nd – 30th (16%)	25 Oct/Mar
Byumba-Pref	22nd - 28th (14%)	20th – 24th (2%)	22nd – 27th (16%)	19th – 23rd (2%)	15 Oct/Mar
Rwerere	19thSep-1stOct (5%)	19thOct-1stNov (0%)	20th – 29th (5%)	18th – 24th (0%)	15 Oct/Mar
Kamembe	21st- 26th (8%)	18th – 22nd (0%)	19th – 24th (5%)	19th – 22nd (0%)	15 Oct/Mar
Gisenyi	23rd – 30th (10%)	19th – 25th (0%)	22nd Feb-2nd Ma (7%)	19th – 23rd (4%)	15 ct/Mar

10. PROXIMITY ADVISORY SERVICES FOR CROPS AND LIVESTOCK PRODUCTION

10.1. AGRICULTURAL EXTENSION

10.1.1 Improved farmer based pluralistic extension system.

The goal of the agricultural extension services is to improve farm production levels for crops enterprises and thus an increase in productivity, through enhancement of farmers' production skills and access to adequate inputs. The farmers are organized into farmer groups to serve as the entry point for extension services. Improved access to timely and relevant extension messages to the farmers through establishment of a critical mass of frontline extension agents which include the farmer promoters and the FFS Facilitators**.** Each village identified one farmer promoter through a participatory exercise in line with a criteria developed RAB. A total of 14,837 farmer promoters were trained to train other farmers

The extension services embraced pluralistic approach with many providers playing different roles. The private service providers were contracted to specifically build capacity and mentor the farmer promoters. promotion of an effective pluralistic extension approach whereby many players from both the private and public sector provide extension services was achieved through the following initiatives; Development and successful implementation of guidelines and standards for private extension services providers with clear performance indicators for efficient service provision in the districts; Strengthened private service providers, donors and RAB partnerships in form of tripartite MOUs between RAB, the districts and three Private service providers; Capacity building as well as monitoring and evaluation of the private service providers and providing them with feedback in consultative meetings for improved performance; Development of MOUs on partnerships with NGOs(TUBURA and IFDC) for support and collaboration in provision of extension services in the country.

Varieties of methods are used to disseminate information and messages on agricultural technologies to the farmer groups. On farm harmonized demonstrations, field days, and community radio, simple publications are some of the methods adopted. The following priority activities were carried out:

Season mobilization meetings

Mobilization meetings were conducted across all sites but the frequency of the meetings differed among the districts .While some districts held all the planned meetings, others barely held 50% of the planned meetings. A range of issues were discussed during these meetings with the key ones being the crops to be planted, the land preparation deadline, the sowing dates and the weeding deadlines.

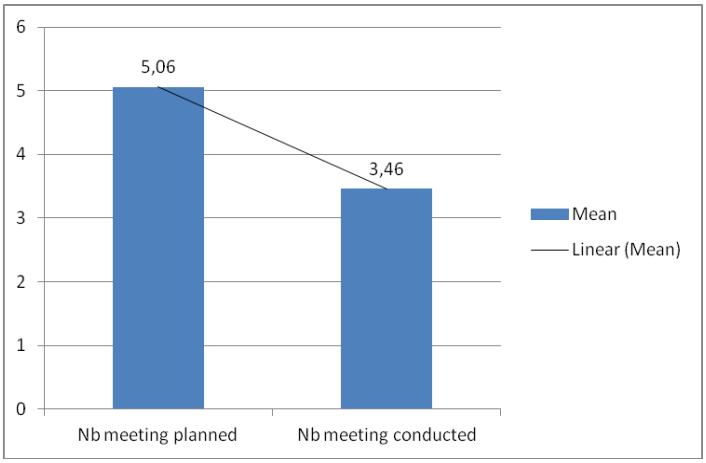


Figure 71: Number of meetings planned versus conducted

Organisation of farmers into farmer groups

In average, the number of farmers on consolidated sites varies between 263 and 370. While the average number of farmers on a site is 370 the average size of land is 65 ha per site. Thus, each farmer owns an average of 0.1756 ha which is very low hectarage per household . Farmers were therefore organised into farmer groups of maximum 10-20 farmers with neighbouring plots and mobilised to form at least one farmer cooperative for each consolidated site. The formation of farmer groups (amatsinda) was emphasised for effective organisation and management of the site activities. Farmers have been organised into farmers groups within 75% of the sites which lead to better access to inputs .The districts where farmers are organised into groups the seasonal activities are successfully implemented. This is due to the collective action of the group members in undertaking the production activities

Establishment of sites committees

The sites committees have been established in 85% of the sites. The commitees are operational but need capacity building in leadership and management skills. Within the large sites the number of farmers is also high and difficult to organise them for seasonal activities. The commitees therefore come in handy in managing the site activities.

The average number of committee members per site is 5 and each one is composed of President, Vice president, Secretary, Accountant and one Advisor. The performance of the site commitees varies within the districts. While the commitees are very active and strong in some districts, they are weak and disorganised in other districts. In districts where the site commitees are strong, the sites are able to meet their targets (e.g. Gakenke).

Field visits and Trainings conducted by farmer promoters Farmer promoters

Farmer promoters are in place within 97% of the villages. Farmer promoters were put in place since the beginning of season 2013A. Majority of them were elected by the farming community in line with the criteria provided by RAB. However a small percentage was appointed by the village chief and in some cases the existing public officers such as village chief, health facilitator, FFS facilitator, village social security , took up the role of farmers promoters. These public officers are however overwhelmed with many other social

responsibilities and can not play the farmer promoters role effectively. In 20% of the sites the farmer promoters are in charge of both agriculture and livestock production activities. On the large sites covering more than one village, many farmer promoters work on the same sites.This encourages competition among the farmer promoters with each one aiming to have their side of the site emerging the best.

The number of field visits to the sites by the farmer promoters are far much higher than those visits executed by the IDPs, Sector and District agronomists.This is attributed to the proximity of the farmer promoters to the sites compared to the IDP and the sector or district agronomist who are stationed far from the sites.

The farmer promoters trained the farmers on the following topics: planting on rows, fertiliser use and weeding , pests and diseases control, and others including sowing, soil erosion control and post-harvest practices. As a result farmers practiced good agronomic practices, such as planting in rows (69.1%), weeding (62.5%), pest and disease control (70%), soil and water management (55%). However not all of them practice these good agronomic practices. Other agronomic practices such as spacing between rows, crop rotation practices on maize and beans are also well adopted on sites however adoption on the neighbouring farms is very low.

10.1.2. Proximity extension provision through farmer field schools approach

FFS is a farmer-based extension approach which has been instrumental in provision of proximity extension services to farmers in the country. The approach adopted two methodologies of FFS (Farmer Field Schools) and CMC (Community Mobilization Campaigns). The focus was on building capacity of FFS facilitators to act as ToTs in provision of extension services through the following:Trials on performance evaluation of local and imported seed varieties of priority crops; Increase the Agriculture production through ToT and FFS organization; Banana rehabilitated in different sites;Training of Rwandan FFS Master Trainers; Initiation of the ToT on soybean; Initiation of the ToT on livestock; Increase the number of potato trainers.

Trials on Performance evaluation of local and imported varieties of maize was carried out whereby 100 facilitators and 2897 farmers drawn from 100 FFS groups from across the country were involved in the process of testing the available maize varieties and twelve varieties were tested .

The process of evaluating genetic resources in cassava was undertaken by 9623 farmers in various FFS groups. The genetic resources were mainly obtained from the local varieties maintained by farmers. These farmers were also trained in cassava production by 363 facilitators and co-facilitators.

In addition, the following activities were undertaken (Table 39)

i)Tamarillo: 3024 farmers and 117 trainers (facilitators and co-facilitators) continued the process of evaluating 3 varieties and production of tamarillo seeds by FFS groups. The tamarillo TcF session continued to run in Gicumbi.

ii)Maracuja: 1628 Farmers and 46 trainers in their various maracuja FFS groups have been provided with potato seeds in view of providing support for diversification of farm activities

iii)Striga: during this period of 3 months, farmers involved in FFS groups continued to control striga. A total number of 2342 farmers trained by 169 (facilitators and co-facilitators) participated in various FFS groups. No additional CMC activities for striga control were organized during that period.

iv) Rice: 109 FFS rice facilitators and 2,926 beneficiaries' farmers in rice continued to test 9 varieties (genetic resources) and the appropriate management practices were identified. The 2926 Farmers trained in rice production have started to expand the learnt innovations after having realized the benefit of the practices learnt in the various FFS groups

v) Potato: 19640 farmers in total are now reached through potato FFS groups.17 varieties were identified and maintained through FFS. The CMC in potato were organized around the operation of potato seed positive selection. This process concerns a set of 9 potato varieties.

vi) Banana rehabilitation and BXW control: At the end of this quarter, 4827 ha were rehabilitated and hectares of land with BXW control through CMC-FFS practices are 2015 ha. About 20,000 farmers participating in banana rehabilitation and 87125 farmers in total were involved in banana rehabilitation and BXW control through CMC and an increase of 23,529 farmers benefited from CMC activities.

vii) Training of Rwandan FFS Master Trainers: The process of Master Trainers training was done in a way respecting the requirement of season long training and regular follow up of the crop evolution by performing AESA whereby 45 staff members were trained.

viii) Initiation of the ToT on soyabean: 78 candidate facilitators selected from the four RAB zones started the training through a participatory process of identification and selection conducted within the soyabean production communities in preparation of FFS groups formation.

ix) Initiation of the ToT on livestock: 80 candidate facilitators started the training and candidates were selected from four RAB zones through a participatory process of identification and selection conducted within the livestock keeper communities. in preparation of FFS groups formation

x) Increase the number of potato trainers: 194 co-facilitators were trained as potato production trainers.

Table 39: Summarized illustration of the FFS situation at the end of June 2013.

Commodity	Number of facilitators	Number of FFS groups	Total of beneficiaries in FFS groups (end June 2013)
Rice	109	110	2,926
Potato	350	911	19,640
Banana	648	946	27,751
Cassava	363	424	9,623
Maize	100	101	2,264
Tomato	50	108	2,381
Tamarillo	117	118	3,024
Maracuja	46	47	884
Striga management	169	111	2,342
Soyabean	78	0	0
Livestock	80	0	0
CMC banana rehabilitation and BXW		6,842 ha	83,432
CMC in Striga management		4,338 ha	23,344
CMC in positive selection of potato seeds		117 ha	606
CMC to mobilize farmers and supervise use of good practices on maize consolidated sites			3,019
Overall total	**2,110**	**2,876**	**181,236**

10.1.3. Program based extension services

a. Wheat production

The wheat program created awareness on improved wheat seed and other technologies to the farmers through exhibition and agricultural show which were organized at zonal level (Musanze and Burera Districts) and national (Mulindi agrishow ground). The varieties exhibited included Musama, EN161, EN48, EN2076, EN213, EN238, EN312, EN315, EN316 and EN2076. Farmers were also sensitised on pre-released or released wheat seed varieties. Fact sheets on yellow rust disease were disseminated to the end-users and partners.

