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The University of Arkansas, Fayetteville
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Rwandan Institute for Agricultural Sciences (ISAR)

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Research Activities Undertaken
by the Soils/Agroforestry Unit
of the FSRP (1985-1990)

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RESEARCH ACTIVITIES UNDERTAKEN BY THE SOILS/AGROFORESTRY UNIT OF THE FSRP (1985-1990).

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INTRODUCTION

The Rwanda Farming Systems Research Program (FSRP) is located in the Ruhengeri Province in the northwestern highlands of the country. This area is noted for its high potential in agricultural production. Consequently, it is one of the most densely inhabited areas in the country, with about 372 people/km^2.

Because of the rugged topography, hillside farming is typical in the four-commune project area. Slopes are generally steep and range from 0 to over 60%. Thus, soil erosion and fertility maintenance are serious problems to sustained crop production. The fundamental constraint, however, is land scarcity.

Since Rwanda is the most heavily populated country in Africa and is under severe land pressure, the use of long fallow periods to rejuvenate soil fertility does not seem to be a feasible option for farmers. The landlocked location of Rwanda about 1000 km from the nearest seaport makes importation and use of high doses of commercial inorganic fertilizers economically unattractive and logistically difficult for small farmers.

Agroforestry and organic matter-based cropping systems, using leguminous plants, are some of the promising interventions experts have recommended to deal with accelerated soil degradation problems on sloping lands.

This report gives in chronological order the research accomplishments and recommendations for use by farmers, extension workers and other researchers.

Diagnosis and Research Themes

In concurrence with the philosophy of Farming Systems Research and Extension (FSR/E), researchable problems were identified through review of secondary data, exploratory surveys with farm families, consultations with scientists who have experience in Rwanda and direct communication with local administrators and key informants. Analysis of information gathered revealed the underlisted technologies as potentially most appropriate for the four FSRP communes covering parts of the Buberuka Highlands and the central Plateau agro-ecological zones. The interventions suggested were as follows:

- tillage (zero and minimum)
- mulch systems (live and in-situ)
- manures and composts
- agroforestry systems
- inorganic fertilizers.

Research began with adaptive trials sited on the research station and on communal plots found outside the station. The areas were strategically selected to represent different agro-ecological zones with respect to altitude, soil type, rainfall and temperature. The trials installed were:

1. Evaluation of an alley cropping system with Sesbania sesban. Sesbania was the leguminous shrub discovered to exhibit good growth performance during the project's diagnostic survey of the area.
2. Evaluation of 12 leguminous cover crops, with and without inoculum, for dry matter and nutrient yields. The legumes used were Mucuna, Canavalia, Alfalfa, Stylosanthes, White Clover, Centrosema, Lupin, Vetch, Desmodium, Glycine wightii, Cajanus cajan and Dolichos.
3. Assessment of leguminous shrubs such as Leucaena, Markhamia, Calliandra and Sesbania for use in alley cropping systems.
4. Studies on a local lime material as soil amendment.

STUDY ONE
EARLY GROWTH OF ALLEY SHRUBS.

As part of the shrub evaluation exercise, early growth of four woody species used in alley cropping was studied in the Buberuka Highland and Central Plateau region of Rwanda. The altitudinal ranges for the two agro-ecological zones are 1800-2400 m and 1500-1900 m respectively.

First, early growth of *Sesbania sesban* (Sesbania) as affected by intercropped bean, potato, pea and wheat was studied. Second, effect of lime and manure applications on growth of Sesbania, *Leucaena* spp (Leucaena), *Calliandra Calothyrsus* (Calliandra) and *Markhamia lutea* (Markhamia) was investigated. Third, growth of Sesbania and Leucaena at selected locations was examined.

Bean growth in association with Sesbania enhanced the growth of the shrub in the Central Plateau region. At both sites, growth of Sesbania was retarded by intercropped pea. Growth of Sesbania increased significantly during the dry season in June and July. Biomass and height after one year's growth of Sesbania were higher in the Buberuka than in the Central Plateau region. Growth of the shrubs is ranked as sesbania > Leucaena > Calliandra > Markhamia in the Buberuka Highlands.