In addition, three radio documentaries were prepared on improved technologies (appropriate varieties, cultural practices, planting densities, fertilizer regimes and soil fertility improvement options, soil and water conservation and crop protection) and broadcasted on local radios, namely, Radio Rwanda, RC Musanze and Huguka Radio. In order to create awareness on the importance of improved crop management practices in increasing the standard of wheat production, three demonstration plots were established: 2 in Burera District and one in Musanze District. The grain yields obtained from demonstration sites were about 4-5 higher than the one obtained from a neighboring equally-sized plot planted to wheat without any input (Figure 72).

Figure 72: Demo plot at Rwerere Village, Gashoro Cell (Left) and a neighboring plot combining wheat, potatoes, peas and many other weeds without application of fertilizers (Right)

b. Rice production

Rwanda has agro ecological zones where Rice farming is performed mainly in the middle altitude areas (1350-1500m). Rice is the predominant crop in irrigated ecosystems.

In order to increase the impact of research through improved technologies among the rice value chain actors, three rice sector development hubs were established in the Eastern Zone (EZ), Southern Zone (SZ) and the Western Zone (WZ). During the reporting year, key activities included:

i. Data collection on seasonal production and marketing
ii. Follow up and assessment of level of cooperatives management
iii. Training Seed producers on rice postharvest handling and storage
iv. Training rice farmers cooperatives on rice postharvest handling and storage
v. Distribution of booklets of postharvest handling and storage

During the 2013A cropping season 8,050Ha were planted representing 94.3% of the year target which was 8,534 ha to be cultivated throughout the country. Comparatively,during 2013B cropping season, 9,168ha (88.2%) of the projected 10,390 Ha was cultivated.In order to reduce rice post harvest losses,183 farmers and 44 agronomists were trained in rice postharvest handling and storage technology through field days and demonstrations**(** Figure 73 **)**. In addition, 6,200 booklets on postharvest technology were distributed to rice farmers' cooperatives. Farmers were also trained in best practices to grow rice; Water management; Fertilizer use ;Rice pest and diseases and their management.

Figure 73: Field study at Duhuzimbaraga Figure.2 Training farmers on the use of combined rice thresher (Ngoma)

c. Sorghum

Production of sorghum in the country was affected by infestation of *Striga* weed. To build the farmers capacity in the control of the weed, educational materials were developed and disseminated. The materials included leaflets and posters written in Kinyarwanda. A one day training of sorghum farmers from the *Striga* infected areas was organized where model sorghum farmers were trained and issued with the training materials. The training covered the following topics; *Striga* weed concept, its mode of infestation, *Striga* species existing in the country and their methods of control.

d. Beans

During the year, the program promoted both ordinary and high Fe bush and climbing bean varieties and clean seed produced for both varieties. However, the proportion of seed of high Fe bean varieties was greater than for ordinary beans (Figure 74). The high Fe bush varieties: ISAR BB 102 (RWR 2154) and ISAR SCB 103 (RWR 2245) and the climbers: ISAR CB 102 (RWV 1129) and ISAR CB 107 (MAC 44) were the most popular varieties (Figure 75 and 76).

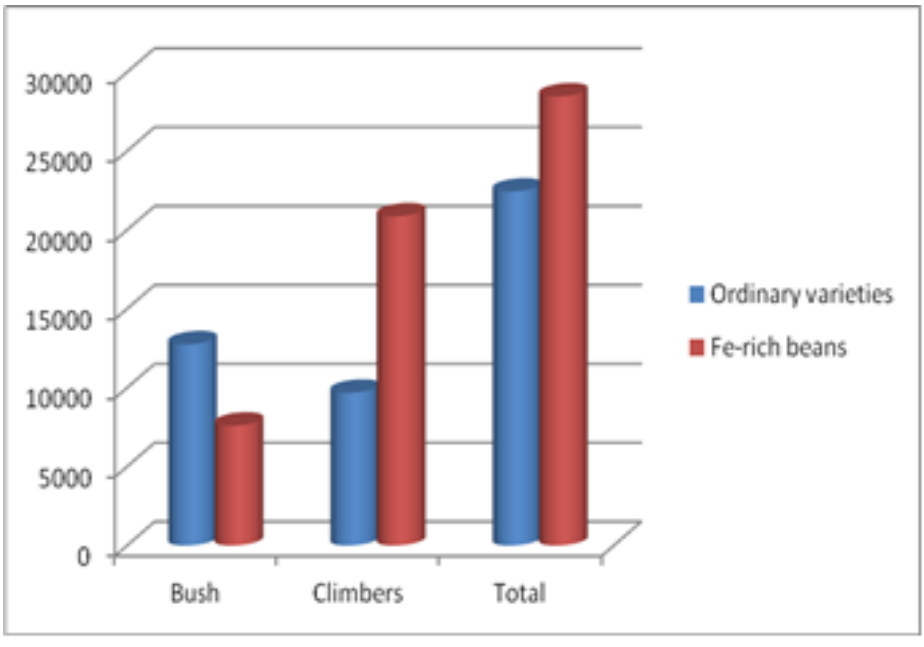


Figure 74: Seed production of high Fe bean varieties compared to that of ordinary one

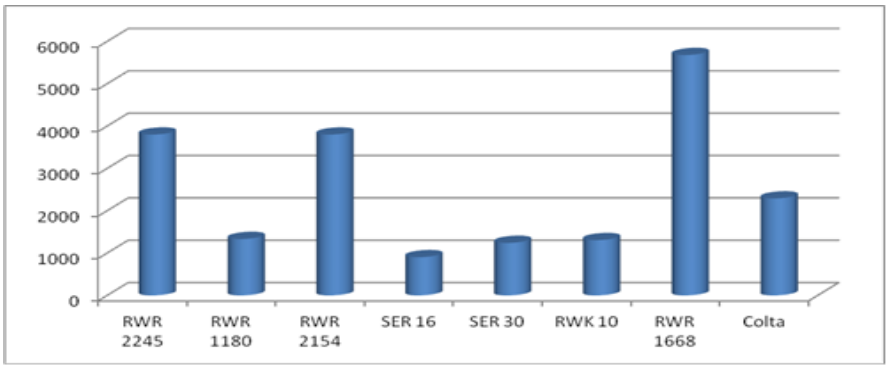


Figure 75*: Most popular bush bean varieties were RWR 1668 and two high Fe content RWR 2245 and 2154*

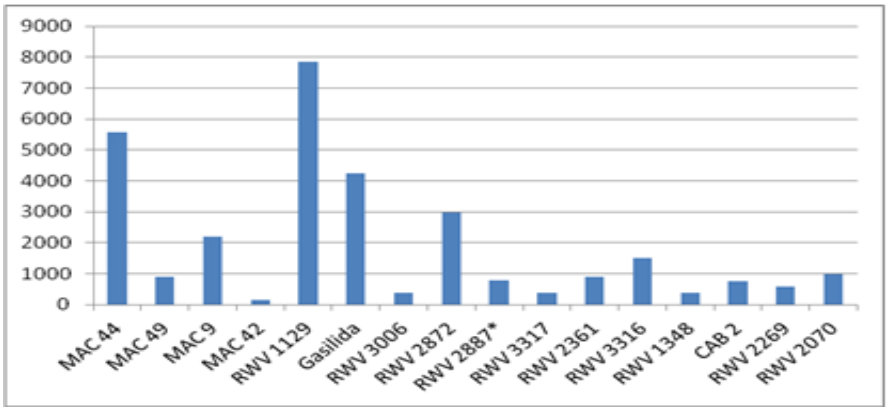


Figure 76*: Gasilida and two Fe-rich ISAR CB 107 (MAC 44) and ISAR CB 102 (RWV 1129) were the most popular climbing bean varieties*

Validation and promotion of Integrated Crop Management Innovations for bean production.

Staking innovations

Staking needs of climbing beans remains the most important challenge that hinders wider adoption of climbing beans, especially in new areas where agro-forestry isn't established. A farmer participatory study recommended staking option that reduced over reliance on wood by 67% and complementing it with trellises. It had insignificantly different yields compared to 100% wood staking. Some farmers adopted the innovation and preferred it to the full wood staking. They cited convenience and even better yields under heavy rains as the innovation was less prone to logging, disease pressure and flower abortion due to lighter and better aerated canopies. Demo plots were established on ten locations alongside the farm/multilocation climbing variety trials (Figure 77).

Figure 77*:* Demonstration and utilization of wood-trellises staking innovation on farmers' fields and display of bumper harvests by some of the farmers in Musanze district

Promotion of bean based food products

The farmers were trained on the nutrition importance of high Fe beans and products that were processed from them. The topics covered include; beans are an excellent nutrient-dense important food sources of protein, fibre (both soluble and insoluble) and an excellent source of minerals and vitamins and that, those nutrients are available whether it is whole or powdered form.Beans can be pound and the flour can be used to manufacture many different foods by adding other flours such as of rice, potato, Moringa and carrot to fortify the nutrients. The following food products were introduced to the farmers: bean soup, karasev, cakes, biscuits, cokies and breads bean / wheat composite flour, Moringa, sugar and other ingradients.

e. Irish potato production

Farmers were trained on appropriate agronomic practices and crop management for the potatoes through establishment of demonstration plots of potato selected varieties. Among those technologies include planting quality seed, use of appropriate dose of organic and mineral fertilizer, disease management.Five demonstration plots were established in Rugarama, Cyuve, Gicumbi, Rulindo and Gataraga where four potato cultivars (Mabondo, Victoria, Kinigi, CIP393077.54) and one farmer variety were planted.

Positive potato seeds selection

Positive potato seed selection through FFS were conducted so as to train farmers to select potato plants which are free from diseases from their fields. This technique helped farmers to keep quality potato seed for the next coming season. A total of 195 FFS groups were engaged in seed production. In addition 106 new FFS groups were created in the Northern zone and involved in seed production. As an output, 1030 tons of quality potato was collected by farmers' trough FFS approach.

f. Sweet potato production

During the year, 25 farmers were trained on participatory variety selection, sweet potato production and vine conservation. In Muhanga, Gakenke and Rulindo districts, 24 pilot members and technicians were trained on tunnel construction for clean planting material production. 35 farmers were trained on vine conservation and processing. Four sweetpotato programme technicians were trained in vitro multiplication and media preparation at Rubona

research station. 15 FFS were established and received 772,800 clean cuttings for SMS and TMS.

g. Cassava production

In order to have good quality high yielding planting materials, capacity building of cassava producers and seed multipliers was carried out**.** In total three hundred and fifteen (315) farmers were trained on cassava seed multiplication and production in Bugesera, Huye, Gicumbi and Karongi districts. In addition three hundred and fifteen (315) other FFS were established in four Zones of RAB in 2012-2013: Eastern Province (61 FFS), Northern Zone (60 FFS), Southern Zone (151 FFS) and Western Zone (51 FFS). The services provided by FFS to the farmers were : Training of farmers, Implementation of good agricultural practices related to integration pest and disease management (IPM/IDM) and Integrated crop management (ICM),Participatory research, Self-Organization of target groups/ beneficiaries.Improved cassava varieties known to be resistant to major cassava pest and diseases were introduced. These were Mavoka, Seruruseke, Rwizihiza, Garukunsubire, Mbakungahaze and Kizere. Local varieties which adapt well in their respective agro ecological zones but susceptible to major cassava pest and diseases were also promoted. These varieties are: *Mushedire, Mburamuzi, Nyirakarasi, Kagaja, Nyiramabuye, Imisurupiyo, Gihingamukungu, Senkanti, Imitarina, Gacyacyali, Rutanihisha, Gahene, Bukarasa, Iminayiro* and *Gitamisi*. This is good to maintain cassava genetic diversity for research purpose in breeding program activities.

h. Banana development programme

The main objectives of Banana Development Programme are: (i) to increase acreages under cooking and dessert banana through new plantings; (ii) improve banana productivity through rehabilitation of existing fields and trainings; (iii) increase access to high quality plant material through dissemination of improved, disease resistant and high yielding varieties and (iv) sustainably control banana diseases, particularly, Banana Xanthomonas Wilt (BXW).

Increased land under cooking banana production

During FY 2012-13, RAB has delivered new planting material in form of tissue culture or macro-propagated plantlets and conventional suckers derived from local or regional tissue culture laboratories, farmer-based macro-propagation units and informal seed multipliers throughout the country. This material was used to establish new banana fields on a total of 883.44 Ha (Table 40).

Table 40: Newly established banana yields per province, FY 2012-2013

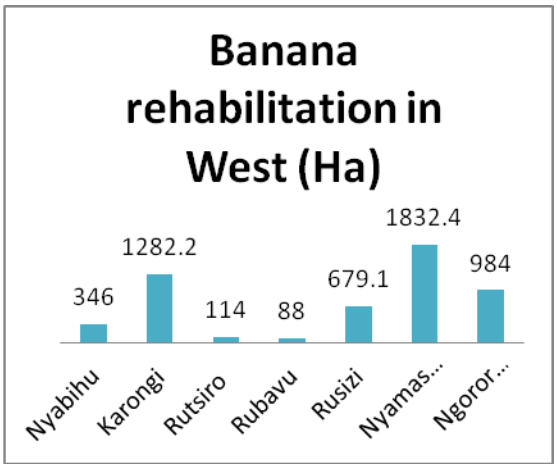
Province	Planted Area (ha)	% achievement vis a vis to the targets
Western	180.8	120.5
Eastern	433.5	173.4
Northern	123	123
Southern	146.14	146
TOTAL	**883.44**	**147**

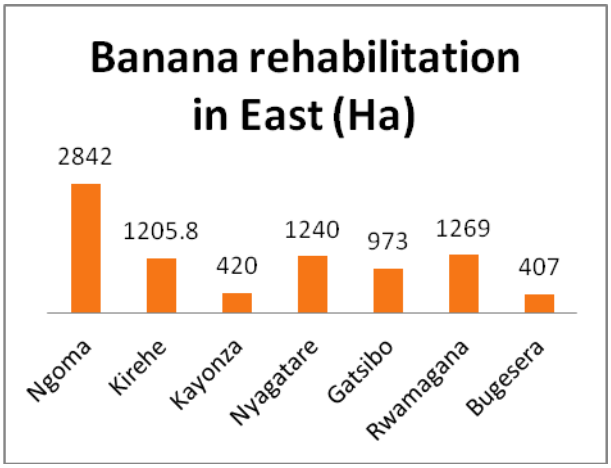
Rehabilitation of existing banana plantations

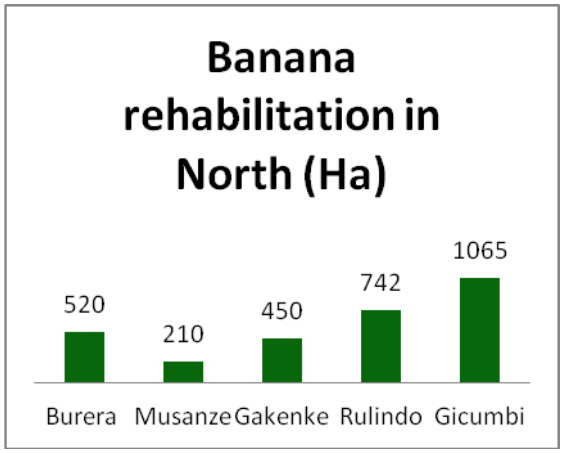
During the year, banana rehabilitation through organized community mobilization campaigns at district and sector level with help of technically skilled FFS facilitators and co-facilitators, trained IDPs and farmer cooperative members under support from local leaders (mayors, vice-mayors FED and sector executives), district and sector agronomists, farmer promoters and cell and village leaders. A total area of existing banana fields rehabilitated was 22,379.5 ha (Table 41 and Figure 78)

Table 41: Banana rehabilitation area per province, FY 2012-2013

Province	Area rehabilitated (ha)	% achievement vis avis to the targets
West	5325.7	118.3
East	8266.8	87
North	2987	99.6
South	5800	116
TOTAL	**22,379.5**	**101.**







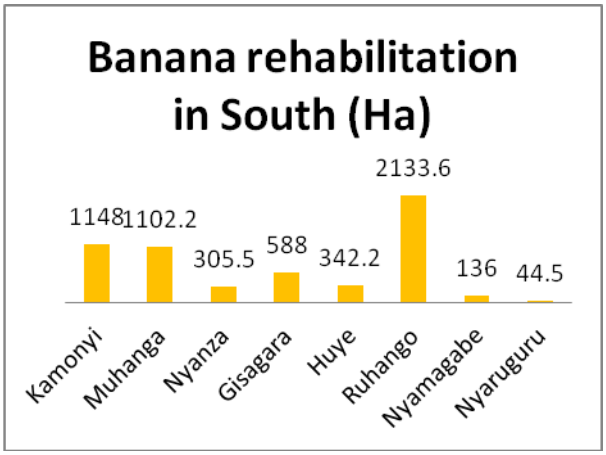


Figure 78: Banana rehabilitation per District in main provinces, FY 2012 -13

Improved and high yielding banana varieties disseminated

A total of 422,602 banana plants were delivered to farmers, cooperatives, farmer's groups and individual seed producers during 2012-13 (Figure 79). The varieties disseminated were Injagi, Nkazikamwa, Mpologoma (belonging to cooking type), FHIA 17 (multiple use, cooking and dessert type), FHIA 25 (juice type) and Kamaramasenge (dessert apple banana).

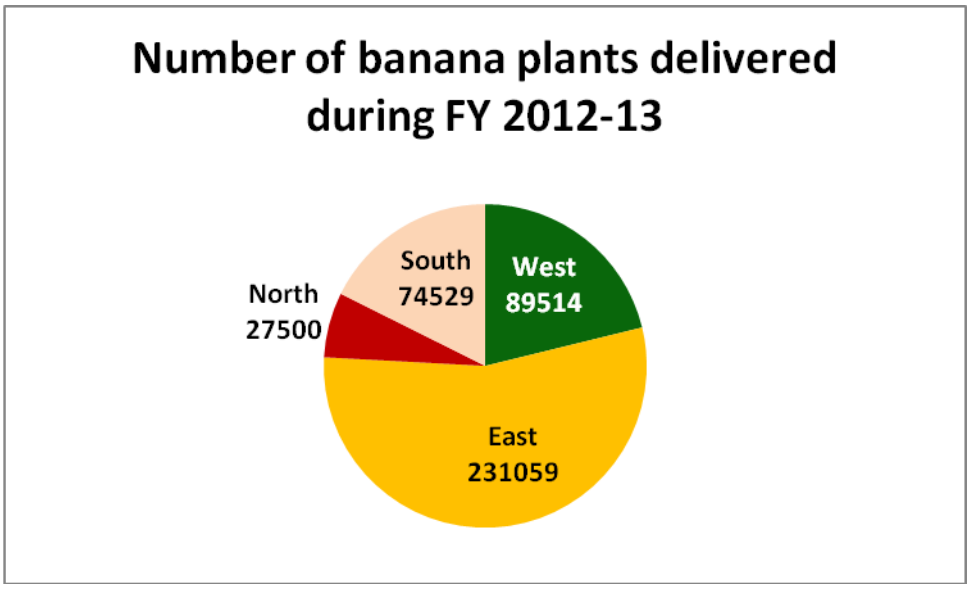


Figure 79: Improved of Banana plants delivered per Province, FY 2012-13

Improved management of pest and diseases for banana

During the year, further spread of the BXW was controlled. Although the disease has affected few new areas, a general effort to reduce its spread was greater, especially in newly affected areas, and within the last year the disease extent was reduced by 51.4% as compared to 2011-2012 (85.7% target achieved).

The infected banana plants were uprooted on a total of 1727 ha, while the disease is currently spread on 1631.7ha which have moderate to low infection. The efforts on disease control and currently affected areas as on June, 30, 2013 are shown in Figure 80.

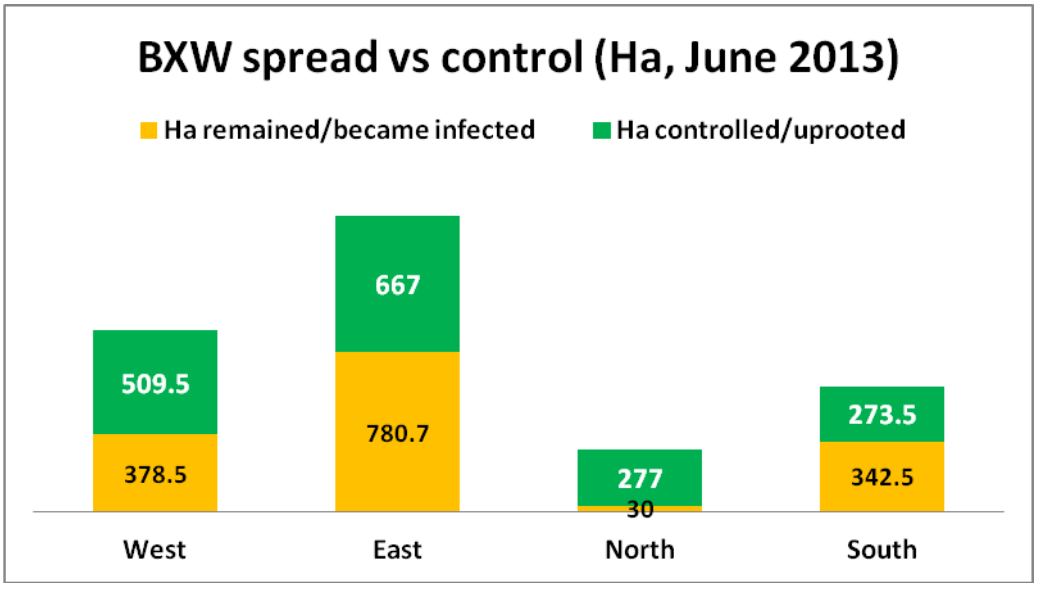


Figure 80: Banana area affected by BXW versus current disease extent in 4 provinces of Rwanda (June 2013)

Banana seed sub-sector optimized

High quality planting material is one of the key factors controlling banana productivity. Disease pressure, cultivation of low yielding varieties and increasing demand for highly marketable varieties create a countrywide need for regular supply of quality seeds. Conventional propagation capacity of banana is low, while the use of rapid propagation methods, such as tissue culture and macro-propagation, is very limited. For the last 5 years, National banana seed sub-sector was relying almost entirely on importation of high quality plant material and its conventional field propagation via informal seed producers from banana farming across the country.

To identify the constraints and opportunities existing in the banana seed sub-sector, a survey was done in 24 districts in all provinces of Rwanda during main rain season 2013 targeting the existing informal banana seed producers. A total of 284 seed producers answered a structured questionnaire (36 in South, 64 in North, 59 in West, 125 in East). Data were collected about gender, land devoted to banana seed production, production cost, varieties grown, price, existing market opportunities and challenges.