Farmyard manure generally increased the growth rates of the shrubs. Calliandra and Leucaena were most responsive to liming. The response of Leucaena to liming decreased with manure application, but no definite trend was observed for Calliandra, Sesbania and Markhamia. Sesbania and Markhamia were least influenced by application of lime. Their respective LRI's were 0.35 and 0.46. The average growth rates for Sesbania and Leucaena at selected locations ranged between 26.4 and 62.2 cm/month and between 13.1 and 27.4 cm/month, respectively.

Our findings demonstrated that it was best to establish the shrubs by interplanting them with food crops, but it is cautioned that association of Sesbania with pea may retard growth of the shrub in the early stages of establishment. The growth retardation of the shrub may be ascribed to the vigorous and aggressive growth nature of pea irrespective of initial site condition.

Manuring apparently enhanced the growth rates of the woody species. Since the success of alley cropping depends largely on quick and easy establishment of the shrubs, it would be advisable for farmers to follow their routine cultural practices of manuring, weeding and pest control, which indirectly promote good shrub establishment.

Lime application improved the growth rates of Leucaena and Calliandra, but this could not be said of Sesbania and Markhamia. Where lime is available locally, farmers are encouraged to explore the possibility of using it as a soil amendment to improve shrub establishment. The intercrops would also benefit from the applied lime.

Furthermore, it has been shown in this study that Sesbania, Leucaena, Calliandra and Markhamia thrive in high altitude areas of Rwanda. Sesbania grew fastest, followed by Leucaena, then Calliandra and finally Markhamia. Markhamia is a species commonly found on farmlands in the study area. But from our viewpoint, its growth is too slow for the shrub to be of immediate value in alley cropping systems. Growth of Leucaena and Sesbania in particular was favored on the moist and relatively fertile valley bottom soils.

About a million seedlings of Sesbania, Leucaena and Calliandra were produced and distributed free of cost to interested farmers.

STUDY TWO
ALLEY CROPPING SESBANIA SESBAN (L) MERILL WITH FOOD CROPS

This study examined the effect of Sesbania prunings plus moderate levels of N and P on bean (*Phaseolus* spp) and maize (*Zea mays*) yields in alley cropping. Experimental design was a randomized complete block with split-split plots. Main plots were alley width: 2, 4, 6 and 8 m. Phosphorus (P) at 0.30 and 60 kg P_2O_5/ha occupied the subplot, and nitrogen (N) at 0, 30 and 60 kg/ha was assigned at the sub-sub plot level. No P was applied to maize during the second cropping season.

Crop yield in kg/ha included the land space taken by hedgerows. Bean yield in 6-m alleys (1100 kg/ha) was about twice that in 2-m alleys (500 kg/ha). Bean responded to N and P. Optimum alley width and N for bean yield were 6 m and 30 kg/ha, respectively.

Cuttings from alley hedgerows provided stakes for climbing beans. Maize responded to N but not to residual P. The highest maize yield came from 8-m alleys with 40 kg/ha, but yields from 8- and 6-m alleys with the same N treatment were not significantly different. Maize plants in middle rows were significantly taller than plants in rows adjacent to hedgerows.

Maize rust development showed significant alley width and row position effect. There were significantly fewer uredinia in the Sesbania alleys relative to the control plots without shrub hedgerows. Rust development on maize in middle rows was significantly greater than development in border rows.

This study concludes that Sesbania is a promising woody species for agroforestry in the highland region of Rwanda where altitudes range from 1500 m to over 2400 m. Prunings of Sesbania in combination with moderate quantities of N and P increased yields of pole beans and maize in the wider (6- and 8-m) alleys. Intercrop yields in narrow (2- and 4-m) alleys were low due to greater cultivable area sacrificed to shrubs and to shading by hedgerows.

Shading is a serious problem with Sesbania because complete removal of foliage kills the shrub. Mortality of Sesbania is low once the shrub is established, but care is required to ensure shrub longevity. There are reports that mortality of Sesbania is affected by nematode infection, but there is no evidence of this in Rwanda. Alley cropping might reduce the impact of foliar plant pathogens on crop yield by slowing disease development.