In all provinces, a majority of respondents were males (87%) with average land of 4.4 Ha (30% of land devoted for banana seed production). More than 90% of seed producers had difficulties to estimate production cost. The varieties with most demand were FHIA 17, Injagi and FHIA 25 (Figure 81 below).

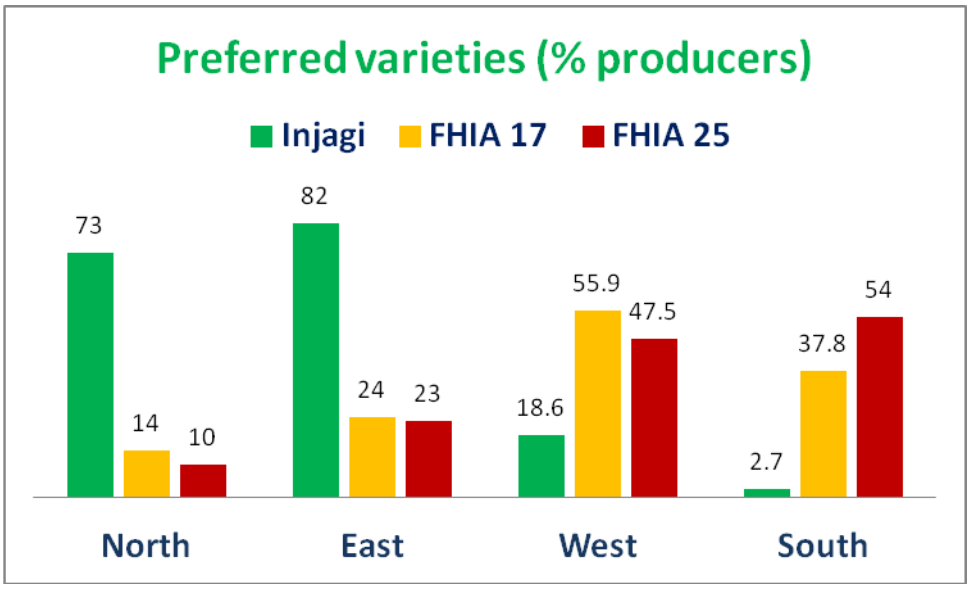


Figure 81: Preferred banana varieties per province, FY 2012-13

Price per sucker was highly variable, from 60 up to 1000 Rwf while unstable and irregular market, traditional mindset of getting plant material for free, limited access to organic fertilizers and low availability of new exotic varieties were mentioned as the main constraints in the seed sub-sector (Figure 82 below).

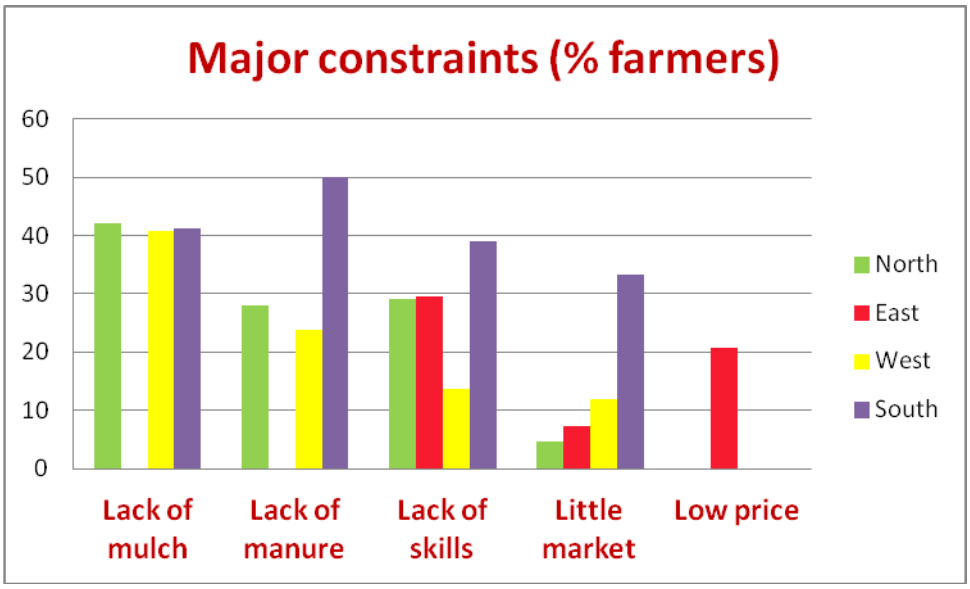


Figure 82: Major constraints for banana seed production per province, FY 2012-13.

Most of the informal banana seed multipliers were active and intend to continue banana seed multiplication while considering it as a good investment and growing business opportunity, however, Northern Province had larger gap between the perception on availability of market and current sales that were more similar in other provinces (Figure 83).

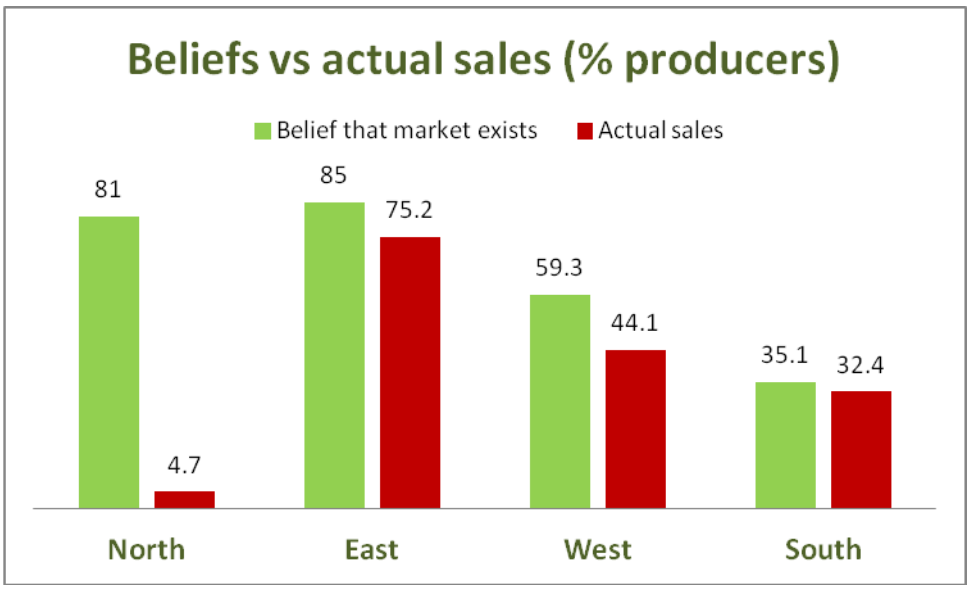


Figure 83: Availability of market and current sales

BXW and fusarium wilt were the major disease problems (Figure 84) affecting banana seed fields. However, most of the existing producers have adopted appropriate disease strategies (cultural control for BXW and switch to resistant varieties for fusarium wilt).

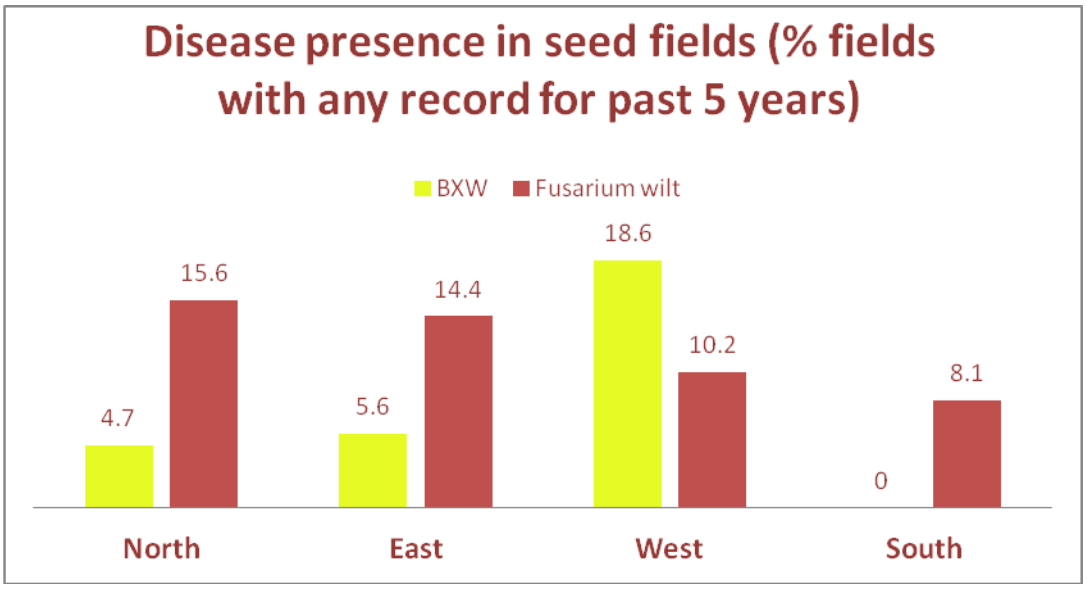


Figure 84: Disease presence over last 5 years in fields of informal banana seed multipliers.

The findings of this study were presented at RAB biennial conference 2013 (August).

New quality requirements for seed multipliers were developed, and selection of seed multipliers for certified and QDS seed production was done.

Success story: increased banana production

Through the combination of the above practices and described extension approaches, the banana production has increased significantly when farmers have adopted integrated crop management practices (particularly through access to FFS groups and trained facilitators). Bunch weight increase was observed for different banana varieties (Figure 85, 86 below)

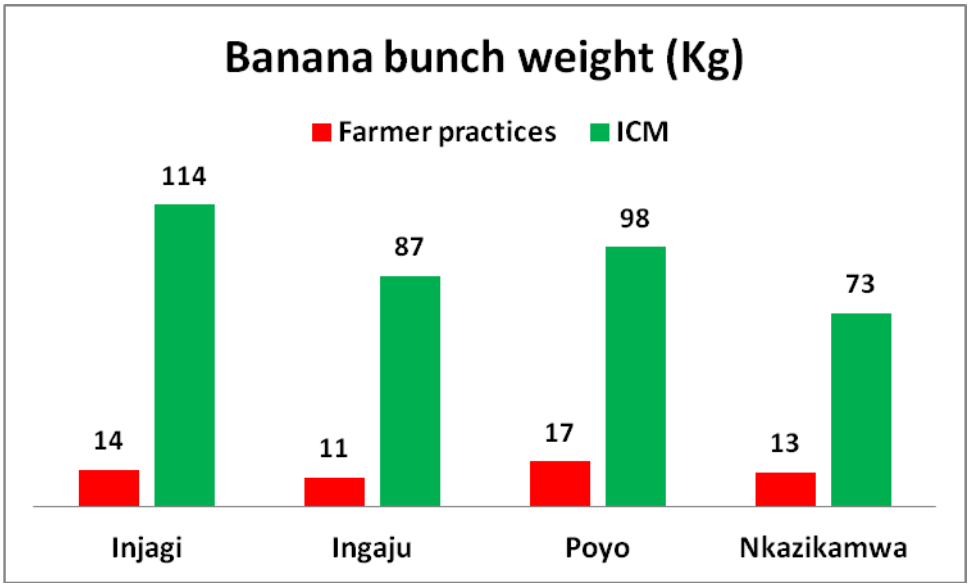


Figure 85: Recorded banana bunch weight increase after adoption of ICM for different varieties, FY 2012-13 (Eastern Rwanda)

Figure 86: Increased banana bunches with ICM practices learned by farmers in FFS groups. Ingaju variety (2 left bunches – without and with ICM use), Injagi variety (2 right bunches – with and without ICM, respectively).

i.Coffee

Mobilization of key stakeholders including farmers to participate in farm based activities and establish linkages with Farmer Field School

A survey was conducted in collaboration with the project for increasing the resilience of coffee production to leaf rust and other diseases in India and 4 African countries (Kenya, Rwanda, Uganda and Zimbabwe) to find out how farmers who participated in Farmer Field School for three years benefited from this extension approach. The results indicated that farmers gained a lot from FFS including farm and pest management. In addition, other farmers not belonging to the Farmer Field School were copying the technologies observed in FFS member and applying them in their farms.

10.2. EXTENSION IN NATURAL RESOURCE MANAGEMENT

Increasing awareness on the use of travertine among smallholder farmers

Different approaches were used to raise awareness on the use of travertine and other integrated soil fertility management options among smallholder farmers of the southern province where soils are acidic and less productive. These included training of farmers, organizing of farmer field days and exchange visits around demonstration plots (Figure 87).

A documentary and booklet were produced to serve as dissemination materials of findings from demonstration trials to a large number of farmers.

Figure 87: Farmer field days and farmer exchange visits around demonstration plots.

Increase farmers exposure to water management options in watersheds

Under the support of AAP project , and water productivity , small scale irrigation activities have been implemented in Isangano cell, Ndego sector, Kayonza District and Murama cell, Nyamata Sector, Bugesera District in in Eastern province of Rwanda and Tare sector in . After installation of dam sheets in six farm ponds, the next planned activities that were carried out during the last quarter of the fiscal year 2012-2013 consist of irrigation system installation and capacity building of farmers. Two drip irrigation systems have been installed as well as two gravity systems (drag hose application technique) in Kayonza District. 14 ponds systems were equipped with treadle pumps. The research perspective is to do participatory testing of best practices in term of daily rates, deficit estimation and alternative components. The trials will start in the next fiscal year.

Figure 88: Irrigation components (pipes, hydrants and accessories/fittings) for gravity system installation

Forestry and agroforestry

In extension program**,** two watersheds were managed by using participatory on farm tree planting on contour lines where one of about 8 ha in Muyira- Nyanza and another of 15 ha in Mwendo-Ruhango and About 60 participatory on farm small-size woodlots of about 10.8 ha were established in Muyira Sector. More than 100,000 forestry & agroforestry seedlings were planted in Muyira and Mwendo Sectors. Tree species include *Calliandra calotyrsus, Leucaena trichandra, Grevillea robusta, Cedrela serrata and Maesopsis eminii.* Moreover, one demonstration site of 2.5 ha was established at Muyira –Nyanza with nine forest species under evaluation.

10.3. LIVESTOCK EXTENSION

10.3.1. One Cup of Milk per Child: Fighting malnutrition from its roots

Consumption of adequate amounts of milk is a proven way of achieving nutritional security which enables children to develop normally and reach their full potential as healthy, productive adults. The program targets to enhance retention of children in school, improve malnutrition and health of school-going children.

During this reporting year, One cup of milk per child programme in schools registered success by scaling up from 30 schools to 100 primary schools, and 1,841,893 liters of milk distributed to school going children. Each child was given 0.5 liter of milk during a milk drinking session twice a week.

Figure 89: Celebration of World Milk Day in Nyanza District

10.3.2. Investing in people's welfare: GIRINKA program (One Cow per Poor Famiy Program)

The Government of Rwanda through the National Social Protection Program aimed at reducing poverty and improving nutrition of her people instituted the One Cow per Poor Family popularly known as *Girinka* in 2006. Currently, the program is being implemented in the whole country and targets poor farmers by giving them an in-calf heifer. During this reporting year, **19,369** cows were distributed to farmers of which 4,013 cows were procured by districts through

government earmarked funds while the remaining heifers were sourced from various stakeholders as donations and local initiatives as well as pass-on the gifts.

Table 42: Sources of funds for procurement of heifers and recipient districts during 2012/13

Province	Districts	Decentralization	Others	Total	Decentralization %
	Burera	155	499	654	23.7
North	Gakenke	125	858	983	12.7
	Gicumbi	125	200	325	38.5
	Musanze	110	62	172	64.0
	Rulindo	90	1083	1173	7.7
East	Bugesera	150	467	617	24.3
	Gatsibo	125	1890	2015	6.2
	Kayonza	120	32	152	78.9
	Kirehe	115	376	491	23.4
	Ngoma	100	257	357	28.0
	Nyagatare	120	503	623	19.3
	Rwamagana	90	198	288	31.3
West	Karongi	110	1311	1421	7.7
	Ngororero	330	477	807	40.9
	Nyabihu	110	155	265	41.5
	Nyamasheke	140	1844	1984	7.1
	Rubavu	125	364	489	25.6
	Rusizi	170	1367	1537	11.1
	Rutsiro	112	824	936	12.0
South	Gisagara	125	410	535	23.4
	Huye	148	335	483	30.6
	Kamonyi	155	929	1084	14.3
	Muhanga	135	29	164	82.3
	Nyamagabe	115	107	222	51.8
	Nyanza	123	96	219	56.2
	Nyaruguru	320	21	341	93.8
	Ruhango	120	207	327	36.7
Kigali C.	Gasabo	102	121	223	45.7
	Kicukiro	78	124	202	38.6
	Nyarugenge	70	210	280	25.0
Total		**4,013**	**15,356**	**19,369**	**33.4**

Figure 90: Cows ready to be handed-over

Figure 91: Members of diaspora in France to the beneficiaries in Kamonyi district donating to Girinka

In order to equip recipient farmers with skills to manage the donated animals better, a total 18,148 Girinka beneficiaries received training in animal husbandry practices during the course of 2012/13.. The training emphasized improved animal husbandry techniques particularly basics in animal feeding, housing, breeding and reproduction, disease control, general management and record keeping. The training imparted aimed at improving on farmers skills to effectively manage their stock for increased animal productivity.

10.3.3. Milk Collection Centre (MCC) Hub Model: Transforming MCCs into Dairy Business Centres

This activity aimed at revitalizing the Milk Collection Network for efficient service delivery to the farmers who are delivering their milk to the MCCs and be able to get all services needed and farm inputs at MCCs including artificial insemination services, drugs among others. In the Eastern Province, 18 MCCs were linked to agribusiness companies for farm input supplies. Mobilization campaigns and guidelines for MCCs business transformation were produced and shared with local government officials and cooperatives members. RAB procured 2,000 milk cans for distribution to MCCs at a fair price.

Figure 92: The Hub Model at Rwabiharamba Milk Collection Centre, Nyagatare district

10.3.4. Milk competition, creating the culture of excellence in smallholder dairy farmers

RAB in collaboration with the Private sector in the dairy business organised Milk Production Competition in dairy cows on 16th June 2013. The purpose of the competitions was to recognize farmers with the highest milk producing animals and to promote high producing animals for profitable livestock business. These competitions also provides an opportunity for appraisal of the maximum genetic potential of the animals in terms of their milk production while providing an opportunity for livestock farmers and agri-business companies to interact and share their experiences with in the field of livestock business.

The milk production competition attracted more than 150 progressive farmers from across the country. The winners were rewarded with non-cash prizes and Certificates of appreciation.

Figure 93: The champion cow, Friesian group, yielded 12.5 liters of milk per milking

10.3.5. Improved access to high quality animal feeds

During the year 2012-2013, extension activities in animal nutrition achivements were as follows:

- 39 tonnes of forage seed and 30,000,000 of *Brachiaria* rooted tillers were produced;
- 36 tonnes of forage legumes (Mucuna and Lablab) were distributed to farmers in
- 30 farmers were trained on forage seeds production;
- Forage legumes and grasses demostration plotswere established at 50 milk collection centres (MCC).This will help farmers to understand and to adopt forage improved in these MCC and beyond;
- 10 tonnes of rice straw and 5 tonnes of concentrate were collected and used to demonstrate to farmers on how to treat maize stover using molasses and urea and feed to cattle was conducted in Mpanga and Nasho sectors (Figure 94);

Figure 94: Farmers learning how to treat maize stover with urea and molasses in Kirehe districtMpanga and Nasho sectors

- One technique using boxes for hay making and one using silo for silage making were disseminated;
- More than 30 tonnes of hay (Chloris gayana and Medicago sativa) were produced;

- 98 farmers participated in a training on the role of Innovation Platforms, analyzing constraints and opportunities in the beef value-chain, sharing roles and responsibilities;

- In collaboration with SPAT II, a Farmer Field School (FFS) on animal feeds and feeding was conducted in Ntarama sector, Bugesera district . This FFS was considered as training of trainers. At least 2 farmers per district attended the school and it is expected that by the end of the learning, many farmers in the whole country will benefits knowledge in feeds and feeding through the farmer trainers.

10.3.6. Apiary

In the just ended financial year, the apiary program promoted beekeeping-oriented entrepreneurship directed at reducing poverty by promoting value chain development of bee products. Specific activities included: survey status of beekeeping in the Western zone; training of bee farmers in improved beekeeping technology and hive artisans; distribution of beekeeping materials and bee health particularly verroasis.

a. Training of different stakeholders

Visit of different apiaries from different cooperatives and training of master beekeepers the management of bee diseases.

i) Western Zone: UNICOAPIGI and CODEAM in Rutsiro district, UNICOAPIGI, Nyundo orphanage apiary and INDAHEMUKA in Rubavu district, RAB apiary in Gakuta station – Karongi district

ii) Northern Zone: *Cooperative Abusuzubumwe* in Musanze district, CAR in GICUMBI, Cooperative *Abakunda Inzuki* and COOPASK in Burera district

iii) Southern Zone: *Girubuki* Cooperative in Huye, *Cooperative Abatica umugambi* and Military apiary in Nyamagabe, *Cooperative Impuyabaki* group I in Gisagara and *Cooperative Impuyabaki* group II in Nyaruguru

iv) Beekeeping workshop and exhibitions in Eastern province in partnership with JICA from 7-28/02/2013 in Rwamagana districts where 70 beekeepers from different districts were trained on different topics including the Role of International aid organization in sustainable development; economic importance of honey and future roadmap of beekeeping sector for sustainable development; youth and Women participation and profitability in beekeeping sector; importance of cooperative management, beekeeping development, sharing about varroa diseases and successful stories in honey production and quality by KOPAKI and KARANGAZI cooperatives. After the training, beekeeping products were exhibited.