From a management standpoint, shrubs should be pruned once a year when rainfall is adequate and reliable to enhance biomass production. Economic appraisal is necessary to determine if Sesbania alley cropping with these inputs is a viable and feasible alternative for the resource-poor farmers who dominate the region. An economic analysis should also consider the value of stakes for pole bean production that are produced by hedgerows. It is this aspect of alley cropping technology that attracts farmers to plant Sesbania.

STUDY THREE
CHOOSING SUITABLE INTERCROPS PRIOR TO PRUNING SESBANIA HEDGEROWS IN AN ALLEY CONFIGURATION.

The study was conducted to choose suitable intercrops with Sesbania for alley cropping prior to cutback of the shrub, a practice that would enable farmers to continuously crop their fields. Potato, pole bean, dwarf bean and maize were tested in 4-m alleys.

The following conclusions were drawn:

1. Performance of intercrops with 6- to 12-month-old Sesbania decreased in the following order: Pole bean, potato, dwarf bean and maize. In fact, planting of maize in unpruned Sesbania hedgerows should be discouraged unless a farmer is prepared to be present on his farm all the time to chase away birds. Even then, maize, a C4 plant, can hardly withstand shading imposed by vigorously growing Sesbania. Maize is recommended as an intercrop at the very early stages of shrub establishment when there is no shading.
2. With the exception of maize where performance was poor, the hedgerows did not adversely affect population of intercrops, i.e. number of plants/row. For beans, it was number of pods/plant that was negatively affected by the hedgerows. In the case of potato, yield reduction in the alleys was due to poor vegetative development that might have resulted from shading and late blight infestation.
3. In this study, yield reductions of intercrops in the alleys were blamed principally on shading by Sesbania hedgerows. But competition for nutrients, water and soil space as well as possible disease incidence cannot be exculpated. These are worth investigating.
4. In practice, the 4-m alley width used for this study appears too narrow to be welcomed by farmers. Perhaps by using wider alleys of 6 m or more, additional land could be freed for cultivation, and shading would also be minimized.

STUDY FOUR
HERBACEOUS LEGUMES AS NUTRIENT SOURCES AND COVER CROPS

Herbaceous legumes were assessed for their suitability as nutrient sources and as ground cover for the northern highlands of Rwanda. There were three investigations that followed the Farming Systems Research (FSR) methodology.

First, exploratory studies were conducted to measure biomass yield and percentage ground cover. Second, 12 legumes were screened on station for biomass production, nutrient yield and ground cover. Yields of maize (*Zea mays*) grown as a test crop following incorporation of the legumes were compared with yields of maize grown at different nitrogen levels. Third, following farmers' comments on the second study's results, five legume species were chosen for multilocational testing on 11 farmers' fields.

Preliminary studies showed high biomass yields and good ground cover for *Desmodium* spp, *Trifolium* spp (red clover), *Vetch* spp and *Stylosanthes* spp . Trifolium repens (white clover) demonstrated a prostrate and complete ground cover--ideal characteristics for live-mulch species.

On-station experiments indicated significant accumulation of nutrients by the legumes, but with substantial site-species interaction. Legumes with high biomass yields decreased maize yields when compared with maize grown with no nitrogen.

The multilocational testing confirmed the inconsistent performance of the species at different sites and led to the definition of three sub-regions (North, Central and South) for which different promising legumes were selected.

Selection criteria such as vegetative yield, nutrient content and ground coverage resulted in the following selections by region and in order of preference: North: Canavalia, Lupin, Mucuna; Central: Vetch, Lupin; and South: Mucuna, Lupin and (on fertile soil) and Canavalia.

The experience gained suggests the need for initial moderate fertilization, extended growing periods, high seeding rate and mixtures of legumes as possible means of achieving high productivity of herbaceous legumes.

Mixtures of legumes in particular give farmers both flexibility and insurance. In the Rwandan highlands, however, both fertilizer application and prolonged vegetative growth may not be an acceptable practice due to the acute shortage of arable land and capital in the region.

A management strategy that might facilitate widespread utilization of herbaceous legumes is to relay-crop the legumes with a cereal such as maize or sorghum planted with modest applications of phosphorus and nitrogen.

STUDY FIVE
GREEN MANURING WITH VETCH ON AN ACID SOIL

Green manuring with vetch was evaluated on an acid soil in the Buberuka highland region. Incorporation of 5-month-old vetch lowered soil pH as well as raising exchangeable Al and H and reducing exchangeable Ca, Mg and P.