In addition, three radio talks were organized at Huguka; Radio Fash, Radio Rwanda and Rwanda Television concerning the awareness of varroa disease and the proper use of pesticides in the management of varroasis in bee hives.

b. Training of farmers and artisans

A two-day farmers' cooperative training was held in Nyabihu district on Potential of Agroforestry-Bee keeping technology and income based generation support by LDCF project. Thirty farmers were trained from 28 to 31/08/2012 and were selected from three cooperatives of bee keepers.

c. Evaluation of three Varroacides in Honeybee *Apis mellifera* (Hymenoptera:Apidae) colonies in Rwanda

Eight sites were identified for the tests (2 in Rubavu, 1 in Burera, 1 in Byumba, 2 in Huye and 2 in Nyamagabe) by The Belgian expert Didier Gillet. The effect of Fluvalinaat, Oxalic acid, Thymol and destruction of drone broods were evaluated. Results showed that the removal of male brood and changing queens through rearing slowed the development of mite populations. The crystalline Fluvalinate and Oxalic acid were recommended for further use in the control varroa mites in both wet and dry seasons, while Thymol, an essential oil, should only be used during the dry season. Other measures to curb the proliferation of mites and reduce the risk of infestation recommended were removal of male brood and queen rearing to ensure queens remained young. Uwingabire, a bee farmer from Cooperative COPABAHU reported a new technique in control of varroasis by destroying drone broods ; showed 70 % reduction of varroa in bee colonies.

-In partnership of SNV and RAB, master beekeepers and stakeholders from REDO, ADEPE and SERUKA were trained at Gisenyi sector in Rubavu district on management of apiary and awareness of bee diseases including Varroa from 23 to 28/09/2012.

Beekeeping workshop and exhibitions in Eastern province in partnership with JICA from 27-28/02/2013 in Rwamagana districts where 70 beekeepers from different districts were trained on different topics including the Role of International aid organization in sustainable development, Economic importance of honey and future roadmap of beekeeping sector for sustainable development, Youth and Women participation and profitability in beekeeping sector, Importance of cooperative management, beekeeping development , sharing about varroa diseases and successful stories in honey production and quality by KOPAKI and KARANGAZI cooperatives. After the training, exhibited products were visited followed by observation and comments of guests of honor (DDG Animal Resources and Extension, JICA Representative and Governor Representative). One radio talk was organized at the end of the workshop

In addition, three radio talks were organized at Huguka; Radio Fash , Radio Rwanda and Rwanda Television concerning the awareness of varroa disease and the proper use of pesticides in the management of varroasis in bee hives.

d. Training of farmers and artisans

A two-day farmers' cooperative training was held in Nyabihu district on Potential of Agroforestry-Bee keeping technology and income based generation support by LDCF project. Thirty farmers were trained from 28 to 31/08/2012 and were selected from three cooperatives of bee keepers.

10.3.7. Small livestock gives poor families new lease of life

Thanks to the program 'Support to small livestock' APEL (Appui au Petit Elevage) a big number of very poor families countrywide have seen their living conditions improve significantly. The program is a project funded by the Belgian government through the Belgian Technical Corporation (BTC) and executed by the Rwanda Agriculture Board (RAB).

Figure 95: Philomene Muhorakeye and her 'golden' pig in Huye District

The following table gives a situation of the technical implementation of the project at the end of the project (January 2013)

Sheds

	Planned					Implemented on 31/12/2012					
District	pigs	goat	sheep	rabbit	Total	pigs	Goat	sheep	rabbit	Total	% impl
Huye	996	904	0	40	1 940	996	904	0	40	1 940	100
Nyamagabe	2 080	907	0	37	3 024	1 000	907	0	37	1 944	64
Gisagara	972	712	0	52	1 736	972	712	0	52	1 736	100
Ngororero	1 758	675	365	2	2 800	1 695	640	345	2	2 682	95
Nyaruguru	300	200	0	50	500	300	200	0	0	500	100
Total	**6 106**	**3 398**	**365**	**131**	**10 000**	**4 963**	**3 363**	**345**	**131**	**8 802**	79

Animals

	Planned					Implemented					
District	pigs	goat	sheep	rabbit	Total	pigs	Goat	sheep	rabbit	Total	**% impl**
Huye	1 118	3 434	0	200	4 752	1 118	3 434	0	200	4 752	100
Nyamagabe	2 080	1 800	0	185	4 065	2 080	1 800	0	185	4 065	100
Gisagara	1 698	3 765	0	260	5 723	1 698	3 765	0	260	5 723	100
Ngororero	1 898	1 410	730	12	4 050	1 898	1 410	730	12	4 050	100
Nyaruguru	1 100	4 744	1 048	250	7 142	1 100	4 744	1048	250	7 142	100
Total	**7 894**	**15 153**	**1 778**	**907**	**25 732**	**7 894**	**15 153**	**1 778**	**907**	**25 732**	100

Beneficiaries

	Number of beneficiaries					Implementation					
District	pigs	goat	sheep	rabbit	Total	pigs	Goat	sheep	rabbit	Total	**% impl**
Huye	1 118	1 717	0	40	2 875	1 118	1 890	0	40	3 048	106
Nyamagabe	2 080	907	0	37	3 024	2 080	907	0	37	3 024	100
Gisagara	1 698	1 898	0	52	3 648	1 698	1 898	0	52	3 648	100
Ngororero	1 898	705	365	2	2 970	1 898	705	365	2	2 970	100
Nyaruguru	1 100	2 438	548	40	4 126	1 100	2 480	524	40	4 144	100
Total	**7 894**	**7 665**	**913**	**171**	**16 643**	**7 894**	**7 880**	**365**	**171**	**16 834**	101

Figure 96: APEL beneficiaries in Ngororero District

At the end of 2012 APEL imported a flock of 120 pigs for distribution to UP, ISAE and 10 private breeders. APEL provided also 3 kits for pig artificial insemination for the named Institutes and the pig breeding center of Kisaro. 2 Boars were trained to mount the dummy sow.

Figure 97: CPPA – Kisaro Pig breeding Center

A number of infrastructures were built or rehabilitated by APEL Projet: The satellite veterinary laboratory of Huye and the satellite veterinary laboratory of Nyagatare

District of Nyamagabe: 2 animal markets (Ryarubondo , Ruganda)

District of Nyaruguru: 1 slaughterhouse and 2 animal markets (Viro , Uwinteko)

District of Huye: 1 slaughterhouse and 1 animal market (Matyazo , Karambi)

District of Gisagara: 1 slaughterhouse and 1 animal market (Save , Kansi)

District of Ngororero: 2 slaughterhouses (Ngororero, Kabaya)

Before Rehabilitation After Rehabilitation

Figure 98: Huye Satellite Veterinary Laboratory

Figure 99: Nyagatare Satellite Veterinay Laboratory

Figure 100: Kansi Animal Market Photo : Ngororero Slaughterhouse Photo: Ryarubondo Animal Market

Figure 101: Rwanza – save Slaughterhouse

These infrastructures are useful and do ensure a better marketing of animals and meat products. The management of the infrastructure in the Districts is done by associations of butchers

10.3.8. Veterinary services

Emphasis has been put in the disease control through mass vaccination of economically important livestock diseases, strengthening boarder control of transboundary animal diseases (FMD, CBPP and LSD), strict control of cattle movement and inspection for animals and animal products. In this regard, total 1006 Community Animal Health Workers have been trained in Eastern Province in basic animal health practices and good animal husbandry practices to provide primary care at farmers' door step. All those workers have been given manual for their routine activity and equipped with animal health kit as well as give means of transport to facilitate their movement.

The control measures to stop the spread of FMD outbreak (quarantine measures, mass vaccination, stamping out of clinical cases) in Eastern Province have been taken and successfully implemented and achieved, thus there is no clinical case to be found. The second outbreak of FMD which occurred in March this year in Western province has been controlled quickly by applying sanitary and medical measures including quarantine measures, vaccination, stamping out and continuous surveillance. Since May 2013, this outbreak has been stopped. Second vaccination to reboost immunity for the Eastern province outbreak was done in April, while it is scheduled in September for the western Province. Nyagatare Satellite lab has been rehabilitated to provide diagnostic services to the farmers. Equipping all satellites laboratories and procuring reagent for diseases diagnosis has has started for Nyagatare laboratory and will continue with other laboratory in the coming year.Training for satellite lab staff has been organized to refresh their mind on routine diagnostic methods and up date them on new technics related to the new equipiment they have received.Negociation with Gicumbi District and Gatsibo Districts have started to operationalize the lnew laboratories established in those districts. Surveillance of animal diseases has been conducted in risk zones and control measures applied where it was required. Mastitis has been surveyed in East and North and antibiogram realised for its better treatment. Surveillance of Rift Valley Fever has allowed identifying first cases of RVF in Districts neighbouring zones of Akanyaru valley and other risk zones and has aloowed to calculate its incidence in the zone. Vaccine for this disease has been introduced and vaccination started in positive tested cattle herds.

To better control Brucellosis aiming at its eradication, in addition to its systematic surveillance on all breeding cattle before any movement, vaccination of calves under 10 months of age, using RB 51 vaccine has been introduced in farms located in Kigali and its surrounding area,as well in Gishwati area.

Surveillance of Helminthiasis in Eastern province (Kirehe) was conducted on 604 cattles and training on their control was done for 120 farmers in the same area.

Tsetse and trypanosomiasis control activities have been enforced in Gatsibo and Nyagatare, including meeting with farmers to discuss on control measures and installing traps for Tsetse.

Surveillance on Varroa parasites have been conducted in Disticts where beekeeping activities are developed (Huye,Gisagara, Nyaruguru, Rutsiro, Rubavu, Musanze, Burera, Gicumbi).
One week Rabies campaign has been organized to raise public awareness on this disease and conduct mass vaccination of dogs and cats against it. Continuous measures to control the population of stray dogs and cats have been applied to reduce incidence of biting cases.
New guidelines for meat and milk inspection have been developed and inspection activities of abattoirs, butcheries and milk sell points in Kigali have been successfully conducted. Meeting with veterinary drugs sellers and other stakeholders allowed us to start reorganization of this sector insisting on how to better control illegal trading of vet drugs and reviewing strategy of use of acaricides in the county based on new survey conducted on their efficacy on field. At East African Level, new guideline to harmonize registration of Immunological Veterinary Products has been developed with participation of Rwanda and principle of mutual recognition of IVPs registration agreed on.

10.7. PUBLICATIONS

One of the important activities of RAB is to generate scientific information, add value to information and share the information nationally and internationally. Publications in the form of research and extension papers in peer reviewed journals, books/ book chapters, training manuals, etc. are an integral component of the information system. During the report period, RAB scientists brought out quality publications both in English and Kinyarwanda.
The details of these publications are given below:

10.7.1 Research papers

Wheat

Habarurema, I., Asea, G., Lamo, J., Gibson, P., Edema, R., Séré, Y. and Onasanya, R.O. (2012). Genetic analysis of resistance to rice bacterial blight in Uganda. *African Crop Science Journal 20 (1):105-112*.

Habarurema,I., Edema,R., Gibson,P., Lamo,J., Asea,G., Séré,Y and Gasore,E.R. (2013). Population diversity of rice bacterial leaf blight isolates in Uganda. *Asian Journal of Plant Science and Research 3 (1):1-9*.

Beans

Cyamweshi R. A., Tenywa, J.S., Makooma, M.T., Okiror, J. J., Dusengemungu, L., Mutimura, M and Musoni A. (2013). Farmers' Coping Mechanisms for Common Bean Production under Water-Logged Soil Conditions in Uganda-Rwanda Boarder Region. *Journal of Environmental Science and Engineering* 2: 46-52.

Coffee

Bigirimana, J., Njoroge, K., Gahakwa, D and Phiri, N. A. (2012). Incidence and severity of Coffee leaf rust and other coffee pests and diseases in Rwanda. *African Journal of Agricultural Research,* 7(26), 3847 – 3852.

Bigirimana, J., Njoroge, K., Muthomi, J.W., Gahakwa, D., Phiri, N.A., Gichuru, E.K and Walyaro, D. J. (2013).Resistance of Arabica coffee genotypes (*Coffea arabica* L.) to Coffee berry disease and Coffee leaf rust in Rwanda. Accepted for publication by *International Journal of Farming and Allied Sciences*.

Bigirimana, J., Njoroge, K., Muthomi, J.W., Gahakwa, D., Phiri, N.A., Gichuru, E.K and Walyaro, D. J. (2013). Genetic Diversity among disease resistant coffee varieties and cultivars in Rwanda based on RAPD and SSR markers. Accepted for publication by *Journal of Renewable Agriculture*

Livestock

Mutimura, M., Lussa, Myambi, C.B., Mutabazi, J., Cyamweshi, R.A and Ebong, C. (2013). Status of improved forages as animal feed resources and environmental protection in Rwanda. In: *Revitalising grasslands to sustain our communities*. Proceedings of the 22nd International Grassland Congress, held in Australia, Sydney from 15-19th September 2013.

Mupenzi M., Birthe P., Kigongo, J., Wrage, M. N., Maass, B.L. (2013b). Selecting Drought-Tolerant Forage Legumes for Mixed Crop-Livestock Systems in Eastern Africa. In: Agricultural development within the rural-urban continuum. Tropentag, September 17-19, 2013, Stuttgart-Hohenheim, German.

Mutimura, M., Myambi, C. B., Gahunga, P., Mangheni, D. M., Laswai, G. H., Mtenga, L. A. Gahakwa, D., Kimambo, A. E and Ebong, C. (2013). Rumen Liquor from Slaughtered Cattle as a Source of Inoculum for *in-vitro* Gas Production Technique in Forage Evaluation. *Agricultural Journal*, 4(8): 173–180.

Mutimura, M., Ebong C., Dusengemungu, L., Musana, B and Gahakwa, D. (2013f) Household characteristics and livelihood strategies in pilot sites for beef enterprise development in Eastern Province of Rwanda. *International Journal of Animal Sciences and Veterinary Advances*, in press.

Myambi, B. C and Mutimura, M. (2012). Effect of supplementing different levels of *Leucaena diversifolia* leaf meal on milk yield of crossbred dairy cows. *Research Journal of Dairy Sciences, 6: 19-21.*

Biryomumaisho, S., Munyagishari, E., Ingabire, D., Gahakwa, D. (2012). Risk factors that influence the distribution and acaricide susceptibility of ixodid ticks infesting cattle in Rwanda. *Bulletin of Animal Health and Production in Africa*, 60 (2): 139-148.

Enyaru, J.C.K., Biryomumaisho, S., Balyeidhusa, A. S. P., Ebong, C., Musoni, A., Manzi, M., Rutagwenda, T., Zimurinda, J., Asiimwe, T., Gahakwa, D. (2012). Comparison of competitive ELISA, PCR and Loop Mediated Isothermal Amplification of mycoplasmal DNA in confirmatory diagnosis of an outbreak of contagious bovine pleuropneumonia in Eastern Rwanda. *International Journal of Animal and Veterinary Advances,* 4(1): 22-28

10.7.2. Books

Habarurema, I., Edema, R and Lamo, J. (2013). Inheritance of resistance to rice bacterial leaf blight: Implication for rice improvement in Uganda. *LAP LAMBERT Academic Publishing, Saarbrücken, Deutschland/Germany. 104 pp*. ISBN: 978-3-659-32543-4.

Technical publications

Habarurema, I. and Uzayisenga, B. (2012). Wheat Stem Rust. *In*: Noah A. Phiri and Steve Edgington (Eds). Plantwise Factsheets for Farmers, *CABI* (English version). http://www.plantwise.org/FullTextPDF/2012/20127801775.pdf

Habarurema, I na Uzayisenga, B. (2012). Umugese w'umukara mu ngano. Imfashanyigisho y'Abahinzi, *CABI*.(Kinyarwanda), http://www.plantwise.org/FullTextPDF/2012/20127801790.pdf

10.8. PARTNERSHIPS, LINKAGES AND COLLABORATION

10.8.1. Capacity building and partnerships among stakeholders in the bean value chain

a. Partnerships

We facilitated partnerships with five major actors in the seed value systems and other partners in nutrition through LoAs, including KIST, IMBARAGA, Rwanda Improved Seed Company (RISCO) and Win-Win Agrotech LTD. We strengthened linkages and held four stakeholders meetings in 2012/2013. By engaging these private seed companies, NGOs, Farmers Federation and Cooperatives,and seed based projects such as Harvest Plus, we were able to scale out seed production of all categories to 1200 MT for both climbers, bush and snap bean varieties in the year (Fig 8 left).

b. Training of partners

We trained 70 ToTs that in turn trained 125 seed producers and regional extension workers based in the three innovation platforms in in eastern (Nyagatare), Southern (Muhanga) andNorthern (Musanze/Burera). These were able to train and additional 120 actors in the bean value chain that included farmers, traders, transporters, bankers and processors in July, 2013 to give total of 250 trainees in 3 IPs. An additional 515 farmers, extension, students from universities and colleges or visiting farmers and technicians from Burundi were given practical trainings and tours of bean based technologies, particularly on diseases management, seed production and marketing of climbing beans across the four zones. Other training topics included good husbandry practices, bean diseases, soil fertility and fertilization issues and integrated management options, seed systems, marketing skills and market linkages, post-harvest qualities. They also included principles of innovation platforms, their formation, operations and sustainability. These targeted seed inspectors, technicians, extensionists, farmers, bankers, nutritionists, traders from the private and key institutions and organizations (Figure 102 right).

Figure 102*: A group of partners from RAB,*

seed companies, NGOs, IMBARAGA, Farmers Organization and Cooperatives during a stakeholders' meeting in Kigali (left); and a group of scientists, extension, seed producers and farmers from Burundi admiring seed produced by a farmers' cooperative, KOPAMA in Mahoro village of Mimuri sector in Nyagatare district (right)

10.8.2. A workshop/ field day with all stakeholders conducted

A field day for all stakeholders involved in sweetpotato planting material multiplication was conducted. A field day was organized during participatory release of 8 new varieties in order to create awareness on the new varieties. Among the 8 released varieties, four clones namely RW11-2560, RW11-2910, Gihingumukungu and Ukerewe have orange or yellow-fleshed storage roots, while the remaining 4 clones RW11-17, RW11-1860, RW11-2419 and RW11-4923 are white or cream-fleshed varieties. The event was held on February 22, 2013 in one of

major agro-ecologies of Rwanda, where one demonstration plot owned by Mrs Drocella Yankurije was visited. Participants to this field day were (1) Ministry of Agriculture/ RAB, (2) Local authorities (Districts Mayors, District agronomists, (3) NGOs representatives (Africare, World vision, CRS, YWCA), (4) CBO's and farmer cooperatives (UDI, Lumiere de la Paix), (5) Donor agencies and CGIAR (AGRA, CIP) and Farmers.

Figure 103: Field visit to Drocella's on-farm field

Figure 104: Organoleptic test and variety naming

10.8.3. Collaboration with other stakeholders in natural Resources Management

During the year 2012/2013, RAB through the department of infrastructure and mechanization has been working closely with other projects involved in the field of small/medium scale irrigation activities. These groups which included Ministry of Agriculture and Animal resources projects (KWAMP and PAPSTA), water productivity project, AAP/REMA project and ADRA Rwanda had a common goal of increasing area under irrigation through the use of runoff ponds as well as capacity building of different stakeholders. In summary, Table 4 shows the achievements in the respective projects. Currently a total of 59 water ponds and 10 water ponds have been created by KWAMP and PAPSTA respectively. No training of farmers has yet been done through these projects. The water productivity project which has managed to work with two cooperatives has been able to reach many farmers in its training program. Water productivity project as well as the AAP/REMA funded project are still progressing and would probably wind up before the end of the fourth quarter. ADRA staff as well as farmer TOTs were trained in rain water harvesting activities as well as irrigation technologies.

Table 43: Projects achievements

Project title	Achievements		
	No. of ponds created	**Area irrigated (ha)**	**Trained farmers**
KWAMP	59	29.5	-
PAPSTA	10	5	-
Water productivity project	12	6	183
AAP/REMA funded project	6	3	50
ADRA Rwanda	-	-	53
Total	**87**	**43.5**	**286**

11. INFORMATION & COMMUNICATION TECHNOLOGY

Rwanda Agriculture Board (RAB) has the national mandate of delivering research based extension services to farmers; like in other government agencies RAB has put ICT on the forefront as crosscutting support unit which facilitate the dissemination of various technologies and services to be delivered to the public.

RAB has developed a website which facilitate in the information sharing, institution visibility and the postage of all institution key successful stories among others.

This web domain also hosts all staff email where staff share official emails for all official communications,this fits in the state policy of harmonization of government web presence and Hosted in the national data center.

RAB had regularly updated it website and share the weekly achieved key activities with MINAGRI to be part of the ministry weekly flash news.

As part of implementation of the recent government retreat, RAB has created institutional both twitter @RwandaAgriBoard and face book,rab_agricultureboard@yahoo.com social media accounts, where are posted news, online public interaction with RAB head office.

RAB has acquired a toll free line **4675** where farmers who cannot afford access to internet and read information can call free of charge 24 hours/7 days to RAB querying for all related farming issues and receive respective answers.

RAB has implemented the closer user group(CUG) through TIGO networks to facilitate its staff to communicate omong themselves free of charge and this has eased the work.

Complying to the government policy of ICT Govnet,RAB has connected its gereral premises to the fiber optic High speed internet broadband, this facilitates staff acess to internet and share information.

As RAB operates countrywide, and need to share online information,with the help of RURA in its mandate of connecting rural area to internet networks, where the fiber links are not applicable, RAB has succefully connected it northern zone offices to the satellite internet networks.

in line with the government policy of software development, RAB has implemented a strong accounting software called TOMPRO to automate all accounting transaction, this software is in use in the whole RAB and its registering succefull results as RAB has main source of funds.

RAB has implemented store management software which facilities seeds entries and exit.

As a only three years old RAB is going to mobile resources and implement online web applications, knowledge management systems, increase the spreading of high speed internet broadband to all its offices across the country and develop ICT policy and procedure as the promotion of ICT in agriculture and animal husbandry with the aim of transforming the social economic development of Rwandans.

12. HUMAN RESOURCES AND CAPACITY BUILDING

For the financial year running from July 2012 up to June 2013 the Human Resource Services have been busy by providing Human Resources related services as well as providing advises on issues related to Human Resources internally and/or externally.

As far as staff concern, RAB had 391 permanent staff counting 133 women and 258 men. In addition to those permanent staff who are regulated by Labour law and General Status, RAB has 144 staff who work under contract including 79 who are paid on RAB revenues and government funds, and 65.paid by different projects as support staff in order of achieving the objectives of those projects.

To achieve its mission and to help staff aquire more skills for the interest of work and for the staff motivation, during the financial year 2012-2013, RAB has not stopped building capacity of its staff in different domains,it is in that order that 45 went for study leave 13 for PHD training, 32 for Msc and 9 experts who are working with RAB employees in different field .

In support to the national program of helping Rwandan youth to gain professional experience, RAB have hosted 56 professionals internship during the financial year 2012-2013 who have been sent by RDB, they help in different departments and programs.