Consequently, bean and wheat yields for the subsequent season were reduced by 71 and 33%, respectively. There was no response to fertilizer N on either main treatment. There were no significant yield differences for either crop with respect to vetch treatment during the second season.

Third-season crop yields were superior on the control plot with that of beans being significantly different. Application of lime raised exchangeable Ca, K and ECEC and reduced exchangeable Al. Bean more than wheat was affected by exchangeable Al.

Half-life for decomposition of the vetch was 3.5 weeks, and nutrient release pattern followed the order K > N > P > Ca, indicating that liming may be required to supply Ca and to neutralize soil acidity at the initial stages of decomposition.

In conclusion, vetch grows rapidly and provides a quick cover to control erosion in the Rwandan Highlands. However, its use for green manuring on the acid soils in this region must be treated with caution because decomposing vetch material initially made the soil acidic, and crops that immediately followed vetch incorporation suffered severe yield losses.

For better results, it may be advisable to allow three to four weeks after incorporation before seeding food crops. As well, lime application may be necessary to counteract adverse effects of soil acidity during early stages of decomposition and also to supply Ca. Field trials currently underway show positive response from vetch and other green manure materials when lime was added.

STUDY SIX
APPLICATION OF EXPERT SYSTEMS TO STUDY OF ACID SOILS

Two expert programs, soil fertility capability classification (SFCC) and ACID, were used to assess fertility of some soils in the highland region of Rwanda. Soils were grouped with respect to altitude, rainfall and parent material into three agro-ecological zones.

Soils in Zone 3 with high rainfall, low altitude and underlain by quartzite-schists complex were lower in fertility and more acidic than their counterparts in Zones 1 and 2. N, P and K were generally deficient. Ca and Mg were considered as borderline cases and are expected to fall below acceptable levels after few years of cultivation.

The SFCC identified clayey topsoils (>35% clay), acidic (Al saturation between 10 and 60%) and low K reserves (exchangeable K > 0.2 meq/100 g) as the dominant fertility class. Crop residue management, agroforestry and green manure systems are recommended in addition to P and K fertilization to alleviate nutrient deficiency problems.

Soil acidity was associated with exchangeable Al, and Al saturation was >50% at pH <5.2. Base saturation was negatively correlated with Al saturation and positively related to Ca + Mg. Therefore, liming to supply Ca and Mg may reduce exchangeable Al and improve ECEC and nutrient retention.

Lime requirement ranged from 0 to 6 t $CaCO_3$/ha and was directly proportional to exchangeable Al (r=0.95**) and inversely related to pH (r=-0.73**). Results from the lime prediction equation estimated lime requirement (Y) = 1.332 x Al-0.11 as computed for soils in the region and concurred with those of other workers.

The expert programs have been installed on the FSRP microcomputers for use by interested researchers.

STUDY SEVEN
AGRONOMIC EVALUATION OF LOCAL LIME MATERIAL.

Agronomic value of lime from a local source was evaluated on acid soil in the highland region of Rwanda. There were four levels of lime (0, 2, 4 and 8 t/ha) combined with NPK fertilizer at 0 and 60 kg/ha. Wheat, beans and potatoes used as test crops were planted within leucaena hedgerows spaced 5 m apart.

Wheat yield increased linearly and significantly with lime from 1653 kg/ha for control to 2128 kg/ha at 8 t/ha. Wheat yield was inversely related to exchangeable Al (r = - 0.63**). At the high rates of lime (4 and 8 t/ha), wheat floret length and root weight were increased by 24 and 118%, respectively, compared to control. Bean yields from residual lime were 823, 1132, 1312 and 1389 kg/ha, respectively. Potato yield was not significantly affected by residual lime even though the high rates were still superior. Soil pH was 4.4, 4.6, 5.2 and 5.6, and exchangeable Al was 4.2, 3.3, 1.5 and 0.75 meq/100 g for the respective lime treatments.

There were significant differences between low (0-2 t/ha) and high (4-8 t/ha) lime rates for bean yield, pH and exchangeable Al after the second crop. This suggests application of lime once every two seasons when low rates are used.

The lime is being tested by farmers on a wider scale.

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