Table 44: RAB employees

STATUS	NO	PhD	MSc	BSc	Technical staff
Permanent	391	11	70	186	124
On study Leave	45	13	32		
Sub contract	79	1	1		
Projects	45				
Experts	9	9			
Professional Internship	56			56	

12.1 STAFF CAPACITY BUILDING STATUS BY JULY 2013

were on study leave:

snr	field of study	level of study	Nr
1	Land and water management	MSC	1
2	Aquaculture and fisheries	MSC	2
3	Agriculture Science	MSC	1
4	Animal Science	MSC	1
5	Soil science	MSC	1
6	Molecular Genetics	Msc	**1**
	S/Total		**7**
1	Plant breeding(Cassava Crop)	PhD	2
2	Program in plant breeding(Rice,heat root)	PhD	1
	S/total		**3**
	Grand total		**10**

graduated:

snr	field of study	level of study	Nr
1	Agricultural and Rural Management	**MBA**	**1**
2	Agricultural entomology	**Msc**	**1**
3	Horticulture(In plant Breeding)	**Msc**	**1**
4	Food science and technology	**Msc**	**1**
5	Agrometeology	**Msc**	**1**
6	Soil science	**Msc**	**1**
7	Plants protection	**Msc**	**1**
8	Plant breeding and seed sytems	**Msc**	**1**
	s/total		**8**
7	PhD Soil science	**PhD**	**1**
	s/total		**1**
	Grand total		**9**

12.2.STAFF STATUS SUMMARY (CONTRACTUAL AND PERMENENT STAFF) BY July 2013

	Classification	Nr of staff
1	Support Staff	137
2	Researchers	145
3	Technicians	76
4	Extensionists	126
5	Support to Spat II	34
	Total	**518**

12.3. CAPACITY BUILDING OF BEAN PROGRAM STAFF AND SUPPORT STUDENT STAFF

During 2012/2013 period, 21 bean program staff and affiliated student internees or project partners attended more than 70 internal or externally organized short course trainings, workshops or scientific conferences. Three of the staff have completed MSC training programs in plant breeding and seed systems (F. Mukamuhirwa), soil agronomy (A. Rumongi) or in marketing and socio-economics (D. Mukankubana) (Appendix 1).

Wheat

Courses and workshops attended

- Innocent Habarurema attended (with a certificate of attendance) a course on "Standardization of stem rust note taking and evaluation of germplasm with emphasis on emerging threats of yellow rust and leaf rust", held at KARI-Njoro, Kenya, on 25/09/2012-5/10/2012.
- Two wheat staff members (Athanase Hategekimana and Innocent Habarurema) attended a workshop on" Creating awareness on the development of *Striga* resistant sorghum lines using marker-assisted selection (MAS)" that held at NAZD-Musanze on 18-19/12/2012.
- Marie Aimée Ingabire has been trained for about half a year by experts for being a farmer field school (FFS) master trainer.

Mentorship

Several internees have been mentored by wheat program staff. The internees were from National University of Rwanda-NUR (3), ISAE-Busogo (3), RDB (1) and 4 from different secondary schools of Bukure, Bigogwe and Rushashi. Under the supervision of wheat staff, one student (Arlette Igabe) from NUR has conducted her research on "Adaptability of four new wheat varieties in Kinigi station, Musanze district" to obtain her BSc. degree in Agriculture. Additionally, Wheat staff trained 20 seed technical assistants and inspectors on wheat seed

production and field inspection on 17th-18th September 2012, at La Palisse, Kigali. Later on 14th June 2013, 16 seed producers most of which represented seed producing cooperatives were trained at Gicumbi District on seed production, inspection and certification.

Coffee

In March 2013, a staff of the Coffee Program (**Stanislas Mushimiyimana**) attended a workshop in India with the topic: "Closing and dissemination of technologies developed in the Project for increasing the resilience of Coffee production to leaf rust and other diseases in India and four African countries.
In December 2012, a staff of Coffee Program (**Joseph Bigirimana**) attended a workshop sponsored by ASARECA in Musanze on variety development using Marker Assisted Selection (MAS).

The Coffee program developed a training manual on banana-coffee intercropping in collaboration with IITA (International Institute for Tropical Agriculture) and CAB Internantional.

Natural Resources Management

Enhanced Knowledge and skills of the target groups

Different approaches used in capacity building include individual farm visit where the beneficiaries were trained on the site. Group training also was done particularly where farmers were in cooperatives.

Individual farmer training

Individual farmers were visited and training done depending on the need. This approach was effective where the farmer could get into closer contact with the trainer. This approach was effective since immediate solutions to farmers' problems were got through a proactive discussion. Farmer groups were also organized for training. Figure 105 shows farmers conducted on a training process in the farm.

Figure 105: Training conducted during a farm visit on crop management through runoff pond

Group training

Farmers organized in groups particularly in cooperatives were trained. This strategy was effective in reaching a large population and the expectation is that early adopters become further trainers of late adopters as well as the laggards. This is shown in figure 106 and 107.

Figure 106: Training on site selection, layout, installation and tree seedlings management

Figure 107: ADRA staff as well as farmers TOTs conducted in a classroom training as well as field training

Figure 108: Installation of gravity system on the field (to cover 1ha of land)

Figure 109: Drip irrigation system (2000m^2) installed on the field (500ltr water tank, drip laterals and connectors).

The on farm trials are link with capacity building activities. In Kayonza district, on the job training was adopted where farmers were first informed on what was being done during each irrigation system installation and later they worked together with the technicians during installation of the systems. Approximately 50 farmers have been trained on runoff water

harvesting through the water pond, use of treadle pump for water abstraction, modern irrigation technology including drip irrigation system installation and gravity system using drag hose pipe application technique.

Figure 110: farmers trained on water harvesting, abstraction, conveyance and application (drip irrigation, use of drag hose and treadle pump).

In the two sites runoff harvesting ponds each measuring 120m^3 were laid out , and constructed in Nyamagabe district (Tare sector, Kaganza and Gasarenda cell, Muse and Bivumu village). Before the laying out activities, the cooperatives representing beneficiairies in both sites have received damsheets and treadle pumps to be use in this activity related to

For both sites Tree nurseries were developed. They sites were regularly visited to find out the progress as well as give technical advice to the cooperative members. A tree nursery in Kiyogoma village (Murama Watershed, in Bugesera) was further visited to check on progress of transplanting of the tree seedlings. The seedlings under production in Nyamagabe (Muse-Bivumu Watersheds) are 65,000 *Calliandra,* 65,000 *Laeceana,* 300,000 *Alnus,* and 1000 Avocadoes. The seedlings under production in Bugesera (Murama watershed) are 200,000 *Calliandra and Laeceana,* 30,000 *Cena spectabilis,* and 1000 Avocadoes.

Figure 111: Runoff harvesting in Muse Bivumu watershed

Training

By now, there has been a training course on water and soil conservation with more emphasis on terracing; this training course took place in Nyanza district where 18 technicians were trained on how doing terraces for LWH pilot project of terraces and irrigation in Nyanza. Theses technicians would have been in charge of 450 ha of land prepared for terracing. On 17th, September, we would have a training course for Rwanda university students.

Figure 112: Training course on water and soil conservation held at Nyanza

Demonstration

There have been activities of putting in place demonstration sites in Huye District as shown by the following picture.

Figure 113: demonstration sites in Huye District

The center's expert worked together with RAB expert had been to Huye, Nyamagabe, Nyaruguru and Rusizi Districts to check the side. We wanted to set up of 5 demonstration plots. Until now, we have finished two plots about 3000 m^2 at MARA in Huye. And we plan to extend the scale (around 1 ha) for terracing at MARA village in September month of this year.

Figure 114: Doing terraces for demonstration at Mara cell of Huye district

13. BUDGET

13.1. BUDGET EXECUTION FY 2012-2013

Description	Approved budget Amount	Execution, amount	Budget Balance	Current Execution rate
1. DEVELOPMENT BUDGET	**4,722,853,166**	**4,722,853,166**	**0**	**100.0%**
Banana program	220,000,000	220,000,000	0	100.0%
Genetic improvement	770,000,000	770,000,000	0	100.0%
Poultry Development	220,000,000	220,000,000	0	100.0%
One cup of milk per child	1,500,000,000	1,500,000,000	0	100.0%
One Cow per Poor Family	2,012,853,166	2,012,853,166	0	100.0%
2. RECURRENT BUDGET	**4,694,342,371**	**4,669,410,346**	**24,932,025**	**99.5%**
2.1 **Operating funds** and activities coordination	1,871,262,131	1,873,083,655	-1,821,524	100.1%
2.2 **Salaries**	2,823,080,240	2,796,326,691	26,753,549	99.1%
TOTAL (Recurrent + Development Budgets)	**9,417,195,537**	**9,392,263,512**	**24,932,025**	**99.7%**

NB: In order to pay the permanent Staff Performance bonuses for the Fiscal Year 2011-12, Minecofin allowed to RAB an overspending of Rwf 63,268,132

13.2.STATEMENT OF REVENUES AND EXPENDITURE FOR THE PERIOD ENDED 30TH JUNE 2013

	Notes	Financial Year 2012/13 12 Months to June 2013	Financial Year 2011/12 12 Months to June 2012
Revenues			
Operating revenue			
Tax Revenue	1	0	
Fees, fines, penalties and licenses	2	0	
Transfers from Treasury	3	9,458,674,501	7,873,773,282
Transfers from other Government Reporting entities	4	6,707,103,779	6,033,513,688
Grants	5	1,280,654,736	1,440,657,144
Other revenue	8	1,128,978,400	1,154,784,522
Total operating revenue		18 575 411 416	16,502,728,636
Capital Receipts			
Proceeds from sale of capital items	6	0	
Loans and borrowings			
Proceeds from borrowings	7	0	
Total Revenues (A)		18 575 411 416	
Expenses			
Operating expenses			
Compensation of Employees	9	2,862,758,231	4,545,014,899
Use of Goods and Services	10	14,353,069,444	10,880,312,950
Transfers to Reporting Entities	11	153,817,619	143,229,319
Grant and other transfer payments	12	1,324,440	15,014,396
Social Assistance	13	0	
Finance cost	14	0	
Other Expenses	15	0	
Total operating expenses		17 370 969 734	
Capital payments			
Capital Expenditure	16	1,726,735,990	253,777,352
Repayment of borrowings		**0**	
Loans repayments	17	0	
Total expenses (B)		19 097 705 724	**15,837,348,916**
Surplus/deficit (C=A-B)		**-522,294,308**	**665,379,720**

13.3. FINANCIAL ASSETS AND LIABILITIES AS AT 30TH JUNE 2013

	Notes	Financial Year 2012/13 As at 30th June 2013 Frw	Financial Year 2011/12 As at 30 June 2012 Frw
Financial Assets			
Bank Balances	18	3,189,426,523	3,589,372,364
Cash Balances	19	121,869	125,087
Accounts Receivables and Advances	20	1,020,436,293	1,020,063,403
Less: Financial liabilities			
Accounts Payables	21	1,287,180,527	1,337,736,655
Net Financial assets		**2,922,804,158**	
Representing			
Accumulated surplus (Deficit) from previous years	22	3,271,824,199	2,609,484,479
Net surplus / (Deficit) for current year		-522,294,308	665,379,720
Prior year adjustment	23	173,274,267	-3,040,000
Total closing balances		2,922,804,158	3,271,824,199